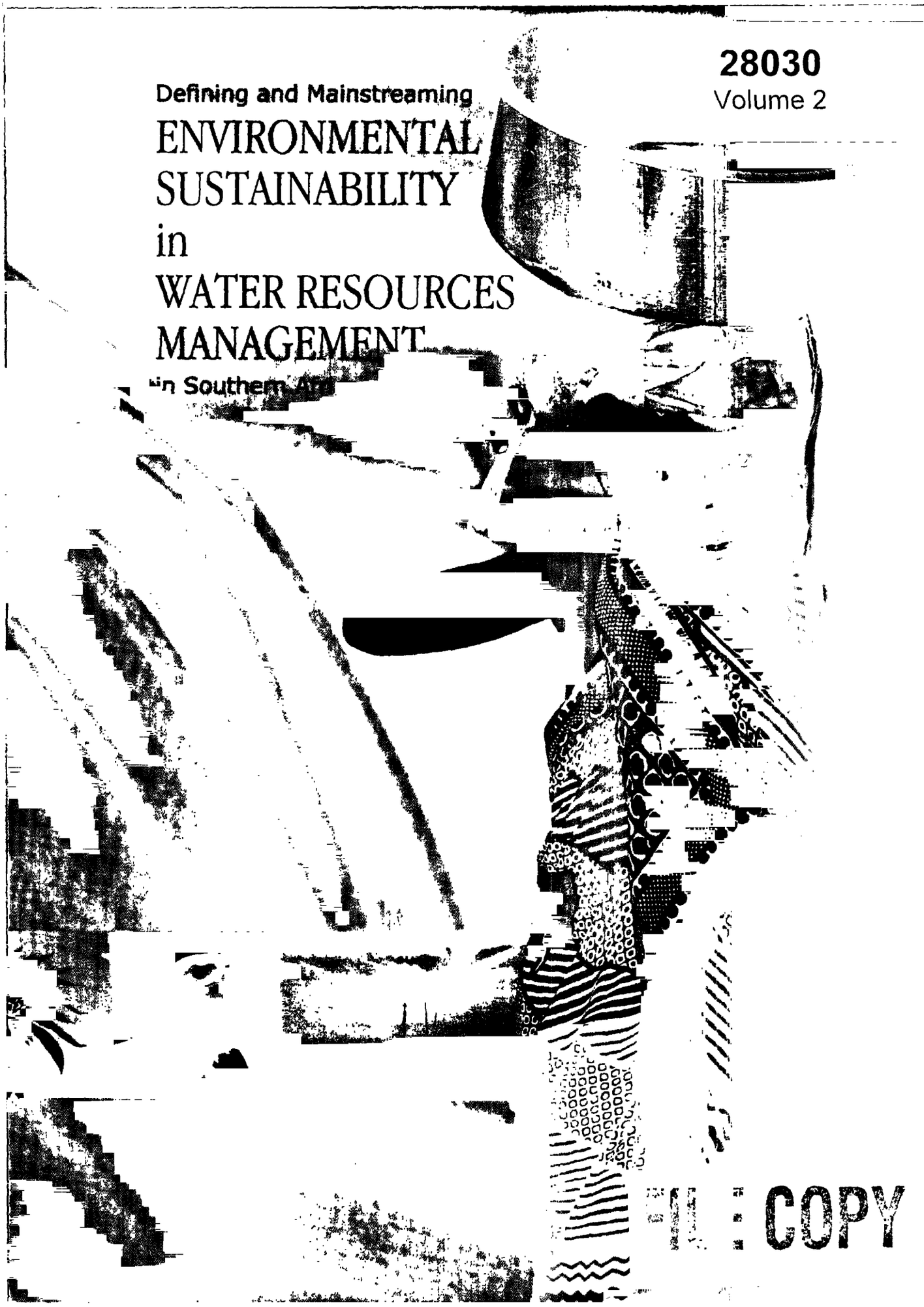
Volume 2

Defining and Mainstreaming

ENVIRONMENTAL SUSTAINABILITY in WATER RESOURCES MANAGEMENT

in Southern Afr



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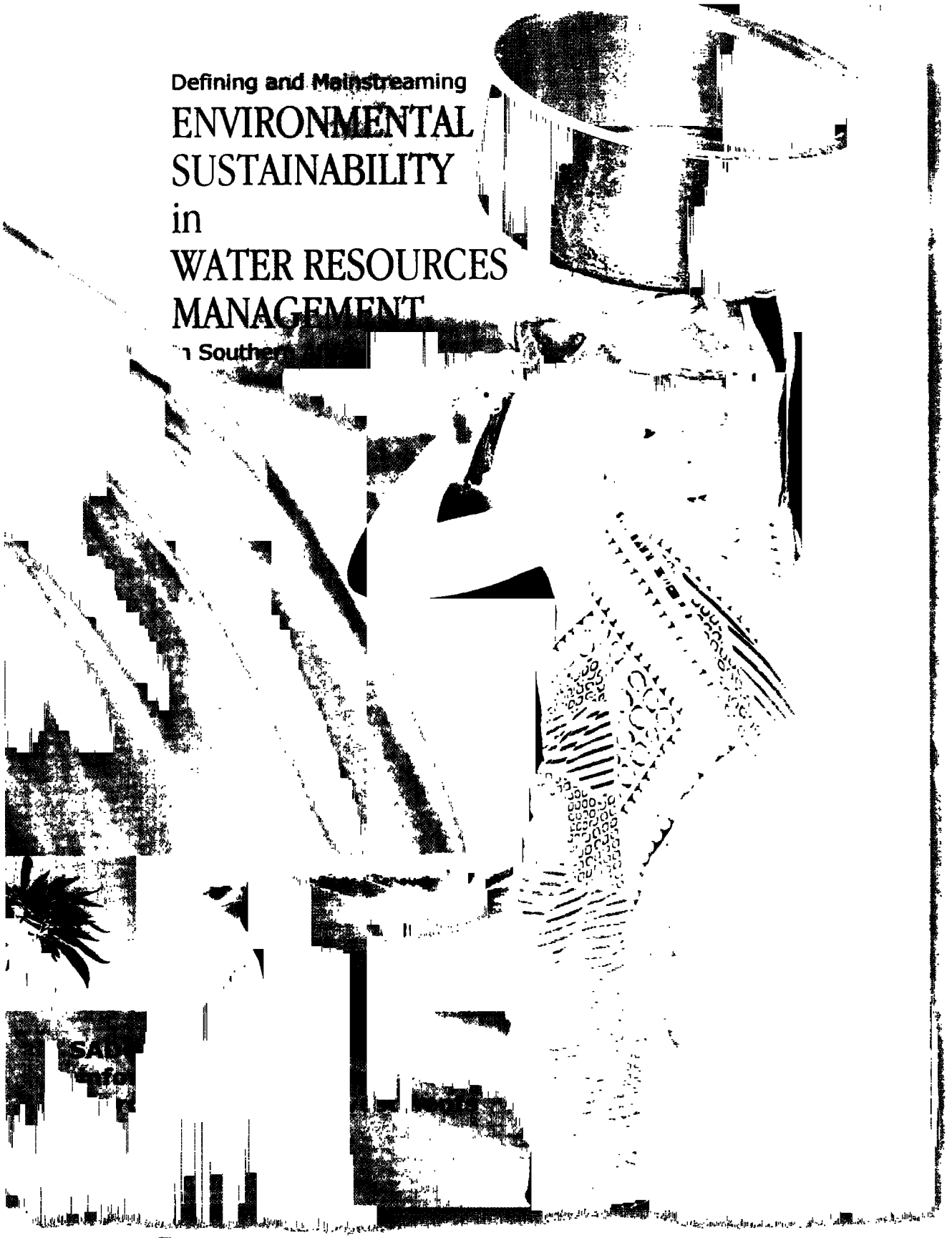

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[illegible] and Mainstreaming
ENVIRONMENTAL SUSTAINABILITY IN
WATER RESOURCES MANAGEMENT in Southern Africa

A technical report by the Southern African Development Community (SADC)
and development partners:

World Bank, Sida, IUCN and SARDC

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This technical report was prepared as part of the Communicating the Environment Programme (CEP), a southern African partnership of the SADC Environment and Land Management Sector (ELMS), SADC Water Sector, Zambezi River Authority, IUCN-The World Conservation Union, and the Southern African Research and Documentation Centre (SARDC), India Musokotwane Environment Resource Centre for Southern Africa (IMERCSA), with technical support from the Africa Water Resources Management Initiative and the Environment Department of the World Bank. This report was funded by the Swedish International Development Cooperation Agency (Sida).

PREFACE

Water is a precious and scarce resource that we take for granted in our daily life, while in the rural areas of the region, people are confronted more directly with its elusive nature as they are more vulnerable to the ravaging cycles of drought and flood, and the slowly [illegible] resource base. Our natural environment also needs water, if it is to continue to provide important social, ecological and hydrological functions, although we seldom consider that wider context. This technical report showcases the threats to our precious water resources, and to the environment that sustains them, and it also offers solutions for long-term protection and appropriate utilization.

The effective and sustainable utilization and management of water resources is an essential pre-requisite for sustaining all forms of life, improving livelihoods of the people and fostering overall socio-economic development in southern Africa. Water is a necessary input for many productive activities including agriculture, forestry, industry, mining, commercial and livestock development, energy production, tourism, wildlife conservation, etc. Environmentally sustainable management of water resources is linked to poverty alleviation in many important ways. Strategies to reduce or [illegible] poverty should not lead to further degradation of water resources or ecological functions and services. Sustainable water use and improved environmental quality should contribute directly to reducing poverty.

Since the majority of the people in southern Africa depend on and derive their livelihoods directly from natural resources, the region has placed a high priority on the need "to achieve sustainable utilization of natural resources and effective protection of the environment" and has enshrined this priority as a policy objective in the 1992 Treaty of the Southern African Development Community (SADC).

Water [illegible] considerably across the region and within countries. Overall, it is a scarce resource, which is vulnerable to global factors such as climate variability and climate change, and to regional constraints imposed on the management of transboundary waters. Water is also vulnerable to national and local factors such as the growing demands of urban and rural populations, increasing sectoral demands, greater competition and potential for conflict over water, worsening water pollution, land and catchment degradation, destruction and encroachment on aquatic ecosystems, and proliferation of invasive weeds. Increasingly, environmental degradation from unsustainable land and water use patterns and other anthropogenic factors is undermining and threatening the sustainability of the water resource base itself, and if this remains unchecked then it is likely to further exacerbate water scarcity in a region that has a limited endowment of water.

Although awareness about environment has increased since the Earth Summit in Rio in 1992, the operational integration of environmental quality objectives, economic efficiency principles, and social equity goals in water resources planning and management decision-making remains a major weakness to be addressed in water resources policy and institutional reforms and water resources development.

This technical report on *[illegible] and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa* is SADC's contribution to the debate on and search for environmentally sustainable solutions to the water resources management problems. It has been prepared through joint efforts of the SADC Environment and Land Management Sector, SADC Water Sector and their development partners—World Bank, Sida, IUCN and SARDC. The objectives of the report are to inform and guide the policy and decision makers about the complex biophysical, social and eco-

nomic dimensions of environmental sustainability in the water sector, and to enhance the integration of the ecological dimensions in water resources planning and management decision-making.

The various chapters of this book provide practical approaches and operational tools for enhancing sustainable management of water resources. The authors share knowledge, experiences and lessons about environmentally sustainable, water resources management practices from the region. The book provides a framework for effective integration of environmental quality objectives into the implementation of the SADC Protocol on Shared Watercourses and the Regional Strategic Action Plan for Integrated Water Resources Development and Management in the SADC Countries (1999-2004).

This report is therefore a vital contribution to the region's development agenda. It fills an important knowledge gap and shares best practices from within the region. It charts a way forward for systematically improving awareness and sharing knowledge on a critically important subject. It provides a framework for defining the complex and elusive concept of environmental sustainability in water resources management and mainstreaming that concept in operational terms in water resources policies and institutional reforms, and in the decision-making for water resources planning and development. The report supports the new environment strategy of the World Bank, and the implementation of the recommendations of the World Commission on Dams that address environmental sustainability issues. And it paves the way forward for developing sound, sensible and sustainable water resources investments and management systems for meeting the region's priority goals.

The knowledge contained in this volume provides a useful reference for the water, environment and all water-related sectors such as agriculture, energy, industry, mining, tourism, and livestock. The target audience includes sector managers and policy-makers, water-resources and environmental specialists, planners and decision-makers from public and private sectors, researchers, and students of natural resources management.

The report was wholly prepared by an inter-disciplinary team of specialists and technical experts who are citizens or residents of SADC countries. The preparation and management process was guided by experts from governments, non-governmental organizations, and academic and research institutions.

The publication of this report is very timely as African countries and development partners are searching for new, practical, cost-effective and innovative solutions to the sustainable management of a priority common property resource – water. The book is a key SADC contribution to the World Summit on Sustainable Development in Johannesburg in August 2002 and to the New Partnership for Africa's Development (NEPAD).

Finally, we would like to urge the people of the region, their communities, public and private-sector institutions, non-governmental organizations and development partners to work together in a cooperative and constructive spirit to support SADC member states and institutions in the implementation of the recommendations and follow-up actions contained here, in order to protect our precious water resources and to achieve sustainable development goals including poverty eradication, for current and future generations.

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ACRONYMS AND ABBREVIATIONS

AMCEN	African Ministerial Conference on the Environment and Natural Resources
AU	African Union
AWWA	Australian Water and Wastewater Association
BAT	Best Available Technology
BATNEEC	Best Available Technology Not Entailing Excessive Costs
BBM	Building Block Methodology
BOD	Biological Oxygen Demand
BMP	Best Management Practices
CBD	Convention on Biological Diversity
CCD	Convention to Combat Desertification
CEP	Communicating the Environment Programme
COD	Chemical Oxygen Demand
CSC	Commonwealth Science Council
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DDT	Dichloro-diphenyl-trichloroethane
DO	Dissolved Oxygen
DRC	Democratic Republic of Congo
DRIFT	Downstream Response to Imposed Flow Transformations
DRU	Dambo Research Unit
DWAF	Department of Water Affairs and Forestry (South Africa)
EFA	Environmental Flow Assessments
EFR	Environmental Flow Requirements
EIA	Environmental Impact Assessment
ELMS	Environment and Land Management Sector
FAO	Food and Agriculture Organization
FAW	Floating Aquatic Weeds
FLOWRESM	Flow Restoration Methodology
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GEM	Group for Environmental Monitoring
GWP	Global Water Partnership
HEP	Hydro-Electric Power
HIV	Human Immuno-Deficiency Virus
HYCOS	Hydrological Cycle Observing Systems (SADC)
IBRD	International Bank for Reconstruction and Development
ICM	Integrated Catchment Management
ICOLD	International Commission on Large Dams
IOBC	International Organization of Biological Control
IPM	Integrated Pest Management
IUCN-ROSA	World Conservation Union - Regional Office for Southern Africa
IWM	Integrated Watershed Management
IWRM	Integrated Water Resources Management
KARI	Kenyan Agricultural Research Institute
LAI	Leaf Area Index
LHDA	Lesotho Highlands Development Authority
LHWA	Lesotho Highlands Water Authority
LHWP	Lesotho Highlands Water Project
LVEMP	Lake Victoria Environmental Management Project
MAR	Mean Annual Runoff
MEAs	Multilateral Environmental Agreements

NCSs	National Conservation Strategies
NDP	Net Depletion of Natural Resources
NDVI	Normalized Difference Vegetation Index
NEAPs	National Environmental Action Plans
NEPAD	New Partnership for Africa's Development
NPV	Net Present Value
OAU	Organisation of African Unity
PAR	Population at Risk
PPRI	Plant Protection Research Institute
REA	Regional Environmental Assessment
RSA	Republic of South Africa
RSAP	[illegible] Strategic Action Plan
RWQO	[illegible] Water Quality Objectives
SADC	Southern African Development Community
SADCC	Southern Africa Development Coordination Conference
SADC-ELMS	SADC Environment and Land Management Sector
SADC-FANR	SADC Food, Agriculture and Natural Resources
SADC-IFFW	SADC Inland Fisheries, Forestry and Wildlife
SADC-WSCU	SADC Water Sector Coordination Unit
SAPIA	Southern African Plant Invaders Atlas
SAPP	Southern African Power Pool
SAPs	Structural Adjustment Programmes
SARCCUS	Southern African Regional Commission for the Conservation and Utilization of Soil
SARDC	Southern African Research and Documentation Centre
SAWWQ	SADC Aquatic Weeds and Water Quality Committee
SEA	Sectoral Environmental Assessment
SS	Soluble Solids
UNCED	UN Conference on Environment and Development
UNEP	United Nations Environment Programme
UNFCCC	UN Framework Convention on Climate [illegible]
VWC	Village Water Committees
WASA	Lesotho Water and Sewerage Authority
WQM	Water Quality Models
WRMS	Water Resources Management Strategy
WSCU	Water Sector Coordination Unit
ZACBASE	Zambezi River Basin Information System and Database
ZACPLAN	Zambezi River Action Plan
ZACPRO	Zambezi Action Project (Part of ZACPLAN)
ZINWA	Zimbabwe National Water Authority
ZRA	Zambezi River Authority

Units of Measure

		cu m/s	cubic metre per second
cu km	cubic kilometres	M cu m	million cubic metres
cu km/yr	cubic kilometres per year	mg/l	milligrams per litre
cu m	cubic metre	mm	millimetres
cu m/month	cubic metres per month	ppm	parts per million
cu m/p/yr	cubic metres per person per year	ppmv	parts per million by volume
ha	hectare	per capita	per person
l/d	litres per day	sq km	square kilometre
kg	kilogram	sq m	square metre
kg/p/day	kilogram per person per day	t	tonnes
kg/cu m	kilogram per cubic metre	t/km/yr	tonnes per kilometre per year
km	kilometre	t/sq km/yr	tonnes per square kilometre per year
m	metre	000	thousands

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ENVIRONMENTAL SUSTAINABILITY IN WATER RESOURCES MANAGEMENT

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This SADC technical report provides a framework for promoting [illegible] sustainable use and management of the region's water resources. Its preparation was supported by a collaborative partnership between the SADC Environment and Land Management Sector and SADC Water Sector with technical assistance and support from many partner institutions, individuals who are citizens and/or residents of the SADC countries, and institutions anchored in the region. Jobo Molapo from SADC ELMS and Phera Ramoeli from the SADC Water Sector have been instrumental in facilitating the report preparation and completion process.

The report preparation, including the SADC regional workshop held in Harare in October 1999 to review the draft chapters of the report, and the production and dissemination of the final product, has been funded by a Swedish International Development Cooperation Agency Trust Fund managed by the Environment Department and the Africa Water Resources Management Initiative of the World Bank.

The World Bank provided overall technical assistance to the report preparation process. Nine of the eleven commissioned chapters were prepared by a team of multi-disciplinary specialists who included environmental planners, managers and engineers, natural resources economists, river scientists, freshwater ecologists, civil engineers, biologists, land-use specialists, geographers, wetlands specialists, hydrologists, water resources management specialists, political scientists, sociologists, and journalists. The authors, co-authors and supplementary authors for each chapter are profiled on the previous pages. The draft chapters of the report were reviewed by the National Technical Committee members of both SADC ELMS and Water Sector at a SADC workshop in Harare from 28-29 October 1999. The 65 workshop participants included regional experts from the government, academia and non-governmental organizations. (see Annex 1)

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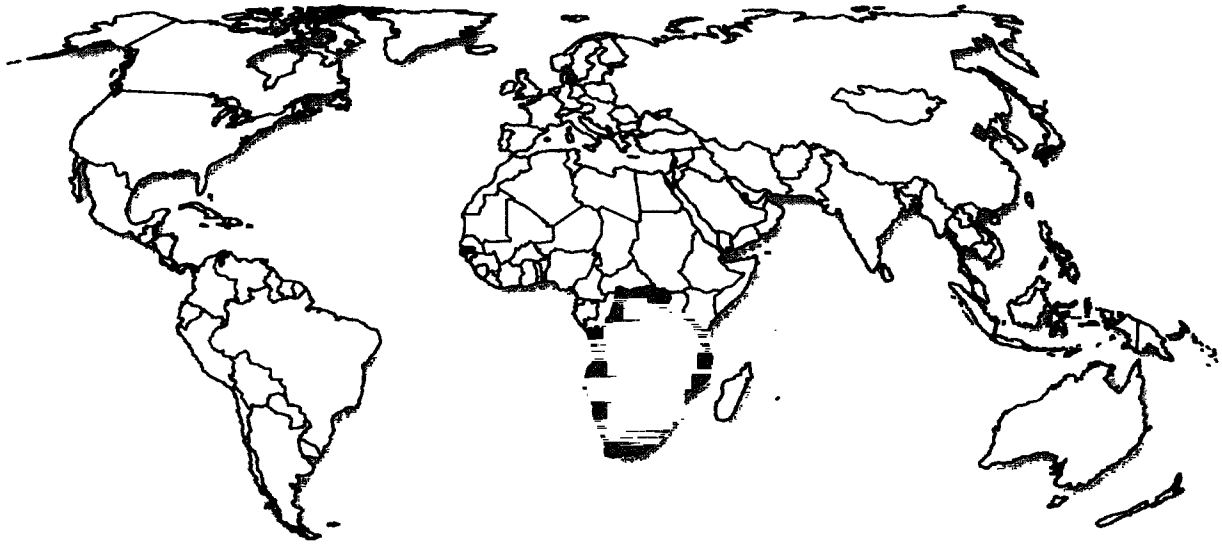
Rafik Hirji, July 2002

Southern Africa showing SADC Member States

Map 0.1



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ENVIRONMENTAL SUSTAINABILITY IN WATER RESOURCES MANAGEMENT:

CONTENTS

ENVIRONMENTAL SUSTAINABILITY IN WATER RESOURCES MANAGEMENT: A CONCEPTUAL FRAMEWORK

1.1 INTRODUCTION

The Southern African Development Community (SADC) commissioned the preparation of this technical report on *[illegible] and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa* to contribute to the public policy discourse and to support the development of practical approaches for the integration of environmental quality objectives in the planning and management of the water sector.[1] The report addresses a key SADC objective, "to achieve sustainable utilization of natural resources and effective protection of the environment", and supports the integration of environmental quality objectives into the implementation of the SADC Protocol on Shared Watercourses and the Regional Strategic Action Plan (RSAP) for Integrated Water Resources Development and Management in the SADC Countries ([illegible] 2004). This technical report is also a SADC contribution to the United Nation's World Summit on Sustainable Development (WSSD) in Johannesburg in August 2002 and to the New Partnership for Africa's Development (NEPAD).

The report provides policy guidance and practical tools for addressing the specific [illegible] related to the water, environment and poverty nexus. The central messages of the report are that,

(a) effective development and effective management of water resources are essential for sustainable growth and poverty reduction in the SADC region, and

(b) sustainable water resources management must balance between the short term needs of the people for their social and economic development and the protection of the natural resource base.

Protection is a longer term goal for ensuring that the resource base is utilized wisely so that it can continue to provide benefits for improving people's livelihoods and [illegible] of life, reducing poverty and fostering economic growth into the future on a sustainable basis.

The report is based on two fundamental assumptions that link water and environment to poverty alleviation.

First, strategies to reduce poverty should not lead to further degradation of water resources or ecological functions and services.

Second, sustainable water use and improved environmental quality should contribute to reducing poverty.

Table 1.1 below summarizes the elements of a basic framework for [illegible] environment, and poverty. A broad definition of poverty is adopted, that extends well

Dimensions of poverty	Examples of water and environmental linkages
Income and Consumption	Access to water for productive use, access to natural resources, sustainable growth
Inequality and Equity	Secure tenure and access to natural resources, water rights and entitlements
Sustainable Livelihoods	Sustainable land and water use practices
Health	Water quality, safe drinking water and sanitation, protection against water-borne disease
Security and Vulnerability	Improved disaster preparedness and response, water harvesting and conservation
Inclusion and Empowerment	Participation, devolution of ownership, rights and responsibilities to water users, community groups, basin organizations, local governments

1 This report is a joint initiative of the SADC Environment and Land Management Sector (ELMS) and the SADC Water Sector

beyond income and consumption, to include inequality, health, opportunity, [illegible] and [illegible]

Understanding the biophysical, social, and socioeconomic [illegible] is critical to addressing the environment, water, and poverty nexus because in many cases it is the poor, who are most directly or indirectly dependent on terrestrial and aquatic ecosystems for their livelihoods and [illegible]

"Because of social and economic [illegible], the poor often live in fringe areas, where access to potable supplies and adequate sanitation facilities is limited and where higher mortality, morbidity, and disease rates prevail. Or they live in highly vulnerable areas [illegible] and degraded watersheds), where [illegible] capacity to natural and anthropogenic shocks and disasters is limited. Also, poor downstream communities relying on flood recession agriculture, dry season livestock water supplies, fodder, [illegible], or fishing are often left out when major upstream water allocation or urban/industrial development decisions are made without adequate considerations of downstream uses." (Hirji and Ibrekk 2001: 2)

The overall goal of the report is to inform the policy and decision makers about the complex biophysical, social and economic dimensions of environmental sustainability in the water sector The report underscores the fact that sustainable management of water resources must incorporate at an operational level, the ecological, economic and social considerations into water resources planning and management decision-making. Another goal is to,

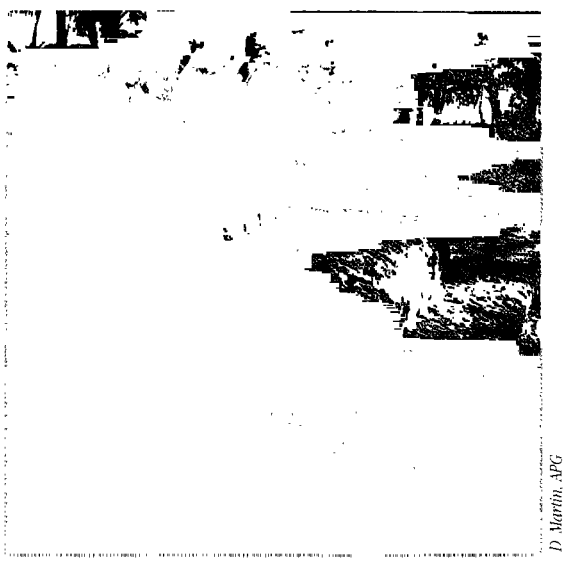
- provide policy guidance, practical approaches and operational tools for developing and managing the region's basic and vital resource – water – in an environmentally sustainable manner,
- share successful lessons and experiences about environmentally sustainable water resources management practices from the region, and
- define in operational terms the elements of "environmentally sustainable water resources management".

The report attempts to dispel myths about water and dependent ecosystems (Box 1.1) in order to assist policy makers and water managers to make informed project decisions on how to address [illegible] adverse impacts on important natural systems and livelihoods of downstream communities. Often, these voiceless communities are excluded during the planning and operations of major hydraulic infrastructure, and in this regard, the report underscores their important role in project planning and management decision-making. The report, however, does not focus on individual water sector issues (such as domestic water supply or irrigation or hydropower) or on groundwater; and it does not focus on climate variability or climate change considerations.

Misconceptions about water and water-dependent ecosystems — **Box 1.1**

There are a number of misconceptions about water and water-dependent ecosystems that are so widespread they are often taken as fact by various sectors and individuals, including in some cases, at high levels of decision-making:

- That water originates from pipes, and not from watersheds, springs and aquifers.
- That wetlands are wastelands with no social or economic value to society.
- That freshwater biodiversity is not important to the region
- That water flowing into the sea is wasted water.
- That downstream impacts of major water projects are insignificant and therefore should be ignored.
- That environmental management is a concern of outsiders and not of the region's people.
- That environmental management provides few benefits to society, but is costly and poses a huge economic burden.
- That existing Environmental Impact Assessment policies and laws are sufficient for integrating environmental sustainability criteria into water resources planning and management decision-making.



D Martin, APG

This water well, built over 1 [illegible] at Unguja Ukuu in southern Zanzibar and still in use, illustrates the long history of development and management of resources in the SADC region.

This chapter provides the conceptual framework for the report. It begins with the objectives of the report, and an overview of the key water resources issues in the region and the emerging water policy reforms. It also highlights the weakness in water policy reform of the operational integration of environmental sustainability criteria into the decision-making process. The conceptual framework for sustainability is highlighted next. This is followed by a review of the existing challenges to sustainable management of water resources. The chapter then identifies the opportunities at global, regional and national levels that can be used as a foundation to promote effective integration of environmental sustainability in the water sector. Finally, an overview is presented of the other chapters in the report.

1.2 OBJECTIVES OF THIS TECHNICAL REPORT

Compared to most developing regions of the world, the Southern African Development Community (SADC) is ahead of the curve in the search for environmentally sustainable solutions for managing its limited and fragile water resources. However, much needs to be done to have in place both an optimally effective policy and an institutional framework, and practices that reflect effective integration of sustainable management principles. As a contribution to the discourse on environmental sustainability in the water sector, the SADC Environment and Land Management Sector (ELMS), with the SADC Water Sector and partners[2] has prepared this technical report with the overall objective of,

enhancing the understanding of the ecological dimensions, and

promoting more effective integration of these dimensions into the management of water resources, thereby,

addressing a key SADC objective, "to achieve sustainable utilization of natural resources and effective protection of the environment."

The specific intention of this report is to provide a framework for defining tools for sustainable management of water resources and for operationalizing complex concepts related to the impacts on the water environment of changes in the amount, timing and quality of water resulting from direct water development activities, as well as indirect land use and other activities within the river basin. The report is based on an analysis of best practices from the region. The implementation of the recommendations of this report will contribute towards the mainstreaming of environmental sustainability in water resources management in the SADC region.

The report has been prepared by specialists from the SADC region,[3] and they include environmental planners and managers, natural resources economists, river scientists, freshwater ecologists, civil engineers, biologists, land use specialists, wetlands specialists, hydrologists, water resources management specialists, political scientists, sociologists, and journalists. The draft chapters of the report were presented for review to the National Technical Committee members of both SADC ELMS and SADC Water Sector at a workshop in Harare from 28-29 October 1999, and to a scientific advisory committee. More than 65 participants at the workshop included regional experts from governments, academia and non-governmental organizations. (See list of workshop participants in Annex 2) The final draft was peer reviewed by specialists from the region, the SADC ELMS and SADC Water Sector, and the World Bank.

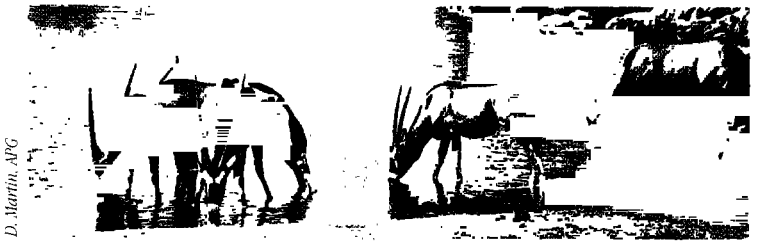
The target audiences of this report include water resources and environmental policy makers, planners, managers and decision-makers from the public and private sectors, and undergraduate and graduate students interested in various natural resources management disciplines.

1.3 KEY WATER RESOURCES ISSUES

In southern Africa, water is not only an essential resource, but also a limited and fragile resource. The availability of water underpins the social and economic fabric of the society in the region which is characterized broadly as underdeveloped with widespread poverty. The SADC region's population is largely rural-based but is urbanizing rapidly; and, although it is heavily dependant on agriculture, access to land and water in a few countries such as Namibia, South Africa and Zimbabwe has remained the domain of minorities, due to racially skewed policies of the past. Low coverage of water supply and sanitation facilities for the rural and

2 The partners include IUCN The World Conservation Union Regional Office for Southern Africa (ROSA), the Southern African Research and Documentation Centre (SARDC), India Musokotwane Environment Resource Centre for Southern Africa (IMERCSA), the Africa Water Resources Management Initiative (AWRMI) and the Environment Department of the World Bank, and the Swedish International Development Cooperation Agency (Sida)

3 The specific numerical data on pollution, water use, and water scarcity and other related parameters were derived by individual experts on the basis of the information that was available and may therefore vary from some of the officially sanctioned numbers. The authors and editors have tried to use official data when available and they take full responsibility for other data which cannot be attributed to SADC.



D. Martin, APG

Oryx at Namibia's Etosha pan, where water is a limited and vulnerable resource.

urban poor has a significant impact on public health. The region's wetlands support the livelihoods of 60 percent of rural farmers and pastoralists, as well as wildlife and other biodiversity. The region's energy is generated mostly from hydroelectricity.

In short, water is an **essential resource** for supporting human and other forms of life, maintaining ecological systems and sustaining economic development in all sectors.

1.3.1 Water scarcity in southern Africa

Water is also a **limited resource** in southern Africa (see Map 1.1). It is already scarce in a number of local basins. By 2025, on the basis of data on renewable supplies and demographics (Map 1.2), it is expected that Malawi and South Africa will be facing absolute water scarcity,[4] and Lesotho, Mauritius, Tanzania, and Zimbabwe will be water stressed;[5] while Angola, Botswana, DRC, Mozambique, Swaziland and Zambia are likely to experience water quality and [illegible] problems in the dry season. (See also Table 2.1 in chapter 2) Water demand for a rapidly increasing population (growing at a rate of 3 percent per annum) and an urbanizing population (growing at a rate of 6.5 percent per annum) will increase the stress on the limited water resources, and exacerbate competition and conflict between and among sectoral users.

In southern Africa, water is a **vulnerable resource**. Its vulnerability stems from several factors including:

extreme climate variability and emerging climate change which, in a predominantly rural-based society and agrarian economy determines if a season will result in bountiful harvest or a catastrophic event (such as the recent floods in Mozambique);

increasing degradation of water resources due to unsustainable water and land use practices such as overabstraction of surface sources or overpumping of groundwater (Box 1.2), pollution of water, watershed degradation (Box 1.3), loss of and encroachment on wetlands, [illegible] of aquatic weeds and introduction of alien species; and

Impact of groundwater overpumping — **Box 1.2**

Groundwater is used to supply an increasing number of urban and rural communities in the SADC region. The amount of groundwater that can be obtained in an area depends on the character of the underlying aquifer and the extent and frequency of recharge. If extraction exceeds the net recharge and these practices are sustained over long periods, severe irreversible impacts could result. These may include a drop in the water table, land subsidence, and saltwater intrusion, which in turn can trigger impacts on ecosystems — habitat destruction, potential loss of species, and reduction of environmental services performed by the degraded ecosystems and increase the cost of pumping.

Impacts of land degradation in the Lake Malawi-Shire River Catchment — **Box 1.3**

Soil erosion is resulting from deforestation caused by woodfuel harvests and cultivation on steep slopes in the Lake Malawi/Shire River catchment in Malawi, Tanzania and Mozambique. This is seriously affecting water resources, inhibiting fish reproduction, and possibly having serious impacts on lake levels.

In Malawi, the pondage at Nkula on the Shire River, supplies both the main power plant in Malawi and the pumping station, providing the entire water supply for Blantyre. Sediment bedload transported during the wet season by the Shire River tributaries between Liwonde and Nkula is accumulating in the Nkula pondage, affecting power output and Blantyre's water supply. As a short term measure, the power utility plans to dredge about 500,000 cubic metres of silt at a cost of up to US$3 million.

Even more serious, recent falls in Lake Malawi levels have threatened to stop flows into the Shire altogether, and cause almost complete failure of national power generation, Blantyre water supply, major irrigation schemes in the Lower Shire, and several wildlife habitats. Together, this would cripple the national economy.

The Malawi government recognizes the importance of improved water resources management in addressing the threats, but this also needs the cooperation of co-riparians Mozambique and Tanzania.

Grey 1996

4 Water scarcity can be defined as the availability of 1,000 cu m of freshwater, person/year, or less (PAI 2000) See Chapter 2, Table 2 1 for a more detailed calculation.
5 Water stress can be defined as the availability of 1,000-1,700 cu m of freshwater person/year. (PAI 2000) See Chapter 2, Table 2 1 for a more detailed calculation.

numerous transboundary waters in the region with complex water rights issues, contributing to the insecurity of downstream uses and nations.

1.3.2 Emerging policy reforms

It is now recognized that the effective management of water resources in southern Africa is an essential condition for alleviating poverty and improving human health, food security, environmental sustainability, overall economic development and regional security.

Actions to foster institutional and policy reforms for improving the management of surface and ground water are underway at the national, international, and regional levels. Most reforms are incorporating principles of economic efficiency, environmental sustainability, and social equity in water resources planning and management decision-making. At the national level, new water policies, strategies and master plans are being prepared and new institutional arrangements (river basin and catchment agencies) are being established. At the international level, agreements are being put in place for joint development and management of specific shared water resources.

At the regional level, the SADC Water Sector Coordination Unit has prepared a Regional Strategic Action Plan for Integrated Water Resources Development and Management in the SADC countries (1999 – 2004), which is being used as a basis for developing particular projects and programmes.

1.3.3 Integration of environmental sustainability criteria

Water resources management activities in the region include investments for urban, rural, industrial, mining, livestock, wildlife and agricultural water supply; sewage treatment; flood control; irrigation and drainage; hydropower and navigation projects or other projects which directly alter the quantity and quality of water resources. Other sectoral activities affecting waters resources include changes in land use to agriculture, forestry, mining, and construction (indirectly influencing runoff characteristics and infiltration regimes and sediment loads carried in surface waters), and industrial and agricultural discharge (impacting the chemical, biological and physical properties – or quality – of water).

A review of past and ongoing efforts, and of specific actions on the ground, indicates that, in spite of the ongoing important and innovative reforms taking place to address the water resources management challenges, many weaknesses remain and among the weakest areas of water policy reform is the integration of environmental sustainability objectives in operational terms into the planning and management decision-making on water resources investments.[6] This is a result of many complex factors that are the focus of this report and are examined in depth. Box 1.4 describes the different orders of resulting environmental impacts that can result from typical water resources management activities.

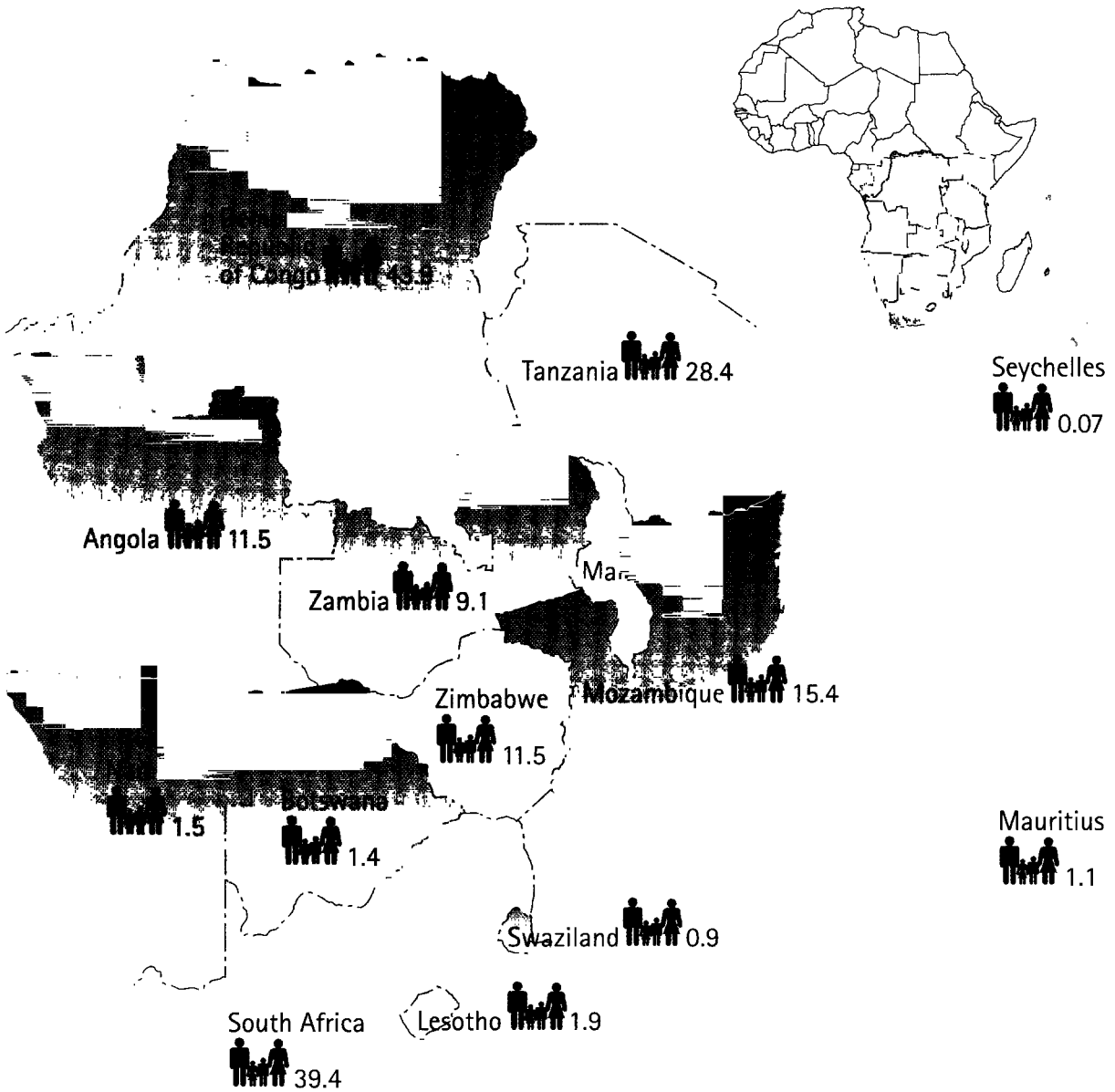
Principal environmental impacts of water resources management — **Box 1.4**

The principal environmental issues related to water resources concern effects on the quantity, timing and quality of water (first order impact)—from direct use or management of surface and groundwater, and from all sectors that use water or affect water resources in a catchment. Hydrological and water quality modifications caused by water management and other activities may in turn cause second order impacts (including primary productivity) and third order impact (on the food web) with consequences on downstream aquatic ecosystems, including wetlands, flood plains, estuaries and the marine environment and human settlements.

Although awareness about the environment has generally increased over the past three decades, the actual practice of integration of environmental quality objectives in water resources planning and management decision-making remains problematic. The concept of environmental sustainability is neither defined clearly by the environmental community nor is it articulated adequately in operational terms or integrated properly in water projects and policies by water managers. For example, few environmental managers and even fewer water managers understand properly the concepts and methods for determining water requirements for ecological uses. It is therefore not surprising that environmental uses of water invariably tend to be compromised in water allocation and use decisions, and particularly during water-use conflicts. Often, complex decisions are made on the basis of inadequate data, information and analyses or as a result of introduced biases. Even when sound analyses are carried out, the decision-making process is often overridden by economic and political considerations.

6 Other important weaknesses to be addressed include the effective participation of water users and stakeholders in the planning and management decision-making, and the realization of water as an economic resource with adoption of policies for recovering the cost of water services, and water resources protection and management.

Water Scarcity in Southern Africa: Water and People, 1995 **Map 1.1**



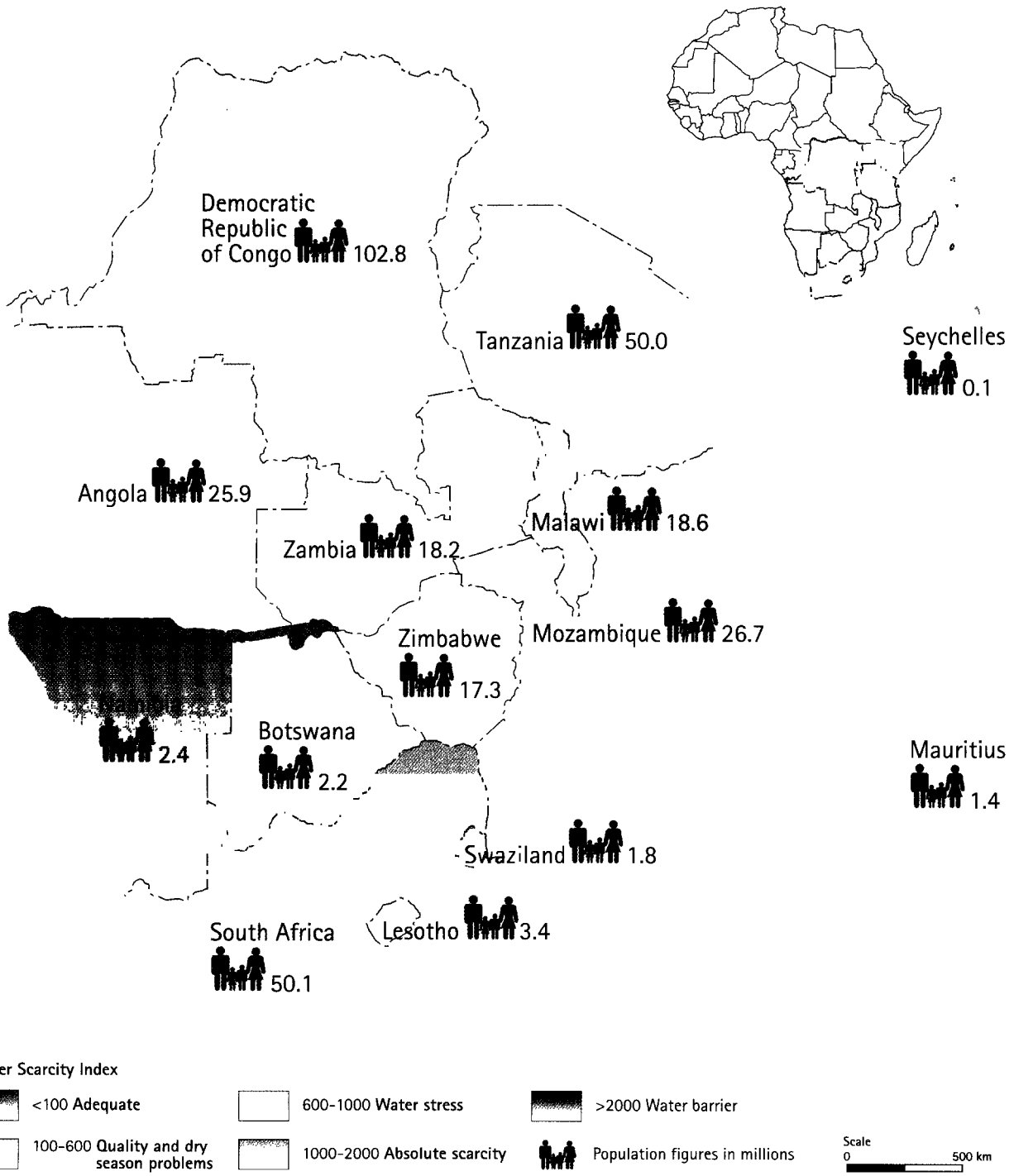
Water Scarcity Index

- <100 Adequate
- 100-600 Quality and dry season problems
- 600-1000 Water stress
- 1000-2000 Absolute scarcity
- >2000 Water barrier
- Population figures in millions

Scale 0 500 km

Water Scarcity Index from Falkenmark 1993. Recalculated using water availability data from Gleick 2000. Population figures 1995 from SADC, in *SADC Statistics 2000*. Data on availability represent average annual freshwater resources, as the actual will vary from year to year. The data cover surface and ground water including surface inflows from neighbouring countries, what FAO (1995) calls "total natural renewable water resources". Most countries do not measure or report internal water resources data, and estimates are produced using indirect methods. Data from small countries and countries in arid and semi-arid zones are less reliable than are those for larger, wetter countries. (Ohlsson 1995) Serious gaps in regional hydrological data still exist. (see also Table 2.1 in chapter 2)

Projected Water Scarcity in Southern Africa: Water and People, 2025 **Map 1.2**



Water Scarcity Index from Falkenmark 1993. Recalculated using water availability data from Gleick 2000. Population figures 1995 from SADC, projected for 2000 using 1999 population and annual growth rates in *SADC Statistics 2000*. Population projections for 2025 based on projections 2000-2025 from UN Population Division 1998, in UNFPA 2000, and recalculated at the same rate using SADC data for 2000. Comparative data for 2025 are reliant on population projections which are not calculated uniformly for each country, thus showing outdated and unadjusted figures, for example, for Angola and the Democratic Republic of Congo. Geographical variations within countries are also a factor, for example in Malawi and Namibia, where water resources are concentrated mainly in one part of the country while other parts of the same country are already short of water. However, Maps 1.1 and 1.2 represent the situation based on the most reliable data currently available. (see Table 2.1 in chapter 2)

This finding is not unique to the SADC region, but represents a fundamental and widespread problem. The African Water Resources Management Policy Conference in Nairobi in 1999 reinforced the need for managing water resources in an environmentally sustainable, socially acceptable and economically efficient manner. The World Water Vision presented at the second World Water Forum in the Hague in March 2000 highlighted environmental degradation as a serious emerging challenge to the water sector. The Report of the World Commission on Dams (WCD) issued in November 2000 proposes a new framework for decision-making for dam projects (Box 1.5), which emphasizes consideration for environmental and social issues and more active involvement of stakeholders.

1.4 CONCEPTUAL FRAMEWORK FOR SUSTAINABILITY

1.4.1 A system in crisis: a degrading and undervalued resource base

The water resources system, comprising water and water-dependent ecosystems, is essential for the sustenance and health of all species, human beings, plants, and animals. Although water in the region is treated as a source of natural capital that provides fundamental input for a whole array of human needs and economic development activities, and as a sink that is used as a receptor for wastewater discharges from municipal, industrial, mining, urban and agricultural activities, the important hydrological and ecological functions of freshwater dependent ecosystems are less well recognized, and are consequently, poorly addressed in planning and management decision-making.

1.4.2 Ecosystem goods and services

Aquatic ecosystems serve important ecological and hydrological functions which people, especially the poor, often directly depend upon. (Hirji and Ibrekk 2001) Box 1.6 highlights the multiple uses, values, services and functions of water and water-dependent ecosystems. Riverine, riparian and wetlands ecosystems provide many social and economic services and benefits, such as fisheries, nutrient removal, water supply, and forest products.
Understanding the range of benefits and services provided by aquatic ecosystems has vital equity and distributional implications when assessing possible changes to flow and quality as a result of upstream actions.

WCD priorities for sustaining rivers and livelihoods — Box 1.5

The World Commission on Dams (2000) has suggested the following strategic priorities for sustaining rivers and livelihoods:

- A basin-wide understanding of the ecosystem's functions, values and requirements, and how community livelihoods depend on and influence them, is required before decisions on development options are made;
- Decisions that value ecosystem, social and health issues as an integral part of project and river basin development, and that reflect avoidance of impacts are given priority, in accordance with a precautionary approach;
- A national policy is developed for maintaining selected rivers with high ecosystem functions and values in their natural state. When reviewing alternative locations for dams on undeveloped rivers, priority is given to locations on tributaries;
- Project options are selected that avoid significant impacts on threatened and endangered species. When impacts cannot be avoided, viable compensation measures are put in place that will result in a net gain for the species within the region; and
- Large dams provide for releasing environmental flows to help maintain downstream ecosystem integrity and community livelihoods, and are designed, modified and operated accordingly.

Water and water-based ecosystem values — Box 1.6

The diverse values of the services and functions provided by water and water-based ecosystems are:

- Direct values associated with consumptive and non-consumptive uses of water for domestic purposes, industrial outputs, irrigating crops, watering stock, production of hydro-power, for wild plants and wildlife, fishing, transport, recreation, etc.
- Indirect values which derive from ecosystem functions and services such as nutrient retention, filtering contaminants, regulating and storing flows, groundwater recharge, flood control, protection against storm surges, shoreline stabilization, micro-climate, etc.
- Option values based on premiums placed on possible future use and applications including for agricultural, industrial and pharmaceutical uses, etc.
- Non-use, intrinsic values on the basis of cultural, aesthetic, heritage, bequest and spiritual significance.

Turpie and van Zyl 2002

The World Water Vision highlighted the fact that there is a persistent and systemic water crisis in many countries that is being manifested in several different ways. (World Water Council 2000) On one hand, the gap between water supply and demand for urban, industrial, agricultural and energy uses remains very high, but on the other hand, unsustainable land and water-use practices are resulting in the depletion of the resource base. Some of the main problems in the SADC region, which are also cited in the World Water Vision Report are:

- Aquifers are being mined at an unprecedented rate and watertables are dropping in aquifers;
- Excessive water diversions for irrigation and regulation for power production have had devastating effects on downstream uses with some rivers ceasing to flow to the sea;
- Tensions and conflicts over water use are increasing;
- Lack of attention to maintenance in catchments has contributed to [illegible] and flood damage;
- The problem of pollution and water quality in rivers, lakes and aquifers is worsening;
- The rate of freshwater fish species extinction is high;
- Deforestation and land degradation are having significant negative impacts on urban water supply and reservoir siltation;
- The rate of wetland degradation is reaching alarming proportions;
- Aquatic weed infestations are impacting on water resources and imposing huge operational and maintenance costs.

1.4.3 Elements of sustainable water resources management: balancing use and protection

Sustainable water resources management encompasses two related components which are in a dynamic tension and which must be brought into balance:

- **utilization** (or development) of the water resources for various human needs; and
- **protection** (or management) of the water resources so that they can continue to be utilized for present and future generations.

Water is used to provide various services that are utilized for the benefit of people, through equitable distribution of goods and services. However, utilization of water resources has impacts. Poor planning and use of water resources can, for example, result in pollution, or abuse and degradation which in turn negatively impacts on the resource base. Thus, water resources need to be protected from these impacts in order to sustain the flow of goods and services. Protection of water resources underpins their utilization for the long term and ensures that sufficient water quality and quantity is available to meet basic human needs and protection of biodiversity. Equally important is the protection of ecosystem structure and function to maintain the resilience and sustainability of the resource. Protection is also important to ensure that the water quality requirements of water users can be met for the long term. (DWAF 1997)

1.5 CHALLENGES TO SUSTAINABLE MANAGEMENT OF WATER RESOURCES

1.5.1 Conceptual challenge

A central challenge facing the region is that the concept of sustainable water resources management is poorly understood by policy makers as well as by water resources planners and managers. The concept of the "environment" continues to remain elusive in spite of the progress made since the United Nations Conference on the Human Environment in 1972, the African Ministerial Conference on Environment and Natural Resources in 1985, and the United Nations Conference on Environment and Development in 1992. Although the First Dublin Principle, also known as the ecological principle, has been widely accepted, its implementation in the water sector is poor. There is a wide disconnect between water managers and environmental managers. Important hydrological and ecological services provided by the aquatic environment are considered to be of marginal value, and wetlands continue to be seen as wastelands and not an integral part of the water resource base. Water flowing into the sea is considered "wasted water". It is therefore not surprising that the environment continues to be addressed narrowly, its protection is seen by water managers as a "green" issue promoted largely by external interest groups.

Three decades after Stockholm and a decade after Rio, environmental protection is still considered as anti-development. The intrinsic properties of ecosystems are not well understood or appreciated, and consequently, biota are not seen as important indicators of the health of aquatic ecosystems – river, lake or wetland – upon which the livelihoods of millions of people, livestock, and wildlife depend, and which comprise important habitats

for biodiversity. This challenge reflects the fundamental failure of the global environmental community to adequately articulate to society the rationale, both economic and intrinsic, for the protection of aquatic resources. It is important to address this in order to improve the understanding of the ecological and hydrological services provided by aquatic ecosystems.

1.5.2 Absence of environmental quality criteria to define sustainability in the water sector

A related challenge is the absence of clear criteria that define environmental quality goals or objectives to guide water resources planners and managers in their decision-making. The absence of clear criteria, especially local criteria, typically compromises the environmental use requirements of water over the uses of water for sectoral purposes. The lack of specific measures of sustainability (for allocating water and setting water quality objectives) complicates the task of defining acceptable or allowable levels of change in quantity or quality, and this can result in an ambiguous level or degree of compliance to stipulated provisions. A set of clear guiding principles defining sustainable use and management of water resources is needed, to form the basis for developing specific national, international, and regional priorities.

1.5.3 Inadequate economic analysis

A third challenge relates to the use of limited and outdated economic evaluation methods – cost/ benefit analysis (CBA) – in project evaluation. (Turpie and van Zyl 2002) CBA typically considers economic issues related to the use and management of water resources, in which maximizing economic efficiency entails maximizing net benefits that contribute directly to the standard measures of economic performance, for example, Gross Domestic Product (GDP). Sustainability is perceived in terms of the benefits from economic activities associated with the direct use of water resources rather than for sustaining a full range of benefits, including ecological services, functions and biodiversity. This limited approach ignores the benefits of environmental management, the economic implications of degraded water resources and aquatic ecosystems, and their accounting as an opportunity cost of damaging economic activities and management approaches. Understanding the opportunity cost implications of water supply and allocation is central to making informed decisions about development and allocation trade-offs.

1.5.4 Ineffective environmental impact assessment processes

A fourth challenge is the over-reliance on environmental impact assessment (EIA) as a tool for effectively integrating the environmental concerns in project planning and decision-making. Even though EIAs are being implemented in most SADC member states, only a few countries have adopted EIA legislation, and even fewer countries implement this legislation effectively; fewer still have complementary sector policies that are essential for effectively implementing EIA. While EIAs are beginning to be considered as important tools for screening and predicting the environmental impacts of projects, in most cases the EIA requirements are not implemented effectively. Experience has indicated that the actual influence of EIA on project decision-making is typically limited. Often, EIAs are used only to legitimize decisions already taken (Hirji and Ortolano 1991). However, there is no question that the adoption of EIA policies has increased awareness about the environmental impacts of different investments and development activities.

1.5.5 Inadequate consultations and participation during the EIA process

The perception that the EIA process only legitimizes decisions that are already formed arises from several factors. In societies with mature EIA practice, the EIA process broadens the planning and management decision-making process. In most SADC countries, the EIA practices are still nascent and are tightly controlled. Opening up the project decision-making process is often considered as a loss of control and a threat by project authorities. A related factor is the limited or controlled consultation process adopted during the preparation and implementation of EIAs.

Major water sector investments not only alter the river flows and associated ecosystems, but also impact the upstream and downstream riverine communities and people dependent on the waters, ecosystems and associated products. Often, the proponents of major water resources investments are large and powerful public and private utilities (for example, responsible for the generation of energy, provision of irrigation or domestic water supply) or agencies (for example, river basin authorities, irrigation districts or corporations) with the financial, technical and human resources to procedurally influence the EIA process, and content-wise even influence the EIA

Pastoralists such as Maasai and other small rural communities are often [illegible] in the decision-making process because they lack adequate representation and resources.

outcome. Whereas, downstream interests typically impacted directly by major infrastructure investments are smaller rural communities, pastoralists, and environmental and other interests, who lack representation, standing and adequate resources to effectively participate in project decision-making processes which have [illegible] consequences for their livelihoods. Without adequate consultation, affected communities and important users of water are often [illegible] in the decision-making process. Consequently, the important values associated with the whole range of uses of water are often undermined or skewed, thus biasing the decision-making process. Furthermore, often the benefits derived from major investments (such as hydropower revenues from exports, for example) are typically for urban users far away from either the project sites or project-impacted locations. Thus, the impacted communities are twice worse off. They do not even benefit from the investments that are damaging or destroying their livelihoods.

Improving project decision-making requires timely and appropriate levels of consultation and participation, and careful attention to the factors which can diminish the influence of EIA (Box 1.7). It also calls for sharing the benefits of the development with the impacted communities. This is a key recommendation of the World Commission on Dams (WCD) Report as well.

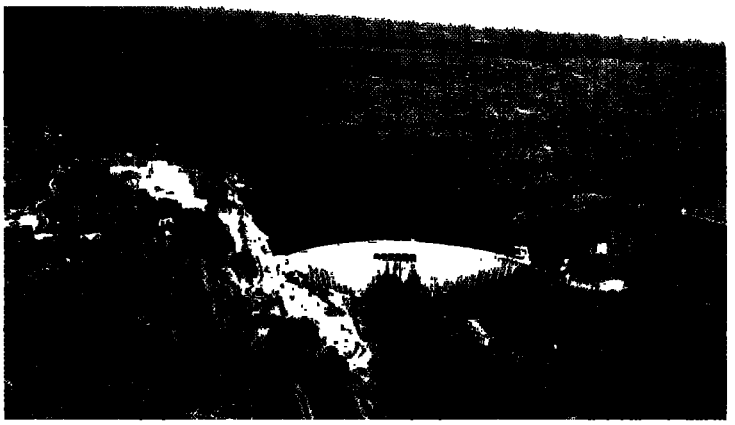
1.5.6 Environmentally unsustainable water management policies

Reliance on outdated water policies based on command and control approaches, impedes the development of environmentally sustainable, water resources management investments and programmes. Few water policies explicitly define and prioritize in operational terms the environmental uses of water. The influence of EIAs on

Factors that can undermine the influence of EIAs on project decision-making — **Box 1.7**

The influence of EIA on project decision-making can be diminished if,

- the scope of the EIA is narrow (for example, if downstream impacts of a dam project located in a sensitive ecological area are not evaluated properly);
- the methods used to predict and forecast the impacts are not adequate;
- the EIA is implemented late in the decision-making process (for example, after the project has been sited or after the major project design decisions have been made);
- there is a conflict of interest involved (between the project proponent and a regulatory agency or between the design firm and the firm that is carrying out the EIA);
- there is no independent body to oversee implementation;
- no analysis of alternatives is carried out;
- the economic value of resource degradation is not incorporated into the project's cost/benefit analysis and decision-making.



M Kullberg

The benefits of major investments such as hydropower [illegible] to urban dwellers while impacted communities may lose their livelihoods. Above, Kariba dam generates power for Zambia and Zimbabwe.

project decision-making is limited if the associated water policies do not clearly define the principles of water allocation and prioritize water use for ecological purposes (for example, specifying the amount and timing of flows for ecological purposes in a hydropower project). Under such circumstances, EIAs would be required to define and determine the downstream flow requirements, and also to legitimize such requirements. The latter puts an enormous burden on the EIA process that can be manipulated when major development interests are at stake.

Equally important is the need for developing water resources management policies that integrate appropriate instruments:

- economic (*eg*, pricing, tariffs, demand management, subsidies, etc.);
- regulatory (*eg*, laws and regulations); and
- participatory (*eg*, user representation, transparency, participatory planning and decision-making, education, awareness, consultations, etc.).

In the SADC region, the post-independence tendency has been an over-reliance on inherited colonial laws and regulation (command and control instruments) which have proved ineffective because the overall legal and institutional environment is weak. Under such conditions, the chances of enforcing a good "water law" or "environmental legislation" are limited if most laws are poorly enforced.

Most pollution control measures including those that relate to discharging treated or semi-treated industrial and municipal effluent into receiving water bodies, or re-using partially treated wastewater, are poorly enforced. Alternative economic and participatory instruments which provide incentives encouraging the wise use of water and disincentives against harmful practices of water use and management and user participation and consultation, which have been successful in other contexts, need to be explored and encouraged.

A rich tradition of successful community-based, water management activities exists in the SADC region, some of which were discontinued after independence. Lessons from successful practices need to be learned and institutionalized. The tradition may also be amenable to promoting innovative participatory resource management through consultative approaches, improved public education and awareness building, and the introduction of public disclosure measures.

DWAF, South Africa

The Lesotho Highlands Water Project [illegible] Lesotho [illegible] water sales and hydropower, and provides South Africa with reliable access to cheap, [illegible] water. Phase 1B includes a detailed study of Instream Flow Requirements (IFR) to address downstream impacts in Lesotho.

1.5.7 Environmental regulations for international waters

A seventh challenge relates to the weak legal framework for addressing environmental issues related to the management of international waters. National water policies generally have weak environmental provisions, but the provisions for international waters dimensions are even weaker or non-existent. A major consequence of this is that most international waters treaties and arrangements that are in place are without an adequate assessment of the downstream environmental flow requirements. Thus, important ecosystems in downstream countries are impacted disproportionately. In a few instances, minimum flow provisions derived on the basis of hydrological information are used to define such flows. It is only in recent years that the concept of environmental flow requirements has been adopted as a principle in water allocation decisions.

The Lesotho Highlands Water Project (LHWP) Phase 1B includes a detailed Instream Flow Requirement (IFR) study to stipulate IFRs. The IFR study has just been completed. The LHWP, based on a 1986 treaty between the governments of Lesotho and South Africa, provides compensation releases (of between 3-5 percent of the mean annual runoff) for the purpose of maintaining downstream ecosystems, however these releases were not determined on the basis of a sound knowledge base about the downstream ecosystem flow requirements. The IFR study for the LHWP addresses downstream impacts in Lesotho. The Department of Water Affairs and Forestry in the Republic of South Africa has carried out an independent IFR assessment on the Orange River from the border of Lesotho to the Gariep Dam. Effective implementation of the IFR study recommendations will form the real test of the degree to which the LHWP balances between its economic and environmental objectives. This will also be an important case to test the new Water Law in South Africa and the SADC Protocol on Shared Watercourses.

Most other international waters treaties and arrangements in the region do not adequately address the environ-

mental flow requirements for downstream uses, which is a major shortcoming of the existing allocation practices that also shortchanges the downstream nations. For the SADC region, this poses a [illegible] challenge since 15 major international rivers are shared by more than one country. (see chapter 2, Table 2.5) Mozambique, which is the downstream riparian in nine river basins, bears the greatest impacts of upstream development.

1.5.8 Capacity constraints

An eighth challenge is the limited capacity to carry out the complex environmental management analysis. There is need to develop effective in-house capacity to carry out the complex tasks related to the management of natural resources. Effective water resources management is a complex task. Effective environmental planning and management is even more complex and requires many and varied skills, a network of capable institutions and [illegible] analytical capacity. Much of the environmental management work in the region's water sector is being undertaken by a very [illegible] group of ecologists, environmental engineers and environmental planners of public sector and academic institutions. Often [illegible], these professionals are commonly over-burdened, under-resourced and poorly compensated. They generally have limited access to professional associations, peer review, mid-career training, books and journals, and other professional incentives.

There is also a critical need to go beyond basic ecology, engineering and environmental science to incorporate, for example,

- social science inputs to discern the population at risk and the social risk factors involved,
- economic skills that can place a value on the losses resulting from wetland and watershed degradation,
- limnology to ascertain the limiting nutrient in a eutrophic body or nutrient loads entering a water body, or
- to link [illegible] hydrology to estimate environmental flow requirements.

Developing proper biophysical/socio-economic linkages is essential for properly addressing the environmental sustainability considerations in the appropriate socio-economic contexts.

Few specialist skills exist in the local private consulting industry, and most come from international consultants and advisers. There is need to develop greater capacity to be able to address the emerging challenges.

1.5.9 Emerging trends

Addressing the growing water resources management challenges with rapidly increasing populations in general, and urbanization in particular, and associated multi-sectoral demands is a daunting task, but meeting these challenges in a sustainable manner is a huge and complex task. Nonetheless, it is essential to address the emerging multi-pronged challenges because water resources in the region are both limited and vulnerable.

The recent trend in management of water and energy sectors towards privatization and deregulation of utilities, and increasing vulnerability due to the implications of climate change, compound the complexity of the [illegible]. While the rationale for privatization of utilities, in order to improve service delivery and efficiency and to raise capital might be obvious, it is important to ensure that the process of privatization and/or deregulation is carried out carefully, with the appropriate regulatory safeguards in place to protect the water resource base. It is also essential to ensure that such a process does not lead to dismantling of important water resources and environmental management regulations and legislation. The privatization process should be expected to strengthen, not weaken the capacity of national governments to regulate and manage the water resources effectively. The private sector on the other hand, values certainty. Thus, clear criteria and guidelines are necessary to ensure that investment is guided to be responsive to the social and ecological constraints and interests.

1.6 OPPORTUNITIES TO BUILD UPON

The challenges for addressing the mainstreaming of environmental quality objectives in the water sector cannot and should not be promoted in isolation, but need to be complemented with or integrated as part of the ongoing innovative activities and actions taking place on the ground. There are many opportunities to build upon and some of these are reviewed below.

1.6.1 Consensus on principles of sound water resources management

There already exists an international consensus on the principles of sound water resources management. The Dublin Principles call for:

- placing greater emphasis on integrated, cross-sectoral water management;

addressing water quantity and quality, and environmental considerations in water management;
linking land-use management as an integral part of sustainable water management;
using river basins as management units;
recognizing water as an economic good and promoting cost-effective interventions;
supporting participatory efforts to manage water resources;
focusing on actions to improve the lives of people and the quality of their environment;
adopting positive policies to address women's needs and empower women; and
incorporating mechanisms for conflict prevention and resolution.

Box 1.8 highlights the important environmental management principles relevant for the water sector.

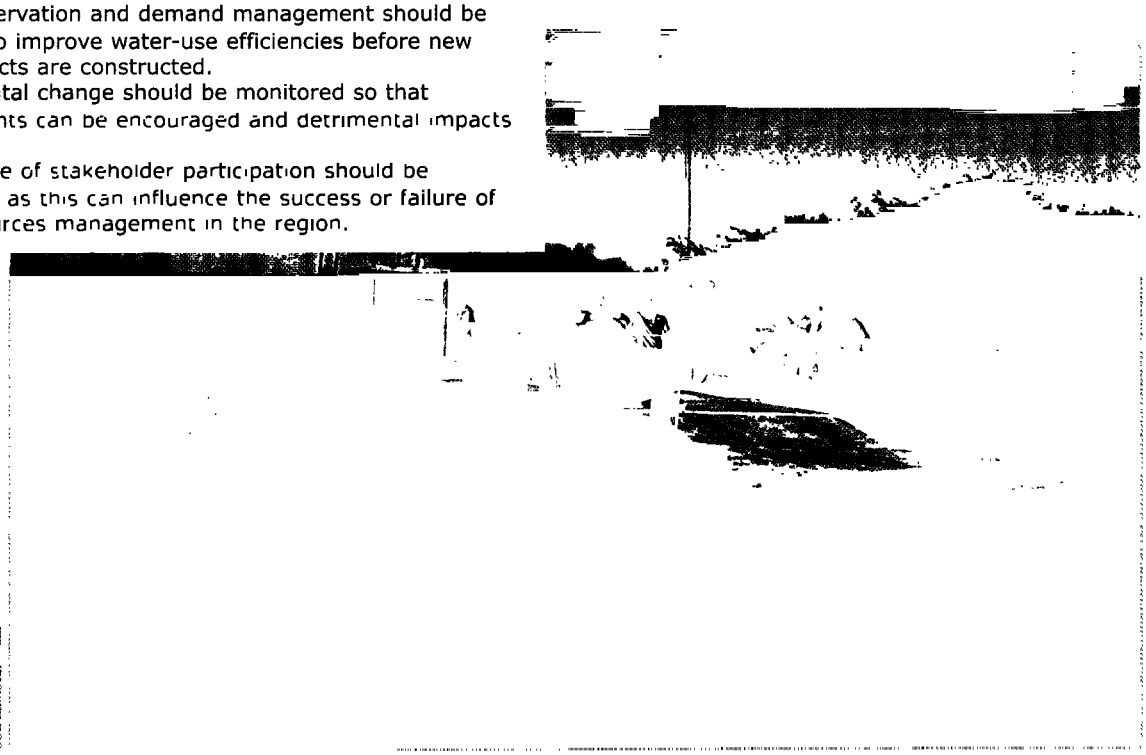
Environmental management principles for the water sector **Box 1.8**

- Water-related activities should aim to enhance or to cause the least detrimental effect on the natural environment and its health- and life-giving properties.
- The allocation and consumption of water for environmental purposes should be recognized and given appropriate emphasis.
- Water conservation and demand management should be promoted to improve water-use efficiencies before new water projects are constructed.
- Environmental change should be monitored so that improvements can be encouraged and detrimental impacts minimized.
- The principle of stakeholder participation should be encouraged as this can influence the success or failure of water resources management in the region.

1.6.2 International agreements, conventions and initiatives

A number of international agreements, conventions and initiatives such as Agenda 21, the Convention on Biological Diversity (CBD) and the Convention to Combat Desertification (CCD), which SADC member states are party to, promote the principles of sustainable management of water resources and the environmental management for the water sector. Recent initiatives such as the Second World Water Forum (WWF) and the World Commission on Dams (see Box 1.5) have expanded the core principles related to the social and environmental sustainability considerations in water resources management. Follow-up initiatives to support the implementation of the WCD and WWF recommendations are underway, some of which will support water management reforms in the SADC region.

In addition, partners from multilateral and bilateral institutions are supporting various water resources management activities at the regional and national levels. These include the World Bank, UNDP, UNEP, Global Environment Facility (GEF), and a consortium of several agencies under the Global Water Partnership, several bilateral agencies, and non-governmental organizations



SOE Zambezi – CEP

Water-related activities should cause the least detrimental effect on the natural environment and it's life-giving properties.

such as IUCN, many of which have embraced their own policies or developed programmes on water resources management. The World Bank, for example, has issued a new Environment Strategy and is finalizing a Water Resources Sector Strategy and the World Development Report. The UN is preparing the first edition of the World Water Development Report. The GEF supports international waters, biodiversity and climate change projects to safeguard the global commons. These initiatives and activities potentially provide the region with important opportunities for soliciting support for building and strengthening local capacity for effectively mainstreaming the environment in water resources management.

1.6.3 Regional water management and environmental initiatives

The following factors contributed to the realization that a regional coordination mechanism for water resources was required:

- recurrent droughts (particularly 1991/92 and 1994/95);
- occasional flood disasters;
- increasing demand for water;
- the possibility of conflicts over access to water;
- increasing pollution; and
- heightened awareness among SADC member states of the importance of Integrated Water Resources Development and Management.

There are a number of important regional water resources initiatives which lay the foundations for further cooperative action. The most significant development towards achieving integration of the regional use and management of water resources was the ratification in 1998 of the SADC Protocol on Shared Watercourse Systems, which was further reviewed in 1999/2000. The Revised Protocol on Shared Watercourses was signed by SADC Heads of State or Government at their annual Summit in August 2000 in Windhoek, Namibia, and comes into force upon ratification by two/thirds of Member States.

This followed the establishment by SADC of the Water Sector Coordination Unit (WSCU) in 1996, in recognition of the role water resources play in the wellbeing of the people of the region.

In view of SADC's overall development goals of poverty alleviation, food security and industrial development within the framework of an integrated regional economy, the vision of the Water Sector is to attain the sustainable and integrated planning, development, utilization and management of water resources that can contribute to the attainment of SADC's overall goals.

In pursuit of its vision, the SADC Water Sector developed in 1997 and 1998, in a participatory and consultative manner, the Regional Strategic Action Plan (RSAP) on Integrated Water Resources Development and Management. In December 1998, the Water Sector organized a successful roundtable conference in Geneva to mobilize resources for implementation of the RSAP. Some 34 cooperating partners attended the conference, and a substantial number have pledged their support for implementation. Box 1.9 lists the main objectives of the RSAP.

The preparation of this technical report on *[illegible] and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa* by the SADC ELMS in conjunction with the SADC Water Sector is intended to provide a conceptual basis for the preparation of a wide range of environmental management programmes and projects related to water resources management. For example, the SADC Water Sector is preparing a project to be funded by the GEF on the management of aquatic weeds; chapter 8 of this report provided the basis for the preparation of that project.

This technical report also presents specific recommendations for strengthening the environmental aspects of the SADC Protocol on Shared Watercourses and the implementation of the SADC Regional Strategic Action Plan for Integrated Water Resources Development and Management in the SADC Countries (1999 – 2004).

1.6.4 National water policy, legal and institutional reforms

Several countries (for example, Malawi, Mozambique, Namibia, South Africa, Tanzania, Zambia, and Zimbabwe) have initiated innovative water resources management policies, legal and institutional reforms. Such reforms include the preparation of new water resources management strategies and river basin management plans and activities. Some reforms include innovative, environmentally sound water policies and provide a unique opportunity for sharing experiences. The ongoing water policy reforms in general offer a key opportunity for mainstreaming environmental considerations in the formulation of policy on water resources management, and in river basin planning and management.

Main objectives of the Regional Strategic Action Plan for Integrated Water Resources Development and Management in the SADC Countries Box 1.9

The major objective of the Action Plan is to provide a framework for the region to successfully meet the challenge of developing a comprehensive and integrated approach to water resources development and management. Such an objective is to be accomplished through a commitment to:

- Attaining a much stronger human and institutional capacity to formulate laws, policies and norms which allow water resources to be used cost effectively as an economic and social good; and
- Ensuring the more efficient use of existing and planned infrastructure projects which harness water's potential in an environmentally and economically sustainable manner.

Strategic Objective 1
Improve the Legal and Regulatory Framework at the National and Regional Level

- Harmonize water laws
- Set standards for drinking water
- Develop water quality standards
- Enforce standards
- Provide framework for adequate dispute settlement mechanisms
- Create equitable use of shared waters through river basin commissions

Strategic Objective 2
Improve National and Transboundary River Basin Management, Planning and Co-ordination

- Improve capabilities of national water authorities
- Improve regional co-operation in river basin management
- Develop equitable use of shared waters through river basin commissions
- Establish better inter-sectoral planning and co-ordination of water sector in each country
- Strengthen SADC Water Sector Co-ordination Unit

Strategic Objective 3
Strengthen Linkages between Macroeconomic, Social and Environmental Policies

- Shift water use to most efficient use based on economic values
- Establish cost recovery mechanisms
- Balance water resource demand and supply
- Conserve water resources

Strategic Objective 4
Improve Information Acquisition, Management and Dissemination

- Monitoring programmes
- Assessment methods
- Information access and exchange
- Regional hydro-meteorological data banks
- Interdisciplinary knowledge
- Research for new initiatives

Strategic Objective 5
Support Awareness-building, Education and Training

- Share knowledge about water resources
- Identify best management practices
- Support regional and national centres of excellence
- Expand educational programmes
- Demonstrate effective technical co-operation
- Develop training courses on water resource management

Strategic Objective 6
Promote Public Participation

- Identify stakeholders and stakeholder contributions
- Ensure full and effective stakeholder participation, and promote stakeholders' participation
- Establish community-based water management groups
- Adopt positive policies to address the needs of women and the disadvantaged

Strategic Objective 7
Invest in Infrastructure

- Expand infrastructure development and implementation
- Meet demands of multiple users
- Ensure efficient use of water resources
- Plan and implement works in a holistic manner
- Balance social and environmental concerns with infrastructure development.

http://www.sadcwscu.org.ls/programme/rtc/rtc-VI.htm

1.7 AN OVERVIEW OF OTHER PARTS OF THE REPORT

This report is organized in four parts and contains 11 chapters. The report discusses the principal areas of environmental management related to the water sector, presents practical methodologies and approaches to address the major challenges in each of the key areas, draws lessons and best-practice information on topical issues related to environmental sustainability of water resources management, and recommends specific actions for effectively integrating environmental sustainability criteria in water policies, for improving water resources project-planning and management decision-making, and for strengthening the capacities of water and environmental management agencies.[7]

Part 1

Water Resources Development and Management: Striving for a Sustainable Balance

Part 1, with four chapters, provides the overall context of the report which is to strive to achieve a sustainable balance between the development of water resources for beneficial uses and their protection.

Chapter 1 presents the conceptual framework for defining and mainstreaming environmental sustainability in water resources management.

Chapter 2 on *Water and the Economy* provides the socio-economic and ecological context of the water sector in the region.

Chapter 3 on *The Role and Importance of Aquatic Ecosystems in Water Resources Management* describes the principal threats to freshwater ecosystems and biodiversity and discusses the associated social and economic costs and implications of resource degradation.

Chapter 4, *Valuing the Environment in Water Resources Management*, focuses on a central issue in the debate on the sustainable management of water resources, and describes the methods for the valuation of environmental damage and the economic trade-offs often made in allocation decisions.

Part 2

Water Resources Management: Safeguarding the Resource Base

Part 2 also has four chapters, each focusing on particular aspects of water resources management that impact on the sustainability of the resource base.

Chapter 5, *Environmental Flows: Requirements and Assessment*, discusses the single most difficult issue in the debate, that is, how much water to allocate for downstream ecological purposes when planning a major storage dam or abstraction project for generating power, or for irrigation, municipal supply or flood control.

Chapter 6 on *Water Quality Management and Pollution Control* addresses issues which have not received the attention they deserve because of the misperception that water pollution is not yet a serious problem in the region.

Chapter 7 *Watershed Degradation and Management* covers another problematic topic in the region and it links upstream actions (land use and management) with downstream effects on water resources, underscoring the importance of protecting source waters.

Chapter 8 *Aquatic Weeds and Their Control* is a detailed review of the growing problem of water weeds and their control in the region, and it evaluates the physical, chemical, biological and integrated methods for controlling water weeds.

Part 3

Legal and Institutional Framework: Mainstreaming the Environment in Water Resources Management

Part 3 of the report, with two chapters, addresses the mainstreaming of the environment in the water sector.

Chapter 9 on *Community-based Water Resources Management* focuses on the critical role of ownership and participation as essential ingredients in successful community-based, water resources management programmes, and recommends actions for institutionalizing community-based water management practices in existing programmes and policies.

Chapter 10, *Legislative and Institutional Framework*, reviews the adequacy of existing planning tools, water policies and environmental policies, and institutional arrangements for effective integration of environmental quality considerations.

Part 4

Lessons Learned and Recommendations for the Way Forward

Chapter 11, *A Framework for Mainstreaming the Environment in Water Resources Management*, draws from and is a synthesis of all the other chapters, defines a set of sustainability criteria for the water sector in the SADC region and recommends specific measures for mainstreaming environmental quality considerations in the water sector.

[7] Each of the technical chapters, 3 through 10, can be used as stand alone chapters that address a particular topic or theme. Consequently, some overlapping information may exist and has been left in to safeguard the integrity of each chapter.

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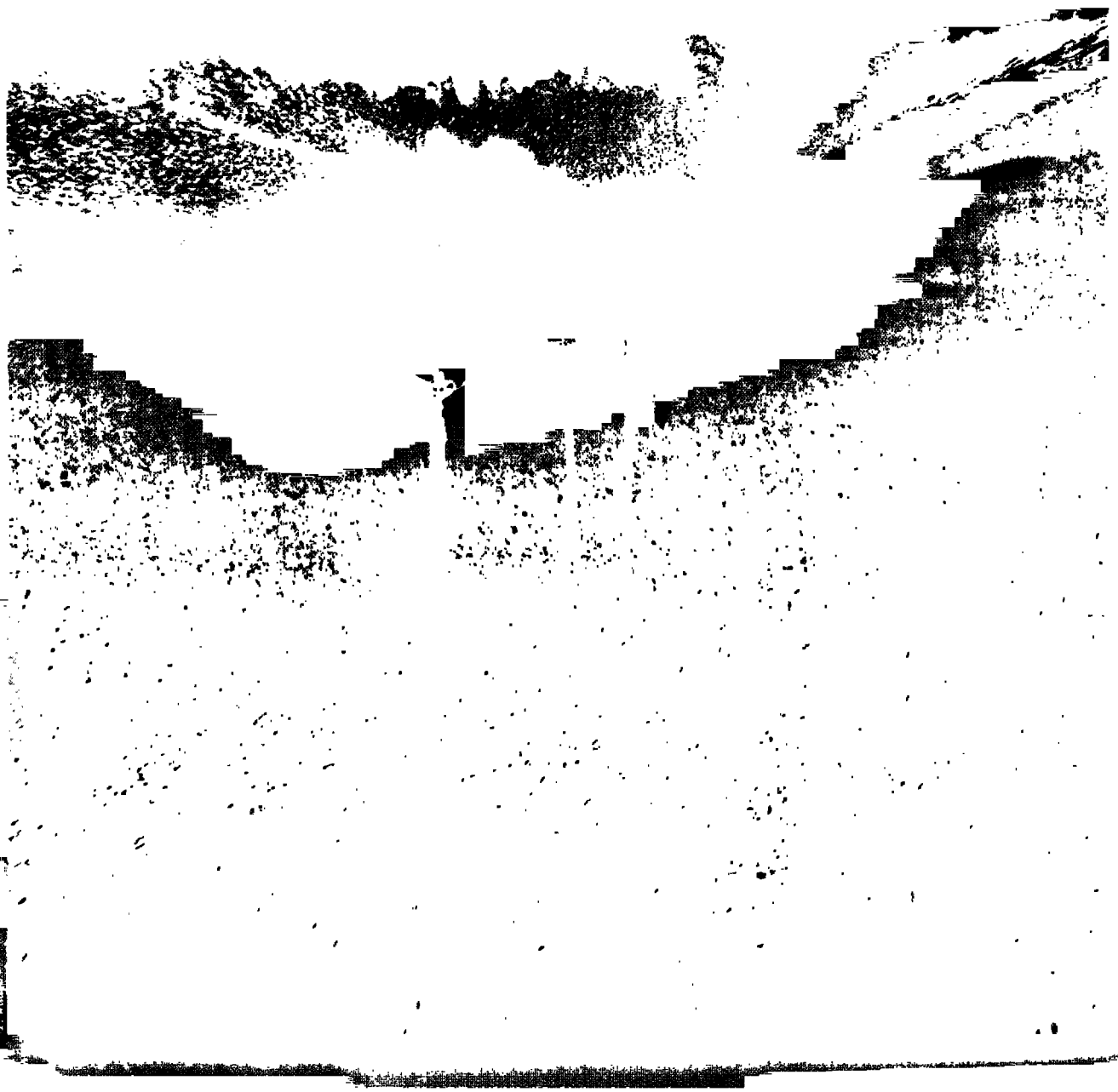
WATER AND THE ECONOMY

Tabeth Matiza Chiuta, Phyllis Johnson and Rafik Hirji



CONTENTS

ACKNOWLEDGEMENTS This chapter builds on earlier SADC work through the Communicating the Environment Programme (CEP) partnership with IUCN and SARDC, such as *State of the Environment in Southern Africa* (1994), *Water in Southern Africa* (19[illegible] *and Woodlands* (2000), and *State of the Environment Zambezi Basin 2000* (in English and Portuguese). The authors would like to acknowledge the work of the former Director of SARDC IMERCSA, Munyaradzi Chenje, now at UNEP, whose first draft was used in the development of this chapter.

WATER AND THE ECONOMY

2.1 OVERVIEW

Freshwater is a scarce resource in southern Africa, and its level of development for consumptive and non-consumptive uses is very low. These are limiting factors for sustainable growth and poverty alleviation. For a region whose population is [illegible] rural-based and still heavily dependent on agriculture for their livelihood, the availability of water largely determines when and where development can take place. (Pallett 1997) For every country in the Southern African Development Community [illegible], water is an essential resource for all sectors of the national economy, [illegible] the generation of hydropower, commercial and industrial development, sustenance of wildlife and national parks, terrestrial and aquatic ecosystems, sanitation and navigation; and water also nourishes a range of spiritual values that contribute to the [illegible] of society.

Subsistence and commercial agriculture, livestock production, fisheries and tourism account for the bulk of employment, economic output and export earnings in much of the region, and all of these activities are dependent on water supply.

Floods and droughts directly impact on livelihoods and quality of life, and poor people are most vulnerable to such water shocks. Local and seasonal water scarcity is [illegible] competition between and among sectoral uses of water, and a [illegible] consequence is that ecological uses of water are being undermined as they are typically accorded the lowest priority. This in turn is compromising the sustainability of the resource base.

This chapter highlights the importance of water to the region's economy and the huge gaps that exist in water demand and developed supplies in many sectors. The existing and emerging water resources management challenges are summarized, raising fundamental questions about the conventional (or supply side) water-resources development approaches that have been used and [illegible] for a reassessment. The chapter lays the foundation for the rest of the report, which,

- looks at water resources from a broader perspective, as a resource with multiple uses and functions;
- defines specific issues and practices that are unsustainable and therefore economically inefficient as they threaten the resource base; and
- proposes policy and institutional reforms, planning and management practices that are environmentally sustainable, socially acceptable and economically efficient.

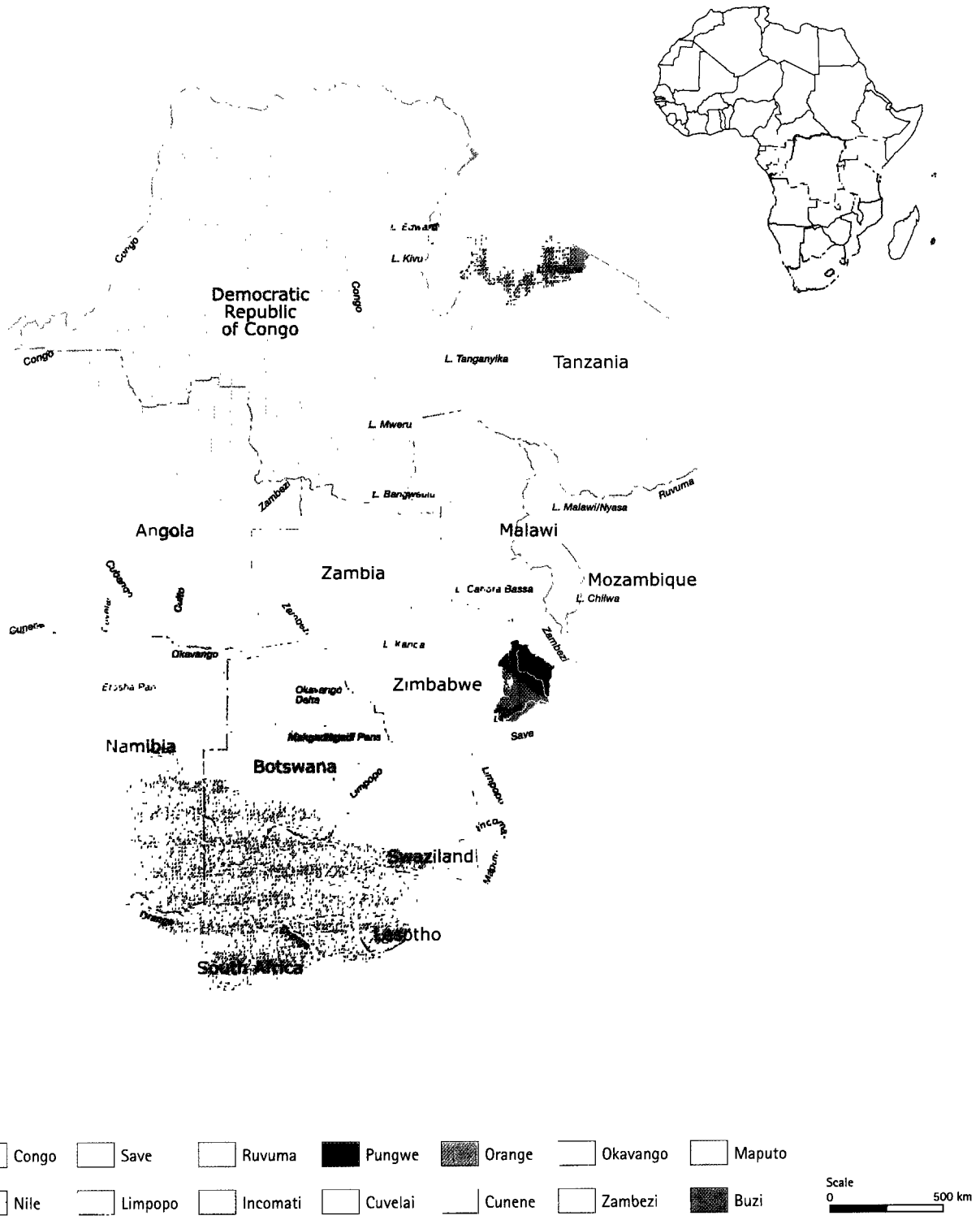
2.2 FRESHWATER RESOURCES

Freshwater is a renewable resource made available by the sun's [illegible] evaporates water into the atmosphere from the oceans and land surfaces, and [illegible] it into the stocks, flows and interactions of ice, liquid and vapour that are known as the hydrological cycle. Through rainfall, mist and dew, there is a continuous transfer of water to the land, which runs off in rivers and streams or is stored in lakes, soils and groundwater aquifers. Water is in continuous and rapid transformation from one form and stock to another. (Gleick 2000) Southern Africa's freshwater resources are found in [illegible] order by volume as determined for global freshwater stocks):

- Fresh groundwater aquifers;
- Freshwater lakes and reservoirs;
- Soil moisture;
- Atmospheric water vapour;
- Freshwater aquatic ecosystems, [illegible] wetlands;
- Rivers.

Main International River Basins of the SADC Region

Map 2.1



SADC Water Sector 2002
The smallest international river basin in the SADC region, the Umbeluzi, is not shown here. (see Table 2.5 in chapter 2)

Map 2.1 shows the lakes and major international river systems in southern Africa, and it is evident from the map that these river basins cover a large part of the SADC region. Namibia, for example, has access to five international river basins, yet it is one of the most arid countries in the region. Mozambique shares nine rivers with neighbouring countries upstream. (Table 2.5) The largest river basin wholly within the SADC region is the Zambezi, which drains part of eight countries.

A river basin is the area that contributes hydrologically to a river system that ends in the ocean or a terminal (closed) lake or inland sea. A basin is considered "international" if any perennial tributary crosses the political boundaries of two or more countries. These international river basins are the foundation of the SADC Protocol on Shared Watercourses and the main focus of the Regional Strategic Action Plan (RSAP) for Integrated Water Resources Development and Management in the SADC Countries.

2.2.1 Water availability and use

Freshwater is unevenly distributed within national boundaries and across the countries of southern Africa. Table 2.1 shows the availability of renewable freshwater resources for each country per year, population pressure over a period of 30 years, and a Water Scarcity Index. Table 2.2 shows per captia availability. Data on [illegible] represent average annual freshwater resources, as the actual renewable supply will vary from year to year. The data cover both surface water and groundwater, including inflows from neighbouring countries, thus "total natural renewable water resources". (UN FAO 1995)

Most countries do not directly measure or report internal water resources data, and estimates are produced using indirect methods. Data from small countries and countries in arid and semi-arid zones are less reliable than are those for larger and wetter countries. Ohlsson (1995) adds that many figures still in frequent use are drawn from Belyaev's work in the 1970s at the Institute of Geography in the Soviet Union. He compiled data on water resources availability from models using other data, such as area under irrigated agriculture, livestock populations, and precipitation.

Serious gaps in regional hydrological data still exist, and Ohlsson concludes that the unsatisfactory state of

	Year of estimate and source	Annual renewable water resources (cu km/yr)	Population (000)			Population pressure on water availability (people/M cu m/year)			Water scarcity index		
Country			1995	2000	2025	1995	2000	2025	1995	2000	2025
Angola	1987 b	184	11 558	13 302	25 940	63	72	141	1	1	2
Botswana	1992 c	14.7	1 459	1 651	2 270	99	112	154	1	2	2
DRC	1990 c	1 019	43 900	50 730	102 830	43	50	101	1	1	2
Lesotho	1987 b	5.2	1 930	2 140	3 400	371	412	654	2	2	3
Malawi	1994 c	18.7	9 374	10 160	18 695	501	553	1000	2	2	4
Mauritius	1974 c	2.2	1 122	1 205	1 410	510	548	641	2	2	3
Mozambique	1992 c	216	15 400	17 245	26 730	71	80	124	1	1	2
Namibia	1991 c	45.5	1 590	1 817	2 460	35	40	54	1	1	1
Seychelles	-	n/a	75	82	110	-	-	-	-	-	-
South Africa	1990 c	50	39 477	44 000	50 160	790	880	1003	3	3	4
Swaziland	1987 b	4.5	908	1 046	1 800	202	232	400	2	2	2
Tanzania	1994 c	89	28 400	32 422	56 090	319	364	630	2	2	3
Zambia	1994 c	116	9 100	10 755	18 285	78	93	158	1	1	2
Zimbabwe	1987 b	20	11 526	13 485	17 395	576	674	870	2	3	3
SADC		1 784.8	175 820	200 040	327 525	98.5	112	184	1	2	2

***Water Scarcity Index 1 Adequate 2 Quality and dry season problems 3 Water stress 4 Absolute scarcity 5 Water barrier**

Index from Falkenmark, 1993: <100=1, 100-600=2; 600-1000=3; 1000-2000=4;>2000=5

Recalculated using water availability data from Gleick 2000, as indicated above b/Belyaev 1987 and c/UN FAO 1995. Population figures 1995 from SADC, projected for 2000 using 1999 population and annual growth rates in *SADC Statistics 2000* Population projections for 2025 based on projections 2000-2025 from UN Population Division 1998, in UNFPA 2000, and recalculated at the same rate using SADC data for 2000 (see also Maps 1.1, 1.2 in chapter 1) Population projections to 2025 rely on the UN calculations which are not uniform by country, and show unadjusted figures for Angola and DRC

Country	Total annual renewable freshwater available (cu km/yr)	1995 Population (000)	1995 Per capita water availability (cu m)	2000 Population UN medium projection (000)	2000 Per capita water availability (cu m)	2025 Population UN medium projection (000)	2025 Per capita water availability (cu m)
Angola	184	11 558	15 920	13 302	13 832	25 940	7 093
Botswana	14.7	1 459	10 075	1 651	8 904	2 270	6 476
DRC	1 019	43 900	23 212	50 730	20 087	102 830	9 909
Lesotho	5.2	1 930	2 694	2 140	2 430	3 400	1 529
Malawi	18.7	9 374	1 995	10 160	1 840	18 695	1 000
Mauritius	2.2	1 122	1 960	1 205	1 826	1 410	1 560
Mozambique	216	15 400	14 026	17 245	12 525	26 730	8 080
Namibia	45.5	1 590	28 616	1 817	25 041	2 460	18 496
Seychelles	n/a	70	-	82	-	110	-
South Africa	50	39 477	1 266	44 000	1 136	50 160	997
Swaziland	4.5	908	4 956	1 046	4 302	1 800	2 500
Tanzania	89	28 400	3 134	32 422	2 745	56 090	1 587
Zambia	116	9 100	12 747	10 755	8 275	18 285	6 345
Zimbabwe	20	11 526	1 735	13 485	1 483	17 395	1 150
SADC	1 784.8	175 820	10 151	200 040	8 922	327 525	5 449

Water availability data and population projections as indicated for Table 2.1. Note that despite improvements in monitoring technology, estimates of water availability are approximations, and the average annual figures mask large seasonal, inter-annual and long-term variations. Geographical variations are also a factor, for example in Namibia and Malawi.

basic data for water [illegible] in southern African merits development assistance to basic hydrological investigations, giving priority to programmes designed for local [illegible]

Table 2.3 contains the most up-to-date data on total freshwater withdrawals by country, illustrated in Figures 2.1 and 2.2, and gives a breakdown of water use by the domestic, industrial and agricultural sectors. "Withdrawal" refers to water taken from a water source for use; it does not refer to water "consumed" in that use. Domestic sector includes household, municipal, commercial and governmental water use. Industrial sector includes water used for power plant cooling and industrial production. Agricultural sector includes irrigation and livestock. A major limitation of these data is that they do not include the use of rainfall in agriculture, and many countries in the SADC region use a significant fraction of the rain falling on their territory for agricultural production. However, this water use is not accurately measured or reported.

In the past few years, the UN Food and Agriculture Organisation (FAO) has begun a systematic reassessment of water-use data, and hopefully a more accurate picture of national, regional and sectoral water use will soon emerge.

Based on the calculation of annual renewable freshwater resources, current consumption patterns and the projected population growth, a sharp reduction in per capita freshwater availability is predicted for most countries of the SADC region by the year 2025. (Figure 2.3)

Water demand, use, need, withdrawal, consumption and consumptive use — Box 2.1

There continues to be confusion in the water literature about the terms "use", "need", "withdrawal", "demand", "consumption", and "consumptive use". Therefore, great care should be used when interpreting or comparing different studies. Typically, the term "withdrawal" refers to water removed from a source and used for human needs. Some of this water may be returned to the original source with changes in the quantity and quality of the water. The term "consumptive use" or "consumption" refers to water withdrawn from a source and made unusable for reuse in the same basin, such as through irrecoverable losses like evaporation, seepage to a saline sink, or contamination. Consumptive use is sometimes referred to as "irretrievable losses". The term "water use", while common, is often misleading or at best uninformative, referring at times to consumptive use and at times to withdrawals. "Need" for water is also subjective, but typically refers to the minimum amount of water required to satisfy a particular purpose or requirement. It sometimes refers to the desire for water on the part of a user. "Demand" for water is used to describe the amount of water requested or required by a user, but the level of demand for water may have no relationship to the minimum amount of water required to satisfy a particular requirement.

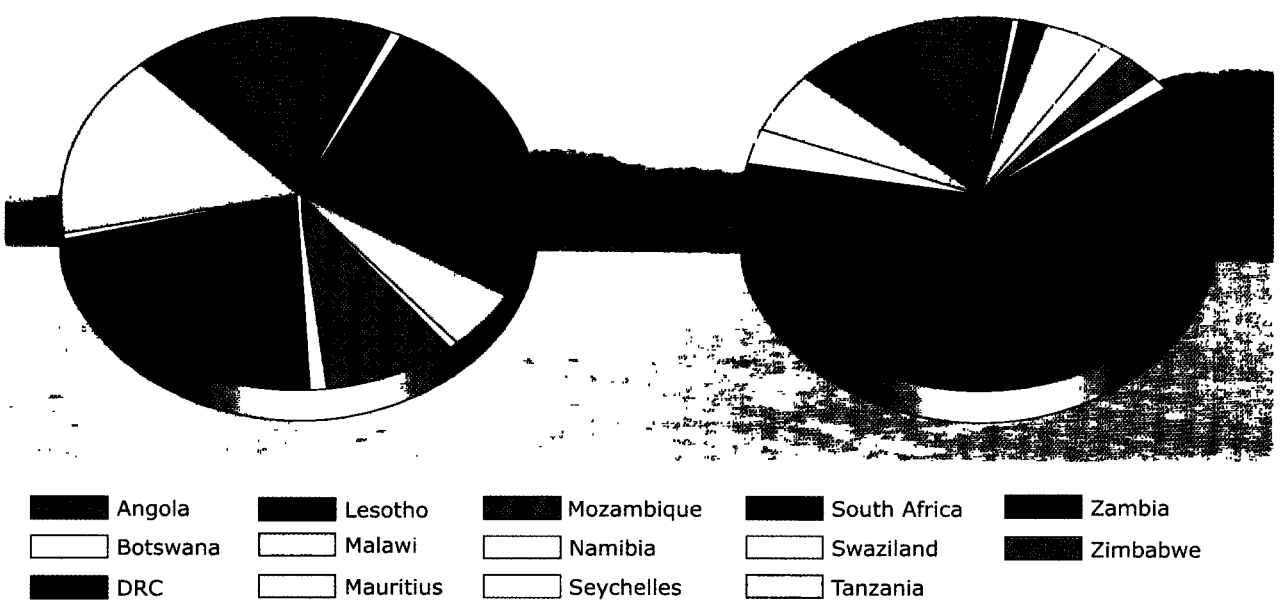
Gleick 2000

Country	Year	Total freshwater withdrawal (cu km/yr)	Estimated year 2000 per capita withdrawal (cu m/p/yr)	Water use: Domestic (% of total water use)	Industrial	Agricultural	Domestic (cu m/person/yr)	Industrial	Agricultural	Estimated year 2000 population (000)
Angola	1987	0.48	36	14	10	76	5	4	27	13 302
Botswana	1992	0.11	67	32	20	48	22	13	32	1 651
DRC	1990	0.36	7	61	16	23	4	1	2	50 730
Lesotho	1987	0.05	23	22	22	56	5	5	13	2 140
Malawi	1994	0.94	92	10	3	86	9	3	80	10 160
Mauritius	1974	0.36	300	16	7	77	48	21	231	1 205
Mozambique	1992	0.61	35	9	2	89	3	1	31	17 245
Namibia	1991	0.25	138	29	3	68	40	4	94	1 817
Seychelles	-	-	-	-	-	-	-	-	-	82
South Africa	1990	13.31	302	17	11	72	51	33	218	44 000
Swaziland	1980	0.66	631	2	2	96	10	15	606	1 046
Tanzania	1994	1.17	36	9	2	89	3	1	32	32 422
Zambia	1994	1.71	159	16	7	77	26	11	122	10 755
Zimbabwe	1987	1.22	90	14	7	79	13	6	71	13 485
Total SADC		21.23	106							200 040

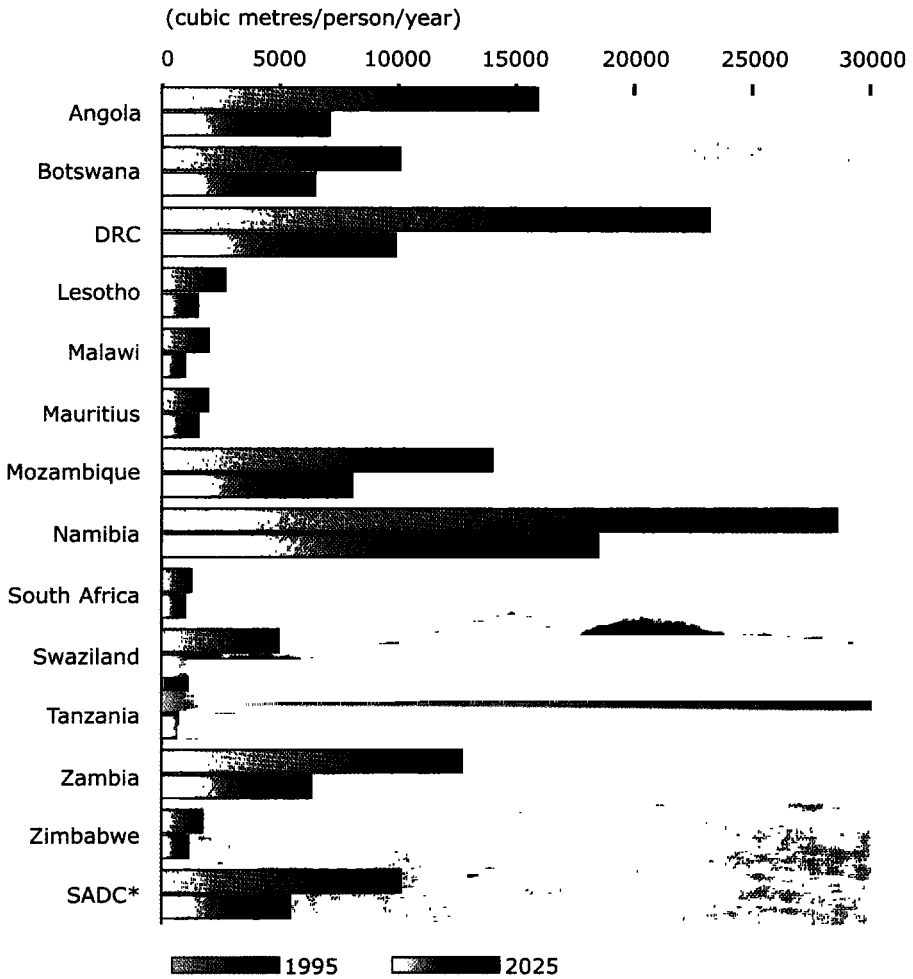
Withdrawal estimates UN FAO 1995 in Gleick 2000. Population figures for the year 2000 calculated using *SADC Statistics 2000* for 1999 population figures and the annual growth rates by country

Population Distribution in SADC 2000 — Figure 2.1

Total Annual Freshwater Withdrawal by Country — Figure 2.2



Per Capita Water Availability by Country, 1995-2025 **Figure 2.3**



*excluding Seychelles
Per capita water availability from Table 2.2

2.2.2 Transboundary waters

One important feature of the region is the presence of 15 transboundary rivers and consequential groundwater resources. The combined drainage areas of these international rivers cover over 78 percent of the region's continental land area (Table 2.4). As populations grow and their demands increase, the need to coordinate the development and management of the shared watercourses is becoming a very real regional priority, without which there could be substantial economic losses and potential for conflict. More regional disasters could occur due to lack of preparedness to manage floods and droughts on a basin-wide basis. The absence of cooperative management of water resources, including data sharing and appropriate regulatory and institutional frameworks, has resulted in inefficient water usage between the countries and their key economic sectors. However, the framework for establishing and developing joint management arrangements is now in place through the SADC Protocol on Shared Watercourses.

Most of the continental countries within the SADC region lie entirely or largely within international river basins, and all but one have more than half of their total land area in international basins. (Table 2.4)

The Congo river basin (3,699,100 sq km), which lies almost entirely within the SADC region, is second in size only to the Amazon basin (5,866,100 sq km) in South America, and is larger than the Nile basin (3,038,100 sq km) in central/north Africa. (Table 2.5)

"The development of these shared river basins is complex, whether large or small, since existing national uses occupy preferential positions and foreclose other projected or anticipated uses, including regional. This is valid for both upstream and downstream riparian countries. To overcome this situation and reach a sustainable development option, trust must be built and sustained, and joint management regimes developed by all riparians on the shared watercourses. This concept emphasizes a move from sharing the actual volume of water towards sharing the economic benefits of different uses between riparian states." (Alemu *et al* 2001: 4)

These data do not provide information on the actual cross-border water flows. Thus a country can have a significant fraction of a watershed but generate only a small or negligible fraction of a total river flow, or conversely, may have a small fraction of the watershed, but be responsible for generating a large amount of flow. In many cases, the flow and runoff of rivers contained within national boundaries are as high or higher than that of international rivers. Table 2.6 shows some comparative figures.

Country	Total area (sq km)	Area in international basins (sq km)	Fraction of country in international river basins (%)	International river basins
Botswana	581 730	581 730	100	Zambezi, Orange, Okavango, Limpopo
DRC	2 345 000	2 345 000	100	Congo, Nile and others
Zambia	752 614	752 614	100	Zambezi, Congo
Zimbabwe	390 759	390 759	100	Zambezi, Sabi, Okavango, Limpopo, Buzi, Pungwe
Swaziland	17 164	16 800	97.9	Umbeluzi, Incomati, Maputo
Malawi	118 484	111 170	93.8	Zambezi, Ruvuma
Namibia	824 269	563 670	68.8	Zambezi, Orange, Okavango, Cunene, Etosha-Cuvelai
Angola	1 246 700	846 830	67.9	Zambezi, Okavango, Cunene, Etosha-Cuvelai, Congo
Lesotho	30 352	19 900	65.6	Orange
South Africa	1 221 040	797 500	65.3	Orange, Maputo, Limpopo, Incomati
Mozambique	802 000	455 080	52.8	Zambezi, Umbeluzi, Sabi, Ruvuma, Maputo, Limpopo, Incomati, Buzi, Pungwe
Tanzania	945 087	410 800**	43.5	Zambezi, Congo, Ruvuma, Nile, Lake Natron, Umba
SADC	9 275 199*	7 291 853**	78.6	As above and Table 2.5

*excluding the islands of Mauritius and Seychelles
**Umba river and Lake Natron in Tanzania are shared with Kenya and not with other SADC members, and DRC also shares basins with non-SADC members. This causes a slight difference between the Country area in international basins in Table 2.4 and Basin area in SADC region in Table 2 5.
Wolf *et al* 1999 in Gleick 2000; adapted using Pallett 1997 in SADC Water Sector 1998, total areas from Deconsult ZACPRO study 1998 and *SADC Statistics 2000*

The SADC region also contains some of the major aquatic ecosystems on the African continent (see chapter 3) including key wetlands, as well as three of the largest freshwater lakes. (Box 2.2)

There is limited data on the status of groundwater resources in almost all of the countries in southern Africa, even though a large part of the region's population is dependent on groundwater for domestic and indus-

D Martin, APG

Lake Victoria is used for navigation, recreation and fisheries, and the indented shoreline [illegible] landscapes.

Major lakes in the SADC region — Box 2.2

Lake Victoria is the largest in area of all African lakes and the second widest freshwater body in the world. The lake covers an area of 68,800 sq km and has a total water volume of 2,750 x 10^9 cu m. The maximum depth of the lake is 84 m and the mean depth is 40 m. The water level is regulated and the shoreline is 3,440 km. Lake Victoria drains at the rate of 600 cu m/second at Jinja, Uganda. The lake is a source of water, navigation, recreation and fisheries, and the indented shoreline provides beautiful landscapes used for tourism and sightseeing. The towns of Bukoba, Mwanza and Musoma (Tanzania), Kisumu (Kenya) and Entebbe (Uganda) rely on the lake for domestic and industrial water supply.

Lake Tanganyika, one of the Rift Valley lakes, is the second largest lake in area in Africa and the second deepest and longest lake in the world. The surface area is 32,000 sq km, with a water volume of 17.8 x 10^{12} cu m. Maximum depth is 1,471 m, while the mean depth is 572 m. The length is 670 km. The water level is generally unregulated and the shoreline is 1,900 km. Lake Tanganyika is extraordinary in terms of fish species. Of the 214 native fish species found in the lake, 176 are endemic. The lake is generally used for fisheries and navigation.

Lake Malawi/Nyasa is the southernmost of the deepwater lakes associated with the formation of the East African Rift Valley. The Rift Valley lakes are of moderate antiquity and, despite major fluctuations in water level over the centuries have been the sites of much evolutionary radiation, especially in some fish groups and freshwater molluscs. This lake is 560 km long with a maximum width of 75 km, and covers a total area of 6,400 sq km. The lake holds a total volume of 8.4 x 10^{12} cu m. Its maximum depth is 706 m while the mean depth is 292 m. The water level is regulated, and the lake is used as a source of water, navigation/transportation, tourism and fisheries.

Kira 1994, Owen *et al* 1990
www.ilec.or.jp/database/afr/afr-06.html

River basin	Basin area in SADC region (sq km)	River length (km)	Mean annual runoff at river mouth (M cu m/yr)	No. of SADC states	SADC states in river basin	Basin area within country* (sq km)	(%)
Congo	2 942 700	4 700	1 260 000	4	●DRC	2 307 800	62.39
	of total 3 699 100				●Angola	291 500	7.88
					●Zambia	176 600	4.77
					●Tanzania	166 800	4.51
Zambezi	1 388 200	2 650	94 000	8	●Zambia	577 900	41.63
					●Angola	256 500	18.47
					●Zimbabwe	215 800	15.55
					●Mozambique	163 800	11.80
					●Malawi	110 700	7.97
					●Tanzania	27 300	1.97
					●Botswana	19 100	1.38
					●Namibia	17 100	1.23
Orange	947 700	2 300	11 500	4	●South Africa	565 600	59.68
					●Namibia	240 600	25.39
					●Botswana	121 600	12.84
					●Lesotho	19 900	2.09
Okavango/Cubango	708 600	1 100	11 000	4	●Botswana	359 000	50.67
					●Namibia	176 800	24.95
					●Angola	150 100	21.18
					●Zimbabwe	22 700	3.20
Limpopo	415 500	1 750	5 500	4	●South Africa	184 100	44.31
					●Mozambique	87 300	21.01
					●Botswana	81 500	19.61
					●Zimbabwe	62 600	15.06
Etosha-Cuvelai	167 600	430	ephemeral	2	●Namibia	114 370	68.24
					●Angola	53 230	31.76
Ruvuma	152 200	800	15 000	3	●Mozambique	99 530	65.39
					●Tanzania	52 200	34.30
					●Malawi	470	0.31
Nile	142 000	6 700	86 000	2	●Tanzania	120 300	3.96
	of total 3 038 100				●DRC	21 700	0.71
Sabi/Save	116 100	740	7 000	2	●Zimbabwe	85 780	73.88
					●Mozambique	30 320	26.12
Cunene	110 300	1 050	5 500	2	●Angola	95 500	86.57
					●Namibia	14 800	13.43
Incomati	46 200	480	3 500	3	●South Africa	29 200	63.19
					●Mozambique	14 300	30.97
					●Swaziland	2 700	5.84
Pungwe	32 500	300	3 000	2	●Mozambique	31 050	95.54
					●Zimbabwe	1 450	4.46
Maputo	31 300	380	2 500	3	●South Africa	18 600	59.43
					●Swaziland	11 000	35.02
					●Mozambique	1 700	5.55
Buzi	27 900	250	2 500	2	●Mozambique	24 780	88.81
					●Zimbabwe	3 120	11.18
Umbeluzi	5 400	200	600	3	●Swaziland	3 100	57.41
					●Mozambique	2 300	42.59
SADC	7 234 200						

*Some area totals may not add up to 100% due to rounding.

Basin areas and states from Wolf *et al* 1999, in Gleick 2000; Pungwe basin area in Zimbabwe, Mawere 2002. River length and runoff from Pallett (ed) 1997, in SADC WSCU 1998

River	Mean annual runoff (M cu m/yr)	Countries
Congo	1 260 000	DRC, Angola, Tanzania, Zambia
Zambezi	94 000	Zambia, Zimbabwe, Mozambique, Malawi, Angola,Tanzania, Botswana, Namibia
Cuanza	26 000	Angola
Rufiji	22 250	Tanzania
Kilombero	14 470	Tanzania
Orange	11 500	South Africa, Namibia, Botswana, Lesotho
Okavango	11 000	Botswana, Namibia, Angola, Zimbabwe
Lurio	7 000	Mozambique
Cunene	5 500	Angola, Namibia
Limpopo	5 500	South Africa, Mozambique, Botswana, Zimbabwe

FAO Source Book 1990: Rudengre *et al* 1997. Pallett 1997 in SADC Water Sector 1998

trial supply. A project to address groundwater management in the region is in preparation by the SADC Water Sector Coordination Unit (WSCU), funded by the Global Environment Facility (GEF). (Box 2.3)

Protection and strategic uses of groundwater resources in the Limpopo basin and other drought-prone areas of the SADC region **Box 2.3**

The objective of the SADC project on groundwater management is for member states to co-operatively develop a strategic regional approach to support and enhance their capacity in the definition of drought management policies, specifically in relation to the role, availability (magnitude and recharge) and supply potential of groundwater resources. This will reconcile the demands of socioeconomic development and those of the principal groundwater-dependent ecosystems. At regional level, the project seeks to:

- identify transboundary impacts of groundwater development in the various river basins of the region;
- identify priority groundwater resources in drought- prone areas; and,
- provide regional management tools such as hydro-geological maps, drought vulnerability and water scarcity maps, a minimum regional groundwater monitoring network, and a regional information system.

At the river basin level, the role of groundwater in proactive drought mitigation will be demonstrated in the semi-arid Limpopo river basin.

SADC WSCU 2000

2.2.3 Climate variability: an uncertain water resource base

Climate variability is the most important factor affecting the temporal and spatial distribution of rainfall and water resources within countries and across the region. It has a significant influence on the amount, timing and frequency of precipitation events and runoff patterns, and on resultant droughts and floods. Year-to-year rainfall variability can be as high as 30 – 35 percent. The trend over the past century is for the region to experience periods of wetness and dryness. For example, the 1970s was a relatively wet decade. (Figure 2.4) The rainfall of the early 1990s was about 20 percent lower than that of the 1970s. (Chenje and Johnson 1996) There were significant drought years in the 1980s and early 1990s prior to the drought conditions that gripped the region in 2002. (Box 2.4) The climate variability of the region is strongly influenced by the El Nino/Southern Oscillation (ENSO) phenomenon, the periodic warming of the tropical Pacific Ocean and related shifts in the atmospheric circulation, which brings disruption to many low latitude areas. (Hulme 1996) The ongoing ENSO signals are worrying signs as parts of the region including Malawi, Zambia and Zimbabwe have already started to experience serious deficits in rainfall and massive food shortages are anticipated.

2.2.3.1 Rainfall

The distribution of rainfall is spatially and temporally uneven within the countries and across the region, and this results in unreliable water supplies. The surface runoff in the region is characterised by seasonality and this has an impact on water resources. Many SADC countries are partially or largely arid or semi-arid, and in a typical year there maybe no runoff. Annual rainfall reliability is low and droughts are endemic in the region. Rainfall ranges from about 10 mm in some parts of Namibia to about 2800 mm in some parts of Malawi and Tanzania.

The Inter-Tropical Convergence Zone (ITCZ) brings

Rainfall trends in southern Africa 1967 - 2000 **Box 2.4**

1967-73	This 6-year period was dry across the entire region. Some records show a severe drought in 1967.
1974-80	This period was relatively moist over much of southern Africa. In 1974 the mean annual rainfall was 100 percent above normal throughout the region.
1981-82	Drought in most parts of southern Africa.
1982	Most of sub-tropical Africa experienced drought.
1983	A particularly bad drought year for all parts of the continent.
1984-85	Near normal seasons, but drought strains from the previous three years were still felt in most parts of the region.
1986-87	Drought conditions returned to the region.
1988-90	Near normal seasons.
1991-92	Severe drought in southern Africa, excluding Namibia.
1993-94	Conditions improved.
1994-95	Many SADC countries were hit by the worst drought in memory, surpassing effects of the 1991-92 drought in some parts of the region.
1995-96	Widespread rains in most parts of the SADC region prompted forecasts of a bumper agricultural yield.
1996-97	Normal rainfall for most of the region.
1997-98	Normal rainfall throughout the region including the north-east, although impacts of El Nino were significant.
1999-2000	Cyclone Eline hit the region and widespread floods devastated large parts of the Limpopo basin (southern and central Mozambique, south-eastern Zimbabwe, parts of South Africa and Botswana).

Chenje 2000

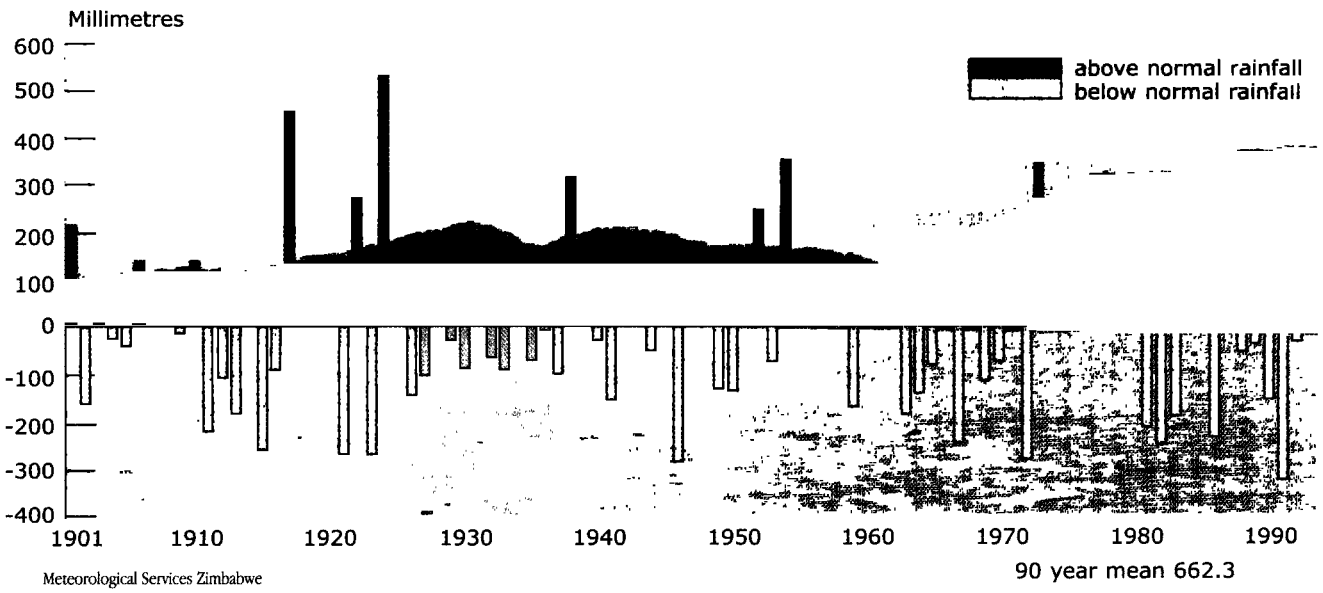
most of the rainfall to the region. The ITCZ is a zone of intense rain-cloud development between a dry, equatorial warm air mass and a moist, cool northern air mass. The movement of the ITCZ southward away from the equator marks the start of the main rainy season in the Southern Hemisphere.

The migration of the ITCZ between mid-Tanzania and southern Zimbabwe brings good rains to most of southern Africa, while the Botswana Upper High creates unfavourable conditions for heavy or widespread rainfall and its frequent occurrence almost always results in drought in some countries in the region. (Matarira 1990) In some instances, it pushes the rain-bearing ITCZ and active westerly cloud-bands out of the region and over the Indian Ocean. During winter and dry spells, the Botswana Upper High, along with the eastern mountain belt stretching from the Drakensberg in South Africa right up to Tanzania, blocks the moist air from entering the region.

2.2.3.2 Evaporation

In most parts of the region, potential evaporation is almost twice as high as rainfall totals and this plays a dominant role in the overall water balance, with the consequence that generally less than 15 percent of the rainfall contributes to runoff, river flow and infiltration to groundwater. The high evaporation rate is also an indicator of the region's arid and semi-arid state in which irrigated agriculture plays an important role in national economies. Table 2.7 lists the

Mean Annual Rainfall in Zimbabwe, Departure from Normal, 1901/2 - 1992/3 **Figure 2.4**



Meteorological Services Zimbabwe

Table 2.2

Country	Rainfall range (mm)	Average rainfall (mm)	Potential evaporation range (mm)	Total surface runoff (mm)
Angola	25 - 1600	800	1300 - 2600	104
Botswana	250 - 650	400	2600 - 3700	0.6
Malawi	700 - 2800	1000	1800 - 2000	60
Mozambique	350 - 2000	1100	1100 - 2000	275
Namibia	10 - 700	250	2600 - 3700	1.5
South Africa	50 - 3000	500	1100 - 3000	39
Swaziland	500 - 1500	800	2000 - 2200	11
Tanzania	300 - 1600	750	1100 - 2000	78
Zambia	700 - 1200	800	2000 - 2500	133
Zimbabwe	350 - 1000	700	2000 - 2600	34

Pallett 1997: 14

rainfall, evapotranspiration and surface runoff ranges in the region. These determinants of the hydrological processes have a direct influence on the occurrence and distribution of water in the region. However, a significant portion of runoff in southern Africa is not harvestable, especially in countries where runoff is strongly seasonal. Other natural factors such as geological formations also influence the occurrence and availability of groundwater resources.

2.2.3.3 Distribution

The distribution of freshwater resources in the SADC region is very uneven, and one consequence of this is localised water scarcities that affect economic development and social security. Demand for water by the different competing users in the region is increasing against a background where the cheaper water sources for most countries have already been developed and any new sources require more financial resources. In addition, some of the countries consume more water than they have within their own boundaries. For example, South Africa accounts for 63 percent of total annual freshwater withdrawals in the region, primarily for agricultural purposes (Table 2.3), and yet its annual renewable freshwater resources are just 50 cu km/yr (Table 2.1), less than three percent of the regional total.

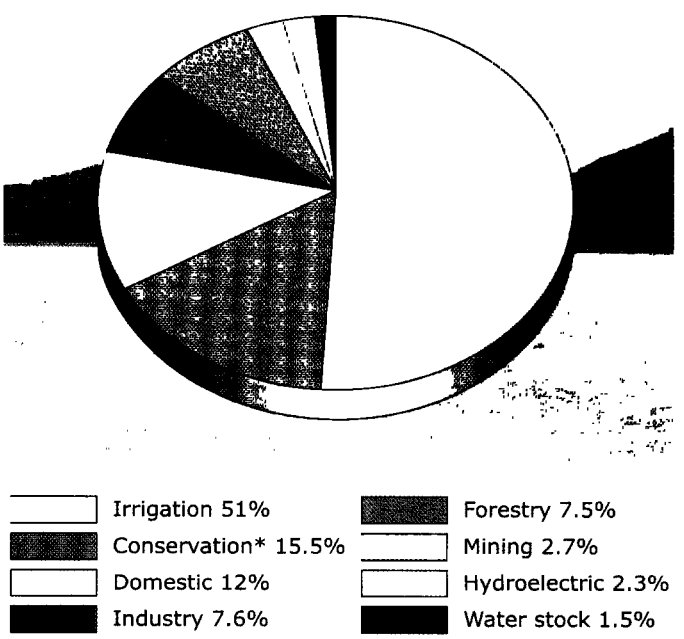
The spectre of water scarcity in the region is now a reality and it is likely to seriously undermine food production, environmental conservation and economic development unless mechanisms are sought and effectively implemented for joint monitoring, planning and management of the availability and use of freshwater resources.

2.3 SECTORAL USES OF WATER

2.3.1 Irrigated agriculture

Seasonal variations and unreliable rainfall have made irrigation an essential factor for sustained agricultural production in the region, particularly as growing populations increase the demand for food. Irrigation is often regarded as a way of increasing agricultural productivity without increasing the amount of land under production. South Africa is the region's largest irrigator, and although only one percent of the agricultural land is irrigated, this produces 30 percent of the value of national agricultural production. (Chenje and Johnson 1996) Over 50 percent of the available water resources in South Africa are used in irrigated agriculture, while the other sectors combined consume the remainder. (Figure 2.5)

Water Usage in South Africa by Sector **Figure 2.5**



*Nature conservation and ecological concerns
Government of South Africa, "National Water Conservation Campaign Launch" 1995, in Chenje and Johnson 1996

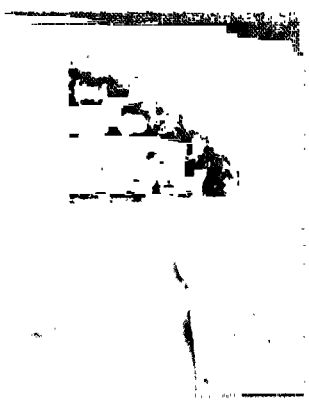
Country	1961	1965	1970	1975	1980	1985	1990	1995	1997
				(thousand hectares)					
Angola	75	75	75	75	75	75	75	75	75
Botswana	1	2	1	1	2	2	2	1	1
Lesotho	3	3	3	3	3	3	3	3	3
Malawi	1	1	4	13	18	18	20	28	28
Mauritius	8	12	15	15	16	17	17	18	18
Mozambique	8	16	26	40	65	93	105	107	107
Namibia	4	4	4	4	4	4	4	7	7
South Africa	808	890	1 000	1 017	1 128	1 128	1 290	1 270	1 270
Swaziland	36	40	47	56	58	62	67	69	69
Tanzania	20	28	38	52	120	127	144	150	155
Zambia	2	2	9	18	19	28	30	46	46
Zimbabwe	22	34	46	70	80	90	100	150	150

*no information available for DRC, Seychelles Gleick 2000

Although irrigated agriculture has a vital role to play in meeting the demand for food from an expanding population, the water-use efficiency in this sector is very low. In order to reduce the volume of water consumed by irrigated agriculture and improve water-use efficiency, many countries in the region are exploring and introducing water demand management measures that could release water resources from irrigated agriculture for other uses.

Table 2.8 shows total irrigated areas (in thousands of hectares) by country in the SADC region, between 1961 and 1997, the latest year for which reliable data are available. The data depends on in-country surveys, national reports, and estimates by the UN FAO, and no differentiation is made regarding the quality of land in production.

The Botswana National Water Master Plan Study from 1991 is one of the most realistic plans for sustainable water resources on the continent (Ohlsson 1995), and clearly demonstrated that Botswana's water resources do not allow for any largescale irrigation. As a result of the study, Botswana abandoned its previous strategy of self-sufficiency in food production and adopted an alternative policy of economic development for food security, in which the economy has to be strong enough to purchase food from abroad. This deliberate policy decision which is counter intuitive represents a sound analysis and definition of a water resources management and development strategy appropriate for the country.



SOE Zambezi – CEP

2.3.2 Hydropower generation

Hydropower generation is one of the most important instream uses of water in the region because most countries rely heavily on hydroelectric energy for domestic and industrial use as well as for water pumping and other agricultural uses. Often, hydropower production is associated with the construction of large dams, which in recent years have become a source of increased concern largely because of the way the associated social and environmental impacts and consequences have been addressed.

Southern Africa has a few, very large dams intended primarily for hydropower generation – Cahora Bassa, Inga, Kariba and Kafue Gorge. Large hydroelectric dams which release water through the top, hold vast amounts of water known as "dead storage" which cannot be used otherwise, although it can serve as fish habitat. Lake Kariba has 114 cu km of dead storage, equivalent to almost 20 percent of the entire region's annual runoff (Ohlsson 1995) and more than five times the annual freshwater withdrawals for the region (21.23 cu km/yr, see Table 2.3), yet little of this can be used without jeopardising power generation.

Hydropower generation is a function of several factors including water flow and the hydraulic head. Although often thought of as a non-consumptive use of water, water for hydropower generation is also associated with substantial evaporation and seepage losses. Sometimes the location of the power facilities can influence other water uses. In Tanzania, although the total electric generating capacity is low, about 80-90 percent of the electricity is generated from hydropower. In the Pangani and Rufiji basins the major hydropower generating facilities are located downstream from major irrigated

areas. During drought years, hydropower generation is in direct conflict with irrigated agriculture. Tanzania's national electricity authority, TANESCO, has accused upstream irrigation schemes of depriving its hydro dams of water and has demanded their closure. In Malawi, hydropower generation uses more water than irrigated agriculture.

The Congo river holds the potential for Africa's largest hydroelectric resource (SADC 2001), and some 40 possible sites for new hydropower plants have been identified in the Zambezi basin. About 85 percent of this capacity is on the Zambezi river and the remainder on its tributaries. About half of the mapped potential is in Mozambique, 25 percent in Zambia and 20 percent in Zimbabwe. (Chenje 2000) Angola, DRC, Mozambique and Lesotho have great potential to develop more hydroelectric power. The Lesotho Highlands Water Project which draws water from Lesotho to supply South Africa's industrial heartland, is designed to include a total of 274 MW of hydroelectric generating capacity. (www.un.org/esa) Some of the major hydroelectric installations in SADC countries are shown in Table 2.9.

Facility	Country	Capacity (MW)
Cahora Bassa	Mozambique	2 075
Inga	DRC	1 771
Kafue Gorge	Zambia	900
Kariba South	Zimbabwe	666
Kariba North	Zambia	600
Kidatu	Tanzania	204
Lower Kihansi	Tanzania	180
Victoria Falls A-C	Zambia	108
Nkula B	Malawi	100
Mtera	Tanzania	80
New Pangani Falls	Tanzania	68
Tedzani III	Malawi	52
Tedzani I &II	Malawi	40
Nkula A	Malawi	24
Hale	Tanzania	21
Mulungushi	Zambia	20
Lunsemfwa	Zambia	18
Lusiwasi	Zambia	12
Nyumba ya Mumbu	Tanzania	8
Wovwe	Malawi	5

Deconsult. 1998. ZACPLAN Sector Study 5, in Chenje 2000
www.ich.no.he2001/fact-tanzania.htm
www.un.org/esa/africa/energyreport.htm

2.3.3 Domestic supply and sanitation

Access to safe water supplies and sanitation is limited in many parts of the SADC region, with better coverage in most urban areas, although peri-urban areas and informal urban settlements face severe difficulties in this regard. A majority of the rural population generally still does not have access to safe water or sanitation. (see Tables 2.10, 2.11) There is, however, a huge variation in access across the region, and some countries such as Botswana, Mauritius and Zimbabwe have been doing very well in terms of extending supply of safe water and sanitation to the rural population.

More than 60 percent of people in the region as a whole have access to safe drinking water, while 40 percent of the population does not; and more than 50 percent are without access to sanitation, thus increasing their exposure to water-borne diseases. In the period 1990-1996, for example, only 27 percent of people in Zambia had access to safe water, and just 16 percent of Malawi's population had access to sanitation. (SAPES 1998)

In DRC, Malawi, Mozambique, Swaziland and Zambia, between 25-50 percent of the population has access to safe drinking water, while in Namibia and Lesotho, between 50-75 percent have access. Botswana, Mauritius and Zimbabwe have higher coverage of between 75-99 percent. In many countries of the region, the coverage has been fluctuating from high to low (Angola, Lesotho) while in Mauritius, high coverage has been maintained since the 1970s.

In southern Africa, women are the main managers of water resources. "As food producers, water collectors, and fuelwood gatherers, rural women are in frequent and direct contact with land, water and forest resources. Women fetch and supply drinking water for their families, and are heavily dependent on rain-fed agriculture and, in some parts of the region, on fisheries. Rural women spend a lot of their time tending, collecting and using water and other natural resources." (Chenje and Johnson 1996: 11)

D Reed IUCN

Industrial Water Use in SADC Countries as % of Total Annual Freshwater Withdrawals Figure 2.6

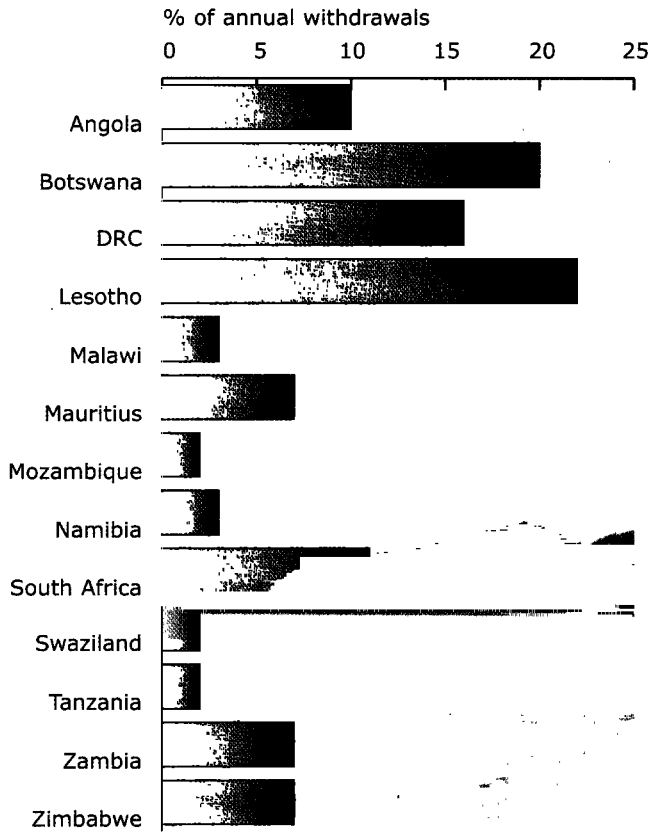


Table 2.3

2.3.4 Water for mining and industrial use

This sector has the lowest usage of the available water in the SADC region, according to Table 2.3, well behind agricultural and domestic uses. The above graph, Figure 2.6, shows industrial water use in some SADC countries as a percentage of total annual freshwater resources available.

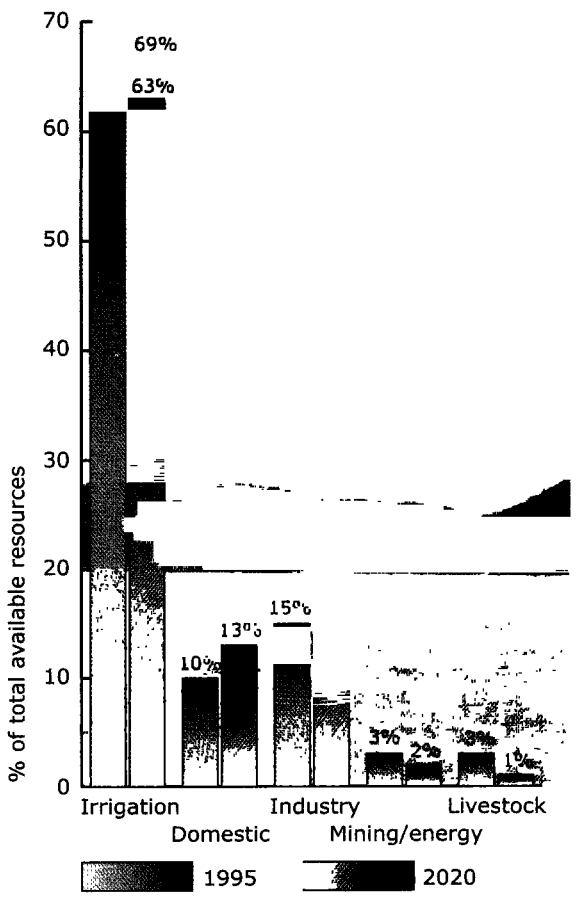
Comprehensive figures on water use in mining are not readily available for the SADC region. However, individual country statistics show that, in South Africa's Crocodile/Limpopo and Olifants basins, mining water requirements were estimated at eight percent of the total available water in 1996 and this is expected to rise to nine percent by the year 2030. (Basson 1997)

Mining groundwater in Botswana Box 2.5

Rural people in remote areas of Botswana depend entirely on underground sources of water, as do the large diamond mines and associated towns at Orapa and Jwaneng. The mineral industry is the largest contributor to the country's economy, and in Botswana's policy, the immediate social and economic considerations get first priority. It is accepted that mining groundwater is justified as long as sufficient value is generated for the nation, in terms of national economic wealth and improved living conditions. It is argued that using fossil water buys time to develop other options such as deeper aquifers, distant (and therefore more expensive) surface waters, or new methods of water conservation. Supplying water for the mining industry forms a central part of the National Water Master Plan, which contains guidelines for groundwater abstraction.

Pallett 1997

Current and Projected Water Demand by Sector Figure 2.7



Pallett 1997: 38

Commercial forestry is also a consumptive water user which competes with aquatic ecosystems for water, and in South Africa it is listed as a streamflow reduction activity. (Mackay 2002)

The general pattern of water use by the major sectors of the region's economy is not expected to change in the next 20 years, although the total volume of water required to satisfy human needs will almost treble. (Heyns 1995) Irrigated agriculture is likely to continue to consume more than half of the available water resources, although total water use by this sector is expected to decline by about 5 percent. Industrial use is expected to increase by around 20 percent and domestic use by about 35 percent. The increase in water use in industry and domestic sectors will be a direct result of population growth and planned expansion of the industrial sector. (Figure 2.7)

2.3.5 Environmental uses of water

The environment uses and needs water to sustain river health and ecological functions. As shown in Figure 2.5 for South Africa, the environmental sectors of conservation, forestry and water stock, when taken together, use a significant amount of water, second only to irrigation. The use of water by the environment is both consumptive and non-consumptive. Fish and other aquatic life require water of certain quality and quantity for survival. Vegetation (both terrestrial and aquatic) and wildlife consume water to sustain growth.

The use of water by the environment in southern Africa has not yet been well studied although initiatives have been started in South Africa, where the national water policy gives priority to the use and allocation of water to the environment. It is believed that the demand for water by this sector will remain largely constant up to year 2030 in all basins except the Mgeni/Mzimkulu, Mzimvulu and Mbashe/Kei basins. (Basson 1997)

Water allocated to the environment (and to some extent hydropower) is also used for recreational activities. Recreational use of water has been increasing in the SADC region as the tourism industries of many countries are developing. Lakes Kariba and Malawi/Nyasa are important recreational centres. At times, however, the recreational use of water is in conflict with other uses.

2.4 WATER MANAGEMENT CHALLENGES

Many countries in southern Africa are facing the challenge of effectively managing the available water resources to meet the needs of a growing population as well as the ecological needs on which the available water resources depend. Some of the major challenges are discussed in more detail in subsequent chapters.

2.4.1 Population and declining per capita supply

Demographic changes and rural-urban migration have a major impact on water demand. Rapid population growth and urbanisation are increasing the demand for domestic, industrial and agricultural uses of water resources, posing a major challenge for the region. The combined population of 14 SADC member countries increased by more than 30 percent in just a decade, from 153 million people in 1990 to 200 million in the year 2000.

Water for the environment – what does this mean? Box 2.6

A range of terms and meanings is used by different authors, although there are quite significant policy implications associated with the different terms:

- water for the environment (meaning aquatic and terrestrial ecosystems)
- water for the environment (meaning aquatic ecosystems only)
- water for ecosystems (meaning sometimes aquatic and terrestrial, or sometimes just aquatic)
- water for environmental use
- environmental water
- water for conservation
- ecological use of water
- water for environmental maintenance
- [water for] ecosystem maintenance.
- [water for] river maintenance

It is recommended that the term "water for aquatic ecosystems" be used, since this is reasonably specific but not too limiting, and that when the intention is to indicate something different, such as water for aquatic and terrestrial ecosystems, then this is explicit.

Mackay 2002

Population Growth and Water Availability in the SADC region **Figure 2.8**

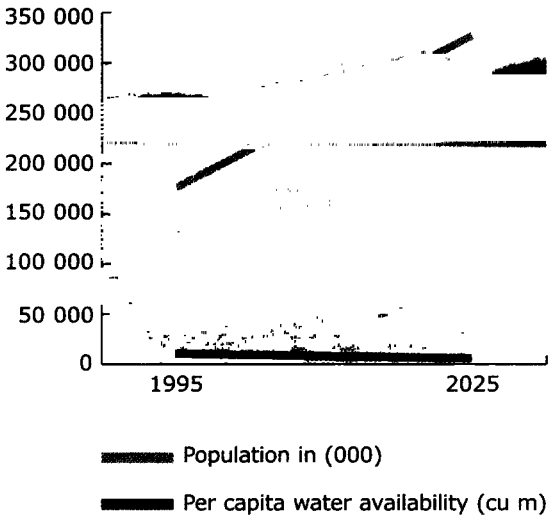


Table 2.2

However, the total supply of renewable freshwater resources available remained the same, or in some case was reduced due to pollution. The regional population is projected to reach beyond 327 million in the next 25 years. (Table 2.2)

The estimated amount of water available per person per year in the SADC region was just over 10,000 cu m in 1995, but this is projected to decrease significantly to less than 5,000 cu m per capita by 2025. (Table 2.2)

The impact of population growth on water availability is likely to be significant, and innovative and cooperative solutions based on equity and sustainability considerations will be necessary to meet the growing water needs of the region. Development policies in the region generally have not emphasised rural areas as potential growth nodes. As a result all water development projects have been geared largely towards serving the urban areas rather than meeting the water needs of rural areas.

2.4.2 Water supply and sanitation coverage

Meeting the urban and rural water supply and sanitation needs will remain a fundamental challenge for the region. Tables 2.10 and 2.11 show the rural and urban populations of SADC countries in relation to coverage of water supply and sanitation. Due to the scarcity of water and infrastructure in many countries in the region, women, particularly those in rural areas, are forced to walk long distances to fetch water. According to a World Bank estimate, some African women use 40 percent of their daily nutritional intake in travelling to collect water.

Despite increasing urbanization, rural areas will continue to be home to tens of millions of people in southern Africa, and activities in these areas will continue to impact on natural resource use, including water resources and the environment. National populations have been increasing steadily, and this increase is taking place against a background of diminishing quality and quantity of water resources. Water that has been contaminated with untreated human waste and sewage often facilitates the spread of cholera and other water-borne diseases. Two-thirds of Mozambique's population, for example, draw water from unprotected sources, and less than half of the population has latrines. (Box 2.7) Inadequate sani-

Country	Total 2000 population (000)	% rural population 1995	Rural population (000)	Population % with access to safe drinking water 1998	Population % with access to sanitation 1998
Angola	13 302	68	9 046	22	27
Botswana	1 651	72	1 190	88	41
DRC	50 730	71	36 020	7	-
Lesotho	2 140	77	1 650	57	35
Malawi	10 160	86	8 740	40	1
Mauritius	1 205	59	710	100	100
Mozambique	17 245	66	11 380	37	26
Namibia	1 817	63	1 145	71	20
Seychelles	82	-	-	-	-
South Africa	44 000	49	21 560	70	80
Swaziland	1 046	-	-	-	-
Tanzania	33 422	76	24 640	58	83
Zambia	10 755	57	6 130	10	57
Zimbabwe	13 485	68	9 170	69	32
SADC	200 040	66	131 381		

tation was one of the main causes for recent cholera outbreaks in some parts of Mozambique, Zambia and Zimbabwe.

Water supply and sanitation in Mozambique **Box 2.7**

According to a survey conducted and published by Mozambique's National Institute of Statistics (INE) in October 2001, just 37.1 percent of the country's population has access to safe drinking water through piped water or protected wells. The rest of the population derives its water from sources such as rivers, lakes or unprotected wells, which may be contaminated.

Worse still is basic household sanitation. The majority of the country's population (57.5 percent) has no latrines in their homes, and only 9.7 percent use modern flush toilets.

The picture is not homogeneous across the country. In general, the healthiest place to live in is Maputo, while the provinces with the most severe problems are Zambezia and Nampula.

In Zambezia, 74.6 percent of the population and in Nampula 69.7 percent, walk for at least an hour to the nearest health facility, whereas in Maputo the figure is only 3.8 percent. In Zambezia, 93 percent of the population has no latrines, while in the capital city Maputo the figure is just 0.7 percent.

Mozambiquefile 2001, Gumende (ed) 2001

Country	Total population (000)	% urban population 1995	Urban population (000)	Population % with access to safe drinking water 1998	Population % with access to sanitation 1998
Angola	13 302	32	4,256	46	62
Botswana	1 651	28	461	100	91
DRC	50 730	29	14,710	53	-
Lesotho	2 140	23	490	91	56
Malawi	10 160	14	1,420	95	18
Mauritius	1 205	41	495	95	100
Mozambique	17 245	34	5,865	85	68
Namibia	1 817	37	672	100	93
Seychelles	82	-	-	-	-
South Africa	44 000	51	22,440	99	92
Swaziland	1 046	-	-	-	-
Tanzania	33 422	24	7,782	92	98
Zambia	10 755	43	4,625	84	94
Zimbabwe	13 485	32	4,315	99	96
SADC	200 040	34	67,531		

Table 2 10 and 2 11: Total population 2000 calculated using 1999 population and annual growth rates in *SADC Statistics 2000*. Rural/urban population % from UNFPA 2000; safe water and sanitation from UNICEF 2000.

2.4.3. Implications of climate variability

The high degree of rainfall variability provides for an uncertain water resource base. The associated water shocks (droughts and floods) that result from extreme climatic events pose a constant risk to the region's economy and its people.

2.4.3.1 Drought

Droughts are endemic to southern Africa, and often trigger serious hydrological imbalances, causing loss or damage to crops, a shortage of water for people, livestock and wildlife, as well as famine and disease. Drought exerts a severe impact on a wide range of environmental and economic activities. As a result of drought during the 1994-1995 season, cereal harvests in southern Africa declined by 35 percent compared to the previous season, with maize harvests falling by 42 percent. (SADC 1996) In Zimbabwe for example, the aggregated Gross Domestic Product (GDP) dropped by six percent as a result of drought during the 1991–1992 season, while the manufacturing sector declined by 9.2 percent in the city of Bulawayo where water shortages were severe. The impact on hydropower generation was significant.

There was considerable variation in harvest outcomes across the region during the 1994-1995 drought and three countries (Botswana, Malawi and Mozambique) actually produced more cereals than their five-year production average, while six countries (Lesotho, Namibia, South Africa, Swaziland, Zambia and Zimbabwe) fell far short. There was a north-south pattern to the harvest failure rate, consistent with El Nino events, and this was reflected internally in Mozambique where the challenge lay in transporting the surplus from the northern part of the country to the drought-stricken south, a problem eventually resolved by exporting from the north and importing for the south. In Zimbabwe,

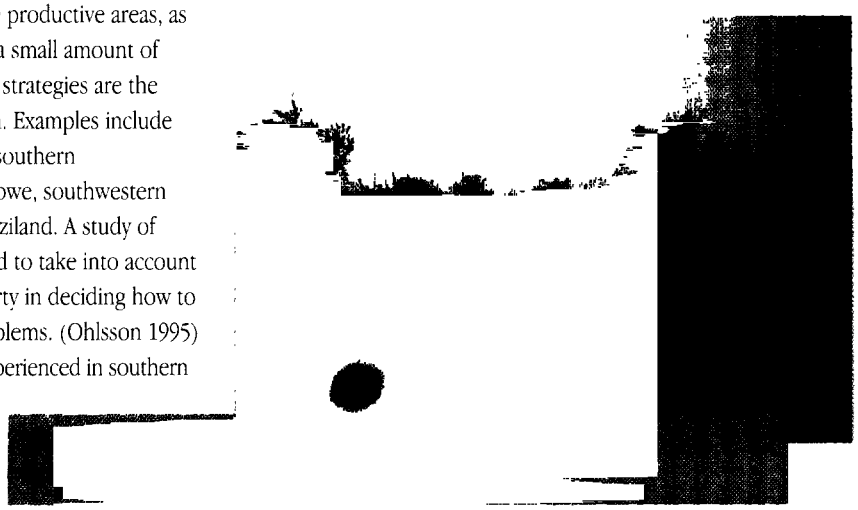
the highest levels of crop failure were found in a crescent running from the northwest to the west and then to the southwest. Southern Zambia was vulnerable, and also the highly productive maize triangle around the Northern, Gauteng and Free State provinces of South Africa. (Ohlsson 1995)

In many cases, however, "emergency" food needs are related to chronic poverty and chronically high malnutrition rates due to endemic food deficits rather than drought. In many areas, people are short of food even in good production years. Other areas are perennially identified as drought-affected, since they are almost always dry. In arid, non-agricultural areas, in fact, crop failure will be felt less intensely than in more productive areas, as local production accounts for a small amount of total consumption and coping strategies are the norm rather than an exception. Examples include southern Namibia, Botswana, southern Mozambique, southern Zimbabwe, southwestern Lesotho and southeastern Swaziland. A study of these trends indicates the need to take into account the underlying causes of poverty in deciding how to address "drought-related" problems. (Ohlsson 1995)

The recurrent droughts experienced in southern Africa highlight the sensitivity of the region's water resources to climate variability. With recurrent droughts and chronic water shortages experienced in many parts of the region, most countries and people will pay an increasingly high price for water or for lack of it. This will affect the poorer people, especially women and children, who will spend more time and energy fetching water and may suffer impaired health from contaminated water or too little water. The ability to monitor and forecast changes in climatic patterns and to internalize climatic variability in water-resources planning and management decision-making is an essential prerequisite for improving the security of the region's people and economy. Interventions to deal with a temporary production deficit will generally not address the long-term structural problems.

2.4.3.2 Floods

Over the last two decades, heavy floods have devastated parts of the region, resulting in massive damage to physical infrastructure, crops and livestock, loss of lives, and public health hazards due to water-related diseases. The 1999-2000 floods during Cyclone Eline had a severe impact on the Mozambican and Zimbabwean economies.



L. Basto

(US$ millions)	Direct	Indirect	Relief	Reconstruction
Food Aid			35.5	
Health	15.7		5.2	25.8
Education	18.7		0.5	37.3
Housing & private property	29.1			43.6
Government property	5.2		6.0	10.2
Sub-total: Social sectors	68.7		47.2	116.9
Water & Sanitation	13.4		6.6	13.4
Energy & telecommunication	13.6	7.4		15.5
Roads	47.0	30.0	11.0	87.2
Railways	7.3	10.7		49.2
Sub-total: Infrastructure	81.3	48.1	17.6	165.3
Agriculture	57.9	63.0		57.9
Livestock	7.9	0.8		7.9
Fisheries	8.5	6.1		8.5
Industry	25.7	68.0		30.8
Trade	15.7	15.0		15.7
Tourism	2.0	10.5		2.5
Sub-total: Productive sectors	117.7	163.4		123.3
Sub-total: Environment	2.0			2.8
Sub-total: Disaster prevention	3.4			19.4
Grand total	273.1	211.5	64.8	427.7

Direct costs = physical damage to assets and inventories Indirect = output losses and foregone earnings

Table 1, Technical Annex for a proposed credit of SDR 22.4 million to the Republic of Mozambique for a Flood Recovery Project, Report No. t-7370-MOZ, 7 April 2000; in Christie and Hanlon 2001

The government of Mozambique reported that GDP grew by only 3 percent compared to 6 percent predicted before the floods. Agriculture production grew by 2 percent compared with 9 percent in 1999, and livestock production fell to 4.3 percent compared to the 21.3 percent in 1999.

2.4.4 Climate change

Climate variability has always been a fact of life in southern Africa, and the emerging challenge is the expected increase in variability due to global climate change.

Climate change as a result of the coupled effects of global warming and greenhouse gases is likely to have a measurable impact on the water sector in the region. In response to climate change, southern Africa is expected to experience gradual warming, and the most significant warming in mean surface temperature of more than two degrees is expected to occur over the interior upland plateaux encompassing Botswana, eastern Namibia and Angola, and western Zimbabwe and Zambia. Rising temperatures are likely to increase evapotranspiration rates and reduce the potential water [illegible]. Climate-change rainfall scenarios suggest that annual rainfall will decrease by up to 5 percent and this will be experienced in Namibia, Mozambique, and parts of Zimbabwe and South Africa. (Hulme 1996) It is also predicted that the wet season will shorten and become less reliable.

One of the most significant impacts of global climate change is likely to be on the hydrological system and this will affect river flows and the region's water resources. Climate change will also impact on water uses; and irrigation, the most climate-sensitive sector, is likely to be impacted significantly, as well as power production and other uses.

2.4.5 Urbanization

More than 65 percent of the people in southern Africa still live in the rural areas (Table 2.10), but most SADC states will see urbanization continue to grow over the next decade. South Africa and Zambia already have more than 50 percent of their populations living in urban areas. In Malawi, the population is getting more urbanised with projections showing that 3.8 million Malawians will be living in urban areas by 2012, a 400 percent jump from less than one million in 1988. (Government of Malawi 1998)

With urban population increasing at more than seven percent per year in some countries, it is becoming clear that most cities in the region have not been able to develop the basic services (such as water supply and sanitation, solid waste disposal systems, sewage treatment, and adequate industrial pollution control) to keep pace with the rapid growth of the urban population. Urbanization is presenting new challenges to urban authorities in terms of provision of facilities and services. For example, the population influx into urban areas such as Harare and Chitungwiza in Zimbabwe, Lusaka in Zambia, and the Johannesburg-Pretoria area in South Africa is greater than the capacity of the existing sewage systems.

Urbanization could be the biggest threat in terms of water pollution if not properly planned, due to the problems of improper sewage disposal. Most water bodies close to urban areas tend to have localised high coliform counts. This is caused by the discharge of untreated sewage into nearby water sources such as rivers and lakes, contributing to water quality degradation, which in turn is reducing the volume of water [illegible] for consumptive use or requiring costly treatment before it can be re-used. Urban health hazards resulting from a lack of clean water and proper sanitation have a disproportionate impact on the poor.

Urban runoff carries significant amounts of sediment, nutrients and organic material and this is a major factor in the degradation of urban dams and rivers. In southern Africa, dams whose catchment areas have been heavily urbanised are eutrophic. There is massive proliferation of aquatic plants and blue-green algae in these water bodies. Signs of deterioration of lakes, streams and rivers in the region are evident and a number of lakes register high levels of conductivity, as well as high concentrations of dissolved solids, nitrates and suspended solids. Marine pollution caused by urban runoff and by direct discharge of domestic sewage is a problem for coastal cities throughout the region.

2.4.6 Degradation of water and other resources

Associated with growing rural and urban populations and low level of service delivery is another serious and a growing challenge, the increasing degradation of the region's water resources, which poses a serious threat to the sustainability of the water resource base. This is due to several factors including unsustainable and over abstraction, insufficient regulation of surface and groundwater for con-

sumptive and non-consumptive uses, increasing water pollution from municipal, industrial, mining, agricultural wastes and urban runoff and forest clearing, and watershed degradation resulting from poor land-use practices, proliferation of invasive weeds and species. These issues form the core concerns addressed in this report and are discussed in detail elsewhere in this report. (see Part 2, chapters 5 through 8)

2.4.7 Artificial water storage

Water storage (natural or artificial) retains water during periods of excess supply for use during periods of reduced natural availability. Natural storage can be provided by properly managed catchments, wetlands and groundwater aquifers and artificial storage from construction of instream or offstream dams and development of groundwater banks. Often, natural and artificial storage facilities are not considered as complementary parts of a single system of storage requirements in a river basin. Often artificial storage is built to replace natural storage but without adequate understanding of the natural storage characteristics. Artificial storage structures such as dams and reservoirs are also used to store floodwater and provide flood-control benefits. The artificial storage per capita is a useful indicator of the level of development of water resources available for direct consumptive and non-consumptive use.

Africa as a whole has a very small amount of artificial storage per capita compared to all other regions of the world, and consequently, its ability to buffer itself against major water shocks such as floods and droughts is very small. Compared to North America and Australia the per capita storage in Africa is smaller by more than 1-3 orders of magnitude.

In the SADC region, the Cahora Bassa and Kariba dams have created large storage and account for 90 percent of the storage in Zimbabwe, Zambia and Mozambique. South Africa, Namibia, Botswana and Tanzania have grossly inadequate artificial storage facilities. (Alemu *et al* 2001)

The region has more than 300 medium-sized dams and thousands of small ones for urban and rural water supply, livestock watering and irrigation. South Africa has over 500,000 dams, and Zimbabwe has about 8,000. Botswana has just 300 dams, largely for livestock, with additional storage to allow for limited irrigation. Namibia has 13 major state dams and another 500 small farm-dams. There are no supply dams in Swaziland, and water rationing is becoming common during dry months. (Ohlsson 1995)

Dams collect a huge amount of runoff, and farm dams in South Africa have reduced runoff by up to 40 percent in the Orange river basin. There can be serious downstream flow impacts of damming, especially on local communities, if this is not jointly managed in a manner that includes the governments of all riparian states as well as other stakeholders. (see chapter 5)

Siltation of dams is also a major concern in the region, generally resulting from soil erosion caused by poor land-use practices. Siltation can cut the useful life of a dam by one quarter, and major dams can silt up in less than 20 years. (Ohlsson 1995)

It is important to recognize the limitations in the use of artificial storage per capita as a proxy for development if storage facilities are only operated as single purpose facilities such as many structures in the SADC region. "The Cahora Bassa and the Kariba reservoirs were built during the colonial period and were designed for a single purpose – electricity generation. Due to this operational orientation, it is difficult to convert them into multi-purpose dams and use them, without major change and costly investment, to effectively mitigate water shocks. However, opportunities exist for conjunctive management of the two reservoirs to increase hydropower production within the framework of the Southern Africa Power Pool (SAPP). This would entail the establishment of an inclusive, riparian-led management framework that also could consider the existing reservoirs on the Kafue and Shire rivers as well as other planned reservoirs in the basin. The output of this cooperation would be a joint strategy addressing other key issues and objectives (besides hydropower development) such as environmental flows.

Without the contribution of Cahora Bassa and Kariba which provide more than 90 percent of storage capacity for Mozambique, Zambia and Zimbabwe, the investment in storage capacity is not at an appropriate level to ensure adequate risk coverage and protection against the regional effects of water shocks. This is clearly demonstrated by looking at the disastrous human and economic consequences of the 2000 floods in the Limpopo basin in Mozambique and Zimbabwe, and in the lower parts of the Zambezi basin in 2001. Such effects could have been mitigated if an appropriate joint management framework at both national and regional, basin-wide levels had been in place at the time." (Alemu *et al* 2001: 9)

2.4.8 Inter-basin transfers

Proposed solutions to water scarcity in the short term include demand management (Box 2.8) and inter-basin water transfer from other countries. The Lesotho Highlands Water Project is the largest water transfer scheme in the SADC region, under an agreement in which South Africa pays royalties to Lesotho for water exported from the Senqu/Orange river to the water-scarce Gauteng province. The export of water across other boundaries has also been suggested, such as the import of water by South Africa from as far away as the Zambezi river and even further north, from the Congo river. However, such inter-basin transfers are not without costs, and some entail substantial social and environmental risks that need to be evaluated and mitigated early in the planning and decision-making process. This case is discussed further in chapter 5.

2.4.9 Competing demands for water

There are competing demands for water from the major sectors of the region's economy. These include agriculture, mining, energy, transport, recreation, and environment. Irrigation places the highest demand on water and the ecological needs are only now being recognised. The greatest challenge facing the SADC countries is the management of the ever-growing demand on the waters of the region to ensure sustainable growth and poverty alleviation.

Since the economies of southern Africa are heavily dependent on water resources, any expansion in the economy usually results in a corresponding increase in water demand. Long-term growth prospects will depend on how well agriculture performs since it is expected to be the main source of foreign exchange and water savings in most countries, as well as sustenance. Agriculture will also be an important source of inputs for industry and a major contributor to the market for newly established industries. If the current trend in water use in agriculture does not change, the excessive use of water in agriculture will remain a serious threat to the sustainability of the resource.

While inter-basin transfer is an option in the medium to long term for augmenting local water supplies, water demand management (WDM) in the short to medium term provides a more cost effective and sustainable solution to addressing the increasing demands for water.

Water Demand Management: the case of Mozambique and Namibia — **Box 2.8**

Water Demand Management (WDM) is a management approach that aims to conserve water by controlling demand. This involves the application of selective incentives to promote efficient and equitable use of water. A range of measures can be used to modify the demand for water and these include economic measures (water pricing), regulation, education and awareness-raising, technology improvements, water-loss control, water reuse and recycling.

The Mozambican study was carried out at the Chokwe irrigation scheme. The price of raw water for agricultural production is heavily subsidized and water is wasted because consumers are not told about the real value of the resource. Given the vulnerable nature of the water resources in Mozambique, WDM strategy is of crucial importance. However, due to the lack of research in water management associated with the shortage of measuring and regulating devices for controlling the supply and use of water, coupled with the general lack of financial and human resources, WDM principles have not yet received sufficient attention. A serious constraint to the establishment of demand management is the lack of data relating to water quality, quantity, accessibility, dissemination, and use. An appropriate legal and institutional framework for the water sector in Mozambique would contribute significantly towards the creation of an environment in which WDM strategies could be implemented.

The Namibian case study concentrated on the urban water supply (residential, commercial and industrial), and agricultural (commercial irrigation), mining and tourism sectors. A wide range of WDM measures were implemented. In the urban sector these included a block tariff system to reflect the real cost of water and to curb excessive water use. Public campaigns were used to educate the people about the importance of water. In order to prevent undue water consumption on private properties, Water Control Officers were employed to ensure that water wastage is addressed immediately. Efforts were made to reduce unaccounted for water through a leak detection programme, repairing and replacement of leaking pipes, carrying out continuous water audits and properly managing water meters. The report however suggests that the price charged for water still does not reflect its true cost.

In the tourism sector, the case of Etendeka Mountain Camp is noted, where all staff members are trained to use water efficiently. Guests, mainly from overseas, are informed about the scarce water resources of Namibia and are asked to help by minimizing their water use. The showers are restricted to 15 litres per person by using a bucket shower system.

In the agriculture sector, WDM techniques include drip irrigation management and use of sprinklers on days without wind, the use of plastic covers over the soil to reduce evaporation and the use of tensiometers at the pump to control the pumping pressure. WDM techniques also include laser leveling of the land to avoid excessive losses from the flood irrigation (pooling and flooding etc), optimizing the irrigation scheduling and the use of special crop varieties which have short growing periods. However, farmers generally lack the skills required for optimal irrigation techniques, and extension services could improve the water consumption figures substantially.

The Desert Research Foundation of Namibia has contributed to greater awareness of WDM in the SADC region through two recent publications, *Sharing Water in Southern Africa,* edited by John Pallett and *Namibia's Water — a Decision-makers's Guide,* edited by Piet Heyns, Sharon Montgomery, John Pallett and Mary Seely.

Goldblatt *et al* 2000

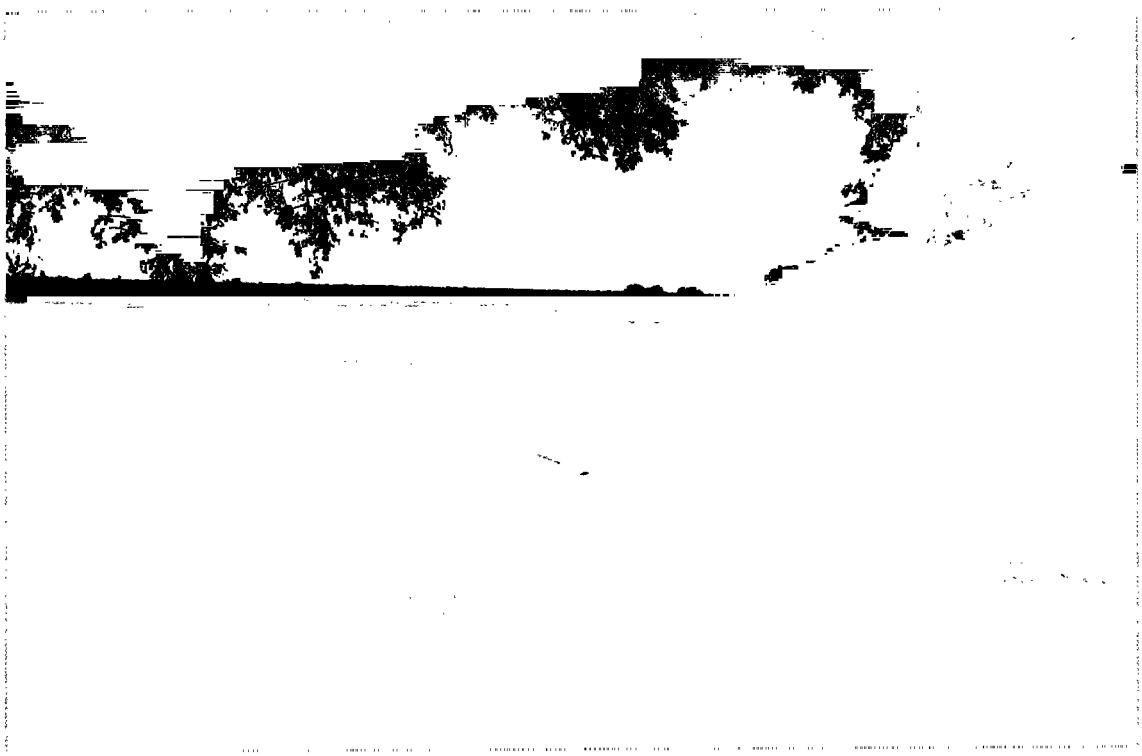
WDM is aimed at maximising water-use efficiency to derive the greatest value from the available water resources. Various methods and tools are used to manage water demand and these include economic measures, regulation, education and raising awareness, improved technology, controlling water loss, and re-using and recycling water. WDM is now widely accepted in the SADC region and various studies have been undertaken to promote its use.

2.4.10 Conflict over water resources

Tensions over access to water and competition for decreasing water supplies can create the conditions for conflict, and SADC is establishing mechanisms to deal with these concerns, such as the Protocol on Shared Watercourses, the Regional Strategic Action Plan, and the establishment and strengthening of river basin organizations. However, while these strategies can facilitate joint management and strengthen channels of communication, the implementation requires full commitment of the member states in an atmosphere that will often require close consideration of national interests within the framework of the interests of neighbouring countries and the region as a whole. Achievement of this appropriate level of implementation will immeasurably strengthen the region and its development, but failure could precipitate confrontation and conflict. Stronger mechanisms for communication and mediation, and early warning of potential conflicts are essential to the future stability of the region.

2.5 IMPLICATIONS FOR ECONOMIC DEVELOPMENT

The unreliability and variability of water resources in southern Africa have a severe impact on economic development in a region where economic growth rates are among the lowest in the world, partly due to water scarcity and related problems. In several countries there is growing evidence of a positive correlation between rainfall variability and real GDP growth. Inefficient management of water resources, including unsustainable land and water use practices are compounding the problem, and are not only impacting the economy, but are also degrading the resource base and threatening its sustainability.



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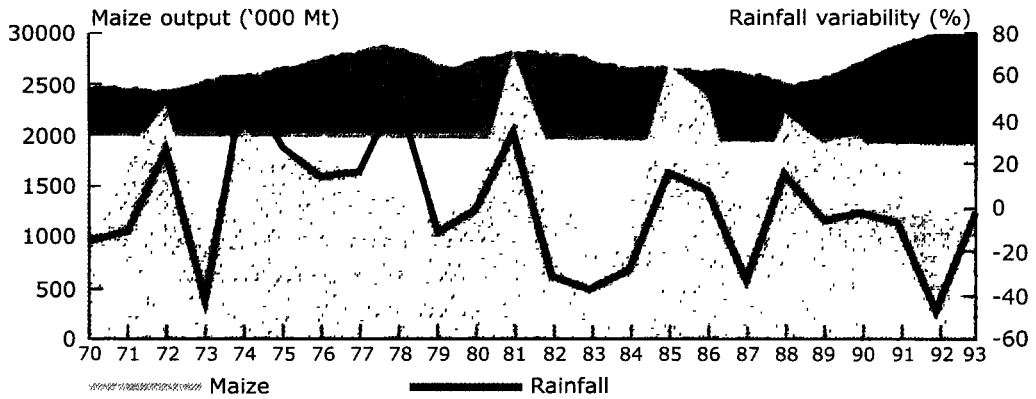
[illegible] plans to draw water from the Okavango river (above) in times of need, drew protests. However, the Ramsar Convention, which binds signatories to the "wise use" of wetlands such as Okavango, does not provide guidance on how to balance the protection of environmental resources which water sustains, and community demands for basic water supplies.

Rainfall Variability and Maize Output in Zimbabwe, 1970-93 **Figure 2.9**



Alemu *et al* 2001

2.5.1 Agricultural output

The recurrent droughts and floods that southern Africa has experienced have resulted in the loss of human life, livestock and other property as well as severe localized shortages of the main cereal crops and other food. During the 1991–92 drought, cereal production in Namibia dropped by 70 percent, while in Zimbabwe agricultural production declined by 45 percent. Due to the massive crop failure, the region spent about US$2 billion on drought relief. In early 2000 and 2001, massive flooding and a cyclone caused severe damage with loss of life and property in Mozambique, South Africa, Zambia and Zimbabwe. Agricultural output and food production have suffered due to water scarcity in some seasons and water damage to infrastructure at other times. Increasing competition in demands for water threatens to curtail irrigated agriculture unless that sector becomes more efficient in its use of water resources.

Figure 2.9 shows a strong positive correlation between the variability in rainfall and the output of maize production during the period 1970-93 in Zimbabwe. The average annual precipitation fluctuated from 335 to 1004 mm, and averaged 640 mm. Maize output strongly followed the volatility. Such volatility can even disrupt the agro-industry production chain. (Alemu *et al* 2001)

2.5.2 Domestic water supplies

Floods and droughts have had negative impacts on domestic water supplies. During the 1991–92 drought and 2000–2001 floods, a number of the affected areas in the region experienced major failures in water supply. During the drought many sources of supply, including groundwater, failed. Overall, water supply systems were not prepared for the impact of these events. Box 2.10 describes the impact of the 1996 El Nino floods on Dar es Salaam's water supply.

Flood damage to city water supply in Dar es Salaam **Box 2.9**

The El Nino-related floods in 1996 resulted in severe damage to the Dar es Salaam water supply, which is dependent on an unregulated river, the Ruvu. The torrential floodwaters exceeded the hydraulic capacity of the Ruvu river and almost altered the course of the river system away from the water supply intake because large sections of the riverbank were breached due to excessive bank erosion. A large segment of the lower Ruvu pipeline, which carries two-thirds of the city's supply was washed away at a critical point due to the floods and bank erosion, and this resulted in almost a million people in the city going without reliable water supply in the midst of major floods for almost 10 days, a potentially dangerous situation for a serious outbreak of water-related diseases and a public health crisis.

Hirji *et al* 2001

2.5.3 Hydropower generation

Hydropower is one of the major sources of energy in southern Africa. The availability of affordable sources of energy is seen as a strong impetus for economic growth. However, the uncertainty of the water resource base, competing demands for water, and droughts have significant impacts on hydropower generation. Hydropower is also usually in direct conflict with aquatic ecosystems due

to the highly regulated and non-natural flows as a result of hydropower requirements. In Tanzania, competing water demand between irrigation and electricity is affecting hydropower generation. Increasing watershed degradation in the Luangwa river basin in Zambia is believed to threaten power generation at Cahora Bassa in Mozambique. During the 1991-92 drought, Zimbabwe suffered a 15 percent decline in power generation. Water supply for thermal power stations is also affected by drought.

2.5.4 Commercial and industrial development

Water scarcity is a serious threat to commercial and industrial development. In South Africa for example, water scarcity has retarded industrial development and mining. Industrial development in Zimbabwe's second largest city, Bulawayo has been handicapped by water scarcity. In order to boost industrial development and investment in this city, the Matabeleland Zambezi Water project has been proposed, estimated to cost Z$1,650 million based on the 1994 estimates (approx. US$ 180 million at that time). The estimates will be significantly higher in 2002.

Drought sends negative shockwaves through the commercial sector in the region. During the 1991-92 drought, about 20 million people were affected and almost 70,000 jobs were lost. In South Africa, the economic impact of the 1991-92 drought was modelled and the results indicated a reduction in real disposable income of about 1.8 percent, an increase in consumption expenditure of 0.5 percent due to lower disposable income and higher food prices, reduction in gross domestic saving of 5 percent and an incremental rise in the rate of inflation of 0.8 percent. Overall, the drought was estimated to have a net negative effect of at least R1, 200 million on the current account of the balance of payments. It also resulted in the loss of 49,000 agricultural jobs and 20,000 formal sector jobs in non-agricultural sectors. The effects of drought go far beyond agricultural production alone, impacting on a wide range of economic activities. Box 2.10 shows the impact of drought on the economy of Zimbabwe.

While droughts can cripple the economy of a country, floods often destroy infrastructure, property and livestock. During the 1998 El Nino floods, the transport system in Tanzania suffered major damage to bridges, roads, railway infrastructure and city water-supply pipelines. This was also the case in Botswana, Malawi, Mozambique, South Africa and Zimbabwe during the 2000-2001 floods, with the impact most severe in Mozambique.

Drought impacts on Zimbabwe's economy **Box 2.10**

The 1991-92 drought had a devastating impact on the economy of Zimbabwe. The specific impact on the manufacturing sector was as a result of water and electricity shortages. Most of the municipalities imposed rationing of water, with severe water shortages affecting urban areas such as Bulawayo, Chegutu and even Mutare in the eastern highlands. Electricity shortages led to load-shedding. Rationing from September 1992 and increased electricity tariffs affected the whole country. Load-shedding caused a reduction of about US$56 million (Z$560 million) in GDP in 1992, US$20 million in exports and loss of 3,000 jobs.

Zimbabwe's manufacturing output declined by 9.3 percent in 1992 and there was a 6 percent reduction in foreign currency receipts from manufactured exports, equivalent to a two percent reduction in total export receipts. The most severely affected sub-sectors were textiles (including cotton ginning), clothing and footwear, non-metallic mineral products, metal and metal products, and transport equipment.

The value of the Zimbabwe stock market declined by 62 percent in 1992 partly as a result of the drought, leading the International Finance Corporation (IFC) to identify the country's stock market as the worst performer of 54 world stock markets in that year. GDP declined by 11 percent.

Benson and Clay 1994

2.5.5 Commercial and subsistence fisheries

The degradation of water resources has severe consequences on the region's fishing industry, which is the backbone of some national economies. Pollution in some surface water bodies has affected aquatic life in many parts of the region. In the early 1990s eutrophication and the subsequent invasion of aquatic weeds in Lakes Chivero and Manyame in Zimbabwe, resulted in massive fish kills that affected both commercial and subsistence fisheries. The excessive regulation of river flows affected prawn production within the Sofala bank of Mozambique, well known as a key element in the country's commercial fishery.

Climatic and human-induced desiccation of wetlands and other water bodies has destroyed fishing industries in

some parts of the region. In Botswana and Namibia for example, the drying of Lakes Ngami and Liambezi completely destroyed thriving fishery industries, making fish-processing facilities obsolete.

2.5.6 Tourism and recreation

Recreation and water-based tourism is an important economic activity in the region. The Zambezi river and its associated water bodies are extensively used for recreation and tourism. The Victoria Falls between Zambia and Zimbabwe is one of the world's unique scenic sites while the gorges downstream of the falls are renowned for whitewater rafting. Tiger fishing is an important international sport supported by the Zambezi river. Water pollution and over-abstraction of water have a serious affect on these activities.

The coral reefs off the coast of Tanzania are attracting visitors interested in diving and snorkelling but the reefs continue to be damaged by illegal dynamite fishing, despite national laws against it. The vast biodiversity of wild animals, birds, insects and vegetation in national parks such as Serengeti in Tanzania, Etosha in Namibia and Kruger in South Africa, and the Okavango delta in Botswana attract large numbers of tourists from all over the world. Droughts and floods can affect the viability and sustainability of these recreation and tourism activities, and some facilities were extensively damaged by the recent floods. Drought reduces water levels and may precipitate the death of wild animals and damage to their habitat, thereby affecting the operation of tourism activities.

2.5.7 Poverty

Poverty levels have been rising steadily in southern Africa, a trend projected to continue over the next 25 years, posing a serious threat to the sustainability of water resources. SADC estimated a decade ago, in 1992, that some 50 million people, one-third of the population of the region at that time, lived in absolute poverty. (SADC ELMS 1996) Current estimates suggest that this figure has more than doubled, to more than 60 percent of a total regional population of over 200 million people.

Poverty (in conjunction with a weak policy environment) is viewed as the main cause and consequence of environmental pressure that continues to degrade the water resource base and threaten its sustainability. Poverty and environmental degradation are linked in a vicious circle in which people cannot afford to take proper care of their environment. Grey and Sadoff postulate that "Africa's water resources endowment seriously constrains economic growth." (2002:1) Mozambique's official report to the UN Conference on Environment and Development (UNCED) stated bluntly that it cannot achieve sustainable development in the short term because it cannot yet meet the basic human needs of its population.

Country	Debt as % of GDP 1997	1990 US$millions	1995 US$millions	1996 US$millions	1997 US$millions	1998 US$millions	1999 US$millions
Angola	127.8	7 281	10 001	8 488	9 589	9 777	9 273
Botswana	32.3	752	1 377	1 406	1 481	1 400	n/a
DRC	140.4	10 170	13 459	13 961	14 390	14 390	14 390
Lesotho	42.1	356	517	531	427	352	514
Malawi	139.5	1 674	2 618.3	3 732.5	3 591.6	3 600	3 800
Mauritius	29.4	830	1 100	1 208	1 205	1 238	1 209
Mozambique	158.5	4 960	5 472	5 692	5 643	5 929	n/a
Namibia	10.5	312	369	357	343	343	343
Seychelles	26.2	126	156	152	149	157	0
South Africa	27.9	23 056	35 554	37 655	41 409	41 164	n/a
Swaziland	19.8	208	218	267	243	203	n/a
Tanzania	110.9	5 902	7 888	7 118	7 601	7 865	n/a
Zambia	192.0	7 237	6 400	6 571	7 144	6 800	n/a
Zimbabwe	20.6	2 153	2 452	2 010	1 607	2 081	n/a
SADC	46.2	75 015	87 583	89 148	94 824	95 298	n/a
Sub-Saharan Africa	67.9						
Least developed(LDCs)	99.5						
Developing countries	42.8						

SADC Statistics 2000

A key factor hampering access to financial resources for appropriate water resources management is the economic instability caused by the region's burden of foreign debt, which continues to climb and which doubled between 1980 and 1991. (Ohlsson 1995) In some cases, the debt burden increased by three or even six times in that period, although economic research shows both positive and negative connections between debt levels and income growth depending on the countries studied. Some countries have foreign debt greater than GDP. (Table 2.13)

The need to increase economic output to meet the need of an expanding population will intensify pressure on resources, and the development of water resources will have to be increasingly self-financing. (see chapter 4) It seems unlikely that most southern African countries would be able to advance in regulation and management of water and environmental resources until the debt burden is reduced, and the most obvious resources to be affected by pressure to increase economic output will be land and water. (Ohlsson 1995) Land is needed to grow food, support industry, graze livestock and support human habitats and livelihoods, while water is needed for all of these activities, for basic survival and for sustaining the health of the natural environment.

Throughout the SADC region the burden of family sustenance falls on women, in both rural and urban areas. In rural areas, this is accompanied by hard physical labour in carrying water and fuelwood over long distances, and for the most part, in generating agricultural production. Policy and behavioural changes can begin to alleviate this burden, including for example, serious support for the infrastructure of solar energy to enable widespread use. SADC's Gender Unit and the SADC Parliamentary Forum, among others, have in place visionary programmes on advancing the role of women in decision-making, which should ultimately assist in mainstreaming some of these basic policies that can reduce the burden on women and free some of these energies for development purposes and income generation to reduce poverty.

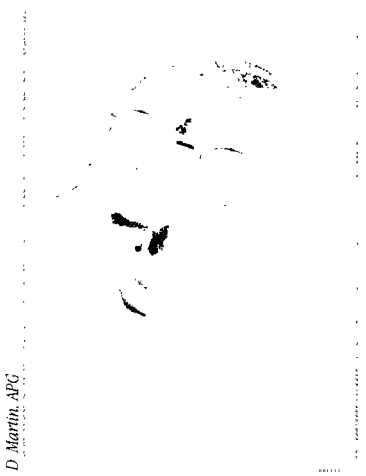
Major changes in economic development policies are needed to address the poverty issues and achieve greater equity for sustainable development. Many of the past and current strategies have largely failed to improve the lives and livelihoods of the majority of the population, as clearly shown by the increasing debt burden and the increasing burden that poverty places on women.

In an attempt to address this problem of poverty and equity, SADC defined the *SADC Policy and Strategy for Environment and Sustainable Development – Toward Equity-led Growth and Sustainable Development in Southern Africa*. This policy and strategy provided the basis for implementing the global action plan for environment and development, Agenda 21, adopted at the 1992 Earth Summit.

The document recognises poverty as the main cause and consequence of environmental degradation, and poverty alleviation as SADC's overriding goal and priority; and identifies equity as a crucial element to be added to environment and development in order to make Agenda 21 more applicable and operational in southern Africa. The document quotes the regional report to the 1992 Earth Summit:

"We must never forget the majority of people and countries in the region and the world are poor. If the poor sometimes behave in a way that degrades the environment it is not because they choose to do so. They only do so when they have no other choices... The Earth Summit and Agenda 21 must expand the development choices and opportunities for the majority of poor people, communities and countries... The Earth Charter and Agenda 21 must provide a new basis for a new deal for the majority of poor people and countries in order to secure and sustain our common future."

With the main goals of accelerating economic growth with greater equity and self-reliance, improving the health, income and living conditions of the poor, and ensuring equitable and sustainable use of the environment and natural resources, SADC as a regional body has put in place the main building blocks for addressing equity issues. It remains to be seen whether the international community will fully support these regional initiatives to overcome poverty.



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2.6 SUMMARY

Water has been described as more valuable than gold and that should not be considered lightly as an exaggeration. The message is that water has a value. Water is priceless in the sense that it is the very essence of life, but it is also scarce, as it is finite, and its scarcity is exacerbated by increasing degradation. Effective legislative and institutional frameworks to efficiently manage the resource are critical for both the current and future generations. The context of sustainability must encompass broad economic policies for sustainable development and to address poverty. Water resources management in the region must attain the sustainable and integrated planning, development, utilization and management of water resources that can contribute to the attainment of SADC's overall development goals of poverty alleviation, food security and industrial development within the framework of an integrated regional economy.

Fruhling (1996) makes the point that "the belief that more water can always be available if only some technology is added is obsolete and destructive. Water must be seen as a limited and vulnerable resource; an element that links land, vegetation, animals and man [*sic* people] together." It must be treated and managed as a scarce resource with important social and economic values.

The region's recurring droughts and floods are predictable and if not preventable, at least carry the potential for significant impact reduction through appropriate planning and communication, and especially, through addressing the root causes of poverty which is accompanied by chronic malnutrition and endemic food shortages.

"Adjusting the structure of the economies and moving the southern African countries out of the water dependent, low-equilibrium, poverty trap requires reducing the uncertainty of access to water that may alter signals sent to local producers and local and foreign investors. The high degree of rainfall variability translates into high output volatility and, as risk coverage against water shocks is not necessarily optimal, this also affects the cost of capital (in)flows and the rate of capital accumulation as well as investor profiles. In this context, the role of domestic and regional investments in artificial and natural storage capacity is crucial in lessening the impact of water shocks. However, investments in the overall storage capacity have to be complemented by cost-effective integrated and sustainable management of the water resources to provide an effective and comprehensive risk coverage." (Alemu *et al* 2001: 7-8)

In southern Africa, water sets the parameters of development, either opening opportunities or foreclosing options. The SADC Regional Strategic Action Plan addresses the needs for the development of the region's water resources in an integrated manner. This report supports and complements the SADC Regional Strategic Action Plan. It provides specific guidance and directions for defining criteria that determine environmentally sustainable water use and management and for integrating them in water resources policies and in water resources planning and management decision-making. The report helps to fill the knowledge gap regarding the different elements of environmentally sustainable, water resources management. These issues are discussed in greater detail in subsequent chapters. Each of the chapters highlight the issues, the signposts and the way forward in terms of enhancing environmental sustainability in water resources management in southern Africa.

Pula **Box 2.11**

Water is so essential to life in southern Africa that people of Botswana use the greeting *Pula*, meaning rain, a term also used for their currency. When a Head of State arrives, the Setswana greeting *A pula e ne*, translates as "Let it rain – may blessings come."

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CONTENTS

THE ROLE AND IMPORTANCE OF AQUATIC ECOSYSTEMS IN WATER RESOURCES MANAGEMENT

3.1 INTRODUCTION

Water scarcity has strengthened awareness of the economic value of water for consumptive and non-consumptive uses in southern Africa. However, the full value to society has yet to be understood and appreciated, of a water resource base which comprises aquatic ecosystems including riverine, estuarine, coastal marine and wetland systems, floodplains, lakes (natural and artificial) and groundwater. Water resources provide a wide range of goods and services which are dependent on the maintenance of healthy aquatic ecosystems.

Aquatic ecosystems are productive systems upon which many people, often the poor, directly depend for their livelihoods and from which they derive important socio-economic benefits such as flood recession agriculture, wildlife and livestock water supply, and fishing. Aquatic ecosystems also perform numerous ecological and hydrological functions, and often are hubs of biological diversity. See Table 3.1, which lists the direct and indirect values derived from aquatic ecosystems in the Zambezi basin. In southern Africa, aquatic ecosystems face severe threats, the consequences of which have potentially significant implications for the sustainability of the water resource base.

This chapter addresses the functions, role and importance of aquatic ecosystems in water resources management, and identifies key ecological aspects such as biodiversity and ecological integrity which underpin the sustainability of water resources in the Southern African Development Community (SADC) region. It complements chapter 4 which details the methods and approaches for determining the economic values of the full range of goods and services provided by water resources. This chapter also identifies and briefly discusses the major threats facing aquatic ecosystems in the region, which include over-abstraction of water and loss of flow, degradation of water quality, proliferation of nuisance species,

Wetland component	Direct use value	Indirect use value
River and channels	Fish, gamefish & wildlife (game)	
Riparian zone	Reeds, wood, fruits, wildlife (game)	Breeding habitat for fish and waterfowl
Reed marshes, papyrus swamps	Reeds, fish, birds, wildlife (game)	Nutrient cycling and pollution absorption
Estuary including mangroves	Fish, wood, wildlife (game)	Breeding habitat for fish and prawns, sediment trap
Floodplain	Fertile agricultural soils, grazing grasses, wildlife (game), birds, wood	Groundwater recharge
Whole wetland	Biodiversity and aesthetic beauty	

Turpie *et al* 1998

degradation of land, and weak institutional and policy frameworks. Each of these threats, and options for mitigation, are addressed in detail in the thematic chapters which follow chapter 4. Chapter 5 relates to provision of water for aquatic ecosystems; chapter 6 relates to water quality management; chapter 7 relates to land degradation; and chapter 8 to the management of aquatic weeds. In conclusion, this chapter provides a list of recommendations for water policy which can support the sustainable management of water resources according to an integrated ecosystem approach.

3.2 DEFINITION OF AQUATIC ECOSYSTEMS

There are several internationally accepted ways to define aquatic ecosystems, but in southern Africa a uniformly accepted definition does not exist. Aquatic ecosystems are considered to include riverine systems, estuarine systems, coastal marine systems, wetland systems, floodplains, lakes (natural and artificial) and groundwater systems. The Ramsar Convention (1971) defines wetlands as,

> areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres.

The widely used Ramsar definition includes all types of aquatic ecosystems, but for the purposes of this chapter, the term "wetland" will be used to refer to typically swampy systems, whether temporary or permanent, and "aquatic ecosystems" will be used as the more encompassing term. Box 3.1 shows the different perceptions of wetlands in the region.

An aquatic ecosystem generally has several components:

- water, whether standing, flowing or underground;
- physical habitat, including channel morphology or bathymetry, sediment characteristics and bedforms;
- vegetation, including riparian or fringing vegetation and instream vegetation (both submerged and emergent), algae and phytoplankton;
- biota, from macrofauna to microfauna; and
- biochemical and ecological processes, such as nutrient cycling.

All of these components are necessary, and must be present with some degree of health, quality or integrity, in order to maintain a fully functional ecosystem, and so must be included in the working definition of an aquatic ecosystem. For the purposes of this chapter:

> An aquatic ecosystem includes the water, physical habitat, vegetation, biota and biochemical and ecological processes contained between the outer edges of the riparian or fringing zones and within groundwater bodies.

Groundwater has tended not to be considered as an aquatic ecosystem until quite recently, rather being seen as a source of water for surface aquatic ecosystems. However, new research from Australia and South Africa has shown that groundwater bodies often contain rich floral and faunal populations, and biodiversity scores measured in certain groundwater bodies in Australia recently, are some of the highest yet recorded in the world. (Humphreys, pers. comm.) The hydrological, biochemical and ecological processes which link groundwater and surface water ecosystems are complex

Multiple definitions of wetlands — **Box 3.1**

The wide range of definitions of wetlands given below illustrate the different perceptions that people have of wetlands in the region. Despite the widespread acceptance of the Ramsar definition, a number of country-specific definitions exist.

- In Malawi, wetlands are areas that are periodically wet or periodically dry, or permanently flooded with a water layer not exceeding several metres.
- In Namibia, wetlands include areas where water accumulates on land even if it happens to dry up temporarily.
- In South Africa, wetlands are places where marine, aquatic and terrestrial ecosystems meet and interact.
- In Zambia, wetlands are understood as areas that are permanently flooded including littoral zones of lakes, rivers, swamps and dambos.
- In Botswana, wetlands are all areas in which water sits on or above the surface of the soil for periods of time thus affecting the ecological characteristics of the area.
- In Zimbabwe, wetlands are understood to be land that is subjected to permanent or seasonal flooding or areas of subsurface water accumulation through seepage such as in *vleis* or dambos.

Adapted from a number of sources including a paper presented at the Malawi National Wetlands Seminar, 1991; Pallett (ed) 1997; *Wetlands of South Africa*, 1995; WWF/Zambia National Parks and Wildlife Service, undated information sheet; and Mukahanana 1994.

and difficult to measure, but are proving to be significant and worthy of attention in water resources management and environmental impact assessments. (Steyn, pers. comm.)

3.3 SUSTAINABLE MANAGEMENT OF WATER RESOURCES

3.3.1 Goods and services provided by aquatic ecosystems

Although there has been and remains a tendency to think of water itself as the only commodity of value which is provided by water resources, in fact aquatic ecosystems provide a number of goods and services that are of value to people (see chapter 4 on valuation of ecosystem services). These include:

- supply of water with reasonable assurance and of adequate quality which can be abstracted for offstream use, to meet commercial, agricultural, industrial or basic human needs;
- the ability to dilute and transport wastes, and to purify some biodegradable wastes (see Figure 3.1);
- biological products for harvest, such as fish, reeds, food plants, medicinal plants and shellfish (see Box 3.2);
- opportunities for transport;
- aesthetic, leisure and tourism opportunities;
- use for cultural and spiritual purposes;
- attenuation of floods (see Box 3.3);
- maintenance of microclimate;
- maintenance of agricultural societies (see Box 3.4); and
- maintenance of terrestrial ecosystems, particularly in the case of groundwater.

The common thread running through all of the goods and services listed above is that their maintenance depends directly on the maintenance of all the components of healthy, functioning aquatic ecosystems. For example, if nutrient cycling is affected by loss of key insect and microbial species which aid the natural decomposition process, then aquatic ecosystems will not be able to process and purify wastes efficiently. Thus there is a need to consider, manage and protect aquatic ecosystems as the resource base from which the commodity of water and other valuable goods and services are derived, rather than as users of water which compete with people for a limited water supply.

Wetlands can also contribute to pollution abatement by removing pollutants such as bacteria and oxygen-demanding substances; reducing dissolved concentrations of toxic heavy metals such as lead, chromium, copper, zinc and cadmium; and processing and storing nutrients such as nitrogen and phosphorus.

Significant inland fisheries resources in the SADC region — Box 3.2

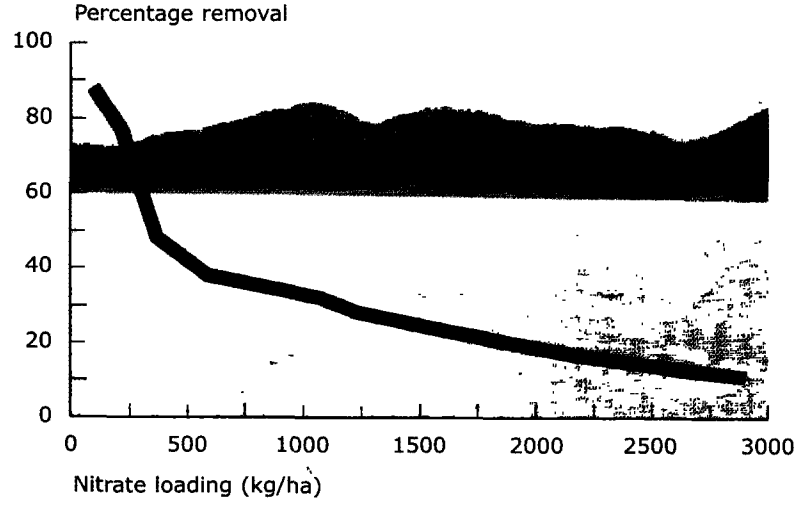
Very important and productive fisheries are supported by the numerous wetland ecosystems of the region, such as:

- Wembere plains and Bahi swamps in Tanzania;
- Bangweulu swamps, Mweru wa Ntipa, Kafue flats and Barotse floodplains in Zambia;
- Lakes Malawi, Chilwa and Chiuta in Malawi;
- Estuaries in Tanzania and Mozambique; and
- Many smaller wetlands that support signficant fisheries.

Dams in the region also support vibrant fisheries. In Lake Cahora Bassa, potential catches are estimated at 15,000 tonnes per year. By 1993, the annual yield from the Lake Kariba fishery was about 30,000 tonnes with a producer value of US$55 million. (Masundire and Matiza 1995)

Annual fish landings from inland fisheries, mostly wetland fisheries, range from about 35 tonnes in Lesotho to 300,000 tonnes in Tanzania. (FAO 1995) The total annual fish catch from inland fisheries is over 4 million tonnes.

Rate of Nitrate Removal by Wetland Ecosytems — Fig 3.1



The role of wetland ecosystems in flood attenuation and flow regulation — Box 3.3

Wetland ecosystems may act as flood detention and flow regulation reservoirs.

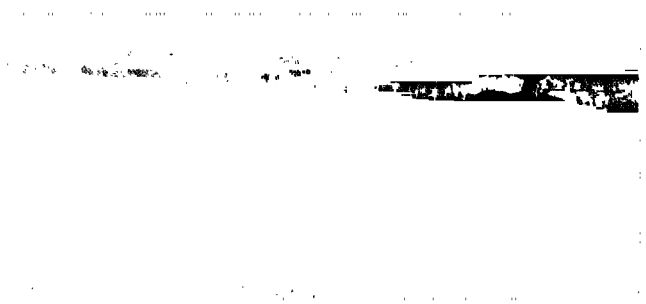
As a flood enters a wetland, flow becomes attenuated. There is a lag period between the time the peak enters the wetland and when it leaves, and the peak flow leaving the wetland is usually significantly lower than that entering it. This has the effect of offering protection for communities living downstream of the wetland.

The Okavango delta, the Linyanti and the Barotse swamps best illustrate this function.

Wetlands store water that is gradually discharged into river systems throughout the year, helping to maintain base flows during the dry season.

The Barotse floodplain stores 8,600m cu m at low flow and as much as 27,000m cu m during peak flood. This wetland ecosystem stores water that contributes towards maintaining the perennial flows of the Zambezi river. The floodwaters of the Zambezi in the Barotse floodplain play an important role in securing year round freshwater supplies for human and animal populations.

The Kafue basin above Itezhitezhi is subject to significant regulation by the Lukanga, Busanga and other swamps.



SOE Zambezi - CEP

Wetland ecosystems may act as [illegible] reservoirs, seen here in Zambezi basin.

The importance of floodplain recession agriculture — Box 3.4

Wetlands have been used for several centuries for flood recession agriculture. Early civilizations and settlements especially in the Middle East thrived on floodplain agriculture. The variations in inundation levels of wetlands result in very fertile soils that attract human settlement.

In the Kafue flats, the permanent area of inundation is 13,000 sq km and seasonal inundation covers a total area of 28,000 sq km. The variations in flooding create fertile soils used to support intensive agriculture.

The main floodplains in the region, *ie* Barotse floodplain, Wembere plains, East Caprivi wetlands and the Kafue flats have a long history of settlement and this is partly attributed to the fertile soils found in these areas.

The Barotse floodplain supports more than 300,000 people whose livelihood is dependent on the fertile alluvial deposits from the Zambezi.

In Namibia, the fertile floodplains of the East Caprivi support a total of 134,708 cattle and 18,470 goats.

Bethune 1998

3.3.2 Aquatic ecosystems as renewable resources

The perspective that aquatic ecosystems are the resource base implies that, in order for water resources to be managed as renewable resources, such that the flow of goods and services from aquatic ecosystems is sustained in the long term, then water resources should be managed as ecosystems, linked to the land and terrestrial ecosystems in a river basin, rather than just as reservoirs or transport systems for water. Water resources management should include the management and protection of all components of aquatic ecosystems, not just the water. Approaches to ensure inclusion of all components of aquatic ecosystems in economic cost-benefit analyses are discussed in more detail in chapter 4.

The sustainability of the goods and services which are so valuable to people, and some of which are critical for our life support, require that the structure, function and health of all components of aquatic ecosystems be protected, by supplying the aquatic ecosystems with sufficient water, at the right time, in the right quantities and of suitable quality; by ensuring that riparian and instream habitat are not degraded as a result of poor land-use practices or over-exploitation, and that natural biotic communities are not compromised by the introduction of invasive alien species.

3.3.3 The importance of ecosystem health to sustainable water resources management

As long as aquatic ecosystems remain healthy and retain a degree of natural ecological functioning, they are resilient, meaning they are able to recover from the pressure of utilisation of various goods and services by people, and are able to sustain a steady flow of goods and services to people. This means that they can be managed as renewable resources, so long as they are not over-exploited beyond their capacity to recover, whether by over-abstraction of water, the addition of too much waste, degradation of habitat or the introduction of invasive alien species.

The resilience of an ecosystem to natural or artificial events, including the pressures of utilisation and exploitation, depends on a number of factors, amongst them:

- the diversity of the system (habitat and species diversity);
- the presence of refuge areas from which the ecosystem can be repopulated if certain species are lost due to degradation, catastrophic natural events or accidents such as toxic spills;

the ecological integrity of the system, which is a measure of its degree of [illegible] from natural conditions;

the ecological health of the system, which is a measure of the degree to which major ecological processes are functional, such as cycling of nutrients, decomposition of organic matter, feeding and reproductive processes of key species.

As a general rule, the more natural an ecosystem is, the higher its integrity and resilience, especially if its natural biodiversity is high. However, an aquatic ecosystem does not have to be in pristine condition to be ecologically healthy: even modified systems can be ecologically healthy and provide goods and services, including water. Hence in water resources management, a balance must be achieved between protecting the ecological health of aquatic ecosystems at a level such that the water resources remain able to sustain utilisation in the long term, and utilising the water resources in order to meet short term imperatives for economic development, subsistence livelihoods or provision of basic water and sanitation services. The two objectives of protection and utilization need not be conflicting, and particularly in rural areas they may often be complementary, since great reliance is usually placed on the natural functions and products of aquatic ecosystems by rural communities.

3.4 IMPORTANT SOUTHERN AFRICAN AQUATIC ECOSYSTEMS

3.4.1 Classification of aquatic ecosystems in southern Africa

There are divergent views on [illegible] and classification of aquatic ecosystems. Numerous classifications of aquatic ecosystems exist and the most quoted one is that of Cowardin *et al* (1979). According to Cowardin *et al*, aquatic ecosystems can be classified into five major systems – marine, estuarine, riverine, lacustrine and palustrine. Some authors have classified aquatic ecosystems by their geographical location, water quality and mode of formation. This has given rise to classifications such as intertidal and sub-tidal marine systems, lakes (natural and artificial), riverine systems, [illegible], swamps, marshes and dambos. Dugan (1990) classified aquatic ecosystems into three main categories, based on the quality of water and mode of formation, *ie* salt water, freshwater and artificial wetlands. Masundire (1995) modified Dugan's classification to provide a more detailed breakdown. Box 3.5 shows the classification adopted in South Africa for the purposes of developing a wetland inventory (Dini *et al* 1998), which is also based on the Cowardin *et al* classification.

3.4.2 Distribution of aquatic ecosystems

The majority of natural inland aquatic ecosystems in southern Africa are associated with major drainage systems of the [illegible] rivers:

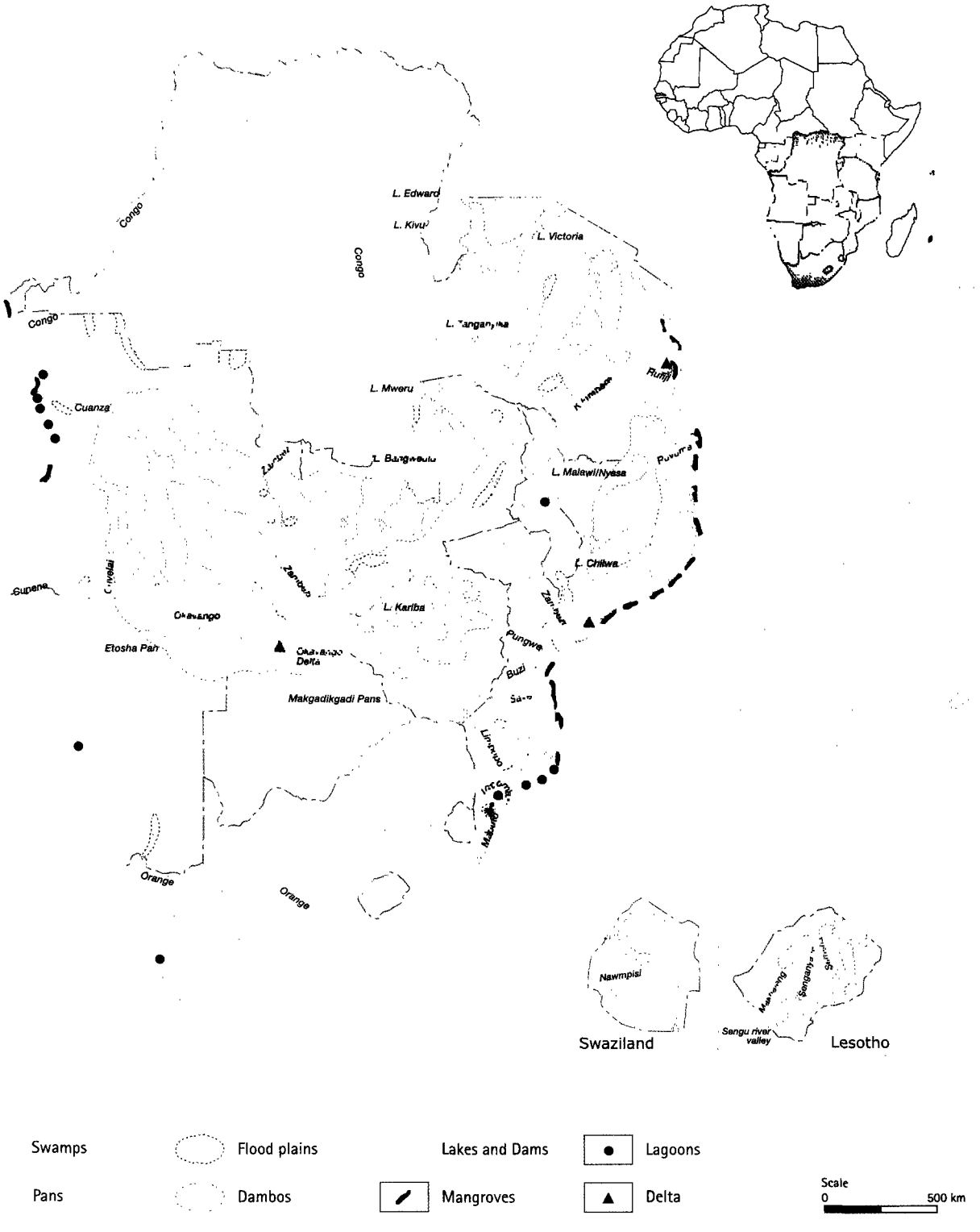
Cunene
Cuito-Cubango
Okavango
Zambezi
Limpopo
Save
Orange
Ruvuma, and
the Lakes Malawi, [illegible] and Victoria. (Map 3.1)

In the arid lands such as in the Kgalagadi and Namib deserts, pans are the prevalent type of aquatic ecosystems. Artificially constructed aquatic ecosystems such as dams are designed to store water during the rather short rainy season for use during the rather long dry seasons. Reservoirs have been constructed to store water for use in agriculture, domestic consumption, hydroelectricity generation and wastewater stabilisation. Many of these have now developed significant aquatic ecosystems that almost overshadow the primary reason for the creation of the reservoirs. Kariba and Cahora Bassa are the largest artificial reservoirs in the southern African region but there are thousands of other large dams throughout the region, as defined by the International Commission on Large Dams (ICOLD), especially in the drier countries: Namibia, Botswana, South Africa and Zimbabwe.

Some of the well-known natural wetland ecosystems are:

the Okavango delta and [illegible] pans in Botswana;
the Barotse swamps, Bangweulu swamps and the Kafue flats in Zambia;
the Linyanti-Chobe swamps in Botswana and Namibia;
the Zambezi delta in Mozambique;
the Wembere plains and Rufiji delta in Tanzania;
Etosha pan, Namibia; and
St Lucia wetlands, South Africa.

Distribution of Major Aquatic Ecosystems in Mainland SADC **Map 3.1**



Modified from Chabwela, H. 1991, *Wetlands – A Conservation Programme for Southern Africa*, in Chenje M. and P Johnson (eds) 1994, *State of the Environment in Southern Africa*.

Classification of aquatic ecosystems Box 3.5

Marine systems
Marine systems consist of the open ocean overlying the continental shelf and its associated exposed coastline. Marine habitats are exposed to the waves and currents of the open ocean and the water regimes are determined primarily by the ebb and flow of oceanic tides. Shallow coastal indentations or bays without appreciable freshwater inflow are also considered part of Marine systems because they generally support typical marine biota.

Estuarine systems
Estuarine systems consist of tidal wetlands that are usually semi-enclosed by land but have open, partly obstructed or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. Estuarine systems include both estuaries and lagoons, and are more strongly influenced by their association with land than is the Marine system. In terms of wave action, estuaries are generally considered to be low energy systems. Salinity and temperature regimes tend to be highly variable, and salinities may periodically be increased above that of the sea by evaporation. Estuarine systems are often highly turbid and contain distinctive fauna. Salt marshes and mud and sand flats bordering estuaries and with an intertidal character are also considered Estuarine.

Riverine systems
Riverine systems include all aquatic ecosystems contained within channels. A channel is an open conduit, either natural or artificial, which periodically or continuously contains flowing water. The following two exceptions are not considered Riverine wetlands:

1 wetlands dominated by mosses or lichens, persistent emergents (*eg Phragmites australis*), shrubs or trees (greater than 30 percent surface area coverage); and
2 habitats with sea-derived salinity in excess of 0.5 g/l.

Water is usually, but not always, flowing in the Riverine system. Non-wetland islands or Palustrine islands may occur in the channel, or on adjacent flooded plains, but they are not included in the Riverine system. Oxbow lakes are placed in the Lacustrine or Palustrine systems unless they are connected to a Riverine system by an open channel at both ends, either permanently or intermittently. Floodplain wetlands are included in the Palustrine system.


I. Rasto

Tembe river, Maputo province, Mozambique.

Lacustrine systems
Lacustrine systems include permanently flooded lakes and dams. Lacustrine waters may be tidal or non-tidal, but ocean-derived salinity is always less than 0.5 g/l. Typically, there are extensive areas of deep water, and there may be considerable wave action. Islands of Palustrine wetlands may lie within the boundaries of a Lacustrine system.

Palustrine systems
The Palustrine system groups together vegetated wetlands traditionally called marshes, swamps, bogs, dambos, fens and *vleis*, which are found throughout southern Africa. Palustrine wetlands may be situated shoreward of river channels, lakes or estuaries; on river floodplains; in isolated catchments; or on slopes. They may also occur as islands in lakes or rivers. The erosive forces of wind and water are of minor importance except during severe floods.

Endorheic systems
Aquatic ecosystems of the Endorheic type are commonly referred to as pans in South Africa, and as small closed basins or playas in geomorphological literature. The Endorheic system has been added to Cowardin's original complement of five systems in recognition of the significant ecological role played by pan ecosystems in southern Africa (Goudie and Thomas 1985). Being located largely in dry regions, pans display characteristic patterns of ephemeral and irregular inundation. Pans in the arid western regions of South Africa may remain dry for years between temporary flooding, while those in the higher rainfall regions display seasonal inundation regimes, and may remain flooded over a number of seasons. Some of the larger pans on the Mpumalanga highveld are permanently inundated, large, deep and have rooted vegetation (Allan *et al* 1995). As such, these pans would be classified as Lacustrine if their water depth exceeds 3 m. Being endorheic, pans lose water largely by evaporation, which also contributes to the high salinity observed in many of these systems.

Dini *et al* 1998, based on Cowardin *et al* 1979

3.4.3 Significant aquatic ecosystems of southern Africa

The major aquatic ecosystems of southern Africa are characterised in Table 3.8 in the Annex to this chapter with an assessment of current threats facing these systems. The following discussion addresses the importance of various kinds of aquatic ecosystems in southern Africa.

All aquatic ecosystems are important to varying degrees within their locality. They may be important as habitats of wildlife and plant biodiversity, as grazing areas for livestock, as sources of fish, as sources of water for human use or as a means of disposal of wastes. However, there are some aquatic ecosystems that are deemed to be of national, regional or even, global importance. Such importance may be because they are representative of a wetland type, or they are unique in one form or another, or they are important as breeding sites for waterfowl and for other reasons. The importance of aquatic ecosystems can be defined using three parameters:

- importance in terms of the ecological/biodiversity significance; or
- in terms of their socio-economic value; or
- their physical/hydrological importance.

3.4.3.1 Aquatic ecosystems of international importance according to the Ramsar Convention

The criteria for listing an aquatic ecosystem as being of international importance according to the Ramsar Convention include the uniqueness of the system, its role in supporting populations of endangered species, and its role in supporting waterfowl populations. In order to designate aquatic ecosystems as wetlands of international importance, states must be parties to the Ramsar Convention. Six of the 14 SADC member states are parties to the Ramsar Convention: Botswana, Malawi, Namibia, South Africa, Tanzania and Zambia. One of the obligations of parties to the convention is that each party should designate at least one wetland as a wetland of international importance. Table 3.2 shows the designated sites in the SADC region (Ramsar Bureau 1999). It can be argued that these wetlands designated as wetlands of international importance or Ramsar sites are the critical wetlands of southern Africa. They have been placed on the Ramsar list because they deserve special conservation effort to maintain, use and manage them.

Aquatic ecosystem	Country	Date designated	Area (ha)
Okavango Delta System	Botswana	09.12.96	6 864 000
Lake Chilwa	Malawi	14.11.96	224 800
Etosha Pan & Cuvelai	Namibia	23.08.95	600 000
Orange River Mouth	Namibia	23.08.95	500
Sandwich Harbour	Namibia	23.08.95	16 500
Walvis Bay	Namibia	23.08.95	12 600
Barberspan	S. Africa	12.03.75	3 118
Blesbokspruit	S. Africa	02.10.86	1 858
De Hoop Vlei	S. Africa	12.03.75	750
De Mond	S. Africa	02.10.86	918
Kosi Bay	S. Africa	28.06.91	10 982
Lake Sibaya	S. Africa	28.06.91	7 750
Langebaan	S. Africa	25.04.88	6 000
Natal Drakensberg Park	S. Africa	21.01.97	242 813
Ndumo Game Reserve	S. Africa	21.01.97	10 117
Nylsvley Nature Reserve	S. Africa	07.07.98	3 970
Orange River Mouth	S. Africa	28.06.91	2 000
St Lucia System	S. Africa	02.10.86	155 500
Turtle Beaches	S. Africa	02.10.86	39 500
Seekoeivlei Nature Reserve	S. Africa	21.01.97	4 754
Verlorenvlei	S. Africa	28.06.91	1 500
Wilderness Lakes	S. Africa	28.06.91	1 300
Bangweulu Swamps	Zambia	28.08.91	250 000
Kafue Flats	Zambia	28.08.91	83 000

Ramsar Bureau 1999 *as of 22 10.99

3.4.3.2 Aquatic ecosystems of socio-economic importance

Although some of the region's most significant aquatic ecosystems are not listed as Ramsar sites, this does not mean that they are not important. Indeed the most local or nearest aquatic ecosystem to a community, however small, is likely to be perceived as very important by the community concerned. The measure of importance is both relative and subjective. In arid areas such as Botswana, Namibia, parts of South Africa and parts of Zimbabwe, any aquatic ecosystem of any size is of significant local importance for human, livestock and/or wildlife use.

Furthermore, it should not be assumed that those countries, which are not yet parties to the Ramsar Convention on Wetlands, do not have important aquatic ecosystems at local, national or international levels. Most of the systems listed in Table 3.2 have socio-economic importance to the communities found around them and the countries in which they are found. These are areas that are culturally or traditionally important for local and indigenous communities and have a potential to contribute to the economy by virtue of their conservation and sustainable management (*ie*, refuge or nursery area, recreation or appreciation by tourists, subsistence by local inhabitants). These are areas that also provide important sources of food and protein for the local diet and generate export revenue. In Tanzania, aquatic ecosystems such as the Wembere plains, Utengule Swamps Bahi swamp, Rufiji delta and many others support large populations of people and underpin the economy of the country. Some 80 percent of Tanzania's prawn harvest is currently derived from the Rufiji delta. This fishery (which is based on several different species of prawn) is of particular economic importance, as it is both lucrative and a major source of foreign exchange. Timber from the mangrove forests is an asset of considerable economic significance. Over 150,000 people inhabit the Rufiji delta and floodplain, the majority of whom rely on the resources of the wetland ecosystems for their livelihoods.

SOE Zambezi – CEP

Shumu'ay (1999) [illegible] provide over 25 percent of the continent's protein.

	1986	1990	1994	1998
Aquaculture Production				
Inland production (000 tonnes)	2	5	7	8
Percentage of world total	0.0	0.1	0.1	0.0
Marine production (000 tonnes)	0	2	4	4
Percentage of world total	0.0	0.0	0.0	0.0
Fisheries Production				
Inland production (000 tonnes)	594	694	560	619
Percentage of world total	10.0	10.8	8.3	7.7
Marine production (000 tonnes)	1 013	1 032	1 038	1 158
Percentage of world total	1.3	1.3	1.2	1.5
Food Balance				
Total food supply (000 tonnes)	1 364	1 511	1 085	n/a
Per capita supply (kg)	10.0	9.9	6.3	n/a
Fish as share of animal protein (%)	21.8	21.8	17.2	n/a
Trade in fishery commodities				
Total imports (US$millions)	223	264	249	256
Percentage of world total	0.9	0.7	0.5	0.5
Total exports (US$millions)	165	203	665	843
Percentage of world total	0.7	0.6	1.4	1.6

UN FAO 2000

Elsewhere in the region, wetlands such as the Bangweulu swamps, Kafue flats, Barotse floodplain, Chobe/Caprivi, Etosha, Okavango, Lower Shire, Zambezi Delta and St. Lucia have social and economic values to the communities living around them. In the Barotse floodplain, the Ndau and Lealui communities derive their entire livelihood from wetland resources. The communities harvest fish, papyrus, water reeds for crafts and fuel, wild birds, grass for thatch and crafts, wild animals, forest products, wild vegetables, clay for pottery, water for livestock and drinking, use grass for grazing and soils for agriculture (Turpie *et al* 1998). Table 3.8 in the Annex to this chapter highlights some of the important values of selected wetlands in southern Africa.

The abundant wildlife and scenic beauty offered by aquatic ecosystems, particularly wetland systems, form the backbone of the tourism industry in the region. Wildlife estates found within and around aquatic ecosystems offer opportunities for game viewing, canoeing, white-water rafting, photographic and walking safaris, boating and leisure cruising. Nature-based tourism is one of the fastest growing industries in the region and a large proportion of this industry is supported by important wetlands such as Okavango delta, Etosha pans, and Lake St. Lucia to name a few. Apart from supporting nature-based tourism, some wetlands provide good soils for agriculture and grazing for livestock. The Kafue sugar scheme and the livestock

industry of Zambia's Western province are supported by wetland systems. Dambos in Zimbabwe and the rest of the region play a very important role in sustaining rural livelihoods.

3.4.3.3 Aquatic ecosystems of physical/hydrological importance

Aquatic ecosystems can also be viewed as important from a physical and hydrological perspective. A number of swamps and marshes in the region perform very important hydrological functions. As indicated in section 3.1, many wetlands, especially palustrine systems, store floodwaters and discharge them gradually, helping to maintain steady river flow throughout the year. In the SADC region, the Barotse floodplains and Chobe/Caprivi swamps on the Zambezi river, the Moyowosi/Malagarasi in Tanzania, and the peat bogs of the Drakensberg mountains in South Africa and Lesotho are critical wetlands from a hydrological point of view. If the Barotse floodplain is destroyed, the Zambezi river may lose its perennial flow. The dambo wetland found in many parts of the region also plays a very important hydrological role in regulating river flows.

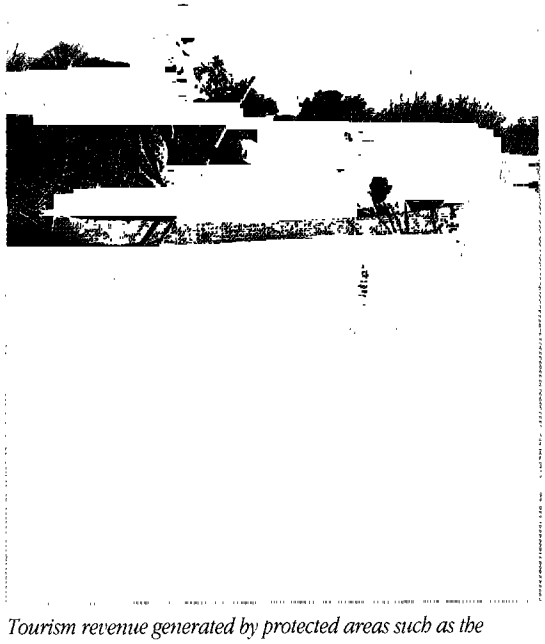
Especially in arid areas, surface water aquatic ecosystems may play an important role in the process of aquifer recharge. An example of this is the Kuiseb river in Namibia, where critically important aquifers which support local communities and the town of Swakopmund are recharged during surface flow events in the Kuiseb. Vegetation in the river bed, and the unconsolidated nature of the bed material, facilitate infiltration of surface water into the soils and to the unconfined aquifer beneath the river bed.

3.4.4 Important freshwater and freshwater dependent terrestrial biodiversity areas

The region's aquatic ecosystems and water bodies contain a variety of biodiversity, some of local significance and others of global significance. Sites are considered of biological importance if they represent unique ecological units and contain globally significant habitats with a wide diversity of species, or habitats for migratory, endemic or threatened species. Freshwater systems that contain unique biodiversity include:

- Lakes Malawi, Tanganyika and Victoria (in each of the lakes, there over 250 species of fish and high endemism);
- Okavango river and delta (about 390 species of birds including 18 threatened species and 99 species of mammals);
- Rufiji delta and surrounding environments;
- Barotse floodplain (more than 7,000 flowering plants, 200 reptiles and 90 amphibians);
- Kafue flats with more than 700 species of birds; and
- the Congo river basin (with more than 700 species of fish). Table 3.4 lists significant examples of the major aquatic ecosystem types in the region, and highlights some of their important uses.

A number of important terrestrial biodiversity sites (some of them National Parks and Conservation Areas) depend on water to sustain terrestrial ecosystems, and water-dependent ecosystems are a central feature of the terrestrial landscapes in these areas. Aquatic ecosystems in the region, particularly the large wetland systems, are often sites of very high biodiversity. The tourism revenue generated by protected areas and National Parks such as Lake Manyara, the Okavango delta, the Kruger national park and its rivers, the Luangwa, Selous and Serengeti parks, all of which are centred around aquatic ecosystems, is critical to the region's economy.



D. Martin, APG

Tourism revenue generated by protected areas such as the Okavango delta in Botswana, is critical to the region's economy.

Type	Major examples	Country	Area (sq km)	Some uses
Floodplain	Barotse	Zambia	9 000	Wildlife, fisheries, livestock grazing
	Pongolo	South Africa	100	Wildlife, fisheries, livestock grazing
	Liuwa	Zambia	3 500	Fisheries, agriculture
	Luangwa	Zambia	2 500	Wildlife, agriculture
	Rufiji	Tanzania	1 500	Wildlife, agriculture, fisheries
Palustrine wetland	Okavango delta	Botswana	16 000	Wildlife, agriculture, fisheries, tourism
	Linyanti-Chobe	Botswana, Namibia	350	Wildlife, agriculture, fisheries, tourism
Floodplain wetland	Kilombero	Tanzania	6 650	Wildlife, agriculture, fisheries
	Malagarasi	Tanzania	7 400	Wildlife, agriculture, fisheries
	Kafue flats	Zambia	6 500	Wildlife, agriculture, fisheries, tourism
Riverine	Zambezi	Angola, Botswana, Namibia, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe	n/a	Wildlife, fisheries, hydropower, water supply, navigation, tourism
	Orange	Lesotho, Namibia, South Africa	n/a	Wildlife, hydropower, water supply, tourism
	Okavango	Angola, Namibia, Botswana	n/a	Wildlife, water supply, tourism
	Limpopo	Botswana, South Africa, Zimbabwe, Mozambique	n/a	Wildlife, water supply
	Congo	DRC, Zambia, Tanzania	n/a	Wildlife, hydropower, water supply, tourism
Shallow lake	Mweru	Zambia, DRC	4 600	Fisheries
	Mweru Wantipa	Zambia	1 300	Wildlife, agriculture, fisheries
	Rukwa	Tanzania	2 300	Wildlife, agriculture, fisheries
Shallow lake and wetland	Bangweulu	Zambia	11 000	Wildlife, agriculture, fisheries
	Chilwa	Malawi, Mozambique	6 500	Fisheries
Deep lake	Malawi/Nyasa	Malawi, Tanzania, Mozambique	17 500	Wildlife, agriculture, fisheries, transportation, tourism
	Tanganyika	Tanzania, Zambia, DRC		Fisheries, transportation
	Victoria	Tanzania		Fisheries, transportation
Human-made lake	Kariba	Zambia, Zimbabwe	5 500	Hydroelectric power, wildlife, agriculture, fisheries, tourism, transportation
	Cahora Bassa	Mozambique	2 660	Hydroelectric power, fisheries
Pans	Makgadikgadi	Botswana	23 000	Mining, wildlife, tourism
	Etosha	Namibia	4 600	Wildlife, tourism
Estuarine delta	Zambezi delta	Mozambique		Fisheries, agriculture
	Limpopo/Inkomati	Mozambique		Wildlife, fisheries

Chabwela 1991, Breen *et al* 1997, Masundire *et al* 1999

Southern Africa is renowned for its biological resources and its diversity. Many species represented in Table 3.5 (see next page) are dependent on aquatic ecosystems for their survival. The physical character of these different aquatic ecosystem types determines the biological diversity that exists in the different habitats.

In terms of animal life, Lake St. Lucia in South Africa is well known for its large population of crocodiles, hippopotami and pelicans. Within the wetland, some 52 dragonfly species have been recorded, 38 freshwater fish species, 182 estuarine fish species and 50 amphibians. Over 350 species of birds have been recorded within the site, 90 of which are wetland birds. (Cowan 1996) Results from a biodiversity study in the Zambezi basin wetlands indicated that wetlands are centres of biodiversity. In the basin, the Barotse floodplain was observed to support 133 bird species, Chobe/Caprivi wetlands 129 species, Lower Shire in Malawi 132 species, and the Zambezi Delta 118 species. These include nine globally threatened species such as Slaty egret, Wattled crane, Shoebill, Rock pratincole, African skimmer and Carmine bee-eater. Changes in the flood regime along the Zambezi are the major threat to these species. (Timberlake 2000)· In the Zambezi basin, 197

Country	Area (sq km)	Mammals	Birds	Reptiles	Amphibians	Fish	Flowering Plants
Angola	1 246 700	276	872	150	80	268	5 000
(endemism)		4	0	0	20	0	1260
Botswana	600 372	154	569	143	36	81	2 000
(endemism)		0	0	0	0	0	17
Lesotho	30 350	33	288	50	35	8	1 576
(endemism)		0	0	0	2	1	2
Malawi	118 484	187	630	124	69	600	3 600
(endemism)		0	0	5	4	450	69
Mozambique	783 030	179	666	170	62	500	5 500
(endemism)		2	0	1	2	400	219
Namibia	824 292	154	640	140	32	97	3 159
(endemism)		0	0	0	2	0	45
South Africa	1 221 040	247	774	310	95	220	20 300
(endemism)		4	4	116	49	0	18 000
Swaziland	17 366	47	496	106	39	45	2 636
(endemism)		0	0	0	0	0	4
Tanzania	886 040	310	1016	273	121	250	11 000
(endemism)		12	13	48	40	230	110
Zambia	752 614	229	732	160	83	156	4 600
(endemism)		6	1	0	1	0	211
Zimbabwe	390 245	196	634	156	120	132	6 000
(endemism)		2	0	0	2	1	95

Cumming 1999


D. Martin, APG

P. Wade

B. Branch

G. Neaton

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species (114 reptiles and 83 amphibians) are found in the wetland systems. The Barotse floodplain has the richest herpetofauna in the basin. The region's wetlands are also known for their freshwater fish diversity. By far the most diverse area is Lake Malawi with around 500 species of fish, 99 percent of which are endemic to the lake. Lake Tanganyika and Victoria have between 200 - 300 species of fish endemic to the lakes.

Several species of southern Africa are classified as threatened. Threat in this context is interpreted to mean critically endangered or vulnerable, according to the IUCN Red List of Threatened Animal Species. IUCN denotes threatened species by placing them on the Red List of Threatened Species and categorizes threat levels as endangered (E), vulnerable (V) or rare (R). Although IUCN has produced extensive data on threatened animal species throughout the world, information on wetland-dependent species in southern Africa is not readily available. There is need for collection of data on species status in a manner that enables the data to be linked to specific wetland ecosystems.

There are 24 species of freshwater fish listed in the IUCN Red List. (Skelton 1993) Of these, 7 are endangered, 7 are vulnerable and the remaining 10 are rare. Table 3.6 shows some of the threatened fish species of southern Africa.

The IUCN Red List of Threatened Plants gives numbers of threatened vascular plants only, and not all the vascular plant species enumerated in Table 3.7 are wetland species. In southern Africa only South Africa listed extinct vascular plant species. The high numbers of threatened plants listed for South Africa could be a reflection of the level of available knowledge and interest on the status of plant species.

Species	Common Name	Level
Austroglanis barnardi	Barnard's rock fish	E
Clarias cavernicola	Cave catfish	E
Nothobranchius sp.	Caprivi killifish	E
Pseudobarbus burgi	Berg river fish	E
P. phlegethon	Fiery red fin	E
P. quathlambae	Drakensberg minnow	E
Tilapia guinasana	Otjikoto tilapia	E
Barbus andrewi	Whitefish	V
B. erubenscens	Twee River red fin	V
B. serra	Sawfin	V
B.treurensis	Treur River barb	V
B. trevelyani	Border barb	V
Chiloglanis bifircus	Incomati rock catlet	V
Sandelia bainsii	Eastern Cape rocky	V

Skelton 1993 E Endangered V Vulnerable

Clockwise from top left, Caprivi killifish, Border barb, Fiery red fin, Drakensberg minnow, Berg river fish, and

Country	Extinct	Endangered	Vulnerable	Rare	Intermediate	Threatened %
Angola	0	0	2	13	15	0.6
Botswana	0	0	0	6	1	0.3
Lesotho	0	1	2	14	4	1.3
Malawi	0	1	3	54	3	3.2
Mozambique	0	5	8	58	18	1.6
Namibia	0	4	5	56	10	2.4
South Africa	53	226	368	1264	357	9.5
Swaziland	1	9	9	17	6	1.5
Tanzania	1	14	63	103	256	4.4
Zambia	0	2	0	9	1	0.3
Zimbabwe	0	4	11	58	27	2.3

IUCN Red List of Threatened Plants 1997

3.5 KEY THREATS TO THE SUSTAINABILITY OF WATER RESOURCES

3.5.1 Over-abstraction of water and river flow regulation

Over-abstraction of water resources and excessive river flow regulation are some of the major factors threatening the sustainability of southern Africa's water resources. With the growing demand for water in response to the increasing population and industrial development, water withdrawals in the region have been increasing steadily over the years to the detriment of aquatic ecosystems and biological diversity. Most of the region's major rivers have been dammed to meet the demand for water from the expanding population and economic development. South Africa and Zimbabwe have the largest number of dams. Because most of the dams were built for single purpose use and without adequate consideration or provisions for addressing downstream uses, they often have resulted in decreased downstream flow rates and reduced aquifer recharge, lowering of the water table, desiccation of wetlands and saltwater intrusion. In many countries of the region, as water becomes scarcer, water requirements for the environment are often given the lowest priority. With increasing demands to support greater agricultural production, industrial expansion and urban growth, more water is required to meet human needs at the expense of maintaining aquatic ecosystems and many other species and environmental services they provide. This does not only affect aquatic resources, but also threatens the sustainability of the water resource base itself.

Both surface and groundwater resources are threatened by over-abstraction in many countries. As far as surface water resources are concerned, the Zambezi is a good example of a river basin threatened by increasing withdrawals of water. Many of the rivers in South Africa and Zimbabwe experience excessive water abstractions, which have resulted in zero flows even during the rainy season. Over-abstraction of water, especially from rivers, affect river ecology as environmental flows available for the river ecosystems are drastically reduced. The impact of water abstraction on river ecology has not been well researched in southern Africa. The issue of environmental flows is discussed in detail in chapter 5.

Over-abstraction also affects groundwater resources. Southern Africa is probably the most boreholed region in the world. (Saleem 1996) In Namibia, 130,000 boreholes have been dug of which 32,000 (25 percent) are currently being used. Botswana has 15,000 boreholes of which 45 percent are productive. Zimbabwe has about 35,000 boreholes, while Tanzania and Malawi have 4,000 and 9,700 boreholes respectively. (Saleem 1996) Studies have shown that as more boreholes are sunk, the ground water levels are lowered, requiring greater depths for both new and existing boreholes. Due to the costs of sinking deeper boreholes, the provision of water in the rural areas has been affected.

3.5.2 Increasing pollution

Pollution is by far the most critical factor affecting the sustainability of the available water resources in southern Africa. There are increasing levels of pollution in the region, resulting in high levels of eutrophication and widespread infestation of aquatic weeds. Much of the water pollution results from human activities such as agriculture, mining, manufacturing and poor management of urban waste. This hampers the use of water for downstream purposes and increases the cost of treatment. Water pollution is a serious problem in South Africa, Zambia and Zimbabwe and a limited problem in Namibia. Chapter 6 in this report addresses in detail the issue of water pollution from both point and non-point sources.

Industrial and domestic waste is increasing at alarming rates in the region, particularly due to rapid economic and population growth. For example, Lusaka with a population of 1.32 million residents produces 1,400 tonnes of solid waste daily of which only 10 percent is collected by the city council. Ninety percent of the solid waste is not collected due to lack of human, financial and material resources. A considerable quantity of this waste finds its way into the region's water bodies.

Mine tailings are another source of serious water pollution. This problem is most serious in South Africa, Zambia and Zimbabwe. In Namibia, uranium mining at Rössing affects both surface and ground water. Mines are sometimes described as "arsenic factories". (Saleem 1996) In South Africa, a dump left by a prospecting team contained so much arsenic and cadmium that it killed all the aquatic life in a nearby dam. (Coetzee and Cooper 1991) It is also believed that 60 percent of the salt load entering the Vaal River Barrage is caused by effluent from the surrounding four mines. The Copperbelt in northern Zambia, the gold and nickel mines of the midland greenstone belt in Zimbabwe and other small-scale mining activities contaminate the watercourses through introduction and deposition of minerals, including heavy metals. These come from the processing plants, leachate dumps or stockpiled by-products and wastes. Studies done by the University of Zimbabwe's Lake Kariba Research Station and the Zimbabwe Department of National Parks and Wildlife have indicated that the agricultural use of the chemical pesticide *dichlorodiphenyl-trichloroethane* (DDT) is threatening aquatic life in the Zambezi basin.

Pollution from industrial and domestic sewage effluent, is a major problem along the main river systems. There are a number of sprawling urban centres in most river basins, particularly in the Zambezi and Limpopo basins. Due to poor sanitation facilities, a number of settlements such as Mongu, Senanga, Katima Mulilo (approx. 18,000 people), Kasane-Kazungula (8,301 people), Sesheke, Livingstone, Victoria Falls, Kariba, Siavonga, Chirundu and Tete are causing serious water pollution, and at times discharge raw sewage into the river. Poor sanitation in densely settled areas such as the wetland areas of the Barotse floodplain, East Caprivi, Chobe enclave, Lower Shire river, Rufiji floodplain and Kafue flats has created problems of human waste disposal resulting in groundwater pollution through contamination.

3.5.3 Encroachment by settlement and land use and threats to biodiversity

Aquatic ecosystems throughout the world play very important roles in river flow attenuation, flood control, water purification and aquifer recharge. In southern Africa, a number of floodplains, marshes and swamps per-

form these functions. The Barotse floodplain, Chobe/Caprivi wetlands, Kafue flats and Elephant/Ndinde marshes are known to perform the functions of river flow attenuation. The aquatic ecosystems of the region are also believed to play a role in maintaining water quality because of their ability to function as water filters for removing pollutants and sediments from water. (Chabwela 1994) Research by the Environment Council of Zambia on the Lukanga swamps on the Kafue river has shown that the quality of water upstream of the Lukanga swamps is of poor quality compared to that coming out below the swamp. Research on constructed wetlands in southern Africa and East Africa also shows that wetlands are effective in treating wastewater.

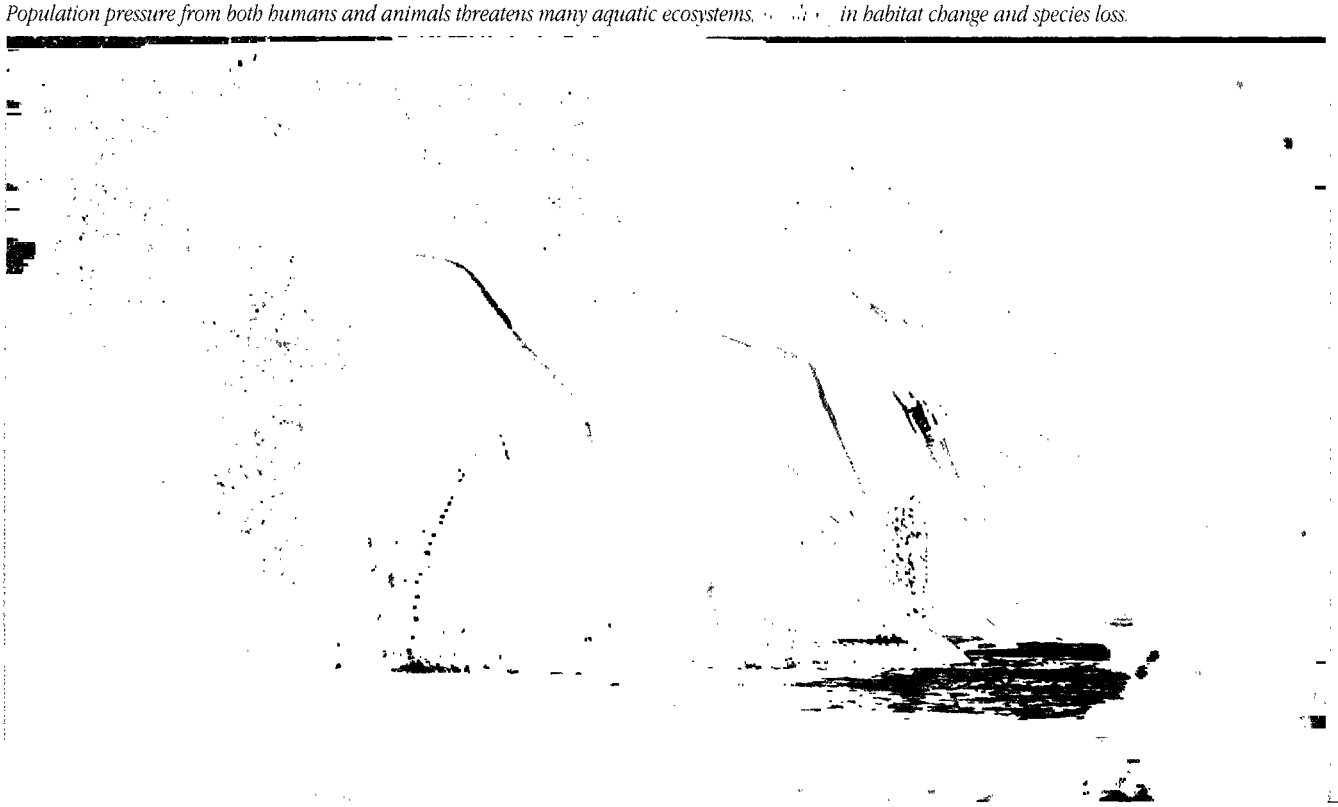
Despite the important functions performed by aquatic ecosystems, many of the region's systems are being threatened by encroachment and biodiversity depletion. This has to a large extent impaired the ability of wetlands to purify water, attenuate river flow, control floods and recharge aquifers, thereby threatening the sustainability of the available water resources. Many aquatic ecosystems in the region are experiencing population pressure (both from humans and animals) and this has resulted in habitat change and loss of species. In the Caprivi, recent estimates are that 83,000 people reside in the wetland areas, exerting immense pressure on the wetland resources. In the Barotse floodplain, people are settled on the river levees, banks of ponds, oxbow lakes and lagoons, and on termite mounds. Uncontrolled fire is a major problem in the Barotse floodplain and Caprivi where large tracts of habitat are damaged every year. In some localities, deep peat fires can go on smouldering for months, destroying flora and fauna. Overexploitation of riverine vegetation such as reeds and grasses is threatening wetland ecosystems. The harvesting of grasses, and reeds in the Caprivi/Chobe, Rufiji, Shire and Barotse floodplains has caused habitat changes that have resulted in the loss of some of the hydrological functions of these wetlands.

3.5.4 Degradation of watersheds

The protection of watersheds that are important sources of water supplies is essential for the sustainability of water resources. Water resources [illegible] and sustainability within a watershed is influenced by both land and water use within the watershed. Studies carried out in many parts of the world and the region show that the degradation of the watershed has a significant impact on water quality and quantity. In poorly managed watersheds, deforestation reduces vegetation cover, resulting in reduced rates of infiltration and increased surface runoff. Studies have shown that the reduction in infiltration affects the recharge of aquifers and the amount of available groundwater resources. The increase in surface runoff causes soil erosion.

Magadza (1995) established that the changes in the flow of the Gwaai river over the last half century are linked to the use and management of dambo wetland ecosystems in the catchment. In that period the river has

Population pressure from both humans and animals threatens many aquatic ecosystems, [illegible] in habitat change and species loss.



N Greaves

been transformed from a perennial river to a highly seasonal river, with a significant increase in the number of days per year on which no flow was observed (Figure 3.2). The headwaters of this river are in the lower Gweru dambos. The observed changes in Gwaai river flow rate reflect fundamental change in catchment performance mainly attributed to mismanagement of the dambos.

Poor land-use practices have exacerbated deforestation and overgrazing, which increase surface runoff and cause soil erosion, impacting the availability and quality of water. Soil erosion is becoming an increasingly serious problem and is having a significant impact on water resources and the aquatic environment. Reports from different countries show that there is widespread deforestation due to agricultural expansion and fuelwood collection. In Malawi, land under agriculture increased from 2.1 million hectares in 1965 to more than 4.54 million hectares by the beginning of the 1990s. (Government of Malawi 1998) On average, the country loses about 20 tonnes of soil per hectare annually. High rates of soil erosion have negative impacts on water resources due to increased sedimentation in rivers and reservoirs. In Zimbabwe, for example, more than 8,000 small- to medium-sized dams constructed throughout the country are threatened by sedimentation induced by soil erosion. The Save, an international river shared by Zimbabwe and Mozambique has been reduced from a perennial to a seasonal river system due to sedimentation induced by soil erosion. In Zambia, the silt-laden Luangwa river is threatening to reduce the useful life span of the Cahora Bassa dam.

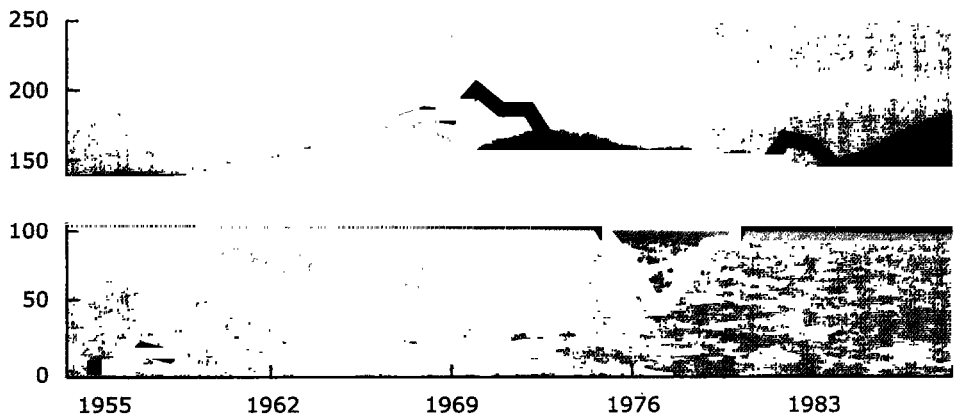
The degradation of watersheds does not only affect the sustainability of water resources but also has negative impacts on economic development. Due to excessive soil erosion, the productivity of the land is affected resulting in the reduction of agricultural productivity. Chapter 7 details the specific issues of watershed degradation.

3.5.5 Proliferation of invasive and alien species

Many aquatic ecosystems have been negatively affected by the release into water resources of invasive alien species (see Box 3.6). Release of alien species can be accidental, such as the transfer of aquatic weeds through movement of people or boats; or it can be deliberate, such as the release of bass and trout to develop sport fisheries. Frequently, these alien species have no natural enemies in the ecosystem into which they have been released, and begin to proliferate to nuisance proportions, crowding out natural species, causing imbalances in natural ecological processes and loss of natural biodiversity. Once released into a system, alien species are very difficult to eradicate (this is particularly true of breeding populations of alien fish species). Hence, early preventive management is usually the most cost-effective approach to control of invasive aliens.

A growing problem affecting water resources in southern Africa is the issue of aquatic weeds. Aquatic weeds such *Salvinia molesta* (Kariba weed) and the water hyacinth *Eichhornia crassipes* are becoming a major problem confronting the region's water resource planners and managers. Aquatic weeds are plants that grow at a place and/or time where it is considered undesirable. There are several types and problems with aquatic weeds in the region. Aquatic weeds affect water supply and quality, interfere with hydropower generation and irrigation schemes, impede navigation and fishing, create habitats for

Gwaai River: Five-Year Moving Average of No Flow Days/Year, Showing An Increase in the Number of Days with No Flow as a Result of Dambo Mismanagement **Figure 3.2**



Magadza 1995

Alien invasive species in southern African aquatic ecosystems **Box 3.6**

Water hyacinth

The problem of alien invasive species is becoming a critical biodiversity issue in freshwater ecosystems. Alien weed species, *Salvinia molesta* and *Eichhornia crassipes*, (especially the latter), thrive very well in southern Africa, having originated in South America. Water hyacinth weed, which causes a reduction in dissolved oxygen and light levels in water, is a major threat to many wetlands. The weed has caused a decline in fish catches in the Lower Shire river in Malawi, Lake Chivero in Zimbabwe and in many rivers in Zambia. The weeds have been observed to cause problems on Lake Victoria, Kafue river, Linyanti-Chobe rivers, the lower Shire river, the Zambezi river and several dams in Zimbabwe. Elimination or control of these weeds is both difficult and expensive (see chapter 8).

Several species of exotic fish have also been introduced into natural lakes and impoundments. One of the best-documented cases is that of the Nile perch introduced into Lake Victoria. Prior to the introduction, Lake Victoria had a very rich species diversity of about 300 haplochromine cichlids. As the population of the Nile perch increased, an estimated 200 endemic cichlids disappeared.

insect vectors, and cause very large water losses due to evapotranspiration. All these consequences impose a huge burden on a water scarce region.

The economic consequence of weed proliferation is very significant. The control of aquatic weeds has not been very effective in many places although the momentum to eradicate these undesirable weeds is now widespread and regional programmes for the control of these weeds are being developed. Today, aquatic weeds threaten the sustainability of the water resources in southern Africa. The problems of aquatic weeds are most severe in Zimbabwe, Zambia, northern Botswana and northeastern Namibia, South Africa and Malawi. Chapter 8 addresses in detail the whole range of issues concerning the control of aquatic weeds.

3.5.6 Policy inadequacies

In addition to social, economic and environmental threats to the sustainability of water resources, continued inadequacies in water policy, legislation and strategies, and weak enforcement are some of the challenges facing water resources in southern Africa. Although many countries in the region subscribe to the Dublin and Rio principles, the operationalization of these principles is still lacking. The water resources management strategies in the region are still very much guided by the traditional approach to water management whose main emphasis remains on engineering solutions for expanding supply without adequate consideration of either social or the environmental dimensions. Sectoral approaches are often used to plan the management and use of resources on which the demands and uses are multi-sectoral. Truly integrated water resources management plans are rare in the region.

While all countries in the region have policies relating to water and environmental management, unfortunately some of these policies are contradictory and their enforcement is weak. Ineffective management of water resources due to lack of accountability and transparency is another problem faced by many SADC countries. Inadequate co-operation and co-ordination (both nationally and regionally), poor institutional arrangements and insufficient human capacity, inadequate regulatory and legal frameworks at local, national and regional levels all combine to create an environment that is not always conducive to sustainable water resources management. Another issue is insufficient stakeholder involvement in water resources management, particularly by women and children.

Most national policies are not well coordinated with regional trends and policies, and at country level, institutional responsibilities can be unclear and overlapping. At the beginning of the 1990s, the SADC states indicated that they have inadequate environmental monitoring, research and planning capabilities. (SADCC 1991) They also have inadequate institutional arrangements, legal framework and enforcement measures for environmental protection and improvement. However, by the end of the 1990s, the situation had improved due in part to the introduction of various capacity-building measures. Since the mid-1990s, the SADC member states have negotiated and ratified various protocols dealing with diverse issues such as trade, mining, shared watercourse systems and transport, meteorology and communications. While the various sector coordination units have mechanisms for collaboration, in reality only limited collaboration takes place and the only

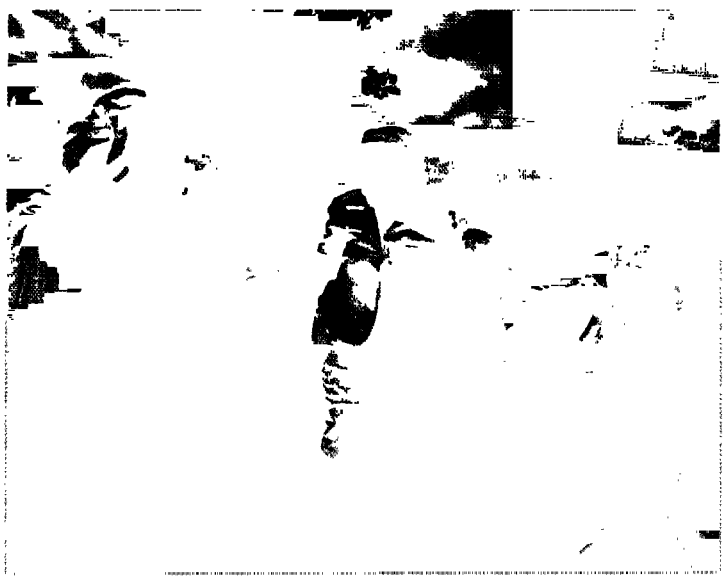
other cross-sectoral policies or documents are the 1992 SADC Treaty, the 1996 SADC Policy and Strategy for Environment and Sustainable Development, and the 1998 Regional Strategic Action Plan for Integrated Water Resources Development and Management.

Another weakness is that SADC-developed policies are not being quickly translated into national policies, resulting in fragmented approaches in different member states. Even though some countries have ratified the protocols, they have yet to be incorporated into national legislation to facilitate enforcement. At the national level, governments have also been reviewing policies and strategies aimed at enhancing natural resource and environmental management programmes. Countries in the region are moving away from command-and-control measures inherited from the colonial period, which have been common for decades, to policies that promote stakeholder interest and participation. However, it is still too early to determine how these policies will change the current management of water resources and the environment. Obstacles include a shortage of human resources and financial capacity. Chapter 10 reviews the water policy, legal and institutional frameworks for water and environmental management.

3.5.7 Institutional deficiencies

Water cuts across a number of user sectors such as agriculture, industry, mining, environment, etc. and the management of water is split among these sectors. While in the past, water resources management was concerned only with supply for consumption and economic activity, today the policies also take into account managing the growing demand, improving irrigation efficiency, monitoring and water distribution systems in urban and rural areas. The sustainability of water resources is exacerbated by sectoral and administrative priorities, which tend to compartmentalise management. The result is that water management generally remains inefficient and expensive. For example, the construction of the Kariba Dam four decades ago was purely driven by the need for hydroelectricity. Other options such as irrigation and tourism were not factored. While tourism has expanded in the Kariba area, many communities adjacent to the dam sometimes suffer serious water shortages. Fortunately, such a disjointed approach should be significantly reduced as the SADC countries begin to implement the 1998 strategic plan for integrated water resources development and management.

The absence of effective institutional arrangements has resulted in disparities in water rights and water user allocations, and poor stakeholder/community participation. In the region as a whole, the general lack of stakeholder/community participation continues to slow the advancement of sustainable water resources management. A number of countries in the region have embarked on National Water Sector Reform programmes whose main thrust has been the amendment of policies, legislation and management structures. However, the success of innovative measures, such as the introduction of catchment committees in Zimbabwe and South Africa to facilitate the sustainable management of water resources and the environment will be limited if issues of land tenure, access to resources, stakeholder participation and others are not adequately addressed (see Box 3.7). Community participation in water resources management is discussed in chapter 9.



Majority World

[illegible] levels is essential to sustainable water resources management. Issues include land tenure and access to resources.

3.5.8 Conflicts and tensions

The growing strain on the quantity and quality of freshwater and its unequal distribution among users are con-

Zimuto-Mshagashe community-based catchment rehabilitation and exploitation project — Box 3.7

The Zimuto/Mshagashe catchment rehabilitation project is an initiative of the Zimuto and Mshagashe communities, co-managed by IUCN and Masvingo Rural District Council in Zimbabwe. The project was funded by the Royal Netherlands government as a pilot model for rehabilitation of catchments. It started in 1995 with the goal of introducing sustainable natural resource utilization and developing institutional co-ordination and community participation in catchment rehabilitation strategies that are applicable to the rehabilitation and conservation of the Save catchment. The main beneficiaries of this project were the grassroots communities of Zimuto Communal Lands and Mshagashe Smallscale Commercial Farming Area. The major lessons from this project are:

- To identify and work at the lowest relevant level of organization of society – the village level. Higher levels such as wards, districts and provinces tend to cloud issues and lose focus.
- It is possible to transform the theories of ecosystem management into tangible results on the ground.
- Local people must be involved in project planning as well as implementation and progress monitoring.
- It is also essential for local and central government authorities to identify with and assume ownership of field projects.

One of the major constraints identified is the lack of capacity at local level as well as in government structures, to competently articulate wetland issues. At the end of phase I, the project was handed over to the communities who have taken charge of the implementation of phase II.

IUCN ROSA *unpublished*

tributing to conflicts and tensions between sectors, communities and across national boundaries. Many conflicts are found among the users of international river basins. As international rivers flow from one country to another, the use or misuse of water in the upstream countries affects its quantity and quality, impacting on downstream users. Upstream nations can affect the flow of water by building largescale dams, with effects spilling over the borders. There are 15 international river basins shared by two or more countries in the SADC region (chapter 2).

In a situation of increasing water demand, international rivers may become a ground for breeding disputes among the riparian states, threatening sustainability in a given country. Although efforts to formulate river basin agreements are gathering momentum, many of the river basins still do not have operational agreements and effective river basin organisations. Due to increasing pressure on the available water resources, access to water has long been a concern and focus of controversy in southern Africa. (Gleick 1998) Although recent SADC protocols have strengthened the framework for negotiations and co-operation, several disputes remain unresolved. In particular, Mozambique has disputes over shared rivers with South Africa and Zimbabwe. (Gleick 1998) While the Protocol on Shared Watercourses has been signed by all countries in the region and ratified by some, the operational procedures for co-ordination, avoiding and resolving international disputes over water remain weak. Box 3.8 illustrates examples of water conflicts that can take place at the basin level.

Water-use conflicts in Tanzania — Box 3.8

The Pangani and Rufiji River basins cover about 23 percent of Tanzania and contain all of the existing hydroelectric power production and much of the irrigated agriculture in the country. Most of the hydropower production potential and a significant portion of the irrigation potential lies in those basins. The surface and ground waters in the basin are also used for urban, rural, industrial, livestock and wildlife water supply, fisheries, shrimp production and habitat conservation.

The surface waters appear to have been over-apportioned and used inefficiently, with irrigation efficiencies of 15-20 percent. Current demands exceed supply. Low water levels in the 1990s in the Nyumba ya Mungu dam on the Pangani river and Mtera dam on the Rufiji river severely constrained energy production at hydropower facilities on these rivers, resulting in nation-wide power shortages. Both basins are facing significant management challenges due to complex and interrelated factors. These include rapidly increasing water demands from growing population and water use, inefficient use of water, recurring drought, growing scarcity of water and emerging conflicts between sectoral uses of water in the two basins. The water use conflicts are between:

- farmers and hydropower interests,
- groups of farmers,
- farmers and pastoralists,
- farmers and water managers, and
- farmers and environmental interest groups.

Hirji *et al* 2001

A number of rivers, lakes and aquifers in southern Africa are shared by two or more countries. Among these are the Zambezi, which is shared by eight countries; Okavango by four; Cunene by two; Orange by four; Incomati by three; Sabi/Save by two; and Ruvuma by three countries. Lakes Chilwa, Malawi/Nyasa, Tanganyika, and Kariba are also shared by two or three countries. While considerable progress has been made in the development

and implementation of joint programmes to manage shared rivers and lakes, Box 3.9 illustrates the type of conflicts that can arise between neighbouring countries.

Potential for interstate conflict over water demands by people and the environment — **Box 3.9**

In 1997, Namibia announced its contingency plans to draw water from the Okavango river system in times of need, despite protests by Botswana and a number of environmental groups. Namibia is perennially threatened with drought and is constantly in need of water, despite strategic planning efforts such as efficient recycling of wastewater in the capital, Windhoek.

Namibia's proposal to abstract 18 million cu m annually met strong objections from its neighbour and from groups such as the International Rivers Network, yet this amount is less than 0.2 percent of the waters of the Okavango. Although there did not appear to be a conflict between protecting the Okavango delta ecosystem and meeting the development needs of Namibia, the argument was that even a relatively small reduction in the flow of the river would reduce the extent of the swamp area.

Writing on this subject in a recent issue of *Conflict Trends* (Accord, 3/2001), Mike Muller, the Director-General of Water Affairs and Forestry in South Africa, notes that Okavango is a RAMSAR wetland, binding all signatories including Botswana and Namibia to promote its conservation and "wise use".

He adds, however, that the Convention does not define "how a balance can be struck between the need to preserve a wetland, and the need to meet the demands of poor communities (inside or outside the country concerned) for basic water supplies and livelihoods. In addition, the convention does not provide guidance as to how a relatively poor developing country can grow."

Muller makes another point that goes to the heart of this study:

"It would appear obvious that this is not a conflict over water. There is a supply of water vastly greater than is needed to meet the economic and social needs of the communities who share the common resource. What is taking place is a conflict over the protection of the environmental resource which the water sustains, and more specifically, the extent to which that resource may be impacted upon. Also contributing to the tension is the question of who has the authority to make a decision about the issue."

This question, he concludes, has important implications for Botswana, Namibia and their neighbours in SADC, as well as for "the international water and environment community in the run-up to the Johannesburg Earth Summit in 2002."

Muller 2001

Strategic planning in the management of water resources and the "wise use" of water are essential to Namibia, the arid home of the Namib desert.

3.6 NATIONAL, REGIONAL AND INTERNATIONAL INITIATIVES FOR THE CONSERVATION AND MANAGEMENT OF AQUATIC ECOSYSTEMS

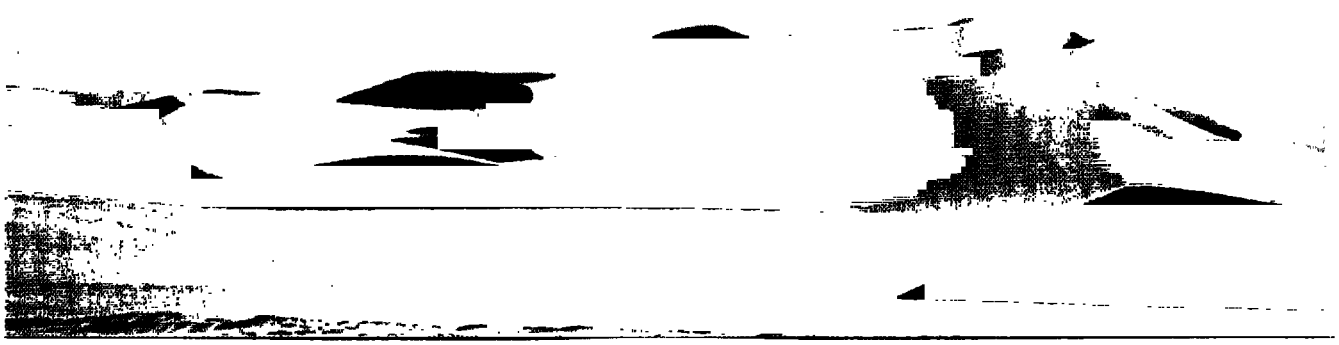
Despite the important role played by aquatic ecosystems in ecological and socio-economic terms, there are very few regional and national programmes targeted at conserving and managing these critical ecosystems. As far as the early 1980s the terms wetland or aquatic ecosystem were not in the vocabulary of many in the region. Wetlands in particular were often seen as wastelands that should be drained for agriculture and for health reasons. Early efforts towards wetland conservation and management were found only in Zambia and South Africa, the first Ramsar contracting parties in the region. Increased awareness on the importance of wetlands only gathered momentum after the SADC Wildlife sub-sector initiated a regional programme for wetlands conservation and management. Although the level of wetland degradation and loss has not been widely documented, there are a number of interventions at national, regional and international levels to address issues pertaining to wetlands conservation. Many of these were developed in the 1990s. Box 3.10 gives the rationale for the conservation of African freshwater ecosystems.

Why should African freshwater ecosystem conservation be supported? — **Box 3.10**

- There are sound economic and development reasons for addressing freshwater ecosystems.
- The socio-economic and ecological value of freshwater ecosystems is significant.
- Freshwater ecosystems provide an important linkage to terrestrial ecosystems; they influence and are influenced by terrestrial ecosystems.
- Freshwater ecosystems are linked to marine ecosystems.
- Management of freshwater ecosystems makes good conservation sense.

Adapted from Shumway 1999

D. Martin, APG



3.6.1 Regional initiatives

3.6.1.1 SADC Inland Fisheries, Forestry and Wildlife (SADC IFFW) wetlands conservation and management

One of the activities that has contributed immensely to putting wetlands on the regional development and conservation agendas is the SADC Regional Wetlands Programme, launched in 1990 with financial support from the Royal Norwegian Embassy. At its launch, the programme aimed to:

survey the wetlands of the SADC region from a biological, socio-economic and land-use perspective;
develop a regional policy and programme of action for conservation and multiple use of wetlands;
focus national, regional and international attention on the importance of wetlands and their appropriate use; and
foster national, regional and international programmes for the conservation and appropriate use of wetlands in the SADC region. (Breen *et al* 1997)

The SADC 1990 wetlands survey and the subsequent wetland initiatives by various member countries identified a number of issues and threats to the region's wetland ecosystems. These included:

a lack of institutional capacity and finance to develop and implement wetlands conservation and wise-use programmes/projects;
sectoral approaches to wetlands management; and
lack of clear wetlands policies and legislation.

The Gaborone conference on wetlands conservation in 1991 called for:

inventories and assessments;
development of legislation and other administrative mechanisms;
reorientation of policies and/or formulation of wetland policies;
extensive training in wetlands ecology, conservation and management; expansion of wetlands awareness; and
an improvement of technical and financial capacities in wetlands conservation and management.

Although this is a regional project the implementation of the activities is carried out by the member states with the support of the SADC IFFW and IUCN Regional Office for Southern Africa (ROSA).

Under the SADC IFFW umbrella, the Ramsar contracting parties in the region, working in collaboration with IUCN ROSA and the Ramsar Bureau, developed a regional programme on the Valuation of the Region's Critical Wetlands. The overarching goal of the wetlands valuation project is to "demonstrate the true values of wetlands in order to promote their conservation and wise use through planned and managed sustainable resource utilisation."

3.6.1.2 IUCN ROSA regional wetlands programme

IUCN is one of the leading organisations in the field of wetlands conservation and management in Africa. Coordinated from its headquarters in Gland, Switzerland, IUCN is implementing a global programme on wetlands and water resources. IUCN efforts in southern Africa date as far back as the mid-1980s when it facilitated the development of the Bangweulu and Kafue Flats wetlands projects. IUCN involvement in regional wetlands initiatives started formally in 1990 when it was invited by SADC IFFW to facilitate the implementation of the regional programme on wetlands conservation. At the end of phase I of the SADC wetlands project, IUCN ROSA launched its regional programme on wetlands conservation and management. The mission of this programme is:

to achieve significant improvement in the conservation and sustainable use of freshwater and tidal wetlands of southern Africa.

Based on the SADC Wetlands Conservation Phase I project, IUCN ROSA forged a partnership with the SADC IFFW and the main focus of its programme is

to enhance the capacities of SADC member states and IUCN members and partners in the region to expand popular wetlands awareness, identify threats to wetland habitats, and design and implement measures required for their conservation and sustainable use so that these habitats can make greater contribution to the conservation of biological diversity and improvement of standard of living in these areas.

In terms of specific efforts, the programme aims to:

expand popular wetlands awareness throughout the region;
facilitate the inventory of all major wetland habitats from regional and national perspectives;
identify those that are threatened by adverse change, and design measures required for their conservation and sustainable use;

- initiate and encourage the development of a regional wetlands policy and legislation, national wetlands programmes and policies;
- initiate and establish training in wetland conservation and management, improve the knowledge and information base on wetland ecosystems, and enhance the quantity and quality of technical advice available to governments and non-governmental organisations;
- advance the socio-cultural and economic issues in wetlands conservation and management; and
- stimulate greater commitment among governments and non-governmental organisations to ensure that wetlands are conserved for the benefit of all humankind, and to improve coordination between them.

Since the establishment of the programme, wetland awareness in the region has increased. The programme facilitated the launch of national wetland programmes in Zimbabwe, Zambia and Malawi, and a number of specific programmes were developed which are currently being implemented. These include the Zambezi Basin Wetlands Conservation and Resource Utilization project and the Community-based Catchment Rehabilitation in Zimuto/Mshagashe in Masvingo, Zimbabwe.

3.6.1.3 Wetlands International waterfowl census

Wetlands International is also an important player in the region's wetlands conservation and management. Through its network of volunteers, the organisation is involved in waterfowl censuses that are carried out periodically. In addition to the waterfowl census, Wetlands International is working with national governments, especially South Africa and Zambia to protect important habitats for waterfowl.

3.6.1.4 Ramsar Convention initiatives

There are six contracting parties in southern Africa. As signatories to the convention, these countries are obliged to identify sites for listing as Ramsar sites. The Ramsar Bureau, based in Gland, Switzerland works very closely with the six contracting parties. The Bureau provides advice, information and technical backstopping to contracting parties. According to the convention obligations, contracting parties are supposed to develop national wetland policies and establish national committees to spearhead the conservation and management plan of wetlands within the country. Currently the Ramsar Bureau is supporting Botswana in its effort to formulate a national wetland policy and the management for the Okavango delta, the world's largest Ramsar site. Working in collaboration with IUCN ROSA, Ramsar is supporting a regional project on the valuation of wetland systems in the SADC region.

3.6.2 National initiatives

Although there are regional initiatives on wetlands conservation and management, the specific actions are at the country level. Under the SADC Wetlands Conservation Action Plan, all SADC member states were encouraged to develop national wetland programmes. Since the 1991 Gaborone conference on wetlands conservation, a number of national wetland programmes have been developed and are being implemented.

3.6.2.1 The World Wide Fund for Nature (WWF) – Zambia wetlands project

Zambia being one of the wettest countries in the region was the pioneer in the field of wetlands conservation and management. During the early 1980s, two wise-use projects were developed for Lake Bangweulu and the Kafue Flats, two of Zambia's major wetland ecosystems, with the support of IUCN and WWF. The main focus of these two demonstration projects is to link floodplain wetland management and socio-economic development. The implementation of these projects is directly supported by WWF International through its Zambia office. These projects began in 1985 with the following objectives:

- to maintain the productivity of wetlands of the Kafue Flats and the Lake Bangweulu basin;
- to improve and broaden the benefits which local people derive from these wetland resources; and
- to mobilise support among local people for the conservation of living resources. (Jeffrey *et al* 1992)

A major lesson from this project is that wetlands conservation can only work effectively with the participation of local communities who feel they own the resources and that it is in their own interests to properly manage the wetland ecosystems. It is essential to identify and work with the most appropriate institutions and institutional arrangements so local participation is enhanced and people realise tangible economic benefits from their conservation efforts. (Chooye 1993) Poverty, access to resources and/or resource ownership, lack of education, perception of project ownership and lack of co-ordination

among project implementation agencies were identified as some of the major constraints. (Chooye 1993)

In addition to these efforts in Bangweulu and Kafue flats, Zambia is among the countries that have carried out a wetlands inventory and initiated the process of national policy formulation. Zambia already has an inventory of its protected and unprotected wetlands. (Chabwela 1992) However, due to lack of resources and technical capacity, the policy formulation process in Zambia has not progressed.

3.6.2.2 Botswana national wetlands policy

Botswana is among the countries in southern Africa that has made strides in formulating a National Wetlands Policy. A policy on its own does not mean that there will be proper utilisation and management of wetlands, but a policy provides the framework for actions that lead to sound management of wetlands. As part of the policy formulation process, an inventory of Botswana's wetlands was carried out. Under the Ramsar Convention, parties are obligated to have management plans for wetlands listed as Ramsar sites. A management plan for the 6,864,000 ha Okavango delta, the largest Ramsar site in the world, is currently being formulated.

3.6.2.3 South African national wetlands programme

South Africa is by far the most advanced country with regards to increased awareness, technical capacity and wetland conservation. Most of the wetlands of South Africa have been mapped and studied. The country has the largest number of Ramsar sites in the region and a Ramsar national committee exists. The Department of Environmental Affairs and Tourism also has a unit which co-ordinates all work on wetlands in the country. South Africa's efforts at producing documented wetlands inventories stretch to as far back as those by Noble and Hemens (1978). Worth noting is the latest Directory of South African Wetlands by Cowan and van Riet (1998) as well as the draft catalogue of South African National Wetland Inventories (Van der Walt and Cowan 1998). The formulation of a national wetland policy is underway in South Africa.

Detailed management plans have been developed already for sites such as St. Lucia and others in South Africa. Approaches for the wise use of wetlands by indigenous people have also been tested with the Kosi Bay Natures Reserve. In this area, traditional harvesting methods were investigated and found to be compatible with the wise-use concept. The success of the Kosi Bay case study depended to a large extent on the blending of correct policy with adequate, appropriate and accurate information as well as the will to carry out the policy for the long term good of the user groups and neighbours. (Kyle 1995) In addition to these efforts, a national project called Wetland Fix: Assessment, Management and Restoration of South African Wetlands was launched in the early 1990s. This project is a good example of how the private sector can be involved in nature conservation efforts. The initiative is supported by Renfreight, South African Breweries, Mazda Wildlife Fund, National Parks Board, WWF South Africa and the Wildlife Society.

3.6.2.4 National wetlands activities in Tanzania

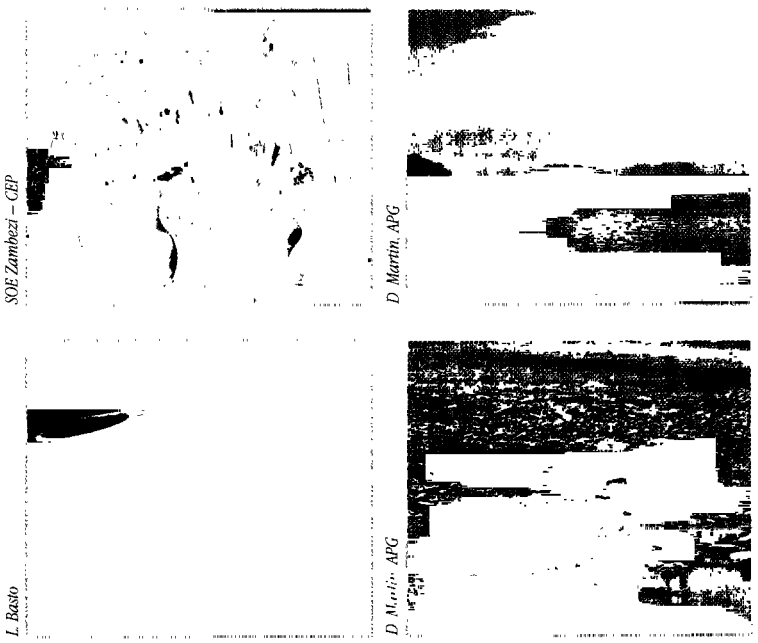
Open water areas, including lakes and fringing swamps, comprise 5.2 million hectares of wetland area. The largest permanent and seasonal freshwater swamps are in the Rufiji/Ruaha river system with 796,000 ha, the Malagarasi-Moyowosi system of 686,000 ha, and along the Ugalla, Suiwe, Mara, Pangani, Wami and Ruvu rivers.

Efforts to formulate a national wetlands programme for Tanzania started in the early 1990s. A framework programme was developed and a number of initiatives are underway. Among national projects worth noting is the Rufiji delta programme facilitated by the IUCN Regional Office for East Africa. The objective of this project is to promote the long term conservation and wise use of the lower Rufiji wetlands, such that biodiversity is conserved, critical ecological functions are maintained, renewable natural resources are used sustainably and the livelihoods of the area's inhabitants are secured and enhanced. The Usangu wetland located in the upstream part of Rufiji basin is also being considered as a Ramsar site because of the diversity of birds. Tanzania has a number of other important and large riverine wetlands and floodplains in the Western and Eastern Rift Valley. Tanzania is also in the process of formulating its national policy on wetlands.

3.6.2.5 National efforts in other countries

There are some wetland-related activities in progress in all SADC member states. In Zimbabwe, Malawi and Mozambique, national wetland programmes were launched in 1991. However very little progress has been made in streamlining these efforts. Zimbabwe's initiatives

are concentrated on dambo conservation and utilization as well as on catchment rehabilitation. In Malawi, the focus is on natural lakes and floodplains, while in Mozambique the emphasis is on coastal zone management. In Namibia, the focus is on ephemeral wetlands.



All SADC countries have wetland-related activities but priorities differ, ranging from dambo conservation and utilization to natural lakes, ephemeral wetlands and coastal zone management.

3.6.3 International initiatives and mechanisms

3.6.3.1 Ramsar Convention on Wetlands

The Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) was adopted in 1971 in Iran. This is an intergovernmental treaty that provides the framework for international co-operation for the conservation and wise use of wetlands and related resources. The Convention entered into force in 1975. By February 2000, there were 118 contracting parties worldwide.

Six countries in southern Africa have ratified the convention: Botswana, Malawi, Namibia, Tanzania, South Africa and Zambia. Parties to the convention are obliged to carry out national inventories on wetlands, formulate national strategies and policies. Only Botswana, South Africa and Tanzania are in the process of formulation of a national policy on wetlands. Zambia is about to start the same process while the new South African Water Act is probably comprehensive enough that a national policy on wetlands might not add much to what the Act provides for.

Parties to the convention are also obligated to name at least one wetland for listing as a wetland of international importance or Ramsar site. According to the Ramsar Convention Strategic Plan (1997 - 2002) operational objective 2.1, the contracting parties are called upon to review and, if necessary, amend national legislation or supra-national legislation, institutions and practices to ensure the wise use of wetlands. Action 2.2.1 under the same operational objective specifically calls for greater efforts to develop national wetland policies.

While it has already been noted that most of the river basins and wetlands associated with them are shared by two or more countries, where one or some of the countries sharing a wetland are parties to the Ramsar Convention while others are not, it implies that full benefits that would accrue from co-operation under the provisions of the Ramsar Convention cannot be realised. For example, of the riparian states of the Zambezi river basin, only Botswana, Malawi, Namibia, and Zambia are parties to the Ramsar Convention while Angola, Mozambique, Tanzania and Zimbabwe, are not.

It is recommended that all the countries of southern Africa sign and ratify the Ramsar Convention so that it will be possible for joint actions and programmes under the Convention. Signing a convention does not in itself mean action. Zambia has been party to the convention since 1991 but it does not have a national policy on wetlands as yet, while Botswana, which ratified the convention in 1997 has made significant strides towards formulating a national policy.

3.6.3.2 Convention on Biological Diversity (CBD)

The Convention on Biological Diversity is a global treaty that was opened for signature during the United Nations Conference on Environment and Development in 1992. The Convention entered into force on 29 December 1993.

The objectives of the convention are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilisation of genetic resources, including appropriate access to genetic resources and appropriate transfer of relevant technologies, taking into account all rights over those resources and technologies, and appropriate funding.

In layman's language, the convention is about conservation, sustainable use of biological diversity and the fair and equitable sharing of benefits arising out of the use of

genetic resources. The convention contains 42 articles dealing with various aspects of biodiversity conservation and management.

All the countries in southern Africa have signed and ratified the Convention on Biological Diversity and most of these countries are developing and /or implementing national biodiversity action plans, which are part of the obligations of the contracting parties. Wetlands conservation, especially the conservation and protection of freshwater (aquatic) biodiversity is highlighted in all the national biodiversity action plans and strategies.

3.6.3.3 SADC Protocol on Shared Watercourses

The most significant development towards achieving integration of the regional use and management of water resources was the ratification in 1998 of the SADC Protocol on Shared Watercourse Systems, which was further reviewed in 1999/2000. The Revised Protocol on Shared Watercourses was signed by SADC Heads of State or Government at their annual Summit in August 2000 in Windhoek, and comes into force upon ratification by two/thirds of Member States.

The Protocol states that the utilisation of a shared watercourse system shall be open to each riparian state in respect of watercourses within its territory and without prejudice to its sovereign rights. The utilisation of watercourse systems mentioned in the protocol includes agricultural, domestic, industrial and navigational uses. Aquatic ecosystems as users of water are not covered in the protocol. However, the protocol urges riparian states to respect and apply the existing rules of general and customary international laws relating to the utilisation and management of shared watercourses.

Under the protocol, riparian states are encouraged to utilise a shared watercourse in an equitable manner. It specifies the prevention of pollution, aquatic weed infestations and environmental degradation, and commits governments to enhance living standards and environmental considerations. The details of the protocol on shared watercourses are contained in chapter 10 which deals with institutional frameworks.

This protocol, under which member states commit themselves to manage shared watercourses at river basin level, is the most directly relevant to wetlands conservation, although wetlands are not specifically mentioned in the protocol. It encourages the formation of River Basin Commissions and River Basin Authorities. For example, the Okavango Basin Commission (OKACOM) covers the states that share the Okavango river basin. The Zambezi River Authority is a two-country body involving only Zambia and Zimbabwe but discussions are underway to set up a basin-wide authority to include all of the riparian states. Bilateral and other similar agreements are at various stages of implementation. (see Table 7.1 in Chenje and Johnson 1996) The effectiveness of the operation of these agreements needs to be fully assessed. The recent floods in Mozambique and other parts of southern Africa have highlighted the need for maximum co-operation in the management of the region's river basins.

3.6.3.4 Protocol on Wildlife Conservation and Law Enforcement in the SADC region

It is under the Wildlife Acts in most countries in the region that wetland systems are accorded any significant protection. The development and implementation of the Protocol on Wildlife Conservation will go a long way to facilitate the conservation of wetlands in the region. The objective of the protocol is to establish compatible approaches to:

- Manage and utilise wildlife sustainably;
- Harmonize legal instruments governing wildlife use and conservation;
- Enforce wildlife laws within, between and among SADC member states;
- Exchange information concerning wildlife, management of human use of wildlife, and enforcement of wildlife laws; and
- Build national and regional capacity in wildlife management for sustainable use and conservation, and in wildlife enforcement.

Most wetland ecosystems that are within National Parks or protected areas in SADC countries are protected by national wildlife acts. Signing, ratification and implementation of this proposed protocol will facilitate effective wetlands conservation and management.

3.6.3.5 Convention to Combat Desertification (CCD)

The convention to Combat Desertification (CCD) has influence on the management and conservation of wetlands. Parties to the Convention are obligated to formulate and implement action to slow down or halt the process of desertification and minimise the consequences thereof. Desertification has negative impacts on water

resources availability and on the hydrology of wetland systems. Desertification can be a consequence or a cause of catchment degradation, already identified as one of the threats to wetlands in southern Africa.

Regional and national actions being undertaken through the Convention to Combat Desertification will bring positive results for wetlands conservation and management. The SADC Environment and Land Management Sector (ELMS) is coordinating regional efforts under this convention with technical input from the Desert Research Foundation of Namibia. All southern African countries have signed and ratified the convention.

3.7 RECOMMENDATIONS FOR WATER POLICY

For water resources management purposes, water resources should be defined as including all components of the ecosystem (habitat, water, vegetation, biota and processes) which are contained within the outer edges of riparian or fringing zones and within groundwater bodies.

National water policy and law should recognise aquatic ecosystems as the resource base from which water is derived.

Water resources management objectives should address the biodiversity and ecological health of aquatic ecosystems as management priorities.

Water allocations for aquatic ecosystems should have clear status in national and regional policy and law in relation to water allocations for offstream and instream use.

National and regional environmental, biodiversity, water and agricultural policies should all be harmonised to ensure adequate protection of aquatic ecosystems and ecological resources such as fish, peat, reeds, etc.

Relevant regional protocols and national legislation should be amended to specifically protect water allocations for aquatic ecosystems.

The values of aquatic ecosystem goods and services should be recognised in national policy, and valuation of goods and services should be included as a mandatory step in Environmental Impact Assessments (EIA) and in water allocation and development decisions.

L. Basto

Gwarezi river, on the border of Mozambique and Zimbabwe. Water resources include all components of the aquatic ecosystem, and the ecosystem is the resource base from which water is derived.

Annex to Chapter 3

COUNTRY	WETLANDS OF CONCERN	THREATS	VALUES*	KNOWLEDGE
Botswana	Makgadikgadi Pans (1) Chobe-Linyati (3) Okavango Delta (3)	(1) Veldt fires, mining, over-grazing, uncontrolled tourism (3) Fires, over-utilisation (hunting, grazing, deforestation, irrigation, water extraction, fishing)	(1) Wildlife (h) Grazing (h) Tourism (h) Mining (m) (3) Wildlife (h) Fisheries (h) Agriculture (h) Grazing (h) Water extraction (h) Tourism (h) Veldt protection (h)	(1) Makgadikgadi Pans No comprehensive knowledge. (3) Chobe-Linyati No comprehensive knowledge. (3) Okavango Delta Limited knowledge on specific issues (*eg* medicinal, plants, birds). No knowledge on cultural and socio-economic issues.
Lesotho	Katse Dam (1) Drakensberg-Maluti (2) Senqu River (3)	(1) Siltation, pollution, population growth (2) Over-grazing, siltation, mining, fire, land tenure (3) Land tenure, siltation, pollution, population	(1) Revenue from water sales to South Africa (vh) (2) Bird sanctuary (vh) (3) River sources (vh)	(1) LHDA studies on the Katse dam. Comprehensive management plans Hydrology for dams in the catchment. (2) Studies within LHDA area. No detailed valuation on small catchments. (3) Limited information on hydrology. No valuation done.
Malawi	Lake Chilwa (1) Lake Malawi/Nyasa (1) Elephant and Ndindi Marsh (2)	(1) Lake Chilwa Over-fishing, over-hunting, siltation, population growth, pollution, dam construction, irrigation, fires (1) Lake Malawi/Nyasa Over-fishing, pollution, deforestation, population growth (2) Over-fishing, fires, agriculture, over-grazing	(1) Lake Chilwa Fishing (vh) Water fowl habitat (vh) Transportation (h) Wildlife (l) Agriculture (l) (1) Lake Malawi/Nyasa Fishing (vh) Transportation (vh) Tourism (vh) Hydropower (vh) Water supply (vh) (2) Dry season Agriculture (vh) Fishing (l) Grazing (h) Water fowl habitat (m) Wildlife harvest (m)	(1) Lake Chilwa Limited biological and ecological knowledge. Very limited knowledge on hydrological, economic and social issues. (1) Lake Malawi/Nyasa Biological, ecological and economic knowledge exists but is limited. (2) Elephant and Ndindi Marsh Limited knowledge on economic and biodiversity issues.
Mozambique	Lake Niassa (1) Limpopo Floodplain (4) Zambezi Delta (4)	(1) Over-fishing, deforestation, fires (4) Limpopo Floodplain Deforestation, over-fishing, erosion (4) Zambezi Delta Deforestation, over-fishing, over-hunting, population growth	(1) Fisheries (vh) Agriculture (vh) Tourism (h) Forestry (h) (4) Limpopo Floodplain Fisheries (vh) Agriculture (vh) Tourism (h) Forestry (h) (4) Zambezi Delta Fisheries (vh) Wildlife (vh) Water fowl habitat (h)	(1) Only social valuation exists. (4) Limpopo Floodplain Gap in the economic valuation. (4) Zambezi Delta Gap in the biodiversity valuation.
Namibia	Oshanas (2) Orange River (3) Walvis Lagoon (5)	(2) Population growth, over-fishing, deforestation, fires (3) Alien species, deforestation, river regulation, fire (5) Siltation, pollution	(2) Water supply (vh) Fisheries (h) Wood (h) (3) Water supply (vh) Wood (h) Recreation (h) (5) Tourism (vh) Recreation (h) Salt mining (h)	Response is applicable to all three wetlands. Respondent unsure of any social cultural valuation done. Biological knowledge is fair to good depending on the system. Economic valuation, very little which is wetland specific.

COUNTRY	WETLANDS OF CONCERN	THREATS	VALUES*	KNOWLEDGE
South Africa	St. Lucia (1) Ndumo (2) Blesbokspruit (3) Lange Lagoon (4)	(1) Dune mining (2) Land invasion, over-fishing, agriculture, irrigation (3) Mining, sewage works (4) Pollution, harbour development	(1) Biodiversity (vh) Water supply (h) (2) Fish stock (vh) Tourism (vh) Water supply (h) (3) Water supply (h) Agriculture (m) (4) Tourism (h)	(1) Methods not developed to valuate wetland types. (2) Few studies on economic valuation. (3) No $ value of biodiversity. (4) Little attention to social values. (5) No integration of values such as tourism, fish stock, water supply. Small wetlands do not get attention.
Zambia	Bangweulu Swamps (1) Kafue Flats (3) Barotse Plain (3)	(1) Population growth, over-fishing, over-hunting, deforestation (3) Kafue Flats Over-fishing, over-hunting, alien species, water extraction (3) Barotse Plain Over-fishing, over-hunting, fire, deforestation	(1) Fishing (vh) Tourism (h) (3) Kafue Flats Fishing (vh) Tourism (vh) Hydro-power (vh) Irrigation (h) Agriculture (m) (3) Barotse Plain Fishing (vh) Tourism (m) Cultural heritage (h) Water supply (l)	(1) Very limited biological knowledge, biological value. (3) Kafue Flats Very limited biological and socio-economic knowledge. (3) Barotse Plain Limited biological knowledge.
Zimbabwe	Mana Pools (1) Dambos (2) Save Valley (3)	(1) Over-grazing, irrigation (2) Siltation, poor catchment management, mining (3) Drainage, dam construction, over-utilisation	(1) Hydro-power Water supply Crocodile farming (2) Reeds harvesting Research Educational Transport (3) Tourism Fishing Wildlife Irrigation	(1) Fisheries diversity, bio-diversity, economic value limits on knowledge. (2) Limited knowledge on biodiversity and social cultural issues. (3) Limited knowledge on bio-diversity, community use and flow patterns.

*Values: (vh) very high (h) high (m) medium (l) low

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VALUING THE ENVI
IN WATER RESOUR MENT

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CONTENTS

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VALUING THE ENVIRONMENT IN WATER RESOURCES MANAGEMENT

4.1 INTRODUCTION

Increasing pressure on scarce water resources throughout the world has led to a global trend to develop policies and mechanisms that encourage the efficient, equitable and sustainable use of water resources.

The efficiency goal concentrates on maximising economic returns to resource use, or achieving the greatest possible net benefit.

The [illegible] goal recognises the limits to natural resources in the light of population growth and economic development, and aims to use resources in such a way as not to compromise the economic opportunities of future generations.

The goal of equity is to ensure that the economic benefits obtained from water resources are distributed fairly.

The latter is largely a socio-political issue, and will not be addressed in detail in this chapter. However, the issues of economic efficiency and sustainability of natural resource use are inextricably linked to environmental management, which is the focus of this chapter.

Traditional economic approaches have had a rather narrow view of the economic issues surrounding the use and management of water resources. In the past, maximising economic efficiency has meant the maximisation of net benefits that contribute directly to standard measures of economic performance, such as Gross Domestic Product (GDP). Sustainability has been perceived in terms of sustaining the benefits from economic activities associated with the direct use of water resources, rather than sustaining a full range of benefits, including ecological services and biodiversity.

This chapter provides the economic rationale for taking a broader view of efficiency and sustainability, which incorporates sound environmental management. The goal of efficiency should take the costs of environmental degradation into account, and the goal of sustainability should be to sustain desirable levels of production of all goods and services over the long term, including those provided by natural systems. Of course, meeting these goals will involve certain trade-offs.

Economic production achieved by means of the abstraction and degradation of water resources, aquatic ecosystems and catchment areas has to be traded off against the benefits from maintenance of healthy ecosystems and biodiversity. Similarly, the costs of controlling alien invasives and managing activities within catchment areas will need to be justified in terms of the resultant benefits. Thus, in order for society or governments to take cognisance of the benefits of environmental management, it will be necessary to understand the full economic implications of the degradation of water resources and aquatic ecosystems and to account for them as the opportunity costs of damaging economic activities and management approaches. [illegible], the opportunity cost implications of water supply and allocation is thus central to making informed decisions on development and allocation trade-offs.

This chapter begins by describing the direct use values of water, the ways in which these uses and other forms of catchment activities and management impact on aquatic environments, and the types of trade-offs that arise. Types of degradation and valuation methods are briefly introduced. This is followed by a description of the costs of catchment mismanagement to water development projects, and considers the non-water economic val-

ues of aquatic ecosystems that are threatened by such projects and by environmental mismanagement. Finally, the two sets of measures that are required to achieve efficient, sustainable and equitable use of water resources, in order to maximise the net benefits to society are examined, and these include:

- the incorporation of environmental costs and benefits, and distributional issues, in economic decision-making; and
- the application of economic instruments to manage water demand and supply.

These measures should be seen as mutually supportive components of the integrated management of aquatic resources, to be combined with broader enabling conditions such as the formulation of appropriate policies, regulations, tenure and institutions, and environmental education.

4.2 THE ECONOMIC BENEFITS OF WATER USE

All of the SADC economies are heavily dependent on the supply of water. Water is used in both the input and output phases of economic processes. Water provides a direct input into economic production in sectors such as agriculture, electricity and domestic consumption, and is used to transport and absorb many of the waste outputs of economic production.

Assigning an accurate economic value to water in agriculture, industry or hydro electric power (HEP) production is a complex and difficult task, and is highly site specific, varying according to its use, location and time. (Young 1996) The benefits accruing to the economy from these uses are all net of the considerable costs of infrastructure, including dams and reservoirs, pumping stations, water transfer schemes, distribution systems and treatment plants, the costs of relocation of people from inundation areas, as well as other inputs into production.

4.2.1 Water as an input into economic production and livelihoods

The value of water is most readily appreciated as an input into economic production, both through consumptive use, via direct abstraction, and non-consumptive use, via the modification of water flows for the generation of hydro-electric power. Thus dams, boreholes and other infrastructure facilitate the transfer of water into economic processes of which the outputs are measurable as the economic benefits yielded by the investments in supply infrastructure.

4.2.1.1 Agriculture

Agriculture is by far the greatest user of water in most of the SADC countries. In South Africa, 69 percent of all water consumption is used for irrigation and watering of livestock (Davies and Day 1998), and irrigation accounts for over three-quarters of groundwater used. The value of water in this regard may be considered as the value added to the productivity of land by water supply, taking into account any government subsidies.

The small area of irrigated agricultural land in South Africa (one percent of national land area) produces 30 percent of the value of agricultural production (Chenje and Johnson 1996), thus producing relatively high returns to agricultural land. However, the agricultural sector (including forestry and fishing) contributes only five percent to Gross Domestic Product (GDP) in South Africa, suggesting that the returns to agricultural use of water are relatively low compared to the industrial sector, which is to be expected.

Similarly, in Namibia, irrigation uses almost twice as much water as livestock (44 percent vs 23 percent of water consumption, respectively), but its returns to water are much lower at N$0.20 vs N$20.20 per cubic metre. (Heyns *et al* 1998) While relatively little irrigation water goes toward producing high value export crops, the remainder is often used to grow low value crops which can be uneconomical, particularly when the opportunity cost of the water is high and/or when these crops are subsidised.

In wetter countries, agricultural consumption of water is somewhat lower. For example, only 26 percent of Zambia's water supply is used in the agricultural sector, yet this sector contributes 19 percent to GDP. This does not necessarily imply that Zambia is a more efficient user of agricultural water, however, as these figures simply relate levels of economic output to levels of water use delivered through the infrastructure system.

4.2.1.2. Industry

Industry accounts for about 11 percent of water consumption in South Africa and Namibia. (Davies and Day 1998, Heyns *et al* 1998) Manufacturing industries such as food and beverages, pulp and paper and petrochemicals are particularly reliant on water. Although some forms of

production utilise vast quantities of water, the returns to water use in this sector are [illegible] high. In South Africa, manufacturing accounts for almost one-quarter of GDP.

Industrial output and development also depend on power supply. Hydroelectric power accounts for 65 percent of the commercial energy supply to SADC countries (Chenje and Johnson 1996), although South Africa relies mostly on other sources of energy, with hydropower contributing only 0.2 percent to electricity supply. (Davies and Day 1998) The Cahora Bassa, Inga and Kariba schemes are the largest in the region, with a capacity of 2,075 MW, 1,771 MW and 1,266 MW, respectively. (Table 2.9 in chapter 2) HEP is one of the cheapest sources of energy, utilising water pressure to rotate turbines before returning the water to its source river. Although this makes it a non-consumptive use of water, it is important to note that this use is effectively consumptive, in as much as HEP schemes impact on the supply of water to downstream ecosystems, and large schemes can lead to significant evaporative losses. Moreover, HEP dams hold vast amounts of water in dead storage, which cannot be abstracted for other purposes. Lake Kariba's dead storage amounts to 114 cu km, equivalent to nearly 20 percent of the region's annual runoff. (Chenje and Johnson 1994)

4.2.1.3 Domestic

Domestic and municipal use of water for drinking, cooking, washing, cleaning and gardening accounts for about eight percent of water consumption in South Africa and 12 percent in Botswana. Domestic use of water does not offer direct returns to GDP. However, clean drinking water and adequate sanitation confers substantial health benefits in the avoidance of diseases such as diarrhoea, and is thus vital to economic performance. In South Africa, the annual expenditure on the treatment of diarrhoea related to inadequate clean water and sanitation has been estimated as R4 million. (PDG 1997) Currently, more than half of the population of the SADC region still lacks access to reliable supplies of clean water and sanitation (see Tables 2.10 and 2.11 in chapter 2). Several studies have elicited people's [illegible] to pay for a regular and sanitary supply of water in developing countries (*eg* Fredriksson and Persson 1989), demonstrating the high economic value of this service.

DWAF, South Africa

Clean water for domestic use does not contribute directly to GDP, but [illegible] indirect returns [illegible] substantial health benefits to the community.

4.2.2 Water as a conduit for waste disposal

Polluting outputs are generated because economic production cannot be 100 percent efficient in its conversion of inputs to outputs, and thus generally emits some types of waste products. Aquatic ecosystems provide a benefit to economic production in that they provide a cheap and easy means of disposing of many of these wastes, although this ecosystem service is seldom considered or quantified in economic terms. Furthermore, when waste disposal into aquatic ecosystems exceeds [illegible] capacity, the resultant environmental damages are similarly unaccounted for. These environmental damages, resulting from the reduction of water quantity and quality, are known as "externalities" in the economic production process.

The environmental externalities, both positive and negative, of modification of river flows and aquatic ecosystems by economic production processes, rarely feature in economic assessments, and are discussed in the following sections.

4.3 THE ECONOMIC TRADE-OFFS

At current population growth rates, almost half of the population of the SADC region will experience chronic water shortages by 2025 (see Maps 1.1, 1.2 in chapter 1, Table 2.1 in chapter 2). In the drier SADC countries, many farms relying on groundwater supplies are already running short. An increased supply of water and power will be vital to economic development and poverty relief, and new water supply and HEP projects are thus considered a priority for development within the region. (SADC 1998) However, such developments carry environmental

D Reed, IUCN

Almost half of the SADC population could face chronic water shortages by 2025.

costs which impact negatively on the economy, and need to be taken into account. Similarly, environmental management tends to be neglected because of its apparent net costs, whereas such management leads to greater security of water supply for future economic development.

The general problem can be illustrated as follows. The utility (or benefit) derived from a catchment system can be considered as a function of both the economic activities that indirectly make use of it, and the goods and services emanating from the system:

$$U_A = U(X_1, X_2 \ldots X_n; Q_1, Q_2 \ldots Q_m),$$

where U_A is the utility derived from catchment system A, $(X_1, X_2 \ldots X_n)$ are the economic activities which impact on the ecosystem, and $(Q_1, Q_2 \ldots Q_m)$ are the goods and services provided by the ecosystem. There is a complex matrix of interactions between these variables. An increase in economic activity $(X_1, X_2 \ldots X_n)$ may decrease the quality or quantity of aquatic ecosystem goods and services $(Q_1, Q_2 \ldots Q_m)$. For example, if X_1 represents the magnitude of sugar cane production, the water abstraction and pollution associated with this production may impact on a certain wetland function, say Q_1. Similarly, an increase in one type of economic activity X_1, may decrease the output of a second economic activity, either through direct competition for water, or due to the change in function Q_1 which affects the productivity of X_2. In this example, the costs are internalised, in that the cost of loss of Q_1 due to an increase in X_1 is borne by the user. In other words, the user would only choose to increase X_1 if the benefit of doing so is greater than the loss of Q_1. In reality, different users may gain utility from different components of this function, and will thus make decisions that are independent of the costs to users relying on other components. This occurs because many of the costs to other users are external, and not reflected in the prices faced by different consumers. Thus the onus is on governments, regional institutions, business and society to recognise all of the costs and benefits of development and management decisions, and to ensure that the overall utility to society UA is maximised.

The main factor hindering this process is that the economic costs of environmental degradation, even if recognised, are seldom known in quantitative terms. The following sections describe some of the environmental costs of development and poor management that negatively affect economic systems reliant on water supply and aquatic ecosystems. Quantification of these costs is a relatively new area of research, particularly in the SADC region, but will be vital to clarifying trade-offs in decision-making with respect to investments in water supply and HEP developments and investment in environmental management.

4.4 THE CAUSES OF AQUATIC ECOSYSTEM DEGRADATION

Aquatic ecosystems are degraded directly due to economic activities which require the supply of water and hydropower and which return polluted flows to aquatic environments. Other productive activities, such as agriculture, livestock, forestry and deforestation in catchment areas may also lead to the degradation of aquatic ecosystems and water supply if not properly managed. In addition, aquatic ecosystems may be degraded by activities that occur within them, such as floodplain agriculture, or the exploitation of natural resources. While the latter activities realise some of the values of aquatic ecosystems, they also impact on the ecosystems. Finally, the invasion of catchment areas and aquatic ecosystems by alien plants and animals may lead to devastating consequences, if left uncontrolled.

These activities and their impacts are summarised in Table 4.1, and are treated in greater detail in subsequent chapters.

4.5 VALUING ENVIRONMENTAL DAMAGE

4.5.1 Valuation techniques

Environmental valuation techniques have been developed in order to quantify the costs and benefits of environmental changes for proper consideration in decision-making. This is a relatively new field in developing countries and

Human activity	Impact on aquatic ecosystems	Reduction in values/services
Afforestation, deforestation and poor land use in catchment areas	Alters runoff patterns, inhibits natural recharge Erosion leads to silt deposition in aquatic ecosystems	Decreased water quantity and quality for other users Decreased economic life of water supply schemes Reduction in biodiversity and resource stocks
Alien invasion of catchment areas	Alters runoff patterns, inhibits natural recharge Change in water chemistry Erosion leading to silt deposition in aquatic ecosystems	Decreased water quantity and quality for other users Decreased economic life of water supply schemes Reduction in biodiversity and resource stocks
Polluting economic activity	Release of inorganic and organic pollutants changes chemistry and nutrient status of aquatic ecosystems	Decreased water quality for all uses Eutrophication, with concomitant negative effects on biodiversity and resource stocks Loss of aesthetic and recreational appeal Decreased waste assimilative capacity for downstream economic activity
Water supply schemes and hydropower schemes	Change in timing of flows Reduction in quantity of water to downstream ecosystems Reduction in downstream sediment loads Changes in temperature and chemical characteristics of water Creation of barriers to movement Increased seismic activity	Reduction in biodiversity and change in stocks of resources in inundation areas and downstream aquatic ecosystems Change in ecosystem functioning and sediment dynamics Creation of low flow conditions suitable for pests and pathogens Loss or gain of aesthetic and recreational appeal Reduction in water quantity and quality available to downstream users
Agricultural and other land use within aquatic ecosystems	Loss of habitat Release of inorganic and organic pollutants into aquatic ecosystems	Loss of infrastructure and arable land Reduction in biodiversity and resource stocks Decreased water quality for other users
Exploitation of aquatic resources		Reduction in biodiversity and resource stocks
Alien invasion of aquatic ecosystems	Siltation of aquatic ecosystems Change in water chemistry	Reduction in biodiversity and indigenous resource stocks Decreased water quality for other users

has only recently started to be applied within the SADC region. Valuation can be used in the following aspects of sustainable water resource management:

The quantification of costs and benefits of catchment management and conservation programmes;

The quantification of environmental costs and benefits for incorporation in the evaluation of hydroelectric and water supply projects;

As inputs into the natural resource accounting process when valuing natural resource stocks and environmental damage costs; and

The formulation of prices, charges and other economic instruments which reflect environmental costs.

This section serves to introduce the reader to the main types of valuation techniques that have been developed, rather than providing an exhaustive account of the details of such methods. A wealth of literature exists on the subject. Valuation techniques can be divided up into those relying on conventional market information, those that make use of implicit or surrogate markets and those that construct artificial, or simulated, markets.

4.5.2 Market value approaches

4.5.2.1 Change in production method

Productive use of water resources and aquatic ecosystems (*eg* irrigation schemes, fisheries) may be positively or negatively affected by environmental change (*eg* instream flow, pollution level). This change is measured as the market value of the loss or gain in output. This approach either requires information on the levels of production before and after the change, or information on production levels during one environmental state and an understanding of the relationship between the state of the environment and production.

4.5.2.2 Defensive expenditures method

When environmental damage leads to defensive expenditures in order to reduce the effects of this damage, these expenditures can be taken as a proxy for the value of the environmental service that is being replaced by the defence measures, such as flood control dykes, or expenditure on health services.

4.5.2.3 Loss of earnings method

This technique is most commonly used to measure the loss in human output due to illness or premature death from, for example, water pollution. Average earnings are established and multiplied by the productive time lost. Dose-response functions that measure the links between dose [illegible] and response (health impact) are also usually necessary for this technique.

4.5.2.4 Replacement cost method

This technique attaches value by estimating the costs of restoring a damaged environment to its original state. For example, it is possible to estimate the costs of restoring a wetland damaged by pollution.

4.5.3 Surrogate market approaches

4.5.3.1 Travel-cost method

This method is usually used to measure the recreational benefits of natural resources in the absence of markets (*eg* entrance fees), or when low fees do not reflect people's true [illegible] to pay to use these resources. The cost of travelling to a site is taken as a proxy for this willingness to pay. The method involves a survey of users to gauge their costs and time spent in reaching a site along with an assessment of their socio-economic characteristics such as income levels. Survey results are then statistically manipulated in order to derive recreational demand curves from which total recreational value can be estimated.

Although relatively straightforward in theory, the travel-cost method is often complicated by several factors. The most confounding problem is that of journeys to multiple destinations, in which case it becomes difficult to isolate the value of the site in question from that of other destinations on the journey. Another difficulty is accounting for substitute sites. A visitor may travel to visit a site which they particularly enjoy, whereas another who has less enthusiasm for the site may travel the same distance simply because there is no other available recreational site near home. The travel cost method may also underestimate recreational value in cases where people access recreational areas by foot or bicycle.

4.5.3.2 Hedonic pricing method

This technique is based on the premise that goods and services are made up of bundles of characteristics each of which makes a quantifiable distinct contribution to overall price. Observed prices and the levels of various characteristics, environmental and others, contained in each good or service provide a measure of the implicit value that consumers place on each of the characteristics that make up the good or service, including the unpriced environmental characteristic. (Dixon *et al* 1996) Hedonic pricing generally applies to property prices and wage differentials. In the case of property prices, for example, the price of a house near a heavily polluted river will be less than a similar house next to a healthy river by an amount that reflects the cost of the pollution. Hedonic pricing is useful in an urban context, but cannot be applied very easily in areas where land is under communal tenure. In the case of wages, for example, the premium that workers are paid in jobs with health risks (where fair compensation exists) can be used to estimate their implicit values for sickness or premature death.

4.5.4 Simulated market approaches

4.5.4.1 Contingent valuation methods

Contingent valuation methods can be used to derive values for almost any environmental change and are the only technique that can be used to derive intangible values. Contingent valuation involves the direct questioning of people to determine how they would react to environmental changes. This is done through the use of a carefully designed questionnaire which ascertains respon-

dents' willingness to pay to gain or prevent a loss of some level of an environmental good or service or their willingness to accept compensation to tolerate a loss. Willingness to pay can be elicited by means of open-ended questions, referendum or dichotomous choice (yes/no) type questions, bidding games, trade-off games, ranking techniques, costless-choice options, or the priority evaluator technique. The method usually has to be tailored to suit each unique valuation situation. Questionnaire results are then analysed using econometric techniques to derive overall values.

Contingent valuation is the only method with which to estimate option and non-use values, and it has also frequently been applied to the measurement of recreational use value. Contingent valuation methods can also be applied to the valuation of direct and indirect goods and services associated with natural systems where the quantification of these outputs is difficult, and are also particularly useful in the valuation of domestic water supply schemes.

Because it relies on direct questioning, rather than observing people's actual behaviour, contingent valuation is open to a number of biases. Indeed, much of the academic literature on contingent valuation has paid attention to these biases and to finding ways of minimising them. These biases include "strategic bias" whereby respondents over- or under-state their true willingness to pay because they believe their response may influence decision-making.

"Embedding bias" varies when people do not see the question in the context of all their wants, needs and budgetary constraints. "Interviewer bias", "information bias", "starting point bias" and "hypothetical bias" tend to steer the thinking of the respondents, and decisions are also influenced by the choice of payment vehicle. A set of guidelines has been produced (Arrow *et al* 1993) which helps practitioners minimise the biases in contingent valuation. Nevertheless, the use of contingent valuation in valuation studies remains somewhat controversial.

4.5.5 Choice of valuation techniques

A variety of techniques are available for the valuation of environmental assets or changes in environmental conditions, with different methods being suitable depending on the situation and type of value being measured. In general, market value approaches are more straightforward and reliable than surrogate and simulated market approaches. Where more than one technique can be used to estimate values, it is often considered good practice to use these methods to cross-check results. Although valuation studies should seek to avoid underestimation or omission of certain values, it is also important to avoid double-counting, where different techniques are used to measure multiple values. Time and cost constraints, and the availability of information also affect the choice of technique. For example market value techniques are straightforward where adequate data exists, but may be extremely costly and time-consuming where it does not. Travel-cost and contingent valuation techniques are generally fairly expensive to carry out.

4.6 IMPACTS OF ENVIRONMENTAL DEGRADATION ON WATER SUPPLY

Environmental degradation resulting from poor management practices and inappropriate investment decisions has a profound effect on the quantity and quality of water available for use in human economic systems, as described below.

4.6.1 The costs of catchment erosion

The major causes of soil erosion in the SADC region are overgrazing, mismanagement of arable land and deforestation. Overgrazing is considered to be responsible for more than half the soil degradation in southern Africa, with cultivation responsible for most of the remainder. These losses are of considerable cost to the economy in terms of the productivity of catchment areas in themselves, but they also form a major source of degradation of water resources.

Soil erosion carries enormous on-site costs. In Zimbabwe, it is estimated that the cost of soil erosion, in terms of loss of productivity, varies between US$20 and US$50 per ha per year on arable lands, and US$10 to US$80 per ha per year on grazing lands, with soil erosion costs on arable land amounting to 16 percent of agricultural GDP. (Norse and Saigal 1993) These on-site costs are internalised to some degree in terms of reduced production, creating the incentives for farmers to reduce these impacts. Once soil and excessive runoff leave the farm, however, they are external costs that are borne by downstream users. While many studies show that soil conservation measures would be justified in terms of mitigating the on-site losses alone, relatively few studies have gone further to estimate the off-site costs of soil erosion (Biot *et al* 1995), especially in Africa.

Over half of Africa's eroded soils are transported by water (Norse and Saigal 1993), thus ending up in aquatic ecosystems. Largely as a result of poor land-management practices, many southern African rivers carry high sediment loads, and it is estimated that about 120 million tonnes of silt go into South African rivers each year. It is often difficult to separate accelerated erosion from natural erosion, however. Grohs (1994) attributes 50 percent of silt loads to erosion from agricultural lands in Zimbabwe. Chapter 7 contains more details on the distribution and magnitude of erosion and watershed degradation.

The most important off-site impacts of soil erosion are (Aylward 1998, Enters 1998):

sedimentation effects on dams, leading to loss of HEP generation and loss of water supply to economic production, or increased prevention costs such as dredging;

increase in operation and maintenance costs incurred by sedimentation of drainage ditches and irrigation canals;

the degradation of potable water, or increased costs of water treatment;

accelerated runoff leading to localised flooding;

reduced hydrological cycling and recharge of ground water; and

in-stream problems of water quality and quantity, leading to loss in production (eg fisheries), loss of recreational benefits, and loss of navigation opportunities.

These effects are discussed in the following section.

All of these effects have negative impacts on the economy. For example, siltation can wear away power-generating equipment, and can cut the useful life of a dam by 25 percent, with some major dams silting up in less than 20 years, representing a substantial cost to investors. (Chenje and Johnson 1996) Thus, in many southern African countries, erosion imposes defensive expenditures downstream: reservoirs, hydroelectric dams, irrigation systems, and urban drainage systems all require maintenance due to catchment erosion. (Convery 1995) In Namibia, siltation has been found to impede recharge of the Omdel aquifer by clogging the openings in the soil. This has had sufficiently severe consequences to motivate the building of costly dam infrastructure in order to increase groundwater infiltration. In the United States, the total annual off-site damage from soil erosion has been estimated as $4 to $15 billion per year. (Ribaudo *et al* 1989)

The costs of sedimentation can be measured in terms of,

change in productivity (*eg* due to reduction in irrigable land because of reduced dam capacity),

replacement costs in terms of replacing worn equipment or replacing the live storage lost annually, or

preventative expenditures that have to be incurred, such as incorporating dead storage in dams to anticipate the accumulation of sediments, or constructing flood prevention structures.

(Grohs 1994, and Box 4.1)

Similar problems of siltation due to poor land-use practices have been recorded in a number of developing countries, and have led to the implementation of major conservation programmes elsewhere, with demonstrable benefits. (Box 4.2)

Problems such as the above, where the economic life of a dam is found to be shorter than planned, frequently arise because sedimentation rates estimated in the pre-project stage are lower than estimates made in the early operational stages. (Enters 1998) This is because potential future land-use changes are either underestimated or not included in feasibility studies of dam projects, and invariably the project area becomes more attractive, resulting in increased land clearing.

Off-site costs of agricultural erosion in Zimbabwe and South Africa **Box 4.1**

Grohs (1994) estimated the economic impacts of sedimentation due to agricultural soil erosion on smallscale irrigation schemes, in terms of loss of irrigation capacity, costs of replacing the live storage lost annually, and costs of constructing dead storage to anticipate sediment accumulation. The annual loss of productivity was estimated to be Z$590 000 (US$59,000), due to agricultural income foregone and dredging costs of the irrigation scheme. The annual replacement costs and preventative expenditures, which take capital costs into account, were much higher on average, ranging between Z$0.8 - 8.8 million (US$80,000 - 880,000) and Z$1 - 12.5 million (US$100,000 - 1.25 million), respectively.

In South Africa, dams in high erosion areas lose 10 percent of their capacity per decade. The cost of constructing new dams to replace storage capacity lost to siltation is estimated at between R100 million - 200 million per year (US$36 - 72 million).

Grohs 1994

Valuation and cost-benefit analysis of a watershed conservation programme in Ecuador — **Box 4.2**

In the first five years of its operation, the Poza Honda watershed reservoir in Ecuador displayed accelerated sedimentation and eutrophication due to intensive land use in critical areas. After five years, it was established that 20 percent of the volume of the reservoir was filled with sediment and that sedimentation was occurring at four percent per annum (10 times the anticipated rate) shortening the projected life of the reservoir to 25 years.

A cost-benefit analysis was conducted for a watershed conservation programme. The proposed programme consisted of land-use changes, conservation of habitats, management, etc. all aimed at halving sedimentation rates. The benefit was the extension of the productive life of the reservoir from 25 to 50 years helping to maintain the agricultural potential of the watershed. The summarised costs of the conservation programme were for reforestation, terracing, grazing control, forest management and general administration.

The *with conservation* option yielded a net benefit of 456.45 million *sucres* and a benefit/cost ratio of 1.43/1. The *without conservation* option on the other hand showed a negative net benefit of 311.92 million *sucres* and a benefit cost ratio of 0.67/1. (Fleming 1979)

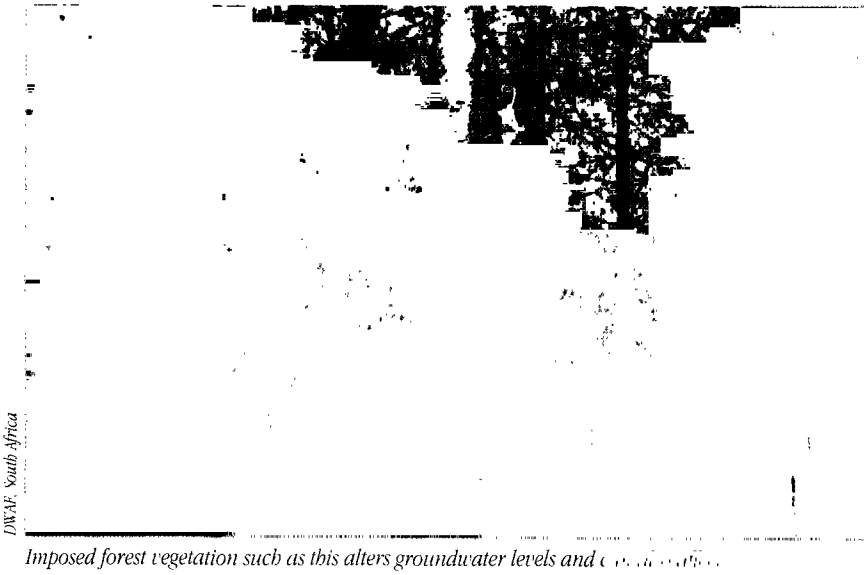
Although a relatively high degree of uncertainty was indicated for the costs of the conservation programme, the benefits were far enough in excess of the costs to suggest the success of the project. The study illustrated the substantial gains generated by a proper holistic management programme to accompany dam construction.

4.6.2 Changes in catchment runoff due to deforestation, commercial afforestation and invasive alien plants

Natural forests and woodlands play an important role in the hydrological cycle, not only in preventing excessive run-off which leads to erosion, but because their root systems aid [illegible] of water into the soil and water table, and evapotranspiration affects local microclimatic conditions. Deforestation thus has the potential effect of decreasing groundwater recharge and increasing aridity. Clearing vegetation (*eg* for agriculture) thus increases runoff and decreases [illegible] rates, lowering the water table. Compaction by stock also decreases infiltration rates and encourages higher runoff. Soil moisture is lost due to runoff being more concentrated in periods of high rainfall. Notwithstanding the resultant costs in terms of lost productivity and biodiversity within catchment areas, the advantage of higher run-off to aquatic ecosystems and water supply schemes (see Aylward 1998) is offset, and can be overshadowed, by the high costs in terms of erosion and sedimentation, described above.

It does not always follow that afforestation of catchments is beneficial to water resources. Commercial plantations of fast-growing alien trees such as pines and eucalypts have the opposite effect in terms of water run-off, yet also produce high amounts of soil erosion during harvesting, largely because of the lack of understorey vegetation cover. These plantations, which usually replace low-biomass vegetation types, intercept considerable quantities of water which would otherwise run off into river systems and dams, a loss which is usually unaccounted for in economic terms. In South Africa, plantation forests have significantly reduced available groundwater and streamflow by as much as 1.29 cu km per year. (Chenje and Johnson 1994)

The invasion of catchments and streams by alien trees has a similar effect. The invasion of riverine systems by alien trees, mainly pines and acacias, is widespread throughout southern Africa, and in the fynbos areas of the western Cape, whole catchment areas can be invaded by trees. The effect of these alien trees on water supplies is dramatic: South Africa loses seven percent of run-off, or 3,300m cu m of water annually to alien vegetation, with losses of up to 30 percent of runoff in heavily invaded catchment areas. (Versveld *et al* 1998)



DWAF, South Africa

Imposed forest vegetation such as this alters groundwater levels and [illegible] the climate. [illegible] watersheds.

The result of these run-off losses is that supplies from existing water schemes are diminished and will be outstripped by demands sooner than would be the case if the catchments were free of aliens. Thus the decrease in runoff translates into an increased expense in terms of the supply of new infrastructure, as well as the additional costs associated with such infrastructure. The clearing of alien trees is costly, but it has been demonstrated that the economic returns from doing so outweigh the financial and environmental costs. (Higgins *et al* 1997, Marais 1998, Turpie and Heydenrych 1999)

Aquatic weeds, which have invaded many aquatic ecosystems throughout southern Africa, also threaten water supplies. (see chapter 8) These weeds, mostly from South America, include Kariba weed *Salvinia molesta*, Water hyacinth *Eichhornia crassipes*, Parrot's feather *Myriophyllum aquaticum*, and Red water fern *Azolla filiculoides*. They are characterised by prolific growth rates, and tens of millions of rands have been spent on their eradication in South Africa alone. (Davies and Day 1998) With insufficient effort to control the problem throughout the SADC region, these weeds continue to proliferate, covering vast areas of rivers, wetlands and lakes. Apart from their negative impacts on ecosystem functioning and biodiversity, these weeds can have a significant effect on water supplies. Some aquatic weeds have extremely high evapotranspiration rates, so that more water is lost from a water body infested with weeds than one without weeds. Water hyacinth can increase evaporative water losses from dams and waterbodies by as much as 3.5 times (Davies and Day 1998), representing an enormous economic loss, in terms of the water available for economic production.

4.6.3 Reduction in water quality due to pollution and eutrophication

Water quality degradation is one of the most serious of all environmental problems because it can affect human health and economic activities as well as biotic communities. With population growth and economic development, surface and groundwater quality is increasingly being degraded by industrial and agricultural activities, and by domestic sewage.

Major industrial polluters include thermal electric power stations, fertiliser factories, textile mills, chemical plants, pulp-and-paper plants, slaughter houses and tanneries. (see chapter 6) These wastes accumulate to a point where they can become a serious health hazard. In Zimbabwe, for example, the Mukuvisi river, which runs into Harare's drinking water supply, contains high amounts of nutrients, sulphate, calcium, magnesium, fluoride, aluminium and iron, largely from industrial dumps along the river banks. (Chenje and Johnson 1996) Similarly, water supplies near Lusaka are polluted by Zambia's copper mines, which discharge waste into the Kafue river.

Nutrients from agricultural fertilisers leach into groundwater and run off into rivers, lakes and reservoirs. They cause eutrophication, stimulating algal blooms that render water undrinkable without further treatment, as well as promoting aquatic weed growth.

Disposal of domestic wastewater is a particularly severe problem in many urban areas where there is high density living, but sanitation is also a problem in rural areas. Cholera and other water-associated illnesses, such as diarrhoea, are often prevalent in areas where water is contaminated with untreated human waste and sewage. Indeed, water-related diseases account for over 80 percent of all diseases in developing countries. (Heyns *et al* 1998)

Polluting water supplies can thus have significant impacts on economies (Box 4.3), either through the loss

Costs of pollution in the Sebou river basin, Morocco — **Box 4.3**

The Sebou river in Morocco accounts for 30 percent of national water resources. However, urban, agricultural and industrial activities in the densely populated river basin have resulted in severe levels of pollution that have rendered water unsuitable for human consumption. In fact several water treatment plants have had to shut down because the water was too polluted to be treated. Routine water treatment costs are already three times higher than anywhere else in the country. The incidence of waterborne disease is particularly high, and fish populations are all but extinct. The costs of water pollution were estimated as the direct economic losses associated with water treatment costs, health costs, and fisheries costs over the next 25 years. Water treatment costs will amount to some US$350 million. Health costs due to diarrhea, cholera and typhoid amount were estimated as $97 million. Fisheries costs will be in the region of nearly US$8 million. This estimate is considered to be an understatement of the true social cost of water pollution in the Sebou basin, as it does not capture losses of aesthetic and recreational benefits, impacts on biodiversity or the true value of pain and suffering and lost lives.

Sadoff 1996

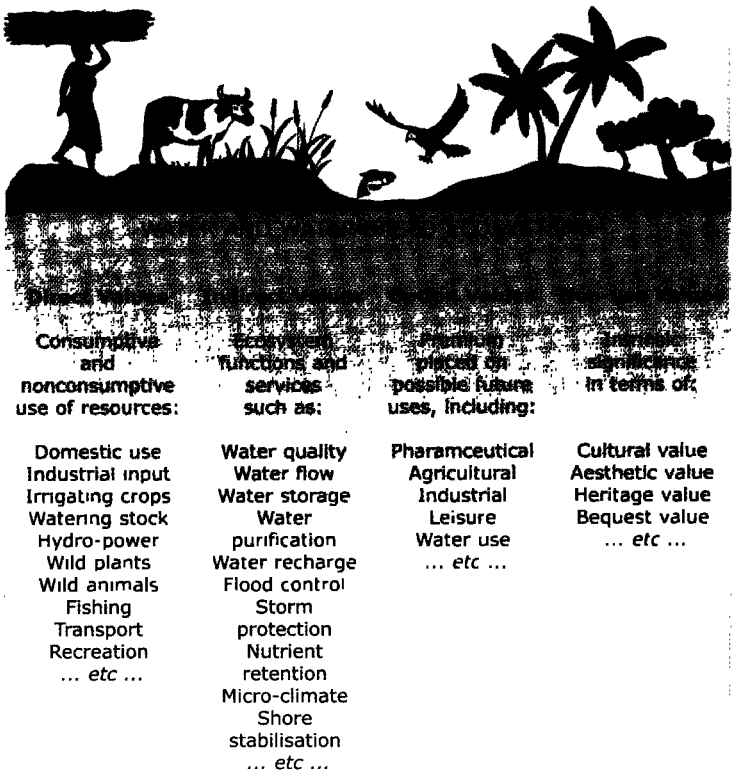
of human productivity and increased healthcare expenditure as a result of increased illness, or through increased preventative expenditure, mainly in cleaning water to acceptable standards for domestic and other consumption. In South Africa, it has been shown that poor water quality has a significant impact on the cost of treating water. For example, the cost of water treatment at Hazelmere, KwaZulu-Natal, increases from R6/cu m to R111/cu m with decreasing water quality. (Graham *et al* 1998) Abiotic water quality factors, including turbidity, have more of an impact than the cost of treating water with increased algal concentrations. Rand Water, which is South Africa's largest bulk supplier of water, recently estimated the increased treatment costs that it will have to incur because of diffused sources of pollution at R111 million in extra capital costs over the next two years, and R4.5 million annually for operating costs.

4.7 THE VALUE OF AQUATIC ECOSYSTEMS AND COSTS OF THEIR DEGRADATION

Resource economics generally recognises the categorisation of values of natural resources into direct consumptive use values, direct non-consumptive use values, indirect values, option value and existence value (*eg* Munasinghe 1992). This ordering also represents a generally decreasing degree of "tangibility", and hence "measurability" of value. Direct use values are straightforward, being the benefits obtained from the use of water for production, harvesting fish and other natural resources, power generation, recreation, etc. Indirect use values are obtained from ecosystem services, such as the absorption of wastes. Option values are sometimes termed "future use values" and represent the value of retaining the option to use resources in future, while existence values are derived from a complex array of motives and ethics to form the value of knowing that a resource exists. All of these values are expressed in terms of society's "willingness to pay" to retain resources in a desired state. Figure 4.1 shows the various direct and indirect values of water-based ecosystems. Although it is not always easy to assign values to these separate categories, this provides a useful framework or starting point from which to examine the value of economic goods and services provided by natural resources.

Aquatic ecosystems derive their most tangible value from the direct use of water and other aquatic resources,

Figure 4.1



particularly direct consumptive use of water. In most cases, the consumptive, and to some extent, non-consumptive, use of water impacts on all other values including other direct use values of aquatic ecosystems. This section examines the different values of aquatic ecosystems apart from the value of water itself, and how these values are diminished by the damaging economic activities and management approaches listed in Table 4.1.

4.7.1 Direct consumptive-use values of aquatic ecosystems

Aquatic ecosystems contain stocks of biotic resources that yield annual flows of products or goods, which in turn provide direct consumptive-use value to a variety of users. Thus these values arise from the harvest of a number of resources that are found in rivers and riparian habitats, lakes, dams, wetlands and estuaries. In particular, they include plant products, such as reeds, sedges, grasses, and mangrove wood, and animals, such as invertebrates, fish, and birds. In the SADC region, these values include the subsistence, or livelihood, values of natural resource use as well as commercial use. The estimation of the use

value of aquatic resources is still in its infancy, but has been attempted for a few aquatic ecosystems in the region. Box 4.4 gives an example of the value of aquatic resources harvested in the Barotse wetland system in western Zambia.

The change in water quantity and quality brought about by water supply schemes, pollution, catchment degradation and invasive plants affect the biomass of many resources that are utilised by local communities or commercial enterprises. These changes can be estimated on the basis of understanding of the biological response to changed water conditions, using the change-in-production technique.

Lack of control of aquatic weeds also poses a serious threat to productive aquatic resources. Aquatic weeds are encouraged by low flows associated with dam schemes, and are also particularly problematic in lake systems. Exotic plant species negatively affect fisheries by reduction of biomass. By contrast, some exotic fish species introduced into aquatic ecosystems in Africa increase the income generated by fisheries, but sometimes with considerable ecological and social costs. (Box 4.5)

The construction of water supply schemes may lead to the inundation of large tracts of productive land, whether for subsistence economies or commercial production. (Box 4.6) However, in many cases, especially extensive shallow systems, these dams may themselves become highly productive fishery resources.

4.7.2 Direct non-consumptive use value of aquatic ecosystems

Non-consumptive use of water and aquatic ecosystems can be divided into several categories: the use of water flow for generation of hydroelectric power, use of water for transport routes, and the use of aquatic ecosystems for recreational, cultural, spiritual, scientific and educational purposes.

Positive and/or negative impacts on recreation, amenity and tourism can be associated with the water resource development and/or degraded ecological functioning. While present recreational benefits can be measured using techniques such as the travel-cost method, the effects of a proposed change can be estimated on the basis of market surveys.

4.7.2.1 Navigation

Major rivers in the SADC region provide important transport routes, especially where roads and rail systems are in a state of disrepair due to low maintenance and flooding. For example, since the collapse of the main railway and due to the poor state of the road, the lower Shire river provides an important conduit for trade, especially informal trade, between Malawi and Mozambique, and commercial enterprises also make use of these transport routes. Navigation in Lake Victoria facilitates transport of people and goods between Kenya, Uganda and Tanzania. Such navigation would be valued by the cost savings by not having to rely on longer and more arduous transport routes and maintenance of infrastructure. No attempt has been made to value this service within the region, however.

4.7.2.2 Recreational value

Aquatic ecosystems are major sources of recreational value. (Box 4.7) This is enhanced when aquatic ecosystems enjoy some form of protected area status. In many SADC countries tourism is reliant on major aquatic ecosystems such as the Okavango delta, the Rufiji, Mara, Zambezi and Chobe rivers, land estuaries and the Lake Manyara groundwater. These ecosystems have immense recreational value and in some countries such as South Africa, high economic and real estate value. It should be noted that water impoundments also yield important recreational value, and in some cases, these benefits could outweigh the recreational value of the area to be inundated. (Leiman 1995)

4.7.3 Indirect use values of aquatic ecosystems

Most indirect use values derive from ecosystem services that play an essential role in maintaining the basic functions of nature. An indirect use of water itself is the maintenance of aquatic and terrestrial ecosystems which give rise to all of the values discussed in this section. Here we consider the indirect use value of these systems as a whole.

4.7.3.1 Maintenance of water quality

Aquatic environments play an important role in the nutrient cycle upon which ecosystems depend. In this way they are able to absorb pollution from human activities including sewage, stormwater wastes, chemical wastes from industrial and agricultural processes, etc. (Box 4.8) Note however, that the value of this service only extends as far as the amount of pollutants assimilated. Thus it is not viable to ascribe the value as simply the costs that would be incurred to treat the full amount of waste entering a system.

Using market prices to estimate the value of wetland resource-use in Barotseland

Box 4.4

Turpie *et al* (1999) conducted a detailed survey of 138 households in the Barotse wetland, Zambia, to ascertain the range and quantity of natural resources harvested annually within the wetland. Market prices were obtained from the survey and from focus group discussions, and the quantity and price of inputs were ascertained for the production of each resource. Wetland resources accounted for 40 percent of the total income (including non-cash income) accruing to households.

Total value of natural wetland resources (US$ 000 per year)	Fish	Reeds	Papyrus	Grass	Palm	Animals	Clay	TOTAL
Gross economic value	5947	193	308	272	12	12	66	6810
Net economic value	4258	131	139	221	3	10	52	4814
Gross cash income	1452	5	39	8	1	0.3	0.5	1506
Gross subsistence value	3504	156	217	219	11	12	65	4184

Introduction of the Nile perch into Lake Victoria

Box 4.5

Following the introduction of Nile perch into Lake Victoria, the fishery saw a massive increase in fish production, which has increased to four times that in the 1960s and 1970s, and represents about 25 percent of the annual total catch from all of Africa's fisheries. (Pabari 1999) However, this apparent benefit is put into perspective on considering the impacts on biodiversity and socio-economic systems. The introduction of Nile perch has been at the cost of the extinction of numerous (possibly 200-300) indigenous and endemic fish species, many of which were the source of local artisinal fisheries. The development of a commercial industry for the introduced species, including large commercial factories, has created 2,400 jobs, but has also led to the displacement of 15,000 jobs, including thousands of women who were previously engaged in fish processing. (Pabari 1999)

Now, over-fishing and environmental degradation threatens the new industry with a severe shortage of Nile perch since early 2001 when the catch by small fishermen dropped from 400 tonnes to 100 tonnes per day. A dozen fish processing plants in Mwanza and Musoma, which export nearly 400 tonnes of fresh fillets weekly to Europe and Asia, are threatened with closure. The plants were established in the early 1990s after shortages in the Kenyan part of the lake forced some investors to move their operations. These exports earned the Tanzanian government Tsh 4.2 billion (US$4.7 million) in taxes in the 2000/2001 fiscal year. Some 32,000 fishermen and another three million people in Mara, Mwanza and Kagera regions of Tanzania who depend on fishing-related economic activities are affected. Experts have recommended the introduction of seasonal fishing in order to restock the fish population. The Direcor of the Tanzania Fisheries Research Institute, Prof. J. Bwathondi, attributed the shortage to overfishing, illegal fishing and environmental degradation.

Mgamba 2001

Productivity losses on land due to be inundated by the Maguga dam, Swaziland

Box 4.6

The Maguga dam, to be constructed on the Komati river, in Swaziland, will inundate an area of over 1,000 ha of communal land. The woodland and riparian areas to be inundated contain healthy stocks of natural resources that are harvested by over 60 homesteads in and around the inundation area. A household survey revealed that 169 types of plants, animals and other natural resources were harvested from the inundation area yielding a total annual value of R1.3 million.

Turpie and Alberts 1998

The recreational value of Lake Nakuru, Kenya

Box 4.7

Lake Nakuru National Park is an important international tourist destination. Although fees are charged to enter the park, these underestimate the total value that tourists place on the wetland and its component species, especially flamingos. A travel cost survey of visitors elicited information about length of stay, travel costs, place of origin and visitation rates, distinguishing between resident and non-resident tourists. A contingent valuation survey asked visitors how large their personal total costs of travel were, how much they would be willing to increase their expenditures to visit the park, how much they would contribute to a fund to clean up and control the urban pollution which threatens the park, and how much they would contribute to a project to conserve flamingos (all measures of willingness to pay); and the minimum reduction in trip costs that they would be willing to accept should there be no flamingos (a measure of willingness to accept compensation). The results of these surveys demonstrated that the annual recreational value of wildlife viewing in Lake Nakuru National Park was between US$ 7.5 – 15 million, of which over a third was accounted for by flamingos.

Navrud and Mungatana 1994

The role of Nakivubo wetland in processing urban and industrial wastes in Kampala **Box 4.8**

In Uganda, the Nakivubo wetland, covering 6 sq km, stretches from the central industrial district of Kampala and passes through dense residential and commercial areas, and enters Lake Victoria at Murchison bay. The wetland is threatened by urban and industrial development. However, Emerton *et al* (1999) showed that such development would not necessarily make good economic sense, because of the wetland's important role in assuring urban water quality in Kampala. Both the outflow of the only sewage treatment plant in the city, at Bugolobi, and — far more importantly, because over 90 percent of Kampala's population have no access to a piped sewage supply — the main drainage channel for the city, enter the top end of the wetland. These wastewaters equate to the raw sewage from nearly half a million households, and are augmented by untreated domestic and industrial effluents that are discharged directly into Nakivubo.

It is estimated that Nakivubo currently processes almost half the nitrogen and a quarter of the phosphorus that enters it, is effective in removing bacteria and microbes, and has the potential, if properly managed, to improve the quality of water entering Murchison bay still further. These functions are extremely important, as the purified water flowing out of the wetland enters Murchison Bay only about 3 kilometres from the intake to Gaba waterworks, which supplies all of the city's piped water.

Nakivubo provides a much cheaper way of dealing with Kampala's wastewater than other, artificial options. The infrastructure required to achieve a similar level of wastewater treatment would incur costs of over US$ 1 million a year in terms of extending sewage treatment facilities at Bugolobi, or nearly US$ 2 million a year in improving water treatment facilities at Gaba.

When water quality is reduced by excessive organic and inorganic pollution, additional costs are incurred by water treatment plants in providing water to the agricultural, industrial and domestic sectors.

Water quality can also be impaired by reductions in river flow, creating suitable environments for pests and pathogens. These result in the increased incidence of diseases and diarrhoea, which can have serious economic impacts in terms of decrease in human productivity, expenditure on health care and suffering associated with diseases. The loss of earnings technique is most commonly used to measure the loss in human output due to illness or premature death from, for example, water pollution or waterborne disease. Average earnings are established and multiplied by the productive time lost. Dose-response function which measure the links between dose (pollution) and response (health impact) are also usually necessary for this technique. In the case of the Maguga dam, it is predicted that there will be significant increases in the incidence of bilharzia as well as sexually transmitted diseases introduced by construction workers, although these costs have not been quantified. However, several precedents exist which illustrate the extent of health costs which may be imposed by badly planned dam schemes, such as Senegal's Manantali and Diama dams. (Pottinger 1997)

Livestock can also be affected. In South Africa, the suppression of the natural flood regime due to dam construction on the Orange river has led to an increase in the incidence of blackflies, which are capable of causing major livestock losses. It now costs more than US$300,000 a year to control these pests. (WCD 1999)

4.7.3.2 Sediment trapping

Aquatic ecosystems, particularly wetlands, are important for the trapping of sediments that would otherwise silt up dams and other infrastructure. The problem of sedimentation has been highlighted in the previous section. In many cases, sediment transport into water supply schemes is far less than the amount of sediment actually lost from terrestrial catchment areas. The amount of sediment delivery is influenced by the size of the drainage basin, and substantial quantities of sediment can be trapped in aquatic ecosystems, particularly in floodplain wetlands. (Enters 1998) The Utengule swamp upstream of the Mtera dam, the main regulatory structure on the Rufiji river in Tanzania is an important sediment sink filtering the water entering the Mtera reservoir.

4.7.3.3 Maintenance of floodplains, alluvial fans, deltas and beaches

Erosion, sedimentation and flooding are normal processes within catchment areas and aquatic ecosystems. These processes are responsible for the maintenance of floodplains, alluvial fans, deltas, and beaches, many of which are beneficial for lowland economies, being the sites of intensive and high value agriculture and fisheries. Floodplain agriculture is often more productive as a result of soil enrichment by the additions of fertile deposits to floodplains during floods (see Box 4.9). In addition, these areas often constitute attractive tourism destinations. Altered flow and flooding regimes as well as [illegible] can significantly reduce agricultural productivity in aquatic ecosystems.

On the Orange river, the establishment of two large dams led to a drop in the sediment load carried downstream from 35 million tons to less than 20 million tons.

Using the effect-on-production approach to value floodplain agriculture in the eastern Caprivi wetlands, Namibia — Box 4.9

The eastern Caprivi wetlands rely on annual flooding from the Zambezi river for their replenishment. Over 3,000 households live in and around this 170,000 ha floodplain, where they take advantage of more productive soils and livestock grazing. Crop production within the floodplain is worth some US$900,000 per year, of which a significant portion is attributable to the maintenance of the natural flooding regime. Cattle production is four times higher in the wetlands than in nearby uplands, which means that $840,000 of the total production value of $1.125 million is attributable to the maintenance of the wetland.

Turpie *et al* 1999

Avertive expenditures, marine and coastal ecosystem protection services in Seychelles — Box 4.10

Beach protection, storm and flood control provided by wetland marshes, mangroves and coral reefs in Seychelles often used avertive expenditure techniques. (Emerton 1997) The cost of averting the effects of the loss of these marine and coastal ecosystem functions were assessed by looking at expenditures on the construction and maintenance of mitigative groynes and flood barriers. The resulting value of some 4 million rupees a year, or 282 rupees per kilometre, presents a minimum estimate of the indirect value of selected marine and coastal biodiversity services.

(Chenje and Johnson 1996) Similar effects have occurred on the lower Zambezi, following the construction of the Cahora Bassa dam, with noticeable (although unquantified) effects on floodplain agriculture. Following the construction of the Aswan dam in Egypt, which traps the rich sediments of the Nile river, annual losses of nitrogen to downstream [illegible] were valued at US$ [illegible] per year. (Dixon *et al* 1989)

Water exchange between estuaries and marine systems is a complex balance between freshwater inflows and tidal [illegible] and in many cases is important for the supply of sand to nearby beaches which have important recreational value. Disruption of freshwater inflows can disrupt this sediment transport, requiring the costly restoration of beaches. Thus this function can be valued in terms of the beach replacement costs that would have to be incurred if the function was to be lost.

In South Africa, substantial decreases in the annual runoff reaching estuaries due to dam construction has led to the mouths of a number of estuaries closing for significantly longer periods of time. In order to mitigate the environmental damages associated with such closures, mouths have to be artificially breached at regular intervals and at a substantial cost to the country.

4.7.3.4 Flood regulation and coastal protection

Wetlands, in particular, play a vital function in the regulation of floods, acting as "sponges" to absorb floodwaters which would otherwise spill over as potentially damaging floods downstream. Hydrological modelling can be used to demonstrate the level to which flood damage would be increased if wetlands and [illegible] were allowed to be degraded. Coastal wetlands play an important role in erosion protection. An example of the value of this protective service is given in Box 4.10.

4.7.3.5 Groundwater recharge

An important function of aquatic ecosystems, particularly wetlands, is the recharge of groundwater aquifers. Wetlands act like porous sponges, allowing seepage of [illegible] into [illegible]. This form of aquifer recharge is probably more important than any other, such as the infiltration of rainfall into terrestrial habitats. Adams and Hollis (1989, cited in Barbier 1993) showed a clear relationship between the loss of floodplain inundation by [illegible] and the rate of groundwater recharge. Since a reduction of flooding by the Kano river project implemented in 1983, groundwater recharge by the Hadejia-Jama'are wetlands in Nigeria has fallen by an estimated 5,000 cu km.

Box 4.11 illustrates an example of the economic losses associated with reduction in groundwater recharge in northern Nigeria.

Valuing groundwater recharge through agricultural production in the Hadejia-Ngura wetlands in northern Nigeria — Box 4.11

Acharya and Barbier (2000) have estimated, using a production function approach to value groundwater recharge function of the Hadejia-Nguru wetlands of northern Nigeria, with the Madachi fadama (6.600 ha) as a case study.

Farmers cultivate vegetables and wheat using water from the shallow groundwater aquifer, and the value of that water is 36,300 naira (US$413) per hectare. The total loss for the pilot area associated with the 1m change in naturally recharged groundwater levels is estimated as 5,477,938 naira (US$62,249). This represents a loss of 7.56 percent of annual income for vegetable farmers and 77 percent of annual income for wheat farmers.

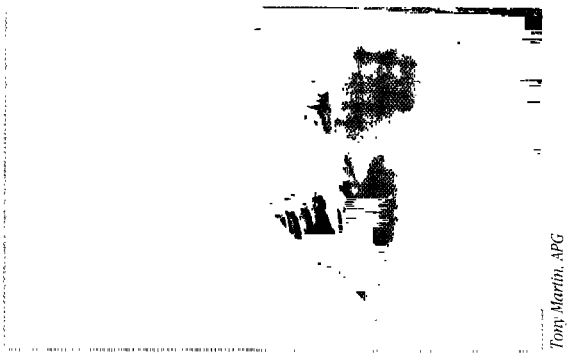
Loss of groundwater recharge, exacerbated by excessive pumping of coastal aquifers though borehole use can also draw seawater into freshwater aquifers. Reduction of river flows has allowed saline intrusion up estuaries and abandonment of some settlements in Mozambique. Little is known about the extent and effect of saline water intrusion, but it can have potentially devastating effects on coastal water supplies.

4.7.3.6 Exports to adjacent ecosystems

This includes exports such as nutrients, and juvenile recruitment to adjacent systems (*eg* marine), which form inputs into other economic activities, *eg* seaweed harvesting and offshore fisheries. This category thus includes the "nursery function" of estuaries and mangroves. Decreases in the quantity and quality of water reaching estuarine and mangrove systems may significantly alter these systems, thereby reducing their nursery function to offshore fisheries. One of the best local examples of this is the effect that the Cahora Bassa dam has in Mozambique. (Box 4.12)

4.7.4 Option and non-use values

Option value is the value of retaining the option to use resources (such as genetic resources in future), and is expressed in terms of a society's willingness to pay to retain this option. In the same vein, people also express a value for the existence of natural resources, irrespective of whether they actually use them. Existence value includes the value of knowing that a resource can be enjoyed by future generations (sometimes referred to as bequest value). Large, biodiversity-rich and unique ecosystems, such as Victoria Falls in Zimbabwe, probably have high existence value from a global perspective as well as a local one. These values are often realised in the form of donations to conservation agencies, or in the amounts paid by international society in debt-for-nature-



Tony Martin, APG

Existence value includes the value of [illegible] unique resource such as Victoria Falls can be enjoyed by future generations.

swaps, such as the $4.5 million paid in 1989 for the Kafue flats and Bangweulu wetlands in Zambia. (Pearce 1993) Existence and option values are difficult to separate and are usually measured by means of contingent valuation methods. (Box 4.13)

4.8 ACCOUNTING FOR ENVIRONMENTAL DEGRADATION IN DECISION-MAKING

4.8.1 Project Assessment

Water projects, such as irrigation schemes or hydropower projects, are generally evaluated by conducting financial and economic cost-benefit analyses (CBA) and environmental impact assessments (EIA). CBA is a rigorous, systematic approach which measures the costs and benefits associated with a project, expressing them as overall net gains, usually in terms of net present value (NPV), or rates of return. In reality, projects are often decided on political grounds, and these analyses are then conducted in order to justify the decision. EIA has largely functioned as a means of identifying ways in which impacts can be mitigated and compensations can be paid, rather than as an integral part of the decision process.

Effect on production of offshore fisheries by the Cahora Bassa dam in Mozambique — **Box 4.12**

Shrimp fisheries (mostly for *Penaeus indicus* and *Metapenaeus monceros*) play an important role in the economy of Mozambique. Most of this resource is located on the Sofala bank, off the central Mozambican coast, and is dependent on freshwater runoff from the Zambezi to stimulate recruitment and provide nutrients to coastal waters. The juveniles develop in mangrove swamps. Shrimp production is positively correlated with the annual Zambezi river discharge. In the 20 years that this discharge has been severely reduced by the Cahora Bassa dam, catch rates have declined from around 90kg per h to 30 kg per h, closely following the declining trend in annual runoff. (Hoguane 1997) The fishery is now worth US$10 - 30 million less per year than it could be if this ecosystem function was restored. (Beilfuss 1999)

National existence value of Zambia's wetland biodiversity **Box 4.13**

Contingent valuation methods were used to ascertain how much Zambians are willing to pay to conserve wetland biodiversity in their country. The following hypothetical scenario was posed:

Suppose the government took ownership of the major wetland areas and auctioned the rights to develop these areas on a unit area basis, but a conservation agency would also be allowed to purchase rights. Respondents were asked how much they would be willing to donate to this agency as a one-off payment in order to contribute towards the conservation agency's bid. Respondents then advised on how they would like their donation split among four major wetland areas. Total values were as follows:

Barotse wetlands	US$ 4 229 000
Luangwa wetlands	US$ 3 996 000
Kafue wetlands	US$ 4 329 000
Bangweulu wetlands	US$ 4 163 000
TOTAL	US$16 650 000

This is a minimum estimate of value, as it only includes the value to Zambians employed in the formal sector, and does not consider global existence value.

Turpie *et al* 1999

This approach has many shortcomings. First, analyses are usually carried out using a limited set of parameters, without taking all environmental and social costs and benefits into account. Second, CBA applied in developing countries often uses relatively high discount rates, effectively giving little weight to long term or irreversible environmental damage. Third, CBA does not usually consider how the costs and benefits are distributed among the various stakeholders affected by the project, and CBA is strongly criticised on the grounds of being non-participative in nature. Thus resulting decisions may not always be optimal in terms of efficiency, sustainability, or equity goals. These problems are generally more serious in terms of the analysis of private sector projects than government projects, because of their emphasis on financial, rather than economic analyses, unless effective and appropriate measures exist which ensure that societal values are taken into account. Given these shortcomings, and the realisation of the extent of the environmental and economic impacts that can be associated with water projects, it is now recognised that it will be necessary to devise means by which environmental impacts and distributional issues can be combined with CBA into a more holistic, comprehensive and consultative assessment process. (Penman 1999)

CBA should take place before the decision on whether to go ahead with a project is made, and ideally, the following steps need to be incorporated into the decision process (based on Penman 1999):

1. Identification of national and project objectives and criteria for project assessment, in consultation with stakeholders

In order to provide the basis on which to evaluate a project, it is important to define short and long-term policy objectives as well as the specific objectives of the project. The criteria for accepting a project should include:

economic efficiency, preferably that it is the least-cost means of meeting the stated economic objectives;

financial viability;

contribution to broad social goals such as poverty alleviation, equitable distribution of costs and benefits, and environmental goals such as minimisation of environmental damage and biodiversity loss.

In general, objectives should adhere to the Pareto principle (that a project should only go ahead if no stakeholders are left worse off) as closely as possible.

2. Identification of alternative scenarios for analysis, including a no-development scenario

The incorporation of several scenarios into a project analysis is essential to the evaluation process, as it allows trade-offs to be better understood by affected parties, and provides greater opportunity to find the optimal solution in terms of defined goals. An analysis of alternatives is also an important component of an Environment Assessment. No-development scenarios are vital as basis for the measure of change under alternate scenarios.

3. Incorporation of full costs and benefits into CBA

Cost-benefit analysis is the main economic analytical tool used in decision-making at a project and programme level. Whereas environmental impact assessment plays an important role in project planning, particularly in terms of the mitigation of potential damages, it is only recently that practitioners have begun to argue for the quantification of these impacts in economic terms, to be included in cost-benefit analysis. With the development and improvement of economic valuation methodology, and its increasing use in the developing world, the formal inclusion of environmental and

social costs and benefits of projects should now be explicitly included in the cost-benefit appraisal of projects and programmes.

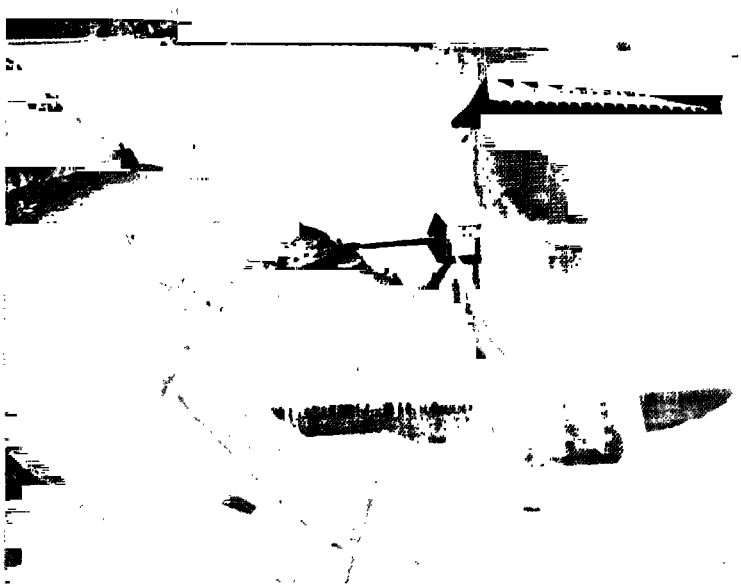
However, because economic valuation of environmental and social impacts is dependent on their adequate quantification in physical terms, this will require the development of more rigorous and quantitative EIA methods, in conjunction with a scenario-based approach. In addition to the [illegible] of environmental impacts, EIA will need to include studies of affected communities and their dependence on the affected systems. The following need to be included in the EIA, as illustrated in the Lesotho Highlands Water Project, one of the pioneering projects in the region:

Assessment of existing physical conditions, biodiversity and resource stocks, by means of scientific study;

Assessment of existing social conditions, health, use and appreciation of natural resources, by means of appropriate survey instruments; and

Assessment of biophysical and social impacts of each scenario, given as direction and degree of change in quantitative as well as qualitative terms, on the basis of modelling and relevant expert opinion.

Physical and social impacts should be expressed in monetary terms using accepted economic valuation techniques, and these values should be incorporated into CBA in addition to the conventional measures which are [illegible] included. Environmental valuation is a controversial issue, due to the limitations of available techniques (see Georgiou *et al* 1997, Vatn and Bromley 1994, Gowdy 1997), particularly as applied to the developing world. However, as these techniques continue to improve and capacity is increased in the SADC region, valuation should play an increasingly important role in integrating environmental concerns into economic decision-making. Nevertheless, because of the formidable problems of obtaining reliable data, particularly historical data against which to measure change, many of the aspects of various trade-offs cannot be quantitatively measured, and precise analysis of all benefits and costs cannot be assured. In the absence of quantitative data, and for the measurement of future and non-use values, contingent valuation can be an effective measurement tool. However, many critics doubt the reliability of this method, which relies upon extreme care being taken in the design and conduct of the study, which in turn relies on a healthy budget. (Young 1996) Where physical quantification is poor or monetary valuation cannot meet acceptable levels of accuracy these impacts should



DWAF, South Africa

Katse Dam, Lesotho Highlands Water [illegible] techniques continue to improve and capacity is increased in the SADC region, environmental studies are increasingly [illegible] decision-making concerning downstream management.

not be incorporated into CBA, but should be presented to stakeholders and decision-makers in qualitative terms (see step 5). In dealing with uncertainty, particularly in the realm of environmental impacts and discount rates, it is critical to incorporate sensitivity analysis into CBA to test the robustness of results.

4. Detailed distributional analysis

Detailed analysis should be undertaken to determine how a project's costs and benefits will be spread among affected groups, particularly the rural poor. This type of approach is far preferable to a social CBA, in which distributional weights are assigned to costs and benefits in order to more heavily weight values that affect lower income groups. It is far more objective and transparent to [illegible] costs and benefits accruing to different groups than to combine weighted values in a single computation of net benefits.

5. Multi-criteria decision analysis

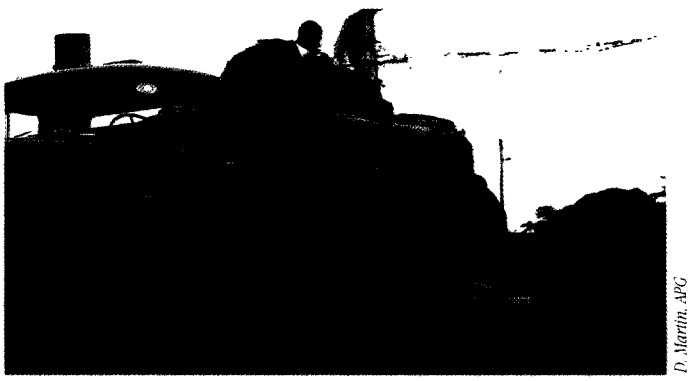
Even with the development of widely accepted valuation methods, the valuation of environmental impacts is [illegible] with uncertainty due to imperfect knowledge of the response of many components of aquatic ecosystems to environmental change. This uncertainty imparts difficulty in the interpretation of cost-benefit data. Multi-criteria decision analysis is increasingly being used as a decision-making tool which can cope with uncertainty and which can more explicitly addresses issues of equity. ([illegible] *et al* 1997) Stakeholders are then presented with the range of possible costs and benefits of proposed projects, and through a ranking and scoring process, can reach acceptable compromises. Impacts which are difficult or [illegible] to quantify can also be presented to the stakeholders in qualitative terms. However, the greater the accuracy of information, and the better the representation of stakeholder groups, the greater the chance that this process will lead to the socially optimal solution.

It is important to note that the use of these five steps in project assessment will require strengthening of the legal and institutional framework for conducting assessments. In addition, it must be realised that improved [illegible] will require additional resources in terms of time and money, especially for initial projects. Detailed monitoring of the physical, ecological and human health impacts of existing schemes will also assist the predictive power of EIA and reduce the resources required for subsequent project analyses.

4.8.2 Natural resource accounting

Economic performance is conventionally measured in terms of national accounting systems, yielding statistics such as Gross Domestic Product (GDP), and Net Domestic Product (NDP). These statistics, in turn, inform government decisions and policy-makers. They do not however, take into account the degradation or depletion of natural resources that occur in generating income. Whereas the depreciation of capital is accounted for in calculating NDP, the depletion and damage of natural resources used in the production of economic wealth, such as forests, fisheries, aquifers and aquatic resources, are not accounted for. Conventional national accounting systems thus give a distorted picture of the state of the economy, and give no indication of the unsustainable use of resources. Similarly, the health and productivity costs of pollution are ignored in conventional accounts except when they result in medical treatment costs or expenditures to mitigate against them. (Dixon *et al* 1996) In response to this realisation, southern African countries and several northern hemisphere countries are developing new systems of Integrated Environmental and Economic Accounts, which will attempt to account for the state of natural resource stocks, and give an indication of the sustainability of national economies. In this system, resource depletion (*eg* timber, oil, mineral, soil and groundwater depletion) and the monetary value of environmental damage (*eg* water and air pollution) is subtracted from NDP.

It is essential that policy- and decision-makers pay heed to these adjusted accounts in order to steer environmental and water resource management onto a more sustainable development path.



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New systems of Integrated Environmental and Economic Accounts are being developed to account for the state of natural resource stocks: depletion of resources such as timber is subtracted from Net Domestic Product (NDP).

4.9 ECONOMIC INSTRUMENTS TO REGULATE WATER USE

User demands on water resources are increasing throughout the SADC region as a result of increasing population and economic growth. In order to meet the quantities and quality of water demanded by increasing numbers of users, the conventional response has been an increase in the construction of water supply, hydropower and purification schemes. However, the water resources necessary to meet increasing demand are often limited, particularly in parts of southern Africa where rainfall is relatively low or unpredictable. The costs of supply also tend to increase after cheaper water sources have been exhausted. There is thus a need to balance demand and supply and close the gap between them. Demand and supply can be regulated by means of "command-and-control" approaches, or by means of economic incentive instruments. In general, the former approach is starting to give way to the latter, as the latter tends to be the most cost-effective way of achieving management goals. A variety of economic tools and measures can be applied to water use and management, to improve their efficiency and sustainability.

4.9.1 Supply-side measures

Supply-side measures for efficient, optimal and sustainable water use and management are primarily concerned with safeguarding the catchments and other ecosystems which are vital to water supply, such as forests, mountains, wetlands, rivers and lakes, as well as improving the efficiency of water supply services. These measures can improve water supply from existing schemes, and meeting growing demands should not rely exclusively upon increased investment in supply infrastructure. In addition to environmental management, engineering improvements and more efficient technologies should be considered a priority. Unaccounted-for water, or leakages, are often higher than 20 percent, with as much as 48 - 50 percent leakages in Tanzania urban supply centres and 60 percent leakage occurring in Mozambican urban supply systems. (Macy 1999) Introduction of water recycling plants can yield considerable savings, particularly in the more arid countries. Namibia recycles 10-25 percent of its effluent, and Botswana plans to achieve 100 percent industrial reuse by 2010. (Macy 1999)

When economic activities degrade aquatic ecosystems, these impacts are not reflected as private costs to the producer or consumer who is giving rise to them. Instead, they appear as externalities – they accrue to the rest of society. For example, farmers in catchment areas benefit from the crops grown under unsustainable land-use practices while downstream populations bear costs associated with sedimentation and siltation. Likewise, industries can save on costs by failing to treat their wastes and effluents before disposing of them into lakes and rivers while adjacent domestic water consumers and fishermen suffer losses to their health and income. Under these conditions, people will continue to degrade aquatic environments, because there is no private cost of doing so. Economic tools aim to institute full-cost pricing – they make sure that the full economic costs of the degradation of the environment, or the full economic benefits of its sustainable management, are reflected in the private costs, prices and profits that consumers and producers face.

Market failure is due in part to the absence of well-defined, secure and transferable rights over land and resources. The primary beneficiaries of resources (including water) yielded by ecosystems are usually the individuals or groups who have recognised rights to own, manage, use and trade in them. If communities have no secure rights over catchment lands and aquatic ecosystems, producers and consumers do not have to bear the on-site implications of their degradation. Well-defined property rights, on the other hand, ensure that these on-site costs are internalised, and provide incentives for better management.

It is more difficult to internalise off-site costs of environmental degradation, such as sedimentation or pollution. One way of doing this is to implement systems of charges, or to use fiscal instruments such as taxes or subsidies. Governments use fiscal instruments to raise and spend budgetary revenues by raising or lowering the relative prices of different products, thus aiming to discourage or encourage their consumption and production. They can be used to correct or counterbalance distorted prices and markets for the resources yielded by catchments and aquatic ecosystems. Thus, the relative price of environment-degrading products and technologies can be raised to reflect the costs of the damage they cause and discourage people from using them, and decrease the relative price of environment-conserving products and encourage people to use them.

Pollution can be abated by means of charges or taxes levied on polluters per unit of polluting output, or

through the introduction of tradable pollution permits. Both of these measures create the incentive to pollute less, although tradable permits are more efficient in controlling the overall level of pollution and create the incentive to introduce pollution abatement measures: firms that face the lowest costs of abatement will tend to abate, and sell permits, while others will seek to obtain permits. Pollution abatement can also be subsidised, but this is an inefficient solution, creating further market distortions, and risks attracting more firms to the polluting industry.

Similarly, damaging catchment activities, such as [illegible] can be taxed to the extent that will reflect the marginal damage caused to aquatic ecosystems, in order to discourage excessive plantation. On the other hand, limits to the amount of catchment areas that can be afforested might be more effective in ensuring an adequate water supply.

In theory, agricultural activities which cause erosion can be treated in a similar way to industrial polluters in order to achieve the socially optimal level of degradation, for example, through the taxation of outputs, or the allocation of transferable soil loss permits. (Sanders *et al* 1995) Alternatively, tax breaks or subsidies can be applied to encourage soil conservation measures by commercial farmers or foresters, but in the case where the catchments are degraded by subsistence users, funding local labour to build soil conservation devices may be the most feasible mechanism.

Problems caused by invasion of alien species are more difficult to overcome using economic incentive measures, especially where these occur on public and communally owned areas. In South Africa, this problem has been tackled to some extent by means of government investment in an alien vegetation clearing programme which creates employment on a large scale: the Working for Water Project. Thus poverty relief is being addressed at the same time as reducing environmental problems which affect society at large. Similar programmes could be [illegible] to the problem of invasive aquatic plants, potentially providing similar social benefits to the unemployed.

4.9.2 Demand-side measures

Demand-side management focuses on ensuring the efficient use of existing supplies. Much of the water supplied to domestic, industrial and agricultural use is wasted due to a lack of incentive to apply water conservation measures. It has been demonstrated that industrial use of water can be [illegible] reduced. Similarly, huge wastage is incurred in irrigation schemes, where simple water saving methods could reduce this demand at little cost. In South Africa it is estimated that irrigated agriculture would be able to achieve the same levels of production with 25 percent less water.

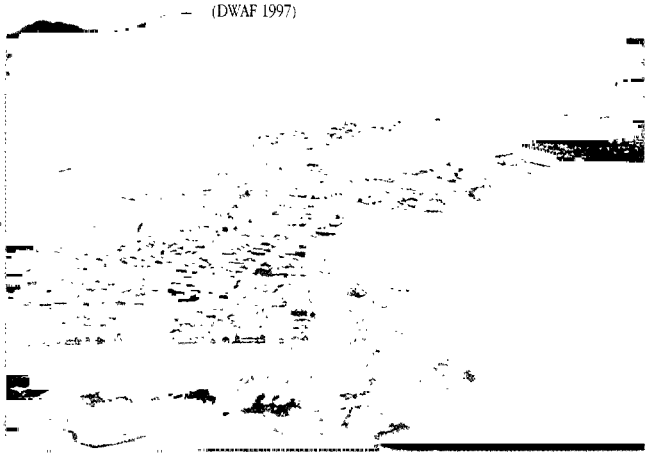
The primary reason for excessive water demand is the under-pricing of water, and excessive demand encourages the degradation of aquatic environments. (Winpenny 1994) The effect of low prices is that users have no incentive to use water wisely or efficiently, or to treat it as a scarce economic good. There is a [illegible] cost to supplying water — which includes, as well as the physical costs of its storage, purification and distribution, its opportunity costs and the costs associated with managing catchments and other water-dependent ecosystems. These costs are rarely reflected in the prices that users pay for water. Marginal cost pricing aims to base the price of the last unit of water on the full costs of its provision — this ensures that users facing such prices will base their consumption decisions on the real economic costs of provision, and thus reach a socially optimal level of consumption. (Dinar *et al* 1997) Although sounding theoretical in economic terms, marginal cost pricing is rarely used in reality, because it is so difficult to apply. (Winpenny 1994) In practice, average cost pricing is more commonly applied to water as a second-best solution.

Stepped pricing is generally an efficient way of achieving cost recovery for water without [illegible] the poor, provided that water outlets are not shared among families. Basic needs are supplied at low cost, and beyond that, users face stepped increases in price with increasing quantities used. Such pricing systems have already been initiated in some SADC countries. Appropriate water pricing is difficult to implement in areas where water supply is unreliable, however, and this problem has to be tackled first. Nevertheless, appropriate pricing systems, if implemented on a local area basis, can be introduced in areas where supply is reliable. The greater Hermanus water conservation programme in South Africa (Box 4.15) illustrates the level of water saving that can be achieved by water demand management. Water demand management involves providing incentives for the use of water-saving devices and creating awareness, as well as adjusting water prices.

The greater Hermanus water conservation programme — Box 4.14

Hermanus is a coastal town near Cape Town in South Africa with a population of approximately 25,000 which swells to three times that in the holiday season. In 1995 it was realised that future water supply options for the town would be prohibitively expensive and that high levels of wastage were occurring. The town municipality, with help from the national Department of Water Affairs and Forestry, decided to implement a water conservation programme that would include tariff changes, alien vegetation clearance, education and public awareness, the introduction of water-saving devices and practices, stricter regulations and informative billing (*ie* users are shown their month-by-month consumption graphically and in comparison to the average for an area). In terms of tariffs, an eleven-point escalating block rate system was introduced based on charging for the marginal price of water, while ensuring equity. The new system meant more than doubling tariffs in the last two blocks while reducing tariffs in the first block to subsidise use for basic needs. During the first summer season of the conservation programme, a 32 percent reduction in water use was achieved at which stage only the tariff changes, alien clearance, education and awareness and informative billing had been implemented.

(DWAF 1997)



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D. Martin, APG

CONTENTS

ENVIRONMENTAL FLOWS: REQUIREMENTS AND ASSESSMENT

5.1 INTRODUCTION

Large water-resource developments on, or excessive abstraction of water from rivers affect their flow regimes, water chemistry, and sediment and temperature regimes, and consequently, affect their fauna and flora. These changes also affect the people dependent on the rivers. Downstream impacts can be reduced by manipulation of flow releases from impoundments for maintenance of the river, or by regulation of water abstractions, or both.

This chapter provides an overview of river regulation in the SADC region, the impacts of this on the region's rivers and the concept of mitigation of the impacts through the provision of environmental flows. Currently used methods for determining environmental flows are discussed, and an operationalised description of environmental flow assessment is provided.

Some of the world's most active water-resource development programmes are located within the SADC region:

Kariba Dam (160 cu km) in Zimbabwe and Zambia, Cahora Bassa (56 cu km) in Mozambique and the Vaal Dam (2.1 cu km) in South Africa are examples of large impoundments in the region's rivers. (H[illegible] and Thornton 1997)

Large water-resource projects currently being developed or investigated in the region include the Lesotho Highlands Water Project (LHWP), the Maguga dam in Swaziland and the Epupa dam in Namibia. Other medium-to-large water resources development projects include the Lower Kihansi and Rumakali water projects in Tanzania, the Batoka, Gwaayi/Shangani, Pungwe and Matebeleland-Zambezi pipeline projects in Zimbabwe.

Many of the rivers targeted for such developments are sites of biodiversity importance and/or have large human populations that are directly dependent on them.

Thorough investigations of the impacts of these developments on the environment and on the affected people, and possible mitigatory actions, should be central to any decisions taken about the feasibility of such developments. Similarly, mitigation of the impacts of extant water-resource developments on downstream rivers needs to be addressed.

World Bank

Environmental concerns for the habitat of the Kihansi Spray Toad have delayed [illegible] ing of the final water right for the Lower Kihansi hydropower project in southern Tanzania. The Lower Kihansi Gorge is shown above. Inset shows a human [illegible] with the tiny toad that is found only in that gorge

5.1.1 Environmental flows: definition and assessment

Water that is [illegible] left in a river or released from an impoundment to maintain a river in a desired condition, is referred to here as the Environmental Flow Requirement (EFR). Box 5.1 describes commonly used terminology for EFRs. As a general rule, the closer to natural the desired condition, the greater the volume of the original flow regime that will be required as an EFR.

EFRs can be supplied by releasing water from impoundments, or by restricting the amount of water that is abstracted from rivers. However, some kinds of releases/restrictions are not EFRs. For instance, water released for downstream irrigation does not have maintenance of river condition as an objective, and is not an EFR.

Determinations of EFRs are referred to as Environmental Flow Assessments (EFAs). EFAs can be done at several levels of detail, from a simple statement of water depth to provide wetted habitat for a valued fish species, to a comprehensive description of a flow regime with intra-annual and inter-annual variability of low flows and floods in order to maintain whole river systems. Early EFAs concentrated on one or more biophysical aspects of river condition, but some more recent EFAs in areas such as the SADC region, where many people depend on rivers for subsistence, have included socio-economic aspects. It is vital that socio-economic aspects such as subsistence (*eg* [illegible]) and/or cultural (*eg* sacred pools) use of aquatic resources not be sidelined. Furthermore, indigenous knowledge systems contain checks and balances for the protection of the natural environment and local knowledge should be included in EFAs.

Common terminology used to describe environmental flow requirements — **Box 5.1**

Several allied terms are used to describe flows for maintenance of rivers. We have used environmental flow requirements (EFRs) because it is a comprehensive term that caters for all components of the river, is dynamic over time, takes cognisance of the need for natural flow variability and addresses social and economic issues as well as biophysical ones. Other terms include:

- **Instream Flow Requirements (IFRs)** is an earlier, less-comprehensive term for EFRs.
- **Maintenance IFR** describes a comprehensive flow regime required to maintain all river ecosystem functions, including balanced and continual recruitment of aquatic and riparian species.
- **Drought IFR** describes a drastically reduced flow regime for recognised drought years, to maintain species in a system without necessarily supporting recruitment.
- **Minimum flow** is a general term that has been used in several ways to represent an EFR. The concept of minimum flow originated in the USA as a streamflow standard to constrain the abstraction of water during the dry season.

All of the above terms are designed to aid, in some way, maintenance of the condition (health) of the river. This contrasts with diversions of water away from the river channel, which constitute offstream uses.

5.2 THE NEED FOR WATER TO MAINTAIN RIVERS

5.2.1 Ecological relevance of different kinds of flow

The flow regime of a river consists of several different kinds of flow, each of which contributes to the river's overall maintenance. (Box 5.2) Naturally, a river ecosystem exists in a state of dynamic [illegible] able to respond to seasonal and annual fluctuations in climate because its species have different tolerance ranges and so differ in their abundances as conditions change. Thus, at any time there is a mix of species that can cope [illegible] pre[illegible] conditions, while other species may be present in lower numbers or surviving as, for instance, eggs, seeds or spores, until more suitable conditions occur. The mix of species and numbers of individuals present usually result, in their natural situation, in assemblages where no one species proliferates to "pest" proportions.

Manipulations of flow regimes represent unnatural disturbances to rivers, with these disturbances increasing in severity the further the flow regime is altered from what lies within the realm of "normal" for that system. Responses of rivers to flow manipulation can take many forms. For instance, hydrological cues that trigger fish spawning or seed germination may occur at the wrong time of the year or not at all, resulting in affected species perhaps failing to reproduce. Seasonal reversal of wet and dry season lowflows could mean that hydraulic and thermal conditions become mismatched with life-cycle requirements, again causing species to decrease in numbers and abundance. Other species, many seen as pests,

Different kinds of river flow and their importance to ecosystem functioning — Box 5.2

Flow variability on a daily, seasonal or annual basis, acts as a form of natural disturbance. This maintains biological diversity through increased heterogeneity of physical habitats. For instance, lack of variability through the absence of small floods may favour fish species adapted to breed under conditions of more constant discharge, with resulting alterations in the relative numbers of fish species and/or loss of native species. Variability in lowflows dictates the width of the vegetation belt along the water line, which protects the banks against erosion. A loss of variability results in a narrowing of this band because the lower portion is no longer regularly exposed or the upper portion regularly inundated.

Lowflows are the flows in the river outside of floods. They maintain the basic ephemeral, seasonal or perennial nature of the river, thereby determining which animals and plants can survive there. The different magnitudes of lowflow in the dry and wet seasons create more or less wetted habitat and different hydraulic and chemical conditions, which directly influence the balance of species. For instance, species which need to spend several months in water to complete their life-cycles are rare in ephemeral rivers, though specific riparian tree species may be able to live on such a river's banks if the groundwater conditions are favourable.

Large floods occur more rarely than once a year. They dictate the general geomorphological character, shape and size of a river channel. Floods mobilise sediments and deposit silt, nutrients and seeds on floodplains. They inundate backwater areas, and trigger the emergence of adults of aquatic insects, which provide food for fish, frogs and birds. They maintain moisture levels in the banks that support the trees and shrubs, and prevent the riparian vegetation from being dominated by any one species. Floods also scour estuaries, ensuring, amongst other things, accessibility to marine fish dependent on them as nursery areas, and the maintenance of habitat diversity.

Small floods occur several times within a year. They stimulate spawning in fish, flush out poor quality water, mobilise sandy sediments, and contribute to flow variability. They re-set a wide spectrum of conditions in the river, triggering and synchronising activities as varied as upstream migration of fish and germination of riparian seedlings.

are often able to take advantage of such environmental conditions, or of the weakening of competition from the affected species, and many then increase in abundance.

In temporary or seasonal rivers, and in wetlands, the dominant role of subsurface flow or groundwater, and its relationship with surface flow, complicates the response of these systems to flow manipulations. Groundwater systems contribute to rivers and wetlands as [illegible] they supply water to vegetation with roots in the near surface zone, and they store water that can be abstracted long after rains have passed and surface waters have dried up. In the very dry parts of the SADC region, such as Namibia and parts of Botswana, the surface flows in many rivers are seasonal or episodic, and groundwater is the major source of water for humans and nature. These [illegible] also sustain seemingly isolated pools between rainfall events and support the vegetation along river corridors.

Ecological processes in estuaries occur along gradients of salinity, and are influenced by river and seawater [illegible] The duration and frequency with which the river is open to the sea depends on, *inter alia*, river [illegible] tidal cycles and channel morphology. These factors influence the numbers and types of estuarine flora and fauna that occur in an estuary, and hence its [illegible] condition. Reduced [illegible] leads to less scouring, so the estuary may silt up and the mouth remain closed for longer periods than naturally. Sustained periods of reduced river [illegible] into closed systems lead to them become progressively more fresh. Conversely, where the mouth remains open, reduced flow can result in an estuary becoming more saline. (Morant and Quinn 1995)

5.2.2 Purpose of Environmental Flow Assessments

EFAs aim to mitigate the potential impacts of water-resource developments on rivers. They do this in three ways:

By reserving some water for river maintenance.

By ensuring that the reserved water is made available at the times when it is most appropriate for river maintenance. For instance, if large floods are needed in a river to maintain beaches and backwaters (Box 5.3), or small floods to stimulate fish spawning (Box 5.4), then the EFA would stipulate the magnitude, duration and frequency of the required floods. Similarly, if a flood is needed to breach an estuary mouth, then the EFA would dictate the timing and size of that flood requirement. (Box 5.5)

Case study: Flushing flows to recreate beaches and habitat on the Colorado river, USA — Box 5.3

In 1996, a large flood was released from Hoover Dam on the Colorado river in the United States of America, into the downstream river in an effort to restore some of the features of the downstream river that had been lost as a result of the presence of the dam. The flood releases lasted 18 days, and were closely monitored by a team consisting of aquatic scientists, engineers and managers. The results were hailed as a success, and included:

- at least 55 large, new beaches in the Grand Canyon were created;
- more than half of the existing canyon beaches increased in size due to the flood, 37 percent remained approximately the same size, and 10 percent lost small amounts of sediment;
- the flood caused scouring of clay and vegetation bases in backwaters and marshes, thus providing habitat for the humpback chub and other endangered fish species;
- in many backwater areas, the increased organic debris (primarily non-native plant species growing very close to the banks of the river), which did not occur on the natural river, was cleared by the floodwaters.

Press release May 1996, Office of the Interior Secretary

Case study: High flows to stimulate spawning of the Clanwilliam yellowfish, Olifants river, South Africa — Box 5.4

The Olifants river in the Western Cape of South Africa supports eight fish species endemic to the river system. The largest species is the Clanwilliam yellowfish, *Barbus capensis*. Two in-channel structures, a dam and a weir, in the middle reaches of the Olifants river, have contributed to the decline in abundance of the species. In particular, the Clanwilliam dam has harnessed the small floods that characterised spring and early summer flows in the river and were thought to have triggered the spawning of *B. capensis*.

In November-December 1994 and 1995, small experimental floods were released from Clanwilliam dam in an attempt to trigger spawning. Extensive spawning occurred after the releases in 1994, with "higher than usual" numbers of fish larvae in the river two months later. This success was not repeated in 1995, due to the lower temperatures of the bottom-released water.

It was concluded that small floods released from Clanwilliam dam between October and January should increase spawning success of *B. capensis*, but only if the temperature of the spawning site is 19°C, and stable or rising. Also, successful spawning will not necessarily lead to higher numbers of fish later if temperatures of the released water are not then maintained at appropriate levels for the development of the juvenile fish.

Cambray *et al* 1997

Case study: Flood to maintain estuary mouth on the Great Brak river, South Africa — Box 5.5

The Great Brak River has a small estuary, approximately 2.5 km long, situated on the south coast of South Africa between George and Mosselbay. The estuary mouth occasionally closes and is breached when river flow increases.

The Wolwedans dam on the Great Brak river was completed in 1989 amid serious concerns about its potential effects on the estuary. An environmental impact assessment, involving the local community, was undertaken during its construction, and a management plan was designed with the objective of maintaining the estuary in a healthy condition. The timing and periods of open-mouth conditions were the key aspects addressed in the management plan, as well as the requirement to release water from the dam for maintenance of the estuary. The main objective of the releases was to maintain open-mouth conditions during spring and summer for the following reasons:

- Juvenile fishes seeking nursery conditions migrate into the estuary from the sea during this period.
- An open mouth and tidal variation in the estuary during spring and summer are essential for the germination and growth of salt marsh vegetation.
- The tidal flows prevent deterioration of estuarine water quality during the warmer summer period, when extra loading from septic tanks could otherwise lead to algal blooms.
- Most of the local inhabitants and the holiday-makers prefer an open estuary mouth during the spring and summer.

An ongoing monitoring programme was established, which included physical and ecological aspects. The results are used to evaluate and refine the effectiveness of the management plan. Initial indications are that the saltmarshes, and the prawn and crab populations, are healthy. The uniqueness of the project lies in the creation of a management plan, the monitoring of its effectiveness and use of the results to refine and improve the original plan.

P. Huizinga, CSIR, Stellenbosch. Pers. comm.

Major reservoirs in SADC countries — Box 5.6

Country	Major artificial reservoirs (> 1m cu m)
Angola	15
Botswana	14
DR Congo	n/a
Malawi	1
Mauritius	10
Mozambique	12
Namibia	19
Seychelles	n/a
South Africa	517
Swaziland	9
Tanzania	3
Zambia	5
Zimbabwe	25

Water Situation Reports

By defining the water quality, physical habitat and biotic characteristics that typify the desired condition of the river. In this manner, EFAs define objectives that can be used for management of the resource.

Even the most successful EFR will only partially mitigate against the effects of a water-resource development. The physical presence of a dam will, in itself, inevitably result in impacts on the downstream river related to, *inter alia*, trapping of sediment, reduction in flow variability, and changes in the temperature and chemical composition of the water, with knock-on social and economic impacts. Nothing is gained at no cost – if flow regimes are manipulated, the targeted rivers will change. Society decides, proactively or through neglect, the extent of that change.

Also, an EFR will facilitate, but cannot guarantee, the achievement of a desired condition of river since other activities in the catchment could also affect river condition. For instance, even if the EFR is implemented and released correctly, pollution from industry or agriculture could result in unacceptable water quality in the river. Thus, an EFR should be implemented as part of a catchment management plan that has as part of its objectives maintenance of the desired condition of the river. The provision of water for socio-cultural requirements, which are not routinely considered, should be an important component of the EFR.

5.3 EFFECTS OF THE REGULATION OF RIVERS IN THE SADC REGION

5.3.1 Extent to which rivers in SADC are regulated

In the SADC region, water-storage facilities are designed to optimise the availability of water for human use. In-channel reservoirs are thus major components of water-resource development, resulting in heavy regulation of the region's rivers. There are more than 630 medium to large dams (> 1 million cu m) in the region (Box 5.6). South Africa's rivers are the most extensively regulated, with an estimated >500,000 dams (including farm dams), which have a total storage capacity of >50 percent of the mean annual runoff (MAR). (Timberlake 1988, DWAF 1986) Zimbabwe has in excess of 10,000 small dams. (Chenje and Johnson 1996)

5.3.2 Consequences of regulation of rivers in SADC

The three driving variables determining the character of a river are climate, geology and topography. These factors dictate the flow regime, the general geomorphological character of the river, the shape and size of the river channel, the size of the bed particles, and the basic water chemistry and temperature. These in turn determine the fauna and flora that inhabit the river.

Flow regulation affects the whole river and, in general, the more the flow regime is altered, the greater the impact. For instance, a large dam(s) in the upper reaches of a river, with poor or no downstream releases, may cause one or more of the following:

decline in water quality, *eg* Kafue river, Zambia;
erosion and collapse of river banks, deltas and coastlines, *eg* Nile River, Egypt;
loss of agricultural land, *eg* Senegal river, Senegal;
collapse of a river fishery, *eg* lower Zambezi river, Mozambique;
decline of an important estuarine wetland, *eg* Berg river, South Africa; or
decline of a marine fishery dependent on that estuary as a nursery area for juvenile fish, *eg* Senegal river.

Several of these kinds of impacts have been recorded downstream of Cahora Bassa dam in Mozambique (Box 5.7) and the two dams on the Kafue river, at Kafue Gorge and Itezhitezhi in Zambia, have drastically reduced flow to and flooding of the famous Kafue flats. These are now inundated only infrequently, and the annual supply of water, nutrients and sediments to the flats has been greatly reduced.

Not only major dams cause problems. In the Sabie river, South Africa, changes in flow, as a result of run-of-river abstraction, have been linked to a decline in the condition of the vegetation growing alongside the river in the Kruger National Park. Groundwater abstraction has been blamed for the declining condition of the oshanas (wetlands) in Namibia. In Mozambique, the downstream and estuarine sections of some of the main rivers are affected by saltwater intrusion, due to reduced river flows, with saltwater intrusion reported in the Incomati, Limpopo, Buzi and Pungwe rivers. Interbasin water-transfer schemes have also had a major impact on rivers. (Box 5.8) For the donor systems these impacts are similar to those described for water abstraction and dams. However, for the receiving systems the problem is often that of too much water rather than too little. For example, the Ash river, which transports water from Katse dam in Lesotho to the Vaal river in South Africa, is severely eroded as a result of receiving unnaturally high discharges.

The impacts of dams on the lower Zambezi river, with emphasis on Cahora Bassa — **Box 5.7**

After the closure of Cahora Bassa dam on the Zambezi river in Mozambique, the water level in the dam was held constant for 19 years, resulting in a near-constant release of 847 $m^3 s^{-1}$ over the same period. Observations before and 20 years after the closure of Cahora Bassa dam, revealed the impacts listed below. Some of these may be contributed to by other dams on the system, *eg* Kariba, and may also be related to the 20-year civil war in that country, but many can be related directly to the over-regulation of a major river system:

- many of the mangroves in the delta dried out and died back;
- the community structure of the floodplain vegetation changed, with a substantial increase in trees;
- meanders and oxbows, once a feature of the floodplain, became clogged with reeds and trees;
- the productive, flood-dependent grasslands were depleted of grasses, the favoured food plants of herbivorous mammals;
- mammals, including the formerly abundant buffalo, practically disappeared from the delta;
- the abundance of waterfowl declined significantly;
- floodplain "recession agriculture" declined significantly;
- vast, vegetated islands, many of which became inhabited by people, appeared in the river channel;
- dense reeds lined the sides of the river channels;
- erosion of the coastal zone was evident, probably as a result of the release of sediment-hungry water from Cahora Bassa dam rather than as a result of changed flow patterns;
- water levels in the lower Shire river, the largest tributary of the Zambezi downstream of the dam, dropped, prohibiting navigation of this river.

Davies and Day 1998, Chenje and Johnson 1996

Major extant and proposed inter-basin water transfers in SADC — **Box 5.8**

Rivers/System	Country
Tugela/Vaal	South Africa
Orange/Fish	South Africa
Usutu	South Africa
Komati	South Africa/Swaziland
Usutu/Vaal	South Africa
Riviersonderend/Berg-Eerste	South Africa
Okavango/ Eastern National Water Carrier	Namibia
Palmiet	South Africa
Amatola	South Africa
Mzimkulu/Mkomaas-Illovo	South Africa
Senqu/Ash-Vaal	Lesotho/South Africa
Mooi/Umgeni	South Africa
Zambezi Pipeline	Zambia/Botswana/ South Africa

Davies and Day 1998

Most of these environmental impacts bear direct or indirect socio-economic costs, particularly because of the high-level of direct dependence on aquatic resources in the SADC region. In South Africa, for instance, lack of water supply to the Pongolo floodplain, following the construction of Pongolapoort dam, led to an outbreak of typhoid in the local community. Changes in the flow regime of the Orange river, South Africa, created conditions that were ideal for the proliferation of a blackfly pest of livestock, which impacted on the agricultural sector in that region by causing poor conditions and low milk production in dairy herds. (de Moor 1986)

Many of these impacts evolve slowly over years or even decades, and so are difficult to link directly to a specific water-resource development. It is thus easy to externalise the costs of these impacts when calculating the costs of a water-resource development, and so they remain largely unquantified. However, it is widely recognised that such hidden costs have considerable long-term implications at a national level. The reader is referred to McCully (1996) for a detailed treatment of the impacts of flow regulation on rivers.

5.4 ENVIRONMENTAL FLOWS AS A RESPONSE TO THE IMPACTS OF RIVER REGULATION

There is worldwide recognition that rivers are changing in nature, and thus in value, as a result of river regulation. This has led to many countries exploring the possibility of mitigating against this through the allocation and management of flows to maintain river functioning. Some 25 countries globally implement EFAs. For instance, in California, USA, in 1992, the Central Valley Project Improvement Act mandated an additional 800,000 acre feet of already allocated water to be reallocated for river maintenance, marking a major shift in water management in that region. In 1996, the Murray-Darling Basin Commission mandated a permanent upper limit on water use in the Murray and Darling rivers at the 1993 level of use (the "cap"), thereby reducing the water being supplied to off-channel users at that time.

5.4.1 Legislated Requirement for Allocation of Water for the Environment

All SADC countries have some national environmental protection legislation, and many are signatories of international and bilateral conventions on, *inter alia*, protection of wetlands, biodiversity, prevention of desertification and

the SADC Protocol on Shared Watercourses. (see chapter 10) Some countries in the SADC region have also begun implementation of EFAs or are researching suitable methodologies. However, South Africa and Zimbabwe are the only SADC countries that have legislated the provision of environmental flows for the maintenance of rivers. The new water policy of Tanzania (still under preparation) also stipulates a provision for the maintenance of EFRs.

South Africa has adopted an innovative approach to safeguarding environmental flows. In recognition of the potentially devastating effects of water abstraction on rivers, the South African Water Act (1998) recognises rivers as the resource upon which all users of water depend. In terms of the law, only two rights to water are recognised: for basic human needs and for the maintenance of rivers. These amounts must be determined and secured before any other allocations of water can be made. These two rights are referred to as the "Basic Human Needs Reserve" and the "Ecological Reserve", respectively. (Box 5.9)

Although other SADC countries may lack the legislative backing now given to EFRs in South Africa, there are several examples of water releases for environmental maintenance in the region. As early as the 1960s, the need for water for environmental maintenance was recognised in Zambia and environmental flows were released from Kafue Gorge dam on the Kafue river (Magadza, pers. comm.). However, following a severe drought in the early 1970s, the dam wall was raised by 1.5 metres. Because these releases were not legally protected, they were stopped. In Namibia, periodic releases are made from Oanob dam to simulate flooding in the downstream Oanob river (Box 5.10) and a minimum environmental flow has been incorporated on the Pungwe river in Zimbabwe.

South African Water Law of 1998 — The Reserve — Box 5.9

The Reserve consists of two parts — the Basic Human Needs Reserve and the Ecological Reserve. The Basic Human Needs Reserve provides for the essential needs of individuals served by the water resource in question, and includes water for drinking, food preparation and personal hygiene. The Ecological Reserve relates to the water required to protect the rivers (the water resource). It refers to both the quantity and quality of the water in the resource, and will vary depending on the class (condition) at which it is wished to maintain that resource. In general, rivers maintained in a near-natural condition will need more of their natural water supply than those maintained in a less natural condition. The Minister is required to determine the Reserve for every significant water resource in the country. Once the Ecological Reserve is determined for a water resource, it is legally protected and the water so reserved cannot be allocated for offstream uses.

South African Water Act 1998

Environmental releases from Oanob dam — Box 5.10

Water is released from Oanob Dam in Namibia into the downstream river, for environmental maintenance. There is a large natural floodplain downstream of the dam. The vegetation on this floodplain is sustained by two alluvial aquifers. The aquifers are separated by a geological barrier, situated approximately 11 m below the surface. Water only flows into the downstream aquifer when the water table is less than 11 m below ground level, *ie* when the water table is higher than the barrier.

Immediately after a release, there is an improvement in the level of the water table, followed by a slow decline with time. Because of this decline over time, it is not possible to release water to recharge the aquifers in rainy years and have them last in years with low rainfall. Thus, releases from Oanob dam are ongoing. Monitoring also indicated that the vegetation along the river becomes progressively more water stressed with distance downstream from the dam.

Although the releases from the dam are intended to maintain the downstream environment, the volume of water in the Oanob dam determines the amount of water released from the dam. A calculation has not been done to determine, independent of reservoir levels, the quantity of water required to maintain the downstream aquatic environment.

N du Plessis, NamWater, Namibia, pers comm

5.4.2 Specific Cases of Environmental Flow Allocations

Recent feasibility studies for large dam developments in Swaziland, such as the Maguga Dam on the Inkomati River, have included full EFAs. (Fakudze, pers. comm.) Phases 1B and 2 of the LHWP have also included a rigorous EFA. (Metsi 1999) The EFA for the Maguga dam, and particularly for the LHWP, included in-depth assessments of the socio-economic implications of the impacts of

water abstraction on the downstream rivers. EFAs are not legislated in either Swaziland or Lesotho, and both of these assessments were required by international funders.

In other cases, EFAs are not yet established water-management tools. A transboundary (Nambia and Botswana) assessment on the environmental impact of water abstraction was undertaken for the Eastern Water Carrier proposed to supply Windhoek with water from the Cuvango river (Box 5.11), but no EFA was undertaken. Flows in the Cunene river, downstream of the sites proposed for the proposed Epupa hydroelectric dam sites in Namibia, were also recommended in the absence of an EFA.

In Tanzania, reductions in the volume of water entering rivers, specifically the Great Ruaha and Pangani rivers, have been identified as a major impact on those systems.

Flow-related impact assessments on the Okavango river — **Box 5.11**

The Namibian Department of Water Affairs has faced considerable pressure to relieve the water shortages caused by recent droughts. One potential option involves abstraction of about 17 million cu m of water per year from the Okavango river at Rundu, and its transfer via a pipeline to the head of the Eastern National Water Carrier at Grootfontein. Part of the overall evaluation of this scheme included an assessment of the potential environmental impacts. The assessment was conducted from a point 40 km upstream of Rundu, to the distal end of the Okavango delta at Maun in Botswana.

Hydrological studies showed that the proposed abstraction represented a reduction of *c* 0.32 percent in the mean annual flow of the Okavango river at Rundu. The abstraction represents 0.17 percent of the mean annual flow at Mukwe, downstream of the Cuito river confluence. The adverse effects of the proposed water abstraction scheme would be insignificant along the Okavango river in Namibia, whilst outflows from the lower end of the Okavango delta to the Thamalakane river would be reduced by 1.44m cu m/year (11 percent).

Additional studies showed that these effects could be reduced by 10-13 percent if abstraction was confined to the falling limb of the hydrograph. The maximum likely loss of inundated area in the Okavango delta would amount to *c* 7 sq km out of a total area of *c* 8,000 sq km and would be a shoreline effect. This would be concentrated in the lower reaches of the seasonal swamps and seasonally inundated grasslands, specifically in the lower reaches of the Boro, Gomoti, Santantadibe and Thaoge channels.

Initial public perception of the proposed water transfer project was strongly negative and the project perceived to have the potential to negatively affect tourism along the Okavango river and in the Okavango delta, with a possible loss of income for local residents. The environmental assessment found that the impacts would be greater in the Okavango delta than along the Okavango river but would be almost imperceptible against the natural inter-annual water-level fluctuations in the Delta or outflows to the Thamalakane river.

Excerpt from Ashton and Manley 1999

However, although Environmental Impact Assessments (EIAs) are required by law, as yet little attention has been given to water needs for maintenance of the aquatic environment. Likewise, Botswana, Malawi, Mauritius and Seychelles do not have specific legislation dealing with environmental flows, and little attention has been given to water needs for maintenance of the aquatic environment. Mozambique has been involved in negotiations on environmental flows with South Africa and Swaziland and, as a downstream country, looks set to pursue EFAs in the near future. (Saranga, pers. comm.) In Angola, little or no environmental flow work has been undertaken as yet, due to the civil war in that country in recent decades.

D Martin, APG

EIAs are required by law in Tanzania but as yet little attention as been given to water [illegible] aquatic environment.

5.4.3 The relationship between an Environmental Impact Assessment and an Environmental Flow Assessment

EIA requirements and procedures have been carried out in the SADC region for some years. The starting point for any EIA is the examination of alternatives for any proposed development, including the "no-development" option. The recommendation to the decision-maker of a favoured alternative(s) is based on,

the severity of environmental impacts that would result from each option, and

the extent to which those impacts can be mitigated.

For new or planned water development projects, an EFA should be an essential component of an EIA, because impacts to the downstream river can be mitigated through release of an EFR. An EFA determines the amount of water that would need to be released to achieve a desired level of mitigation.

Engineering Phase	Engineering Activity	Environmental Impact Assessment	EFR activity
Phase 1 Reconnaissance	Catchment/systems analysis	Issues assessment	Issues assessment
Phase 2 Pre-feasibility	Possible development options	EIA scoping	Rapid EFAs (*eg* hydrological index, hydraulic rating methods)
Phase 3 Feasibility	Detailed investigation of selected option	EIA	Detailed EFA (*eg* habitat simulation, holistic methods)
Phase 4 Design	Engineering management plan	Environmental management plan	Baseline studies for monitoring plan input to dam design
Phase 5 Construction	Implementation of engineering management plan	Implementation of environmental management plan	Design of operating rules for EFR releases
Phase 6 Operation	Engineering audit	Environmental audit	Monitoring: validation of EFR, flows adjusted if required

The EFA should occur during the early stages of the planning process for a development, and the potential downstream impacts of the development should be taken into consideration before a decision is made on whether, and in what way, to proceed.

For existing developments on regulated rivers, EFA requirements would be determined by the policies of individual countries. Table 5.1 shows the schedule of EFA-related activities in relation to EIA and engineering activities for water-resource developments carried out by the South African Department of Water Affairs and Forestry.

5.5 THE SCOPE AND DETAIL OF AN ENVIRONMENTAL FLOW ASSESSMENT

Local circumstances and requirements will affect almost every aspect of an EFA, from the size of the study area to the methodologies used. In this section, activities that can assist in deciding on the scope of an EFA study, the need for future data collection and the most appropriate methodologies are listed. For illustrative purposes, a proposed water-resource development on a hypothetical river is used. However, similar activities would be undertaken for run-of-river abstractions, or for mitigating past impacts resulting from flow manipulation. Indeed, while most EFAs are undertaken in response to a single water-resource development, it is possible to make proactive, coarse-level determinations of environmental flows for an entire country for use in regional planning.

There are two major activities in an EFA:

1 The creation of scenarios in terms of,
the amount and distribution in time and space of water required to maintain the river in one or more conditions,
the implications of these various conditions for all stakeholders, and
the tangible and intangible costs and benefits of each river condition, including any mitigation and compensation activities.

2 The decision-making process whereby one scenario is chosen for implementation.

The activities needed to complete an EFA can be divided into eight steps, which are elaborated below.

STEP 1
ISSUES ASSESSMENT

The issues assessment may be confined to a desktop exercise, *ie* based on available literature and knowledge. There are four main categories of issues, and the level of detail afforded each will depend on the type and scale of the water-resource project, and the objectives of the EFR.

• Issues related to the river

To the extent possible, the components of the river that are important and likely to be affected by the proposed development should be identified. Such components

could include an important floodplain or wetland, a rare species, an area of great natural beauty or a river reach that could easily change with costly repercussions, such as a channel change that could threaten a road or houses. The following information is required for each of the threatened components of the river:

geographic extent;
present condition;
ecological or other importance in a local, regional, national and international context;
past and potential problems related to management; and
species or features of special significance, such as rare and endangered species, known pest species, organisms linked to public or animal health, or a scenic gorge.

• Issues related to the people directly dependent on the river

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The people who will be directly affected by changes to the river may be referred to as the Population at Risk (PAR). The PAR could range from villagers living in rural communities alongside the river and depending on it for food and other sustenance including cultural, to those who depend on the river for their income. The following data should be gathered at this stage:

location, characterisation, geographic extent, and size of the PAR;
the nature of their dependence on the river;
other relevant aspects, such as river-related diseases or important cultural sites.

• Issues related to national and international obligations and stakeholder interests

Legislation and policy issues relating to rivers, at both national and international levels, should be identified. These could include national environmental policies and laws, international treaties on biodiversity, agreements on the protection of waterbodies (*eg* Ramsar Convention) and international agreements on shared water resources (*eg* SADC Protocol on Shared Watercourses). These could have a bearing on the objectives of a project. For instance, protection of a wetland would be compulsory for countries that are signatories to a relevant treaty.

Laws and policies may also have implications for the methodology that is eventually chosen for determining the EFR. For instance, the South African Water Act recommends assessments at different levels of detail depending on the nature and importance of the river and the size of the proposed water-resource development.

This step should also take into consideration the views of all other stakeholders, and may include the identification of moral, ethical, cultural or spiritual issues related to the river.

• Issues related to the economic value derived from the rivers

The costs of mitigation of, or compensation for, downstream impacts resulting from a change in the flow regime of the river should be included in the cost/benefit analysis for water-resource developments. These costs are often not included in development calculations, usually resulting in these largely unquantified but potentially large long-term costs being overlooked. At this step, all that is required is the identification of the sorts of costs likely to arise from issues related to the river and its subsistence use.

STEP 2
IDENTIFICATION OF DESIRED FUTURE CONDITION AND SELECTION OF THE APPROPRIATE METHODOLOGY

From the Issues Assessment, some clarity should be achieved on society's various perceptions of acceptable future conditions for the river. These perceptions will eventually be distilled into one or more descriptions of potential river conditions and descriptions of a flow regime that would maintain each.

The description of a desired future condition can range from a narrow one of maintaining a valued aquatic species, such as a game fish, to a comprehensive one of maintaining all components of the river in a healthy state. Some desired conditions may consider the environment in a secondary capacity, instead concentrating on the needs of the human population, i.e., maintaining the subsistence resources for rural communities.

There are essentially two ways in which to approach the setting of desired conditions for an EFR:

Single-scenario approach. A single potential river condition can be set up-front, and an EFR that will facilitate achieving and maintaining that can be determined.

Multiple-scenario approach. A range of different potential river conditions can be chosen, and the EFRs to [illegible] each condition are then determined.

Often the PAR, other stakeholders and the authorities are unable to articulate their concerns and aspirations regarding a river unless they have information about the range of options available and the environmental, social and economic costs and [illegible] of each of those options. Nor may it be possible to reach consensus from all stakeholders on a single EFR objective up-front even when the wider social and economic aspects are known. The multi-scenario approach [illegible] the range of options to be presented to the decision-maker, along with the range of stakeholder views linked to each. The scenario finally decided upon is identified as the desired condition, and the related EFR is the one for which the system is managed.

There is an array of EFA methodologies currently available, which cater for different project timeframes and scales, and constraints in terms of available data, finances, expertise and manpower. (Table 5.2)

The selection of an appropriate methodology is crucial to the success of an EFA. Holistic EFA methodologies, such as the Building Block [illegible] and Downstream Response to Imposed Flow Transformations (DRIFT) have been developed within the SADC region. These were designed [illegible] to cope with SADC-region realities of limited data and time. The BBM is mostly used where a single-objective approach has been adopted, whereas DRIFT is a multi-scenario approach. These methodologies are essentially tools for managing data and knowledge in a structured way. Within them, discipline-specific methods may be used to provide the required information on, for instance, fish or riparian trees.

There are also several "coarse/rapid" methods, which can provide initial estimates of the amount of water that may be required. The level of confidence in the results generated using these rapid methods is low, but they can be of use at the level of regional water-resource planning. (Table 5.2)

STEP 3
DEFINITION OF STUDY AREA AND REPRESENTATIVE AREAS

The delineation (in the Issues Assessment) of the river system and PAR will provide the broad study area for the EFA. The size of this will be affected by both the extent of the downstream influence of water abstractions and by the distance that the PAR travels to make use of the river.

Within this, the areas actually addressed will probably be delineated differently in the social and biophysical portions of the study. For instance, it is unlikely that the study area for the biophysical component would extend much beyond the immediate confines of the river, *ie* probably no further than the level of the 1:100 year flood. The area covered by the social study, on the other hand, could extend for many kilometres on either side of the river. Many factors will affect the distance from the river to which the social study extends. Topography, for instance, is a major determinant. In places where the countryside is flat, people move over much greater distances to reach the river than they do in mountainous areas, and so the corridor of river use tends to be narrower in steeper areas. Within each delineated study area, representative river reaches and social zones for detailed study should ultimately be further delineated, possibly in Steps 5 or 6.

STEP 4
IDENTIFICATION OF UNDERLYING LINKS BETWEEN PEOPLE AND THE RIVER

The social concerns associated with the river, be they at a local, regional, national or international level, link back to the structure and functioning of that system. With some of these the links to the river are obvious, such as a fish or plant that is eaten, water that is drunk or a pool that is used for ceremonies. Riparian agriculture makes use of fertile soils and water supplied by the river. Some small industries, such as brick-making, are also dependent on the river for supplies of raw materials. Other links are less obvious. For instance, vitamins and trace metals supplied by riparian plants may contribute to the overall health of the community, or certain levels of flow may dilute, or aid decomposition of, wastes entering the river, so the water can be drunk without health risks.

Once all of the ways that people use the river, and the specifics of that use, have been identified in a general way (Step 1), on-site investigation should be made of all aspects of the river that are of social relevance. Then, the biophysical specialists linked to the project should ensure that their studies of the river include all socially relevant species or features.

Methods	Examples	Advantages	Disadvantages	Data and expertise requirements
Hydrological index	• Montana Method • Flow Duration Curve Analysis • Range of Variability Approach • Preliminary Reserve Method	Inexpensive, rapid, desktop approaches that are appropriate at the reconnaissance level of water-resource development	Do not address the dynamic and variable nature of the hydrological regime, and lack of ecological input.	• Flow records, preferably gauged, daily average discharges, over the longest period of record possible. • Photographs of areas of habitat exposed at various discharges. • Ecological data, for instance on the timing and magnitude of flows for fish spawning. • Hydrological and ecological expertise.
Hydraulic rating	• Wetted Perimeter Method	Fairly rapid assessment of flows for the maintenance of habitat areas. Incorporate some river-specific and ecologically based information. Sufficiently flexible to be applied for many aquatic species and activities. Only moderately resource-intensive.	Rely on the assumption that a single hydraulic variable can represent the EFR. Results are highly dependent on the placement of the single cross-section. Cannot easily incorporate out-of-channel components of the river.	• Flow records, preferably gauged, daily average discharges. • Measured stage-discharge data for at least one river cross-section. • Hydraulic data at intervals across a cross-section, collected at several discharges. • Standard hydraulic-simulation models. • Hydraulic modelling, land surveying, hydrological and ecological expertise.
Habitat simulation	• Instream Flow Incremental Methodology • River Hydraulics and Habitat Simulation • Riverine Community Habitat Assessment and Restoration Concept • Computer-aided Simulation Model for EFRs	Assess impacts on physical habitat of incremental changes in flow, and have dynamic hydrological and habitat time series components. Computer-based and thus able to process large amounts of data in a standardised yet flexible, interactive manner. Modelling is at a scale relevant to the biota.	Focus on target species and are limited where the aim of an EFA is to maintain a full complement of species. Do not lend themselves to use for certain aspects of rivers, such as riparian vegetation. Require further research, and testing and validation.	• Hydraulic data from a number of cross-sections, at different discharges. • Point microhabitat data on the habitat requirements of the biota as input to the habitat simulation programs. • Average daily hydrological data. • Expertise in hydroecological and hydraulic modelling, and specialist flow-related ecological knowledge on the biota.
Holistic	• Building Block Methodology (BBM) • Holistic Approach • Flow Restoration Methodology (FLOWRESM). • Water Allocation Management Planning Benchmarking • Habitat Assessment Method • Downstream Response to Imposed Flow Transformations (DRIFT)	Consider all aspects of the flow regime, such as the magnitude and timing of both baseflow and flood events, and outputs can be generated at several levels of resolution. Some can incorporate all components of the river, and social and economic aspects. Designed to cope with EFAs where time, finances, available data and expertise are constraints.	Data and results from the various contributing scientific methods are combined. The overall output is then created using a mixture of data and professional judgement. Care must be taken to apply them in a rigorous, well-structured manner, with experienced specialists, in order to ensure reproducible results.	• Comprehensive hydraulic and hydrological data. • In some methods software is available to translate hydrological and hydraulic data into formats readily usable by biophysical specialists. • EFA facilitators need in-depth understanding of all aspects of EFA. • Specialists in the flow-related requirements of each of the ecosystem components, with as much supporting data as possible. • With the BBM and DRIFT, data on the uses of river resources by the PAR are also essential.

Tharme 1996

STEP 5
COLLATION OF EXISTING DATA AND ASSESSMENT OF THE NEED FOR FURTHER DATA COLLECTION

No new data are collected during this step, but available, relevant information is collated, and the need for further data collection [illegible].

Three main fields of data are required for a comprehensive EFA, *viz* biophysical, social and economic. For each of these, examples of questions likely to arise in an EFA are provided below. The extent to which these or similar questions could be answered with existing data should be evaluated, bearing in mind that the accuracy of, and confidence in, an EFA is strongly linked to the quality of data used.

- **Biophysical data**

Long-term, accurate hydrological data, either measured or simulated, are vital to an EFA because they allow the links between the flow of the river and processes within the river to be established. Similarly long-term water-chemistry records for rivers, preferably linked to hydrographs, allow predictions of likely chemical changes with flow manipulations. Geomorphological data describe the nature of the river channel and physical habitat, and how these may change with flow changes. Data on the life histories of riverine species inform on critical life stages and conditions needed to complete these. An understanding of physical and chemical tolerance ranges of these species allows scientists to predict how aquatic communities will change as abiotic conditions change.

Where data are not available, the only alternative in the short term is to rely on experienced specialists in these disciplines. For the rivers within the study area, questions that may need to be answered include:

Hydrology What are the natural, present and projected future daily flow regimes at selected points along the river(s)?

Hydraulics What are the relationships between discharge and channel depth, width and water velocity at selected points/cross-sections on the study rivers?

Channel morphology What is the nature of the present river channel? Which lengths are similar in nature and functioning? Which of the lengths are vulnerable to change when flows change and how would they change? Which changes in flow are most likely to cause channel changes?

Water chemistry What are the present water chemistry and temperature regimes? Are there existing water quality concerns? How is the water quality likely to change when flows change?

Biotic communities What are the composition, downstream and cross-channel distributions, and conditions of the riparian and instream plant and animal communities? What is their relationship with river flow? Are they likely to be affected by changes in flow, or associated changes in channel morphology or water quality? What flow conditions would result in favourable conditions for problem species, and what would those species be? Are there any rare or endangered species? The same set of questions should be asked for terrestrial species that are directly or [illegible] dependent on the river, such as herbivores that drink at the river, or birds that feed on fish.

- **Social data**

Demographics What is the demography of the PAR?

Subsistence needs What is the level of dependence of the local people on riverine resources? What animal and plant species do they use and for what purpose? When do they collect them and from where? Do they use other resources from the river, *eg* sand/or mud for building? Do they drink the water from the river? If so, where do they collect water and at what time of the year? Do they water their animals at the river? Is the river used for washing? If so, where? Are their needs being met? If not why? Does the river present any problems or dangers to the local people, such as [illegible] difficulty crossing, or danger from wild animals such as crocodiles and hippos?

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Public Health What are the main health concerns in the area, and are they linked to the river in any way, *eg* [illegible] If flows were to change, is there the likelihood of new illnesses, an increase in present ones, or a change in nutritional status due to the loss of

river plants or animals? If so, how would this affect the health profile of the PAR?

Livestock Health What is the level of nutrition derived from riparian grazing? What are the main livestock diseases in the area, and are they linked to the river in any way? If flows were to change, would this health profile change?

Culture and recreation Is the river used for cultural events? If so, which features of the river are used, *eg* waterfalls, pools or riffles? What time of the year are they used? Is the river used for recreational activities and, if so, when? What is the general feeling about the river? Is it liked, feared, hated?

- **Economic data**

Subsistence value What is the value, in monetary terms, of the riverine resources used by the PAR? Would it be possible to provide alternative resources and what would the cost be?

Income generation Does the river provide a source of income at a local, regional or national level? This could be through the sale of "unimproved" riverine resources, such as cobbles, fish, wood or herbs, or "improved" resources, such as bricks made from riverine sand or baskets from river reeds, or from ferrying people across the river. Income could also be generated by tourism activities, such as weekend cottages, rafting trips, hiking or large-scale hotel developments. In each case it is important to identify the component of the river that is being used. What is the value of the river as a realised or potential tourist attraction?

Amenity value What would be the cost of providing alternative venues for cultural or recreational events that use the river?

Local development Would reduced flows lead to a reduced capacity for the river to dilute or assimilate wastes, and would this affect potential further development of the catchment?

Intrinsic and intangible value In the SADC region, the culture and quality of life of many rural peoples are inter-linked with the river environment. Many people also believe that environmental assets have an existence value. These kinds of values need to be drawn into the decision-making process. It must be clear that economic value includes direct and indirect use, option and intrinsic value, all in monetised terms as far as possible.

STEP 6
APPLICATION OF THE APPROPRIATE METHODOLOGY

The appropriate methodology will depend on the stage and scale of the water-resource development, the available funds, and the objective to be achieved. See explanation of methodologies in Section 5.6.

STEP 7
ASSESSMENT OF THE BIGGER PICTURE

The potentially negative impacts of a water-resource development need to be considered along with its potentially positive impacts, such as provision of water, hydropower or the establishment of a fishery (such as the kapenta fishery in Lake Kariba, Zimbabwe). Collection of this information is usually outside the ambit of an EFA and the responsibility for ensuring that it is done rests with the decision-maker. However, identification of these aspects at an early stage will allow the relevant data to be collated in parallel studies. These studies could include an analysis of the benefits that would be generated through the use of the water by the industrial sector, income generated by selling hydropower or an assessment of the job opportunities offered by a new irrigation scheme to be supplied from the proposed dam. These should be offset against, *inter alia*, the costs of supplying people with alternatives for the river resources lost in the downstream areas, and other negative results of a loss of river condition, such as the likelihood of flooding and the relocation of people. Without an understanding of these wider aspects, the decision-maker cannot make a balanced, accountable decision. (see Step 8)

STEP 8
DEVELOPMENT OF A STRUCTURED, TRANSPARENT DECISION-MAKING PROCESS

The process by which a final decision will be made on an EFR should be developed independently of the EFA and should be agreed upon, at least in outline, if not in detail, by all interested and affected parties. In the development of this decision-making process the following are needed:

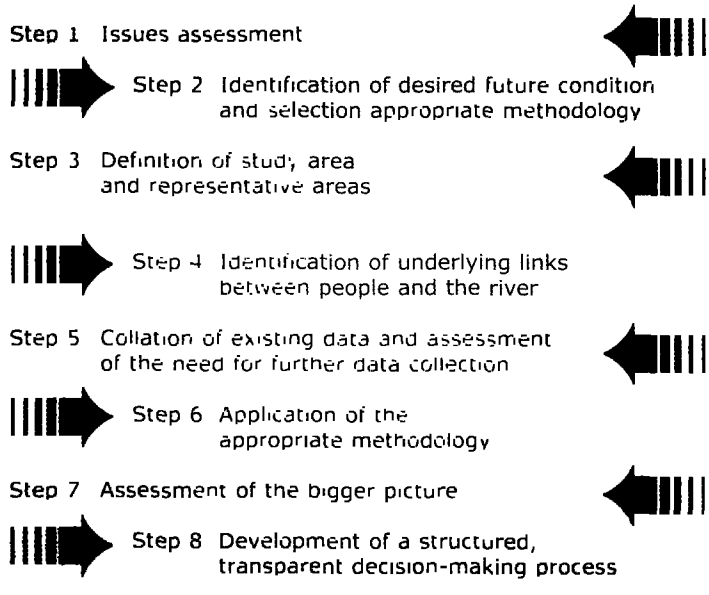
clear identification and participation of all groups whose requirements must be considered;

adequate information on the resource-use by these groups and the relationship between flow regime and adequacy of meeting their requirements (Step 5);

a hydrological systems model that can be used to simulate a range of water-allocation scenarios;
data on the impact of each flow scenario on river condition, social and economic impacts and yield;
a formal way to deal with moral and ethical issues, and intangible costs.

The assumptions and the validity of any tools or models used in the decision-making process should be agreed on before they are used to make a decision. This is particularly important in the SADC region, for many water-resource developments are on shared water courses where agreement on the tradeoffs will have to be reached between two and sometimes three neighbouring countries.

Eight Steps to Complete an EFA Figure 5.1



5.6 ENVIRONMENTAL FLOW ASSESSMENT METHODOLOGIES CURRENTLY AVAILABLE

Many of the environmental flow methodologies that are in use nowadays are fairly robust and flexible, both in their data requirements and in their output. With appropriate modification, they can potentially be applied in different countries, for different types of rivers. There are, however, a number of general limitations that should be considered in the selection of a particular methodology for use in an EFA. These include the degree to which the assumptions inherent in the methodology are met, and the extent of its transferability from its region of origin to the specific river basin where it is to be applied. Other limitations include the data and expertise requirements, the degree to which testing or validation of the methodology has been done, whether or not it lends itself to routine application, access to documentation and training in its use, and whether it encourages or discourages public participation.

5.6.1 Methods for rivers

Four basic groups of methods are widely recognised for assessing the environmental flow requirements for rivers (Table 5.2), although there is an array of alternative approaches, often case-specific, that have been developed to deal with environmental flow issues. (Tharme 1996)

The four basic groups in chronological order of development, are:

Hydrological index methods, which are mainly desk-top approaches, relying primarily on historical flow records for making flow recommendations, with scant attention to ecological criteria.

Hydraulic rating methods, which use the relationship between simple hydraulic variables, such as water depth or velocity, and discharge to develop environmental flow recommendations. As calibration, these variables are measured along one or more representative cross-sections, across the target river at one or more discharges. The calibrated model is then used to predict how values will change over a range of flows.

Habitat simulation methodologies, also known as habitat modelling or habitat rating methodologies, also make use of hydraulic-discharge relationships, but link these to simulations of the extent to which conditions over a range of flows meet the habitat requirements of selected river species.

Holistic methodologies, which form a clearly separate group of methodologies that are designed to address the flow requirements for all biotic and abiotic aspects of a river, and which may incorporate subroutines derived from methodologies of the first three types. They differ from the other three types of

Case study: Application of a holistic methodology for environmental flow assessments in the Lesotho Highlands Water Project (LHWP) **Box 5.12**

When Katse dam was near completion, Metsi Consultants were awarded the contract by the Lesotho Highlands Development Authority (LHDA) to advise on the EFRs for the river downstream of all proposed and extant Lesotho Highlands Water Project dams. An international team of 27 specialists in a range of biophysical and socio-economic disciplines was created for the contract.

In order to manage the two-year study and the resulting EFA, a new methodology, DRIFT, was developed. Using DRIFT, four scenarios were created, each of which described:

- **A modified flow regime** for each river (high flows (floods) and lowflows).
- **The biophysical changes** expected in each river under the modified flow regimes (channel shape, chemistry, temperature, vegetation, aquatic animals).
- **The social impacts** expected as a result of the predicted biophysical changes (social use, public health, and livestock health).
- **The economic implications** of the social impacts.
- **The yield of water** from the LHWP.
- A list of other concerns, which included a description of the intrinsic or intangible values of the rivers.

Metsi 1999

methodologies in that they are essentially a way of organising a disparate array of river data. Of these, the BBM and DRIFT have been developed and applied most frequently in the SADC region (Box 5.12).

Holistic methodologies, because of their wide-ranging focus, are amenable to identifying the flows linked to issues of human use and interest, such as social dependence on the river, maintenance of aesthetic quality, protection of features of cultural or scientific interest, and river-related recreation. (For a comprehensive review of the most commonly used methodologies, see King, Tharme and Brown, 1999)

5.6.2 Methods for wetlands and estuaries

International initiatives to assess EFRs for wetlands and estuaries are broadly centred on the determination of features such as:

runoff and river flow scenarios;
definition of key biological indicators and components;
identification of important interactive processes amongst components;
description of natural and present conditions; and predicted changes which would accompany the various scenarios.

They typically require expertise in hydrodynamic modelling, as well as multidisciplinary knowledge of the structure and functioning of the various wetland and estuarine systems.

5.6.3 Methods for groundwater

In South Africa, within the framework of determination of the Ecological Reserve, procedures are being formulated for the calculation of EFRs for maintenance of groundwater at several levels of resolution, and for the integration of groundwater requirements with EFAs for rivers. Geohydrological investigations have also formed part of a few South African EFAs using the BBM, for instance, that for the seasonally flowing Mogolakwena river.

5.7 IMPLICATIONS FOR A SOUND WATER POLICY

If sustainable use of the freshwater resources of the SADC region is to be achieved, water should be reserved for river maintenance. One structured way of doing this could be to:

- Incorporate EIAs into the water-resource planning process.
- Ensure that EIAs for water-resource developments, or abstractions from the rivers, lakes, wetlands or groundwater fully integrate an EFA.
- Ensure sufficient funds for EFAs. Modern EFAs may be costly exercises, involving many senior specialists over quite long timespans. They should be formally recognized and catered for in budgets. It should be emphasized, however, that cost-effective methodologies should be identified and used to avoid unnecessary and inappropriate expenditure on EFAs, particularly in view the paucity of data on aquatic ecosystems in many SADC rivers.
- In principle, define and prioritize EFA in water policy and protect an EFA in perpetuity, through appropriate legislation.

5.8 CHALLENGES FACING SADC WITH RESPECT TO ENVIRONMENTAL FLOW REQUIREMENTS

Inclusion of EFAs in water-resource planning requires the cooperation and support of people involved in all sectors of a water-resource development. The blending of different perspectives will take time and cooperation from all concerned, and requires overcoming entrenched attitudes in all sectors. Long-term and far-reaching ecological and social concerns need to be injected into the water-development planning arena, and those making the input need to provide clear and relevant information about the consequences of not meeting EFRs.

5.8.1 Political will, public participation, legislation and management strategies

Before EFRs can be included in water-resource planning there needs to be political recognition and understanding of the loss of ecosystem values due to [illegible] degradation of rivers, and of the tangible and intangible costs of degraded rivers to a nation. This recognition should be translated into supporting legislation to empower water managers to manage river flows according to EFA recommendations. EFRs can only be implemented successfully if there is a sound policy framework that supports them. Where the water policy defines the need for an EFR, the EFA is used only to determine the volume and [illegible] of the flows making up the EFR. However, without such a framework, an EFA has the burden of not only defining environmental flows but also of giving legitimacy to them. (Hirji, pers. comm.) It is preferable for the policy framework to be entrenched in a country's laws, and to have wide public support through a management process that generates and encourages public participation in formulation and decision-making. This helps to widen the ownership and implementation at all levels, and also facilitates the inclusion of socio-economic considerations that may be important to the community and the private sector. (Mubvami, pers.comm.)

A structured, transparent and widely accepted decision-making process should be in place whereby the results of engineering and economic studies, EFAs and the concerns of all stakeholders are jointly considered before a decision is made whether, and in what way, to proceed with a water-resource development. In the event such a development is pursued, agreement on future flow allocations and river condition in an open forum will enhance the setting and management of EFRs. Such a transparent decision-making process will strengthen the commitment of communities and political leaders, developers and dam operators to adhere to the agreed EFA objectives.

Regular independent review, possibly every five years, of the operation of a water-resource scheme and the related ecological and socio-economic issues, should be entrenched in the management of the scheme. Management should be sufficiently flexible to allow such reviews to lead to adjustment in either the EFR objectives for the river or the EFR.

5.8.2 Harmonisation of policies throughout SADC

The increasing interdependence among SADC countries will have far-reaching environmental, political and socio-economic implications. Most of the major freshwater systems in SADC are shared by two or more countries, and proposed inter-basin water transfer schemes within the region may increase this number if implemented. (Box 5.8) There is also potential for conflict over water resources at the level of countries or communities, thus an urgent need for harmonisation of environmental policies in the region. The Protocol on Shared Watercourses is a key mechanism for harmonising policies by SADC member states, as are related protocols and declarations including for example, the Trade protocol and SADC Declaration on Gender and Development. EFRs should be set for an entire river system and should involve all its stakeholders. (Saranga, pers.comm.)

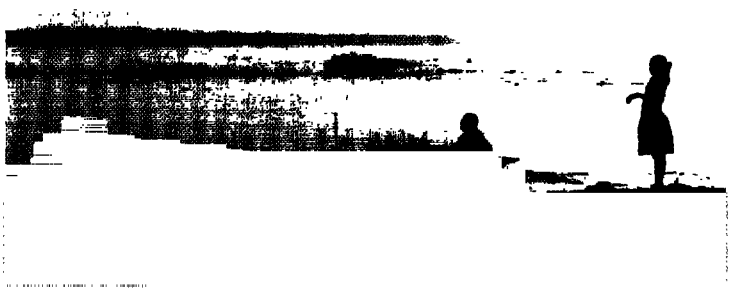
5.8.3 Awareness and training, and recognition of community-based knowledge

Balancing the multiple and competing demands for water is one of the greatest challenges facing water managers, and the allocation of water for environmental maintenance is often a controversial issue. It is imperative that environmental flows are calculated in a scientific and defensible way that also takes cognisance of local community needs and values. (Mubvami, pers.comm.) Supporting data on the rivers are often lacking, and so advice on environmental flows is based to varying degrees on expert opinion. This should be expanded to include community-based expertise. The qualifications, experience and standing of the freshwater specialists and the knowledge systems of the local communities can be crucial in dictating the defensibility of the final determination of environmental flows. In this regard, methodologies that require consensus between several qualified specialists, and that take account of indige-

nous knowledge systems, are easier to defend than are those based on the opinion of one individual.

Accordingly, EFA facilitators who are knowledgeable about international developments in EFA methods and experienced in managing EFAs are important to their success, as is the partnership with the local community which will have an interest in the sustainability of such initiatives. Scientists with a first-hand knowledge of the rivers of concern, and in the EFA-related aspects of the following disciplines are required: hydrology, geohydrology, hydraulics, geomorphology, sedimentology, water chemistry, biotic integrity, physical habitat, riparian and instream vegetation, fish, invertebrates, and possibly herpetofauna and river-dependent terrestrial wildlife. Socio-economic and cultural aspects must be included if the EFA is to be relevant and sustainable, therefore specialists in the following disciplines are also required: sociology, human geography, anthropology, community culture and language, gender roles, public health, domestic-stock health, resource and project economics, and public participation procedures. Also required are specialists with first-hand knowledge of the flow-related aspects of water-borne diseases, and those of parasites and/or their hosts.

The number of people in the SADC region with experience in managing an EFA process is small relative to the size of the region, as is the number of scientists with an in-depth knowledge of the specialist components of an EFA. However, these skills can be multiplied in a proper working partnership with the skills and knowledge of the local communities. (Mubvami, pers.comm.) If EFRs are to be successfully implemented, the need for them must be understood and accepted by all those who will be affected, and the local conditions and culture must be understood by the scientific experts who are assessing them.



L. Basto

Public participation should be inclusive of the perspectives of both women and men.

Thus:

- biophysical specialists need to be trained in EFA work, then train others through undergraduate and post-graduate studies and technology-transfer workshops;
- social scientists and economists need to understand EFAs, and then develop structured ways of extending biophysical predictions of change to the social and economic implications;
- indigenous knowledge systems need to be properly documented and understood by all participants, and community expertise accorded its proper place and value in the mix of required expertise; (Mubvami, pers.comm.)
- water managers, water engineers, dam owners and dam operators need to understand the philosophy, nature and limitations of EFAs, and the potential implications at all scales from local to international. They need to be willing to explore new ways of managing water resources through public participation and in close cooperation with the local communities, and committed to adhering to agreed EFA objectives;
- the public need to be aware of EFAs and understand their purpose and limitations, and be encouraged to add their perspectives and expertise, thus public awareness programmes that recognize this role must be an integral part of the EFA process; (Mubvami, pers.comm.)
- private sector and investors must be sensitised and made aware of the results of their actions that may facilitate short term profit but have harmful long-term effects, and they must be included in the decision-making process in a manner that encourages them to continue to invest in a more sustainable manner; (Johnson, pers.comm.)
- the roles of all involved in and affected by a proposed water-resource development need to be determined through public participation and be clear and acceptable, in a process that is inclusive of the perspectives and role of both women and men.

5.8.4 The need for data on SADC rivers

Confidence in the outputs of an EFA inevitably increases with investment in time and with specialist and community inputs. If EFAs are to take a prominent place in water-resource management, long-term data collection programmes must be initiated, against which the proposed

changes in flow regimes can be assessed. These sorts of data can seldom be collected for EFAs, which are relatively short-term activities, and thus should be collected as part of a country or a community's routine data collection for management of their systems. The kinds of data required are described in Section 5.5, Step 5.

5.8.5 Inherent unpredictability of complex systems

In some cases, the inter-linkages and complexities of rivers are simply too many and too great for the outcome of all potential management activities to be predicted accurately. For instance, the loss of a species or a reduction in the resilience of native aquatic communities could make way for invasions by exotic species not previously recorded in the area. These inter-linkages and complexities are compounded by the impact that human utilisation other than water abstraction, and changes in that utilisation, can have on rivers. This is especially so if river conditions decline as a result of water abstraction, but the levels of utilisation remain the same or increase. For instance, should the riparian zones decrease in width and biomass and grazing pressure remain constant, the result will be a concentration of grazing on a smaller area, and thus an increase in grazing pressure on the remaining vegetation. Changes in utilisation also complicate predictions of future condition.

In the Lesotho rivers for instance, increases in the abundance of the Orange River Mudfish are likely if flushing flows are removed from the system by LHWP dams, as the fish will benefit from the resulting increased sedimentation. The local people do not use these fish at present, mainly because mudfish do not take baited hooks. However, the fish are easily caught with nets and thus a change in fishing methods would facilitate greater utilisation of this species. Overfishing is far more likely with nets than with baited hooks, and thus a change in fishing methods could have a dramatic negative impact on the abundance of the one native species of fish likely to thrive in the modified flow regimes.

5.8.6 The influence of climate change on runoff

Long-term changes in the climate of the SADC region will have major implications for both the use and the protection of water resources. Much of the region is predicted to become drier than at present, and so freshwater resources of the region are likely to be more stressed in the future. For instance, in the Zambezi river basin, relatively small increases in temperature will result in large additional water losses through evaporation. (SADC ELMS 1994) Using past hydrology to predict future water availability will become less acceptable and ways need to be sought for ensuring that EFRs are met in the face of declining water availability.

5.8.7 The need for monitoring

Monitoring is an interactive process whereby the condition of key components is measured at repeated intervals following a disturbance, the results compared with the same kinds of data collected prior to the disturbance and adjustments made to management activities where necessary. For rivers, monitoring whether or not flows for environmental maintenance are occurring and are achieving their stated objectives is an essential part of implementation of an EFR.

Once an EFR has been decided upon and implemented, it will be necessary:

- to establish whether or not the agreed-on EFR is released;
- to verify that the overall objective (desired river condition) is being achieved;
- to verify that the objectives for different components of the flow regime are being met;
- if the objectives are not being achieved, to be able to adjust either the EFR or the objectives.

Monitoring programmes that are created, adequately funded and which involve the local community are likely to be more successful, as there is a clear commitment to support them, specialists are employed to design and, where necessary, direct them and they enjoy the support of and assistance from the local residents. Many a well-intentioned plan fails simply because it is nobody's paid job to make it work, and everyone else is too busy to do it part-time. However, it is more likely to be sustainable if some of the funds for monitoring are expended in the local community for that purpose. Funds for monitoring programmes should thus be realistic and secured as part of the operating costs of the dam, so that long-term plans can be made.

5.8.8 Dam location, design and operation

The feasibility of releasing different magnitudes of flows from a proposed dam should be a vital input to an EFA, since it is pointless describing floods within an EFR that simply cannot be released through a dam. Similarly, dam design should not be completed until the flood, and other

requirements of the EFR are well understood. It is possible that an EFR may require outlets that are bigger or more numerous than those required for routine dam operation. Release structures should not be decided upon based on construction costs alone, as the cheapest construction option may well be the most damaging one for the river, and thus have the greatest long term costs. Engineers should rise to the challenge of designing dams that can release water in ways that do the least damage to rivers, and not necessarily rest on tried and tested methods.

Features that should be considered for inclusion in dam design include:

fish ladders;
multiple-level releases, so that water from different strata in the reservoir can be released separately or in any combination;
water-chemistry and temperature sensors should be placed at the different off-take structures, so that water from the different strata can be mixed to some required quality in the downstream release, with computerised control of this facility;
outlet pipes must be able to take the volume from all the off-takes simultaneously if necessary;
release or other structures should be used that minimise anticipated water-quality conditions such as anoxic or super-saturated water;
continual recording of volumes and quality of all water being released from, or spilling over, the dam;
linkage between the release structures and a facility recording natural flow higher in the catchment, so that releases can be matched with current climate and thus the natural flow variability of the system;
the ability to release small floods of specified temperatures as biological cues;
the ability to release large floods;
built-in flexibility of design that allows changes in dam operation, such as for river rehabilitation, during the medium to long-term; and
a facility for passing sediments through reservoirs and past the dam walls.

The location of a dam can affect the cost and feasibility of releasing EFRs. For instance, dams situated upstream of the confluence with a major tributary instead of downstream of it, would trap less water but impact the downstream river less by ensuring bigger floods and more flow variability. It would also reduce the costs of having to construct larger-than-normal outlets to release EFR floods.

5.8.9 Rectifying past mistakes

Most extant impoundments in the SADC region do not have environmental releases incorporated into their operation. Impoundment structures here as in most other parts of the world, were designed without cognisance of the need to release environmental flows. There is scope to improve the operation of these impoundments to mitigate some of their effects on the downstream rivers. This can be done in four ways:

by redistributing releases made from these dams for other purposes, such as downstream abstraction for agriculture, in a manner that enhances river condition;
by implementing an environmental release where such is absent;
by changing the design of the dam;
by decommissioning the dam.

5.8.10 Water as a finite resource

Freshwater should be recognised as a finite, and indeed diminishing resource. Before future dams are built or abstractions allowed, potential users of the water should have to demonstrate that the proposed water use is efficient. Water demand management should be implemented to reduce wastage of water already being abstracted from the region's rivers, before additional water-resource schemes are implemented. If present trends in water usage, and wastage, in the region continue, there will come a time when all the freshwater resources are fully utilised and other options, such as recycling and demand management, will have to be explored. In the light of this, the most sensible course would be to implement those options before all rivers reach an advanced stage of degradation.

5.9 CONCLUSION

Ensuring environmental flows for river maintenance should be an essential component of the management of any inland water resource. Methods are now available that can quantify the water required in space and time, and develop scenarios so that wider implications of a range of options can be considered. The figures provided by EFAs allow estimates to be made of the true amount of water still available for future development under the principles of sustainable use and protection of resources. At all levels, from local to international, these figures provide new perspectives that allow water managers to make more informed decisions on the equitable use of water.

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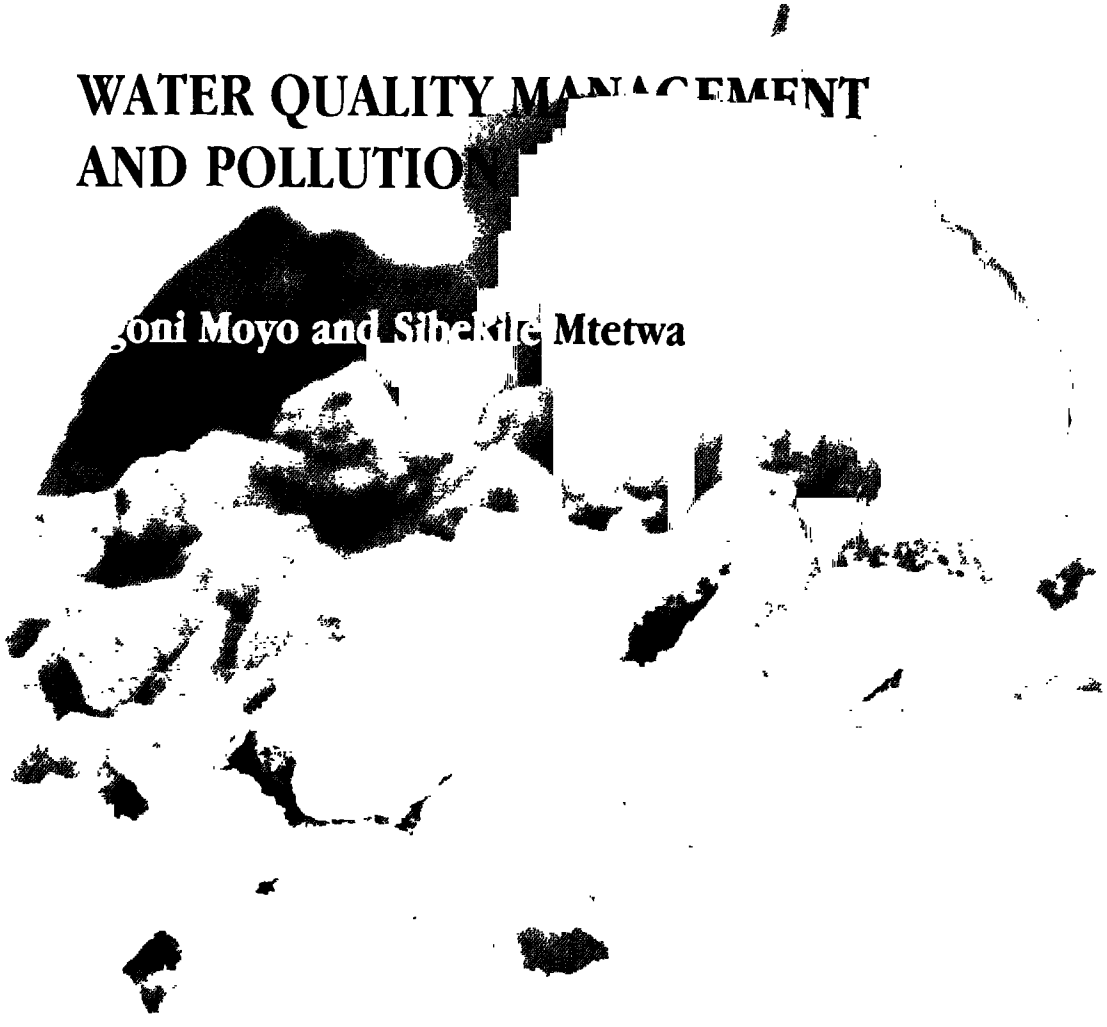
Worldwide Web. Relevant sites include: www-dwaf.pwv.gov.za, www.dams.org, www.irn.org.

WATER QUALITY MANAGEMENT AND POLLUTION

goni Moyo and Sibekile Mtetwa



CONTENTS

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WATER QUALITY MANAGEMENT AND POLLUTION CONTROL

6.1 INTRODUCTION

Earlier chapters have highlighted that water is a limited resource in the region and scarce in some countries and stated that pollution of rivers, lakes and aquifers from domestic and industrial wastewater discharges, mining runoff, agro-chemicals and other sources is a growing threat to the water resources in the region.

Solid, liquid and particulate waste by-products of urbanization and economic activities are contaminating air, soil and water quality. The quality of water supplies in the SADC region, once taken for granted, is becoming the focus of increasing concern. The quality of a particular water body determines the use that it is suited for or the level of treatment that would be required before it can be of a particular use.

Water pollution impairs the use of water in several ways. It directly impacts public health and functioning of ecosystems, and imposes a burden on downstream users due to the additional cost of treatment required. Water quality is also impacted by changes in water quantity. In water short regions, water quality degradation exacerbates water scarcity. Water pollution also poses a threat to aquatic biodiversity. The management of present and future water quality in southern Africa is fundamentally important if the continued existence of both the resource, and the populations reliant on the resource, is to be ensured. There is therefore an urgent need for changing the misperception among policy makers that water pollution is not a serious problem in the region.

In the SADC region, water quality is impaired by natural and anthropogenic factors. Water pollution from point and non-point sources is however the principle factor that impairs water quality in the region. The main point sources are the untreated or partially treated effluents from municipal, industrial and mining wastewater discharges. Non-point sources of pollution include runoff from smallscale mining operations, urban stormwater and runoff from agricultural, livestock, and poultry operations.

Water quality changes also result from water resources developments. For example, water stored in reservoirs undergoes changes in temperature and dissolved oxygen as a result of [illegible] and this can have an impact on the quality of water abstracted from the reservoir depending on the depth from which water is abstracted. Excessive abstraction, can reduce the capacity of a water body to dilute incoming waste loads and also alter the dynamics between the freshwater/saltwater interfaces in estuaries and induce saltwater intrusion. Irrigation concentrates salts leached from the soil and irrigation return flow often has higher salinity than the original applied water. Cooling water effluent often has higher temperature than the temperature of receiving waters.

This chapter discusses the water quality management and pollution control challenges facing the SADC region, and addresses a range of water quality management strategies. A water quality management strategy needs to address point sources and non-point sources of pollution and consider other factors impacting water quality.

The chapter starts with a broad discussion of the water quality requirements for a wide variety of consumptive and non-consumptive uses. Then it describes natural factors that impair water quality, and discusses the severity and extent of the problem and consequences. Next, major point and non-point sources of pollution and their effects on receiving water bodies, public health and ecosystem health are analysed. (see chapter 4 on valuation of resource degradation) This is followed by an evalu-

ation of existing pollution control management in the region. Water quality management policy options including both resource-focused (receiving water quality objectives) and source-focused approaches (discharge standards and best management practices) are discussed. Finally, a variety of pollution control options are recommended and these include: pollution permits, self-regulation, economic incentives, and pollution penalties.

6.2 WATER QUALITY REQUIREMENTS FOR VARIOUS USES OF WATER

Water quality is not an intrinsic property of water but is linked to its use. Good quality water is important for various uses. Typical uses of water in the region are for domestic, industrial, irrigation, hydropower, livestock, mining, recreation and environmental purposes. The uses of water also dictate its necessary quality. If the presence or introduction of any material into water interferes with the intended use then fitness for the use is affected and a measure is required to assess such effects on the fitness for use.

The protection of water quality is a growing concern in southern Africa. Most countries have developed a combination of water quality standards, guidelines, criteria and objectives for quantification of water quality requirements in terms of physical, chemical, biological, and aesthetic characteristics, and to define requirements for different uses of water according to their local conditions. Typically,

Standards are numerical concentrations of substances which are allowed in water or wastewater, and which are legally enforceable.

Guidelines may be numerical or descriptive, provide an indication of desired concentrations of substances in water or wastewater, and are not generally legally enforceable.

Criteria are rigorously derived numerical levels, indicating the concentrations of substances at which certain clearly defined effects take place (such as mortality of 50 percent of the test population of aquatic organisms).

Objectives are numerical or descriptive targets for desired quality of water or wastewater, and may or may not be legally enforceable.

A number of governments have adopted the World Health Organisation (WHO) guidelines or other internationally recognized standards for the different uses of water and for effluent discharges.

6.2.1 Drinking water quality

Of all the physical parameters, turbidity or cloudy water due to sediment is a common problem in the region and this affects the aesthetic quality of the water as well as the biological quality, as bacteriological factors and pathogens are often associated with turbidity. The chemical impurities vary from place to place depending on the local activities, local conditions and even the geology of the area.

An important phenomenon is the occurrence of high fluoride levels in some areas due to geological conditions. Microbiological quality refers to the presence of organisms such as protozoa, bacteria and viruses, and this is mainly due to faecal contamination. (DWAF 1996a)

To meet the drinking water quality standards or requirements, the water can receive basic treatment, which may include using bleach or boiling to disinfect, at community level. For large towns and cities, conventional treatment is common and this involves coagulation, flocculation, filtration and disinfection (usually by chlorine).

6.2.2 Industrial water quality

Industrial processes vary and may include cooling, steam production, process water (solvents etc), product water (beverages), utilities water (domestic, fire protection) and wash water, and they all require different qualities of water. The fitness for use of water for industrial processes depends among other things on:

its potential for causing damage to equipment (corrosion, abrasion);

problems it may cause in the manufacturing process (precipitate, colour change);

impairment of product quality (taste, discolouration);

complexity of waste handling as a result of using the water.

Water quality requirements for industrial use vary from water of any quality, water of domestic quality, intermediate quality water requiring further treatment, and high quality water requiring specialized treatment. (DWAF 1996b) Generally, industries meet their own water quality requirements through pre-treatment of inflow water, for example, the beverage industries further treat domestic water before bottling.

6.2.3 Irrigation water quality

Irrigation water is used to supply the water requirements for a wide variety of crops, at widely varying degrees of intensity, with a range of different distribution and appli-

cation systems, to a wide range of soils over all climatic ranges in southern Africa. Different irrigation uses require different qualities of water, and a wide spectrum of problems may be encountered where water does not meet requirements. All SADC member states depend on the UN Food and Agriculture Organisation (FAO) guidelines for irrigation waters, and South Africa has developed its own guidelines based on those from FAO. (Box 6.1)

The important water quality parameters for irrigation in the region include chloride levels, which affect such crops as tobacco at levels above 10mg/l and elements such as boron, which are toxic to plant growth at very low concentrations. Sodium is also very important, and if applied in excessive concentrations, it can affect the soil structure and fertility.

6.2.4 Environmental water quality

Aquatic ecosystems are part of the water resources and maintaining good environmental water quality benefits people by,

- providing an [illegible] capacity in the water body for waste through self purification;
- providing an aesthetically pleasing environment;
- serving as a resource used for recreation;
- providing livelihood to communities dependent on the water body;
- maintaining biodiversity and providing habitats to those biota.

The protection of the health, structure and function of the aquatic environment is therefore important to ensuring that water remains available for other uses. In southern Africa, only South Africa has developed water quality guidelines for aquatic ecosystems and is applying them. (DWAF 1996d)

6.2.5 River water quality

Degradation of river water quality can result in an increased risk to consumers if it is abstracted for domestic or others uses.

The WHO and FAO guidelines for drinking water and river water quality have been developed based on scientific, health and environmental standards, and can be adopted as they are or used to develop local standards, considering factors such as the regional geology, hydrology and biophysical environment, and types of human activities. (WHO 1993) Not all countries have adopted or derived their own standards. Tanzania, for example, still has temporary drinking water standards because they envisage that adopting permanent standards, say for fluoride, would present difficult economic choices and compliance problems for a large segment of the population. The Annex to this chapter shows the WHO-recommended limits for various pollutants.

In addition to protecting the water resources for human consumption, it is also necessary to consider the aquatic ecosystems. The same Annex shows the guideline values used in South Africa. It should be noted that the chemical-specific criteria for aquatic ecosystems have limitations and need to be complemented by instream biological monitoring, direct assessment of whole-effluent toxicity and bio-toxicological assessment of sediment quality.

South African water quality guidelines **Box 6.1**

The South African Water Quality Guidelines for domestic water use are essentially a user needs specification of the quality of water required for different domestic uses. The guidelines are intended to provide the information required to make judgements about the fitness of water to be used for domestic purposes — primarily human consumption but also bathing and other household uses. The Department of Water Affairs is the custodian of South Africa's water resources and has the guidelines as its primary source of information.

DWAF 1996c

6.3 NATURAL FACTORS THAT IMPACT ON WATER QUALITY

Because water is a universal solvent, it picks up an assortment of gases, minerals, and other substances as it moves through the hydrologic cycle. Substances found naturally in water may be in suspension or in solution. Suspended particles commonly found in raw water supplies include sediments and micro-organisms; and dissolved substances found in raw water include different types of salts. Human disturbances, for example land degradation, can accelerate natural processes including soil erosion, sediment transport (in suspension) and particulate deposition (in stream beds and storage structures), which can increase turbidity and suspended solid concentrations in receiving water bodies.

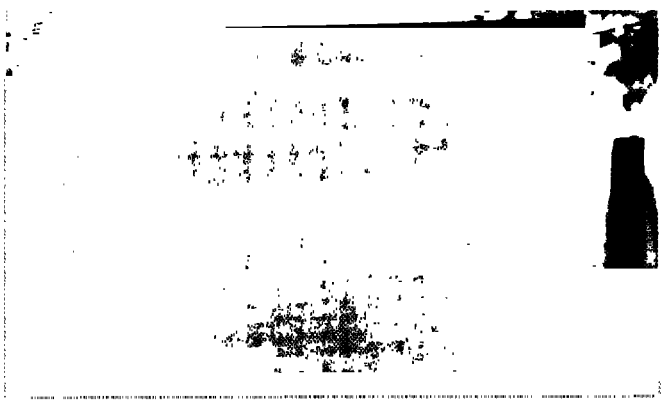
Monitoring ambient water quality in rivers helps to establish baseline conditions, which can be useful to assess the type, causes and degree of pollution contributed by anthropogenic factors such as municipal, industrial or mining operations and, to develop alternate

pollution control measures. For instance, heavy metals associated with industrial pollution are not likely to be found in a stream in a granite catchment under natural unimpacted conditions. However, this may not be true of rivers passing through basalt areas.

The concentration of fluoride in potable waters is a double-edged issue. In modest concentration, fluoride is an important and desirable element for dental health, especially for children. Too high a concentration, however, can result in dental or even skeletal fluorosis. The desirable amount in water varies with ambient temperature. Recommended levels are,

0.9 – 1.7 mg/l at 10° C
0.7 – 1.2 mg/l at 20° C
0.6 – 0.8 mg/l at 30° C.

In the fluoride belt of northeastern Tanzania which includes the Kilimanjaro, Arusha, Singida, and Shinyanga regions, rivers, streams and groundwater tend to have very high concentrations of fluoride emanating from the geological formations across which they flow. Values of up to 32 mg/l have been found in several locations there.



D. Martin, APG

Sign at demonstration plant near Arusha National Park.

Generally groundwater and surface water chemistry is dictated by the geology of the area. At times the concentrations of substances can increase as abstraction affects the natural balance of the chemicals. This can happen with some heavy metals which are insoluble under normal conditions but are oxidized and become unstable and soluble if groundwater tables are lowered by excessive abstraction. This then leads to increases in the levels of the chemicals in the groundwater.

Nutrients can be introduced naturally from decomposing vegetation, carried by runoff from the catchment surface or through airborne particulates originating from bush fires. Combined phosphorus tends to be adsorbed to silt particles, thus removed from the main body of water as the particles settle to the bottom. The phosphorus tends to be locked in sediments unless the redox conditions change, causing it to be re-dissolved and released into the water column again.

6.4 SOURCES OF POLLUTION

There are two categories of pollution: point and non-point sources. Point sources are distinct, identifiable sources. Non-point sources are diffuse in nature and pollutants are discharged over a wide area or from a number of small inputs rather than from distinct identifiable sources.

The broad categories of pollutants generated from point and non-point sources may include oxygen-demanding wastes, disease-causing agents, synthetic organic compounds, nutrients, inorganic chemicals and minerals, sediments, radioactive substances, thermal discharge, and oil. (Rao 1995)

Oxygen-demanding materials are compounds that can be oxidized in receiving water, a process that consumes dissolved oxygen. The consumption of Dissolved Oxygen (DO) in water poses a threat to higher forms of aquatic life that depend on DO in order to survive. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) analyses are used to determine the strength of oxygen demanding materials. Micro-organisms in wastewater include bacteria, virus, and protozoa. These can be introduced by human or animal excreta and can cause the spread of waterborne and water-related diseases and infections. Wastewater with high temperatures increases the rate of DO depletion in oxygen demanding waste. Toxic compounds from industrial and agricultural runoff may bio-accumulate and concentrate in the food chain, making fish and shellfish unsafe for human consumption.

While there is no doubt that point sources of pollution are having a major impact on water quality in African countries, the role of agriculture and other types of non-point sources, though not as well known, can be substantial. Runoff and infiltration from fields treated with herbicides and pesticides result in contamination of surface and groundwater resources. Urban runoff carries significant amounts of sediment, nutrients and organic material. Soil erosion and the resulting increase in suspended and deposited sediments, are having a serious impact on the aquatic environment.

The disposal of wastewater in rivers and lakes can lead to eutrophication. Lakes are more sensitive than rivers as they have longer retention time and less self-purification capacity. Low dissolved oxygen and high bacteria concentrations are the most frequent critical pollution problems for rivers. In southern Africa, lakes whose catchment areas have been urbanized are often eutrophic, with a massive proliferation of aquatic plants and blue-green algae.

Urbanization is increasing in the SADC region, but most cities have not been able to develop the basic utilities (for water and electricity) and environmental services (solid waste disposal systems, sewage treatment, and industrial pollution control) to keep pace with the rapid growth. Urban health hazards resulting from a lack of clean water and proper sanitation disproportionately affect the poor. Inadequate sewage disposal has been one of the main causes of recent cholera outbreaks in some countries in the region.

Urban solid waste disposal is also emerging as a key water pollution concern. Open dumping is the most common method of solid waste disposal throughout the region. Leachate from these dumping sites could be an important source of river and lake pollution.

The overall impact of pollution on environmental and human health in southern Africa is difficult to judge, as there is little baseline information. No long-term study of pollutants has been undertaken at regional level, and appropriate control mechanisms are not in place or are poorly enforced. In many cases, pollution is not monitored. However, a review of the individual sources of pollution and their known impacts would provide a starting point for assessment.

6.4.1 POINT SOURCES

6.4.1.1 Municipal wastewater

Human waste in urban areas is disposed of using dry sanitary methods (pit latrine, ventilated improved pit latrine) and water-borne sanitary methods (pour flush latrines). The latter generates large quantities of domestic wastewater. Disposal of sewage from urban centres can be on-site using septic tanks, pit latrines and ventilated pit latrines, or off-site through biological treatment plants such as waste stabilization ponds, aerated lagoons, oxidation ditches, activated sludge and trickling filters for treatment prior to discharge or disposal. The composition of sewage varies and may include human waste (faeces and urine) and sullage.

Sullage is domestic wastewater that does not contain excreta or toilet waste, but it often contains some pathogens at concentrations similar to that in sewage. The main characteristics of sewage are its oxygen demand, pathogenic organisms and toxic compounds. (Cairncross and Faechem 1993) Sewage contains all types of pathogens that are excreted by the contributing population. Faecal coliform bacteria are usually present in very large numbers in faeces – the average adult excretes about 2,000,000 coliform each day. The presence of coliform in water indicates that faecal pollution of water has occurred and that the water may therefore contain pathogenic organisms. These constitute a health hazard and any decision about the treatment and disposal of sewage must take these hazards into account. Poor management and disposal of sewage may cause waterborne infections, water-related diseases, water-based and excreta-related infections such as cholera, dysentery, typhoid and paratyphoid fever and diarrhoea.

Untreated sewage disposed in aquatic systems causes depletion of DO due to oxidation of organic matter, increases nutrients such as nitrogen and phosphorous, and results in faecal contamination. If the volume and the strength of sewage disposed to the river is high compared to the dry weather flow of the stream then the resulting contamination of water can endanger the life of aquatic organisms. Seepage of sewage from the soakaway pits and pit latrines can cause groundwater contamination. The strength of sewage usually is dependent on the amount of water used by the community.

Existing wastewater treatment facilities in many countries in the region are overloaded and facing serious difficulties in handling the ever-increasing volumes of wastewater generated by an increasing urban population. Many sewage treatment works are old. Most have been maintained poorly and are overdue for rehabilitation. In Zambia, for example, inadequate sewage treatment and sanitation has led to widespread eutrophication of water bodies near towns and cities. It is estimated that sewage treatment plants in many Zambian towns are handling just 20 percent of sewage collected and even that is not adequately treated. (Chipungu and Kunda 1994) The remaining 80 percent is lost into storm drains because of leakages or blockages. Many African cities have open-drain systems, which often are flooded during the rainy season, leading to highly contaminated discharges to the receiving waters over short periods of time.

Sewage treatment works may be well designed but are often overloaded. A classic example of such a plant is the Firle sewage treatment works in Harare. (Box 6.2)

Firle sewage works overloaded — Box 6.2

The Firle sewage works treats half of Harare's sewage. It was designed to treat 72,000 cu m of wastewater per day, but the plant now receives more than 100,000 cu m of wastewater a day. The Firle sewage works discharges into the Mukuvisi river, which ultimately feeds into Lake Chivero. The sewage effluent, which is partially treated and nutrient-rich finds its way into the lake contributing to its eutrophication. Average results of raw sewage and final effluent from the sewage treatment conventional system for the period 4 January to 28 March 1996 are shown below:

Parameter	Raw Sewage	Final effluent	Permissible level
PH	6.9 – 9.0	7.2	6.5 – 8.0
	(mg/l)	(mg/l)	(mg/l)
COD	906	219	60
Nitrogen	65	28	10
Phosphorus	12.0	4.4	1.0
SS	500	99	25
BOD_5	400	164	25

In Tanzania, only seven out of more than 52 urban system centres had some form of central sewerage system in the mid-1990s, including Dar es Salaam, Mwanza, Moshi, Dodoma, Tanga and Arusha. (World Bank 1995) These sewerage systems provided only partial coverage, and were aged, in need of rehabilitation. As much as 80 percent of the urban population in Tanzania is not served by sewerage and uses traditional pit latrines. The Mirongo river, which drains into Lake Victoria, receives sewage from squatter settlements because of the breakdown of pumps and stabilization ponds. The river has been turned into an open sewer, which transports 160 tonnes of BOD, 400 tonnes of COD, 10 tonnes total phosphorus and 60 tonnes of total nitrogen into Lake Victoria every year. (World Bank 1995) Box 6.3 shows the contribution of organic loading from sanitary facilities into Lake Victoria.

The bacteriological quality of [illegible] rivers, especially those flowing through Blantyre, Lilongwe, Zomba and Muzuza is poor due to effluent discharges. Counts as high as 20,000 faecal coliforms per 100ml have been observed in Lilongwe river downstream of the sewage plant during periods when the plant has broken down. (Government of Malawi 1998)

Most rural people in southern Africa use pit latrines. However, if latrines are not constructed and maintained

Pollution of Lake Victoria from domestic sewage — Box 6.3

The Lake Victoria catchment in Tanzania encompasses Mara, Kagera, and Mwanza regions. The main lakeshore towns of Musoma, Bukoba and Mwanza are growing rapidly due to the thriving commercial, agricultural and industrial activities within the lake region. Mwanza town has a sewage system that collects sewage and discharges into Lake Victoria via the Mirongo river. A study in the early 1990s estimated pollution loading due to untreated wastewater was as follows.

Town	Sources	COD (kg/day)	BOD (kg/day)
Mwanza	Sewered	4861	2430
	Septic tanks	3646	1823
	Hilly areas	1128	564
Musoma		995	498
Bukoba		669	334

properly, they can cause pollution of groundwater. This is particularly serious for countries such as Botswana where surface water is scarce, and most rivers and streams are ephemeral. Consequently more than 10,000 boreholes have been sunk. There is need to investigate the microbiological quality of the groundwater in Botswana.

Municipal sewage is also discharged untreated or partially treated into the ocean, and marine pollution is becoming a major concern in coastal towns throughout the region. (Box 6.4) Sewage from the central business districts of Dar es Salaam and Tanga, for example, is discharged directly into the Indian Ocean without treatment. Coastal urban areas in southern Africa discharge more than 850 million litres of largely untreated wastewater (industrial and human wastes) into the sea. (Cock and Kock 1991) Although coastal pollution in Mozambique is still comparatively light by global standards, studies in Maputo harbour in the mid-1990s indicated that the beaches of Maputo and Beira were polluted from increased erosion, human-induced pollution [illegible] and faecal), from domestic and industrial residues, and from ship traffic, and were not safe for swimming. Six out of 13 sampling sites in Maputo bay indicated strong contamination by faecal coliforms. (Couto 1995)

6.4.1.2 Industrial effluents

Manufacturing and service industries are the primary sources of pollution in southern Africa, producing millions of tonnes of effluents (contaminated wastewater),

Impact of conflict and informal settlements, Luanda

Box 6.4

Informal settlements generated by conflict or poverty can replicate many of the urban domestic sources of pollutants, through unplanned settlements, and lack of access to water and sanitation facilities. These settlements are often located in coastal areas or near freshwater bodies, and the type and extent of the impact of refugees or displaced people on the local resources depends on their number and duration of stay in a particular area. Generally, if large numbers settle in a small area, they cause more damage than fewer people spread over a large area. The longer they stay, the more damage can be caused to water resources, unless they are integrated into local communities, as in the Kagera region of Tanzania in the 1990s or in southern Malawi during the 1980s.

In Angola, people fleeing the conflict in rural areas settled in coastal, urban areas, resulting in overpopulation, overburdening of sanitation facilities and localised pollution. The capital city, Luanda, was built for 500,000 people but the population multiplied due to the civil war, until the city had the highest population density in the country – 500 people/sq km. Luanda's population had grown to about 3 million by the early 1990s and the National Institute of Statistics projected a 5.5 percent annual urban growth rate for 1990-2000. Rapid and unplanned settlements created a city with virtually no sanitation facilities, sewerage system and refuse collection. Solid-waste collection is sporadic, and non-existent in many settlements, and a fraction of the urban population has sewerage connections or septic tanks. People living around Luanda's industrial park have no sewer pipes, and the artisanal fishing is almost non-existent. Marine pollution in and around major urban areas with large informal settlements such as Luanda, has in some cases, reached toxic levels.

Chenje and Johnson 1994

tens of millions of tonnes of solid waste (rubbish stored on land) and hundreds of millions of tonnes of emissions (air pollutants). Major polluters include thermal-electric power stations that burn coal or petroleum products, fertiliser factories, textile mills, chemical manufacturing plants, pulp-and-paper plants, slaughterhouses and tanneries. Water is the usual recipient of industrial pollution because disposal of wastes into water bodies is cheap and convenient. Eventually these wastes can accumulate to a point where they become dangerous. There are four main categories of water pollutants.

Organic materials from sewage and animal-products industries.

Nutrients from soaps, fertilisers and eroded sediments.

Poisons, such as agricultural chemicals, and industrial and mining wastes.

Fouling substances such as oil.

(Chenje and Johnson 1994)

Examples of industrial pollutants include dust from smelting and metal processing; heavy metal solutions used in plating, galvanizing, and pickling; metal and metal compounds used in paints, plastics, batteries, and tanning. Many industries in southern Africa involve wet processing of agricultural commodities. Heavy metals and synthetic organic chemicals accumulate at higher levels of the food chain, thereby posing a special risk to humans and aquatic systems.

Industrial wastewater is generated at industrial plants where water is used for various processes such as washing and rinsing of equipment. Its quantity and quality are determined by the nature of the raw materials and the processing methods used. (Mudrack and Kunst 1986) Since a majority of the industries are water-based, a considerable volume of wastewater is generated. Table 6.1 shows the amount of water required for production by various industries that are commonly found in the SADC region.

Some industries use water for cooling purposes and thereafter discharge wastewater with high temperatures into water bodies. High temperature causes a faster depletion of DO in water bodies and may have adverse effects on the ecosystem of the receiving water body.

Although industrial sources of pollution in southern Africa are relatively minor compared with those in developed countries, the absence of adequate enforceable discharge standards and lack of monitoring makes the task

Industry	Unit Of Product	Water Requirement
Bread	Tonne	2 100-4 200
Beer	Kilolitre	15 000
Milk products	Tonne	20 000
Wood pulp	Tonne of pulp and paper	236 000
Cotton bleaching	Tonne	300 000
Gasoline	Kilolitre	7 000-10 000
Steel	Tonne	260 000
Sulphuric acid	Tonne of 100% H_2SO_4	10 400

Rao 1995

of controlling industrial pollution difficult. In many countries, highly toxic industrial waste and chemical liquid waste are discharged into municipal sewage systems or directly into rivers without adequate treatment. Pre-treatment of industrial effluent is generally non-existent for most industries that use old technologies. The biological composition of the wastewater depends on the type of the industry, *eg* waste from food processing industries mixed with sewage may contain pathogenic organisms. Table 6.2 shows the characteristics of wastewater from various industries commonly found in all urban areas in the region.

The cities of Harare and Chitungwiza in Zimbabwe are sitting on their own catchment, the Manyame catchment, and their street runoff containing excess nutrients such as nitrogen and phosphorus washes into Lake Chivero (the main water source for both cities), thus contributing to the eutrophication of the lake. Box 6.5 outlines specific pollutants from a case study of industries in the Upper Manyame basin.

Industrial production contributes heavily to air pollution, land contamination and water pollution, *eg* chromium waste from leather tanneries and shoe manufacturers, chemicals used in dyes from textile factories. (Chipungu and Kunda 1994) The consequence of multiple sources of discharge is eutrophication and significant loads of persistent toxic substances in rivers such as the Kafue in Zambia, which is now inaccessible to navigation due to proliferation of the water hyacinth.

Industrial pollution in the Upper Manyame basin, Zimbabwe — **Box 6.5**

There are more than 45 different types of industries in the Upper Manyame basin, which have become major pollution sources as they discharge sub-standard effluent into the municipal sewer system of the capital city, Harare. A recent study identified the types of industries which discharge highly concentrated effluent. High heavy metal concentrations were detected in wastewater discharged from the following type of factories:

INDUSTRY	POLLUTANTS
Processed food	Mercury, Iron
Pulp and paper	Mercury, Nitrogen, Iron
Chemicals	Mercury, Nitrogen
Plastic products	Aluminium and Lead
Ceramics, store and clay products	Mercury
Metal products	Aluminium, Nitrogen, Iron
Transportation equipment	Zinc, Nitrogen

Generally, iron and nitrogen concentrations are high in most industries. BOD, COD and SS were highest from food processing, pulp/paper and chemical industries. Processed foods and chemical industries are major sources of nitrogen and phosphorus. Often, because of inadequate pre-treatment, discharges from these industries are exceeding effluent quality standards more than tenfold.

JICA 1997

Industry	Origin of major waste	Major characteristic
Textile	Cooking of fibres, de-sizing of fabrics	Highly alkaline, colour, high BOD and temperature, high SS
Leather goods	Unhairing, soaking, deliming and bating of hide	High total solids, hardness, salt, sulphide, chromium, pH, precipitated lime and BOD
Laundry trades	Washing of fabrics	High turbidity, alkalinity and organic solids
Dairy products	Dilutions of whole milk, separated milk and butter milk	High dissolved organic matter, protein, fat and lactose
Coffee	Pulping and fermenting of coffee beans	High BOD and suspended solids
Fish	Rejects from centrifuge, pressed evaporator and other wash wastewater	High BOD, total organic solids and odour
Soft drinks	Bottle washing, syrup storage tank drains	High pH, SS, and BOD
Pulp and paper	Cooking, refining, washing of fibres, screening of paper pulp	High or low pH colour, high SS, colloidal and dissolved solids, inorganic filters
Metal plating	Striping of oxide, cleaning and plating of metals	Acid metals, toxic minerals
Fuel oil use	Spills from fuel tank, filling waste	High emulsified and dissolved oil
Pesticides	2,4D and DDT	High organic matter, benzene ring

Industrial pollution in Swaziland is impacting on poor communities residing near waterways used as receiving waters. Matsapha is the main industrial area, and a growing number of industries use the Usushwana river (Little Usuthu) as a receiving body for waste discharge. These include a brewery, textile mill, steel and wire factory, cotton gin and a bottling company. The polluted water poses a severe health risk to communities located near the river who use it for domestic activities, such as cooking, washing and bathing. A 1992 study to evaluate the impact of the discharges of the industrial area on the quality of Usushwana river, showed conclusively that industries in Matsapha pollute the river. (Mtetwa 1992) The Swazi Paper Mill on the Great Usuthu river is another [illegible] contributor to water pollution, and a government report to UNCED indicated that the treatment of wastewaters was well below standard. ([illegible] of Swaziland 1991)

Pulp-and-paper mills are among the worst industrial polluters, as production requires strong chemicals, such as chorine, to soften wood pulp and bleach it. Large quantities of water are used, thus generating a large volume of liquid waste. Dioxins and other organochlorines end up in rivers, where they impair the reproduction of fish, retard their growth, or kill them.

Companies that manufacture military equipment can also pollute the environment through toxic and radioactive substances generated during the production of weapons. One example is the Kogelberg reserve in South Africa where the testing of missile fuels in the 1980s left residues that caused long-term contamination of aquatic ecosystems. In late 1991, the Atomic Energy Corporation of South Africa caused a huge spill of 80,000-100,000 tonnes of caustic soda near the Hartbeesport dam, killing fish and aquatic animals. (Chenje and Johnson1994)

In coastal areas, most industries dispose of untreated wastes directly into streams or rivers running into the ocean. Industrial wastes are found in ocean waters near major centres along the entire coastline – from Dar es Salaam and Maputo on the east coast, past Natal and Cape Town to Walvis Bay and Báia do Cacuaco, 15 km north of Luanda. In Angola, untreated industrial residues from cement and battery factories, an oil and soap factory, and a petroleum refinery are drained directly into the Báia do Cacuaco. (Chenje and Johnson 1994)

6.4.1.3 Mining effluents

Mineral extraction has four main processes which can be extremely damaging to the environment. These are mining, mineral processing, pyrometallurgy and hydrometallurgy. The first two processes produce mined waste. This is essentially earthy in nature, and is hazardous if the mineral being extracted is dangerous (such as radioactive rock) or if it has been washed with toxic or harsh substances (such as cyanide, mercury, sulphuric acid) to separate the valuable materials from waste products. The waste rock and soil dug up during ore extraction, called overburden is piled in dumps which pollute soil and water. Surface waters draining the dumps of waste rock carry pollutants to agricultural land, drinking water supplies and aquatic ecosystems. The remaining processes (smelting, roasting and other methods [illegible] ore) produce waste materials in solid, liquid and gaseous form. (Chenje and Johnson 1994)

Any form of heating (combustion, smelting or calcining of minerals) produces contaminated water, noxious gases and fine dust. Gold ores in Botswana, South Africa and Zimbabwe contain arsenic which is released during roasting [illegible] and this is an extremely dirty process, although some gold-roasters (such as Kwekwe in Zimbabwe) have sourced improved [illegible] to reduce the release of arsenic. Poisons often build up in the water systems near smelters, and some of these toxins find their way into food crops. The treatment of bentonite (highly absorbent clay used as a binding, filling or filtering agent) at Boane in Mozambique generated waste that could contaminate the water of the Matola and Umbeluzi rivers making it undrinkable. In Alto Ligonha, the rivers and other water sources surrounding the Morrua and Muane mines were also contaminated by waste products from the treatment of pegmatites. (Government of Mozambique 1991)

After the extraction of minerals, toxic substances remain in solid mine-waste and waste-rock powder which is deposited in the [illegible] at the mine-site, and can contaminate rainwater or other water passing through the tailings. In Zambia, the mining industry contributes heavy metals such as cadmium, lead and mercury into the river systems. Copper-mining activities are concentrated in the upper part of the Kafue river catchment. The river originates from the Zambia/Congo border and deteriorates substantially in quality as it passes through the Copperbelt because of the concentrated waste discharges. A great variety of concentration and refinery processes have been used and have resulted in the generation of large quanti-

ties of mineralised waste deposited in many dumps in the mining areas. (Chishiba *et al* 1997) The leachate from the dumps is contributing to the poor quality of the Kafue river. (Box 6.6) The pollution burden is passed on in the form of higher treatment costs to the urban communities who use the water for domestic supply.

The SADC Mining Sector reports that mining generates about 60 percent of foreign exchange for the SADC region, makes up 11 percent of the region's Gross Domestic Product (GDP) and 5 percent of total employment. (SADC Mining Sector 2000) The mining industry is an essential element of the economies of Botswana, Namibia, South Africa, Zambia and Zimbabwe as well as DRC, and is a major source of surface and groundwater pollution. (Moyo *et al* 1998) Ore extraction disturbs land surfaces and groundwater flows. In large excavations, groundwater drains downwards into the mine where it dissolves chemicals used in the mine and trace metals naturally present in underground rock. The contaminated water is then pumped out into surface waters. At Maamba colliery, an open-pit coal-mine in Zambia, acid drainage produces wastewater about 1,000 times more acidic than natural water. Similar problems occur at Emaswati in Swaziland, Moatize in Mozambique, and Morupula in Botswana, among others. (Chenje and Johnson 1994)

Mining industries pollute the Kafue river in Zambia **Box 6.6**

Copper-mining activities are concentrated in the upper reaches of the Kafue river catchment, in the northwestern region of Zambia. The Kafue is polluted upon entering the mining area; its water quality (suspended solids, hardness and chloride) is altered, and associated with the suspended solids are trace metals.

The national environmental standards for effluents are 100mg/l for suspended solids, yet suspended solids from run-off dumps in the rainy season are as much as 894mg/l. The permissible effluent level for dissolved copper has been set at 1mg/l.

At Hippo-pool, Chingola, copper levels were 120mg/l before declining to 21mg/l at Kitwe, 26mg/l at Ndola and 23mg/l at Mpongwe. Permissible dissolved cobalt levels are 0.5mg/l but at Hippo-pool, the cobalt levels are as high as 6.2mg/l.

The water is rendered hard when it enters the mining area. This arises from calcium and magnesium sulphate from the mines. At Mwambashi, 1426mg/l sulfate has been recorded. High sulphate levels lead to low pH. The mining activities in the Copperbelt have degraded the Kafue river, which is a source of drinking water for a number of urban areas in Zambia. The costs for treating the water for human consumption have escalated as the quality of the raw water deteriorated due to the mining activities.

Chishiba and Nkolonganya 1997

Acid mine drainage is an important phenomenon occurring in old gold- and coal-mines due to the presence of sulphur in the sulphide minerals, which become highly mineralised on contacting air and water. The reaction, which occurs when iron sulphide minerals are exposed to the atmosphere, produces ferrous sulphate and sulphuric acid. Effluent from the operating mines of the Wankie colliery in Zimbabwe is of poor quality and from their abandoned mines is worse because of acid mine drainage due to the presence of sulphide minerals and poor mine-closing practices. Sengwa coalfields, which are relatively new, have not exhibited much pollution. (Moyo *et al* 1998)

South Africa is also experiencing water pollution problems from its mining activities, which are probably causing the worst groundwater pollution problems in the country and also pollute surface water sources. (Box 6.7) A typical example is in the Upper Olifants river catchment where coal is mined for power generation. This has lowered the pH values to 2.9 (highly acidic) in the polluted headwaters of the Oliphants and Limpopo rivers (Van Zyl 1999) when the natural pH is 7.5.

Acid streams **Box 6.7**

The Klipspruit stream that flows through Soweto has been extremely polluted by acid and toxic metals from old mine-dumps and tailings dams. Residents of the informal settlements known as Chicken Farm and Klipspruit rely on the stream for drinking and bathing. Water sampling has found sulphates more than 2,000 times over the WHO standard. Cadmium and lead were at double the standard. Nickel levels were four times the standard, aluminium 20 times over, and mercury 60 times. Levels of dissolved uranium, cyanide and arsenic were also far above WHO standards, enough to make someone bathing regularly in the stream develop skin lesions, and possibly skin cancers.

Coetzee 1991

6.4.1.4 Radioactive and other hazardous wastes

When uranium is milled for use in nuclear power plants, about 15 percent of radioactivity is removed and the rest is discarded as "tailings". At the Rossing uranium mine, outside Swakopmund in Namibia, radioactive dust from tailings is controlled by applying large amounts of water, about 2,500 cu m/day, and by spreading natural non-radioactive material on top, which is expected to reduce the radiation emitted by about one-third. (Bergstrom

1992) A major concern at the Rossing mine is seepage and spills from the watered wastes, causing radioactive contamination of groundwater and the Khan river, after the containment pool leaked radioactive tailings into the river systems in the 1980s in a massive spill eight times larger than any previous spill. (Dropkin and Clarke 1992)

The only African country using nuclear power is South Africa, with a small fraction of the country's electricity provided from one site at Koeberg, some 30 km north of Cape Town. High-level waste is stored in cooling ponds at Koeberg for 10 years before the contaminated fuel rods (and medium and low-level wastes such as discarded equipment and disposable overalls) are trucked to one of the few nuclear-waste disposal sites in the world, opened in 1987 in the desert at Vaalputs in the northern Cape. After further storage in silos, it is sent to France for reprocessing – the separation of spent fuel into plutonium, uranium and other radioactive products. No system has been developed, anywhere in the world, for the permanent disposal of high-level nuclear wastes. (Fig 1994)

A related concern is the international trade in toxic and hazardous waste. The industrialised countries of Europe, North America and Asia have developed stringent controls over toxic waste which make disposal complicated and expensive, but the lack of controls in some parts of the SADC region make it an attractive destination for companies managing toxic waste.

The importation of hazardous substances into southern Africa was a major issue a decade ago, when South Africa's former homelands received lucrative offers from foreign companies to accept shipments of toxic wastes, although most refused. Botswana, Mozambique, Zambia and Zimbabwe also rejected overtures by Prodev, a South African waste-hauling company, to import and bury wastes, expressing concern that these would leak into groundwater. Pesticides, asbestos and chlorine compounds were on offer, as were industrial sludges containing lead and heavy metals. Manufacturers in industrialised countries were facing tougher and more expensive restrictions on local disposal of hazardous wastes, with incineration costs in the United States at US$1,500 per tonne and in Europe, $2,000 per tonne. A World Bank survey found that Africa was more economic, with the cost for toxic-waste storage facilities in West Africa, at most, $50 a tonne. The issue was of grave concern because southern African countries lacked the facilities, regulations and safeguards to handle such waste. (Opsal 1990) South Africa and most countries in the region have now ratified the Basel Convention on the Transboundary Movements of Hazardous Wastes and their Disposal, which governs movements of dangerous waste products, requiring governments to be notified of the import or export of the defined wastes. (Box 6.8)

Mercury (Hg) **Box 6.8**

A US newspaper investigating reports of pollution resulting from US waste shipments in the late 1980s found massive concentrations of mercury downstream of the Thor Chemicals plant in South Africa, then the world's largest mercury recycling plant. Water samples contained more than 1,000 times the WHO standards for drinking water, among the highest levels of mercury pollution ever recorded. Greenpeace subsequently collected river sediment samples containing more than 8,000 times the amount necessary to classify it as a hazardous waste in the US. (Vallette and Spalding 1990)

The stream is used locally for drinking and bathing, and further downstream joins the Umgeni river which supplies drinking water to Durban and Pietermaritzburg. Mercury, the only metal that remains liquid at normal temperatures, is extremely poisonous, attacking the central nervous system and the brain, causing seizures and eventually coma.

Following the newspaper's investigation, the then government closed Thor Chemicals for four months due to "trouble controlling mercury in effluent" because of increased production and "recent heavy rains" which caused the holding ponds of mercury contaminated liquids to overflow. However, Thor soon resumed its operations. South Africa's laws did not bar imports of the mercury waste recycled by Thor Chemicals because loopholes existed which allowed the waste to be considered raw materials or materials to be "recycled".

Chenje and Johnson 1994

6.4.2 NON-POINT SOURCES

Non-point sources of pollution are diffuse in nature and may be discharged over a widespread area or from a number of small sources. Such sources are difficult to control since pinpointing the origin of the pollution is not altogether possible, but their cumulative impact can be significant to the receiving waters. Much of the non-point source pollution occurs during the rainy season, which can result in large flow rates that make their control difficult.

6.4.2.1 Smallscale and diffuse mining operations

The mineral endowment in southern Africa has resulted in a proliferation of smallscale mining activities around the mineral-rich belts such as the Copperbelt of Zambia and the Great Dyke of Zimbabwe. The gold-mining boom in Tanzania poses a serious pollution hazard because of weak controls and enforcement. Siltation caused by smallscale diamond-mining has destroyed fishing in some areas of northeastern Angola. (Chenje and Johnson 1996)

Smallscale mining operations are fraught with problems in large part because of the absence of effective regulatory controls, and activities such as illegal gold panning resulting in the generation of poor quality leachates and effluents, which are polluting the water resources. Increased river siltation occurs during heavy rains in areas where improper gold panning is practised. This is due to soil compaction and deforestation along the riverbanks, which accelerates runoff, washing of sifted material piled loosely on the riverbanks and in the riverbeds, and collapsing riverbanks which have been undercut with tunnels.

In addition to the physical degradation, highly toxic chemicals such as mercury and acids are often used to separate gold from the ore and poor handling practices result in pollution of the waterways. Recently, mining activities for gold and other minerals in Tanzania have expanded rapidly. This is occurring without adequate safeguards in place and if it is not checked and properly controlled then the potential for serious mercury contamination exists in rivers draining Lake Victoria. Such an occurrence could prove disastrous for the lucrative export fishery.

6.4.2.2 Agricultural chemicals

The use of fertilizers and biocides has brought major benefits to agriculture in the region but uncontrolled handling, storage and application have also led to widespread contamination of surface and groundwater. The term "biocides" refers to toxic chemicals produced specifically to kill pest organisms, *eg* herbicides, insecticides and fungicides. FAO issued a warning in April 2002 that the threat of dangerous and obsolete pesticides is at its worst ever in parts of Africa, amid concerns of these chemicals entering the water supply and the food chain. The SADC countries singled out for mention by FAO are Botswana, Mozambique, South Africa and Tanzania.

Botswana's fertilizer usage is 1-2 kg/ha. (Mpotokwane 1992) This figure is extremely low when compared to South Africa (65), Swaziland ([illegible]), Mauritius (256) and Zimbabwe (57). (Cooper 1991) However, these average national figures may conceal high local variations. Mishandling, storage, transport, and excessive application of fertilizers, pesticide, and herbicide use can lead to severe pollution of water resources, soil, wildlife species and other biota. While industries and domestic sewage are the main sources of pollution in developed countries, agriculture plays a relatively bigger role in developing countries due to clearing of land, the use of fertilizers and pesticides, and irrigation.

A case study of agricultural development in Botswana has noted that in 1988 and 1989, 21 different kinds of pesticides and related chemicals were in use, ranging from aldrin to aldicarb, both of which are suspected carcinogens. In Mpandamatenga, the possibility of borehole contamination has been attributed to types of pesticides which are either banned or highly controlled in most developed countries. (Cooper 1991)

The organochlorine pesticides aldrin, chlordane, DDT, dieldrin and lindane are prohibited in Mozambique. However, DDT and dieldrin are still used in Swaziland and there is reason to believe that DDT is still in use illegally at small farms in Mozambique, since it is cheap and easy to handle.

DDT, which can bio-accumulate in living tissues, has been extensively used in the northern part of Namibia to control malaria mosquitoes. DDT levels in Namibia have been monitored in the environment by analyzing for chlorinated hydrocarbon residues in the eggs of fish-eating birds. While DDT levels along perennial rivers are generally low, higher levels were found in the eggs. One of the best-documented cases of pesticide bioaccumulation involves DDT on Lake Kariba. (Box 6.9)

6.4.2.3 Livestock, wildlife and poultry

In a catchment that is predominantly rural-based, the activities from farming still have a profound effect on the quality of impoundments. The washings of animal droppings and burnt vegetation have been found to cause an impoundment to become eutrophic and bacteriologically contaminated. These sources have not been taken seriously in this region but experiences from other parts of the world suggest that they are important sources of pollution and often it is the cumulative impact of many such

DDT levels in Lake Kariba **Box 6.9**

Although DDT and other persistent pesticides are now banned in most industrialized countries, they are still used in some African countries. DDT was widely used in Zimbabwe for tsetse fly control operations, which may be the main reason for current levels of DDT in the aquatic fauna of Lake Kariba. The local people around the lake depend on fish as a food resource, and one consequence of the widespread use of DDT in the Zambezi valley has been high levels in the breast milk of nursing mothers. A study by Berg *et al* (1992) investigated organochlorine pesticides, mainly DDT and metabolites in fish, mussels, prawns and birds in Lake Kariba. DDT seemed to be bio-accumulating and the levels were relatively high but did not differ much from temperate lakes.

- The macrophyte feeder, *Tilapia rendalli* had 1900ng DDT g^{-1} fat; while
- the level in the predatory tigerfish, was 5000ng DDT g^{-1} fat;
- the highest levels were found in bottom-living species, the mussel (*Corbicula africana*) at 10 000 DDT g^{-1} fat; and
- bethic feeding fish such as *Labeo altivelis,* 5700ng DDT g^{-1} fat.

The main commercial fishery in Lake Kariba is for kapenta (*Limnothrissa miodon*) which was found to contain 1 000ppb, based on fat weights. These DDT levels do not yet pose a health hazard to human beings, but indicate a growing trend that could pose potential problems in the near future.

Berg *et al* 1992

Pollutants	Sources
Nutrients, pathogens, organic matter	Domestic wastes, overloaded sanitation systems, night soil dumping, surcharging sewers, absence of sewage services
Heavy metals, hydrocarbons, oils, toxins, NO_x, SO_2	Vehicle emissions, industrial emissions, spills, atmospheric deposition, pavements, roads
Plastics, paper, glass, organic compounds	Litter, inadequate, services, solid waste dumping
Suspended solids	Erosion, construction, vegetation removal
N-compounds	Urban pesticide spraying, fertilizers and herbicides
P-, N- and organic compounds	Vegetation, pollen, atmospheric deposition
Dust, chlorides, S-compounds leachates	Wind, rain and groundwater
Dissolved solids, chlorides phosphates	Washing of clothes, vehicles, etc.
Dissolved solids, sulphates, carbon, particulates	Burning of litter, wood and coal

sources that becomes problematic. Chapter 7 on watershed management outlines the stock levels in the region, which have [illegible] impacts on the environment.

6.4.2.4 Stormwater runoff

Urban runoff washes off dust, vehicle emission particulates, chemicals spilled or discharged in storm drains and other debris into the receiving water bodies. Such drainage water, if the storm drains are not properly designed, can be dirtier than the partially treated sewage effluent and is difficult to manage because of its non-point source nature.

The runoff from towns and cities can contribute high concentrations of lead (from exhausts), phosphorus and nitrogen (from decaying matter), spillages from sewage works due to storm water ingress into sewers and in addition, fertilizer residues from small cultivated areas and soils, sediments and silts from eroded lands to rivers in flood. Table 6.3 outlines the pollutants of concern in urban run-off and their sources.

6.4.2.5 Land degradation

Chapter 7 discusses the various contributing factors and implications of land and watershed degradation on the hydrology and sediment transportation deposition. Thornton and Nduku (1982) showed that drainage waters from heavily urbanized areas had nutrient contents 2 – 20 times higher than forested and savanna areas. The rate of deforestation in the region could be as much as 40 percent. ([illegible] and Manyenza 1989)

Before deforestation, rainfall over the catchment was intercepted by tree canopy; surface runoff and hence soil erosion was minimal. Clearance of protective vegetation has resulted in increased surface runoff and breakdown of soil structure. Livestock overstocking has led to widespread denudation of pasture and soil erosion, especially in Botswana and Swaziland, and overgrazing has led to widespread soil erosion in Zimbabwe's communal lands.

Erosion leads to sedimentation, which is a serious threat to the longevity and efficiency of surface water storage works in southern Africa. On a regional scale, most reservoirs lose 25-35 percent of their storage capacity in 20-25 years. (Magadza 1995) Imagi dam in Tanzania is an appropriate example of the role of deforestation in sedimentation of dams. (Box 6.10)

Reservoir sedimentation: Imagi dam, Tanzania **Box 6.10**

Imagi dam was constructed in 1929. In 1940, clearing of the woody vegetation of the catchment was initiated resulting in an increase in the transport of silt into the Imagi dam but also resulting in a gradual improvement of the grass cover. A dense grass cover is a comparatively efficient barrier to splash, as well as sheet, erosion. Consequently, the annual sediment yield during this period was kept at a reasonable level (500 cu m/sq km) until the end of the 1940s. Then, limited grazing by livestock started and that immediately effected an increase on the rate of erosion. By 1980, 89.7 percent of the original volume remained. In the beginning of the 1980s, a number of dry years occurred and grazing in the catchment became more intense. The annual total sediment yield then increased to 833.3 cu m/sq km. Imagi dam still continues to lose its storage capacity. Only 40 percent of the original volume now remains.

The extent to which turbidity is a natural feature of southern African streams is unknown, although silt-laden rivers seem to be a feature of many parts of the Southern Hemisphere. It is known that practices such as overgrazing, non-contour ploughing and removal of riparian vegetation accelerate the rates of erosion and result in increased quantities of suspensoids in streams.

Many South African waters are naturally silty, and quite a number have seen their silt loads increase noticeably as a result of agricultural malpractices. (Davies and Day 1998) Most impoundments in the Free State, the Northern and Eastern Cape, KwaZulu-Natal, the Northern (now Limpopo) province, North-West and Mpumalanga, suffer from rapid siltation. The high silt load in the reservoirs causes the water to be brown and turbid, thus reducing sunlight penetration.

The Olifants river in South Africa is well known for its sediment load. The river has a permanent muddy appearance and sediment loads up to 100mg/l during high flow periods. (Van Zyl 1999) The capacity of such impoundments as Phalaborwa barrage has been reduced by 30 percent. There is little research information on the state of erosion in Mozambique but observed evidence suggest that soil erosion is a localized problem, and is confined to the hilly parts of Manica province, cotton fields in Nampula and Cabo Delgado provinces, around urban centres and steep coastal slopes.

6.4.2.6 Airborne particulates

Pollution that is emitted into the air from both point and non-point sources eventually settles back to the ground and is then carried as non-point source pollution across the landscape or into watercourses. The burning of fuelwood, bushfires, exhaust fumes and the use of coal in factories has similar effects. The major emitters in the SADC region are located in the Gauteng and Cape provinces of South Africa, the Congo-Zambia copperbelt, the Great Dyke mining area of Zimbabwe, eastern parts of Botswana, and the Tsumeb area of Namibia. This is where most smelters are situated.

One of the major and more obvious forms of air pollution is sulphur dioxide emissions (Table 6.4) which can be deposited back on land either as wet precipitation (acid rain) or dry deposition (on soil, plant leaves and water), potentially destroying forests, acidifying lakes and rivers, corroding materials and affecting human health. Rainwater dissolves the pollutants in the air and on the ground and introduces them into waterways and impoundments affecting the water quality, as was the case with Goreangab dam in Windhoek, Namibia.

The major air pollutants that affect water quality in southern Africa are sulphur compounds, carbon monoxide, hydrocarbons, nitrogen compounds and a range of volatile organic compounds.

Particulate matter, which contains toxic metals such as lead, is also a major problem. Poisonous metals such as

Country	Power production	Industry/mining	Domestic	Traffic	Total
Botswana	8 363	197 213	240	457	206 273
Lesotho	-	75	845	71	991
Mozambique	1 400	758	2 012	1 277	5 447
Namibia	500	29 205	150 940	30	795
South Africa	599 207	99 220	12 300	29 305	740 032
Swaziland	-	3 400	161	260	3 821
Zimbabwe	60 090	52 330	1 523	2 361	116 304
TOTAL	669 560	382 201	17 231	34 671	1 103 663

Sivertsen *et al* 1995, in Chenje and Johnson 1996

mercury, lead and the carcinogenic spirit benzene are present in the air and can potentially contribute to water pollution. For most southern African countries the average annual concentration for suspended particulate matter is about 45 micrograms (μg)/cu m which is below the WHO maximum permissible level of 60μg/cu m. (Ngara *et al* 1998) No attempt has been made to quantify the contribution of suspended particulate matter in the air in water pollution, but it appears that this is not a significant problem.

Sulphur dioxide is increasing in quantity and current levels in some major cities in southern Africa are approaching the WHO's maximum permissible level of 150 μg/cum. The annual average level in most countries of the region is about 102 μg/cu m. The impact of sulphur and nitrogen compounds in the air on water pollution has yet to be evaluated.

Properly designed sanitary landfill **Box 6.11**

A properly designed sanitary landfill can help to improve otherwise useless land for a variety of productive uses. It involves daily covering the waste with soil, lining the base for leachate trapping, leachate collection and treatment, establishment of run-off control drainage and covering it at the end of its life.

Advantages
- Can receive all types of solid wastes.
- Operation can be terminated without a great loss in equipment or land.
- Requires less land than open dumping.
- Usually the most economical method of solid waste disposal.
- A complete form of disposal with nothing remaining for further disposal.
- Subsequent land can be reclaimed for use as parks, playgrounds, golf courses, etc.

Disadvantages
- Large amounts of land required.
- Groundwater pollution prevention may be costly.
- Cost of waste transfer may be considerable.

6.4.2.7 Solid waste

Solid wastes are non-liquid waste materials arising from domestic, trade, commercial, industrial, agricultural and mining activities, and the disposal of such waste is a problem in all SADC countries. The problem of solid waste management is associated with rapid population growth, unplanned urbanization and overcrowding of large cities, industrialization, generation of agricultural wastes, inadequate organisational and legislative provisions, and lack of public participation.

Urban areas are growing at a much faster rate than the expansion of the necessary infrastructure and services, and this presents a major waste management challenge to the authorities in large cities such as Luanda, Lusaka, Dar es Salaam, Maputo, Kinshasa, Blantyre, Johannesburg and Harare. Box 6.11 makes the case for sanitary landfilling as a practical solution.

Much of the solid waste generated in developing countries is composed of vegetables and biodegradable matter, more than in developed countries where much of it is composed of paper, wood and plastic. Full knowledge of the composition of solid waste serves the selection of the type of storage and transport, determination of resource recovery, choice of a suitable method of disposal, and the determination of the environmental impact exerted by the wastes if they are improperly managed.

In some Angolan cities, trash is dumped into rivers close to the dwellings because excreta disposal facilities may not be available and garbage collection is infrequent or non-existent. When the rains come, all the accumulated waste is washed away.

During the past three decades, urban centres have continued to grow in terms of population, but efforts to control and manage environmental pollution in urban areas have been insufficient. The volume of garbage that must be stored, collected, transported and disposed of has increased substantially in recent years, and urban solid waste now creates large environmental problems in most countries in the region. Box 6.12 depicts the solid waste generation rates for different types of settlements in general, and in Tanzania in particular. In Arusha, Mwanza, Mbeya, Moshi and other towns in the country, it was estimated a few years ago that just 20-30 percent of urban solid waste generated was collected and disposed. (Yhdego 1995)

The situation in Lusaka is similar to Dar es Salaam. It is estimated that over 1 million tonnes of municipal wastes are generated per year in Zambia, with Lusaka province accounting for 1/3 of this figure. (Chipungu and Kunda 1994) Most of the waste is crudely dumped in open spaces, at roadsides, or in disused quarries and pits. The waste is composed of paper, packaging plastics, glass, vegetables, textile and agricultural wastes. Most of the solid wastes generated in the country are not collected. The city of Lusaka, for example, is able to collect only eight percent of the total amount of waste produced per day. The remaining 92 percent contributes to pollution.

General

The municipal refuse generation rate depends on the level of the income. The following rates may be used to estimate the quantity of solid waste generated per day from several types of settlements in urban areas.

Types of settlements	Generation rates (kg per capita/day)
Residential refuse	0.3 to 0.6
Commercial refuse	0.1 to 0.2
Street refuse	0.05 to 0.2
Institutional refuse	0.05 to 0.2

Case of Tanzania

A study conducted in Tanzania over a decade ago indicated that more solid waste was generated in high-income areas than in squatter areas due to the fact that in low income areas the process of recycling was more developed. The generation rate of solid waste in urban areas of Tanzania at that time in comparison to other cities in Africa is shown below.

Municipality	Generation rate (kg per capita/day)	Average density (kg/cu m)
Arusha	0.19 in squatter areas	275
	0.36 in serviced areas	
Dar es Salaam	0.17 in squatter areas	550
	0.33 in serviced areas	330
Moshi	0.49	-
Kano, Nigeria	0.46	250
Cairo, Egypt	0.50	330

Mashauri and Mayo 1989

While such statistical data is not available for Maputo city, the failure by successive municipal authorities to organize regular refuse collection is legendary. However, in early 2002 the Maputo city council put in place an innovative new mechanism to ensure payment of refuse collection fees by reaching agreement with the publicly owned electricity company to collect on behalf of the city. This is expected to raise US$1.25 million a year. (Telinforma 2002)

Similar problems are being faced in South Africa's Jukskei river catchment (Box 6.13), located in the heart of the Gauteng province, one of the wealthiest areas in the SADC region. The catchment is highly urbanised, containing both high-income and low-income areas, and the river is South Africa's most polluted river. (Van Zyl 1999)

Effluent from dumps often contains hazardous materials such as mercury or cadmium from old batteries, cadmium from fluorescent lights, toxic chemicals, paints, old motor oil, cleaning solvents and chromium-contaminated sludge from the tannery. Most municipal wastes contain little hazardous material, but solid wastes of industrial origin may contain a much higher proportion of toxic materials such as metals and organic pollutants. The most serious threat to groundwater occurs where there is uncontrolled disposal of and illegal dumping of materials rather than controlled sanitary landfill.

Solutes are transported by the bulk movement of the flowing groundwater, a process called advection. Solutes pose particular risks to groundwater in the vicinity of landfill sites. Leachates may contain contaminants such as pathogens, metals and organic chemicals depending on the materials deposited at the site. However, most leachates from municipal wastes are usually rich in biodegradable organic matter. But it is also important to monitor methane in groundwater close to waste disposal sites, especially where oils and greases are dumped.

Solid waste has a direct health impact and an indirect impact on the ability of people to tolerate disease caused by other factors. Illnesses related to solid waste are mainly caused by five groups of organisms: viruses, bacteria, fungi, parasitic protozoa, and helminths. These organisms may be transferred by common vectors such as rats, flies, cockroaches etc. Improper discharge of solid waste in open drains or streams may result in creation of breeding sites for disease vectors. Generally if solid waste is not properly disposed and treated it may cause:

- rodents infestation and odour; as well as illness (plague, marine typhus, rat-bite fever, salmonellossis, and others) and inability to tolerate disease caused by other factors;
- atmospheric pollution due to onsite burning of solid waste or uncontrolled and incomplete combustion of materials hence increasing sulphur dioxide, nitrogen oxide, and other noxious gases;
- environmental degradation; and
- water pollution due to washoff of solid waste to surface water or the flow of leachate from the open crude dumps to surface waters and groundwater.

Solid waste disposal dumps are now emerging as major sources of surface and groundwater pollution in most of the urban centres in southern Africa. For example, one study showed that the total waste generation for Gaborone is 84 tonnes/day (Dorham *et al* 1991), and

Impact of open crude dumping of solid waste on surface water – Jukskei river pollution, Alexandra **Box 6.13**

The sprawling township of Alexandra is adjacent to the Jukskei river, in the heart of the Sandton/Johannesburg industrial area. It has a population density of 600 to 700 persons per hectare and is obviously over-populated.

Up to the mid-1980s there was no sewer system and a system of night buckets was in operation. When the sewer system was finally put in place, some areas were still not covered. This resulted in an overloaded system prone to failure, and sewage being discharged into waterways.

Informal settlements are a common phenomenon in South Africa, and some dwellings are built on top of covered stormwater drains which are then used as handy dumps for refuse which gets washed away during storm events. Refuse is also dumped into the river and on the main streets.

In 1992, an initiative was started by forming an integrated team based on participatory and cooperative management. The team first took to understanding the problem, then focused on capacity-building, empowerment, training, creation of a new, urban water-care culture, development of strategies and control mechanisms.

An extensive situation analysis was carried out, management and water quality goals were developed and a catchment management monitoring system was implemented. Clean-up and river restoration operations were undertaken. The blocked sewers were unblocked and a refuse removal system was put in place.

Despite all this effort, the diffuse pollution problems got worse and the E-coli. counts in the river were averaging 3 million counts per 100ml.

Action was then extended to address cultural values, attitude, and social issues. Awareness campaigns were established targeting women and schoolchildren. Cultural activities and empowerment programmes were initiated, stormwater capture systems were put in place and informal settlers were resettled properly.

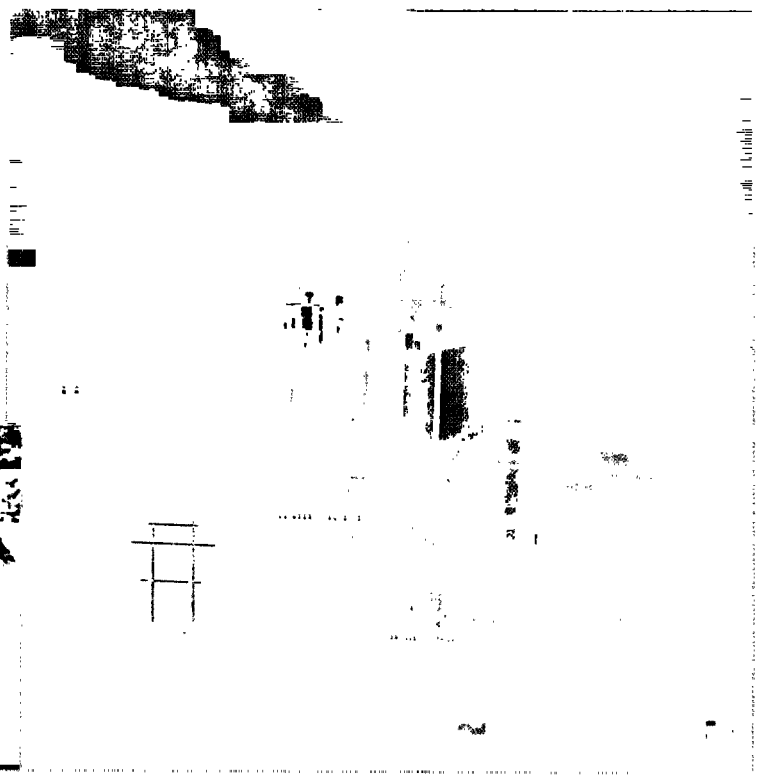
Nonetheless, pollution continued to worsen and E-coli. counts went up to 8 million counts per 100ml.

This goes to show how difficult it is to bring down the effects of diffuse pollution emanating from stormwater drainage, especially in overpopulated areas. It is clear that diffuse source pollution requires extensive strategic and tactical management.

Adapted from Van Zyl 1999

refuse is a mixture of domestic and industrial refuse. The indiscriminate mixing of waste substances is a very poor management practice that may lead to a highly toxic leachate. Largescale groundwater pollution near landfills is caused by contamination through the leachate. Refuse dumps in Botswana are poorly designed. They are not fenced, and compaction, which is an important management activity, is not regularly and properly done at the city dumpsite. (Dohrman *et al* 1991) There are anxieties about the proximity of the present dumpsite to the Gaborone dam, as leachate may seep into the dam.

SOE Zambezi – CEP



SOE Zambezi – CEP

I. Basto

6.5 CONSEQUENCES OF POLLUTION

The degradation of water quality limits its uses and can render a whole water body useless. The effect is not only on aquatic life, but also on the water resource base itself. Pollution may exacerbate water scarcity and impose a huge cost on other uses.

This section briefly discusses the main consequences of water pollution including algal blooms and eutrophication of impoundments, effects on aquatic life, salinization and general deterioration of domestic water quality with serious impacts on treatment. Water quality degradation has a major economic impact because the value of the resources is grossly affected and often requires significant input to bring it to a useable state. However, the cost of rehabilitating a degraded resource is usually not quantified and thus not considered in the decision-making process.

In addition, the consequences of water pollution often fall disproportionately on the poorer segments of the society because of their limited access to water supply sources and sanitation facilities as well as limited options in general.

The effects of some common pollutants are summarized in Table 6.5

6.5.1 Algal blooms

Nitrogen and phosphorus are the key nutrients that contribute to the eutrophication of surface water bodies. Thornton and Nduku (1982) suggest that the 25-30 micrograms(mg)/l phosphorus concentration which is generally accepted as being the borderline for eutrophication might be somewhat low for tropical African lakes, especially artificial ones. They imply that these systems can withstand a higher level of phosphorus-loading than temperate lakes without being demonstrably eutrophic, and they suggest that 50-60 mg/l might be a more realistic range for phosphorus.

Nitrogen concentrations measured in tropical systems are not significantly different from those of temperate systems insofar as their effect on eutrophication is concerned. The concentration between 0.2 - 1.0 mg/l (total nitrogen) is the critical range for nitrogen in African lake systems. (Thornton and Nduku 1982) Water quality management strategies must therefore target the reduction of nitrogen and phosphorus in wastewater before it is discharged into rivers and lakes.

The Jukskei/Crocodile river system in South Africa, which receives treated sewage effluent from parts of Johannesburg, is an "excellent" example of severe eutrophication in the Southern Hemisphere. Over the last few years, total phosphorus loads to Hartbeespoort dam on the Crocodile river have varied between 80 and 418 t/yr, and the concentrations have ranged between 0.2 – 2.0 mg/l of which 60 percent is immediately accessible to aquatic plants. (Davies and Day 1998)

In the Eastern Cape, the Buffalo river also receives sewage effluent, which is drained into the Laing reservoir. Other examples of reservoirs made eutrophic on a seasonal basis by sewage effluent are Lake Chivero in Zimbabwe, Roodeplaat dam in South Africa, and Lake Victoria in East Africa. Total nutrient loads entering Lake

POLLUTANT	SOURCE	EFFECTS
Nutrients	Municipal waste Run-off from agriculture	Eutrophication of impoundments Health effects in drinking water
Salts/salinisation	Poor drainage High evaporation rates Overpumping of coastal aquifers Irrigation Clearing of natural forests for agriculture	Aesthetic value of water lowered Agricultural land lost Difficult to remedy Damage to pipes and pumps
Organic wastes	Domestic sewage Industrial sewage	Oxygen depletion Complexing into carcinogens
Organic micro-pollutants	Industrial origin Urban and agricultural runoff Atmospheric fallouts Urban and industrial wastewater Solvents and aerosols	Immediate short term toxicity Long term exposure toxicity Carcinogenic
Faecal material	Domestic sewage Stormwater drainage Onsite sanitation contamination	Contain pathogens Water-borne infections
Toxic compounds/Heavy metals	Processing of ores Industrial use of metals Leaching from dumps	Bio-accumulation in aquatic organisms Heavy metal poisoning
Atmospheric emissions	Fossil fuel combustion	Acid rain Decrease water and soil pH Impair reproduction of aquatic life Exposes humans to toxic metals leached from soils
Sediments/Turbidity	Soil erosion Organic formation within a water body Human activity by-products	Impairment of aquatic life Increases costs of treatment

Victoria have not been measured yet, but estimates indicate that the most significant contributor is airborne particulates originating from bushfires and dust from outside the lake boundary.

The immediate consequence of severe eutrophication is the massive algal blooms, particularly *Microcystis aeruginosa* which dominate the phytoplankton population in Hartbeespoort dam and Lake Chivero. *Microcystis* scum accumulates along the edge of most eutrophic reservoirs, and can produce a toxin called microcystin, which has killed a number of cattle in South Africa. However, no cattle deaths have been reported around Lake Chivero, suggesting that the strain of *Microcystis* in that lake does not produce the toxin. The algal blooms also interfere with the drinking water treatment process because of filter clogging.

Generally, eutrophication leads to water purification problems, and taste/odour in potable water is associated with eutrophic water bodies.

6.5.2 Proliferation of macrophytes

Hartbeespoort dam, Lake Chivero and Kafue river are examples of "hot spots" where eutrophication has led to proliferation of aquatic weeds, especially the water hyacinth (*Eichhornia crassipes*), and where urgent measures are required to curb pollution. (See chapter 8)

The water hyacinth is a cosmopolitan plant that is found in water bodies with both low and high nutrient levels. Its growth is seasonal and is enhanced in eutrophic water bodies. In 1989, water hyacinth infestations reached unprecedented levels in Lake Chivero, prompting the government to declare it a national disaster. The weed was brought under control after spraying with 2,4D. The main problem with the water hyacinth is that it interferes with

navigation, causes localized deoxygenation which may lead to fish kills and a decline in plant species, and it also interferes with fishing activities.

The rapid spread of the water hyacinth in recent years in Lake Victoria has been exacerbated by of the increasing pollution of the lake resulting from the region's burgeoning population. In the last few years, places like Lake Kariba, which did not previously have water hyacinth, have become infested.

6.5.3 Impairment of fish and other aquatic species

Water pollution can impair the reproduction of fish and other aquatic species, retard their growth or even kill them. Massive fish deaths have occurred in Hartbeesport dam, Lake Chivero and the Kafue river. More than a million fish died in a four-week period in Lake Chivero, Zimbabwe in early 1996 as a result of deoxygenation of water, which was compounded by ammonia toxicity. (Moyo 1996)

Endosulphan spraying operations in the Okavango delta for tsetse fly eradication resulted in a significant accumulation of the insecticide in fish, which can lead to death. Douthwaite *et al* (1981) and Matthiessen *et al* (1982) showed that endosulphan is highly toxic to fish, and Douthwaite also reported the effect of endosulphan on the reproductive behavior of *Tilapia rendalli*, reduction in the number of nests and development of a weak year-class related significantly to the year of spraying. The toxicity to those who consume fish that have survived endosulphan spraying was considered minimal. Fish kills have also been reported from Swaziland, downstream of the country's pulp mill.

In Lake Kariba, Berg *et al* (1992) found that DDT was bioaccumulating and biomagnifying. High levels of DDT in tigerfish eggs indicate that the reproduction of fish is at risk. (Matthiessen *et al* 1984) Evidence already suggests that there are lower numbers of insects and insect larvae in Lake Kariba now than in the earlier stages of the lake's history. (Berg 1996)

It is important to note that pollution of small waterbodies occurs as a result of their use by humans. In Lesotho, for example, dams around towns tend to be used by the population for washing clothes, cars and engines. As a result, they have become so polluted that they can support few fish other than carp, *Cyprinus carpio*.

Contamination by heavy metals is associated with industrialization. In their study of heavy metals in African Lake ecosystems, Greichus *et al* (1978) showed that the levels of these substances were highest in Hartbeespoort Dam because of the heavily industrialized catchment area. Little is known about the effects of these pollutants on fish in the region. However, a recent study by Mwase *et al* (1998) on the effect of metals on fish in the Kafue river gave some insights. Copper and cobalt are present in high concentrations in fish caught in the Copperbelt area. Larval stages are the most sensitive to copper. Sediments with high concentrations collected near Kitwe caused dramatic fish mortalities under experimental conditions. The gills of these fish were hyperplastic. (Mwase *et al* 1998)

As noted previously, soil erosion is a serious problem in much of southern Africa and is having an impact on aquatic environments. There is evidence to show that the littoral areas of Lake Tanganyika are beginning to suffer from the blanketing effect of sediment carried into the lake. (Cohen *et al* 1993) Suspended sediments in the water lead to high turbidity, which, in turn, affects productivity and fish growth. The growth rates of *Barbus* and *Labeo* species in Lake le Roux, South Africa were greatly reduced when transparency of the water decreased. (Merron and Tomasson 1984)

When anthropogenically derived increases in suspensoids are infrequent, the communities of organisms living in a stream may easily tolerate them. Continuously high levels of suspensoids may, however, have serious consequences for the biota of a river. There is need to institute research to quantify the impact of turbidity on the biota of rivers and lakes.

6.5.4 Salinization

Salinization is an increased concentration in water or soil of mineral ions, particularly sodium, chloride and sulphate. Increases in the salinity of inland waters are an emerging problem in southern Africa where certain human activities are increasing the total dissolved solids content of water bodies. Irrigation is a major culprit, and the Vaal–Hartz irrigation scheme in South Africa is responsible for a three-fold increase in the concentration of total dissolved solids in the Hartz river. (Allanson *et al* 1990) Disposal of domestic and industrial effluent has led to salinization of some water bodies. Sewage effluent discharged into the Crocodile river north of Johannesburg, for example has caused the concentrations of chloride and sulphate ions to rise by 178 percent and 151 percent respectively. (Allanson and Rabie 1989)

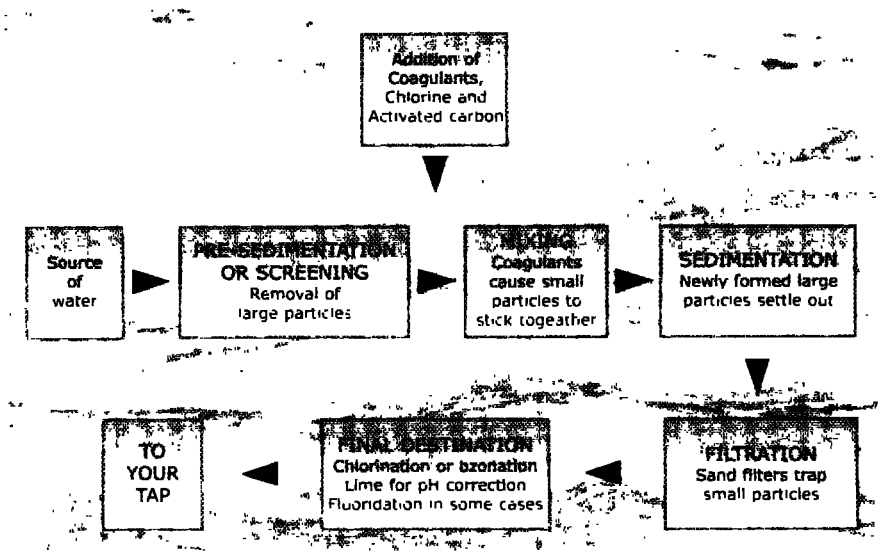
Salinity in the Vaal river and Vaal dam has increased at

an alarming rate in the last 25 years, with the concentrations of total dissolved solids in the dam are rising at a rate of 2.5 mg/l every year. (Davies and Day 1998) The levels of solids in Lake Chivero have risen from 7 mg/l in the 1950s to 37 mg/l in 1991 because of sewage effluent discharged into the lake. (Marshall 1994)

Purification of water from the Vaal dam and Lake Chivero has become expensive. In South Africa, the quality of water of many rivers, particularly the Great Berg and Breed rivers in the south-western Cape, and the Sundays and Fish rivers in the Eastern Cape, is rapidly declining as a result of irrigation-induced salinization. Total dissolved solids levels in the Sundays river exceed 1000 mg/l. The effect of salinisation resulting from mining activities are evident not only in the Vaal river, but also the Buffalo, Mkuzi, Pongolo, Wasbank, Mfolozi and Tugela rivers.

The latest research on the effects of changes in salinity on warm-water aquatic species is being carried out at Rhodes University in South Africa, at the Centre for Water in the Environment, and tolerance levels for southern African invertebrates will soon be published in the journal *Water SA*. Generally, the effects of changes in salinity are physiological, particularly affecting osmo-regulation processes. Sensitive species may be lost from ecosystems if salinity increases too much. The impact of increased salinity on fish is poorly understood but is an emerging problem.

Simplified Flowchart of Potable Water Treatment **Figure 6.1**



6.5.5 Deterioration of drinking water quality and waterborne diseases

Inadequate water supply and sanitation are largely responsible for the high levels of waterborne diseases in southern Africa. The vast majority of people in southern Africa live in rural areas and do not have appropriate sanitation systems. Not surprisingly, infectious waterborne diseases such as diarrhoeal diseases, dysentery, cholera and hepatitis are almost endemic in rural areas. Most of the faeces are deposited on land, providing an easy pathway for pathogens to enter surface and groundwater, and hence to the local population via contaminated drinking water.

Destroying pathogenic micro-organisms remains the primary reason to treat drinking water. Bacteria are naturally occurring in water. However, the presence of faecal coliform bacteria indicates the presence of human or animal wastes. Figure 6.1 shows a simplified flowchart of drinking water treatment processes.

If a dangerous pathogen, such as *Vibrio cholerae*, is introduced into a community with poor sanitation, poor water supply and poor food safety, an epidemic may ensue. Cholera is now endemic in some southern African countries. During the rainy season of 1998, Mozambique notified 26,783 cases of cholera and 619 deaths, DRC notified 13,440 cholera cases and registered 775 deaths. Cholera cases have also been reported in Angola, South Africa, Tanzania, Zambia, and Zimbabwe.

Exposure to faecal pollution has led to outbreaks of diarrhoea and dysentery in southern Africa. Children under 5 years of age living in settlements with rudimentary access to water supply and sanitation are the most susceptible. In 1995/1996, a *Shigella dysenteriae* type 1 epidemic in Kwazulu-Natal resulted in thousands of observed cases with many hundreds of deaths. (Rollis 1996) Levels of sanitation, standard of living and education are key factors in the transmission of intestinal pathogens. Countries in conflict such as Angola and DRC have very high incidences of diarrhoea and dysentery, but there is little data available.

6.5.6 Sediments/turbidity

Extensive farming within the river catchment areas has resulted in gully erosion causing rapid siltation of reser-

voirs and rivers in southern Africa. In recent years deforestation has become widespread, especially in areas with high population concentrations.

Soil erosion leads to an increase in suspensoids, which contribute to turbidity, the milky or murky appearance of water. Turbidity interferes with the passage of light through the water column and the deposited sediment alters the habitat of bottom-dwelling animals and plants in lakes and coral reefs. Wind and wave action in the shallow areas of such lakes stir up the sediment, preventing colonization of the shoreline by large plants and disturbing the spawning grounds of fish, particularly cichlids. Excessive quantities of suspensoids are a serious concern in South Africa and therefore are being subjected to a fair amount of attention. (Davies and Day 1998)

Clearance of protective vegetation results in increasing surface runoff and hence soil erosion. Sedimentation is a serious threat to the efficient utilisation of surface water storage works, and may even render water supply infrastructure useless.

The significant consequences of sedimentation and high levels of turbidity are in domestic water-supply treatment, causing water treatment to be difficult and expensive. The removal of suspended materials is effected by coagulation, sedimentation and filtration. If there is an increase in these impurities there will be an increase in the amount of coagulant used and hence an increase in the cost of treatment, to levels which may be uneconomic in terms of gross pollution.

6.6 EVALUATION OF WATER POLLUTION CONTROL AND MANAGEMENT

Water pollution includes the discharge by humans of substances into the aquatic environment that may be hazardous to human health, harmful to living resources and aquatic ecosystems, damage the amenities or interfere with other legitimate users of water. To know how much waste can be tolerated (assimilated) by a water body, the characteristics of the water body (flow, timing and quality) must be known, as well as the type and quantity of the pollutants discharged and the manner in which they affect water quality.

Water quality management is intended to protect the proposed uses of a water body while using water as an economic means of wastewater disposal within the constraint of its assimilative capacity. The standards-based approach to managing water quality relies heavily on regulations as the basis for achieving pollution control. Implementing such an approach is a daunting administrative challenge because of the inefficiencies involved. It does not appropriately take account of the assimilative capacities of water bodies nor does it promote innovations or any trading of pollution rights to take advantage of the economies of scale. It brings into question the viability of the traditional legislative or command-and-control approach.

Also most countries are shifting from the comparatively simple application of uniform effluent standards to a complex and yet integrated resource-based approach, *ie* the receiving water quality criteria, in which the concept of assimilative capacity of a water body is taken into account to avoid being unnecessarily over-protected.

The emerging framework of water quality management integrates the following:

legislative, including direct regulation;
standards of effluent or water quality,
and licensing;
legal, including compensation for damage and
fines for violation of laws; and
economic incentives including effluent charges or
tax subsidies and accelerated depreciation
allowances.

6.6.1 Regulatory approach

Water pollution control legislation in southern Africa started to be taken seriously in the 1970s when appreciable development started impacting on the aquatic environment. Table 6.6 shows the water-related legislative instruments in southern Africa. Some of these, such as the Water Acts of Angola, South Africa and Zimbabwe are fairly new. While most countries have legislative instruments in place to deal with pollution, the implementation is often ineffective. Most stakeholders including individuals and governments, and especially the private sector, have lacked the capacity, but also the political will, that is necessary for effective pollution control.

The Zambian and Zimbabwean Acts are similar to a large extent. They provide for control of discharges into public streams through permits; discharge without a permit is illegal. Discharging of substandard effluent is an offence and deterrent fines for offenders have been stipulated in the Acts. The levies in the regulations also help in discouraging discharge of poor quality effluent. Although the Standards of Effluent and Wastewater in Zimbabwe

Country	Agency responsible	Instrument	Subsidiary legislation
Malawi	Ministry of Water	Water Resources Act 1978	
Zimbabwe	Zimbabwe National Water Authority	Water Act-1998	Water Pollution Control (Effluent and Wastewater) Regulations -1999
Zambia	Environmental Council of Zambia	Environmental Protection and Pollution Control Act No.12 - 1990	1. Pesticides and Toxic Substances Regulations -1994 2. Water Pollution Control (Effluent and Wastewater) Regulations -1993 3. Waste Management (Transport and Waste Disposal Site) Regulations - 1993
Namibia	Department of Water Affairs	Water Act No. 54 - 1956	
Angola	Ministry of Energy and Water	Water Act-1996	
Tanzania	Ministry of Water	Water Utilisation (Control and Regulation) Amendment Act No.10 - 1981	Temporary Standards -1978
Mozambique	National Water Council	Water Law Act No. 16 of 1991	WHO Guidelines
South Africa	Dept. of Water Affairs and Forestry	Water Act - 1998	General and special effluent standards; General authorizations relating to water use
Swaziland	Swaziland Environment Authority	Water Act of 1967	
Lesotho	Department of Water Affairs	Water Resources Act No. 22 of 1978	
Botswana	Department of Water Affairs	Water Act of 1968	

were applied in a uniform fashion, the quality of water in rivers continued to deteriorate because in instances where water quality was already under stress, even effluent complying with standards could have a negative impact. To counter this deterioration and to meet the challenges of the future, a receiving water quality approach is being adopted, as already applied in South Africa.

The main thrust of the Zimbabwean legislation is the introduction of economic incentives and/or disincentives to reduce pollution. The first is the "polluter pays" principle, an economic disincentive (Box 6.14), and the second is a system of tax breaks related to pollution reduction measures. This is a positive economic incentive still to be worked out with the Finance Ministry. Another economic incentive is access to loans and grants for use in pollution abatement work and research, to be drawn from the revenue that is raised from levies.

The *water quality standards* reflect the quality of water to be supplied for human consumption, recreational or aquaculture farming and irrigation; while *effluent standards* refers to the quality of treated wastewater to be discharged to the receiving bodies. In this region, water treatment and wastewater treatment are aimed at removing pathogenic organisms rather than other pollutants.

Most southern African states have standards for various uses of water ranging from drinking water, recreation, agriculture and waste discharge (section 6.2 above). South Africa, Zambia and Zimbabwe have well-established standards for controlling water pollution, and Tanzania uses temporary standards for water quality and effluents passed in 1979. Where water quality standards are not yet set, the WHO guidelines are used, *eg* Angola, Malawi and Mozambique use WHO guidelines.

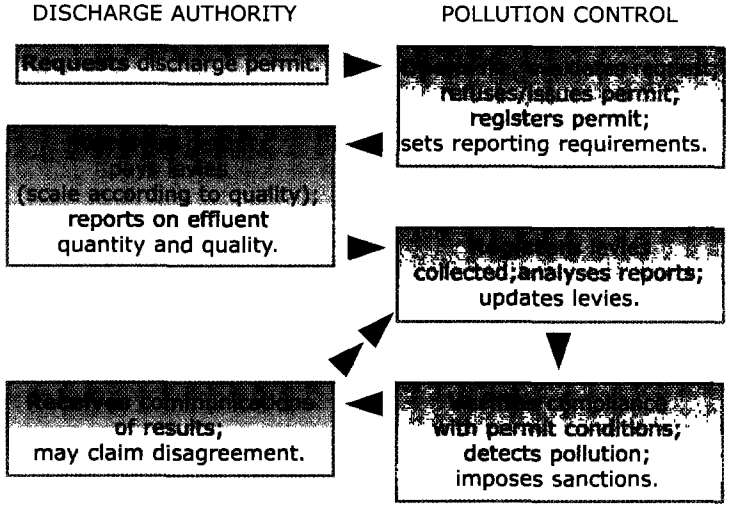
Water pollution control system, Zimbabwe **Box 6.14**

The key element of the system is the polluter pays concept, which generates revenue for the monitoring system required by government to monitor the quality of the nation's water. This ensures that the monitoring system is adequately funded and that charges are directly related to the cost of the pollution control program.

Basic concepts system

- All agencies/ authorities/ private individuals wishing to discharge any effluent into any water body, whether surface water or groundwater should seek a permit to do so.
- Polluters pay to be allowed to discharge and the scale of charges provides an incentive to reduce pollution.
- Effective policing of the regulations is essential and polluters should pay for this.
- The burden of monitoring is on the permit holder.
- Penalties are clear and punitive.
- The polluter remedies the damage caused.

Schematic presentation of roles and responsibilities



The pollution control programmes have tended to be rigidly sectoral but there is a need for a more inter-sectoral and participatory approach so as to achieve co-ordination. National agencies, which deal with water pollution, are scattered in various ministries and institutions. A more unified approach to water pollution control is required with framework environmental legislation administered by a body responsible for the co-ordination of the activities of the different national agencies in their respective sector ministries. This will achieve greater co-ordination and channeling of efforts to avoid resources being wasted.

Awareness campaigns to publicize the effects of water pollution are generally lacking in southern Africa, and so is public participation. There are useful examples of public disclosure programmes (for example, in Indonesia) that have harnessed the power of the public and consumers to influence changes in the polluting industries (through social or public sanctions and consumer boycotts). Such approaches may be useful for the SADC countries to learn from or adapt, in conjunction with existing efforts.

6.6.2 Status of water quality monitoring and analysis

The effectiveness of any monitoring programme depends on the setting of appropriate monitoring objectives, design of monitoring networks, particularly the location of sampling points, and informed interpretations of the analytical results. (Box 6.15)

It is crucial to decide upon the precise objective of a water quality monitoring programme so that resources can be used effectively and results utilized in the proper context. The desirable outcome of monitoring is to measure trends and to confirm the absence of pollution, or the extent and severity of pollution, and to evaluate the efficiency of the wastewater treatment methods used.

Water quality monitoring is carried out regularly in some countries in southern Africa. However, many national agencies focus on conventional water quality parameters such as major ions. Very little sediment analysis is carried out in a region that has an enormous problem related to soil erosion and sediment transport and deposition, and when it is well known that many water pollutants are found partially or exclusively attached to solids or colloidal particles.

The existing water quality programmes concentrate on collecting data on pollution levels for various water bodies that receive wastewater discharges. There are also water quality programmes that concentrate on collecting water quality data for the management of water supplies. However, SADC countries have not yet established opti-

mal water quality monitoring networks. In most cases the water quality monitoring activities in each country are carried out by several government agencies at points of interest other than the gauging stations. The co-ordination necessary to ensure good quality data collection among various agencies is usually lacking.

In Zambia, for example, there are no routine water quality monitoring programmes at hydrometric stations to correlate flows with quality in order to calculate pollutant loads, but a number of agencies collect water quality data on an ad hoc basis. The main ones are the Water Affairs Department, the National Research Council, and the Zambia Consolidated Copper Mines. The latter carries out water quality monitoring in the Copperbelt area at the headwaters of the Kafue river, while the Water Affairs Department and the National Research Council cover the

Water quality monitoring Box 6.15

Monitoring is a process that can add value to the existing investment, and address various questions regarding the cause, nature, effects, and processes of water pollution. This may address groundwater, surface water or rainwater quality.

The aim of water quality monitoring should be to:

- produce useful data for understanding the aquatic ecosystem and its dynamics;
- produce scientific data and information on contemporary problems to inform policy makers; and
- assess environmental problems and options for addressing the damage within the stipulated social, economic, and environmental constraints.

The level of monitoring has to consider the sources of pollution, and the nature of the body of water to be monitored. Lake water monitoring programmes may be different from those for groundwater monitoring, although the objective would be the same:

- to provide information to guide actions which will render the water safe for aquatic life, human consumption, agricultural and industrial activities.

The monitoring checklist should include:	Monitoring stations should be established at:	Three types of stations can be used:	For establishing the sampling points, the criteria should be:
background of water quality	the abstraction point for public supply, fishing and recreational areas	baseline stations, are those where no direct influence of diffuse or point sources of pollutants is likely to be found	natural water quality regime
nature of pollution hazards, both chemical and microbiological	the point of all abstraction for agricultural uses	impact stations are those located along water bodies with consideration of water usage	effects of various human activities
sources of pollution, whether steady state has been reached or pollution is still spreading, whether wastewater or variation in pollution with time or due to season, etc.	the point of river confluence and where the river discharges in the lake or ocean	trend stations are used to represent areas which might be heavily affected by pollution of other sources.	impact of point and non-point sources on water quality.
the type of pollution source, point or non-point	where international boundaries are crossed.		
methods that can be used to abate the pollution			
identification of the pollution indicators			
a sanitary survey of the source of the pollution and the water body			
sampling, method of analysis			

For better water quality monitoring it is advised to categorize water sources based on the potential uses, eg Category A surface water for drinking after disinfecting, Category B surface water for outdoor bathing, etc.

whole country. The sampling methods and protocols of these agencies are not necessarily the same nor in accordance with established water quality monitoring standards and standard methods. Despite this, Zambia appears to be among the more advanced countries in the region in terms of water quality monitoring.

Water quality analysis depends on the sampling procedures used and the laboratory analysis carried out. The availability of properly equipped laboratories is key. Most countries in the region have more than one laboratory capable of water quality analysis, and often each agency that carries out water quality monitoring has a laboratory of its own for analysis. However, most of these laboratories are equipped with old and unreliable equipment, and many are not used efficiently. In Malawi, for example, the Water Department's Central Water Laboratory has been unable to carry out full chemical analysis in recent years because of frequent breakdowns or non-functioning of equipment. Even biological analysis was not done for several months because of equipment breakdown. (Shela 1993)

The distribution of water quality laboratories in each country is limited. This has created problems when samples have had to be sent long distances and over long periods, further limiting the water quality monitoring coverage in each country. The areas close to laboratories tend to have more sampling points than those far away. The lack of appropriate storage facilities necessary for transporting the samples to distant places is also a constraint.

Comprehensive water quality assessments are rarely carried out, often due to the lack of well-defined objectives, design and resource constraints, and inadequate data. Assessments are usually limited to meet specific objectives such as the water quality requirements for drinking water supply schemes and perhaps for pollution control of receiving waters. In water supply schemes, water quality assessments are used for planning and management of treatment plants. Water quality assessments in Malawi, for example, are also done for semi-treated or untreated rural piped water supplies to ascertain their suitability for consumption. Such practice is common in a few other countries, for example Tanzania. Water quality monitoring and assessment of groundwater supplies often takes place during the development and maintenance of wells, and aims at determining whether the supply is suitable for consumption. The monitoring and assessment of groundwater quality for general groundwater management is rare.

6.6.3 Municipal wastewater treatment

Wastewater from a municipal or industrial facility should be treated adequately to remove the pollutants to a level commensurate with the receiving water standards before being discharged into receiving water. There are three constituent and interrelated aspects of wastewater management: collection, treatment, and re-use.

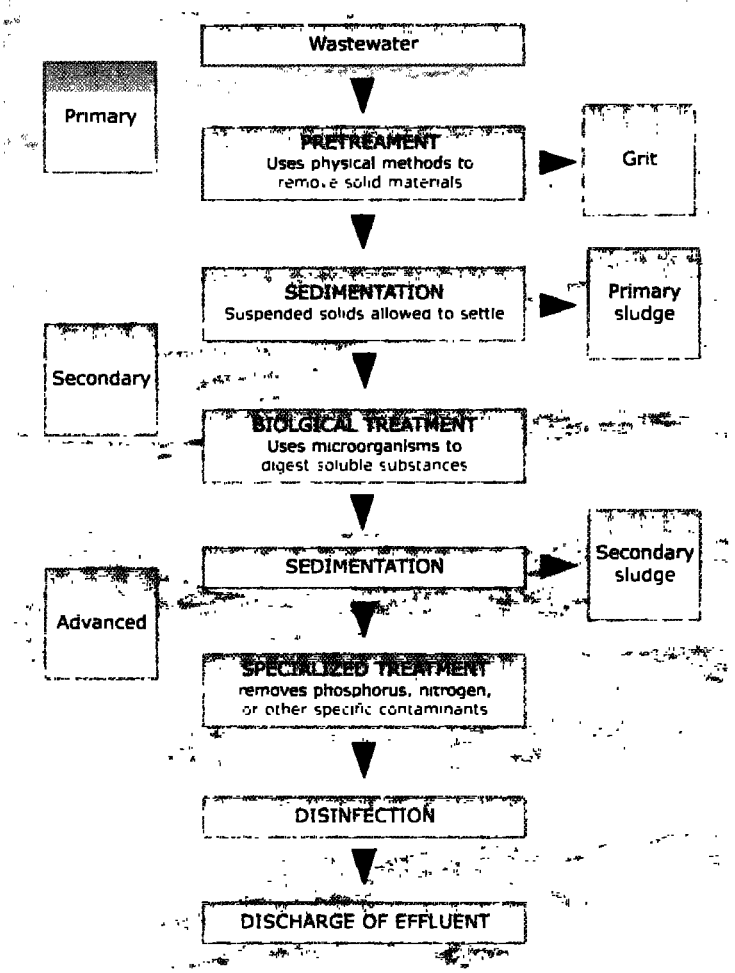
Human waste must be properly disposed of so there will be no contamination of drinking water supply or public health hazard caused by being accessible to insects, rodents or other carriers that may come into contact with food or drinking water; there will be no violation of laws or regulations governing water pollution or sewage disposal, or nuisance caused by odour or unsightly appearance. These criteria can be met by the discharge of domestic sewage to an adequate public or community sewage system. However, centralized sewage systems are very costly and not all urban municipalities, let alone rural communities, can afford them. Many sewage systems are also inefficient and do not operate fully nor are their benefits greater than the costs. Given that existing water policies are inadequate for implementing effective cost recovery, the chances of extending sewage systems more widely and rapidly is going to be a major challenge for the region. At the same time, by deferring the pollution challenge, the governments, private sector and other stakeholders will continue to waste scarce economic resources due to the growing cost of pollution.

Figure 6.2 summarizes conventional wastewater treatment processes. There are many variations to this conventional treatment system including waste stabilization ponds, artificial wetland systems, chemically enhanced treatment and new developments in membrane technologies, to name a few. Wastewater treatment can also be accomplished through the use of constructed wetlands designed specifically to achieve certain wastewater quality objectives.

Sewage treatment authorities in many SADC countries face difficulties in constructing adequate treatment facilities to keep pace with the ever-increasing volume of waste. There is need to expand and upgrade the existing sewage treatment works in most cities in the region. New facilities require financing that is often not available and the problems of operating and maintaining existing sewage treatment works are usually financial.

Solutions depend upon the technical, administrative and financial capabilities of the responsible local authorities. There is reluctance on the part of many authorities to

Simplified Flowchart of Wastewater Treatment Figure 6.2



charge water users for the cost of sewage collection and treatment, but sewage treatment capacities in each works are unlikely to improve unless the local authorities become financially viable.

Three options are available for industries to treat and dispose of their effluents:

1 Give the effluent full treatment at the factory and reuse the treated water, but most industries find this costly option;
2 Discharge the effluent after full treatment to a watercourse, which will also be costly for the industry and most do not have the expertise for such treatment, or are not compelled to do so;
3 Discharge the effluent to a municipal sewer with or without pre-treatment. This option is more acceptable to most industries since it is not too costly.

Some industries in South Africa and one in Zimbabwe are using bio-digesters to improve the quality of their effluent before discharge. Pre-treatment of industrial effluent will go a long way towards decreasing the pollution load and it is also a cost-effective option.

6.6.4 Industrial wastewater treatment

Industrial wastewaters usually contain chemical pollutants and toxic substances in large proportions. The characteristics of the wastewater vary from industry to industry and also from process to process within the same industry, and cannot always be treated easily by the usual methods of treating domestic sewage. The key characteristics of industrial wastes are divided into three main categories: physical, chemical, and biological. (Table 6.7)

Before deciding on the type of treatment, an inventory of the characteristic load from the industrial effluent should be prepared. The treatment methods for industrial wastewater can be classified into four main categories: equalization, physical, chemical and biological.

Equalization consists of holding the wastewater for some pre-determined time in a continuously mixed basin to produce a uniform wastewater. This is necessary when

Production goods	Wastewater volume (cu m/month)	Treatment method
Opaque beer	2 250	Bio-digester/settlement
Cooking oil/soaps/baker's fats	25 000	Fat/oil/separators
Pork products	20 000	Settling tanks/filtration
Detergents powders/cooking oil	15 381	pH control and fat control
Pulp and paper	84 000	Clarifier and lagoon
Chemicals (paints)	200	Settlement
Leather	6 600	Oxidation/flocculation

the wastewater produced by industry varies in characteristics and quantity over the entire day. (Garg 1996)

The physical treatment of industrial wastewater may include the following unit operations:

- coarse or fine screens as well as bar screens to remove large objects;
- compacting device such as a grinder to break solids;
- grit chambers for removal of sand, dust stones, cinders and other heavy inorganic settleable solids;
- grease traps for removal of oil and grease; and
- plain sedimentation tanks to remove suspended organic solids from the wastewater prior to biological treatment of wastewater.

Chemical treatment of industrial wastewater includes processes such as neutralization, coagulation and flocculation, reverse osmosis, adsorption, deionisation, thermal reduction and chemical destruction of toxic substances such as cyanides. The biological treatment process harnesses natural fauna and flora, both micro and macro for the treatment of wastewater.

With the recent introduction of stronger environmental laws and regulations in the SADC region, some industries have now started treating their wastewater to meet effluent standards for discharge into streams.

6.6.5 Use of constructed and natural wetlands for pollutant removal

Wetlands vary widely in their pollutant removal capacities. Among the most important removal processes are the purely physical processes of sedimentation via reduced velocities and filtration by hydrophytic vegetation. Generally, well-constructed wetlands can remove 70 percent ammonia nitrogen, 99 percent nitrite and 95 percent total dissolved phosphorus from wastewater as it passes through them. (Mitsch and Gosselink 1998)

The use of constructed wetlands for stormwater treatment is still an emerging notion. There is need to develop guidelines for the use of wetlands for wastewater treatment management. The use of wetlands for wastewater with high levels of heavy metals needs careful consideration because heavy metals may bioaccumulate. Wetlands may be useful for the reduction of pollution loads in the management of urban lakes and rivers, andinitial results are promising, given that land for wetland development is often not a serious constraint, but clearly more studies are needed to understand the effectiveness.

6.6.6 Management of non-point source pollution in agriculture

Management of non-point sources of pollution is a complex task as there are many more factors to consider, and enforcement is less dependent on techniques and methods, and more on behaviour.

Pollution from agriculture (pesticides, herbicides and fertilizers) is influenced by the method of handling, storage, transport and application, and the location of farming activities in relation to the water sources. Fertilizer or pesticide when applied on a rainy day is likely to be washed into the watercourses. The amount of agrochemical applied on farms also has an influence on the pollution load entering the water sources. Farmer training needs to be encouraged to teach the proper methods of handling, storing and transporting agro-chemicals as well as the application of right quantities of agro-chemicals.

Countries which irrigate large areas are likely to generate large quantities of return water that could add salts to surface sources, and could also percolate to groundwater.

In many instances, information is available on technical measures to prevent and control diffuse sources of water pollution. This applies particularly to agriculture through best practices for the reduction of inputs of nutrients and pesticides into waters. Lack of implementation is often the key problem. Thus, the achievements in prevention, control and reduction of water pollution originating from agriculture vary among southern African countries, and stronger policies are needed. A total or partial prohibition of the production or use of substances hazardous to the water environment is not yet common practice, and the enforcement of provisions to restrict activities in sensitive areas meets difficulties in many places. Herbicides such as atrizine and simazine are still used, for example, although prohibited in Europe. Diffuse pollution from abandoned mines is another threat. Specific regulations, guidelines, methods and techniques are needed to control water pollution from these sources.

Agriculture is a major diffuse source of runoff into waterbodies, but some counter measures to reduce pollution by contaminated runoff can be adopted by:

- Planting a buffer strip of vegetation alongside a water body to retain contaminants in runoff.
- Zero tillage, which is becoming important in the limitation of serious problems of soil erosion and soil runoff into water. In no-till farming, crop residues are left on the soil instead of being tilled into the ground.

However, no-till farming is an environmental trade-off because it requires increased use of herbicide to manage the weeds that are not ploughed into the ground. Some commercial farms in Zimbabwe have adopted this strategy.

Integrated pest management (IPM) is also being used by commercial farmers in Zimbabwe and South Africa to determine when a pesticide is really needed, instead of making routine applications according to a calendar schedule. Reduced applications mean less pesticide in runoff from treated fields as well as saving money for the farmer.

Applying only sufficient fertilizer to meet the actual needs of crops. It may be necessary to employ specialists to determine the minimum amount of fertilizer required.

Controlling construction-site runoff by building a settlement pond to trap soil, oil and grease.

Soil conservation methods.

Retention/detention ponds.

Land-use planning/zoning.

Algaecides have also been used in South Africa when heavy algal blooms create problems in water treatment and recreation. Some herbicides, however accumulate in sediments and in the tissues of living organisms and create health problems.

Preventive management focuses on creating conditions that do not produce water quality problems in the first place. A typical example is the use of constructed wetlands for pollution control. This is cheap, long lasting and has no side effects.

Sustainable management, which addresses the needs of future generations and global environmental concerns, involves an advanced planning component. Integrated management, ecotechnology, material recycling and clean production are central to sustainable management, which is a more recent concept and may provide the best long-term solution for southern Africa. However, adopting such an approach on a large scale would require strengthening local capacity to develop it on an operational basis as well as close cooperation by governments, private sector, community groups and individuals.

6.6.7 Approaches to water quality management

Water quality problems are influenced by intensively interacting components both within and outside the water system. Three possible approaches to water quality management are shown in Table 6.8.

Corrective management is the approach most commonly used in southern Africa, although this can be very costly and the effects short-lived, often with undesirable side effects. Typical examples of corrective measures employed in water quality management in the region include removal of macrophytes by chemical or manual methods. 2,4D has been extensively used in Zimbabwe, South Africa and Zambia to control the water hyacinth (see chapter 8).

Corrective management	Preventive management	Sustainable management
This involves remedying the pollution effects in the receiving water through:	This involves mitigation and interception before pollution or waste actually reaches the receiving water, including:	This involves addressing economic,social and environmental costs of water quality management strategies, and would require:
• releasing water to blend and reduce high salinity	• interception of runoff and treatment by detention ponds or constructed wetlands	• integrated planning, looking at pollutant life cycles, fate, transport and effect of contaminants in the receiving water
• re-oxygenation by physical means (weirs or stirrers) or chemical (addition of hydrogen peroxide)	• lining of waste sites	• identification of externalities, valuation of costs and benefits of both corrective management and preventive management
• control of nuisance aquatic plants by physical, chemical or biological means (see chapter 8)	• pre-treatment of domestic and industrial wastewater discharges	• designing an appropriate mix of corrective and preventive management strategies to promote social and economic development without causing irreversible damage to the resource base.
• dredging and disposal of contaminated sediments.	• introduction of waste minimization practices and cleaner production technologies in industry.	

Mackay 2002

6.7 WATER QUALITY MANAGEMENT POLICY OPTIONS

Untreated or insufficiently treated industrial and municipal wastewater, inappropriate agricultural practices and poor quality mining and industrial effluent are the main causes of water pollution in southern Africa. Various water quality management tools (such as standards and objectives) can be used together within a sound policy and strategy framework to confront this problem. A water quality management strategy should incorporate some combination of the following tools:

- Receiving water quality objectives;
- Effluent discharge standards (uniform standards and site-specific standards);
- Best management practices;
- Zero discharge of listed hazardous pollutants such as mercury and cadmium;
- Whole effluent toxicity approaches and biomonitoring.

Regulatory emphasis has previously been on uniform effluent standards, with little attention given to the setting of Receiving Water Quality Objectives (RWQO). More recent trends are to employ a balance between the setting of receiving water quality objectives, the derivation of site-specific effluent standards in sensitive catchments, and the use of uniform effluent standards elsewhere which will ensure that RWQO are met in most catchments, for most discharge situations.

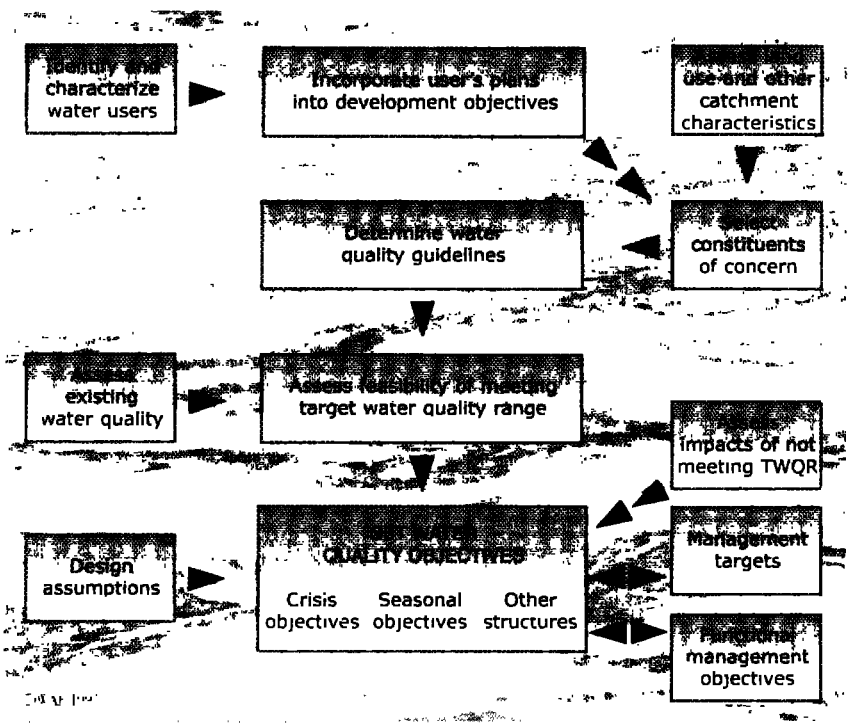
6.7.1 Receiving Water Quality Objectives

The traditional command and control approach was heavily reliant on prescribing end-of-pipe discharge standards, usually blanket over a large region, regardless of localized conditions of individual catchments. Of late there has been a shift towards the application of the receiving waters criteria in which the local conditions are considered and the capacity of the water resources to assimilate pollutants is also taken into account. Receiving water quality objectives are quantitative statements of the desired quality in a water body that must be maintained. This entails a thorough knowledge of the state of the aquatic environment as well as the ambient conditions prior to setting the objectives.

Setting the objectives can be an iterative process, which seeks a balance between the requirements of different water uses, the general public, and other interested parties. The process takes account of the various environmental, technological, economic, political and social factors, which affects the use of water in a water body.

Figure 6.3 depicts the steps that can be taken in setting site-specific water quality objectives.

Setting Water Quality Objectives **Figure 6.3**



6.7.2 Effluent discharge standards

Legal, administrative and technical measures are necessary tools in formulating an effective water quality management strategy to mitigate the undesirable effects of water pollution. These may be carried out in conjunction with other instruments such as economic incentives and disincentives, and public disclosure. Multidisciplinary teamwork is needed for successful water pollution control. At national level, control of water pollution is achieved by:

1. Formulation of national policy for pollution control;
2. Enactment of appropriate legislation; and
3. Establishment of appropriate arrangements (administrative and technical) for regulating, implementing and monitoring pollution.

Many southern African countries will have to invest large sums of money to improve treatment of industrial and municipal wastewater, thus cutting down pollution from point sources. Furthermore, the promotion of low cost and non-waste technologies must be the cornerstone of policies and strategies to prevent water pollution from industrial point sources. The core of these policies has been the application of the best available technology (BAT).

BATs are not necessarily affordable or cost effective, and in addition, BATs are often heavily dependent on technical expertise to operate the technology used in the treatment facility within its design specifications. BATs may be very expensive and possibly over-protective for many developing countries. For the SADC region, a modified BAT, such as the Best Available Technology Not Exceeding Excessive Costs (BATNEEC), may be more appropriate for addressing the current level of challenges that exist. Before such an approach is adopted however it will be necessary to identify the environmental costs of BATNEEC and who actually pays these costs.

6.7.3 Planning tools (models)

Water Quality Models (WQM) are a set of mathematical expressions defining the physical, biological, and chemical processes that are assumed to take place in a water body. WQM consists of equations based on conservation of mass and/or energy. The mass balance takes account of input from outside the system, transport of materials in the system and reactions within the water body. There are several types of WQMs used to predict the fate and effects of pollutants in rivers, lakes, estuaries and groundwater systems. WQMs can be useful for solving complex problems from multiple sources, but they are also an expensive undertaking that requires a large quantity of data.

Modelling of fate and effects is essential when applying the receiving water quality objectives approach and working back to site-specific effluent standards. WQMs can assist to predict the future effect and may help to predict the level of treatment to be achieved by wastewater treatment plants before the effluent is discharged to the river.

The existing models assume the use of wastewater effluent standards, specifying the maximum allowable constituent concentration in the wastewater effluent that can be discharged into a water body or a wastewater charge based on the notion that pollution charges can be purchased and traded between various parties. The maximum allowable concentrations may vary depending on their location within the water body. Numerical models have been proposed for use in estimating the degree of wastewater treatment at various point sources sites along a water body that will meet both effluent and water quality standards. (Box 6.16)

Formulating a Water Quality Model (WQM) — **Box 6.16**

Several steps need to be taken to formulate a sensible Water Quality Model:

- defining the objective of the model;
- conceptualisation;
- mathematical expression of the model;
- calibration;
- verification of the model;
- sensitivity analysis;
- documentation; and
- application of the model.

Water quality goals are usually expressed in the form of wastewater effluent standards or water quality standards in waste-receiving water bodies or both.

Any model should state variables and forcing functions.

The most common form of this model applies to the management of the DO concentrations in streams and rivers. There is no best single WQM for all water bodies and for all planning situations. In some cases the models should be simple, while in other cases they may be more complex. Most models used today apply to water bodies receiving wastewater from point sources. Many DO models are an extension of two simple equations proposed by Streeter and Phelps (1925), for modelling BOD of various biodegradable pollutants and the resulting DO concentrations in the river. Often used with these BOD-DO models are other fairly simple first order exponential decay, dilution and sedimentation models for other non-conservative and conservative substances.

6.7.4 Best Management Practices

Best Management Practices (BMP) is a technical term that refers to prescribed on-site practices, production processes or waste management techniques which must be employed in order to minimize pollution impacts of certain categories of land-use activity or industry. For example, the use of lining in solid waste sites; the careful handling, storage and applications of agro-chemicals; and the on-site retention and pre-treatment of the initial portion of storm water before discharge from industrial premises to a watercourse.

6.7.5 Whole effluent toxicity approaches and biomonitoring

Whole effluent toxicity approaches and bio-monitoring are new developments in water quality management that are being added to the suite of water quality management tools in many developed countries. At present, their use in the SADC region has not been well understood or adopted.

6.8 RECOMMENDED APPROACHES TO WATER QUALITY MANAGEMENT

6.8.1 Ecosystem approach

The ecosystem approach focuses on integrated water resources management. It is a departure from the earlier focus on localized pollution and the management of separate components of the ecosystem. The ecosystem approach recognizes the social, economic, technical and political factors that affect the ways in which human beings use nature, and promotes solutions for sustainable water utilization.

For example, the maintenance and improvement of conditions in aquatic ecosystems should be laid down as basic requirements in water laws. The ecosystem approach requires planning to be based on ecosystem boundaries rather than political boundaries, and calls for increased intergovernmental cooperation at all levels, since many aquatic ecosystems cross national boundaries. The ecosystem approach advocates for management responsibility to be channelled to local authorities, as they generally make land-use decisions, and land-use activities in the catchment area have an important influence on aquatic ecosystems.

6.8.2 Environmental Impact Assessment

Environmental Impact Assessment (EIA) has already proven to be an important instrument in implementing and strengthening sustainable water management as it not only combines the precautionary principle with the principle of preventing environmental damage at source but also calls for public participation. EIA has become an important tool for implementing an integrated approach to the protection of the environment, as it requires a comprehensive assessment of the impacts of an activity on the environment contrary to the traditional sector-based approach. In most southern African countries an EIA is carried out for new projects but is not mandatory.

6.8.3 Developing and applying water-quality objectives

Water-quality objectives aim at ensuring the multi-purpose use of freshwater, while supporting and maintaining aquatic life and the functioning of aquatic ecosystems. Water-quality objectives have to be developed by water authorities to set threshold values for water quality to be maintained or achieved within a certain time/period. For river basins, action plans covering both point and diffuse pollution sources have to be designed.

6.8.4 Polluter-pays principle

The "polluter-pays" principle has been suggested for adoption by SADC countries, because the perception that water is in abundance as a freely available public good can no longer be maintained. The polluter-pays principle requires that costs of pollution prevention, control and reduction measures should be borne by the polluter. Adoption and enforcement of the polluter-pays principle is likely to induce changes in the behaviour of individuals, industries and municipalities, and foster prevention measures as well as low- and non-waste technologies. However, introduction of the polluter-pays principle may need to be phased, to take account of social and economic implications.

Reducing water pollution in urban areas requires coordinated policies and steps to decrease municipal and industrial discharges of wastewater. To reduce the cost of wastewater treatment both industries and municipalities should be given incentives to reduce their waste loads based on the principle that the polluter pays. (World Bank 1993) Municipal sewers and sewage treatment surcharges can be included in water supply fees, preferably on the basis of volume. The industrial use of municipal sewage systems should be based on clearly established standards for pre-treatment and user charges based on the volume and the pollution load of industrial effluent.

Reducing the strength and volume at the source is not only environmentally attractive but is also economically sound. Many industries do not see the direct benefit of treating wastewater.

The polluter-pays principle has three bases for collection of fees, based on:

- the quantity of wastewater produced, or
- the quality of the effluent discharged from the industrial wastewater treatment plant, or
- the load of a particular substance discharged.

The principle of paying based on the quantity of wastewater applies to industries which may discharge wastewater to the municipal wastewater treatment plants, thus sharing the costs of running the wastewater treatment plant.

Paying based on the quality of effluent to be discharged to the receiving water body requires industries to have their own treatment plants. If the effluent is discharged to rivers, and does not meet the requirements, then the polluter will have to pay for polluting. This principle requires a monitoring mechanism to check if the industries are following the standard and hence the laboratory should be well-equipped. Profit-making industries will prefer to pay for polluting if the amount required for paying is small compared to the profit they get.

Most wastewater treatment plants in southern Africa are owned by municipal and city councils or industries; however monitoring of the quality from industrial effluents is poor due to lack of personnel and laboratory equipment.

6.8.5 Self-regulation

The number of potential polluters in any given catchment is generally substantial and if an agency has to fully regulate everything in the catchment, then the workforce would be too large to be economic. An option is to have the polluters regulate themselves and the authority or responsible agency then concentrates on monitoring compliance. Such a system can take the following form:

- All dischargers have to be registered and permitted to discharge;
- Negative incentives for discharging illegally have to be enshrined in legislation;
- Positive incentives should be clearly defined;
- Discharger has to bear the burden of monitoring and submitting results to the authority at an agreed rate for,
  - discharge volumes,
  - quality of discharge, and
  - ambient water quality;
- Authority inspects randomly for compliance;
- Penalties for non-compliance are clear and punitive;
- Discharger remedies damage caused.

6.8.6 Economic incentives

The traditional command and control approach has a number of weaknesses, especially in implementation. The policing of controls is difficult and costly, while the development of economic incentives offers an approach that is flexible and can lead to cost savings. Economic incentives may include:

- Controlling water demand (allocation, water pricing and water marketing);
- Subsidies per unit of pollution emission abatement;
- Tax on entrepreneurs to internalize pollution externalities;
- Tax rebates for pollution abatement implementation and equipment;
- Emission charges; and
- Tradable permits.

In general, both positive and negative economic incentives have to be implemented to achieve the desired reduction in pollutants generated.

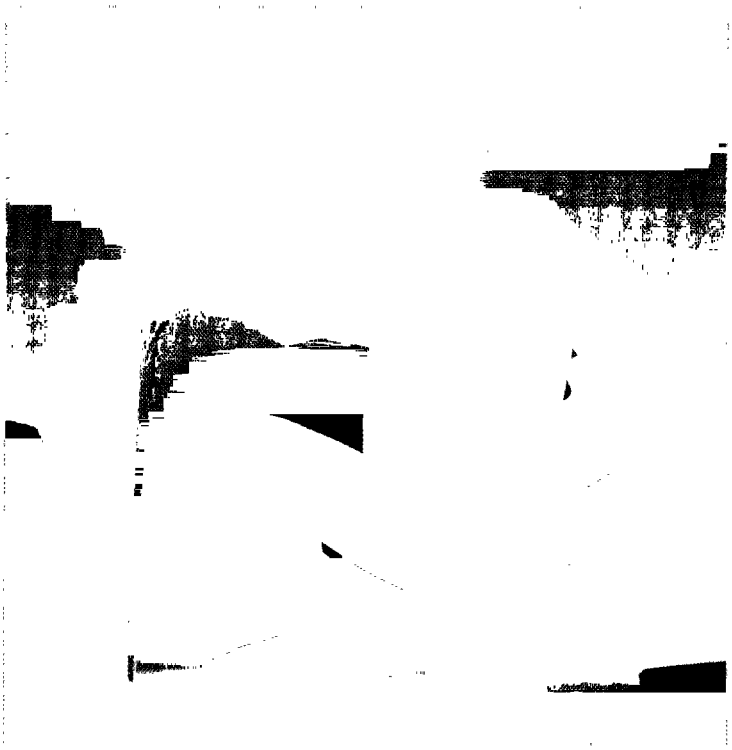
6.8.7 Regulation

Legislation provides the basis for government action in the regulatory and operational areas and establishes the context for action by private sector, community groups and individuals.

Regulatory systems monitor and enforce established law, agreements, rules and standards. (World Bank 1993) In many countries regulatory functions are weak and are formulated and enforced inconsistently by different agencies. Penalties are applied to those who do not follow the laws or by-laws used for the protection of water. There are regulations governing the collection, disposal and treatment of domestic and industrial wastewater to be regulated by municipal or city councils. There are also regulations for importing toxic compounds, fertilizers, pesticides, and other chemicals used for agricultural activities. Other than having regulations for the prevention of water pollution by proper disposal of industrial and domestic wastewaters, the penalties applied to date are not sufficient to discourage the polluters.

6.8.8 Public participation

The role of the public in water-resources planning and management should be actively explored. There is a general misconception that it is only state organs that can monitor water resources. The public also has an impor-



DWAF, South Africa

A participatory approach to water resources planning and management should be adopted, involving all stakeholders, [illegible] private sector, [illegible] and individuals as well as local and central governments, in a holistic manner

tant role and should be seen as a potential ally in monitoring the effects of water degrading activities

A more participatory approach must be adopted, involving all stakeholders, including but not only, the private sector, community groups and individuals as well as local and central governments. There has been a perception that pollution control is entirely the responsibility of central government, specifically the line ministry responsible for water resources or environment, and there must now be recognition by all players of a more holistic and inclusive approach.

Public players should not wait to be invited by government but offer their ideas, and government bodies should make themselves receptive to such ideas and support, particularly from the private sector but also from other groups and individuals. Rather than adding to the administrative load, this reduces it through shared responsibility for implementation and results monitoring. However, initiation of this approach involves the sharing of available information and may require an outreach programme of awareness that could involve printed, electronic and broadcast materials as well as meetings and discussions.

6.9 CONCLUSIONS

Water pollution is a very serious problem that is growing rapidly in SADC countries, and threatens the sustainable utilization of the resource. Both point source and non-point sources of pollution have contributed to the deterioration of water quality. Pollution abatement measures must be put in place.

Appropriate monitoring systems need to be established to check the health of aquatic environments and the effects of pollution on the biota and on human health. Adequately equipped laboratories are necessary for monitoring purposes and individual laboratories in each country must network. Monitoring must be carried out using a suite of relevant parameters.

Water quality [illegible] and environmental engineers are needed and these skills should be developed through intensification of training and education, and civil service reforms that encourage retention of specialists within the public and private sectors.

All stakeholders including private sector, communities, interest groups and individuals as well as governments must have the will to participate in tackling the water pollution problems in a curative but also in a preventive manner. A vigorous public awareness campaign for improving the understanding of key issues at the political level should be promoted, at national levels and in the SADC region.

Recommendations for effective WQM policy development and implementation Box 6.17

- The government should realise and translate the policies into action-oriented activities, and give priority to WQM by providing funds and technical expertise.
- It is impossible to lay down standards in advance for all possible pollutants, and the most useful control measure is to empower a single agency such as the national water authority or ministry to decide and enforce the standard to be applied to each case. The system should be in terms of guidelines rather than standards so as to be flexible enough to take downstream use into account.
- Where toxic or hazardous substances are concerned, the policy should be in such a form that,
  - the pollution control agency can define which substances are to be included,
  - prior consent of the agency is required to discharge them,
  - this consent is conditional and can be revoked,
  - a register is kept of all hazardous substances imported or manufactured, including what quantities are involved and where, and
  - a zero discharge limit may be imposed on listed hazardous materials such as mercury and cadmium, in specific instances.
- There should be an agency responsible to scientifically assess, evaluate and monitor the implementation of water quality policy. The agency must be empowered to enforce the regulations and guidelines governing the act or policy.
- One of the most important instruments for translating environmental policies into action is the law, not only as a means of command and control but also as a framework for coordinated work. Yet the legal process, which ought to facilitate progress towards sustainable implementation of policy, is often ill-adapted to the scale and pace of social change and the degree of public participation and transparency of decision-making required for this purpose.
- An institutional setting should be created within an effective legal and regulatory framework to facilitate cross-sectoral actions that contribute to improved WQM policy. There should be a proper coordination structure to avoid overlapping of responsibilities. In many cases the regulatory system and coordination structures may exist but function poorly because they lack authority and appropriate resources for enforcement.
- There should be an adequate number of well-equipped laboratories which will run an analysis of effluent samples and advise effectively on what should be done to control or improve performance of wastewater treatment plants.
- Stringent standards should be set for the highly polluted water bodies so as to prevent any further indiscriminate disposal of wastewater.
- Penalties should be equal to the damage caused by the pollution, rather than low penalties which encourage the polluter to pollute.

Fresh clean water in Lake Piti, Maputo province, Mozambique.

I. Basto

ANNEX to Chapter 6

Parameter	WHO Action Levels	Aquatic Ecosystems Levels (South Africa) mg/l
PH	6.5 to 8.5	Not vary by > 0.5
Turbidity (NTU)	5	
Colour (Hazen Units)	5	
Total Dissolved Solids	1 000 mg/l	Not vary by> 15%
Dissolved Oxygen		> 60%
Fluoride (F)	1.5 mg/l	1.5
Chloride (Cl)	250 mg/l	
Sulphate (SO_4)	400 mg/l	
Cyanide (CN)	0.1 mg/l	0.004
Nitrate (N)	10.0 mg/l	
Total Hardness ($CaCO_3$)	500 mg/l	
Arsenic (As)	0.05 mg/l	
Cadmium (Cd)	0.005 mg/l	0.005
Chromium (Cr)	0.05 mg/l	0.014
Lead (Pb)	0.05 mg/l	0.001
Mercury (Hg)	0.001 mg/l	0.00008
Nickel (Ni)	0.05 mg/l	
Selenium (Cr)	0.01 mg/l	0.002
Aluminium (Al)	0.20 mg/l	0.01
Ammonia		0.007
Arsenic		0.01
Copper (Cu)	1.0 mg/l	0.0015
Iron (Fe)	0.30 mg/l	10% of background
Manganese (Mn)	0.10 mg/l	0.18
Sodium (Na)	200 mg/l	
Zinc (Zn)	5.0 mg/l	
DDT	0.001 mg/l	
24 D	0.10 mg/l	
Lindane	0.003 mg/l	
Chloroform	0.03 mg/l	
Coliform bacteria per 100 ml	Nil	
Faecal coliform bacteria per 100 ml	Nil	

WHO, Geneva 1986; Government of South Africa

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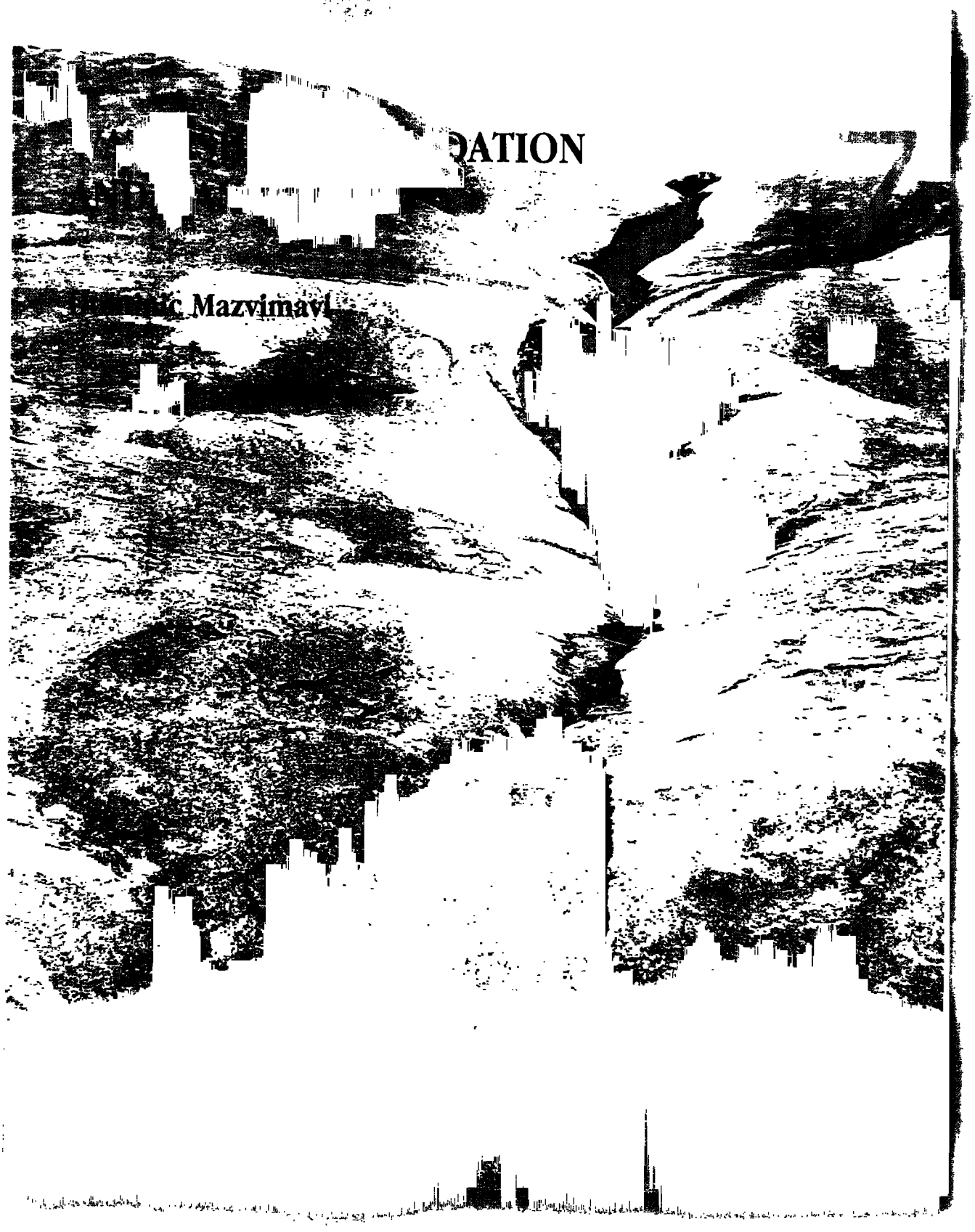
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CONTENTS

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WATERSHED DEGRADATION AND MANAGEMENT

7.1 INTRODUCTION

Watershed degradation resulting largely from poor land-use practices poses a significant threat to the water resources of many countries in southern Africa. In a water-scarce region, the importance of watersheds as sources of surface water that should be held sacred and protected is not fully understood nor appreciated by decision-makers and other stakeholders. Nor has adequate attention been placed on using water wisely and efficiently.

The huge economic costs associated with watershed degradation are not fully realized. These costs are caused by many factors including loss of soil cover, nutrients and agricultural production, altered hydrology, deteriorated water quality, reduced economic life of storage dams, and damaged water infrastructure due to sediment transport and deposition. Often, these costs are not accurately quantified due to inadequate data, and therefore the significance of economic losses associated with watershed degradation is not appreciated.

This chapter provides an overview of the conceptual issues and challenges related to watershed degradation, and the importance of managing watersheds very carefully, as they are essential to our survival and the economic wellbeing of the region. It starts with a description of the components that make up a watershed, and examines causes and consequences of watershed degradation. Approaches to watershed management are then assessed for their effectiveness in southern Africa. The chapter concludes with recommendations to consider for inclusion in policy for the management of watersheds.

7.1.1 Definitions

A watershed is defined as an area from which all surface runoff flows through a common point.[1] Other related terms are catchment, river basin, and drainage basin. Box 7.1 describes important biophysical and social elements of a watershed.

Biophysical and social elements of a watershed — Box 7.1

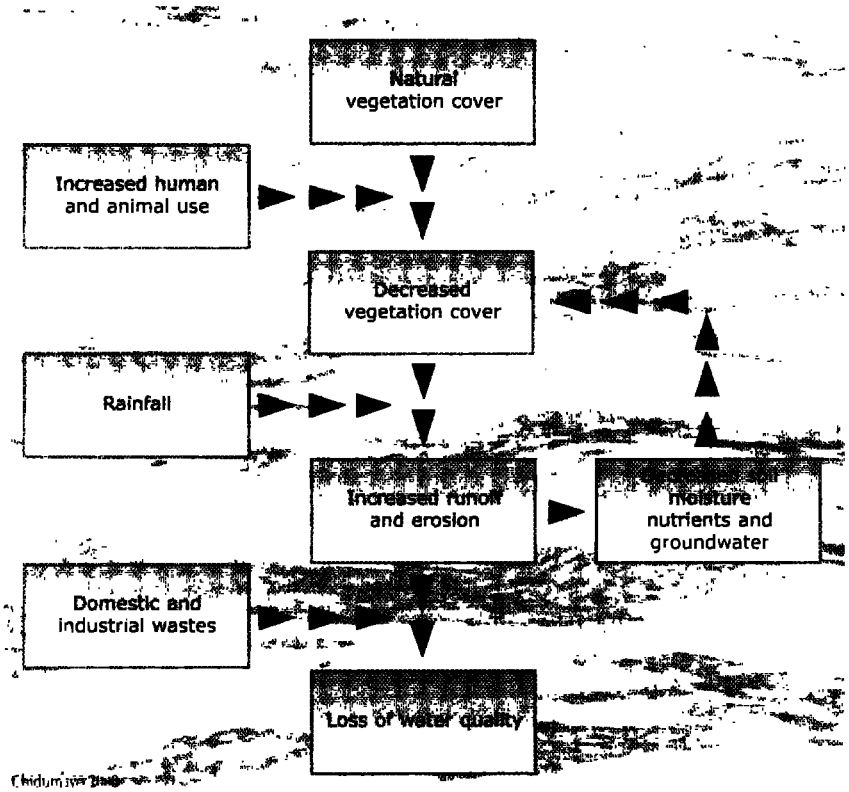
A watershed comprises several interconnected elements. The biophysical elements include: vegetation, slopes, weathered rock or regolith, bedrock, and channels. Each can be treated as a sub-system depending on the scale of analysis. An output of one element becomes an input of another element. Water which flows from slopes becomes an input to channels. Similarly soil eroded on slopes becomes an input into channels. The elements that make up a watershed are linked by movement of mass and energy.

Changes in conditions of these linked elements will affect how inputs are transformed to outputs. Thus changes in upstream elements will affect downstream elements. For example, a change in the amount of water which infiltrates into the soil will affect the amount of water that flows into streams and also affect the amount of water available to vegetation and groundwater.

Human activities form an important social element of the watershed system which interacts with the biophysical elements of the watershed. These interactions affect processes occurring within watersheds, and therefore the movement of water and debris. For example, human activities can increase or decrease areas under vegetation. Such changes will affect the flow of mass (water and debris) and energy within a watershed. The interactions between human activity and other elements of the drainage basin need to be managed so that adverse effects such as reduction in water resources are minimized.

1 The term watershed may have a different meaning elsewhere. In the United Kingdom, for example, it means a divide which separates surface drainage areas

Vegetation-Land-Water Interactions in a Watershed Figure 7.1



Hydrological characteristics of a watershed Box 7.2

The transfer of water into and out of a watershed can be described by a water balance equation:

$$P = Q + E + \Delta S$$

Where P is precipitation, Q is runoff, E is evapotranspiration and ΔS is the change in water storage in the watershed. Precipitation may occur as rain or snowfall, although rain is the predominant form of precipitation in the region. A portion of the precipitation falling over a vegetated watershed is intercepted by the vegetation and evaporated back into the atmosphere. The remainder that reaches the soil surface is divided into three sub-components:

- Runoff into watercourses which may be stored in reservoirs, lakes or eventually flows to oceans.
- Water which evaporates from the soil, channels, reservoirs and lakes, and transpired from leaf-surfaces after being absorbed by plant roots.
- Water stored in soils and as groundwater.

The combined process of evaporation of water from soil, channels and reservoirs, and transpiration is referred to as evapotranspiration. The difference between precipitation (P) and the sum of runoff (Q) and evapotranspiration (E) represents the change in water storage (ΔS) in a watershed.

Figure 7.1 shows the linkages between human activities on land and vegetation, and their impact on the movement and quality of water in a watershed. Box 7.2 describes the hydrological characteristics and the main elements of a water balance in a watershed.

7.1.2 Watershed degradation

Watershed degradation is a long-term reduction in the quantity and quality of water resources due to anthropogenic and natural factors. Sometimes land degradation is perceived synonymously as watershed degradation, but there is a clear distinction between the two. Land degradation concerns the reduction in the productivity of land[2] and may cause degradation of watersheds, whereas the focus of watershed degradation is on water resources.

There are elements of watershed degradation which are usually not taken into account when considering land degradation. For example, the leaching of fertilizers from agricultural lands may lead to eutrophication of water bodies. Eutrophication of water bodies adversely affects the quality of water resources, and therefore causes watershed degradation. Such issues are not included in land degradation as long as the leaching of plant nutrients does not cause a decline in the productivity of lands.

7.1.3 Reversible versus irreversible degradation

There is no unanimity with regard to whether the reduction in the potential of a watershed should be reversible or irreversible when used to define watershed degradation. According to Nelson (1988) and Abel and Blackie (1989), these changes in the watershed that are not reversible within human timescales constitute watershed degradation because it would be uneconomic to reverse them. The consideration of whether changes which have taken place can be reversed has caused some controversy about the severity and

2 Hellden (1994) defines land degradation as "a reduction of the resource potential by one or a combination of water and wind erosion, sedimentation, siltation, long-term reduction in the level of diversity in natural vegetation, crop yields, soil salinization and sodification."

magnitude of watershed degradation. If irreversibility is taken as an important aspect of watershed degradation, then some of the losses in vegetation which can be reversed within say 30 years cannot be regarded as part of land or watershed degradation.

7.2 NATURAL VEGETATION COVER IN SOUTHERN AFRICA

Rainfall and altitude determine the pattern of vegetation cover in southern Africa. (Map 7.1) Lowland tropical forest occurs in the Congo basin in the Democratic Republic of Congo (DRC) and Angola. In response to decreasing rainfall, the tropical forest is replaced by moist savannah in the central region of the sub-continent and this vegetation type extends over much of Angola, southern parts of DRC, Zambia, Tanzania, Malawi, Mozambique and northern parts of Zimbabwe.

Further south, moist savannah is replaced by dry savannah which occurs in north-eastern Namibia, Botswana, southern Zimbabwe, the middle Zambezi and Luangwa valleys, north-eastern South Africa as well as north-central Tanzania. Semi-desert and desert vegetation occurs in the south-western portion of the sub-continent, extending from Namibia to South Africa.

The influence of the Indian ocean on the eastern coast of the sub-continent has resulted in the development of a coastal tropical forest stretching from Tanzania to South Africa. Isolated patches of high altitude afromontane vegetation occur in a north-south band from central Tanzania, through Malawi, eastern Zimbabwe, South Africa, Lesotho and Swaziland.

Vegetation is one important element of the watershed system, and changes in the status of this element will have several effects on other components of the watershed, and in particular on water resources. The watershed protective function of the different vegetation types and the associated transpiratory water losses depend on vegetation density and its leaf area measured as Leaf Area Index (LAI). Vegetation is one of the major elements through which water in the soil is transferred back into the atmosphere.

Generally, there is a decrease in vegetation density, canopy cover and productivity, and therefore of the watershed protective function from the tropical forest in the north to semi-desert vegetation in the south-west. However, it is noteworthy that grassland can also provide

D. Martin, APG

Vegetation is a key element of the watershed system, shown here at Sanje Falls, Udzungwa National Park, Tanzania.

as much cover as other vegetation types. Similarly the rate of transfer of water from the soil into the atmosphere through transpiration decreases from the tropical rainforest to the semi-desert vegetation.

The tropical rainforest which has high canopy cover will tend to intercept rainfall, therefore reducing the potential energy of raindrops when they reach the ground surface. This will generally minimize soil movement through raindrop impact. In contrast, the dry savannah and Nama-karoo vegetation has low canopy cover, raindrops are not intercepted and reach the ground surface with sufficient energy to move soil. This leads to soil loss. Reduction in vegetation density and therefore canopy cover which is due to human activities is one of the major causes of watershed degradation. The causes and implications of these changes are further discussed in 7.3 and 7.5 below.

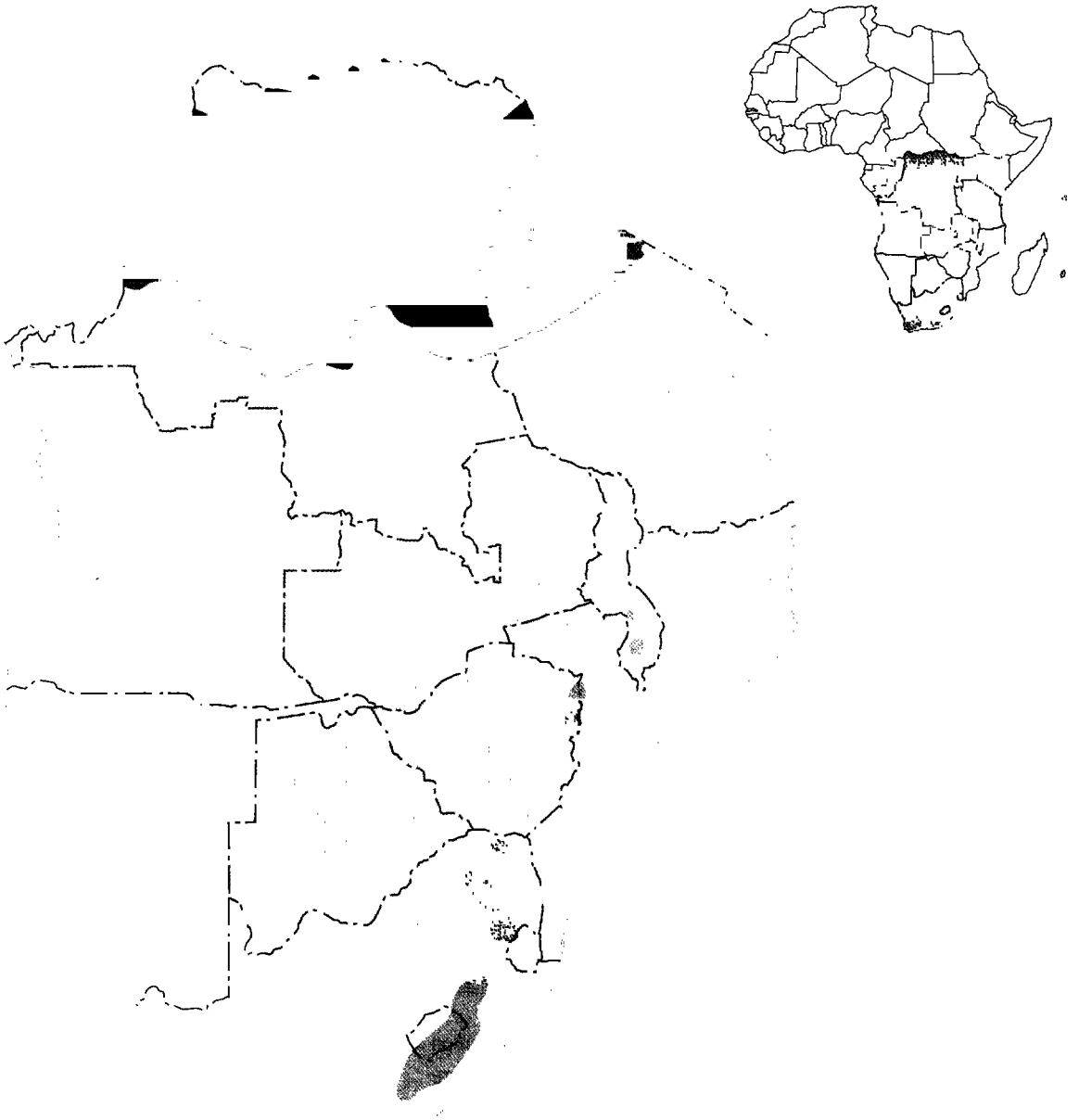
7.3 ANTHROPOGENIC CAUSES OF WATERSHED DEGRADATION

The most common causes of watershed degradation in southern Africa are:

over-cultivation;
overgrazing;
deforestation;
poor waste disposal systems; and
the invasion of alien plants, which is often ignored.

A number of other factors also contribute to the degradation of watersheds. Based on his analysis of land degradation in Lesotho and Zimbabwe, Darkoh (1987) says this is due to land pressure arising from inequitable land distribution during the colonial period and the resultant overloading of carrying capacity, followed by

Vegetation Distribution in Mainland SADC Countries **Map 7.1**



Lowland Tropical Forest (rainforest)
Afromontane/ Temperate Forest
Savanna (dry)
Succulent Karoo
Desert
Lowland Tropical Forest (coastal)
Savanna (moist)
Nama-karoo
Fynbos
Grassland
Scale 0 500 km

Modified from Frost, P.G.H , 1993, Determinants of Structure and Function of Southern Africa Biomes. for SARDC; Rutherford, M.C. and R.H Westfall, 1986, Biomes of Southern Africa: An Objective Categorization, *Memoirs of the Botanical Survey of South Africa,* Department of Agriculture and Water Supply, Pretoria, no 54; Laporte, N. *et al* 1997, The Use of Time-Series Satellite Data for Characterization and Monitoring of the Seasonal Forests and Savannas of Central Africa, Executive Summary, Biodiversity Support Program, Washington, DC

modernization of agricultural production which marginalized subsistence agriculture. Others have argued that watershed degradation in general is a result of a combination of some of the following:

social and economic factors;
natural events;
short term pressures on land users;
short-sighted policies of governments and donor agencies; and
an increase in both human and animal populations.

This shows that the causes of watershed degradation are complex and not always universally applicable. Therefore solutions to these problems may need to be case specific.

7.3.1 Overgrazing

Overpopulation of domestic livestock is reported to cause more than half of the soil erosion in southern Africa (UNEP study in Chenje and Johnson 1994) and it is likely to be the major contributor to watershed degradation in the region. Overgrazing and compaction of soils occur when stocking rates exceed the capacity of the relevant area to sustainably support the number of animals. This leads to a reduction in vegetation cover and compaction of soil through trampling, which promotes soil erosion. Other effects of overgrazing are:

changes in soil structure;
decrease in perennial grasses;
shrub encroachment;
deterioration of the quality and quantity of forage; and
reduction in palatable and nutritious plant species.

Overgrazing directly affects the vegetation and the soil. The reduction of vegetation cover reduces infiltration rates and increases the amount of water delivered to channels, thus accelerating soil erosion and increasing the amount of debris delivered to channels.

Watershed degradation due to overgrazing is a serious problem in countries with very high livestock densities such as Lesotho, Swaziland and Tanzania. The highest cattle densities in the Southern African Development Community (SADC) region are found in Swaziland and Tanzania while Lesotho has the highest density of small stock, followed by Tanzania. (Table 7.1) In Tanzania, about 90,000 livestock had to be removed from 125,600 ha in the Kondoa area during the early 1980s to reverse the degradation process. (Christiansson *et al* 1991) There are reports of serious degradation in the Lesotho lowlands due to overgrazing. (Chakela *et al* 1986) Ringrose *et al* (1995) also reported that intensive grazing, especially by goats, in the vicinity of villages in the Rakops area of north-eastern Botswana had degraded the land. Other reports show that the most extensive serious degradation due to overgrazing is found in central and western South Africa, while localised areas of degradation occur between Luanda and Huambo in Angola, north-eastern Botswana, and central and north-eastern Tanzania. (Chenje and Johnson 1994) In both Botswana and Namibia, overgrazing tends to be a problem around livestock watering points. (Moyo *et al* 1993)

Country	Livestock		Pasture land	Density per sq km	
	Cattle	Sheep/Goats (000)	(sq km)	Cattle	Sheep/Goats
Angola	3 130	1 250	311 750	10.04	4.01
Botswana	2 520	2 180	425 250	5.93	5.13
Lesotho	530	2 500	24 000	22.08	104.17
Malawi	990	1 110	47 000	21.06	23.62
Mozambique	1 370	500	431 200	3.18	1.16
Namibia	2 060	9 080	n/a*		
South Africa	11 860	36 910	805 860	13.88	45.80
Swaziland	650	360	13 600	47.79	26.47
Tanzania	12 960	13 230	265 800	48.76	49.77
Zambia	2 770	610	482 950	5.74	1.26
Zimbabwe	6 250	3 150	234 600	26.64	13.43

WRI 1992, in Chenje and Johnson 1994 *data not available

Land degradation also occurs in national parks and game reserves, which are protected areas for biodiversity conservation in southern Africa. When large game populations exceed the carrying capacity of the habitat, vegetation cover and land can be degraded leading to watershed degradation. However, in the natural cycle in the wild, when vegetation becomes sparse, the animals move on to another area to allow recovery and regrowth.

Overpopulation by animals was a key factor contributing to the sedimentation in rivers and reservoirs in the 1960s in the Luangwa valley of Zambia (Caughley 1976), which has been exacerbated by a drastic decline in the elephant population due to poaching, so the vegetation has not fully recovered. (Lewis 1991) Although elephants

are often perceived as destructive as they consume a large quantity of vegetation, often pushing over trees in the process, they also move around re-planting the area through their dung, which contains both seeds and partly digested waste for fertilizer. Although a reduction in elephant populations will reduce direct destruction of vegetation, it also reduces the cycle of re-seeding.

Extensive destruction of woodlands has been reported in Zimbabwe's game reserves in Chizarira, Matusadona and middle Zambezi valley areas. (Whitlow 1980) The wildlife population pressures may also be induced by encroachment, for example, farming in or near the game reserves and protected areas.

7.3.2 Deforestation

Deforestation caused by cultivation, bushfires, timber and fuelwood harvesting and the development of settlements and infrastructure, is another major cause of watershed degradation in southern Africa.

7.3.2.1 Cultivation

Cultivated lands are without any vegetation cover at the beginning of the growing season. Without adequate soil conservation measures, soils are susceptible to erosion and this may be particularly serious in vulnerable areas, for example, on steep slopes or near stream banks. Excessive erosion may impair the quality of water and reduce the capacity of streams to store and convey water.

More than two-thirds of the people in southern Africa are rural farmers who cultivate land on shifting and semi-permanent basis. Forests and woodlands are being cleared in order to grow crops to support an increasing human population. In Malawi, 24 percent of the total forested area has been converted to arable land. (Lele and Stone 1989) Of the estimated 0.9 million ha deforested in Zambia in 1990, shifting and semi-permanent cultivation were responsible for 95 percent and the remaining 5 percent was attributed to charcoal production. (Chidumayo 1997)

Shifting cultivation has been a traditional method of farming in Zambia for centuries, in which farmers move on after a number of years to allow resting of soil and regrowth of vegetation. However, population growth and modern land-use pressures have hampered this traditional method of sustainable cultivation. This system is also used by commercial farmers who have sufficient arable land to leave some fields fallow at intervals while they plant other fields. The difference is that the fields are ploughed and vegetation is not allowed to grow, and the soil can be removed by wind or rain.

In Zimbabwe the main decreases in woody vegetation between 1963 – 1973 were in areas of moderate to high population densities, particularly in communal areas where extension of croplands and wood harvesting had resulted in annual cover losses of 3 – 10 percent. Whitlow (1980) observed that shortages of land had forced residents of Zimunya communal lands in Zimbabwe to extend cultivation to the foothills of dwalas and inselbergs which are prone to high soil erosion rates.

In the lowlands of Lesotho, nearly 60 percent of the natural grasslands have been converted to cropland. (Chakela *et al* 1986) The per capita arable land in Lesotho is now estimated at about 0.002 ha, perhaps the lowest in the region. Apparently, as per capita arable land decreases, the rate of deforestation increases sharply until available forestland becomes the limiting factor. (Table 7.2) The shortage of suitable arable lands has resulted in the extension of cultivated lands to marginal lands.

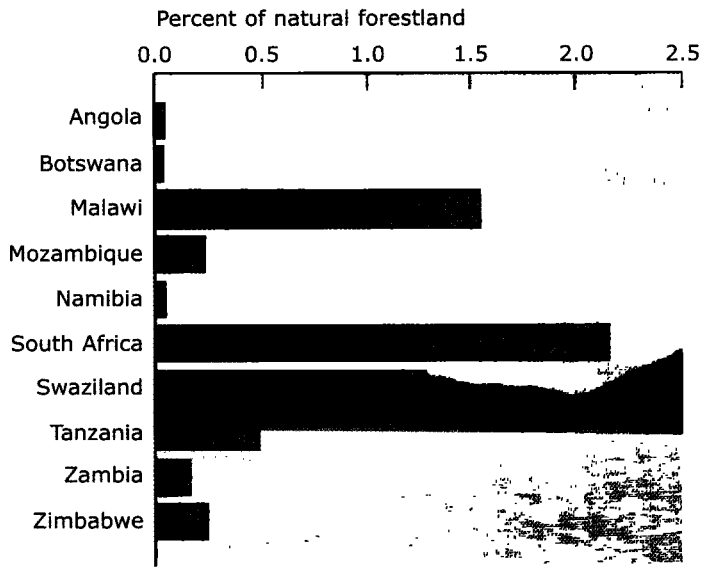
7.3.2.2 Fuelwood harvesting

Most rural people in southern Africa use fuelwood for cooking and heating, and this often results in cutting trees if no underbrush or deadwood is available. This contributes to deforestation, with annual rates ranging from 0.03 to 2.2 percent. The highest rates of deforestation are in Malawi, South Africa and Swaziland. (Figure 7.2) Lesotho has theoretically the highest rate of deforestation but because most of the accessible natural forest has already been cleared, the percentage rate of deforestation is much less. Misana and Nyaki (undated) estimated that 60 million cu m of fuelwood would be

Country	Arable land in hectares (per capita)	Annual deforestation (%)
Zambia	3.13	0.002
Tanzania	2.3	0.005
Malawi	0.7	0.024

1 Rate of deforestation = -0.94 per capita – 3 02; P for Logistic regression is 0.99
Chidumayo 2000

Estimated Annual Rates of Deforestation Figure 7.2



Chidumayo 2000

required annually in Tanzania by the year 2000, but the natural forests can only supply 20 million cu m of fuelwood. They estimated that this imbalance between the demand and supply will result in the deforestation of between 300,000 – 400,000 hectares every year.

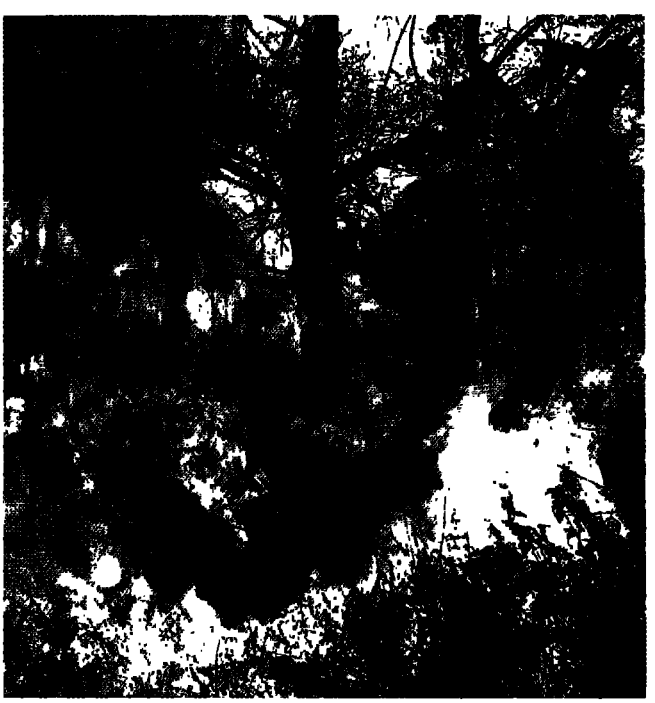
The agriculture sector is also a major user of cordwood fuel to cure tobacco and tea. Live trees are often cut for fuel. Tobacco estates in Malawi account for 21 percent of the national fuelwood consumption (Moyo *et al* 1993) and cause nearly 47 percent of the deforestation due to fuelwood harvesting. Misana and Nyaki (undated) estimated that there were 26,291 hectares under tobacco in the smallholder sector in Tanzania, and this required about 1.3 million cu m of fuelwood.

Other uses of cordwood fuel include the curing of bricks, especially in rural areas. In Zimbabwe, the wood used for brick-making is said to equal that used for cooking in some rural areas. (Bradley and Dewees 1993)

Coastal vegetation such as mangroves has been similarly affected by vegetation cutting for timber and fuelwood. Mangroves cover 48 percent of the coastline of Mozambique, and in Tanzania between 500 – 820 sq km of mangroves provide valuable timber and fish resources. About six percent of the total land surface of Zanzibar is covered with mangroves. However, throughout the coastal zone, unsustainable timber and fuelwood harvesting threaten mangrove resources, as does the conversion to agriculture or aquaculture. Deforestation reduced the area of mangroves at Maruhubi in Zanzibar to 75 ha in 1989 from 1040 ha in 1949. (Shunula 1995) This pattern of unsustainable exploitation, usually triggered by high population growth and commercial motives, is widespread in the mangrove zone of southern Africa.

7.3.2.3 Bushfires

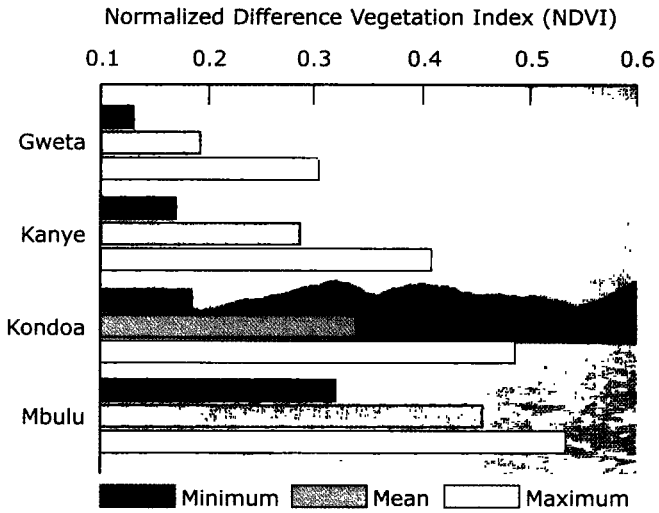
Vegetation in southern Africa is also subjected to annual or periodic burning. Depending on the severity of the burn, fire can degrade forests by converting them to grassland or wooded grassland. Apparently, fire is frequent in grasslands, moist and dry savannah and in *fynbos* of South Africa. The areas affected by fire are difficult to estimate but global estimates indicate that 440-505 million ha of African savannah are burnt annually. (Lacaux *et al* 1993) About half of the African savannah is found in southern Africa. Fire can therefore be expected to be a major cause of degradation of moist and dry savannah in southern Africa.



P. Wade

Fire impacts on water by damaging the watershed, [illegible] by con- [illegible] grasslands or wooded grasslands.

Changes in Vegetation Cover at Some Sites due to Watershed Degradation **Figure 7.3**



Dry savannah at Kanye (good cover) and Gweta (degraded cover) in Botswana
Miombo woodland at Mbulu (good cover) and Kondoa (degraded cover) in Tanzania. Chidumayo 2000

Figure 7.3 shows the changes in vegetation cover at some sites due to the various causes of watershed degradation. The Normalized Difference Vegetation Index (NDVI) is determined from the difference in reflectance between near infrared and red electromagnetic radiation. The difference is normalized by the sum of the near infrared and red radiation bands. NDVI values range from -1 to 1, with values close to 0 characteristic of areas with bare vegetation cover, *eg* Gweta in Figure 7.3, and vegetation with dense cover has NDVI values close to 1, *eg* Mbulu in Figure 7.3.

7.3.3 Alien invading plants

The invasion of alien plant species along rivers or riparian zones is a problem of particular concern in South Africa (Versveld *et al* 1998) and some other parts of the SADC region, such as the Eastern Highlands of Zimbabwe. The major concern over alien plants is about their effects on water resources; an invasion by alien plants will alter the water balance of the watershed. In particular, the rates of transpiration are likely to be altered, which could have adverse effects on the available water resources. It has been estimated that alien plants cover about 10 million hectares or 10 percent of South Africa, and if nothing is done about these plants the rate of invasion will increase by five percent per year. Table 7.3 shows the top 10 alien plant species that are of concern in South Africa.

Species	Total area invaded (ha)	Density* (%)
Acacia cyclops	1 855 792	18.28
Prosopis species	1 809 220	9.57
Acacia mearnsii	2 477 278	5.30
Acacia saligna	1 852 155	5.83
Solanum mauritianum	1 760 978	5.08
Pinus species	2 953 529	2.61
Opuntia species	1 816 714	4.15
Melia azedarach	3 039 002	2.39
Lantana camara	2 235 395	3.10
Hakea species	723 449	8.86

*Density refers to the estimated mean cover in the total area invaded
Versveld *et al* 1998

The Mpumalanga and Western Cape provinces have 13 percent and 17 percent of their areas invaded by alien plants. The implications of such changes within a watershed are examined in section 7.5.5.

7.4 EXTENT AND SEVERITY OF DEGRADED WATERSHEDS

It is rather difficult to quantify the extent and severity of degraded watersheds in southern Africa since most countries have never undertaken such studies at the national level. In addition, there is no universally accepted measure of degradation. There is also the tendency in the literature to exaggerate the problem of degradation and this is not based on factual evidence.

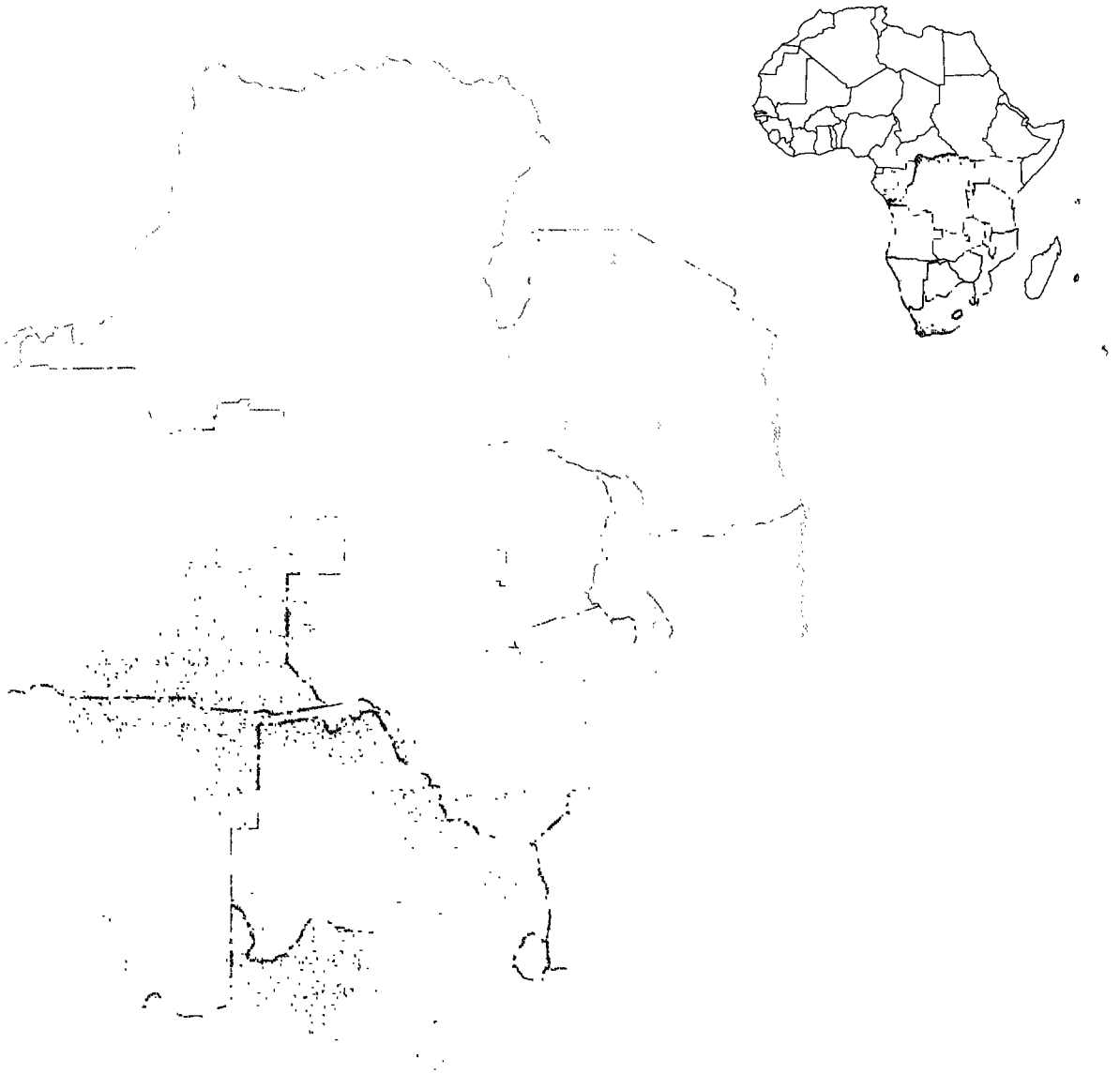
Map 7.2 attempts to show the spatial extent of degradation in southern Africa. Information presented in this figure is based on the work of Middleton and David (1990), who classify the severity of degradation into the following four categories:

1 Stable – no evidence of degradation.
2 Low degradation – the topsoil has been removed which reduces agricultural production, but restoration is possible.
3 Moderate to high degradation – this will require major improvements in land use practices in order to restore the degraded land. Agricultural production has been greatly reduced.
4 Very high degradation – it is not possible to restore the land without major engineering works.

According to this classification, the extreme southern part of the region in parts of the Cape provinces of South

Severity of Land Degradation in the SADC region

Map 7.2



Stable | Low | Medium to High | Very High

Scale
0 500 km

Stable	No degradation
Low Degradation	The land has somewhat reduced agriculture suitability with part of the topsoil removed. On rangelands, restoration of full productivity is possible with improvement of the agricultural system at farmer level.
Medium to High Degradation	The land has greatly reduced agricultural productivity. Major improvements are required to restore it.
Very High Degradation	The land is not reclaimable at farm level without major engineering works.

UNEP/ISIRIC, CRU/UEA as in Middleton, N.J. and D.S.G. Thomas, 1992, *World Atlas of Desertification*, UNEP and Edward Arnold, Nairobi and London.

Africa fall within the very high degradation class. This coincides with areas under the Nama-karoo vegetation. Watershed degradation is due to overgrazing by sheep and erratic rainfall. Bush encroachment is reported to have rendered 14 million hectares unusable for grazing. The steep slopes between Lesotho and Kwazulu-Natal in South Africa also fall within the very high degradation class, due to overgrazing, cultivation and fuelwood collection on overcrowded areas under subsistence farming. Very high degradation also occurs around cattle watering points on ranches in Namibia.

Parts of the grasslands of South Africa which are under irrigation have been degraded through salinization, sodification and waterlogging. It is estimated that 10 percent of the 1.8 million hectares under irrigation in these grasslands have been affected. Within Lesotho these grasslands have been severely degraded by overgrazing.

Parts of the dry savannah have moderate to high degradation. These areas have been degraded by overgrazing and clearing of land for agriculture. The central part of Tanzania, especially the Dodoma district, has high degradation due to poor land-use practices by agro-pastoralists. Fifty percent of the land in Dodoma district has been affected by loss of topsoil and gullying.

The eastern and southern parts of Zambia which are under moist savannah are being degraded by poor farming methods. Expansion of cultivation in Malawi is causing degradation of the moist savannah region.

7.5 ECOLOGICAL IMPACTS OF WATERSHED DEGREDATION

7.5.1 Soil erosion

Soil erosion is a natural process which can be accelerated by overgrazing, deforestation and inadequate soil conservation measures on cultivated lands. This was recognized as far back as the beginning of the 20th century. During the 1930s there were several reports indicating that soil erosion was a major problem in the eastern parts of Botswana. Similar concerns were raised by the 1939 Commission of Enquiry which was tasked to assess the state of resource degradation in the then Rhodesia, now Zimbabwe. In the United States of America soil erosion on farmlands was recognized as a major threat to dams developed for hydropower generation within the Tennessee valley and elsewhere. In response to the problem, the Tennessee Valley Authority (TVA) was formed in 1933 for the purpose of developing dams for hydropower generation and managing the relevant watersheds in order to minimize problems arising from watershed degradation.

Although soil erosion is recognized as a serious problem in southern Africa, there have been very few studies that have assessed the severity of this problem at national levels. Most of the studies have assessed the rates of soil erosion on selected experimental plots or watersheds. Chakela (1981) concluded that the rates of soil erosion in one valley studied in Lesotho were between 100 and 200 tonnes/sq km/yr. Stocking (1986) estimated the rates of soil erosion for land under different land tenure systems and uses in Zimbabwe as:

commercial farming land under grazing
3 tonnes/ha/yr
communal land under grazing
75 tonnes/ha/yr
commercial arable lands
15 tonnes/ha/yr
communal arable lands
50 tonnes/ha/yr.

It was also estimated that an erosion rate of 75 tonnes/ha/yr would result in the stripping away of soil at a faster rate than new soils were being formed. The severity of watershed degradation through soil erosion in communal lands of southern Africa is further illustrated by the results of the national soil erosion assessment made by Whitlow (1988) in Zimbabwe. This assessment, based on aerial photo-interpretation showed that 40 percent of communal lands in Zimbabwe had evidence of moderate to very severe soil erosion, while 4.8 percent of land in commercial farming areas had this severity of soil erosion.

At the time the study was undertaken, communal lands covered 46 percent of the country, while commercial farming areas covered 39 percent. The quality of the land allocated to each type of usage before independence when the African majority were forced to crowd onto the poorest land in what were then called Tribal Trust Lands, and the resultant overpopulation, are a legacy of the skewed land distribution system inherited from the colonial period.

7.5.2 Results of catchment studies

A number of catchment studies have been carried out in the SADC region to assess the effects on water resources of changes in watershed conditions. Some of these studies have been undertaken on experimental catchments

that were set up, while others are based on analysis of flow characteristics over a long period, with the hope that changes in flow characteristics could be linked to changes in watershed conditions.

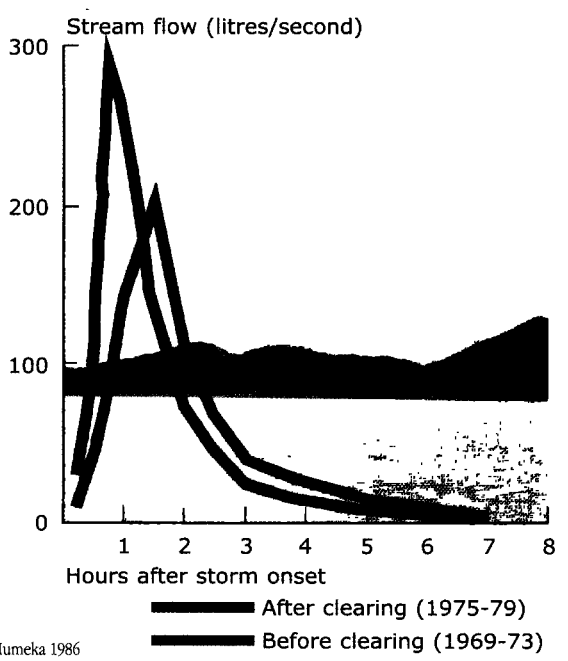
7.5.2.1 Effects of deforestation, overgrazing and bushfires

Andrews and Bullock (1994) have reviewed several experimental catchment studies set up to examine the effects of vegetation clearance on water resources. The main conclusion from these studies is that clearance of vegetation results in an increase in runoff from watersheds. Studies done in Zambia showed that 95 percent deforestation of *miombo* woodlands increased annual flows by 56 to 74 percent. Sharma (1985) and Mumeka (1986) concluded that clearing 75 percent of wet *miombo* woodland in the Copperbelt area of Zambia and temporary conversion to subsistence agriculture had the following effects:

- surface runoff increased by 10-18 percent;
- peak flows increased;
- annual evapotranspiration was reduced; and
- baseflow increased.

Figure 7.4 illustrates some of the observed hydrological changes.

A Comparison of Runoff on the Luano Catchments Before and After Clearing Wet Miombo Woodland **Figure7.4**



Mumeka 1986

The increase in the annual yield of watersheds following deforestation is partly due to the reduction in transpiration losses. Vegetation does also increase infiltration rates of soils through the addition of organic matter content. Deforestation will reduce the infiltration rates of some soils. Peak flows will increase as a result of deforestation. However, the increase in peak flows is usually not beneficial since water is readily available in most rivers during the wet season.

Flooding problems tend to occur as a result of these increases in peak flows. It is believed that flooding in the Mtwara and Lindi regions of Tanzania during the late 1980s was due to vegetation clearance. (Misana and Nyaki, undated) These floods which caused loss of life and property, are thought to have been triggered by the clearance of the Makonde escarpment. The reduction in infiltration rates will cause lowering of groundwater levels and depletion of dry season flows in those areas with permeable formations and depletion of dry season flows. Misana and Nyati note that 90 percent of the streams outside catchment forest reserves in parts of Tanzania were no longer flowing due to vegetation clearance. The increase in surface runoff also accelerates soil erosion rates.

Overgrazing has similar effects to clearing of trees. Stromquist (1985) observed that infiltration rates increased and peak flows decreased after an overgrazed catchment in Uganda had been allowed to recover by excluding cattle and allowing the regrowth of grasses. Snyman and Fouche (1991) concluded that poor grasslands had twice the amount of annual runoff that occurs on good grasslands in a study undertaken in South Africa.

The effects of bushfires have been analysed for only one watershed in South Africa, where streamflows increased immediately after the burning of *fynbos*. Wet season monthly flows were increased by between 7 – 15 percent after burning of *fynbos*.

7.5.2.2 Effects of cultivation

The effects of the extension of cultivated lands on water resources have not been widely investigated at the catchment scale. Stormquist (1981) analysed the data collected during the East African Experimental Catchments Project. The Mbeya catchment in Tanzania which was part of this project was cleared of evergreen vegetation and replaced with smallholder cultivation

on steep slopes. The results did not show any significant changes in annual yield of the watershed following change to cultivation.

Cultivation did however increase infiltration rates and groundwater storage which resulted in the doubling of dry season baseflow. Figure 7.5 compares the runoff coefficients for forested and cultivated land in the Iringa catchment in Tanzania. Box 7.3 presents the results of an analysis of the effects of cultivation on the Iringa catchments in Tanzania.

A detailed analysis of the impacts of land-use change on the Mgeni Catchment in Kwazulu-Natal province of South Africa was undertaken by Kienzle *et al* (1997). Commercial forest or sugar plantations decreased streamflows by up to 60 percent in those sub-catchments with high proportions of these land uses. These reductions in flows were attributed to high transpiration losses. The extension of land under maize production increased streamflows due to the sparse canopy of maize, particularly during the early stages of its growth. This study noted that the effects of cultivation on water resources are rather complex as they depend on crop type, cropping patterns, tillage systems, rainfall, and soil characteristics. Figure 7.6 shows the influence of forest cover on soil moisture in four Blantyre catchments in Malawi.

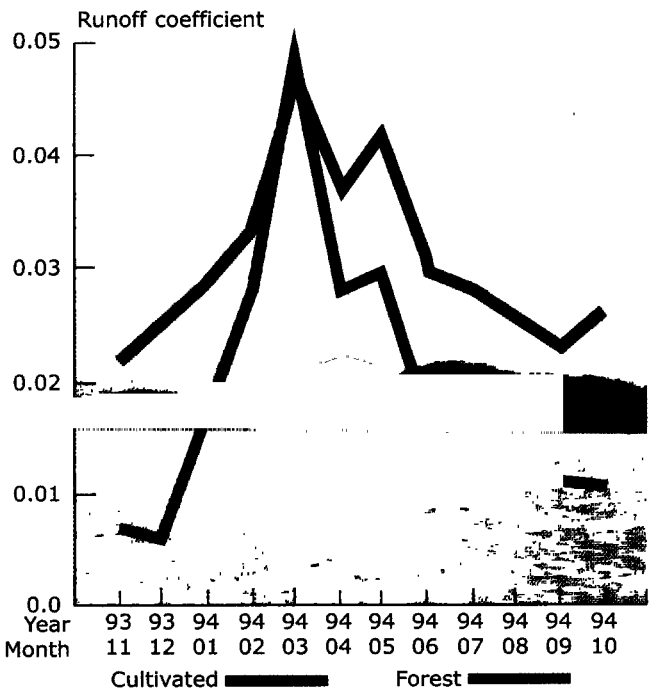
Effects of cultivation on the Iringa catchments in Tanzania — **Box 7.3**

In Tanzania a comparison in runoff between a watershed under montane forest (85 %) and two watersheds under cultivation (65-70 %) south of Iringa yielded the following results:

- Annual runoff from the forested catchment was 30-36 percent lower than from the cultivated catchments.
- Actual annual evapotranspiration from the forested catchment was higher than from the cultivated catchments.
- The major part of the higher annual runoff from the cultivated catchments occurred during the dry season and this was twice as high as from the forested catchment.
- The higher wet season flows from the cultivated catchments was due to a higher baseflow rather than increased surface runoff. Direct runoff from the heaviest rainfall events never exceeded four percent of the rainfall amount.
- Infiltration capacities were much higher in the forested catchment compared to a maize field in one of the cultivated catchments.

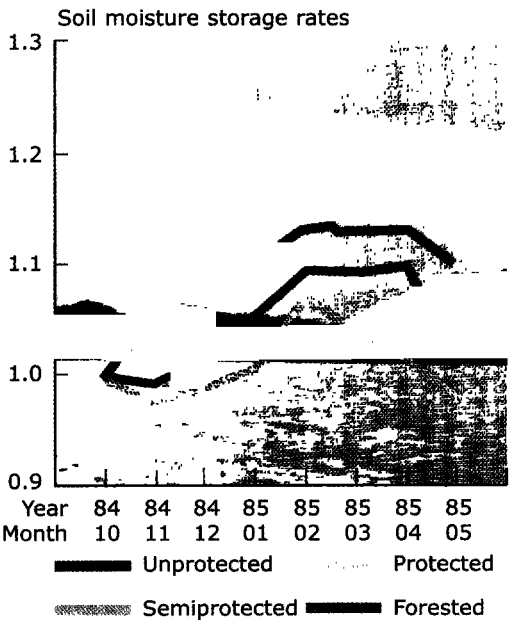
Lørup and Hansen 1997

Runoff Coefficients for Forested and Cultivated Land in the Iringa Catchment in Tanzania — **Figure 7.5**



Lørup and Hansen 1997

Influence of Forest Cover on Soil Moisture in Four Blantyre Catchments in Malawi — **Figure 7.6**



Chidumayo 2000

7.5.3 River sedimentation

Sedimentation refers to the combined processes of soil erosion, entrainment, transportation, deposition and compaction of sediments.

This section, however, deals with the transportation and deposition of sediments along rivers. Rivers under natural conditions will transport or deposit some sediments. Without the interference of human activities on elements of a watershed, there is an equilibrium between materials delivered to a stream and its capacity to transport such materials. Human activities such as cultivation or road construction within a watershed often disturb this equilibrium. The transportation of sediments by rivers causes reduction in the quality of water, therefore impairing the use of such water. Deposition of sediments in streams reduces channel capacity and therefore reduces the potential of a watershed to yield water.

The amount of sediments that are transported by rivers does not only depend on the rate of soil erosion within a watershed since not all the soil that is eroded from a watershed ends up in a stream. The ratio of the eroded material that is delivered to a stream to that which is eroded within the watershed is referred to as the sediment delivery ratio. This ratio depends on size and texture of materials eroded, relief of the watershed, and availability of places where deposition can take place. Large particles, and coarse textured particles are likely to be deposited before they reach streams. Watersheds with steep slopes will have high sediment delivery ratios.

Table 7.4 shows the comparative rates of sediment yield for selected rivers in southern Africa and other regions of the world. However, these figures must be viewed cautiously as most countries do not routinely monitor sediment transport rates. In most cases the figures are based on few samples taken in one season and may not be representative of prevailing sediment transport rates.

In addition, sediment transport rates of very large rivers such as the Orange, Limpopo and Zambezi mask some of the very high sediment yield rates which exist in parts of these watersheds. The estimated sediment production rates for South African rivers vary from 50 to 1,000 t/sq km/yr. (DWA 1986) Kienzle *et al* found that sediment yield rates of sub-catchments of the Mgeni catchment varied from 2 – 629 t/sq km/yr. The highest sediment yield rates were observed on watersheds with large proportion under informal settlements or communal areas. The estimated sediment yield rates for Zimbabwe are from 10 – 704 t/sq km/yr.

The sediment transport rates for most parts of southern Africa are low in comparison to rates experienced in very high rainfall and steep regions of south-east Asia. For most of southern Africa, high sediment transport rates occur at the beginning of the rainy season when most of the vegetation would have previously dried up. It has been observed that the first major flood may carry most of the seasonal sediment load.

There are several problems that arise from the transportation and deposition of sediments in rivers. These are indicated in Table 7.5.

Name of river	Mean Annual Runoff (mm)	Sediment yield (t/km/yr)
Orange	10	17
Zambezi	190	17
Limpopo	10	51
Congo	330	11
Manyame, Zimbabwe		21
Gwayi, Zimbabwe		127
Odzi, Zimbabwe		53
Caledon, Lesotho	100 - 200	200 - 300
Mgeni, South Africa		2 - 629
Amazon, Brazil	1 020	146
Ganges, India	660	1 128
Tsengwen, Taiwan	2 000	28 000
Haast, New Zealand	6 000	13 000

Transportation	Deposition
Damage to bridges, trees, fences, telephone lines	Damage to crops in floodplains
Damage to pumps and turbines	Waterlogging due to fine particles which restrict vertical drainage
Frequent replacement of worn parts of pumps and turbines	Reduced capacity of drainage ditches and irrigation canals
Reduction in light penetration with adverse affect on aquatic organisms	Reduced storage of water in channels causing overflows
Increased water treatment costs	Hinders navigation, needs frequent dredging

These problems are experienced in several watersheds of southern Africa. Reports abound of rivers which 20 - 30 years ago had major pools which supplied water to whole communities but are no longer existing, *eg* Save river in Zimbabwe. The siltation of Mulunguzi river in Malawi has adversely affected water supply to the city of Zomba. Sediment deposition along the Pangani river in Tanzania reduced its channel capacity, and this exacerbated damage to property and agricultural lands during the 1991 floods. One of the most serious consequences of deposition of sediments in rivers is the loss of aquatic habitats. Silted rivers hardly support fisheries and these are an important source of protein in rural areas.

7.5.4 Reservoir sedimentation

When water flows into a reservoir, its velocity is reduced which results in the reduction of the water to transport sediments. The coarsest fractions of the sediments are deposited first, often within the stream before it enters the reservoir. These deposits are referred to as backwater deposits. Such deposits promote the growth of phreatophytes that increase evaporation losses from these water bodies. Sediments of sand size are usually deposited soon after the flow enters the reservoir, and may cause the formation of a delta. Clay size sediments are deposited into the pool to form bottom deposits.

The rates of reservoir sedimentation will depend mostly on the prevailing rates of soil erosion within the watershed, the sediment delivery ratio, and the trap efficiency of the reservoir.[3] A reservoir with a small storage ratio will tend to spill almost every year, thus allowing some of the inflowing sediments to pass through the reservoir.

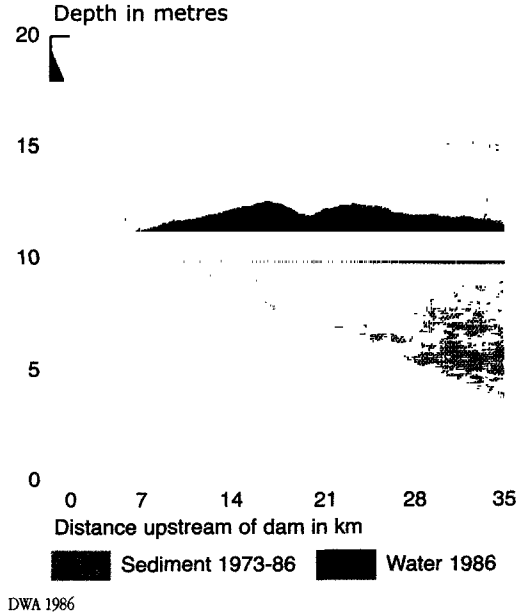
Reservoir sedimentation is a major problem in South Africa, particularly in the southern and eastern Cape regions which have a high erosion hazard. (Dept. of Water Affairs, SA 1986) It was estimated that large reservoirs in South Africa lose about 10 percent of their capacities every decade due to reservoir sedimentation.

In one part of Lesotho several small reservoirs silted up within the first 10 years, and after 30 years all had silted up. (Chakela 1981) The rates of loss of storage capacity due to sedimentation were estimated to vary from 4 – 20 percent per year for this part of Lesotho.

Reservoir sedimentation was not perceived to be a major problem in Zimbabwe until the mid-1980s when some small- to medium-sized dams which had just been completed filled up within the first 5 years. Siltation surveys of several dams in Zimbabwe during the 1980s showed that some of the large reservoirs had lost between 2 – 10 percent of their capacity due to sedimentation after about 20 years. (Interconsult A/S 1985) A survey of 132 small and medium dams in the Masvingo province of Zimbabwe revealed that 16 percent of the dams had silted up, while 50 percent of them had their storage capacity reduced by half. (Elwell 1993)

The major consequence of reservoir sedimentation is the loss of storage capacity. This reduces the amount of water which a reservoir can supply with a specified reliability, *ie* the yield. Figure 7.7 shows the rapid loss of storage capacity of a dam on the Caledon river in South Africa. In order to overcome the problem of the reduction in yield of a reservoir during its economic lifetime, a dead water storage is included in the design of a dam. This is the extra storage provided for storage of sediments. Watersheds with high sediment yield rates require large dead storage volumes, which increases the cost of constructing dams. It was estimated several years ago that the cost of constructing new dams to replace the lost storage due to reservoir

Loss of Storage Capacity of a Dam on the Caledon River, South Africa **Figure 7.7**



DWA 1986

3 Trap efficiency of a reservoir is the proportion of the incoming sediments that is deposited within the reservoir to the total volume of inflowing sediments. The trap efficiency of a reservoir increases with its storage ratio which is defined as the ratio of the storage capacity of a reservoir to its average annual volume of inflow.

sedimentation was about US$36 – $72 million per year in South Africa. (Chenje and Johnson 1994)

7.5.5 Effects of alien invading plants

Alien invading plants cause a decrease of the available water resources due to the increased transpiration losses. It has been estimated that these plants have caused a decrease of about seven percent of the mean annual flow of South Africa. This loss is equivalent to 3,300 million cu m of surface water. (Versveld 1998) The effects on groundwater have not yet been analysed. The reduction in water yield due to the invasion of alien plants in the various provinces of South Africa is given in Table 7.6.

The reduction in surface water availability due to the invasion of alien plants is estimated to be 17 percent or an equivalent of 91 mm of rainfall in the Northern Cape province, and 16 percent in the Western Cape province or an equivalent of 166 mm of rainfall.

7.5.6 Water quality

The transportation of eroded soils into rivers by running water, and the disposal of domestic and industrial wastes into rivers can degrade water quality. Sedimentation and pollution of water bodies are caused by runoff carrying soil particles and pollutants. Pollutants include nutrients from agricultural lands and domestic and industrial wastes from urban areas. All of these contribute to poor water quality. Some of the main causes of degradation of water quality are summarised in Table 7.7.

Silt causes water turbidity due to high concentration of dissolved and suspended solids. Small particles in the sediment, especially clay, are carried in colloidal suspension for long periods and these cause water in rivers and reservoirs to remain murky for long periods. This increases the costs of water treatment to achieve acceptable levels of clarification using compounds such as aluminium sulphate.

Province	Mean Annual Runoff (MAR) (M cu m)	Water use by alien plants (M cu m)	Water use by alien plants as % MAR	Annual rainfall equivalent* (mm)
Eastern Cape	9 999	558	6	369
Free State	3 546	86	2	356
Gauteng	552	54	10	414
Kwazulu-Natal	12 518	576	5	230
Mpumalanga	6 303	446	7	241
Northern Cape	910	151	17	91
Northern	3 384	298	9	113
North West	1 082	95	9	170
Western Cape	6 555	1 036	16	166

*Rainfall equivalent is the amount of water used by alien plants expressed as an equivalent of annual rainfall used
Versveld *et al* 1998

Cause	Sources in a watershed	Associated Problems
Suspended sediments	Runoff, resuspensions from bottom sediments	Turbidity, colour deterioration
Human and animal organic waste	Runoff, septic tanks, human contact and point loadings of effluents	Health effects, eutrophication
Industrial waste disposal and wash-off of agriculture (rural and urban), chemicals	Runoff, diffuse and point loadings of effluents and urban stormwater	Toxic pollution, eutrophication
Atmospheric deposition of sulphates (SO_4) and nitrogen oxides (NO_x)	Coal-fired power stations and industrial emissions, washout by rain, diffuse washout in basin and particulate deposition on land and water	Acidification, loss of biodiversity
Changes in water and salt balance	Runoff, diffuse and point loadings of irrigation outflows and urban and industrial wash-off	Salinization
Modification of natural flow	Release policy and regime	Downstream effects
Algal blooms and macrophyte weeds	End-products of eutrophication	Water transparency, deoxygenation Loss of biodiversity

Chidumayo 2000

Country	Urban population in coastal cities (000) Total	% with sewers	BOD of treated sewage (t/year)
Mauritius	415	64.0	5 300
Mozambique	1 220	12.7	3 100
Tanzania	860	14.4	2 450
Seychelles	25	25.0	125
Total	2 520	21.9	10 975

Chidumayo 2000, based on Osare 1983

Sediments are both sources and sinks of the chemical and organic constituents of channel and reservoir water. The finer sediment particles consist mostly of clays, hydrated oxides of iron and manganese, and organic matter. These provide the geo-chemically active sites that permit the uptake and release of chemical elements and compounds.

Contaminants such as plant nutrients, *eg* phosphorus and nitrogen, as well as toxic pollutants affect water quality. In most reservoirs, the net flux of contaminants is towards the bottom sediments due to settlement of either particulate or adsorbed contaminants. However, under certain conditions, especially in eutrophic waters enriched by excess plant nutrients, the release of nutrients from bottom sediments may exceed the input from incoming sediments resulting in a process called internal loading.

Urban domestic and industrial wastes, and runoff from fertilised croplands provide nutrients to reservoirs which can ultimately cause eutrophication of these water bodies. This problem is particularly important in the coastal states with significant proportions of their population lacking adequate sanitation. (Table 7.8) The amount of Biological Oxygen Demand (BOD) as a result of domestic sewage discharged into the Indian ocean from major cities in Tanzania, Mozambique, Mauritius and the Seychelles in 1980 was estimated at nearly 11,000 tonnes. (Osare 1983)

7.5.7 Effects on the coastal zone and water supply infrastructure

Sediments carried by rivers that open into the ocean can block river mouths due to the formation of sandbars caused by the combination of wave action, abstraction of water upstream and the attenuation of floods. Consequently, the estuaries tend to become shallower even when the sediment load carried by the river may have been substantially reduced. Such cases have been observed along the coastal zones of Mozambique, South Africa and Tanzania.

There is little data on total riverine sediments reaching the oceans, however it has been estimated that 480 million cu m of terrigenous sediments reach the Indian ocean each year from coastal states in southern Africa. (Finn 1983) As a result of the increase in silt carried by major rivers to the oceans, deltas have expanded and formerly sandy beaches have become dumps of river sediments while coral reefs fringing coastlines have been

Water supply problems at the Baricho intake, Kenya — **Box 7.4**

The Baricho intake located about 40 km north of Malindi was constructed in 1981 with a design capacity of supplying Mombasa and coastal areas with 60,000 cu m/day. These key sources of supply had a conventional water treatment plant. However, during the short period of operations not more than 35,000 cu m/day was ever realized from the source, and by 1986, very serious siltation problems at the intake had resulted, due to upstream catchment degradation on the Galana-Sabaki rivers. These high sediments in the water during the wet season elevated turbidity levels to 6000 NTUs. Dry season levels were 40-100 NTUs.

The heavy silt load created severe operational difficulties during the wet season and were very costly to mitigate. The intake facilities at Baricho had to be de-silted every day, dosage and volume of coagulants (Aluminium sulphate) tripled from 4 to 12 tonnes/day, and the pump and pump bearings wore down frequently due to the abrasive action of silt and sediments.

During the wet season, pump bearings often had to be replaced every two weeks. Because of the excessive maintenance and replacement costs, the surface intake facility at Baricho including the treatment works was abandoned in less than a decade of operation, representing a huge economic and financial cost, primarily due to poor catchment management!

The surface source was replaced with nine boreholes located in the vicinity of the Baricho intake along the Banks of the Sabaki river and a 5,000 cu m contact tank for chlorination. The boreholes provide about 55,000 cu m/day of which 45,000 cu m/day goes to Mombasa and 10,000 cu m/day to Malindi.

Hirji 2001

smothered or killed in turbid water. (Bliss-Guest, 1983) Furthermore, a decrease in sedimentation caused by upstream dams has also led to erosion of river deltas from ocean waves.

Sediments delivered to the ocean also adversely affect other coastal resources such as coral reefs, whose productivity and survival is being threatened. Excessive sediment deposition from the Galana Sabaki river, a tributary of the Athi river in Kenya has turned the colour of the ocean water around Malindi to red. The coral colonies that were once part of the largest reefs along the eastern coast of Africa are rapidly becoming unproductive because of high turbidity and lack of sunlight. It is estimated that the rate of sediment deposition from the Sabaki river into the Indian ocean increased from about 50,000 tons a year in the 1950s to 8.4 million tons a year by 1992, a 168-fold increase. The high sediment loads in the Galana-Sabaki river have caused serious problems to the Mombasa water supply from the Baricho intake. (see Box 7.4)

7.6 WATERSHED MANAGEMENT

Watershed management is aimed at maintaining and enhancing the potential of both the biotic and abiotic components of a watershed to provide goods and services to society. Some of the components of a watershed as discussed previously, are plants, animals, soil, channels, and lakes. Watershed management takes into account the interdependencies of these components, and regards a watershed as a functional unit. Some of the functions which a watershed performs are the provision of terrestrial and aquatic habitats, and a health function through the provision of safe drinking water. Water performs a service or a carrier function within a watershed by transporting dissolved and suspended materials. Some solid and liquid wastes that are products of human activities can be purified within a watershed.

The main objectives of sound watershed management should be to:

Optimize the utilization of land and water resources for multi-sectoral needs without compromising the ecological integrity of aquatic ecosystems;

Reduce surface runoff, soil erosion, sedimentation of wetlands, floods and water pollution; and

Ensure adequate supply of quality water.

Some of the measures that have been adopted in order to achieve the above objectives are presented in Box 7.5.

Measures adopted for watershed management — **Box 7.5**

- Conservation of natural vegetation cover and ecosystems in headwaters of rivers.
- Implementation of sound soil conservation practices, both structural and non-structural, at farm and community levels through training, extension education and credit support.
- Construction of specific hydraulic structures, such as dams, to store waters and control floods and sedimentation in downstream areas.
- Implementation of water conservation and demand management programmes in order to support the optimal and equitable utilisation of limited water resources.
- Development of appropriate, acceptable and implementable land-use plans using democratic and participatory approaches.
- Enforcement of pollution control regulations.
- Establishment of watershed authorities to regulate water resources development at national and international levels.
- Establishment of pilot catchment protection and/or rehabilitation projects involving local people and promotion of exchanges of knowledge and experiences among projects and countries.

DWAF, South Africa

The Drakensberg mountains are an important component of watershed management, which takes account of the various components and regards a watershed as a functional unit.

7.6.1 Approaches to watershed management

Two main approaches to watershed management have been adopted in order to implement the management measures presented in Box 7.5.

The first is based on the concept of river basin planning and development which has often been implemented through the creation of river basin authorities.

The second approach which is of recent origin is the integrated watershed or catchment management approach. This started to become popular in the 1990s.

7.6.1.1 River basin authorities

The main objective of forming these authorities has been to coordinate the development of water resources projects within watersheds so as to maximize benefits such as the provision of water for hydropower generation and irrigation. Some river basin authorities have been formed:

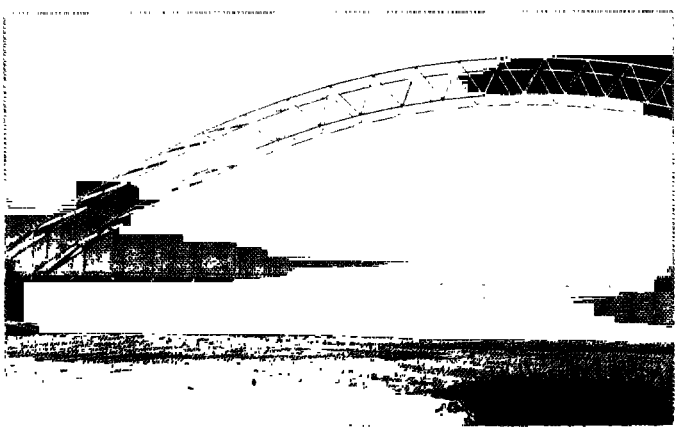
- Damodar Valley Corporation which was formed in 1948 in India;
- Awash Valley Development formed in 1954 in Ethiopia;
- Tana and Athi Rivers Development Authority of Kenya;
- Sabi-Limpopo Authority formed in Zimbabwe in 1965; and
- Zambezi River Authority (Zambia and Zimbabwe).

These authorities often fall within a ministry responsible for water development or irrigation, and have no mandates over the utilisation of other resources such as forests and land within watersheds. For example the main goal of the Sabi-Limpopo Authority in Zimbabwe was the planning, coordination, development and operation of water resources projects for water supply to large-scale irrigation schemes in the south-eastern part of Zimbabwe. Despite the existence of this authority and its successor the Regional Water Authority, the Save catchment has the most severe problems of soil erosion and siltation in Zimbabwe.

For those river basin authorities that have responsibilities for the management of problems such as deforestation and soil erosion, this management has been undertaken in order to protect downstream dams, and not necessarily to enhance the potential of arable lands to produce crops. River basin authorities have also tended to emphasize benefits that are too distant in both space and time to local communities.

Peasant farmers are often told to put in place soil conservation measures for the purposes of ensuring water to downstream urban communities. These local communities do not perceive any immediate benefits from such approaches. In some cases local communities are told to stop clearing forests/woodlands for the benefit of future generations and yet they cannot obtain sufficient food for their immediate benefit. Local views and indigenous knowledge systems have rarely been taken into account in some of the watershed management approaches. In addition river basin authorities have tended to over-emphasise the need to produce goods for export without taking into account the local needs, *eg* food.

The river basin authority approach has therefore not been successful in managing watersheds as these authorities have not been given a mandate to maintain and enhance the potential to produce various goods and services but instead have had their mandate constrained to deal only with water projects.



The Save river catchment shown here at Birchenough Bridge has the most severe problems of soil erosion and siltation in Zimbabwe.

7.6.1.2 Integrated watershed management

Integrated watershed management (IWM) is a holistic approach that seeks to manage a watershed as an ecosystem. (Box 7.6)

Integrated watershed management Box 7.6

Integrated watershed management is "a holistic natural resources management system comprising interrelated elements of land and water in a river basin, managed on an ecological and economic basis. It is a system that favours the integration of environmental policy across government, community, and industrial sectors through partnerships and extensive stakeholder inclusion."

Australian Water and Wastewater Association (AWWA) 1999

The objectives of integrated watershed management are:

- co-ordination of policies, plans and actions of government, private sector and individuals in the use and conservation of land, vegetation and water;
- maintenance of the stability and enhancement of the productivity of land, water, and vegetation;
- using land within its capability; and
- increasing the awareness of communities regarding sustainable and balanced resource utilisation.

The basic planning and management unit is the watershed. An integrated approach to watershed management recognizes that policies, plans and programmes of government agencies need to be co-ordinated and not based on a sectoral approach.

Whereas previous approaches to watershed management were based on a single resource which is water, this approach requires that government agencies adopt a multi-sectoral approach to management of resources. The utilization of one resource such as clearing of vegetation to make way for cultivation or livestock grazing will affect other resources such as water. Solutions to problems of watershed degradation must be part of broader developmental efforts.

IWM is based on the establishment of partnerships between government agencies, the private sector, groups and individuals. Each of these parties, and especially local communities, have an important role in identifying and prioritizing problems and suggesting potential solutions. Previous approaches to watershed management tended to be too centralized without creating opportunities for local communities to become part of the solution to problems of watershed degradation.

Within southern Africa, the IWM approach has been adopted in South Africa, while Zimbabwe is in the process of implementing this in pilot catchments. Water resources management in South Africa is based on watersheds through the delineation of Water Management Areas. Box 7.7 presents some of the motives for adopting an integrated approach in South Africa.

Umgeni Water, which has responsibility for water supply in Kwazulu-Natal, South Africa is in the process of implementing an integrated watershed or catchment management plan. Umgeni Water views integrated watershed management as,

> the co-ordination of management of land-use activities to ensure that there is sustainable balance between utilisation and protection of all environmental resources within a catchment.

Motives for adopting an IWM approach in South Africa — **Box 7.7**

- Increasing scarcity of water due to increase in water demand;
- Conflicts between different water users, eg irrigation of sugar and water supply to urban areas;
- Decrease in water yield due to afforestation;
- Deterioration of water quality arising from poor sanitation in rural areas, disposal of hazardous substances, and use of agro-chemicals;
- Reduction in recreational opportunities;
- Degradation of estuaries;
- Decline in the diversity of species occurring in aquatic ecosystems;
- Loss of life and property due to floods; and
- Soil salinization.

All groups of stakeholders are involved in the implementation of this approach. Central government has the responsibility for providing guidelines on water resources management. A catchment management committee was formed for the Ungeni watershed, with representatives of different groups of stakeholders and a mandate to implement integrated watershed management. This is the forerunner of a catchment management agency for the Ungeni watershed.

The Umgeni watershed has been subdivided into subcatchments for which a catchment management forum was formed for each one of them. A catchment management agency is a corporate body and its primary aim is to devolve responsibility for water resources management to local communities. Each catchment management agency has several catchment management forums which are non-statutory bodies formed to facilitate the participation of local communities in watershed management. These forums consist of representatives of the following stakeholders:

local authorities,
farmers,
business organizations,
organizations involved in water management such as irrigation boards and water committees,
non-governmental organizations,
educational institutions, and
community representatives.

The catchment management forums identify problems and prioritise them, and this becomes the basis on which the catchment management agency will produce a

catchment/watershed management plan. Some of the issues that have been considered in these plans are the removal of alien invasive plants from riparian zones, depletion of water yield due to afforestation and intensive sugar cane irrigation.

The experiences of Australia, New Zealand, and South Africa suggest that an integrated watershed management approach should be considered by other SADC countries. In addition to solving problems that are of a local nature, this approach can be implemented to manage shared watersheds such as the Zambezi, Limpopo, Orange, Incomati, Save, and Shire.

7.6.1.3 Broad guidelines

Watershed degradation in southern Africa is largely due to lack of a holistic approach to the utilization and management of land and water resources. In addition, there is rarely any coordination of efforts by various government agencies that have mandates over issues related to watershed management. For example, soil erosion on arable lands may be a responsibility of the department dealing with agriculture, while soil erosion on communal grazing lands is the responsibility of a department dealing with natural resources conservation, and siltation of reservoirs may be under another department dealing with water affairs. IWM creates opportunities for co-ordinating efforts of different government agencies and stakeholders.

One of the major weaknesses of approaches used in watershed management has been the lack of involvement of local communities in identifying and prioritising problems emanating from watershed degradation. Top-down approaches towards the solution of watershed degradation which do not take account of local needs such as food security and fuelwood, for example, have been the norm in southern Africa.

IWM provides a framework for the participation of local communities and other stakeholders, and one of its pillars is the need to have a balance in resource utilisation, which can be achieved only through negotiation with resource users within a watershed. Chapter 9 considers in detail community involvement in water resources management.

A fundamental requirement for the successful implementation of IWM is the commitment to environmental management. Most SADC countries have some form of a national environmental management policy, and in some cases with legislation to enforce this policy, for example, the:

Environmental Management Act of Malawi
Environmental Conservation Act of South Africa
Environmental Protection and Pollution Act of Zambia
Environmental Assessment Policy of Namibia
Environmental Impact Assessment Policy of Zimbabwe.

Such policies and legislation could be used to undertake strategic environmental assessments of policies and plans that are likely to be implemented in watersheds. For example, a strategic environmental assessment of a policy to improve rural incomes through introduction of cash crops and livestock is likely to identify adverse environmental impacts such as extension of arable lands which may contribute towards watershed degradation. These strategic environmental assessments will be complemented by environmental impact assessments of specific projects as part of policy implementation, *eg* environmental impact assessment of an irrigation project.

Another requirement for the successful implementation of IWM is the existence of institutions that will implement this approach. Since the scale at which watersheds are dealt with varies from the international shared watersheds to national and local watersheds, there is a need to have institutions that can deal with such differing scales.

Within the SADC region, the Protocol on Shared Watercourses provides a framework for dealing with watershed degradation problems that may affect the relevant basin states.

At the national level there is need for a government agency which coordinates all the efforts directed at watershed management. In South Africa, for example, the department responsible for water issues has this responsibility. Since watershed management issues cut across sectors, an institutional framework for coordinating all the diverse watershed management efforts is ideally required. The organization of governments along sectoral lines is a major problem in creating such a framework.

At the watershed level, there is a need to have a management agency or authority mandated to develop IWM plans that address the utilization of resources including watershed degradation. The experiences of South Africa and Zimbabwe suggest that these agencies have a great potential to address degradation problems when the

agencies are representative of major stakeholder groups. Local issues related to watershed management should be addressed by bodies below the catchment agency/authority, *eg* sub-catchment committees made up of representatives of all stakeholders at that level.

One of the major problems that has been encountered in creating institutions for watershed management, is that current planning by all agencies is based on administrative units that use political boundaries which may not be compatible with watersheds. In the case of Zimbabwe, it was recommended that administrative units such as district councils should form sub-committees that deal with watershed management issues for those watersheds which they share. (Water Tech 1999)

Another issue in the implementation of IWM is that individual farmers are not likely to participate in initiatives with benefits that will be realized only in the distant future. It is therefore recommended that where possible, the initial watershed management activities should provide benefits within a reasonable timescale, so that the enthusiasm of local communities is maintained. At the local level, watershed management initiatives should aim at providing tangible benefits to farmers that encourage them to participate in the implementation of these initiatives. Watershed management initiatives should be owned by the farmers and local communities. Government agencies should be facilitators in this process. Use should be made of Indigenous Knowledge Systems (IKS) in solving watershed management problems.

7.6.2 Optimising the utilisation and management of limited water resources

Within a watershed, the utilisation of finite and limited water resources is often expected to help water resource managers to achieve several objectives, some of which may be complementary, and some of which may be conflicting. There is need to ensure that:

- there is equitable distribution of the benefits of utilisation of the water resources;
- sufficient water of adequate quality is reserved for the purpose of maintaining the structure and function of aquatic ecosystems, in order to ensure the environmental sustainability of the water resources;
- technology which is implemented for water resources development and management is cost-effective, appropriate and sustainable within the constraints of available expertise and human resources capacity; and
- water resources are developed and utilised to generate socio-economic benefits which are critical in breaking the poverty cycle.

In order to achieve these multiple objectives, the utilisation and management of water resources in a watershed must be optimised, to promote maximum socio-economic benefit with minimum environmental costs. In general, there are two approaches to optimising utilisation of water resources: supply-side management and demand-side management. These are elaborated on in section 3.5 of Chapter 10.

7.6.3 Financing arrangements for watershed management

Cost-benefit analysis of watershed protection is necessary to provide a sound basis for recommending financing mechanisms and arrangements. Generally, people and communities living in or adjacent to river headwaters bear most of the costs of watershed protection while benefits such as water, aquatic resources and hydropower accrue mainly to users of downstream resources. How to equitably share the costs and benefits of watershed protection requires further study. For example, the controversy about commercial forest plantations and their impacts water supplies in South Africa was partly because of the lack of a full cost-benefit and social welfare analysis of forestry and alternative land uses (DWAF 1995). The situation is probably similar in other SADC countries.

One of the key tasks that government agencies can undertake is to work together with the local leaders so that communities fully appreciate the fact that watershed degradation causes a deterioration of their livelihoods, while watershed management initiatives are a form of investment that will improve livelihoods. Thus local communities will bear the costs of watershed management, in the form of their labour for example, so they can reap the benefits. The establishment of woodlots, for example, should enable households to obtain timber and fuelwood for their own use, and also market some of the products.

Rangeland management should lead to improvement in the quality of livestock. Such initiatives will lead to improvement in the quantity and quality of water resources, which is another benefit. The critical issue in watershed management should therefore be to work at the local level and derive benefits at the local level.

Individual households should be the investors in watershed management.

7.7 RECOMMENDATIONS FOR A SOUND WATER POLICY

This chapter has identified the causes of watershed degradation that emanate from poor land-use practices, and the need to [illegible] additional land in order to support rapidly growing populations. These fundamental causes of watershed degradation have been known since the colonial era and they still persist in the region up to now. The approach adopted during the colonial era in order to eliminate the causes and solve problems associated with watershed degradation involved production of land-use plans together with the implementation of soil and water conservation measures.

The implementation of these land-use plans often involved forced changes in settlement patterns (*eg* linear settlements in Zimbabwe), construction of soil conservation works, and in some cases destocking. These measures were very unpopular and were considered part of the discriminatory and oppressive land policies of colonial governments. Consequently, post-colonial governments were not very keen to implement such policies.

Over the years most governments in southern Africa have realised the need to eliminate the causes of watershed degradation. This is reflected by the various national conservation strategies and national environmental action plans that have been formulated by most countries. In some cases these policies have not been genuinely implemented.

Most of the approaches adopted for watershed management have been driven by one or a few government ministries, *eg* Ministry of Agriculture or Natural Resources. Other government agencies that are responsible for other natural resources such as water, vegetation and roads have often been treated as interested observers. In addition, users of natural resources within a watershed such as peasant farmers tend to be told what is best for them in terms of watershed management without any meaningful input into the identification of the problems and formulation of solutions. This approach is ineffective with regard to watershed management. Therefore a sound water policy should integrate horizontally and vertically the efforts of various government agencies and those of local communities in order to combat watershed degradation. This integrated approach is applicable at the regional, national, watershed, and local levels.

SADC sectors should ensure that their initiatives take cognisance of the linkages between elements of a watershed in order to combat degradation. For example, initiatives aimed at improving food security at the regional level should incorporate the need to manage soil loss, vegetation clearance for the purpose of increasing cultivated lands, and use of inorganic fertilizers, all of which have the potential to cause watershed degradation.

For the management of watersheds of international river basins, the SADC Protocol on Shared Watercourses forms an ideal foundation for facilitating watershed management initiatives. Basin states should integrate their approaches and actions regarding watershed management. Upstream states have to recognize that they have an obligation not to cause unreasonable effects on both the quality and quantity of water which flows to downstream basin states.

In this regard river basins authorities or commissions such as those for the Zambezi, Orange, Cunene, Incomati, and Limpopo rivers should adopt an integrated approach and "see beyond" their immediate objectives for which they are primarily mandated, such as hydropower. They should also take measures to optimally manage the linkages between land, water, vegetation and human activities within watersheds.

At the national level an integrated approach requires that government policies across all relevant sectors must reflect the linkages between natural resources which are all components of a watershed. Thus an agricultural policy which has as one of its goals to improve agricultural production should take into account the fact that this could affect water resources, vegetation and wildlife that are dealt with by other national policies.

Similarly a water policy will have to take into account the linkages between water, soil, vegetation and human activities. National programmes emanating from these policies should reflect these linkages, and therefore develop specific actions to manage the linkages in order to avoid or eliminate adverse effects like watershed degradation. This integrated approach requires sector ministries to work together in managing natural resources.

The integrated approach is also applicable at the watershed level where the emphasis is again on linkages between resources, and also relationships between upstream and downstream activities. A sound water policy should aim to raise an awareness among stakeholders about these relationships, and facilitate the development

of institutions which manage water resources at the watershed level so as to manage the upstream and downstream linkages. These institutions should create opportunities for users of resources occurring within a watershed to participate in making decisions concerning management of these resources. Institutional provisions in the water policies are discussed in chapter 10.

At the local level a sound water policy should recognize that villagers should participate in identifying problems associated with watershed degradation, and formulating solutions. At this level the farmers may not fully appreciate linkages between their activities and those of distant downstream farmers, and even future generations. However, it is important to develop an awareness of the linkages between cultivated lands, communal grazing areas, forest resources, and immediate water sources.

With such an awareness, the local communities should be encouraged to address the problem of the village from a villager's perspective. This approach has been successfully implemented in the Fouta Djallon region of Guinea where village associations were able to produce village land-use management plans under which soil and water conservation measures were implemented in communal grazing areas and individual fields.

A sound water policy should emphasize the importance of monitoring watershed conditions, *eg* deforestation rates, soil erosion rates, water quality, sediment transport rates and runoff. There is inadequate quantitative information on the net effects of changes in watersheds on socio-economics at farm and catchment levels, and on soil erosion, water quality, and catchment hydrology. The progress in defining the extent and severity of watershed degradation and its ecological and socio-economic effects will therefore remain limited until improved indicators are developed.

Hydrometric networks of most southern African countries are poorly developed or deteriorating. The development of effective data collection systems is a priority area for SADC countries, and this should be an integral component of a sound water policy. Box 7.8 presents some of the information required by decision-makers in order to manage watersheds.

Information required for watershed management — **Box 7.8**

- Rainfall
- Temperature
- Evapotranspiration
- River flows and water quality
- Sediment transport rates
- Vegetation types and cover
- Soil types
- Soil erosion rates
- Land uses
- Demographic data
- Livestock types and population
- Water uses, abstraction rates and storage
- Types and rates of waste water disposal
- Composition of aquatic ecosystems.

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AQUATIC WEEDS A[illegible] ROL[illegible]

Shirley Bethune and Kevin [illegible]erts

CONTENTS

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AQUATIC WEEDS AND THEIR CONTROL

INTRODUCTION

This chapter aims to answer the most commonly asked questions about aquatic weeds and their control, and to provide information to managers and policy-makers. The first questions are often:

What are aquatic weeds?
Which aquatic plants cause the main problems?
Where do they come from?
Where do they occur in southern Africa? and
Can they be useful in any way?

From an ecological perspective it is important to know why aquatic weeds are so successful and what is their impact on natural resources. From a practical point of view, a manager needs to know the nature and magnitude of aquatic weed problems. Planners, managers and decision-makers want to know what the management or control options are and which methods work best. Selected case studies from throughout the region are used to highlight the different types of control and the success that can be achieved. Finally, this chapter addresses how aquatic weeds can be best managed in southern Africa and provides policy recommendations.

To answer the first question, a *weed* is simply a plant growing at a place and/or time where it is considered undesirable. It can be either an introduced or native plant growing where it is considered detrimental to a conservation area, to people or their environment. An *aquatic weed* can be defined as:

a plant dependent on an aquatic habitat, with either emergent, submerged or floating leaves, which causes harm or is a nuisance to the natural environment or to people and their environment. In other words, it is an undesirable water plant.

The five aquatic weeds discussed in this chapter are considered the most important aquatic weeds in southern Africa. They are:

Water Hyacinth. *Eichhornia crassipes* (Mart.) Solms-Laubach (Pontederaceae)
Kariba Weed. *Salvinia molesta* Mitchell (Salviniaceae) (Water Fern)
Water Lettuce. *Pistia stratiotes* L. (Araceae) (Nile Cabbage)
Parrot's Feather. *Myriophyllum aquaticum* (Vell.) Verdc. (Haloragaceae) (Water Milfoil)
Red Water Fern. *Azolla filiculoides* Lamarck (Azollaceae) (Mosquito Fern, Red Carpet Weed)

All five species are true water plants, totally dependent on an aquatic habitat. Parrot's Feather is rooted in shallow water or on the banks and has both submerged and aerial leaves. The rest are all free-floating aquatic plants with buoyant leaves, able to colonise open waters. Two, Kariba Weed and Red Water Fern, are ferns, the rest are flowering plants. All are invasive species and with the possible exception of Water Lettuce, were introduced either as ornamentals or for aquaculture from South America. All can reproduce well vegetatively from small plant fragments. Kariba Weed is sterile and only female Parrot's Feather occurs in southern Africa.

Since the 1970s, aquatic weeds have spread dramatically throughout southern Africa causing increasingly severe resource degradation in most countries. Problems include,

physical impediment (to flow, transport and fishing);
interference with engineering structures;
worsening water quality;
health hazards;
increased evapotranspiration losses, in some cases;

biodiversity changes, as the rapidly growing weeds out-compete native vegetation and conditions beneath decomposing mats are unsuitable for aquatic invertebrates and fish.

Most habitat degradation is directly linked to the sheer mass of dense aquatic weed mats.

The first control efforts started 30 years ago and gained impetus with the more recent introduction of biological control. Today control efforts to combat Water Hyacinth are underway in South Africa, Mozambique, Zambia, Zimbabwe, Malawi, and Tanzania. Kariba Weed is being successfully controlled in Namibia, Botswana and South Africa. Water Lettuce has been successfully tackled in Zimbabwe, Botswana and South Africa, and Red Water Fern has been completely eradicated at some sites in South Africa, whilst Parrot's Feather remains difficult to eradicate.

[illegible]TIC WEEDS, THEIR ORIGIN AND [illegible]RENCE IN SOUTHERN AFRICA

8.2.1 Water Hyacinth — *Eichhornia crassipes*

Water Hyacinth is indigenous to the Amazon Basin in Brazil and Venezuela, and has spread to many of the tropical and sub-tropical countries of the world. It was probably introduced to Africa on account of its attractive flowers and was first recorded from Egypt in the late 1800s and from the Cape in 1908. Water Hyacinth has since spread to several southern African countries and is causing problems in Zimbabwe, Mozambique, Tanzania, Malawi, Zambia and the Democratic Republic of Congo. (Table 8.1) Namibia, Botswana, Lesotho and Swaziland remain free of the weed, as yet.

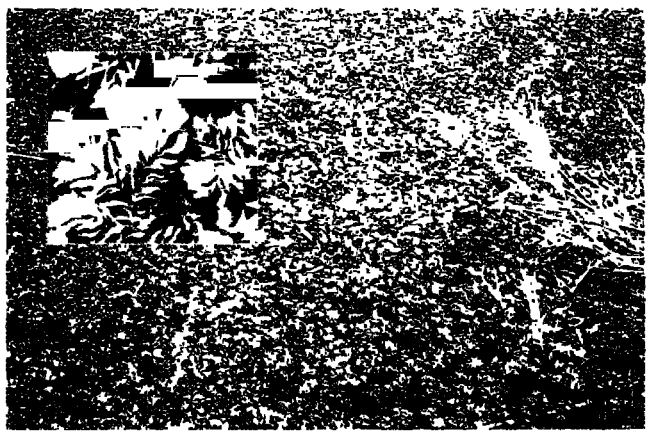
Water Hyacinth is a free-floating aquatic weed, with a short stem, and a rosette of leaves with bulbous leaf stems which add buoyancy and well-developed adventitious roots. The beautiful lilac flowers are borne in spikes. Each flower can produce over 350 seeds. Brittle stolons are produced laterally beneath the water surface and each terminal bud develops into rosettes identical to the parent plant. These daughter plants can either break off and act as potential colonizers or entangle with neighbouring plants to form dense mats. Individual plants can reach a height of one metre, depending on nutrient availability. Flowers are produced in summer and are pollinated by bees or are self-pollinated. Seeds can remain viable for up to 15 years according to Matthews (cited by Scott *et al* 1979).

Factors that favour germination include desiccation, followed by flooding in warm bright conditions *eg* when seeds are exposed on banks and shores as water levels drop in the dry season and are inundated again by the next season's flood. (Jacot Guillarmod and Allanson 1978) Seed propagation is important in both dispersal and re-infestation of cleared areas.

8.2.2 Kariba Weed — *Salvinia molesta*

Kariba Weed is a floating water fern of South American origin. It occurs naturally in southern Brazil. It was probably brought to Africa as a botanical curiosity or ornamental plant, and Mitchell, who first studied and later described and named it *Salvinia molesta* (Mitchell 1972), attributes its introduction to the Zambezi river system to that of a mission worker. Mitchell initially misidentified the plant as a closely related species, *Salvinia auriculata*. He subsequently recognised it as a new species, possibly also from South America. This was confirmed in 1978

Water Hyacinth Eichhornia crassipes *(Mart.) Solms-Laubach.*



Kariba Weed Salvinia molesta *Mitchell.*

Species	Country	First recorded	Standing waters Lakes/ponds/dams	Flowing waters Rivers/floodplains/canals
Water Hyacinth *Eichhornia crassipes*	Angola			Kwanza R. + irrigation canals
	DRC	1952 (Evans '63)	Lake Albert	Congo River
	Malawi	1968 (Harvey '91)	Lake Malawi	Zambezi, Lower Shire River
	Mozambique	1946 (Phiri '97)	Lake Cahora Bassa	Zambezi Delta, Incomati R
	South Africa	1908 (Stent '13)	Roodekopjes, New Years, Bon Accord, Hammersdale, Bloemhof and Shongweni, Hartbeespoort. Laing dams, and Lake Nsezi + Seekoeivlei, Umtata sewage works	Vaal, Crocodile (east + west), Swartkops, Bree, Berg, Kluitjieskraal Nseleni, Umlazi/Malazi, Mgeni, Mposa, Letaba and Yellowoods, Buffalo rivers
	Tanzania	1955 (Taylor '93)	Lake Victoria	Pangani, Kagera + Sigi Rs.
	Zambia	1937 (Brain '37)	Kafue Gorge dam, Lake Kariba	Kafue River
	Zimbabwe		Lake Chivero (former Lake McIlwaine) Lake Kariba	Manyame, Sabi, Makabusi rivers
Kariba Weed *Salvinia molesta*	Angola			
	Botswana	Early 1950s (Schlettwein '91)		Kwando/Linyati/Chobe Okavango Delta/Moremi
	Malawi	1975/8 (Bond and Roberts '78)		Lower Shire
	Mozambique	Early 1950s	Lake Cahora Bassa	Zambezi Delta, Incomati River, and near Maputo
	Namibia	1967 (Cilliers '99)		Kwando/Linyati/Chobe Zambezi River floodplains
	South Africa		La Motte + other farm dams – Letsitele area, Mtshawu dam. (NE Tvl, Natal, southern + SW Cape)	Sabi, Letaba River
	Zambia	1949 (Mitchell '67)	Kafubu dam – Ndola Lake Kariba	Kafue River
	Zimbabwe		Lake Kariba	Zambezi River
Water Lettuce *Pistia stratiotes*	Botswana	1989 (Smith '89)		Selinda spillway and Zebadianja
	Malawi			Middle and Lower Shire R
	Mozambique		Disaneng dam	Incomati River
	Namibia	1985 (Hines '85)		Linyati swamps, Chobe R
	South Africa	1987 (Cilliers '87)	Nhlangaluwe, Dakamila pans Orpen +Sunset dams	Limpopo River, Crocodile (eastern Tvl), Sabie + Salitje Incomati River
	Tanzania	own observation		Lower Moshi Irrigation S
	Zambia		Kafubu dam	
	Zimbabwe	1953 (Chikenwere '94)	Lake Chivero	Manyame River
Parrot's Feather *Myriophyllum aquaticum*	Lesotho	1918	University pond - Roma	
	South Africa	1973 (Jacot-Guillarmod '80)	Golden Pond reservoir, Hartbeesport, Vaal, Bux, Nursery and Rooi-kraal dams and the Klawerfontein reservoir. Numerous farm dams.	Mokolo, Vaal, Bronkhorst-spruit, Jukskei, Elands, Crocodile, Sterkstroom, Mlazi, Umgeni, Boontjies, Swart, Berg, Bree, Eerste, Liesbeeck, Buffels, Kariega, Crocodile (east + west), Umhlatuzan, Mgeni and Selons, Tugela, Limpopo R
	Zimbabwe			Hunyani, Gwai + Lundi rivers
Red Water Fern *Azolla filiculoides*	South Africa	1940s (Jacot Guillarmod '79)	Wide-spread in small farm dams.	Widespread in small streams *eg* Oorlogspoort, Orange + Limpopo R

Based on Jacot Guillarmod 1979, 1980; Mitchell 1967, Chikwenhere and Forno 1991; Cilliers 1991 a,b,c; de Groot 1991, Schlettwein and Bethune 1992, Zimmermann 1994; Labrada 1996, Bond and Roberts 1978, Cilliers 1999 a; Hill and Cilliers 1999, Henderson 1999; Hill 1999, and minutes and country reports of SARRCUS Aquatic Weeds subcommittee meetings 1984 – 1997

when the Australian aquatic weed expert, Wendy Forno, found *Salvinia molesta* in its native habitat in South America. (Forno and Harley 1979)

Table 8.1 lists the spread of Kariba Weed through the region. It was first collected on the Zambezi river at Katombora, near Kazungula in 1948 (Mitchell 1967), and soon spread to the Chobe and Linyati rivers between Namibia and Botswana. It now also occurs in South Africa, Zambia, Malawi, Angola and Mozambique.

Kariba Weed has a horizontal stem with a pair of aerial leaves and a submerged "root" that is actually a modified leaf, at each node. Air-trapping, water-repellent hairs on the surface of the leaves keep the plant buoyant. The cage-like shape of the hair tips distinguishes the species. The common name, Kariba Weed, refers to where it first caused problems in Africa in the 1960s, on the newly impounded Lake Kariba on the Zambezi river downstream of Victoria Falls. Kariba Weed has two distinct growth forms. New infestations are typified by plants with flat, open leaves spread out on the water. This is the colonising or pioneer form. In denser infestations, the mat forms with larger, densely packed V-shaped folded leaves are found.

Mats form as plants are pushed together and grow into each other. *S. molesta* mats can be up to half a metre thick and other vegetation, such as wetland grasses, sedges and reeds can in turn grow on these so called "Sudd" islands. These can form impenetrable blockages in river channels.

8.2.3 Water Lettuce / Nile Cabbage — *Pistia stratiotes*

Water Lettuce is a free-floating plant, first recorded in Egypt in 77 AD and now found throughout the tropics and sub-tropics. This cosmopolitan species may have originated in South America. As shown in Table 8.1, it was present in the Mukuvisi river in Zimbabwe in 1937 (Chikwenhere 1994) and along the north-eastern border between Namibia and Botswana in the 1980s (Hines *et al* 1985, Smith 1989), as well as in the Kruger National Park in South Africa. (Cilliers 1987)

This pale-green, lettuce-like floating plant has a rosette of velvety, conspicuously veined, leaves and long fibrous roots. It can also survive rooted in mud. The pale white flowers, one female flower with 3 – 8 male flowers above it, are inconspicuous and surrounded by a bract with long hairs. The fruit is a berry with small seeds capable of germination, but reproduction is mainly vegetative. Daughter plants bud off from horizontal rhizomes.

Water Lettuce grows rapidly in quiet or slow flowing waters, yet can invade and persist in fast flowing rivers too, but is susceptible to frost. It can form thick mats, but problems are usually localised. Plants can spread from one water body to another by river flow, floods and wind, and animals such as hippopotami and by people via boats and possibly fishing gear. People use Water Lettuce as ornamental plants in ponds and to shade fishponds.

Water Lettuce Pistia stratiotes *L. (Araceae).*

8.2.4 Parrot's Feather — *Myriophyllum aquaticum*

Parrot's Feather is a rooted, partly submerged aquatic weed that can also exist on muddy banks or sandbars above the water level. It was first recorded in Paarl, South Africa in 1918, but was not considered a weed until its spread was seriously affecting rivers such as the Berg in the Western Cape. (Jacot Guillarmod 1980) (see Table 8.1) Like the other aquatic weeds, it is native to South America and has been introduced and dispersed by people. It is sometimes planted in aquaria but has spread mainly via fish hatcheries where it was used to provide shelter for fish. In the Cape, its early distribution is linked to rivers and ponds stocked with fish from the trout hatchery at Jonkershoek and the Amalinda fish hatcheries. (Jacot Guillarmod 1980) It was first noted in Lesotho in a pond on the university grounds in 1993.

Parrot's Feather has dark green, finely divided, feathery leaves carried in whorls at each node. The plant is rooted and usually has both submerged and aerial leaves. It is usually restricted to water less than 1.5 m deep and occurs typically in shallow ponds and along riverbanks.

Parrot's Feather Myriophyllum aquaticum *(Vell.) Verdc.*
Shown here between insect-damaged Water Hyacinth plants.

Young plants can be entirely submerged. A closely related indigenous species *Myriophyllum spicatum* is a completely submerged plant. At one stage it was thought that the submerged stage of Parrot's Feather was a hybrid between the indigenous and introduced species. Laboratory tests proved this to be false. (Jacot Guillarmod 1980) Under favourable conditions aerial growth is resumed. Only the female form of this dioecious plant has been introduced to southern Africa.

The inconspicuous, minute, cream-coloured flowers are borne at the base of the aerial leaves. Reproduction is vegetative, small sections of stem with roots can regenerate. The plants do well in clear, polluted and even slightly brackish water. Growth continues throughout the year but aerial sections may suffer from frost. The plant can be spread by flooding, animals and by recreational activities, and once it has taken root, it is extremely difficult to eradicate.

8.2.5 Red Water Fern — *Azolla filiculoides*

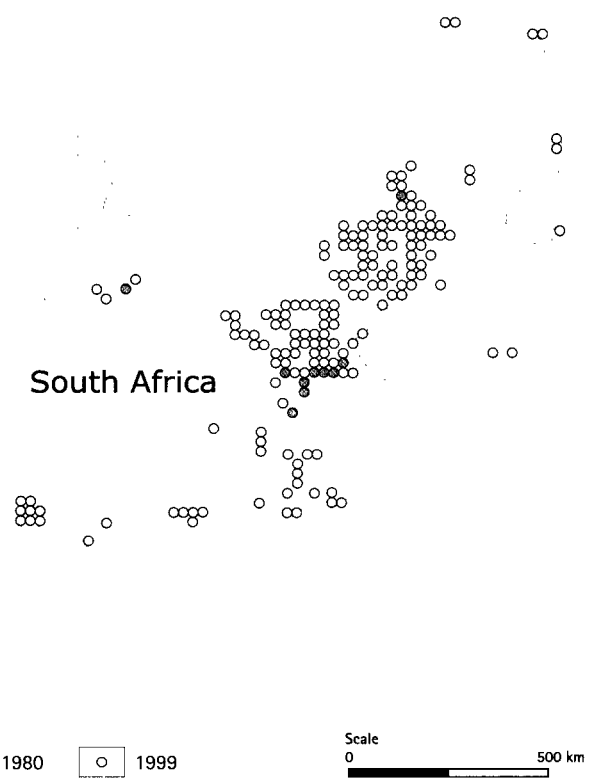
Red Water Fern is native to South America and was first recorded in South Africa near Colesberg in the 1940s, and was most likely imported as an aquarium plant. (Jacot Guillarmod 1979) Initially this small, free-floating plant was restricted to that area but in 1971 it was found downstream in the Orange river near Upington. (Ashton and Walmsley 1976). Its rapid spread in South Africa since then is documented in the *Southern African Plant Invaders Atlas (SAPIA)*. (Henderson 1999) Map 8.1, reprinted from SAPIA, shows how widely this weed has spread over the last decade.

This aquatic fern has a short, branched, floating stem, bears adventitious roots and has small alternate bi-lobed overlapping leaves. Only the dorsal leaf contains chlorophyll. In winter anthocyanin in this lobe gives it the red-wine colour, referred to in its common name.

Interestingly, Red Water Fern contains a symbiotic, blue-green alga, *Anabaena azollae*, within the dorsal leaf cavities. This algae is capable of fixing nitrogen. (Ashton and Walmsley 1976, 1984) The association is truly symbiotic in that both organisms are dependent on the other for normal growth. This ability to fix nitrogen from the atmosphere means that the fern can successfully colonise nutrient poor waters. (Ashton 1978) It can reproduce vegetatively by elongation and fragmentation of small fronds and sexually by spores. The hard, resistant spores are produced in small rounded fruiting bodies in the axils of the leaves and are able to survive desiccation.

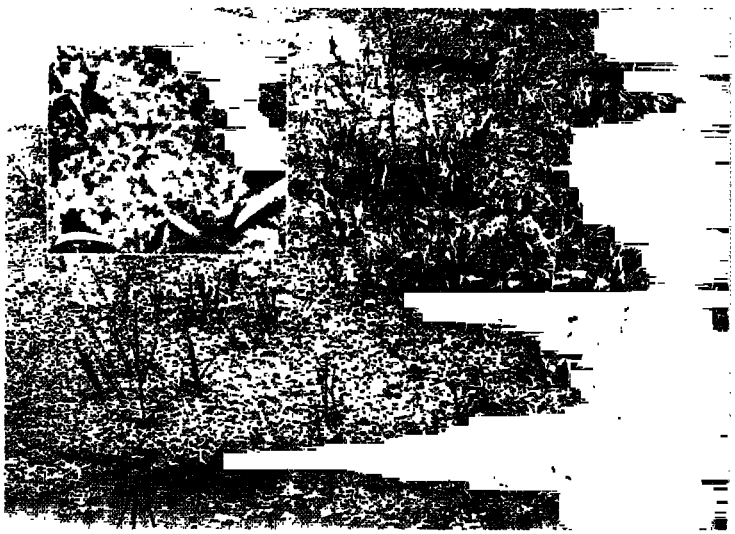
Red Water Fern can form multi-layered mats completely covering small ponds and slow flowing streams or irrigation canals. In larger impoundments such as Gariep Dam in South Africa it is of little significance as the plants are easily dispersed and fragmented by wind

Expansion of *Azolla filiculoides* in South Africa, 1980 – 1999 **Map 8.1**



From Henderson, L. "The Southern African Plant Invaders Atlas (SAPIA) and its contribution to biological weed control". In *African Entomology*, Memoir No. 1, June 1999.

and wave turbulence. (Ashton and Walmsley 1976) One danger is that with its reddish/brown colour, it may appear solid, with the result that livestock venture onto the water and drown. Birds such as Guinea Fowl have been seen to land on a similarly solid looking mat of *Spirodela* and drown. (own observation, Swakoppoort dam, Namibia)



S. Bethune

Red Water Fern Azolla filiculoides *Lamarck.*

8.3 FACTORS INFLUENCING THE GROWTH AND SPREAD OF AQUATIC WEEDS

Aquatic plant infestations are often temporary and may decline naturally, yet the aquatic weeds discussed in this chapter persist in southern Africa. The main reasons are discussed below and summarised in Box 8.1: Why are aquatic weeds so successful in southern Africa?

8.3.1 Absence of natural enemies

In their native environment, plants are invariably fed on by herbivores or are host to parasites that limit their growth rates. When these plants are introduced elsewhere, their natural enemies are left behind. Without their natural enemies they tend to grow more successfully and spread more aggressively, so causing problems. (Harley and Forno 1992) The rapid spread of Kariba Weed along the Zambezi river system can be attributed mainly to the lack of natural enemies.

Why are aquatic weeds so successful in southern Africa? Box 8.1

- **Absence of natural enemies** The aquatic weeds were introduced from South America without their natural enemies that keep them in check there.
- **Rapid growth rates** Aquatic weeds have high growth rates under tropical and semi-tropical conditions ie many have rapid "doubling rates" in southern Africa.
- **Reproductive strategies** Most are able to reproduce vegetatively from small fragments and several have very durable seeds or spores.
- **Ability to colonize new habitats** Aquatic weeds are specialist invaders often with a colonizing growth form able to easily spread to and colonize new habitats.
- **Human activity** Weeds can be both deliberately and inadvertently spread by people.
- **Lack of awareness** Greater awareness of the potential problems and wider recognition of weed species together with keener vigilance is needed.
- **Availability of nutrients** Enriched habitats such as newly inundated impoundments or waters receiving municipal or agricultural effluent provide ample nutrients for plants to flourish particularly when growth rates are nutrient limited.

Water Hyacinth is a successful invader due to its rapid growth rate, particularly in eutrophic waters, rapid rate of vegetative reproduction, ability to produce viable and durable seeds, lack of natural enemies and its relative immunity to insect pests and disease outside its native range. Its rapid spread continues to be aided by people, it is still widely cultivated for its attractive flowers and inadvertently transported by boats, fishing gear and animals. In parts of Asia it is cultivated as a green fodder.

Kariba Weed is such a successful invader on account of its rapid growth rate, special colonizing growth form, the almost linear relationship between nitrogen availability and growth, its floating nature and its ability to reproduce vegetatively from any fragment containing a node. It has no natural enemies in Africa and can be transported easily to new sites by currents, wind, boats and animals moving between water bodies.

Water Lettuce is successful because of its floating nature, ability to reproduce vegetatively and lack of natural enemies.

Parrot's Feather is a successful invader due to its continuous growth, ability to withstand frost, lack of natural enemies its ability to reproduce vegetatively from small fragments and the resilience of its perennial root stock to desiccation.

Red Water Fern's success as an invader can be attributed to a lack of natural enemies, phosphate-rich waters, the fact that the plants are fragile and easily fragmented by turbulence, its ability to reproduce from these fragments, the sporesthat are resistant to drought, and ease of dispersal by floods, people and water birds.

8.3.2 Rapid growth rates

Luxuriant plant growth is intensified in tropical or semi-tropical climates where growth continues unchecked throughout the year. Successful weeds grow best in warm temperatures and only Parrot's Feather shows any tolerance for frost. Generally, the warmer the water the better the plant grows. Light is not a limiting factor for plants with floating or aerial leaves and water is plentiful in the aquatic environment. Box 8.2 Doubling time – How fast can aquatic weeds grow?, gives examples of the rapid growth rates of some aquatic weed species.

8.3.3 Reproductive strategies

All the aquatic weeds causing problems in southern Africa can reproduce vegetatively from small plant fragments. Water Hyacinth and Red Water Fern can also reproduce sexually, from seeds and spores that are resistant to desiccation and can remain viable for many years.

8.3.4 Ability to colonize new habitats

Although the floating weeds tend to prefer quieter, slow flowing habitats, that promote mat formation, they are well-adapted to colonize new habitats. For example, Kariba Weed has two distinct growth forms, the colonizing plants are flatter and more open for greater buoyancy during the dispersal phase, while individual or small clumps of Water Hyacinth plants form small floats that are easily spread to new areas by seasonal or episodic floods. Resistant seeds and spores enable rapid germination in newly inundated areas. This is why new Water Hyacinth infestations often follow an increase in water levels, *eg* in Lake Chivero in Zimbabwe, the problems occuring when good rains follow a dry spell.

8.3.5 Human activities

The increased human utilisation of natural waters, the construction of canals and dams and the enrichment of rivers, floodplains and lakes by agricultural, industrial and urban waste, have magnified the aquatic weed problem. Even indigenous species can be stimulated by altered conditions to create a problem.

8.3.6 Lack of awareness

Most aquatic weeds were probably introduced as ornamental garden plants, via the aquarium trade and as sheltering plants in fish hatcheries. People, moving fishing gear and boats from one waterbody to another can inadvertently spread weeds. A general lack of public awareness about aquatic weeds within southern Africa contributes to this inadvertent spread of weeds. Botswana and South Africa have produced colourful posters and pamphlets to address this. Botswana goes a step further with the *Aquatic Weeds (Control) Act No 58 of 1987,* that strictly controls boat traffic to prevent weed transfers. Infested areas are designated and the use of boats and aquatic apparatus is currently banned by legislation. In 1993, Namibia introduced voluntary boat inspections at border checkpoints to prevent the spread of aquatic weeds between neighbouring countries.

8.3.7 Availability of nutrients

The growth of most aquatic plants is nutrient limited, meaning that an increase in the availability of the limiting nutrient, typically phosphorus or nitrogen in aquatic habitats, can stimulate increased growth. In the early 1960s, Kariba Weed took full advantage of the enrichment caused by the inundation and subsequent decomposition

Doubling time - How fast can aquatic weeds grow? **Box 8.2**

One reason for the success of aquatic weed in southern Africa is their rapid growth rates.

Growth rate can be expressed as a "doubling time", which is the time (usually measured in days), that it takes a plant to double its biomass. The following "doubling times" have been measured for Water Hyacinth, Kariba Weed and Red Water Fern.

Water Hyacinth Doubling time based on field growth rates of 1–12 percent per day measured at Hartbeespoort dam in South Africa varied from 11–30 days (Scott *et al* 1979), and Gopal (1987) reports an optimal doubling time of 6–7 days based on laboratory experiments.

Kariba Weed Gaudet (1973) reports a doubling time as low as four days based on growth rates of 15–30 percent per day under optimal laboratory conditions. In Lake Moondarra near Mt Isa in Australia, field growth rates of up to 19 percent/day were measured. (Finlayson 1984) Field studies in Lake Kariba record rates of 4.8–8.6 percent per day, or a doubling time of 3.4 days. (Mitchell and Tur 1974) In the Eastern Caprivi, field growth rates ranged from 0.3–8.5 percent per day, indicating that under natural conditions, plants can double their mass in 8–20 days, while laboratory experiments showed that under optimum conditions the plants double their mass every 3 days. (Schlettwein and Bethune 1992, Bethune 1996)

Red Water Fern Hill (1999) cites Lumkin and Plucknett who in 1982 reported that under favourable conditions the doubling time of Red Water Fern is 5–7 days, with daily growth rates above 15 percent.

Bethune 1996, Finlayson 1984, Gaudet 1973, Gopal 1987, Mitchell and Tur 1975, Schlettwein and Bethune 1992, Scott, Ashton and Steyn 1979

of the lush vegetation of the Zambezi valley and rapidly covered 21 percent of the lake surface. (Mitchell and Rose 1979) Weeds flourish in nutrient-rich waters and yet also do well even in nutrient poor environments, *eg* in the Eastern Caprivi floodplains. (Haller 1996) Even in slow-flowing waters the nutrient flux remains high and sufficient nutrients are continuously made available for growth.

8.4 PROBLEMS CAUSED BY AQUATIC WEEDS

The problems caused by aquatic weeds are mainly related to the sheer mass of plant material produced and are worst in species such as Water Hyacinth and Kariba Weed that form almost impenetrable mats.

8.4.1 Physical impediment to access, flow, transport, fishing and recreation

In the sheltered littoral zones of ponds, lakes and impoundments, and in slow-flowing river and floodplain reaches, the stabilised, compact, often multi-layered mats develop. Weeds can obstruct flow in rivers, streams and canals, often forming a barrier that initially dams floodwaters, only to increase the damage caused by subsequent flooding. In 1977, Water Hyacinth in the Swartkops river in South Africa caused extensive flood damage.

Dense mats near the shores of rivers and lakes can prevent people reaching the water. Mats are difficult and expensive to remove and alternative water sources are costly to provide and maintain. An added danger is the possibility of crocodiles or snakes lurking in or near the mat. In Lake Victoria, hyacinth mats prevent, disrupt and delay water transport and so increase the cost of water transport on which the rural communities living around the lake depend.

Progressive encroachment of aquatic weed mats into wetlands hampers access to fishing areas and is generally assumed to decrease fish production by lowering dissolved oxygen levels. In the former Lake Liambezi, on the border between Namibia and Botswana, drifting mats and more permanent "Sudd" islands of Kariba Weed caused local catches to decline, and the low oxygen concentrations beneath the Kariba Weed mats impaired water quality making it unfavourable to zooplankton and fish. (Seaman *et al* 1978)

Aquatic weed concentrations affect fisheries by blocking fish landing sites, covering fish breeding areas and getting tangled in fishing gear. This can reduce production, decrease the variety of fish caught, increase the cost of fishing and so result in decreased incomes to fishermen and higher prices to consumers. (Orach-Meza 1995) In Lake Victoria the hyacinth infestation of shallow bays has caused fish to migrate to open waters, reducing the potential of the bays as nursery and fishing areas. The blanketing of fish spawning areas impacts on all levels of the food web. Blocked landing sites mean that fisherman take longer to land their catch and on some days cannot take their boats out at all.

Fishermen in the lower Shire river valley experience lower catches where Water Hyacinth occur and find that the mats impede canoe travel, often making long detours necessary and in severe cases fishing areas have become abandoned. Hyacinth makes it difficult to set and retrieve nets and the weed may even sweep nets and long lines away.

Aquatic weed mats covering dams, lakes and rivers reduce their aesthetic appeal, prevent or reduce the potential for water sports and recreational activities such as yachting, skiing and angling and can reduce the price of real estate on their shores and the tourist value of conservation areas.

8.4.2 Interference with hydropower production, irrigation schemes and water intakes

Aquatic weeds can interfere with the operation of engineering structures. Extensive mats can block water intake points, canals and hydropower installations. At the Owen Falls power station in Uganda, dense mats of Water Hyacinth block the intake screens and filters of the cooling system and, according to Orach-Meza (1996), the shutting down of the turbines and manually removing the weeds, is estimated to cost the Ugandan electricity board US$1 million per day. On the Pangani river in Tanzania, special weed harvesters have been incorporated in the design of hydropower dams and hyacinth eradication is part of daily operational costs. Rooted weeds, such as Parrot's Feather, can have an even greater impact than the floating weeds, often impeding water flow and causing siltation in irrigation canals in South Africa. (Jacot Guillarmod 1980)

8.4.3 Water quality deterioration and health risks

Dense aquatic weed infestations reduce the quality of drinking water, often imparting an unpleasant odour, taste

or colour into the water. Weed mats cause stagnation by the accumulation of organic matter and by preventing light penetration and therefore photosynthesis and oxygen production under the mats. The high organic content also affects the pH, making additional treatment necessary to make the water potable. Farmers, who irrigate from the Mokolo river in South Africa, complain that water pumped from near Parrot's Feather infestations discolours the tobacco crop, halving its market value. (Cilliers 1999a)

Dense mats of floating weeds can themselves enrich still or slow-flowing waters. The plant material at the bottom of the mat dies and sinks to the bottom or slowly decomposes causing anaerobic conditions that in turn liberate phosphorus, nitrogen, manganese and iron from the sediments and decaying plant material. A vicious cycle results, the more nutrients available, the better the weeds grow. Under such eutrophic conditions algal growth can result, the nutrients released by decomposing aquatic weeds stimulate algal blooms which in turn cause taste, odour and water purification problems.

Established weed mats can be a health hazard favouring the spread of certain diseases. Weeds can provide ideal sheltered breeding sites for malaria carrying *Anopheles* and *Monsonia* mosquitoes as well as a suitable habitat for bilharzia snails. Dense mats can hide mosquito larvae from predators.

8.4.4 Habitat alteration and bodiversity changes

Aquatic weeds threaten the survival of native plants and animals by altering aquatic ecosystems. Due to the weed cover and lack of sunlight penetrating the water, the indigenous fauna and flora will change as some species move away from the adverse environment, are out-competed with or suppressed by rapidly growing aquatic weeds. Other native species adapt, and new ones move in to exploit the void created by the change. Slow-flowing streams may be covered for up to six months of the year, fish are unable to survive in the resultant anaerobic water and aquatic insects are replaced by terrestrial species. Weed mats tend to reduce overall aquatic biological diversity.

Aquatic weeds can increase siltation of rivers and dams. Edwards and Musil (1975) report a constant sedimentation of up to 30 cm debris annually beneath hyacinth mats, whilst Jacot Guillarmod (1980) warns that rooted plants, such as Parrot's Feather, trap silt and may cause small ponds to silt up.

CHG Schelnwein

Kariba Weed, mat growth form.

8.4.5 Water loss due to evapotranspiration

Water loss from surface waters covered by aquatic weeds can exceed that from open water. Water Hyacinth mats increased evapotranspiration to 3.5 times that of free water surfaces. Recent studies show that Water Hyacinth transpires at a rate of 5 litres/sq m/100 plants/day, *ie* with a leaf area of 11.2 sq m/sq m water surface area. (Bosman 1999) The impact of smaller plants such as Red Water Fern is less clear. In areas of low relative humidity such as Namibia where evaporation rates are high, transpiration rates may be balanced by lower evaporation due to the plant cover, reduced wind action and shading of the water surface by the plants.

8.5 USE OF AQUATIC WEEDS

In many countries, particularly in Asia, aquatic weeds are harvested and used for fodder, fertilizer, fibre and to produce biogas. They are also used to provide shade in aquaculture ponds, sold as ornamentals for garden ponds and used to remove nutrients in water purification treatment. (Ad Hoc Panel 1976) One drawback of aquatic weed utilisation is that aquatic plants have a very high water content, *eg* Water Hyacinth consists of over 90 percent water, which complicates use as food, fodder, fertilizer, fibre and biogas. Large volumes of heavy, water-laden plant material yield comparatively little product.

A more serious drawback is the very real risk of re-infestation. Gopal (1987) cautions that,

> "The harmful effects of water hyacinth on the environment and man [sic] cannot be mitigated by the newly discovered utility. The developing countries need not encourage propagation of the weed for utilization. The interests of mankind [sic]can only be safeguarded by seeking effective control of water hyacinth, not by its utilization."

This warning is equally true for any of the other aquatic weed species. The experts at a workshop on Control of Africa's Floating Water Weeds were adamant that the problems caused by aquatic weeds are so serious and the danger of infesting other areas so high that utilization should be avoided and is not an effective means of control. (Greathead and de Groot 1993) In southern Africa, the SADC Aquatic Weeds and Water Quality committee (SAWWQ) strongly discourages the utilization of alien aquatic weeds due to this risk.

8.5.1 Food and fodder

Water Hyacinth can be used as a protein-rich, fish feed and fodder. To make it more palatable to cattle it can be made into sileage. Tests on Kariba Weed as a protein source, an organic manure, and as fodder, found its use to be commercially unprofitable and the risk of infestation unacceptably high. (Senarata 1952,cited in Sculthorpe 1967) The Royal Commonwealth Society has proposed trying to extract protein-rich "leaf curd" from Water Hyacinth on Lake Victoria as a food supplement for people and stock. (Thring 1998)

8.5.2 Aquaculture and horticulture

Parrot's Feather, *Myriophyllum aquaticum* was initially used in fish hatcheries. The less invasive, indigenous species, *Myriophyllum spicatum,* should rather be used to provide shelter for fish fry and as substrate for the epiphytes on which they feed. All five aquatic weed species have been noted in parks and gardens throughout southern Africa where they are used as ornamental plants, despite being listed as prohibited weeds.

S Bethune

Water Hyacinth used to display glassware in a shop in Stockholm, Sweden, 1999.

8.5.3 Fertilizer

Water Hyacinth analysis conducted by Sharma in 1971 shows that nitrogen, phosphorus and potassium occur in sufficient concentrations for use as an efficient fertilizer. (cited in Edwards and Musil 1975) In central Africa, dried Kariba Weed is used as mulch for cocoa, rubber and coconut plantations, but carries the risk of re-infestation via run-off to irrigation canals and rivers. Due to its high nitrogen content, Red Water Fern can be economically used as a fodder and green manure. (Ashton and Walmsley 1976) Mishustin and Shilnikova (1971, cited by Ashton and Walmsley 1976) relate that with its *Anabaena* symbiont, it increased rice yields in Vietnam and recommend the addition of 15-20 kg per hectare.

8.5.4 Fibre and pulp products

Dried Water Hyacinth has a 40 percent fibre content and has been used to make baskets, paper and ropes. In Bengal, Water Hyacinth is used in the paper and the cotton industries. The use of Kariba Weed as fibre in hardboard manufacture and as a stabilizer in road surfacing materials has been suggested but is not considered economically viable. (Senarata 1952, cited in Sculthorpe 1967)

8.5.5 Energy

Research by the US space agency *NASA* on the fermentation of Water Hyacinth to produce methane gas as an energy source has proved that it can be done, but is expensive. (Ad Hoc Panel 1976)

Direct combustion of sun-dried aquatic weeds could help to alleviate wood fuel shortages, but the high water content makes it difficult to dry the plants in high rainfall areas, *eg* around Lake Victoria.

8.5.6 Water purification

Studies on conditions beneath a hyacinth mat in Hartbeespoort dam showed that the absorption of particulate matter to the roots increased light penetration in the open water by reducing the amount of suspended solids in the water. (Scott *et al* 1979) This together with their ability to take up nitrogen, phosphate and heavy metals means that Water Hyacinth can potentially be used in sewage effluent treatment. An example is given in Box 8.3 Deadly weed, hidden blessing. If carefully managed, Kariba Weed also has the potential to remove excess nutrients from domestic and industrial effluent. (Finlayson, cited in Harley and Mitchell 1981) This only works if the weeds themselves are subsequently removed and destroyed. In 1980, the Southern African Regional Commission for the Conservation and Utilisation of Soil (SARCCUS), through its sub-committee for aquatic weeds, appealed to member states not to use alien aquatic weeds for water purification or nutrient extraction.

Deadly weed, hidden blessing Box 8.3

A report published in the Kenyan newspaper, *Daily Nation*, on 17 September 1997 tells of the plight of fishermen and boat owners at Kaduong village on Lake Victoria who are unable to get their boats through the dense mats of Water Hyacinth and are thus unable to pursue their livelihood. The migration of commercial fish away from weed-infested areas causes these fishermen to either lose their livelihood and become "environmental refugees" or puts pressure on other fishing areas, thus creating secondary social and economic problems far from the original aquatic weed infestation.

The impact of the weed is not entirely negative though. An environmental education officer, Cyprian K'Oywa, at Homa Bay on Lake Victoria, considers the hyacinth infestation as a "blessing in disguise" as it helps to purify the water near the industrial towns.

Amisi 1997

S. Bethune

Floating island of colonizing Water Hyacinth plants.

8.6 COMPARISON OF METHODS FOR CONTROLLING AQUATIC WEEDS

The different control methods are compared and summarised in Table 8.2 before being discussed in detail. Each control method has both benefits and drawbacks. These can be assessed in terms of the ecological impact, including the impact on non-target organisms and how sustainable the control is, the technical equipment needed, the manpower requirements, both in terms of labour and specialised training, and the financial cost of implementing a particular method. This does vary with the type of weed, climatic conditions, the intensity of the infestation and the available expertise and resources.

8.6.1 Mechanical control

Mechanical control is the physical removal of target weeds. This can be done either by hand *ie* manually or, for large weed infestations, by using specially designed harvesting

Control method	Ecological impacts	Technical inputs	Manpower requirements	Financial costs
Mechanical				
Manual	Localised impact Short-term solution	Low input	Labour intensive Repetitive	Relatively cheap Long-term investment
Machine	Can damage banks Rotting weed problem Short-term solution	High input	Training, maintenance and operation needed	Expensive equipment and maintenance Long-term investment
Chemical	Can affect non-target organisms, long-term toxin accumulation Short-term solution	Can be high - *eg* aerial spraying, boats	Specialised training Often needs follow-up teams	Expensive herbicides Often requires repeated applications
Biological	Low impact on non-target organisms Long-term solution	Initially high Reduced by regional and international co-operation	Requires small specialised team	Comparatively cheap especially in the long-term
Environmental	Can be drastic - *eg* drying out pond, can be beneficial *eg* reducing nutrients Long-term solution	Moderate, varies from engineering solutions to implementation of pollution regulations	Requires specialised input and possibly manual labour	Depends on approach used Usually a one-off investment
Integrated	Carefully controlled impact, combines short-term drastic with long-term sound measures Long-term solution	Includes technical inputs such as booms, sprayers and boats	Specialised multi-disciplinary team, requires co-operation of several institutions and good planning	Initially expensive with cost reduction over the long-term as biological control takes over

machines. Some harvesting combines are designed to both remove the plants from the water and to remove excess water from the harvested plant material.

Another form of mechanical control is the use of cables and suspended grids to trap and concentrate aquatic weeds to or keep floating plants away from important engineering structures such as sluices, turbines and water intake points. Cables placed across a river collect weeds floating downstream and concentrate them to facilitate harvesting or herbicide spraying operations.

Mechanical control is target specific and usually causes little or short-term environmental damage. The physical removal of the weeds simultaneously removes surplus nutrients from the system, thus dealing directly with the problem of nutrient enrichment as well as the symptom.

Mechanical control is repetitive. In the case of rooted weeds such as Parrot's Feather, fragments and rootstocks that remain are able to regenerate. Even a 5 cm stem section with a node is capable of rapid regrowth. Portions of plants removed at the Amalinda Fish Hatchery in South Africa and dumped on the banks resumed growth months later (Jacot-Guillarmod 1980), the same happened recently in a pond at the National University of Lesotho. (Damane, SARCCUS 1997)

Mechanical control of Eichhornia crassipes *at hydro-power scheme at Hale on the Pangani river, Tanzania.*

Manual clearance has the advantage of requiring minimal training and supervision, but is very labour intensive and time consuming which can limit the size of the area that can be cleared. It is hard, slow work and in some cases, workers are unable to keep pace with the growth of the plants. Whether carried out from the shore or from boats this task places workers at risk of diseases such as bilharzia and malaria and to crocodile attacks. Where mechanical harvesters are used, operators and mechanics need to be trained to operate and maintain the equipment. Spares are sometimes difficult to obtain.

Manual removal using only hand tools is often considered the cheap alternative to other control options, but can prove more expensive in the long term because it is laborious and needs repeated follow up operations to keep areas clear.

Manual control is only practical for small, easily accessible, infestations. It is effective for low density, very localised infestations and is often the best option for follow-up operations after successful chemical and biological control. Mechanical harvesting and commercial utilisation of aquatic weeds has not yet been successfully implemented anywhere in southern Africa. (Zimmermann 1994)

8.6.2 Chemical control

Chemical control is the control or suppression of target weeds by the application of herbicides. It is an accepted control measure to rapidly and significantly reduce large aquatic weed infestations. However it is important that environmental impacts, particularly on non-target species, be taken into consideration. As governments have become more aware of these potential impacts some of the herbicides used in the past have been restricted or banned, *eg* Terbutryn has been voluntarily withdrawn worldwide by the manufacturer due to residual effects.

Small infestations and weeds along river or lake margins can be sprayed using knapsack sprayers or high pressure sprayers mounted on boats or vehicles, whilst aerial application is needed to tackle large, dense infestations. Regular follow-up inspections, usually at six-week intervals, are essential to check reinfestation.

Chemicals suitable for aquatic weed control include diquat, glyphosate and glyphosate trimesium for Water Hyacinth, diquat and paraquat for Kariba Weed, and glyphosate for Red Water Fern. Diquat is a contact herbicide which means that it affects only those parts of the plant reached by the spray, whilst the others are systemic herbicides that are translocated within the plant and so kill the entire plant.

Contact herbicides work more rapidly and cause a short, intense period of decay, often causing anaerobic conditions, whilst systemic herbicides provide a slow die-off over an extended period and cause less severe deoxygenation. All herbicides work best if applied to actively growing plants. Detailed information on these herbicides and their application is given in Vermeulen *et al* (1993) and summarized in Zimmerman (1994).

The most effective and environmentally acceptable herbicide is glyphosate, also known as *roundup*. It is absorbed by the green parts of plants, translocated to the roots and causes death by inhibiting amino acids specific to plants and is thus considered harmless to people and animals. Glyphosate degrades rapidly and leaves virtually no residue in water or soil and bioaccumulation is unlikely.

The controlled use of approved herbicides can be a rapid and effective means of aquatic weed control, especially when follow-up procedures are strictly adhered to. Most failures in chemical control can be attributed to insufficient follow-up operations. Re-infestation can occur rapidly from plant fragments, viable seeds or spores and often this regrowth tends to be exponential, especially in eutrophic waters, further enriched by decomposing sprayed mats.

The ecological and health concerns regarding the use of herbicides are often a perceived rather than a real threat and this is eloquently argued by Marshall (1990) in the case of using 2,4D on hyacinth in Lake Chivero in Zimbabwe. If used correctly, chemical control of aquatic weeds should pose little or no threat to the environment. Despite this, environmental concerns, particularly of as yet unknown, long-term effects, will continue to weigh against the use of chemical control. The main threat is from repeated large-scale use of herbicides, misuse and over-application leading to dangerous levels of environmental contamination, and spray drift from wide spectrum herbicides that can kill non-target plants nearby. Application techniques, *eg* aerial spraying, are not target specific. If the treated plants are left to decompose in the water, this causes deoxygenation, nutrient enrichment and general deterioration in water quality.

CHG Schlettwein

[illegible] Salvinia molesta *in the eastern Caprivi.*

Chemical control is most effective in enclosed water systems where complete eradication may even be possible, but it is less successful in open river systems and floodplains because of the continuous influx of new plants from upstream infestations and the inaccessibility of plants along river edges, in floodplains and backwaters.

8.6.3 Biological control

The principal of biological control is to seek and introduce natural enemies onto problem weeds to reduce growth to an acceptable level and in so doing keep the plants under control. In their native environment plants have other organisms living, breeding or feeding on them, activities that "damage" the plants to some extent and restrict their growth. The prudent introduction of a host-specific biological control agent can successfully keep weed growth in check.

Biological control agents must meet three criteria, they must show a definite preference for the target plant, they must inflict damage severe enough to [illegible] retard growth and they must pose no threat to the ecology. (Schlettwein and Bethune 1992) Extreme care is needed when introducing new species as biocontrol agents to ensure that they themselves do not become a pest. Strict tests for host specificity are essential prior to any field releases.

Recently several manuals on biological control have been published giving give clear guidelines for the implementation of this control method. (Box 8.4 summarizes these)

This entire procedure can be shortened when the control agent for a specific weed has already been screened, reared and tested elsewhere. For example, Namibia obtained *Cyrtobagous salviniae* weevils from Australia in 1983 and in turn supplied the insects to Botswana and South Africa for immediate release on Kariba Weed infestations.

Organisations, such as the Plant Protection Research Institutes in South Africa and Zimbabwe, the International Institute of Biological Control in Kenya, the Entomology Division of the Commonwealth Scientific Industrial

Research Organisation (CSIRO) in Australia and the Aquatic Plant Control Research Laboratory in Florida, have done much in the past 20 years to evaluate biological control agents. Within the SADC region, the Plant Protection Research Institute in South Africa is recognised as the leading institution in biological control and provides both expertise and quarantine facilities for screening, breeding and rearing control agents.

Main steps in a classical biological control programme

Box 8.4

- Initiate the biological control programme. This involves checking that the target weed is a problem, reviewing the available literature on both the plant and potential control agents, and finding out where else in the world work is being done on the weed and its control agents.
- Obtain the necessary approval and funding to do the work.
- Undertake foreign exploration if it is necessary to seek natural enemies in the native environment of the target weed.
- Conduct surveys in the introduced range. This is to find out what animals or pathogens are using the plant, whether they are indigenous and to compare them with those found in its native range.
- Study the ecology of the weed and its natural enemies, in both the introduced and native ranges.
- Do strictly controlled host specificity studies to ensure that the control agent will not cause damage to any other plants. This can be done either outside or within the target county, where appropriate quarantine facilities exist. These include studies on the feeding, egg-laying and larval development of the biological control agent on the target weed and other related plants.
- Obtain approval to import the biological control agent. Imported agents are usually kept in quarantine initially and raised through at least one generation to ensure that they are parasite and pathogen free before release.
- Once approved, the control agents can be mass-reared in specially prepared facilities for breeding and rearing them and, when sufficient numbers are available released into the field. It is prudent to maintain a breeding colony for subsequent releases and in case initial releases fail to establish in the field.
- Undertake field studies to monitor and evaluate the establishment, spread and effect of the biological control agent on the weed and surrounding biota.
- Collaborate with other institutions to ensure rapid and coordinated distribution of control agents.

Harley and Forno 1992, Julien and White 1997

Cyrtobagous salviniae *the biological control agent that successfully controls Kariba Weed* [illegible] *Africa. Top, insect rearing* [illegible] *weevil, at Katima Mulilo, eastern Caprivi, Namibia. Middle, the Beetle on a leaf of the weed. Bottom, larva on the "root" of the plant.*

The main advantages of biological control are ecological. Biological control agents are usually target-specific, *ie* the organisms released affect only the target plant, the method is environmentally friendly, non-polluting, and provides long-term, sustainable, self-regulating control, for as long as the plant occurs. Host-specificity is tested prior to release and most of the control agents need the weed as their only or preferred food source and to successfully complete their life cycles.

The main disadvantage to biological control is that it is slow, even though in some cases it has successfully reduced aquatic weeds to acceptable levels within a year, *eg* Water Lettuce in the Manyame river and Red Water Fern at the Austin Roberts Bird Sanctuary. The biological control agent may take several years to be screened, become established and control the weed. Biological control of Kariba Weed normally takes up to two years and successful Water Hyacinth control can take 5-6 years. Table 8.3 lists the biological control agents released in southern Africa and summarizes results achieved.

Two moth species, *Samea multiplicalis* and *Episammea pectinicornis* have potential as biological control agents for Kariba Weed and Water Lettuce respectively but there is no record of the release of either in southern Africa. Another moth, *Bellura densa* was tested for use against Water Hyacinth but rejected because of its potential to attack the crop plant *Colocasia esculenta,* known as taro or dasheen. (Hill and Cilliers 1999) Similarly the flea beetle, *Pseudolampsis guttata,* was rejected as a potential control agent for Red Water Fern because it posed a threat to native *Azolla* species. (Hill 1999) A stem-boring weevil *Listronotus* [illegible] is considered to

Aquatic weed	Biocontrol agent	First released	Site/s	Comment
Eichhornia crassipes Water Hyacinth	*Neochetina eichhorniae* (Curculionidae)	1974	Bon Accord dam, South Africa	Widely established, variable impact
		1991?	L Chivero, Zimbabwe	Effective
	Neochetina bruchi (Curculionidae)	1990	Transvaal and Natal, South Africa	Effective in eutrophic waters and cold-tolerant
		1991?	L Chivero, Zimbabwe	Effective
	Niphograpta albiguttalis (Pyralidae)	1990	Vaal and Crocodile West rivers, South Africa	Cold-tolerant, prefers actively growing material
	Orthogalumna terebrantis (Acarina: Galumnidae)	Found in field 1989	Thornhill farm, E Tvl. South Africa	Culture imported in 1975 died
	Cercospora rodmanii *Cercospora piaropi* (fungi)	1992 Found in field 1986	Eastern Transvaal, South Africa	No significant decline where they occur
	Fusarium solani *Fusarium pallidoroseium* (Fungi)	1991 – 94?	Lake Chivero, Zimbabwe	Improves impact of *Neochetina* weevils
	Alternaria eichhorniae (Fungus)	Found in field 1989	Kuils River, South Africa	Affects mainly older leaves
	Eccritotarsus catarinensis (Hemiptera)	1996	Nseleni R, South Africa	Established well at 6 sites, little impact
Salvinia molesta Kariba Weed	*Paulinia acuminata* (Acrididae)	?	Lake Kariba, Zimbabwe and Zambia	Established, partly responsible for weed decline on Kariba
		1972	Linyati and Chobe rivers Namibia, Botswana	Not found again
	Cyrtobagous singularis (Curculionidae)	1972	Linyati/Chobe rivers Namibia, Botswana	Established, but little impact, since out-competed by *C. salviniae* in Caprivi
	Cyrtobagous salviniae (Curculionidae)	1983	East Caprivi, Namibia, Botswana	Well-established and effective control achieved
		1985	La Motte farm dam NE-Transvaal, South Africa	
		1992	Tengwe, Zimbabwe	
Pistia stratiotes Water Lettuce	*Neohydronomous affinis* (Curculionidae)	1985	South Africa	Well-established and effective control achieved
		1988	Manyame R, Zimbabwe	
		?	Selinda spillway, Botswana	
Myriophyllum aquaticum Parrot's Feather	*Lysathia n.sp.* (Chrysomelidae)	1994	Lindeques drift, Vaal R and on the Mokolo R, South Africa	Cold tolerant, causes defoliation, but plants recover
Azolla aquaticum Red Water Fern	*Stenopelmus rufinasus* (Curculionidae)	1997	Austin Roberts Bird Sanctuary, South Africa	Can achieve complete control

Based on Mitchell and Rose 1979, Cilliers 1991a,b,c, 1999a; Zimmerman 1994, Schlettwein and Bethune 1992; Mpofu 1995,1997, Chikwenhere and Forno 1991; Chikwenhere and Keswani 1997; Hill 1999; Hill and Cilliers 1999, Morris *et al* 1999

have potential as a control agent for Parrot's Feather but further host-specificity tests are needed prior to field releases. (Cilliers 1999)

The best results to date have been achieved using weevils. *Cyrtobagous salviniae* successfully keeps Water Hyacinth in check and works best where the weed is confined in an impoundment, *Stenopelmus rufinasus* has succeeded in completely controlling Red Water Fern at some sites, *Neohydronomous affinis* effectively controls Water Lettuce, while *Neochetina eichhorniae* and *N. bruchi* contribute to the control of Water Hyacinth.

In addition to the more obvious insects used as biological control agents, a variety of plant pathogens or mycoherbicides are currently being sought and tested,

and hold promise for future control of aquatic weeds. (Morris *et al* 1999) Initial results show that they may compliment more traditional biocontrol agents. (Mpofu 1995, Cilliers 1991a, Zimmermann 1994)

Often the control of one aquatic weed leads to another taking over the vacated niche. This happened on Lake Naivasha, where, after Kariba Weed was controlled by the introduction of *Cyrtobagous salviniae*, it was replaced by a far worse Water Hyacinth infestation. (Ngari and Gitonga 1992) Therefore, it is important that reliable biological control agents are available should one weed be replaced by another.

Like the other control methods, biological control requires technical inputs. Initially these may be high, the construction of suitable quarantine facilities, breeding and rearing ponds and equipment for survey and monitoring work, but in the long term maintenance and operational requirements are fewer.

Biological control is not simple but requires a high level of expertise and a dedicated team of field and laboratory researchers and technicians to implement a successful control programme. There is a misconception that biological control is cheap; the research, survey and monitoring can be expensive, yet compared to other control methods it is relatively cheap in the long term, when biocontrol becomes virtually self-sustaining.

An important financial advantage of biological control is that it is essentially a short-term capital investment with long-term ecological benefits. Bethune (1996) calculated that the biological control programme which successfully controls Kariba Weed in the Eastern Caprivi cost R 954,000 from 1980 - 1995 which averaged about R 60,000 (US$ 10,000) a year. This is well below the equivalent cost of chemical control. Chikwenhere and Keswani (1997) compared the cost of different control methods used to control Kariba Weed at Tengwe and report that compared to the unsuccessful manual and chemical methods, the cost of successful biological control was minimal. Biological control may not be suitable where rapid control is imperative, but it has definite long-term ecological and cost benefits.

8.6.4 Environmental control

Environmental control involves the manipulation of the habitat in which the weeds grow to create adverse conditions to suppress growth or kill the plants. One approach is to reduce nutrient inputs into the water. This approach treats the cause of the infestation rather than the infestation itself, and offers a good long-term solution.

In the Moremi National Park in Botswana, a small floodplain lake, Lake Xini was dried out to kill Kariba Weed. Diesel pumps were used to pump water out of the lake and as a backup the control agent *Cyrtobagous salviniae* was also released on the lake. Within six months, the area was dry and was burnt to kill any remaining *Salvinia* plants. The operation cost approximately US$ 100,000. (Forno and Smith 1999)

Limiting nutrient inputs into a system has a long-term beneficial effect on the aquatic habitat as a whole and tackles the cause of the problem rather than the symptom. In the 1970s this approach was advocated for Lake Chivero near Harare and was initially successful, but in the last 15 years the growth of Harare and Chitungwiza has again increased nutrient inputs and contributed to the rapid growth of hyacinth on the lake. (Marshall 1993)

8.6.5 Integrated control

Studies worldwide have shown that a single method of control is seldom sufficient to solve an aquatic weed problem, yet a judicious combination of control techniques, well-timed, can achieve a cost-effective, environmentally sound, favourable outcome. This is integrated aquatic weed control. (Box 8.5)

Integrated control may include manual or mechanical removal of plants where there are access problems or blockages, and be coupled to the profitable utilization of the weed, as well as controlled herbicide applications to severe infestations to gain short-term control, combined with a longer term biological control programme. The most economic long-term control of aquatic weeds is biological control and it is essential that any chemicals used must not affect any biological control agents in the same control programme.

The most effective integrated control programmes use a combination of control methods specific to the plant, its environment and the problems posed. Sound recommendations from the conference on Control of Africa's Floating Water Weeds held in Zimbabwe in 1991, highlight the importance of designing site-specific, integrated control programmes, making use of the best available expertise and assigning one organisation the responsibility of co-ordinating activities. (Greathead and de Groot 1993) Although initially expensive, costs are reduced over the long-term as biological control takes

over. To be successful, integrated control programmes need to be implemented by a well-trained and coordinated, specialised, multi-disciplinary team, backed by firm legislation and regulations. Ongoing success is dependent on good pubic awareness, participation, sound knowledge of the aquatic weeds and the different control options, and good collaboration between different institutions and sectors, and sometimes between countries.

One proven solution is to first reduce the weed infestation to a level where the worst problems are alleviated, *eg* use manual or chemical control to clear dense infestations and then allow biological control agents to keep the plant densities low. It is important to time chemical spraying so that it has the least impact on the biological control insects, *eg* adult *Neochetina eichhorniae* weevils are not harmed by the herbicide used to control Water Hyacinth, thus spraying should coincide with the time when most of the insects are in the adult stage. Ideally an area should be selected and left unsprayed as a reserve area where the biological agents can become established and multiply, and hence survive to attack new weed growth.

Improved integrated management of aquatic weed infestations is the only feasible long-term solution, combining the benefits of the different techniques in a programme best-suited to the specific problem. Examples of integrated control procedures for hyacinth are outlined by Cilliers *et al* (1996) for the Vaal river in South Africa and more generally for infestations in Africa by Neser (1996), Charudattan *et al* (1996) and by Monsanto (1997).

What is integrated aquatic weed control? Box 8.5

INTEGRATED CONTROL is the judicious, well-planned, well-timed combination of aquatic weed control methods.

INTEGRATED CONTROL focusses on long-term, environmentally sound biological control, combined with manual or mechanical control to keep key areas or installations clear, and controlled herbicide applications to initially reduce high density infestations, and provide immediate access.

INTEGRATED CONTROL is backed by,

- firm national legislation and regulations;
- good public awareness, participation and vigilance;
- a sound knowledge of the aquatic weeds and their control options;
- dedicated specialists, good co-ordination and co-operation; and
- scientific collaboration.

8.7 SOME SELECTED SOUTHERN AFRICAN CASE STUDIES

8.7.1 Chemical control of Water Hyacinth – Hartbeespoort Dam, South Africa and Lake Chivero, Zimbabwe

The spraying of Water Hyacinth on Hartbeespoort dam in 1977 offered a unique opportunity for a detailed scientific investigation of the effects of large-scale chemical control in an impoundment. Changes were monitored throughout the period of treatment at ten sampling stations, three of which were only accessible by helicopter.

Chemical control of Water Hyacinth, *Eichhornia crassipes*, Hartbeespoort dam, South Africa Box 8.6

In March 1977, hyacinth mats covered 55 percent of the surface of Hartbeespoort dam. The National Institute for Water Research selected herbicide spraying as the most suitable control method, dismissing mechanical removal as too expensive with little scope for economic exploitation. At that time biological control was as yet untested. In October 1977, 1,250 ha were sprayed from the air with the terbutryn herbicide Clorosan 500. This was followed up by further aerial spraying on a smaller scale in December 1977 and January 1978, supplemented by intermittent spraying from the shore and boats to control the 100 ha of marginal growth inaccessible to aircraft to prevent any re-infestation. Extensive follow-up operations continued.

Biological and chemical analysis showed that although oxygen levels dropped a month after spraying, there was still sufficient to sustain fish and other aquatic life. The gradual decay of plant material, characteristic of the herbicide used, minimised the effects of decomposition on the water.

The temporary accumulation of herbicide residues in fish, water, sediments and agricultural crops irrigated from the dam and remained within the limits specified by the Department of Health and there were no direct adverse effects on fish or aquatic invertebrates. Complete control was achieved. The cost of the spraying operation was R220,000 in 1977/78.

Scott, Ashton and Steyn 1979

Water hyacinth infestations first caused a problem on Lake Chivero, Zimbabwe in the 1950s and was successfully controlled with the herbicide 2,4D and manual removal. The lake remained clear until 1967 when a drop in water level due to drought exposed viable seeds that germinated to infest the lake. This infestation peaked in 1971 and when efforts at manual control with a team of 500 men proved unsuccessful, the weed was brought under control with 2,4D again. (Box 8.7)

Lake Chivero, Zimbabwe **Box 8.7**

In 1986, following the droughts of 1982/83 and 1984/85 and gradual relaxing of control, hyacinth was again a problem, covering 11-13 percent of Lake Chivero. The most seriously affected areas were Tiger Bay, the dam wall area, the upper Manyame river, the shoreline and creeks. Concern about the impacts of deoxygenated water on fishing and the cost of water purification prompted an assessment of suitable control options. At a symposium of the Science Council of Zimbabwe, manual control was ruled out, as was plant utilization on account of costs, the risk of re-infestation and concern about further shore degradation. Biological control was still in its infancy and the meeting agreed that it would take too long to solve the immediate problem. They recommended chemical control using Glyphosate as the only practical solution to the crisis.

However, due to public resistance to the use of herbicides, this was not done and by 1990, good rains caused thousands of tonnes of hyacinth to spill, taking with it a concrete bridge and two large water-pipes. Following intervention by the President, and assurances that, if properly used, the health risk was minimal, the infestation was sprayed with 2,4D in June 1991. Since then good progress has been made with biological control and integrated control is now being attempted.

Marshall 1989, 1990

8.7.2 Biological control of Water Hyacinth in southern Africa – South Africa, Zimbabwe, Malawi

Although first initiated in South Africa as early as 1962, biological control of Water Hyacinth has only recently been actively pursued elsewhere in the region. Today several countries including South Africa, Zimbabwe, Malawi, Zambia and Tanzania are conducting biological control programmes, but current published information remains elusive. A brief summary of recent biological control projects in South Africa, Zimbabwe and Malawi in Box 8.8.

8.7.3 Mechanical and biological control of Water Hyacinth – Lake Victoria

The control of Water Hyacinth forms part of the Lake Victoria Environmental Management Project (LVEMP) that is jointly implemented by the basin countries, Tanzania, Kenya and Uganda, and funded by the Global Environmental Facility (GEF). Water Hyacinth was first noted on the Kagera river in 1987 and in Lake Victoria the next year. It has since spread rapidly, causing problems particularly to lakeshore communities. In 1994, the weed covered 50 – 100 ha and by 1998 estimates were that 5,000 ha of the lake surface

Biological control of Water Hyacinth, *Eichhornia crassipes*, in southern Africa: South Africa, Zimbabwe, Malawi **Box 8.8**

South Africa

The first biological control agent, *Neochetina eichhorniae* imported from Argentina, was released in 1974 and although monitoring stopped three years later, the weevils survived floods and herbicide treatments and spread elsewhere in South Africa. In 1985 interest was renewed and *N. eichhorniae* was obtained from Australia, screened and released at several infested sites. Although successfully established, control continued to be hampered by floods and chemical control treatments. In undisturbed sites the insects are more effective. In the last decade, several more control agents have been tested by the Plant Protection Research Institute. Although at least five species, including *Neochetina bruchi* from Zimbabwe, show promise, control has not yet been successful. Scientists believe that biological control of *E. crassipes* can work and suggest that the different biological control agents should be used together and recommend the implementation of site-specific integrated management strategies.

Zimbabwe

In March 1988, 700 *Neochetina eichhorniae* and 400 *Neochetina bruchi* weevils were imported from Florida and screened at the Plant Protection Research Institute in Harare. Both control agents were released at five infested sites in January 1990. By April, they were established at all the sites. In August, progress was set back by 2,4 D herbicide treatment of all the sites on the Manyame River system. To avoid this happening again, a "reserve" site in the Manyame river was agreed in August 1992 and by November insect numbers had greatly increased. In April 1994, a moth, *Niphograpta albiguttalis* was obtained from Australia and released on Lake Mutirikwi. No recent information could be obtained on the subsequent progress of these releases. Studies on the use of bioherbicides, *Fusarium solani* and *Fusarium pallidoroeium* showed that although neither controlled the weed on its on, when used in conjunction with the *Neochetina* weevils, weed cover decreased by 30 - 50 percent.

Malawi

A project to control Water Hyacinth in the Shire river was initiated in 1995. During the project, four biological control agents, *N. eichhorniae, N. bruchi, N. albiguttalis* and a bug *Eccritotarsus catarinensis* were introduced, while the fifth potential control agent, a mite, *Orthogalumna terebrantis*, was already present in the Lower Shire. Weevils reared in Malawi were released throughout the length of the Shire river in 1997 and 1998. By March 1999, the three main control agents were well established on weeds in the Lower Shire, but visible control of the infestation is not expected before 2001.

Chikwenhere 1994, Cilliers 1991, Hill *et al* 1999, Hill and Cilliers 1999, Mpofu 1994

was covered. The heaviest infestations are in sheltered bays and the main source of new infestations remains the Kagera river near the Tanzania-Uganda border. Increasing eutrophication of the lake contributes to rapid growth rates. Box 8.9 describes the various methods for controlling Water Hyacinth in Lake Victoria.

8.7.4 Biological control of Kariba Weed – Eastern Caprivi, Namibia

Kariba Weed, first recorded from the Zambezi river in 1948, rapidly colonised the Zambezi river system, spreading naturally with floods and wind, and inadvertently transported by fishermen, boats, birds and aquatic mammals such as hippo. By the 1960s, the weed was flourishing on the newly impounded Kariba Lake and a decade later the Zambezi river system harboured the worst Kariba Weed infestations in southern Africa.

During the 1970s, floating Kariba Weed mats and more permanent Sudd islands blocked channels in the Eastern Caprivi floodplains, and fish catches declined on Lake Liambezi, while low oxygen concentrations under weed mats resulted in water quality deterioration, creating conditions unfavourable to aquatic invertebrates and fish. Submerged water plants in the shallow lake were shaded out by the weed cover further reducing oxygen production in the water. (Box 8.10)

8.7.5 Integrated control of Kariba Weed – Moremi Wildlife Reserve, Okavango Delta, Botswana

Kariba Weed infests two regions in Botswana: along the northern the Chobe/Linyati/Kwando river and associated floodplain systems, and within the Moremi Wildlife Reserve of the Okavango Delta. Box 8.11 illustrates how integrated control of the Kariba Weed in Okavango Delta was implemented.

8.7.6 Biological control of Water Lettuce – Kruger National Park, South Africa, Manyane River, Zimbabwe, Selinda Spillway and Savute, Botswana

Water Lettuce was first recorded in the Mukuvisi river in Zimbabwe in 1937 and on the Linyati/Chobe system in Botswana as well as the Kruger National Park in the 1980s. It now occurs in most southern African countries, spreading rapidly by vegetative reproduction.

Under tropical conditions plants reproduce rapidly, producing daughter plants on stolons, these become entangled to form dense impenetrable mats that can

Manual, mechanical and biological control of Water Hyacinth, *Eichhornia crassipes*, on Lake Victoria — **Box 8.9**

Problems

Dense hyacinth mats have had a severe socio-economic impact on artisanal and commercial fishing, transport, recreational activities and water supply. Fishermen have had to abandon areas such as Nduru and Nyamware south-east of Kisumu and some have lost nets not yet paid for. The harbours of important centres such as Mwanza in Tanzania and Kisumu in Kenya are periodically blocked, resulting in delays in boat transport to and from major ports on the lake. Local municipalities, such as Mwanza and Kisumu have had to employ labourers to keep water intakes clear of the weed and they have experienced water quality problems.

Manual and mechanical control

Manual removal has been used with different degrees of success. In places such as Mara and Mwanza in Tanzania, regional and district authorities have organized village self-help groups and over 200 tonnes of Water Hyacinth was removed from the Mara area. In Kenya, the Kenyan Agricultural Research Institute (KARI), responsible for aquatic weed control, distributes hand tools, implements and protective clothing to fishing communities to encourage manual clearing but complain that these efforts are hampered by the attitudes of some lakeshore communities who would prefer payment. KARI has developed a mechanical harvester and several donor countries have also promoted the use of mechanical harvesters. Manual and mechanical control are best suited to clearing small strategic sites but cannot effectively tackle the wider problems of the Lake Victoria infestation of Water Hyacinth.

Biological control programme

All three countries, Tanzania, Uganda and Kenya have initiated biological control as the most suitable long-term solution to the hyacinth infestation on the lake. Two weevils, *Neochetina eichhorniae* and *Neochetina bruchi* were imported into Tanzania in April 1995 and rearing units have been established at the National Biological Control Centre at Kibaha, near Dar es Salaam. Between August 1997 and June 1998, some 318,697 Neochetina weevils were released at 20 sites along the lake shore and the Kagera river. Since then, mobile rearing units have been developed for rapid ongoing insect releases. In Kenya, KARI first released Neochetina weevils at the Police Pier in Kisumu in January 1997; by August 1998, 36,000 weevils had been released at 27 sites in the Kisumu-Nyando, Rachuonyo, Siaya-Bondo, Homa Bay, Migori, Subal and Busia districts, and weevils have spread up to 50 km from their original release sites. Further tests are being conducted on the potential use of indigenous fungal pathogens. The control agents are now well-established on the lake and plants stressed by insect damage are proving more susceptible to opportunistic infections. Researchers report clear insect damage and that growth is suppressed. These early results are encouraging and patience is needed as effective biological control can take more than six years to achieve.

Gilliers and den Breeyen 1999, Mailu *et al* 1999, Mallya 1999, Ochiel *et al* 1999

Biological control of Kariba Weed, *Salvinia molesta*, Eastern Caprivi, Namibia — Box 8.10

In 1980, the Namibian Department of Water Affairs took responsibility for controlling Kariba Weed infestations in the rivers and floodplains of the Eastern Caprivi. After two years of research to determine the status of the problem, the growth potential and ecological requirements of the weed, nutrient fluctuations in the rivers and lake, and to evaluate the different control methods, researchers concluded that biological control was the most viable and ecologically sound option.

A biological control agent breeding facility was built in Katima Mulilo. In 1983, two consignments of 144 and 500 *Cyrtobagous salviniae* weevils were imported from CSIRO in Australia. This host-specific weevils had been screened and tested and had successfully controlled Kariba Weed in Lake Moondarra in northern Queensland in 1981. This was the first time that they were introduced to southern Africa. The second consignment of weevils bred well and in December 1983 the first 450 weevils were released onto an infestation at Sitwa on the Kwando river. By March 1985, over 10,000 weevils had been released on 14 infestations in the Caprivi.

The earliest success was achieved at Ngoma Bridge on the Chobe river, where the Kariba Weed mat sank 15 months after the control agent had been released on it. At the other sites, the weevils took 8-12 months to become established and inflict visible damage, and the time taken for a mat to sink varied from 15 months to 3 years. Since 1985, Kariba Weed has been recorded at 241 sites in the eastern Caprivi floodplains. A survey of 198 of these sites in 1998 revealed that 30 had dried up and of the remainder 80 percent were free of the weed, only one site was entirely covered by a mat and two had fairly large infestations. Adequate weevil numbers occur at 40 percent of the infested sites.

Today, Kariba Weed is well-controlled by the *C. salviniae* weevils in the Eastern Caprivi. On the Kwando/Linyati system, the weeds are limited to the fringe vegetation, and Lake Liambezi dried up in 1989, effectively eradicating what was left of the weed. In the eastern floodplains of the Zambezi river the level of infestation is low. Total eradication is impossible, and both the weed and its control agent are now considered permanent features of the floodplain ecology.

Room *et al* 1981, Schlettwein and Bethune 1992, Taylor 1999

Integrated control of Kariba Weed, *Salvinia molesta* – Moremi Wildlife Reserve and Okavango Delta, Botswana — Box 8.11

In July 1986, a Kariba Weed mat was found for the first time in the Okavango Delta, in Lake Xini in the Moremi Wildlife Reserve, and urgent action was required to stop it spreading. Learning from the experience on the Chobe/Linyati/Kwando system, where despite the heavy use of herbicides from 1975-83, Kariba Weed was not controlled until Namibia introduced the biological control agent, a weevil, *Cyrtobagous salviniae*, a management plan was rapidly formed to deal with the first infestation in the Okavango Delta.

Unlike in the past where selecting a single control option was common practise, the Department of Water Affairs in Botswana considered all available options and put in place an integrated management strategy using a combination of options specific to the nature of the infestation. Their action plan aimed to prevent any further spread of the weed by water, animals or tourists and, by drying out Lake Xini, to eradicate the infestation while keeping environmental impacts to a minimum. As back-up, two batches of *C. salviniae* weevils were obtained from Namibia and released onto the mat. No herbicides were used. The two inflow channels were blocked off by earthworks and pumps were installed to speed up the drying process and the area was fenced off to prevent wildlife transporting the weed elsewhere. By February 1987, the area was dry and no Kariba Weed remained. The dry lake basin was burnt to ensure that no weeds remained. In June 1988, the earthworks were removed, rains of the next season refilled the lake and the native vegetation recovered completely, regenerating from perennial rootstocks and buried seeds. The main operation cost only US$ 100,000.

When a second Kariba Weed infestation was found at Bodumatau in 1988, the experience gained at Lake Xini was put into practise. Again a combination of biological control using *C. salviniae*, and environmental control, drying out the area and keeping animals away, was implemented. By June 1989 the *Salvinia* mat had disintegrated and most of the plants sank, the remainder were manually removed and destroyed. The area was dry by July 1989. Although this did not completely eradicate the weed in areas surrounding Bodamatu, the plants were being kept in check by the weevils and did not form mats again.

Since then the weed has spread to elsewhere in Moremi Wildlife Reserve, most likely transported by animals such as hippo, but is kept under control by the vigilance and concerted efforts of the Aquatic Vegetation Unit of the Department of Water Affairs, a unit dedicated to aquatic weed control in Botswana. In 1991, this unit cost the government just 450,000 Pula a year to run, about one percent of the DWA's recurrent budget. Although current figures are not available, the proportion of the annual budget of the Department should be about the same.

In Botswana, aquatic weed control is backed-up by appropriate legislation, the Aquatic Weeds (Control) Act adopted in 1971 and amended in 1986 and 1987, as well as by good public awareness materials. The key to Kariba Weed control in the Okavango has been biological control, supported by complimentary measures specific to the particular infestations and the vision of the botanist Pete Smith, who initiated integrated control in Botswana.

Adapted from contributions by Jane Prince-Nengu and Wendy Forno, Forno and Smith 1999

block waterways, interfere with the engineering structures and provide a habitat for malaria mosquito larvae. Box 8.12 describes the biological control efforts in South Africa, Zimbabwe and Botswana.

Biological control of Water Lettuce, *Pistia stratiotes* Box 8.12

Kruger National Park, South Africa
The biological control agent, *Neohydronomus affinis*, a weevil, was first released in Kruger National Park to control Water Lettuce on Nhlangaluwe Pan in the Limpopo floodplain in December 1985. In 1986 another batch of control agents were released on a second infestation on Dakamila Pan. In both cases successful control was achieved within 9-12 months. Both pans subsequently dried out in the drought of 1989. Since then the pans have refilled and although Nhlangaluwe Pan remains clear of Water Lettuce, other pans were re-infested by germinating seeds. Experience over the past 12 years in the Kruger park has shown that the biological control agent works best when not interfered with by mechanical or chemical control attempts. Scientists are satisfied that adequate control has been achieved despite occasional new infestations.

Cilliers 1999

Manyame river and various impoundments, Zimbabwe
In September 1987, a colony of 150 *Neohydronomus affinis* weevils were imported from Australia, screened at the Plant Protection Research Institute in Zimbabwe and released onto a Water Lettuce infestation in the Manyame river upstream of Lake Chivero in April 1988. Within four months the weevils were well-established and causing detectable damage to the plants, and plants were noticeably smaller. By February 1989, Water Lettuce was no longer a problem in the river. Subsequently, weevils were released at four other infested sites, Lake Chivero, the Chakoma and Chivake rivers and Kaitano reservoir. The weevil took from 8 –15 months to reduce weed infestations by at least 80 percent. In Lake Chivero, the area cleared of Water Lettuce was rapidly invaded by Water Hyacinth, confirming that control of only one problem weed is not sufficient, but that a holistic approach to aquatic weed control is essential.

Chikwenhere and Forno 1991, Chikwenhere 1994

Selinda Spillway and Savute, Botswana
In Botswana the weevil, *N. affinis* imported from the CSIRO in Australia in 1987 was introduced to Water Lettuce infestations in the Selinda spillway and later to infestations in Savute at Diyei and Zibadianja. The weevil established well and continues to keep the weeds in check.

Smith 1993

8.7.7 Control of Parrot's Feather – Mechanical and environmental (Roma, Lesotho) and Biological control (Mokolo and Vaal rivers, South Africa)

Parrot's Feather was first introduced into southern Africa in 1918/19 and has proved extremely difficult to eradicate as in the case of infestation in a pond in the grounds of the National University of Lesotho at Roma. (Box 8.13) Dense stands of Parrot's Feather can reduce river flow, impede navigation and water recreation and block water abstraction pumps. The plant also provides shelter for mosquito larvae. The weeds reproduce vegetatively from any plant fragment containing a node and the perennial rootstock can survive drying out. Box 8.13 also summarizes the biological control of the Parrot's Feather in the Mokolo and Vaal rivers, South Africa.

Control of Parrot's Feather, *Myriophyllum aquaticum* Box 8.13

Mechanical and environmental control – National University of Lesotho at Roma
In 1993, Lesotho reported to the SARRCUS sub-committee on Aquatic Weeds that Parrot's Feather had been found in a pond on the grounds of the National University of Lesotho and that all attempts at manual removal had failed. By the next year, when the member states met in Lesotho for the 19th meeting of the Aquatic Weeds sub-committee, delegates were taken to view the site. The pond had been dried out and bulldozed in an attempt to eradicate the weeds. Recent enquiries confirmed that even this drastic measure proved unsuccessful and that the problem persists, neither drying out nor letting severe winter frosts permanently remove the weeds.

Biological control – Mokolo and Vaal rivers, South Africa
As no herbicides are registered for use against Parrot's Feather in South Africa and mechanical control has proved impractical, the Plant Protection Research Institute in Pretoria initiated biological control in 1991. This was the first attempt of its kind in the world. Of the natural insect enemies collected from Parrot's Feather plants in South America, a leaf-eating beetle, *Lysathia sp.* was selected as the most promising biological control agent. These were imported from Brazil in 1991 and 1993 and screened under strict quarantine conditions. Tests using 32 other plant species proved that *Lysathia* fed and developed exclusively on Parrot's Feather and it was cleared for field release in November 1994.

The first beetles were revealed a month later at Lindeque's Drift on the Vaal river and at Culmpine on the Mokolo river, and beetles have now been released at a further 23 infested sites in South Africa. Results show that the beetles became established, and multiplied to levels high enough to severely restrict plant growth, but numbers declined in winter, allowing the plants to recover. The beetles recover again in summer and inflicted serious damage to the leaves before moving on to other undamaged plants. Again this allowed the plants to recover. Scientists are confident that biological control of Parrot's Feather has potential, but that other agents in addition to the *Lysathia* beetle may be needed to effect constant control. Research continues.

Cilliers 1999

8.7.8 A case study of biological control of Red Water Fern – Austin Roberts Bird Sanctuary, South Africa

Biological control of Red Water Fern, *Azolla filiculoides*, Austin Roberts Bird Sanctuary, South Africa — Box 8.14

Red Water Fern originated from South America and was first noted in South Africa in the 1940s. It has since been recorded in some 152 quarter degrees squares within South Africa where it can form dense mats on quiet and slow-moving water bodies. The small plants are spread by both people and by waterfowl. In 1974 the weed was inadvertently introduced into the Florence Bloom Bird Sanctuary in Johannesburg as "duckweed" and water birds probably spread it from there to the nearby Austin Roberts Bird Sanctuary and to other water bodies.

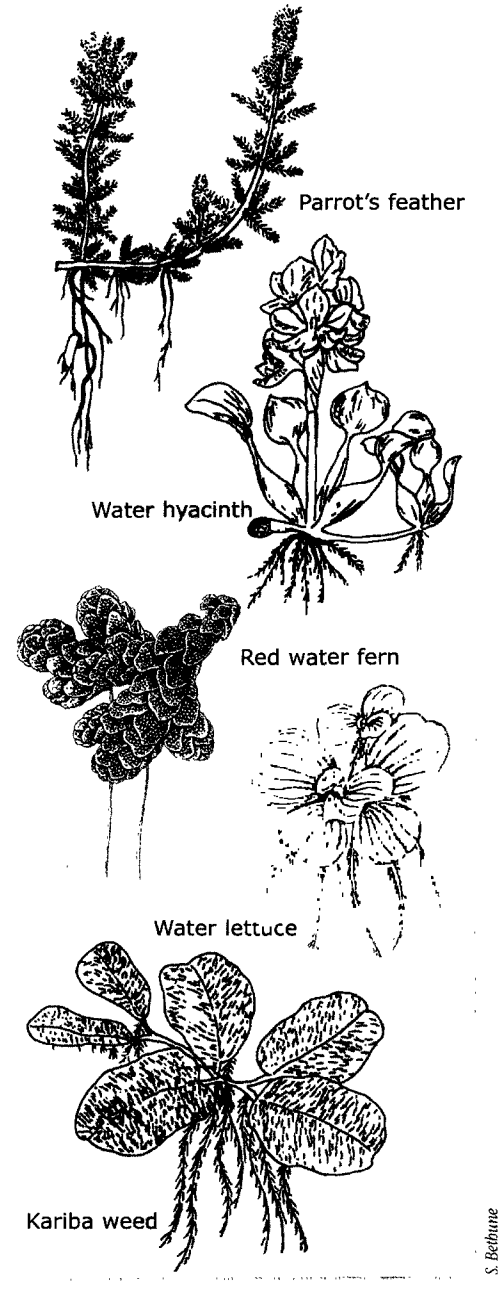
After careful evaluation, scientists at the Plant Protection Research Institute in Pretoria decided that mechanical control would be too labour intensive. In most cases manual efforts have not been able to keep up with growth rates, while cleared areas are rapidly recolonized by new plants brought in by waterfowl or which germinate from resistant spores. Chemical control was also ruled out due to the disadvantages of the expense of continuous follow-up operations to treat plants germinating from spores and risk that spray drift could affect nearby non-target water plants and crops. Although untested, biological control was considered a viable environmentally sound control option and South Africa was the first country in the world to initiate biological control for Red Water Fern. The first site tested was a pond at the Austin Roberts Bird Sanctuary in Pretoria.

The biological control agent *Stenopelmus rufinasus*, a weevil, was imported from Florida in 1995, screened at the Plant Protection Research Institute in Pretoria, and cleared for field release in South Africa in 1997. The first release of 900 adult weevils was made in December 1997, on a 1 ha dam completely covered by a dense mat of Red Water Fern, at the Austin Roberts Bird Sanctuary. Insect numbers on the mat increased rapidly and high feeding rates caused such extensive damage to the plants that only two months later, in February 1998, the mat sank. Nearly 30,000 weevils were found in a 2 sq m sample of decomposing weed.

Since then, the same control insects have been released at 46 more sites infested with Red Water Fern throughout South Africa and are proving very effective. At 20 sites complete control has been achieved. It is unusual for a biological control agent to completely wipe out a weed and it is thought that *S. rufinasus* may simultaneously be infecting the plants with a pathogen.

A year later, the dam at the Austin Roberts Bird Sanctuary and other several other release sites remain clear of the weed and the insects have dispersed to other water bodies up to 38km away.

Hill 1999



8.7.9 Aquatic weed control in Zambia

The aquatic weeds causing problems in Zambia are Water Hyacinth, Kariba Weed and Water Lettuce. Problems encountered include, impaired access to rivers, water quality deterioration, disruption of fishing activities, water loss by evapo-transpiration and increased incidences of diseases such as malaria and bilharzia. Box 8.15 summarizes the aquatic weed problem and control strategies in Zambia.

Aquatic weed control in Zambia **Box 8.15**

Water Hyacinth occurs mainly in the Kafue river within a 100 km stretch from Mazabuka to Kafue Gorge. It became a problem in the late 1980s and mats now cover some 50 ha of open water, excluding plants in the fringes along the riverbanks. At Shimungalu and downstream of the Iolanda waterworks, hyacinth mats have altered the course of the river. Although Water Hyacinth is present in Kariba dam, the wave and wind action tend to prevent the formation of dense mats. Water hyacinth has recently invaded many sewage oxidation ponds in Lusaka, Kabwe and the Copperbelt. In 1997, Konkola sewage ponds at Chililabombwe infected the upper Kafue river.

Kariba Weed occurs in Kafubu lower dambo, the Kafue river and Lake Kariba. There are mats in the Blue Lagoon in the Lochenvar National Park, a few isolated plants in Lake Kariba and the former infestations in the Kafue, downstream of Ndola are being replaced by Water Hyacinth. Water Lettuce first became a nuisance in the 1980s, particularly in the Kafubu dam in Ndola.

Although both Kariba Weed and Water Lettuce have been present in the Kafue system for some time, it was not until the construction of impoundments, water works, and irrigation schemes, coupled with increasing eutrophication from effluent discharges form large agricultural schemes and towns, that they became a problem. Water Hyacinth only appeared in the Kafue in the late 1980s and was almost certainly introduced by fishing or recreational boating, perhaps from as far afield as the Lower Shire. Fishermen use the plants to cover and keep their catches cool, thus spreading the weed.

Weed control strategies

Mechanical control is used by the Ministry of Water Resources and the Zambia Electricity Company, to keep clear critical areas such as the rail and road bridges near Kafue and dam walls in Kafue Gorge water reservoir. In 1994, the Zambian army was engaged to harvest water hyacinth at the road bridge and Kafue Gorge dam, using rubber boats, machetes, ropes and fishing nets. The effort proved effective in the winter months but once it rained, the weed regained its former coverage.

Chemical control has been used to spray Kariba Weed and hyacinth on Lake Kariba, in the 1980s and more recently in 1998. The Zambezi River Authority used 2,4D to control hyacinth on Kariba. Trials conducted on the Kafue river in the Mazabuka area, were impressive. The only drawbacks are the high cost of herbicides and aerial spraying. In 1998, the Kafue Aquatic Weed Control Steering Committee conducted an EIA on the feasibility and environmental consequences of spraying the 50 ha Water Hyacinth infestation into the Kafue river.

Biological control was initiated to control Kariba Weed in the Lower Kafubu dambo in Ndola in 1981. The weevils, *Cyrtobagous salviniae* were obtained from the CSIRO in Australia. This has been a significant success. Subsequent surveys found weevils established on just about every plant now and today Kafubu lower dambo is clear of *Salvinia*. Biological control of Water Hyacinth was introduced in December 1997. *N. bruchi* and *N. eichhorniae* imported from South Africa were released at several sites and seem to be establishing well. Insect damage can be seen on the plants, and the insects are still reared at the insect rearing facility at Mazabuka. The project is currently under-funded.

Adapted from a contribution by Israel H.M. Zandonda

8.8 RECOMMENDATIONS FOR THE EFFECTIVE MANAGEMENT OF AQUATIC WEEDS IN SOUTHERN AFRICA

8.8.1 Regional aquatic weeds management policy

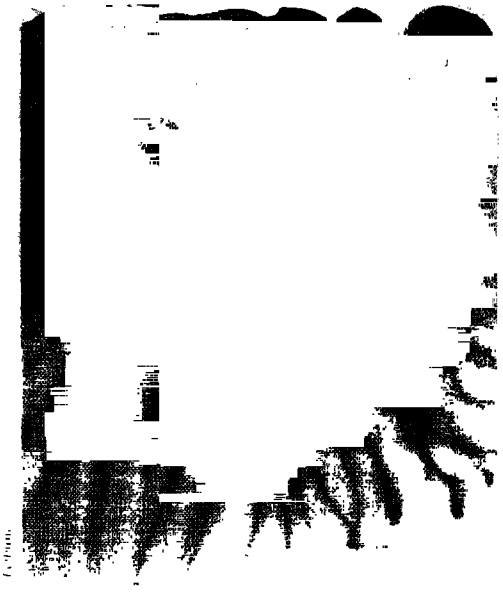
The SADC committee on Aquatic Weeds and Water Quality (SAWWQ), formally established in 1998, plans to assess the current status and magnitude of aquatic weed problems in the region and will in future develop a regional policy to manage aquatic weeds. Based on this review and the case studies assessed, a regional, integrated, catchment-based approach to manage aquatic weeds is recommended. This must be backed up by strong national, regional and international co-operation and the present sound scientific collaboration must continue. To ensure sustainable control, a wider range of stakeholders, including rural communities need to be involved in aquatic weed control programmes. This can be strengthened through participatory planning and greater public awareness. Sound weed control practices require expertise and training and appropriate complimentary legislation throughout the SADC region to prevent the introduction of new invasive species and to control the spread of those already causing problems in the region. Decision-makers, operators of water installations and natural resource users need to be made more aware of the potential hazards posed by aquatic weeds. To prevent further resource degradation and effectively manage the aquatic weeds problem, the following regional policy recommendations are made.

8.8.1.1 Promote a catchment-based approach to integrated control

The role of catchment management, particularly to reduce nutrient inputs, was recognised at the workshop on The Control of Africa's Floating Waterweeds held in Harare in 1991. (Greathead and de Groot 1993) The meeting recommended that aquatic weed control should be seen in the larger context of sustainable land-use management and watershed development.

8.8.1.2 Continue scientific collaboration, regional cooperation and stakeholder participation

Information sharing and improved co-operation on this issue between SADC countries is essential. Considerable progress has been made through regional co-operation in research, control and management of aquatic weeds in southern Africa. For 22 years, the specialist aquatic weed subcommittee of the Southern African Regional Commission for the Conservation and Utilisation of the Soil (SARCCUS) has provided a platform for regional co-operation in aquatic weed management. Member countries (Angola, Botswana, Lesotho, Malawi, Mozambique, South Africa, Namibia, Swaziland, Zambia and Zimbabwe) meet annually to present country reports, to collaborate at a technical level and to advise member governments on aquatic weed issues. After the SADC Water Sector was established, the functions of SARCCUS were taken over by appropriate SADC committees and the SADC committee on Aquatic Weeds and Water Quality (SAWWQ) was established in Maseru. Currently attention is being given to a proposal for a regional project to control aquatic weed infestations and their spread.



Invader plants, [illegible] rous. Kariba Weed.

At the international level, the countries of southern Africa have gained much from world experience in aquatic weed control. Specialist technical support has been given willingly by centres of excellence such as the Aquatic Plant Control Research Laboratory in the United States of America and the CSIRO in Australia. Also, several international organisations such as: the International Organisation of Biological Control (IOBC); CAB International and its International Institute of Biological Control; the Commonwealth Science Council and the International Development Research Centre (IDRC); have funded aquatic weed control projects and conferences in Africa.

8.8.1.3 Improve public awareness

Some SADC countries, most notably Botswana and South Africa, have produced and distributed booklets, pamphlets and posters to make people aware of aquatic weeds and the problems they cause. A popular book *Invader Plants, Beautiful but Dangerous* (Stirton 1978) did much to bring both terrestrial and aquatic weeds to the attention of the South African public. For several years, SARCCUS tried to co-ordinate the development of a field guide to aquatic weeds for southern Africa and recently, work was started on a *Southern African Plant Invaders Atlas* (SAPIA), a computerized database of all records of alien plants in South Africa, Lesotho and Swaziland. (Henderson 1999) This will be expanded to the rest of the SADC region in the second phase.

8.8.1.4 Recognize and develop regional expertise

Many SADC countries share a need for training in aquatic weed control at technical, managerial and academic levels. Training courses are offered, *eg* at the Cedara Weeds Laboratory in South Africa, through the Plant Protection Research Institute and in the past SARCCUS offered short courses, *eg* the aquatic weed training course held in Malawi in August 1988. Further training is needed.

Priorities for research listed by participants to the workshop on the Control of Africa's Floating Water Weeds, that could be used for academic training projects, included:

- ecological studies on affected and threatened ecosystems;
- careful post-release monitoring of biological control agents to determine establishment and their efficacy under particular environmental conditions;
- assessments of the social and economic impact of aquatic weed infestations on local communities; and
- continued research into safer herbicides.

8.8.2 Recommendations for national aquatic weed management programmes

8.8.2.1 Identify a lead agency

At national level, the most successful aquatic weed programmes have been carried out where a lead agency within the country takes on the responsibility for controlling aquatic weeds. In Zimbabwe and South Africa it is the respective Plant Protection Research Institutions, whilst in Namibia and Botswana it is the respective Departments of Water Affairs. Because aquatic weed control tends to be multi-faceted it requires a multi-disciplinary approach and works best where different institutions, individual researchers and government agencies co-operate to deal with a common concern under a single national lead agency.

8.8.2.2 Put regional recommendations and programmes into effect

It remains for individual countries to put into effect the recommendations from international workshops and meetings on aquatic weed control. For example, the 1991 workshop on Control of Africa's Floating Water Weeds held in Harare recommended that site-specific integrated control be implemented. Further recommendations were that, biological control, as the most cost-effective, permanent and environmentally sound method be given preference, whilst other methods be used to deal with urgent problems but should not jeopardise biological control. Other conclusions were that the commercial utilization of aquatic weeds was neither effective nor sustainable but could, with due caution, be coupled to short-duration mechanical removal and that the spread of aquatic weeds should be strictly prohibited through national legislation. In the past SARCCUS meetings passed regional resolutions on the management of aquatic weeds that in many cases were later adopted by member countries. Two examples are the resolution not to allow the use of introduced plants for water purification and the introduction of boat control measures to prevent the spread of aquatic weeds.

8.8.2.3 Develop site-specific integrated aquatic weed programmes

The case studies show that the most successful aquatic weed control programmes have been those that aim at site-specific, integrated management to achieve long-term sustainable control. The emphasis should be on biological control, whilst mechanical and chemical control should only be used to contain or eradicate expanding weed infestations and in small-scale follow-up operations. Well-trained technicians under strict management of scientists and administrators must apply any chemical control.

It is important to use a participatory approach from the beginning of a project. A classical participatory approach to weed management is strongly advocated by (Bilston and Norton 1997), and should form part of any integrated control programme. (Neser 1996, Cilliers 1997a)

Throughout the southern African region, community involvement in natural resource management is becoming imperative, and the management of aquatic weeds is no exception. This was the one of the aspects focused on at the 1997 workshop on Improving Reaction to Water Hyacinth in Affected Countries across Africa and the Middle East. Within SADC, SARCCUS member countries resolved to place greater emphasis on community involvement in aquatic weed control programmes.

8.8.2.4 Develop appropriate legislation and regulations, complimentary to neighbouring states

Appropriate national legislation and enforcement is required to prevent further spread of aquatic weeds and to prevent the introduction of potential invaders. There are several invasive species, such as Alligator Weed, *Alternanthera* [illegible], that do not yet occur in southern Africa but are known to cause problems elsewhere. These must at all costs be kept out of southern Africa. Aquatic weeds that occur in southern Africa are still restricted to certain countries, *eg* Water Hyacinth does not occur in Namibia nor in Botswana and should not be allowed to spread further. Most countries have legislation that lists prohibited plants. In Botswana, Namibia, Lesotho and South Africa, this includes the five aquatic weeds discussed in this chapter. The government of Botswana has gone further with a specific Aquatic Weeds (Control) Act No 34, that declares infested areas and regulates boat traffic to prevent the spread of aquatic weeds. It is necessary to insure that within SADC the aquatic weed legislation is similar across member states and enforced throughout the region.

8.8.2.5 Increase public awareness and vigilance

The publication of research findings is excellent for some southern African aquatic weed projects but for others there is little published information available. The newly

initiated IDRC Information Clearing House for Water Hyacinth Work in Nairobi will help to improve this. In general, there is still an urgent need for the production and dissemination of technical as well as lay information on aquatic weeds and their control, particularly for guidelines specific to southern Africa.

A key factor in the control of aquatic weeds is vigilance. It is essential that at all levels, from the general public to government, people are made aware of the problems caused by aquatic weeds, are taught to identify them, and know who to report to. It is still common to come across all five of these weeds being used as ornamental plants in garden ponds and aquaria. They have been found in university laboratories, on research farms, in botanical gardens and in aquaculture ponds. Both Water Hyacinth and Kariba Weed have been seen in the garden ponds at UNEP in Nairobi. Rural communities can help by reporting the occurrence of these weeds in more remote areas. The production of public information posters and pamphlets and regular media exposure is recommended.

8.8.2.6 Promote regional scientific cooperation, and training

Scientific collaboration has occurred mainly at a technical level directly between researchers involved in aquatic weed control and through workshops. These are vital for cooperation and training.

Important meetings have been:

- IUCN Wetlands Conservation Conference for Southern Africa held in Gaborone;
- CSC workshop on Control of Africa's Floating Water Weeds in Harare in 1991;
- Panel to discuss the Integrated Control of Water Hyacinth in Developing Countries with Emphasis on Biological Control, at Fort Lauderdale, USA in September 1995, and more recently;
- Consultative Workshop on the Capability of Communities, Authorities and Support Organisations to React to and Handle Problems of the Water Hyacinth in the Region held in Nairobi in 1997; and
- First IOBC Global Working Group Meeting for the Biological and Integrated Control of Water Hyacinth held in Harare in 1998.

In addition to these international workshops, scientists regularly attend annual professional conferences where information is exchanged and publish their results in appropriate scientific journals. Regular National Weed Conferences have been held in South Africa since the mid-1970s and southern African researchers regularly present case studies at meetings and symposia of international biological control organizations. Opportunities to exchange training between SADC countries should be encouraged.

It is essential that the strong ties between countries and institutions dedicated to the control of aquatic weeds be fostered. The best example is the ongoing co-operation between CSIRO, Australia, the USDA and the Plant Protection Research Institute (PPRI) in South Africa. These three are internationally recognised as world authorities on aquatic weed research and control. Similarly, Namibia and Botswana have a long history of collaboration to control Kariba Weed in the river systems that they share, while Tanzania, Uganda and Kenya co-operate on Hyacinth control in Lake Victoria.

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CONTENTS

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COMMUNITY-BASED WATER RESOURCES MANAGEMENT

9.1 INTRODUCTION

Community-based management of water resources is not a recent nor an externally inspired activity in southern Africa. The frequent reference to the Dublin and Rio de Janeiro statements, such as – *Water development and management should be based on a participatory approach involving users, planners, and policy makers at all levels* (World Bank 1993) – gives an impression that this is a new approach which is being introduced.

On the contrary, communities in southern Africa have, for a very long time, been managing their water resources in a manner that is being suggested in the Dublin – Rio statements. In many parts of the region, water has been managed by the communities although the management practices have differed from place to place, reflecting the different physical endowment of water, cultural values and socio-political organizations of the concerned communities. It should, however, be pointed out that, although there has been a long tradition of communities being involved in the management of land and water resources in this region, since independence many countries have experienced a systematic shift towards the centralization of water management activities. Centralized management of water resources has, in general, yielded limited positive results but many negative effects on resource management. Thus, the re-emergence of interest marks a shift back from the centralized management to a participatory approach which aims at involving stakeholders and communities in the whole process of water resources planning, development and management.

This chapter discusses selected examples of different types of community-based, water resources development and management activities and practices from the region and their impact on the socio-economic life of the people and on environmental resources. The chapter draws lessons from the case studies and recommends the institutionalizing of these lessons in water resources management policies and practices in order to enhance the social acceptability and environmental sustainability of the investments.

DWAF, South Africa

Water has been managed by communities in many parts of the SADC region, [illegible] management [illegible] place to place.

9.2 RATIONALE FOR PROMOTING COMMUNITY-BASED MANAGEMENT

Before discussing the merits of community-based management, it is necessary to define the terms "community" and "water resources management". (Box 9.1)

Definition of community and water resources management **Box 9.1**

The term **community** is used frequently but applied to numerous different circumstances. Generally, a community is a group of people who live in the same locality and who have some sort of social cohesion and structure. Given the variation in density, scale and spatial proximity of communities, one should accept that they vary tremendously from place to place. A community can therefore be a large formal city, or it can be a remote rural village. Communities are often classified as rural, peri-urban or urban. In the context of this chapter, communities are considered to be rural villages and informal settlements.

Water resources management, in the context of this chapter, will be understood as a dynamic process of devising alternative sequences of interventions, and selecting the sequences or activities that will optimize the achievement of the objectives related to water resources. (Mujwahuzi 1994) Community participation, on the other hand, is defined as a process through which stakeholders influence and share control over development and management initiatives, and the decisions and resources that affect them. (World Bank 1995)

This definition presupposes the existence of several activities and actors. Management is understood as a dynamic process, which is constantly changing to suit new demands on the resource. That dynamic process involves decision-making on a variety of issues such as objectives and strategies. Finally, management involves actors who can be individuals, a group of people, government at different levels and the communities.

So when talking of community-based management of water resources we are referring to a dynamic process which is not uniform throughout the region, but a process that has some common elements which are influenced by the benefits that are expected to be obtained through the process.

The question which comes to mind is: Why is community-based management of water resources already a widespread practice in the member states of the Southern African Development Community (SADC)?

As will be shown through the review of case studies of community-based water management, communities in this region adopted the approach because of the numerous benefits which they perceived could be derived from it. The benefits to be derived from community participation in water resources management can be summarized as follows:

> Water resources management is a very complex process that requires inputs from a broad range of disciplines and stakeholders. Governments, developers and other water resources managers are finding that the management decisions which they have to take need very careful consideration. These decisions are difficult to make without the input of the primary stakeholders, such as the communities who are either to be affected by or will be the beneficiaries of water resources management activities. Consequently, the management of water resources is becoming increasingly reliant on both the participation and co-operation of communities. Communities are usually aware of the nature of water resources endowment in their respective areas. By being aware of the limited nature of the available water resources and the competing demands for water in the region, communities have always appreciated the fact that some difficult choices have to be made in order to manage the limited water resources effectively, use them equitably and in a sustainable manner.
>
> When it comes to deciding on management options, because of their deep understanding of the local conditions, communities are always found to be in a better position to appreciate the possible options. Consequently, communities have, in many cases, been capable of making, and putting in place, well-informed water management policies and strategies which are accepted, supported and implemented by the communities themselves. And in that process water resources have come to be managed sustainably and water-use conflicts have been minimized.

9.3 CASE STUDIES OF COMMUNITY-BASED WATER RESOURCES MANAGEMENT

This section reviews and discusses several types of water resources management practices in the SADC countries. The case studies selected deal with:

- the process of water resources law, policy and strategy formulation;
- irrigation management;
- groundwater management;
- catchment protection;
- management of wetlands;
- flood management; and
- rural water supply management, etc.

The case studies highlight the roles of the communities in the process of management of water resources. The review sheds important light on the institutional, financial, legal, educational, human resources, technological and gender requirements for effective community involvement in sustainable water resource management.

9.3.1 Stakeholder participation in the review of South Africa's Water Act

In 1994 when a new democratic government took office in South Africa, it inherited a multitude of water laws from the past apartheid regime. Under the apartheid regime, access to and allocation of water rights were determined on a racially discriminatory basis, linked to land law and land ownership. The majority of black South Africans (85 percent) were denied access or were dispossessed of their land; thus, their access to water was limited, let alone access to safe and adequate supplies of water. Furthermore, under apartheid, distribution of water took no account of the basic needs of the nation's people as a whole. Under South Africa's new democracy, the reform of water laws was therefore a necessity and an urgent matter of national importance. There was strong political support for the reform process.

The review of South Africa's water laws was, first and foremost, guided by the country's constitution which requires that the National Assembly (national Parliament) must [illegible] public involvement in its legislative and other committees, must conduct its business in an open manner and must hold its sittings, (those of its committees) in public. (Republic of South Africa, 1996) As the South Africa of today is a nation of diversity, "the water law review process squarely confronted diversity through a consistent and diligent programme of widespread and meaningful consultation and consensus-building." (Stein 1999) Box 9.2 describes the consultative process used in the review of the water law of South Africa. This process was designed to broaden the involvement by all stakeholders, communities, civic-based-organisations, non-governmental organisations, environmental interest groups, water users, women, labour, industry, and government, by providing an "environment that was conducive to people to unlock their potential and to play a role in the social and economic development of South Africa and to remove any constraints placed upon them by pursuit of selfish needs of supremacy and political ambition." (Stein 1999)

Consultative process in the review of water laws in South Africa — **Box 9.2**

The success of the water law review process had, in the first instance, to be backed by strong political will. That role was undertaken by the Minister of Water Affairs and Forestry when he initiated the process shortly after he took office in 1994. The Minister sought to ensure direct and hands-on support throughout the process by appointing a Policy and Strategy Team which was an advisory team made up of persons from different racial, political, gender and cultural backgrounds: a team that was essentially demographically representative in nature. Through the Minister, the Policy and Strategy Team gave direction to the Drafting Team, also constituted by the Minister and made up of legal and technical specialists who were representative of the broad spectrum of legal and technical expertise in South Africa.

The Water Law Review process commenced with a detailed review of all South African water laws. In March 1995, a document entitled, "You and Your Water Rights" was published by the Department of Water Affairs and Forestry. The document was intended to solicit views of everyone in the country, on the existing water laws. This public comment on water laws was followed by the publication of the Fundamental Principles and Objectives for a new water law in South Africa. These principles were also developed through consultations and were published for comment.

The next step in the review process was the issuing of the White Paper on a National Water Policy for South Africa. This document was approved by Cabinet as official government policy in April 1997. Following a series of policy discussions led by the Policy and Strategy Team, drafting of the National Water Act started in July 1997. The draft National Water Bill was then discussed throughout the country in workshops. The draft Bill was issued for public comment in early August 1997. Receipt of comments from the public and all other interested parties led to further revision of the draft National Water Bill.

These consultations led to the drafting of a final National Water Bill. The National Water Act was eventually approved by Parliament and was assented to by the President in August 1998.

Stein 1999

9.3.2 Zimbabwe's water resources legislation and management strategy

Like its neighbour South Africa, Zimbabwe at independence inherited a discriminatory pattern of water allocations. It was a system characterized by perpetual water allocations, highly skewed to the minority white farming community, with the majority of the population having limited access. This former system also ignored in-stream environmental needs and the linkage between surface and groundwater, and lacked economic incentives for efficient use. After independence, Zimbabwe had no choice but to address the historically skewed Water Rights system as well as the water resources management system. Now a modern, more flexible and equitable water law has been enacted.

What is particularly instructive is the highly consultative process by which Zimbabwe prepared its proposals for a new water allocation environment. There were, however, difficulties encountered in the Water Resources Management Strategy (WRMS) development process, in

which the process was effected through an initially over-bureaucratic method. Many lessons were learned along the way. The WRMS was, like the legislation, prepared in an inclusive manner, and appears to contain all the elements that are widely considered to be essential in a comprehensive approach, based on sound economic thinking. The two cases of the South African Water Law and the Zimbabwe Water Resources Legislation and Management Strategy highlight the importance of using a participatory and inclusive process to develop a law and strategy. Owner-ship of the law and strategy by the users in their interest is an essential pre-requisite for these to be implementable.

9.3.3 Community-based irrigation management

The community-based irrigation management practices in north-eastern Tanzania offer an interesting set of examples of successful water resources management practice.

9.3.3.1 Upland water use and irrigation on the slopes of Mount Kilimanjaro

The eastern, southern, and western slopes of Mount Kilimanjaro are settled by the Wachagga, who have inhabited the area for 300 – 400 years. Through their long stay in this area, the Wachagga have developed what Alison Grove (1993) calls, "one of Africa's most impressive systems of water management."

The system consists of an indigenous irrigation network with numerous channels or furrows, which run across the mountain slopes. These furrows are cut to follow the contours of the land. They convey water from streams and springs intake high up on the mountain down to the densely populated areas. The water distribution system consists of the main furrows. Branches and sub-branches are constructed from each main furrow. It is these branches and sub-branches which supply homesteads with water for drinking, washing and for irrigating homestead fields known locally as [illegible] (Masao 1974) These water-conveying channels are extensive, involving 1,800 km of main channels with an estimated throughput of 200 million cu m of water annually. (Grove 1993)

The most interesting aspect about the furrows in the Kilimanjaro area is that they were designed, constructed, operated and maintained by the communities themselves without any outside assistance. The organization and administrative structure behind this success is said to be the strong clan system which existed in the place. Through the area clan system a well-defined division of labour was developed, whereby members of the clan became aware of their responsibilities and rights and executed their duties [illegible]. It was also through this well-organized social system (with well-defined and respected social sanctions) that members tendered mutual aid as well as settled disputes. Box 9.3 describes the [illegible] community water management system.

9.3.3.2 Lowland furrow irrigation systems in the South Pare Mountain area

South Pare Mountains, situated in north-eastern Tanzania, extend about 60 km running from north to south. The area is inhabited by Pare people who have developed an intensive agriculture in the lowland area and on the eastern slopes of the mountain range. There are three cropping seasons which are locally known as *vuli* (short rains), *masika* (long rains), and *chamazi* (dry season). Irrigation using water conveyed in furrows is practiced during the two growing seasons of *vuli* and *chamazi*. Most furrows in the area were constructed by clans more than 100 years ago. The clans own the furrows, which are also named after them.

Water utilization

Irrigation furrows provide the security for extending the growing season during the dry season (May – October) and during the *Vuli* season when the dry spell sets in before crops ripen. The main crops grown under irrigation are maize, beans and sweet potatoes. Vegetables are also grown under irrigation.

Water management system

The furrow-owning clan appoints a manager for each furrow with the responsibility for the allocation of water to each member household and for overseeing the operations and maintenance of the furrows. The manager also holds the responsibility for reviewing and approving application for water use by new residents. The new residents are not required to be members of the same clan in order to be granted access to the use of water. After the enactment of the Village and Ujamaa Village Act of 1975, the political structure changed in Tanzania and the registered villages assumed responsibility for managing the furrows. Box 9.4 describes the current furrow management practice.

The Wachagga community water management system — Box 9.3

Ownership of furrows

The Wachagga have for a long time realized the role of water in their socio-economic life. They have developed a sound management system that ensures the sharing of responsibility and benefits from the water available in the area.

Water from springs and rivers from the slopes of Mount Kilimanjaro is conveyed to the homesteads and farms by use of channels/furrows. Construction of the furrows was carried out by the communities. Once the work of digging a furrow was accomplished and the water started flowing, the community instituted a rationale mechanism for addressing allocation issues, protection and management of the resources and for resolving conflicts related to the use and management of the furrow. Furrows were owned by chiefs, clans, or even individuals. Because of the important role furrows play in the whole livelihood of the Wachagga, furrow rights are regarded and held sacred. Tampering with a neighbour's or neighbouring chief's furrow was known to lead to violence.

Use of furrow water

The Wachagga instituted procedures for using water from a furrow in a harmonious and equitable manner. For a person to obtain water for use from the furrow he/she first has to become a member of the furrow group (or board). Where a furrow was owned by a particular clan, the clan members formed the core of the furrow board while others who might need to use the furrow water were admitted to the board as auxiliaries. In areas where the furrow was owned by the people of a defined geographical area, membership of the board was left open as long as interested people paid the prescribed contribution.

The other requirement is that after joining the board the new member was required to obey the instructions of his/her furrow elders and take his/her turn together with others in repairing and cleaning the furrow. Failure to obey such instructions was punished by paying a fine. A fine was mainly in the form of beer which was shared by fellow furrow users. Restriction from using the furrow was usually imposed if one failed to pay the fine

Water from the furrows was and is still being used for irrigating bananas, coffee, and supplying household needs. Masao (1974), looking at operations of the furrow system, noted that, "It is remarkable that with the large and complicated furrow system in the *kihamba* land, so well are matters run by the furrow elders that the number of cases arising out of disputes over water rights are exceedingly few." It is an indisputable fact that through the meticulous use of the irrigation furrows the Wachagga have ensured that there was enough food all the year round as well as cash crops (such as coffee) for providing supplementary income.

Masao 1974

Organization for water management in the South Pare Mountain area — Box 9.4

After the enactment of the Village and Ujamaa Village Act of 1975, the registered villages assumed responsibility for managing the furrows. Management of the furrows falls under the irrigation sub-committee under the Production Committee, one of five committees in the village government. The irrigation sub-committee consists of men whose number corresponds to the number of furrows in the village. In some villages, especially in the mountains, the whole village is divided into irrigation areas and each area is thus managed by one person who becomes a member of the irrigation sub-committee.

Allocation of water from a furrow to households is done by a water manager who usually happens to be an elderly man who is respected by the members of the furrow group. It is his responsibility to ensure that every member of the furrow group gets water and that the furrow system is maintained and in good condition.

Contrary to practices in other places in Tanzania, here in South Pare, farmers get water allocations according to the size of their farm plot. It is, however, an offence for a farmer to draw water from a furrow when it is not his/her turn. Such an act draws a penalty although this penalty differs from village to village.

The furrow maintenance system has five major operations which are:

- routine inspection of the water furrows;
- monitoring and regulating the water level and flow;
- opening and closing the diversion gates;
- cleaning up of the furrows; and
- repair works in case of damage.

The first three operations are usually carried out by the water manager. The last two are performed communally by furrow users. However, mobilization for communal work is the responsibility of the water manager.

Yoshida 1985

9.3.4 Community level flood management

Many communities in the SADC countries are located in floodplains and flood prone areas. The south-eastern coast of Africa is regularly bombarded by tropical cyclones, with Claude in 1966, Domoina in 1984, Nadia in 1994 and Eline in 1999 being the most notable. These cyclones bring long duration but low intensity rainfall, and tend to give rise to widespread flooding at a river-basin scale. It should be noted that other meteorological systems also generate these types of floods. Tropical thunderstorms tend to be of short duration and high intensity, and give rise to localized flooding. The latter type of flooding happens very quickly with little warning, whilst the former type of flooding tends to build up over several days with significant indicators of a pending flood which are often ignored. The hazards to which com-

munities are exposed associated with the two types of flooding, are also different.

Communities living in informal settlements on the peri-urban fringes of formal townships are often at the highest risk. The areas that they settle on are generally the flatter low-lying areas that are easier for informal habitation. These communities are also fairly new and do not have the strong social structures and communication mechanisms normally found in formal townships or rural villages. They therefore do not know the history of the area and often are not aware of the risks and hazards of flooding.

On Christmas Day in December 1995, 173 lives were lost in an informal settlement near Pietermaritzburg, South Africa. A torrential downpour caused a small stream to break its banks and flood the shacks, resulting in collapsed dwellings that were washed away, blocking escape routes.

Communities living in rural villages have normally stayed there for many generations and have experienced the effects of flooding during this time. Although they should be well prepared for floods, and hazards relating to floods, extreme events often catch them unaware. Recent flooding in southern Africa as a result of Cyclone Eline is the worst in living memory. It left hundreds dead and about 1.25 million homeless. Mozambique bore the brunt of the disaster, but South Africa, Zimbabwe, Botswana, Zambia, and the island of Madagascar were all affected. Rivers across the region burst their banks as Cyclone Eline brought more rain to lands already waterlogged by more than two weeks of storms.

In Zimbabwe more than 100 people died, and an estimated 250,000 were left homeless, exacerbating the country's worst economic crisis in 20 years. Crops and village granaries were washed away, and food supplies were destroyed. Roads, bridges, and dams were also destroyed. Reports estimated that Z$10 billion (US$ 185 million) worth of damage was caused to crops, livestock, infrastructure, and property. Thousands of people faced starvation because food distribution was virtually impossible in some areas.

The following year was also followed by severe floods which compounded the devastation, particularly to the downstream communities in Mozambique. Both South Africa and Mozambique have sophisticated flood warning systems, but it is questionable whether the warnings ever reach the communities in time.

It is ironic that floods do not move down a river in the form of a wall of water, and a person standing on a bank of the river would be able to walk away from the danger at a slow walking pace on dry land. This implies that given some warning, most flood-related deaths could be prevented.

Alexander (1998) proposes several options for reducing the risks and hazards to communities from flooding, these being :

move communities to higher ground;
build flood damage mitigation works;
operate active flood warning systems; or
develop community river watch systems.

The option chosen is often dependent on the circumstances of the community, and the case study of Alexandra (Box 9.5), a suburb of Johannesburg, illustrates the complex problems faced in this regard.

Alexander (1998) cautions that before embarking on any flood risk reduction measure all authorities and communities should be aware that complete success is unlikely. This is because of the unpredictability of rainfall and floods as well as limitations on human and other resources required in dealing with emergencies. Furthermore, authorities have tended to adopt the "do nothing" option in the past since this reduces the risk of the authority being sued for its actions. This, however, is becoming a less viable option due to increasing socio-political pressures.

SOE Zambezi – CEP

Floods do not move down a river in a wall of water, a person standing on a bank of the river could walk away from the danger at a slow walking pace on dry land. This implies that, given some warning, most flood-related deaths could be prevented.

A community-based flood management system for Alexandra **Box 9.5**

The Jukskei river rises in the centre of Johannesburg and passes through Alexandra. There are an estimated 6,000 persons living in over 1,500 shacks located below the 1:50 year flood-line. The shacks have been built on all available space, including dumped rubble, right up to the edge of the river channel. This is the highest density of persons at risk during floods in South Africa and there will inevitably be lives lost should over-bank flooding occur. The particular problems with Alexandra are the very short warning times, the organisational difficulties and institutional problems, as well as communication problems with the persons at risk. In this case, a combination of an active flood warning with a community river watch system has been recommended for implementation.

The active flood warning system will be operated by the City Council and involves near real time information acquisition, rapid computer-based data processing and flood forecasting of sufficient accuracy to place observers in the field and rescue teams on standby. Direct warnings will only be issued once life-threatening floods are observed in the river a few kilometres upstream of Alexandra.

The community river-watch system consists of making members of the community within flood-prone areas aware of the potential dangers so they can take appropriate action when necessary. They will also have to become familiar with safe escape routes. Flood levels are marked at appropriate places such as bridges, beacons or posts. Volunteer watchmen from the Alexandra community will be alerted by the active flood warning system and will disseminate any warnings to those people at risk. They will remain vigilant and monitor the flood levels at those places where they have been marked, and take appropriate action as the flood rises or subsides.

Ultimately, the success of the system will depend not only on hydrological technology but also on effective communication with those responsible for the community river-watch system and the trust that they have in those who are responsible for operating the active flood-warning system.

Alexander 1993

No matter which option is adopted, it will require a high level of community participation in the choice of an option, significant education and awareness on the implications of the option, and very clear and open communication channels between the authorities and the affected communities.

9.3.5 Sustainable groundwater management

A significant portion of the population in southern Africa relies on groundwater to serve both basic human needs as well as other agricultural activities, such as livestock watering. The dispersed nature of many rural communities makes surface-water resource schemes prohibitively expensive, and groundwater remains the only viable resource for utilisation. The rapidly growing number of people in these areas is putting an ever-increasing demand on this limited resource base (and other resources which are dependant on water). According to Jacobson, Jacobson and Seely (1995), the availability of water influences the way people utilise other resources, and water is the ultimate regulator of how people live, move and settle in an arid country.

In arid areas, which include most of southern Africa, there is a delicate balance between the naturally available water resources and other resources such as vegetation for grazing. The utilization of an additional resource, such as groundwater, can influence this balance and deplete the other resources. A common problem is that groundwater is abstracted at a rate in excess of the recharge, resulting in overall depletion of the resource and lowering of the water table. Overgrazing of the vegetation surrounding such sites, along with the compaction of the soil that is trampled by livestock, may impede recharge of the groundwater and therefore contribute to the problem.

Rainfall, through recharge, is the driving force behind groundwater. In the long-term, a groundwater resource cannot supply more water than is recharged. The sustainable yield of an aquifer is finite and depends ultimately on the prevailing climatic conditions. Pumping water out of a borehole at a higher rate, or drilling more boreholes, will yield more water in the short term, but this is not sustainable. The recharge of groundwater is difficult to predict and is normally determined theoretically before borehole development. The sustainable yield of an aquifer will, however, depend upon its behaviour under operational conditions.

It is therefore very important for the community to know how much of the groundwater resource they are using, and to adjust their use accordingly. In order to do so, accurate and regular monitoring of rainfall, runoff, groundwater levels and abstractions by the community is essential. Furthermore, simple operating rules need to be

devised so that the community can adjust their usage according to the feedback from the monitoring programme. Box 9.6 outlines an example of where excessive groundwater usage continues at unsustainable levels in Khorixas, Namibia, and where the community can play a significant role in adjusting their usage patterns.

Khorixas depletes its aquifer **Box 9.6**

In Khorixas, Namibia, some 7,400 people consumed nearly 1.4 million cu m of water in 1991 at an average daily consumption of nearly 500 litres per person. Recent investigations suggest that much of the water supplied to Khorixas may not be reaching the end consumer due to pipe bursts and leaks. As much as 66 percent of the water supplied may be wasted. To regulate the use of water, the supply system is turned on for three periods during the day – morning, noon and early evening. This, however, may be contributing to the high rate of water use because taps are often left open all day, whether water is needed or not. The fact that many households are unmetered, or meters are inoperative, further contributes to overuse. On top of this, end-consumers are charged the same amount for water, no matter how much they use.

The aquifer supplying Khorixas has been severely depleted as water is withdrawn at a higher rate than it is recharged, even though efforts to regulate the amount of water used have been implemented since 1980. Currently, rest water levels in the aquifer supplying Khorixas have been lowered more than 50 metres and it is now regarded as exhausted in terms of its potential for further development.

In an effort to meet this high demand, further boreholes have been drilled to supplement the deteriorating yields of several critical production boreholes. Plans are also being considered to build a dam on the nearby Ugab river. While this dam will increase water supply to Khorixas, it will also have a severe effect on the environment in the Ugab river and the nearly 1,000 people below the dam site whose livelihoods are dependant on the river.

It has been suggested that rather than investing a large amount of money on this new infrastructure, the Government should instead invest its resources in refurbishing the reticulation network and providing water meters in an attempt to drive the demand down. Although restrictions have been in place and plans are afoot to augment the supply with further water resources developments, no water demand management programme has been initiated in Khorixas. Without this, attempts at achieving a sustainable use of water in Khorixas will not succeed.

Jacobson, Jacobson and Seely 1995

Jacobson, Jacobson and Seely (1995) are of the opinion that the provision of a water supply from groundwater sets the development scene of a specific area, mainly directed at livestock farming and permanent settlement. The viability of other options, perhaps more economically beneficial and sustainable, may thus be reduced. In many instances, boreholes are installed as drought relief measures, and are done so in the absence of land-use planning and appropriate geohydrological investigations. In a drought-relief programme, it is often not possible to determine the impacts on the regional groundwater situation, and hence on springs and other natural water points which may support other communities, livestock and wildlife. Planning for the movement of livestock between watering points to manage grazing may also be precluded if boreholes have been placed too close together in response to a community's demands.

Sustainable groundwater development and management can therefore only be achieved through the joint efforts of the authorities, groundwater professionals and the communities themselves. Careful planning of groundwater schemes is required and should address the most appropriate and sustainable uses of all resources in a particular area. Thorough geohydrological investigations are required, and once a scheme is implemented, a community-based monitoring system is required.

9.3.6 Integrated catchment management

Integrated catchment management (ICM) is an approach whereby a water resource, and other natural resources which are inter-dependent with the water resource, are utilised and managed in a holistic and sustainable manner. ICM takes a river basin as its basic unit and tries to place communities and their needs at the focal point. The objective is to strive for a balance between the interdependent roles of water resource protection and utilisation. Water resources, being an ecological system, its protection, utilisation and management therefore has to be based on ecological principles, those being(DWAF and WRC 1996):

- a systems approach which recognises the individual components as well as the linkages between them, and addresses the needs of both the human and natural systems;
- an integrated approach in which attention is directed towards key issues of concern identified by all stakeholders in the process;
- a stakeholder approach, which recognises the importance of involving individual communities as well as government agencies, in a participatory process to define all decisions around the conservation and use of natural resources which affect their lives;
- a partnership approach, which promotes the search for common objectives, and defines the roles,

responsibilities and accountabilities of each agency, community and individual that participates in the process of decision-making; and
a balanced approach where attention is given to decisions designed to achieve a sustainable blend of economic development and protection of resource integrity, while meeting social needs and expectations.

In reality, the communities seldom accept plans that they have not been involved in from their formulation. The case study presented in Box 9.7 outlines an approach whereby a paticipatory bottom-up approach has been used to develop a catchment management programme for the Mlazi catchment in South Africa.

Mlazi river participatory catchment management programme — Box 9.7

The catchment area of the Mlazi river in South Africa is some 1,000 sq km, and it drains into the Indian Ocean in Durban's Southern Industrial Basin. Almost half a million people live in the basin, and a further 200,000 people live in the Mlazi catchment itself. Land uses in the catchment include indigenous forest, large plantations of eucalypt, pine and wattle, rural villages with small-scale agricultural production, intensive irrigated vegetables, sugar cane, grazing, conservation, industry and a township area where some 150,000 people live.

This area also includes about 60 schools; another 150 schools are to be found in the Southern Industrial Basin. As a result of the development within the catchment, the natural resources have come under tremendous pressure, especially because the water resources are heavily competed for.

To this end, a catchment management programme has been implemented to provide the framework and institutional mechanisms through which communities can participate with a view to sustainable utilisation of the natural resources. The four main areas of activity are:

- technical research into effective rainwater harvesting and ecological farming systems;
- outreach efforts aiming at establishing water-efficient community gardens and women's craft groups based on the sustainable use of natural resources (especially wetland reeds);
- environmental education for adults and for children (concentrating on School Environmental Action Clubs); and
- platform-building whereby stakeholders are brought together to deal with conflict and to develop a shared appreciation of local problems through joint planning and then collective action.

The development from conflict management to joint planning to collective action only happened after certain preconditions had been met, such as:

- the existence of local leaders who are sufficiently devoted to serving broad local interests;
- facilitation from non-partisan agencies;
- strategies and resources which can meet local constraints to development;
- the development of a catchment identity (through physical modelling, regular biomonitoring and reporting on these and other issues in a newsletter); and
- a process of discovery learning.

The establishment of local Subcatchment Committees was more effective than an overall Catchment Management Committee, as resources are managed at the local level. These committees became effective vehicles for grassroots participation in local activities, and although there are many thorny issues, these are being managed through negotiation rather than violence. These activities reflect the process of platform building as well as adult education.

The School Environmental Action Clubs concentrate on developing school environmental policies, helping the school to formulate an action plan, and stimulating appropriate activities through annual environmental competitions. The schools have also helped to establish a number of community gardens on their properties, which has resulted in improved relationships between local communities and the schools. It has also changed the attitudes of some scholars towards agriculture, as children see respected local people engaged in market gardening. The educational value of the gardens is considerable, as much attention is given to water harvesting, soil conservation and ecological production. Children also see themselves as part of the catchment, and as responsible for caring for their river and their environment.

Outreach efforts (community gardens and craft groups) are modelled on the local Bachs Fen Ecological Research Farm, where water is harvested off roads and a local hill, and led into rehabilitated wetlands. This water is then available throughout the year for irrigation of the market garden. Together with the use of swales, mulches and compost in a farming system where crops and animals are well-balanced, these innovations have helped to develop a model for small-scale, ecologically sound, commercial agriculture. Training courses are also run on the farm.

Auerbach 1999

9.3.7 Management of wetlands

Wetlands are called by various names, such as sponges, marshes, bogs, fens, swamps, *dambos* and *vleis*, to name a few. The term *dambo*, for example, is a Zambian and Malawian Ci-cewa vernacular word used to refer to meadow grazing land. Similar features found in the rest of southern Africa are known as

mbugas (Tanzania),
matoro or *bani* (Zimbabwe, shona vernacular),
molapos (Namibia, Botswana and Lesotho),
naka (Angola), and
vlei (Afrikaans).

Dambos, although small compared to other wetlands are widespread in southern Africa. In Malawi, *dambos* occupy 12 percent of the total land area (259,000 hectares) of the country (Mzembe 1990), while in Zimbabwe, *dambos* occupy 1.28 million hectares. (Whitlow 1990) The distribution of *dambos* in Zambia and Tanzania is even more widespread.

The definition of the collective term "wetlands", and the various derivatives thereof, vary considerably. Davies and Day (1998) consider wetlands to be any ecosystem whose soils show evidence of at least periodic waterlogging. This simple and convenient definition seems to accommodate most of the terminology used for wetlands in southern Africa.

9.3.7.1 Dambo cultivation and community involvement in dambo management

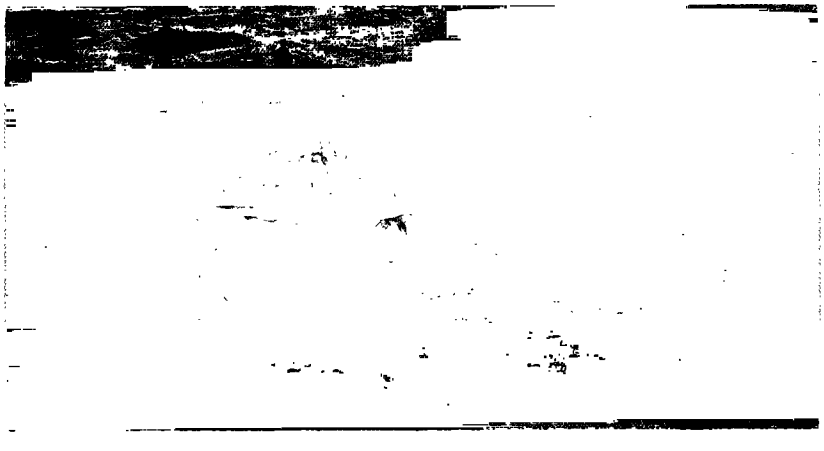
Dambo cultivation and management provides a good example of community-based approaches and effective community involvement in water and land resources management. Dambos have been cultivated and grazed for centuries in southern Africa. This is supported by archaeological studies in Zimbabwe and other countries that have established the existence of *dambo* cultivation in prehistoric time. Because dambos remain moist during the dry season they are used for garden cultivation, cattle grazing and watering, and for domestic water supply.

The near-surface water table found in *dambos* enables localized irrigation from shallow wells throughout the year. (Whitlow 1990) In areas where they occur, dambos present the opportunity to support a range of livelihoods such as agriculture, livestock, fish, wild products, building materials, etc. (as discussed in Box 9.8). In Zambia, McEwan (1993) reported that *dambo* [illegible] has the potential to make a significant contribution to household food supply and cash income. In fact, the utilisation of *dambos* enables a more diversified cropping and enterprise system that protect households against shocks and stresses.

The current uses of *dambos* vary within and between countries in the region. In Zimbabwe, research by the Dambo Research Unit (DRU) 1987, revealed multiple uses of *dambo* resources. These include *dambo* cultivation, grazing, aquaculture, establishment of woodlots and water supply. Kokwe (1991) discovered that dambos of the Luapula province of Zambia are used for market gardening, livestock grazing, fish production, domestic and livestock water supply. In Malawi, *dambos* are even used for large-scale rice production and aquaculture.

Although *dambos* have several uses, it is in *dambo* cultivation that local communities have developed localised approaches and strategies that have managed to maintain an ecological balance within these ecosystems. Many *dambos* in Malawi, Zimbabwe and Zambia provide a suitable environment for gardens in which a wide range of crops such as cabbages, tomatoes, carrots, rape, bananas, pawpaws, yams, irrigated or rainfall rice, sugarcane, green maize and tobacco/tree nursery seedlings are raised. In Zimbabwe, these crops are grown in *dambo* gardens which range from 0.10 to 7 hectares and are fenced with barbed wire, mesh and/or thorns or sisal hedges. (DRU 1987)

Dambo-based aquaculture is also widespread in Zambia, Malawi and Zimbabwe. Most of the fish ponds constructed in Mwanza Mulanje and Zomba (200-400) in Malawi's southern region as well as those in the central (over 100 small ponds) and in the northern regions have been sited in or adjacent to the *dambos*. (Phiri 1993)



SOE Zambezi – CEP

Community approaches to *dambo* cultivation and management **Box 9.8**

Dambo cultivation illustrates examples of how local communities take advantage of the spatial and temporal heterogeneity in the landscape provided by *dambos* to strengthen their household food security. The majority of *dambos* in the region are under common property regimes. In this case, communities have to organise themselves to effectively manage and sustainably use these resources. In Zambia's Mabunda area of Luapula province, *dambo* cultivation activities are programmed and managed as a family affair. (McEwan 1993) Local communities grow tomatoes, beans, onion, sweet potatoes, chinese cabbage, and a variety of vegetables such as spices, ginger, rape and garlic.

The timing of *dambo* enterprises is often carefully assessed to ensure that any labour peaks or bottlenecks are not aggravated, or that the involvement of women will not increase the demands on their labour. This is based on the community's understanding of which enterprises are less labour intensive, take place during slack periods or are amenable to labour saving technology.

This *dambo* cultivation requires finer tuned management of water flow, slopes, field surfaces, soil fertility, space, micro-environments and temporal variations. Micro-level management is more of the manipulation of physical factors. The height and size of the raised beds change spatially and seasonally in accordance with the available moisture. Different tools, labour inputs and factors are involved in different activities (men and women). The key to successful *dambo* cultivation is the ability to adapt to and manage the varying soil moisture conditions. Most local communities rely on residual soil moisture while others resort to simple irrigation techniques such as watering cans.

A study by the DRU (1987) revealed that during the rainy season, due to too much wetness, farmers construct raised beds and trenches to drain excess water. The height and width of the raised bed varies according to its position in relation to the seepage zone. The initial land preparation in most *dambos* is done using ox-drawn ploughs in order to avoid compaction. The cropping is well-timed to go with the moisture content of the garden. Inputs such as manure, fertiliser and pesticides are used. The woodlots are often sited within the *dambo* margin and these usually include indigenous trees, fruit trees, and eucalyptus.

In Zvishavane (Zimbabwe), Scoones and Cousins (1991) observed that local communities have developed strategies of managing water flow and moisture content. Communities construct drainage lines/ditches and water storage is enhanced through the construction of ponds. To retain water, Kikuyu grass is planted above the ponds. This also reduces siltation and increases water harvesting. Wells are also dug to supply water for irrigation and drinking. To manage the slope and field surfaces, bunds are constructed along the contour to conserve the soil. Ridging is used to raise the soil above the waterlogged area, thus allowing an intercropping of rice in the troughs and maize on the ridges. There is intense use of space in dambo gardens with about 23 different crops and 26 different tree species harvested. (Scoones and Cousins 1991) This is achieved through the identification and creation of micro-variations in space to create diversity in the production base. In the Zvishavane area, the same researchers observed that the local communities capitalise on micro-environment variations in *dambos*.

On termitarias, which are familiar features of the drier sections of the *dambo,* fruit trees are grown. Litter fall from these trees creates another spatial variation. The groves of bananas planted in the *dambo* create another particular micro climate suitable for keeping bees. Termitarias are also dug up and spread on particular sections of the *dambo* with poor soils. The seasonal and inter-annual variations in water availability result in cropping pattern adjustments. Dry season use is concentrated on the wetter areas.

9.3.7.2 The Mbongolwane wetland

The widespread use of wetlands for the different agricultural and livestock activities, as discussed above, is causing some environmental problems. The loss and degradation of wetlands in the SADC region is a concern now recognised by most governments, and the protection of wetlands is considered fundamental to the sustainable management of the region's water resources. In order to understand and assist in promoting the sustainable use of wetlands, a pilot initiative was undertaken in 1995 at the Mbongolwane wetland in South Africa, the details of which are provided in Box 9.9.

9.3.7.3 The Kafue flats

At a somewhat larger scale, community development and empowerment has helped to turn around the systematic degradation of the Kafue flats in Zambia. This case study, which is presented in Box 9.10, does not consider the water resources alone, but rather focuses on the management of the other natural resources and related developments which are dependant on the water resources.

The study also shows how community development can be financed out of the sustainable use of natural resources.

The Mbongolwane wetland project Box 9.9

The wetland provides life-sustaining resources to the local community, such as potable water, material for craft making and thatching, grazing for cattle, medicinal plants, and land for cultivation. Added to this is the hydrological importance of the wetland. The catchment of the wetland comprises sugar cane, grazing, cropland and homesteads, all of which contribute to increased sediment and nutrient input into the river system. The wetland plays an important function in water purification and flow regulation. The wetland also provides a diversity of habitats including reed and bulrush marshes, sedge marshes, wet grassland and even open water surfaces.

The whole community has access to the wetland and the Tribal Authority is responsible for allocating land and controlling use of the natural resources in the wetland. The sedges are harvested from December to June to provide fibre for making traditional sleeping mats. The reeds, used for thatching houses, are harvested after April when the plants die back naturally. These harvesting practices result in minimal impacts, and are supported by the traditional belief in *Inkanyamba*, the seven-headed Serpent Spirit that lives in the wetland. According to tradition, if harvesting takes place too early the Spirit is disturbed and causes a violent storm. Harvesting of natural plants is also carried out sustainably and does not harm the wetland's functioning. This has a positive effect in providing an incentive for people not to destroy the wetland and a local craft group has been formed to provide assistance to increase income generation through selling wetland crafts.

About 10 percent of the wetland is used for cultivating crops, particularly potato-like roots called *madumbes* which can tolerate temporarily waterlogged conditions. The cultivation is non-mechanized and is traditional in nature, which is less harmful to the wetland than large-scale mechanized cultivation. Pesticides or artificial fertilizers are not used. Drainage practices are also absent and the cultivated areas are shifted to allow regeneration of the natural vegetation. Nevertheless, crop production may still harm the functioning of the wetland, especially where sensitive areas with high erosion hazards are cultivated.

To this end, management guidelines, many of which were long-established traditional practices, have been re-established to assist the Tribal Authority. The project has also been raising awareness and addressing issues of education and health associated with the wetland.

The pilot project has demonstrated clearly that the conservation and sustainable use of a wetland can be achieved. Possibly the greatest testament to this is that the condition of the wetland is considerably better than the other major wetlands in the surrounding large-scale commercial sugar cane farms. Nevertheless, contemporary socio-economic pressures are making it increasingly difficult to maintain the wetland in its current state.

Kotze 1999

The demise of the Kafue flats Box 9.10

The Kafue flats, located on the Kafue river in Zambia, has been affected by the environmental impacts of hydropower development. The Kafue Gorge Dam was built in 1972, its impoundment permanently inundating a large part of the downstream area of the flats. A second dam was constructed upstream of the flats at Itezhitezhi a little later to regulate flows. Although an environmental operating rule is in place, the hydrological and flooding regimes have been changed markedly.

Aquatic plants and floodplain grasses completely dominate the vegetation, and this supports the Kafue Lechwe, an antelope that is unique to this area. The population of this antelope has diminished substantially since the early 1970s. The flats also support other important wildlife species as well as some 400 species of birds. Today, the wildlife can only be found in protected reserve areas.

For centuries, three main ethnic groups, the Ila, Tonga and Twa, have populated the Flats. The Twa are traditionally fishermen and farmers, however the influx of fishermen from other regions has resulted in a significant decline in fish production over the past few decades. The Tonga, who are subsistence farmers and somewhat less dependant on the flats, have been forced to move to less fertile areas due to the establishment of state land farms. The Ila are cattle herders and have largely resisted external pressures to change their traditional lifestyles. They own many of the cattle grazing on the flats.

Current thinking is that although the demise of the wetland can be attributed to the development of hydropower infrastructure, other major contributing factors have been the neglect and underdevelopment of local communities. To this end the WWF-Zambia Wetlands Project was initiated, the fundamental aims of which are to conserve wetland resources, enhance their natural productivity and improve the living standards of local communities through the sustainable use of natural resources. Sustainable hunting of wildlife, especially the Lechwe, is a major potential source of income for local communities. The project has created the physical and organisational conditions that allow this potential source to materialise, such as the transformation of poaching into legal and controlled hunting, and the participation of local communities in this transformation and in profits generated by eco-tourism. Through the creation of a revolving fund, part of this money is used for community development and services. Participation of local people in the management of the area created training and employment opportunities. Furthermore, the better protection of fish breeding sites will benefit local fishermen in the long run.

Achievements show that the Lechwe population has increased by 10 percent since 1983, and with a sustainable rate of exploitation, safari-hunting could amount to US$1 million. The communities have elected and run committees that organise participation and allocate the accrued benefits. Local government and communities are represented on various Wetland Manage-ment Authorities, which are institutions that decide on resource use and management within defined zones of the wetland area. The community development activities have helped to build support for the project and have contributed to a significant shift in attitude amongst the communities to favouring the statutory responsibility assumed by the project with respect to the management of the project area.

From the onset, it was made clear that no one would be taking over communal land or imposing unwanted development, but would be seeking the active participation of the local people. At the same time, the legal responsibility to respect the integrity of the environment and the enforcement of related statutory rules would be improved, for which co-operation with the community was required.

Chooye and Dryver 1995

The Mbongolwane experience illustrates that positive results arise from a gradual bottom-up process sensitive to local practices and needs. In addressing the issue of wetlands in communal areas generally, a targeted approach is needed in order that support is focused on those areas likely to yield the greatest returns for the investment.

Wetland management on the Kafue flats illustrates that natural wetland resources can be a very productive basis for the economic development of local communities. The revolving fund is a mechanism that directs the income from the exploitation of wetland resources into appropriate channels to serve the interest of managing the biological resources as well as the interests of local communities. The case of the Kafue flats also shows that it makes sense to combine enforcement and control activities with both economic and moral incentives.

In this light, planners and managers should not just focus on one aspect of wetland management, such as sustainable cultivation, but rather consider wetlands in a more holistic manner and consider the overall utilisation and conservation of wetlands. The focus should be on the integration of the objectives of development with the maintenance of wetland functions and values. The key to sustainable use of wetlands seems to be a community-driven management plan and creating an awareness of the importance and functions of wetlands. Furthermore, given the importance of wetlands to communities, the creation of artificial wetlands for pollution control and flood management purposes should also be considered.

9.3.8 Management of dams

In most countries in SADC region, the operation of large dams is the responsibility of a government department or a nominated operating agency. The development and operation of these dams can have a profound impact on the people living in the vicinity or downstream of such infrastructure. Though these impacts are often negative, however, large dams can provide many positive spin-offs. They can support a multitude of resources, such as aquaculture and agriculture, which can then support small industries. The socio-economic aspects and opportunities relating to these dams need to be thoroughly investigated along with the maintenance of the water body in an acceptable condition.

The case study outlined in Box 9.11 is concerned with the people living adjacent to the Pongolo river floodplain, which is located on the eastern coast of northern South Africa and southern Mozambique. This case study attempts to provide an insight into the rapid process of change that has occurred in the lives of these people since the development of the Pongolapoort dam.

This case study demonstrates that community involvement and the management of systems to maintain the ecological integrity of a river on their own do not necessarily ensure sustainability of the water and related resources. The lack of holistic integrated planning and the absence of policies and strategies for natural resource use and development directed at meeting the needs of the community contributed to this failure. Furthermore, the lack of interest from the responsible government departments resulted in fundamental aspects of the management plan being developed and implemented without the necessary support structures.

Planners and managers should be aware that the basic requirement for sustainable water resources management is that all stakeholders should be involved in generating management or development plans, and that they should be made responsible for appropriate aspects of the plan and held accountable to the remaining stakeholders. The issue of responsibility and accountability needs to be defined and agreed upon front during the planning process, and this includes the appropriate government institutions as well as communities.

9.3.9 Community involvement in the management of rural water supply

The development and management approach towards rural water supply in Tanzania has changed over time, responding to the country's overall development objectives. In practical terms, development and management of rural water supply has been carried out by individuals, village communities, different ministries and organizations. After independence, the government assumed the responsibility of developing and managing rural water supply.

Rural communities, which earlier had contributed to the management of water supply, were no longer required to do so. Instead, the official policy was for the government to provide water for domestic purposes and livestock use (free of charge to rural inhabitants). Experience gained from implementing this policy revealed the necessity of reviewing the policy and now the country has come up with a revised rural water policy that puts emphasis on:

Community involvement in the management of the Pongolo floodplain **Box 9.11**

Much of the Pongolo river floodplain has no surface water and people settled where there were secure supplies of water, the highest concentrations of which occurred adjacent to the Pongolo river floodplain. The physical barriers of the Lebombo mountains, the sea and inhabitable swampy land tended to isolate these communities. The existence of *nagana* (sleeping sickness), other human and stock diseases, the aggressive pursuance of apartheid and poor infrastructure also contributed to effectively insulating them from external influence.

Isolation brought with it self-reliance and a dependency on local resources, the availability of which was largely regulated by natural processes. These people had the knowledge, intellect, tools and skills to utilise the resources available to them and to adjust their patterns of use to accommodate the consequences of variability of natural external forcing factors over which they had no control. Flooding was one of the dominant external forces in that it provided a productive environment for fish and other aquatic organisms, rejuvenated the soils and provided water. As the soils dried they were cultivated, the soil moisture sustaining crops to maturity.

After the floods, more than a hundred pans dot the floodplain, retaining water for different periods and providing a continuum of shallow water to be harvested. Resources were communally owned and economic equity prevailed within the context of a largely self-contained economy. The hostile nature of the environment and their limited technology placed constraints on the exploitation of natural resources. These resources therefore remained abundant relative to the people's ability to use them.

In 1974, a dam was built to control these floods and to provide water for irrigation, which changed the patterns of behaviour of the people. For the first time, natural forces which shaped society came under the control of human structures and instability ensued. The natural water-related risk-regime was altered considerably, and it was necessary to establish guidelines to manage releases from the dam. At the time of developing the dam, it was justified in social, economic and environmental terms to sustain the productivity of the floodplain through realising the economic potential of the floodplain: fishery and flood-dependent subsistence agriculture.

Eco-tourism was mooted as a new land use. It was envisaged that, in time, as irrigation based agriculture became a reality on land adjacent to the floodplain, cropping on the floodplain would decline, and as this became less intrusive, tourism would be favoured and a mixed economy would result.

Water committees were first elected in 1987 with the brief of making recommendations to the Department of Water Affairs and Forestry on water releases. The committees were successful in reconciling differences and reaching a consensus on recommendations for flood releases. Unfortunately, such consensuses occurred in the absence of policies and strategies for natural resource use and development directed at meeting the needs of the rapidly growing population.

The outcome of recommendations from these committees was a much more predictable flooding regime. The reduced risk of crop loss through unexpected flooding led to a marked increase in cultivation on the floodplain. Institutional controls over cultivation broke down and areas that were previously not cultivated were cleared and cultivated. River banks became unstable and channel switching resulted. The government Department of Agriculture made no attempt to support farmers cultivating the floodplain or to divert it by promoting small-scale irrigation of the floodplain. The government department responsible for conservation made no attempt to promote tourism or manage fishing activities. Instead it focused on maintenance of the diversity of aquatic fauna in the face of increasingly strident demands to manage releases to optimise cropping on the floodplain.

The social system was not sufficiently robust to survive the transition. Political institutions became unstable, decision-making became less transparent and the forces of cohesion weakened. Property ownership and use changed from communal to "private" and open access. Neither the nature nor the magnitude of the consequences of "opening up" the area were anticipated. If they were, they were largely ignored because of political ideologies or economic opportunism.

Breen, Dent and Mander 1998

enhancing sustainability of rural water supply through community-based management;
communities being legal owners of water schemes and decision-makers on all matters pertaining to water supply schemes and catchment protection;
involving private sector, and recognizing women as being among the principal actors in the provision of rural water supply services. The following two case studies will be used to gain an understanding of how communities can be involved effectively in managing water supply.

9.3.9.1 Ruaha Water Supply Company

Ruaha Water Supply Company is a scheme which serves Ruaha village, in Kilosa district, Morogoro region, Tanzania. The village has an estimated population of 9,000 people. The water scheme is owned and managed by the community as discussed in Box 9.12.

The result of all this elaborate organization is that:

- the water scheme is well operated and maintained with high reliability;
- all domestic water points get uninterrupted water supply;
- revenue collection is good with most water users paying fees voluntarily and in time;
- the financial position of the company is good and now there are plans to enlarge part of the transmission line;
- the company has been able to keep control of the scheme by taking legal action against defaulters including those vandalizing the infrastructure of the water supply system, and

individuals who were diverting water upstream of the intake for irrigation purposes.

Ruaha Water Supply Company — Box 9.12

The Ruaha water scheme which is a gravity water system was initiated by the water users in the village. Although the idea of the scheme was first mooted by the village people, yet the cost of construction was beyond the financial capacity of the village community.

Consequently the village people sought assistance from the government. As a result of their request, the Netherlands government funded the scheme through the Domestic Water Supply Programme which it was supporting in Morogoro region. To show their commitment to the water scheme, the village community contributed at least 6.5 percent of the total investment costs.

In order to ensure the continued operation of the water scheme, the village people formed what is known as Ruaha Water Supply Company Ltd. This is a limited liability company charged with the responsibility of managing the scheme through a board of directors.

Currently the Ruaha Water Supply Company Ltd. meets full operational and maintenance costs, and makes savings for future extension and rehabilitation. All water users are registered and are paying the monthly water fee. The fee levied is based on the tariff which the users agreed upon in advance. In setting the water tariff, the following points formed the basis of agreement. It was agreed by the water users of Ruaha that water service should be considered to be an economic or commercial service and not a purely social service. This means that the water revenue should, at a minimum, meet the operation and maintenance costs and a surplus for future replacement and expansion of the scheme. It was also insisted that the tariffs set should not lead to excessive profits beyond the needs of running the water company. This condition aimed at guaranteeing the users a regular water supply at affordable costs. Thus the company collected its revenue from the 33 water user groups, which were formed in the village and from some 225 private connections.

In constructing the water scheme the village had the following objectives in mind:

- to enable everyone living in the village to have easy access to adequate water;
- to reduce the average workload of women with regard to water collection;
- to ensure that
  - women are participating adequately in all decision-making processes regarding water supply,
  - user groups are operating and maintaining the water supply system without major support from outside, and
  - the scheme would continue to operate with internally generated resources.

Bwire 1998

9.3.9.2 Ismani Water Supply Scheme

Ismani Water Supply Scheme is a group scheme in Iringa district of Tanzania. It serves 22 villages with a total population of 34,000 people. The scheme was built with government and donor funding. After construction, the scheme was operated and managed by the district council with the district water engineer being responsible for operation and maintenance. With the adoption of the revised water policy, Ismani water supply scheme is now operated and managed by the communities through the users association known as Ismani Water Users Association. The objectives and management of the associations are discussed in Box 9.13

Community management of Ismani Water Supply Scheme — Box 9.13

Ismani Water Supply Scheme has the following features:

Its one intake is at Mgera stream with a transmission gravity mainline covering 144.45 km, a distribution network whose total distance is 150.9 km, 12 break pressure tanks, 29 storage tanks, 245 public domestic points and about 90 in house private connections, 13 cattle troughs and five cattle dips.

From 1984 to 1996 all villages served by the scheme formed Village Water Committees (VWC), which were charged with the responsibility of managing part of the scheme which falls within the village boundaries. In order to coordinate the activities of these VWCs, an Ismani group scheme was established and entrusted with the duties of carrying out operation and maintenance of the intake and the main transmission lines.

Scheme management under the group scheme committee and VWCs was not satisfactory. The committees were unable to raise enough funds to meet operations and maintenance costs. Formation of the Ismani Water Users Association was aimed at improving the management of the scheme.

With the formation of the association, the communities are now more involved in the management of the scheme than ever before. They carry full responsibility for operation and maintenance. They now decide on the management structure and tariffs, private connections and expansion/extension of the distribution systems. They also have powers to discipline defaulters.

The day-to-day running of the scheme is under the Management Committee of the Association which consists of eight members, four of whom are women.

Revenue is raised through user fees. Each water user who collects water at a public domestic point pays Tshs. 200 (US$ 0.25) per month while persons with private connections pay Tshs. 1000 (US$1.20) per month. It has proved difficult to collect revenue from users of public stand pipes compared to users with private connections. Revenue collection is hampered by lack of by-laws which can be used to take appropriate actions against users who fail to pay the water fees.

Gwimile 1998, Ismani Water Supply

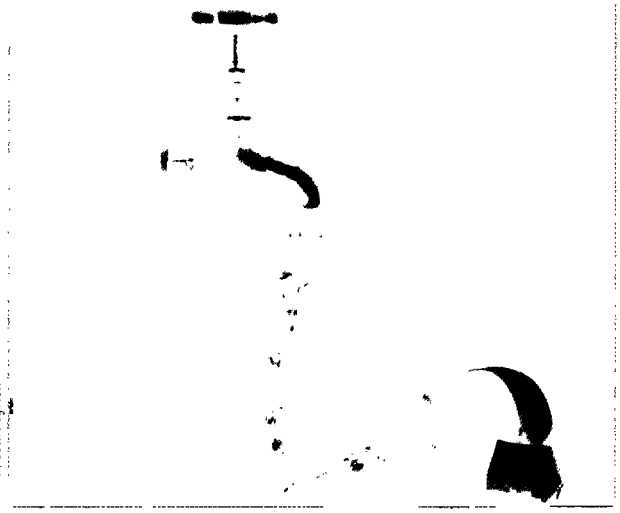
9.4 LESSONS LEARNED

There is much to be learned about community-based management from the above case studies, as will be discussed in this section.

9.4.1 Community involvement in ownership and management

In all the cases reviewed, there has been community involvement in the management of water resources. However, due to differences in physical endowment of water, cultural values and socio-political organizations of communities in the southern Africa region, the nature and degree of involvement has varied with respect to issues being addressed and from place to place and between communities. What is important to note, however, is that community involvement in all aspects of water resource management has been one of the pillars of successes observed in the region.

The question of ownership comes up in all the cases. It is however not clear as to what is owned. Is it water or the infrastructure? In many areas within the region, water is regarded as a common property to which every individual has the right of use, and therefore has the right of access. When it comes to infrastructure, it is not always clear as to who owns what. This is especially the case in water supply schemes which have been developed by the government and are being handed over to communities for operation and management. It is important that this issue of ownership is cleared if communities are going to manage the water supply systems.



DWAF, South Africa

What is owned? Is it water or the infrastructure?

9.4.2 Private sector participation

Water supply development and delivery in the SADC region has been dominated by the public sector. Only in a few cases has the private sector been involved. There are potential areas in which the private sector can be involved, however.

These include: professional services, manufacturing, construction, drilling, spare parts supply and distribution, transportation servicing and financing.

Involvement of the private sector in delivery of water supply services is to be encouraged because in a few places where it has been tried it has brought improvement in efficiency and effectiveness as well as enhancing sustainability of the services, at a cost.

Many SADC governments are now in favour of promoting private sector involvement in water supply. These governments can therefore create an enabling environment for active participation of the private sector by facilitating the following:

- revise or enact laws that will stimulate private sector involvement;
- facilitate increase in investments by giving investment guidance and credit facilities;
- provide other incentives to the private sector;
- strengthen capacity of the private sector.

9.4.3 Public sector regulation and facilitation

Since the current approach in water resources management is to involve stakeholders as much as possible, it is, therefore, appropriate that governments change their role from being implementers to being facilitators. The South African Department of Water Affairs and Forestry (DWAF 1996), for example, recommends that the role of central government in water resources management should be one of leadership.

Government departments should be facilitating and co-ordinating the development and transfer of skills, and assisting with the provision of technical services and financial support to communities and individuals.

Adding to this, the DWAF (1996) recognises that communities and individual landholders must be accepted as competent partners. Where these communities or individuals lack the necessary technical skills for full participation, the lead agencies must take responsibility for assisting with their development.

9.4.4 Financial requirements

It was noted earlier that community participation is a process through which stakeholders influence and share control over development and management initiatives, and the decisions as well as the resources. Generation and control of financial resources is one of the pillars for sustainable management of water resources. It is imperative that for sustainable management of water resources at community levels, concerned communities should be able to generate financial resources from within. If they have to get financial assistance from outside, if for example the initial costs are prohibitively high and beyond their means, they should still have a say on how those resources are used and should exercise control over them.

It has, unfortunately, been observed that many funding and donor agencies exacerbate the situation of communities not having control of funds by insisting on loans and donations being administered by governments and that funds are often only for project-specific purposes. The bureaucracy and inefficiency of this system often leads to the question of whether any of the funding actually reaches the target recipients.

The question that comes to mind with regard to financing is, what type of arrangements should be made to finance water resources management at community levels?

One of the Dublin principles is that water has an economic value and should be recognised as an economic good. To this end, water resources management should be financed by the users of the water and should not become reliant only on donor funding and subsidisation. If one considers other natural resources that rely on water for their survival, then the value of water to these resources, and any revenues that they generate, needs to be paid by those benefiting from utilisation of the resource.

9.4.5 Capacity building

This is perhaps the most important aspect that must be considered when planning and implementing water resources management initiatives at a community level. Any initiative should be responding to a need identified within the community. Furthermore, the community themselves should have the capacity to address the need in the most appropriate manner. On the other hand, it is acknowledged that there is much room for

DWAF, South Africa

Leadership is essential to the process of raising awareness and building capacity, shown here by President Thabo Mbeki of South Africa.

improving the capacity of many of the institutions charged with the responsibility of water resources management.

Capacity-building is a term which has different meanings to different people, and is often used synonymously with other terms including training, education, participation and institutional development. However, capacity-building is rather a process that contains elements of all these issues and is primarily concerned with how to develop personnel that would be able to take correct decisions and implement them. Water resources management, being an ongoing activity, is therefore more important than capacity-building that is promoted on a sustainable and long-term basis. It is imperative for governments to initiate and sustain capacity-building processes among the communities that are involved with water resources management.

9.4.6 Education

Allied to capacity-building, education is also a key to sustainable, community level, water resources management. The saying of "a problem identified is a problem half solved" holds true in this case. If communities become aware of the limitations in the water resources and of the impacts their activities have on the water resources, behaviour patterns and traditions may change to focus on conservation rather than just utilisation.

To achieve this, governments and their agencies will be required to rethink their methods of education and provide a future-based image of what is required. Although water resources management education should start in the schools, it should not be a matter of trying to create awareness through repetition of subject matter and increased

workloads. It should be a stimulating learning experience which pupils can identify with and pass on to others.

9.4.7 Choice of technology

The different case studies discussed in this chapter have revealed a variety of successful technologies that have been used by different communities in managing their water resources. One of the key requirements for successful water management is to ensure that the target groups have a clear understanding of the technologies which are introduced. It is, therefore, important to first evaluate the technologies and indigeneous practices being used by the communities in managing their water resources before new ones are introduced. Preservation of successful existing technologies and practices and building upon them has an added advantage of providing effective alternatives to foreign or imported technologies. Conducting research into indigenous technologies will contribute significantly to the sustainability of community managed water activities.

9.4.8 Institutional requirements

For water resources management to be sustainable at a community level, an enabling environment will have to be created. To do so, appropriate institutional support structures will be required for both recipient communities and the governments or their agencies.

It is therefore recommended that the principle of subsidiarity is applied and that the responsibility and accountability for water resources management is delegated to the lowest appropriate level. To facilitate community-level water resources management, the following institutional structures should be considered:

Local level water resources management institutions need to be established, capacitated and empowered to manage the day-to-day aspects of water resources management. These institutions can be either formal local government structures such as water user associations or informal stakeholder forums such as catchment management forums or water committees. They should be fully representative of their constituencies. A more formal body is preferable since such a co-operative association will constitute a corporate body , and thus be able to manage and possibly raise funds. The roles of these institutions should be to identify specific water resources problems and to plan appropriate solutions within the context of a catchment-specific framework with a broad national water resources strategy. They should be reasonably autonomous, operate a budget and be accountable to the next level of the management institution.

Water resources management institutions responsible for designated catchment areas should be put in place at the level of regional governments. These can be government agencies or informal management committees with delegated powers and responsibilities. They should also have representation from the local level institutions on their management boards or committees. The primary purpose of these institutions will be to consider water resources management at a broader catchment level and to develop a catchment-specific strategy in this regard. They should also vet the plans and actions of the local level institutions to ensure compliance with catchment strategies, prioritise initiatives and co-ordinate activities. Furthermore, they should provide both financial and technical support to the local level institutions whenever required. They should be almost totally autonomous but should still be accountable to a government ministry. Another aspect to take note of is that catchment management entails planning based on ongoing studies and investigations into both the surface and the groundwater resources within the wider catchment area.

9.4.9 Gender awareness

The pivotal role of women as carriers and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources.

Deliberate efforts are now being made to raise awareness and train and empower women to participate at all levels in water management activities. The role of women is now being reflected in the water policies formulated in different countries within the SADC region.

9.4.10 Legal requirements

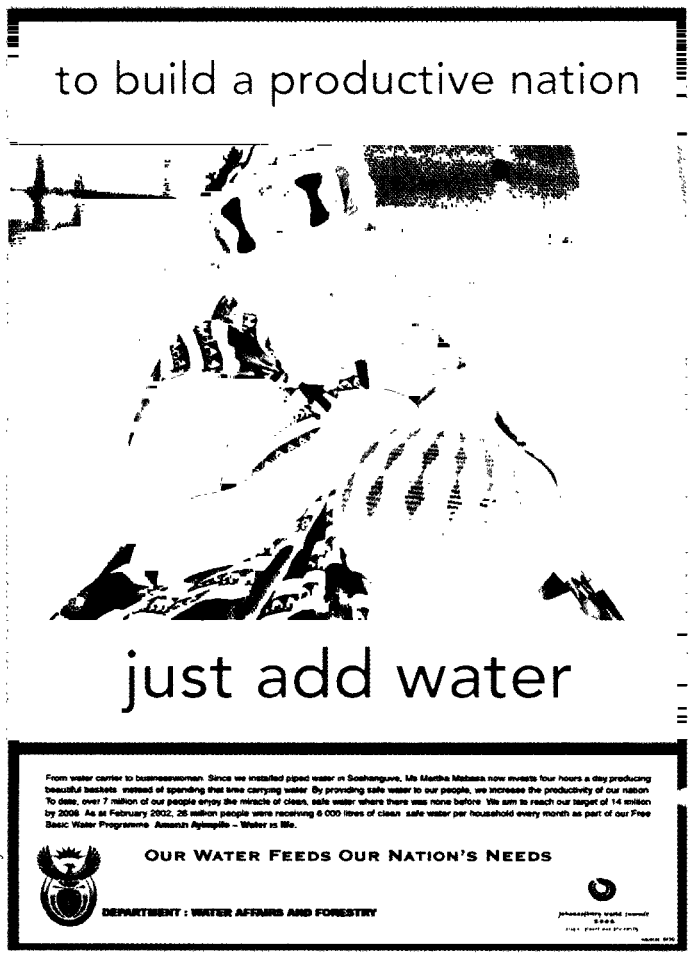
It was also evident that appropriate legislation is a prerequisite for effective management, development and equitable utilization of water resources. The recent review of water laws in both South Africa and Zimbabwe shows the importance of having appropriate legislation which reflects the national aspirations.

Development and management of water resources in the SADC countries has, for a long time, been governed by customary laws. As shown in many of the case studies, water allocation has been done by communities using local customary laws. In some places these customary laws are still being applied alongside the current institutionalised laws. It is therefore necessary to institutionalise these customary laws because they are effective and tend to be understood and accepted by the concerned communities.

9.5 CONCLUSION AND RECOMMENDATIONS

Due to the important role that communities have to play in the management of water resources, it is necessary to ensure that community involvement gets the required support by:

- facilitating the development of appropriate structures and institutions at a national, regional and local level for water resources management;
- developing mechanisms by which funding is provided as quickly as possible to the appropriate water resources management institutions, which should be accountable for the expenditure of these funds;
- ensuring that gender is taken into account in all aspects of water resources management;
- developing and implementing mechanisms to facilitate stakeholder involvement in all aspects of water resources management, from national strategies to local development plans;
- encouraging decision-making in general at the lowest possible levels to promote empowerment of the community;
- developing local education and vocational training programmes within a sound framework of national information and awareness campaigns; and
- building capacity within communities and providing them with resources to undertake their own basic water resources management functions.



DWAF, South Africa

From water carrier to businesswoman. Since we installed piped water in Soshanguve, Ms Martha Mabasa now invests four hours a day producing beautiful baskets, instead of spending that time carrying water. By providing safe water to our people, we increase the productivity of our nation. To date, over 7 million of our people enjoy the miracle of clean, safe water where there was none before. We aim to reach our target of 14 million by 2008. As at February 2002, 26 million people were receiving 6,000 litres of clean, safe water per household every month as part of our Free Basic Water Programme. *Amanzi Ayimpilo* – Water is life.

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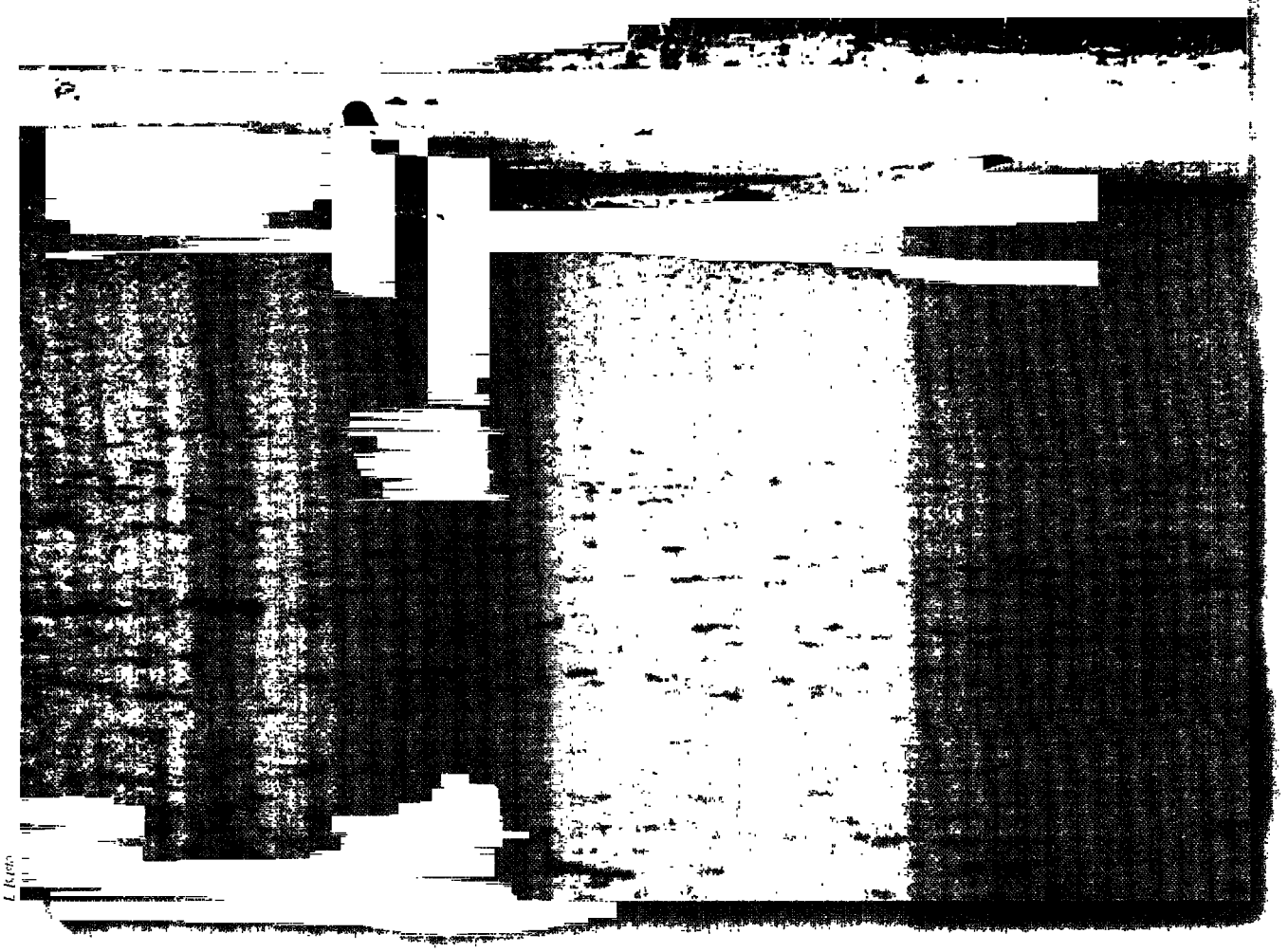
POLICY, LEGISLATIVE AND INSTITUTIONAL FRAMEWORK

10

Paul Maro and Lenka Thamae



CONTENTS

POLICY, LEGISLATIVE AND INSTITUTIONAL FRAMEWORK

10.1 INTRODUCTION

Earlier chapters have underscored the fact that water is the most strategic resource for sustaining all life forms in southern Africa. Its effective management is an essential pre-condition for alleviating poverty and improving human health, food security, environmental sustainability, overall economic development and regional security.

Water is a scarce resource that is vulnerable to climate variability and under threat from global factors such as climate change, regional factors such as the complex considerations for managing transboundary waters, and national and local factors related to increasing population demands, pollution and environmental degradation. Chapters 2 to 4 described the importance of water and aquatic ecosystems, including the valuation of ecosystem functions and services. Chapters 5 to 8 have elaborated various threats to the sustainability of water resources in the region. These include over-allocation of water for consumptive uses without sufficient provision of environmental flow requirements for protection of aquatic ecosystems, as well as water pollution, degradation of watersheds and wetlands, threats to freshwater biodiversity, and proliferation of nuisance species and aquatic weeds. (Box 10.1) Because of these threats and other pressures on the water resources, primarily due to increasing demands and growing competition for water, Southern African Development Community (SADC) member states have begun to adopt national policies and institutional reforms that foster Integrated Water Resources Management (IWRM). These approaches are based on the principles of economic efficiency, environmental sustainability, and social equity to aid the water resources planning and management decision-making.

Key issues relating to environmentally sustainable water resources management — Box 10.1

The key environmental issues relating to integrated water resources management that can protect the fragile ecological base can be identified through an assessment of several factors: the discussion in preceding chapters (especially chapters 4, 5, 6, 7 and 8); the output of the working groups in the Africa Water Resources Management Policy Conference in Nairobi in May 1999; analysis of the major issues related to integrated water resources development and management by the SADC Water Sector in the Regional Strategic Action Plan; and the review of national environmental and water resources management policies and laws. These key issues can be summarized as follows:

- Over-allocation of flows for consumptive and non-consumptive uses and inadequate flows for environmental purposes.
- Watershed degradation, mainly from overgrazing, deforestation, cultivation, fuelwood harvesting, and bushfires which result in soil erosion, runoff and siltation, and poor water quality.
- Pollution, from sewage effluent, sedimentation and economic activities including agricultural chemicals, industrial effluents, and solid waste dumps and storm water, leading to, among other things, water-borne diseases, salinization, algal blooms and proliferation of macrophytes. Water weeds, particularly the water hyacinth, and pollution of groundwater, are two additional issues that merit special attention in water resources management.
- Wetlands degradation and threats to freshwater biodiversity.
- User community participation, consultations and empowerment (legal and through information sharing) in water resources management needs to be addressed, and in this regard emphasis should include the involvement of women.
- Policy, legislative and institutional frameworks are essential management tools in addressing the key environmental issues in water resources management in the SADC region, and need to be strengthened.
- Human resources capacity development (scientific and technical), ecological data collection, analysis and dissemination, and allocation of adequate financial resources are issues which if properly addressed, support sustainable management of water resources.

Sound water policies and appropriate legislative and institutional frameworks are important pre-requisites for sustainable management of water resources. The policy framework must be based on the principles of integrated, sustainable, water resources management. Legislation should be consistent with the spirit and principles contained in the policy. An appropriate, functional institutional framework is required to serve as a vehicle for implementation at national and regional levels. This may require the development of new institutions, or re-structuring or building the capacity of existing institutions, as well as development of linkages for formal collaboration between institutions in different sectors.

10.1.1 Complimentary policy frameworks

Sustainable water resources management requires a well-defined environmental policy framework which is harmonized with the water policy framework and that of other relevant sectors such as agriculture, energy, mining, industry, health, and lands. All SADC states have since the early 1990s adopted environmental policy and institutional instruments and frameworks, including National Conservation Strategies (NCSs), National Environmental Action Plans (NEAPs), national environmental policies, and environmental management strategies, in addition to a plethora of sectoral policies, strategies and action plans.

These efforts have in most cases also been accompanied by the review and enactment of legislation as well as the establishment of institutional frameworks for planning, implementing, monitoring and enforcing the policies. However, the regulatory policy and institutional frameworks have not been particularly effective for addressing the threats to the sustainability of water resources because they suffer from various weaknesses, constraints and shortcomings listed in Box 10.2. These weaknesses and constraints have to be corrected by strengthening the policy, legislative and institutional frameworks in order to integrate environmental issues and enforce environmental stewardship in the management of water resources.

10.1.2 Emerging policy shifts

What is encouraging, however, is that the analysis of recent environmental and water resources policies and legislative frameworks reveals that most SADC states (for example South Africa, Zimbabwe, Botswana and Tanzania) are adopting IWRM approaches that not only emphasize the conservation of the water resource base (including aquatic ecosystems), but also increasingly use economic instruments and set up participatory institutions for water resources management. There is an emerging realization that the environment represents an important use of water and that aquatic ecosystems form a fundamental part of the water resource base. This emerging shift is most significant, and the institutionalization of the policy shift more broadly constitutes the central conceptual theme of this chapter.

A wide range of national and regional environmental management policy and institutional reforms have been initiated and are underway. At the national level, new water policies, laws, strategies and master plans are being prepared and new institutional arrangements (environmental management agencies, river basin and catchment agencies) are being established. At the international level, many agreements are in place for jointly developing and managing specific shared water resources. At the regional level,

Major weakness, constraints and shortcomings of existing policy and institutional frameworks — **Box 10.2**

There are some major constraints in existing water and environmental policy and institutional frameworks, and these include the following:

- Water is utilized by many sectors (such as urban, energy, industry, and agriculture), and water policies and legislation remain sectorally compartmentalized, making them difficult to enforce;
- Weak or poor implementation and enforcement of existing policies and legislation is due mainly to lack of political will, but also due to lack of expertise, and adequate funding, and lack of sectoral and institutional coordination;
- Stakeholders and beneficiaries are not often involved in policy and legislative reforms due to the lack of effective consultations and participation in planning and management decision-making;
- Ecological data and knowledge is lacking to clarify the linkages between environment and water resources;
- Policy and legislative frameworks are not well harmonized with the implementation of regional and international environmental agreements.

the SADC Water Sector has prepared a *Regional Strategic Action Plan (RSAP) for Integrated Water Resources Development and Management in the SADC Countries 1999 – 2004*, which is being used as a basis for developing particular projects and programmes. (see chapter 1)

10.1.3 Ineffective integration of the environment in water policy reforms

A review of ongoing efforts and specific actions on the ground indicates that, in spite of the important and innovative reforms at both national and regional levels, the weakest area of water policy reform is the integration of environmental sustainability criteria into the planning and management of water resources (Box 10.3).

Poorly defined concept of environmental sustainability in the water sector — **Box 10.3**

The concept of environmental sustainability is neither defined clearly nor integrated properly into water policies. It is inadequately operationalized in water projects, and this is weakening the decision-making process and exacerbating conflicts in water uses.

Sustainable water resources management entails two related components which are in a dynamic tension and which must be brought into balance:

- **utilization** (or development) of the water resources for various human needs, and
- **protection** (or management) of the water resources so that they can continue to be utilized for both the present and future generations.

Chapter 1

This chapter reviews the environmental dimensions of water resources management in existing national environmental and water policies in order to assess the adequacy of existing policy instruments and institutional frameworks for effectively integrating environmental quality objectives into water resources planning and management.

Preceding chapters in this report, particularly chapters 5, 6, 7 and 8, have raised various issues impacting on water resources management and have made recommendations on corrective and remedial measures which can succeed only when supported by clearly defined and enforced policy, legislative and institutional frameworks and instruments. Recommendations derived from these reviews emphasize the importance of environmental stewardship in national water policy that recognizes protection of aquatic ecosystems as being among the primary values of water, in order to protect and safeguard the fragile water resource base.

This chapter is organized into six sections, beginning with this Introduction, followed by an analysis and review of national environmental and water policies in section 10.2 to identify their weaknesses and recommend strategies for strengthening them.

An evaluation of environmental controls follows, in section 10.3, including,

water allocation and use controls,
water quality management controls,
land use,
conservation of freshwater ecosystems and biodiversity,
protection against alien species,
water conservation tools, and
environmental impact assessment.

Section 10.4 presents an evaluation of national institutions such as environmental agencies, water resources agencies and community-based programmes. Section 10.5 evaluates the role of regional institutions especially in the management of shared watercourses; and the last section provides recommendations for the key elements of an environmentally sound, water resources management policy.

10.2 EVALUATION OF POLICY AND LEGISLATION FRAMEWORKS

10.2.1 Development of national environmental policy frameworks

Historically, before colonialism was imposed in most of sub-Saharan Africa, populations were smaller and natural resources such as water were managed by communities in a relatively efficient and sustainable manner to meet their subsistence needs. Resource management was decentralized at the local level and resource use conflicts were resolved through well-defined community fora. Community-based and culturally derived sanctions provided significant deterrents against misuse and abuse of water resources.

The colonial period introduced control and planning by centralized government structures, while the post-independence governments generally continued to adopt inappropriate laws and regulations based on colonial government doctrines that disbanded the decentralized, community-based, management of water resources. More recently, the trend has again shifted towards decentral-

ized, community-based actions at the local level and at the river basin level. Another colonial legacy in the region is national boundaries, which were arbitrarily drawn on maps in European capitals, and have left an environment that could lead to conflicts over water use due to the presence of many transboundary rivers and water sources.

Following the Stockholm Conference on the Human Environment in 1972 and the establishment of the African Ministerial Conference on the Environment and Natural Resources (AMCEN) in 1985, most countries in southern Africa established new environmental policies, agencies and laws, and started making serious efforts to develop home-grown environmental policies that meet the needs of their people while pursuing economic development. Zambia (1985), Zimbabwe (1987), and Botswana (1990) prepared National Conservation Strategies (NCS) modelled on the IUCN World Conservation Strategy, to guide national environmental policies; while Lesotho (1989), Malawi (1994), Zambia (1994), Tanzania (1996), Swaziland (1997), South Africa (1997), and Mozambique developed National Environmental Action Plans (NEAP), some of which were associated with the economic Structural Adjustment Programmes (SAPs) of the World Bank.

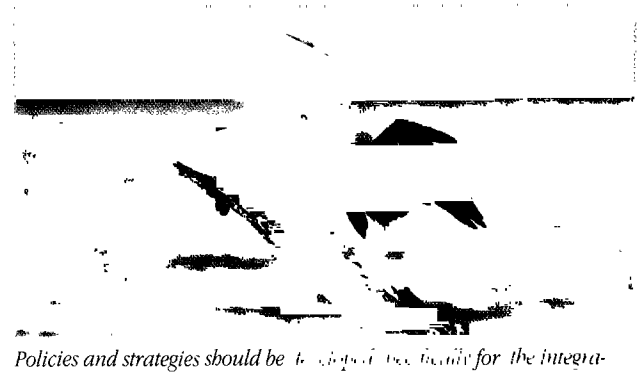
The NCS and NEAP generally did not have action programmes institutional mechanisms for the coordination and implementation of activities. (Chakela 1999) In some countries such as Zimbabwe, the NCS was not even adopted by Parliament and Cabinet, and had neither strategies nor budgets for its work. However, these framework policies initiated the process of incorporating environmental considerations into economic development, facilitated the coordination of environmental endeavours, and provided guiding principles for national environmental policies.

All SADC member states prepared and presented national reports on environment and development to the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992, a process which also highlighted the need for review of environmental laws, policy frameworks and institutions.

National action plans to implement UNCED's Agenda 21 were prepared by each country and this has contributed to the further development of environmental action plans and policies. Lesotho (1996), Tanzania (1997), Swaziland (1998) and Mozambique have formulated national environmental policies, while Namibia and Zimbabwe are preparing environmental management laws. In South Africa, the White Paper on Environmental Policy for South Africa, published in Notice 749 of 1998, is a culmination of extensive stakeholder consultation launched in 1995. The vision of the policy is that of "a society in harmony with its environment" and this vision is being realized through, among other things, the National Environmental Management Act No.107 of 1998 which sets the platform for the participation of communities, civil society and government in active environmental management while recognizing and complying with international obligations and agreements.

A survey conducted by the SADC Environment and Land Management Sector (ELMS) in 1994 on environmental policies and strategies in SADC countries revealed that only five countries had policies/strategies on water resources management, while three countries were then drafting such policies, and the rest had no policies/strategies on water resources management. (SADC 1996) However, the same survey showed that the majority of the SADC countries, except four that were then drafting their environmental policies, had adopted NCS and/or NEAPs which are comprehensive and aim at incorporating regulation and management principles into the fabric of national resources planning and management. Although NCSs and NEAPs have generally included water resources management issues, they have not stipulated approaches for integrating and operationalizing ecological issues into water resources management. This integration should be addressed by policies and strategies developed specifically for water resources management.

At the regional level, SADC member states are committed to implementing the SADC Treaty which has among its objectives the achievement of "sustainable utili-



Policies and strategies should be [illegible] for the integration of ecological issues into water resources management.

sation of natural resources and the effective protection of the environment." (Article 5g)

The SADC ELMS developed, with member states, the *SADC Policy and Strategy for Environment and Sustainable Development: Toward Equity-Led Growth and Sustainable Development in Southern Africa*, which was approved and adopted by SADC Council of Ministers in 1996. The three goals for sustainable development in the SADC region are:

- to accelerate economic growth with greater equity and self-reliance;
- to improve the health and living conditions of the poor majority; and
- to ensure equitable and sustainable use of the environment and natural resources for the benefit of present and future generations.

These three goals constitute one agenda for action. None of these goals are achievable without the other two. Most importantly, economic and environmental sustainability are not achievable without [illegible] improvements in the lives and livelihoods of the poor majority. (SADC 1996) The proposed key environmental policy areas are better addressed through regional programmes and projects as they include cross-cutting and trans-boundary issues such as institution strengthening and capacity building, health, environmental information and education, and water resources management.

At the global level, most SADC member states are parties to various Multilateral Environmental Agreements (MEAs) such as:

- the UN Convention to Combat Desertification (UNCCD);
- the Convention on Biological Diversity (CBD);
- the UN Framework Convention on Climate Change (UNFCCC);
- the Basel and Bamako Conventions;
- Ramsar; and CITES.

The most famous means of implementing MEAs, and environmental policy in general, has been the enactment of legislation and passing of decrees (UNEP 1999), and the elaboration and implementation of national action programmes, which have to be harmonised into existing policies and be integrated into the socio-economic development planning process. MEAs, including sub-regional ones, have provided another opportunity to SADC countries to review their environmental policies and legislative frameworks for sustainable development.

10.2.2 Development of national water policy frameworks

A survey conducted by the SADC Water Sector in 1998 on major issues related to integrated water resources development and management in SADC countries revealed that:

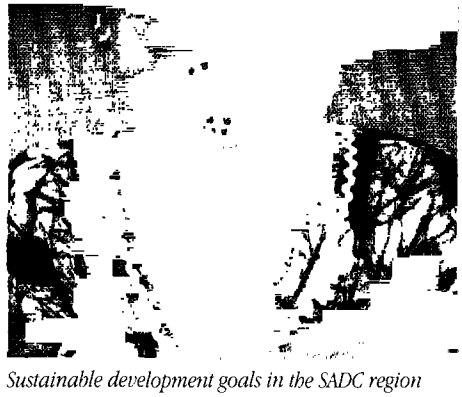
- only five countries had a comprehensive national water law;
- only four countries had overall national water policy or strategies; and
- only four countries had adequate national water institutions. (SADC 1998)

The majority of the SADC countries did not have or were in the process of developing national water laws, policies/strategies and institutions. The survey also revealed that the majority of the SADC countries had inadequate policy frameworks for water resources conservation and protection measures.

Action programmes to implement regional programmes and activities also influence national environmental policy development. The RSAP and the Protocol on Shared Watercourses in the SADC region are two such programmes. The consultative process that culminated in the RSAP identified 31 priority projects to be implemented in the period 1999-2004 that will establish the required legal and institutional framework for the development of infrastructure projects.

However, the capacity available in the region for guiding the process is a significant challenge, both at the regional level and at a national level.

The protocol seeks to establish a premise for sustainable management and development of water resources in shared rivers in the region. Its ratification and implementation will introduce substantial challenges in terms of transparency in decision-making on shared watercourses, stakeholder participation and overall institutional



D Martin, APG

Sustainable development goals in the SADC region include the equitable use of natural [illegible] benefit of present and [illegible]

arrangements. Box 10.4 reflects the main provisions of the protocol related to environmental management and institutional issues.

Environmental and institutional aspects of the Protocol on Shared Watercourses in the SADC region **Box 10.4**

The protocol is a massive leap forward in terms of strategic regional environment and water resources management. The provisions of the protocol and the institutional framework pose significant challenges in terms of closer cooperation and coordination of shared watercourses, and will need to be underpinned by radical reforms and changes in national water institutions.

The protocol aims to foster cooperation for judicious, sustainable and coordinated management, protection and utilization of shared watercourses and to advance the SADC agenda for regional integration and poverty alleviation, by promoting, among other things, the coordinated and integrated, environmentally sound, development and management of shared watercourses.

As part of its general principles the protocol commits State parties to maintaining a balance between resource development for a higher standard of living while conserving and enhancing the environment to promote sustainable development. State parties shall jointly or individually protect and preserve ecosystems; prevent, reduce and control pollution; prevent the introduction of alien aquatic weeds; and protect and preserve the aquatic environment.

Apart from the SADC Water Sector institutions, the protocol proposes the formation of shared watercourse institutions such as commissions, water authorities or boards to ensure implementation of the provisions of the protocol.

Typically, in water management throughout the region, there has been an over-reliance on the traditional regulatory "command-and-control" instruments through direct regulation along with monitoring and enforcement systems, and less reliance on economic instruments which employ market values such as price variations to change the behaviour of the public and resource users. More recently, participatory instruments and approaches that vest ownership and management responsibilities in the resource users such as local communities in river catchment areas, are being emphasized in conjunction with regulatory and economic instruments.

10.2.3 Water components of national environmental action plans

Environmental policy frameworks are usually national and comprehensive, incorporating regulations and management principles into the fabric of natural resources planning and development. Policy and institutional frameworks deal with all sectors of natural resources management, often with distinct sections on water, agriculture, forestry, mining and manufacturing, health, and others. A few examples illustrate the objectives and critical environmental issues addressed in NEAPs, and the programmes which have been developed to guide the implementation of environmental action plans.

The Swaziland Environmental Action Plan (1997) which is typical of other NEAPs, had the objectives to:

- provide an overview of the environment in Swaziland, identify and prioritise national environmental issues and problems;
- suggest solutions to priority problems in the form of practical activities and programmes, and required institutional and legal reforms;
- establish a clear indication of government's priority areas with respect to the environment so as to guide and give proper orientation to donor intervention;
- establish a framework which provides coherent direction for future planning and monitoring; and
- provide a framework for continuous development and environmental policy dialogue within the country and with donor partners.

There has been progressive evolution in all the SADC member states, from NCSs to NEAPs and national environment policies, and to national environment management legislation to provide the legal basis and give effect to the implementation of environmental policies and action plans, often as part of the efforts to implement Agenda 21. Tanzania, for example, identified six major problems for urgent national attention to be addressed in the NEAP:

- land degradation;
- provision of good quality water for both urban and rural inhabitants;
- pollution;
- loss of wildlife habitats;
- deterioration of marine and freshwater systems; and
- deforestation.

In most countries, the problem areas are identified in NEAPs, then translated into action programmes under the different sectoral policies. In order to have proper coordination and harmonisation of these sectoral programmes, the countries have developed and adopted national environmental management policies. National environment policies cover all sectors of natural resources and development, including proposals for institutional and legislative mechanisms as well as stakeholder and

local community participation in environment and natural resources management.

The national environment policy of Lesotho (Box 10.5) includes a section on water resources management whose objective is to "develop integrated and co-ordinated effective and efficient approaches to conservation and use of water resources, and promote its conservation and availability in sufficient quantity and quality on a sustainable basis." (Lesotho National Environment Secretariat 1998)

Implementation of such water management strategies will be based on several guiding principles including:

The involvement of stakeholders contributes to the efficiency, sustainability and success of water programmes and projects as stakeholders often have more detailed knowledge of the local areas.

All people should have access to potable water in order to reduce the incidence of water-borne diseases and the time spent by women and children in water collection.

The training of people in water conservation and pollution control practices and techniques can contribute to judicious management of water resources.

The Lesotho National Environmental Policy [illegible] an emerging trend of including specific water components in environmental policy frameworks, thus promising more integrated and holistic approaches where the management of aquatic ecosystems as the resource base is emphasised.

National environmental policy of Lesotho: Water resources management strategies Box 10.5

Under this section on water resources management, the national environmental policy for Lesotho proposes the following strategies:

- Promote and enhance protection, conservation and sustainable utilisation and management of water resources, based on community needs and priorities.
- Review and amend, as appropriate, legislation pertaining to water rights taking into account environmental and sectoral policies and legislation.
- Promote the implementation of the Water Master Plan through investment programmes, public information.
- Facilitate campaigns, government and community partnership, water harvesting techniques and minimising wastage.
- Establish and promote an appropriate water pricing system, which would discourage misuse of water.
- Establish flood-prone areas management programmes to prevent and control settlement and cultivation in such areas for health and safety reasons.
- Conduct cross-sectoral water resources use and needs assessment, involving agriculture, forestry and industrial sectors.
- Support risk preparedness programmes to combat drought and floods.
- Promote applied research on conservation of water catchment and shared water resources in collaboration with neighbouring countries in the SADC region.
- Develop and strengthen capacities of relevant agencies, including WASA and the Department of Water Affairs, for sustainable use and re-use of water, quality and quantity monitoring and management.
- Identify and promote technologies for the protection of surface and groundwater resources from pollution sources.
- Develop standards for water quality and effluent treatment and discharge by using a monitoring system to control environmental pollution.

Lesotho National Environment Secretariat 1998

10.2.4 Environmental components of water policy

Water policies have historically treated water as a basic "social" good and focused on the promotion of water supply to different sectors of the economy. In other cases, such as Zimbabwe, Namibia, and South Africa, historically skewed water rights and allocation arrangements (predominantly along racial lines) have created enormous challenges relating to access and control over precious water resources and equity considerations. The principles embraced in water policies throughout the region have given priority to the supply of water to communities, agriculture, and industry, including mining and hydroelectric power generation.

The environmental components including the conservation of freshwater ecosystems and freshwater biodiversity, demand management, rigorous environmental assessment of the impact of development projects and related administrative and institutional frameworks have been inadequately addressed in the policies. Environmental issues have been addressed in a reactive manner as part of project safeguards, but not as integrated elements of water resources planning and development, and their enforcement has generally been very weak.

More recently, however, there has been a marked shift; water policies and legislative measures developed in the 1990s in the SADC countries are now emphasizing environmental management principles and encouraging increased stakeholder participation at community levels to promote sustainability.

The Zambia Water Policy ([illegible]), for example, promotes the management of water quality for the use of the resource on a sustainable basis and for the preservation of the natural environment. (Country Situation Report 1997)

The Malawi Water Policy (1994) has as one of its objectives the preservation and enhancement of aquatic and riparian environments. (Country Situation Report 1997)

In South Africa, the Water Policy embodies the principles of the constitution as far as environment is concerned, in particular the people's right to "an environment that is not harmful to their health or wellbeing" and "the right to have the environment protected for the benefit of present and future generations".

These statements make it a duty of government to establish instruments that prevent water pollution and ensure availability of sufficient water for ecological needs of water resources, as well as promoting water conservation and sustainable development. These policy measures reflect a renewed commitment to addressing environmental issues particularly of water development and management projects.

Zimbabwe has developed, through a highly consultative process, new water resources legislation and a new National Water Resources Management Strategy, both of which aim at achieving more equitable access to water by the majority of the population; provide for instream environmental needs; and apply economic incentives to efficient water use. ([illegible] 1999)

The South Africa National Water Act (1998) also developed in a highly consultative process, emphasises community participation and consultation, transparency and equity. (Stein 1999) The Act specifies the "reserve" as the only one right to water in law. The Reserve consists of the basic human needs reserve and the ecological reserve. (Box 10.6)

Similar, but less radical, fundamental shifts are also contained in the Tanzania National Water Resources Management Policy (1999) and in the policies of other African countries such as Namibia and Kenya.

The reserve in South African water law — **Box 10.6**

Part 3 of the South Africa National Water Act (1998):

"deals with the Reserve, which consists of two parts – the basic human needs reserve and the ecological reserve. The basic human needs reserve provides for the essential needs of individuals served by the water resource in question and includes water for drinking, for food preparation and for personal hygiene. The ecological reserve is defined as the water quantity and quality required to protect the structure and function of aquatic ecosystems in order to secure ecologically sustainable development and use of water resources.

The Reserve refers to both the quantity and quality of the water in the resource, and will vary depending on the class of the resource. The Minister is required to determine the Reserve for all or part of any significant water resource. If a resource has not yet been classified, a preliminary determination of the Reserve may be made and later superseded by a new one. Once the Reserve is determined for a water resource, it is binding in the same way as the class and the resource quality objectives."

South Africa National Water Act 1998

In most SADC countries, however, the mandate for monitoring the effective application of the environmental requirements lies with the Department/Ministry of Environment or with Environmental Councils. This calls for close coordination between Environmental Departments and Water Departments to realize the ideals of environmentally sustainable water resources management. The South African case provides a good model for future review and further development of affective management of water resources, and Box 10.7 highlights some of the main issues addressed by the new legislation.

A key challenge is that while some of the water institutions, for example, the Ministry of Water and Livestock Development in Tanzania, are already incorporating the determination of environmental flow requirements (EFR) into water policy, the sister environmental agencies such as the National Environment Management Council and the Division of Environment are ill-equipped to implement and operationalize such complex provisions of the water policy. Capacities to address such provisions are only now being developed.

South Africa - new laws make an impact Box 10.7

New policy and legislation with regard to water have been implemented in South Africa, including:

- the White Papers on community water supply and sanitation;
- the National Water Act;
- the Water Services Act; and
- the National Water Supply Regulations.

In addition, the national water conservation strategy has been drafted. The Working for Water programme, which was launched in 1995, has also become a national government flagship programme. The aim of Working for Water is to clear catchments of invasive alien vegetation in order to increase runoff to surface water bodies.

The response to the new legislation has been stormy, which is not surprising, taking into consideration all the ramifications of the legislation, such as pollution control and the proposed charges on water, which was previously regarded as a private commodity.

Industry, often a major cause of pollution, will be facing more stringent pollution control methods. Stream-flow reduction activities will also have to pay for water used that could have serviced people and livestock further downstream. Over and above forestry, which has already been declared a streamflow reduction activity, other activities could be added to the list, such as recreational dams, fishing and farm dams.

"The legislation calls for a tightening up all round and water flow in rivers will now be strictly monitored. The command and control method used to prescribe the pollution standards has been fairly successful, but the department will now look at the water flowing in a river and determine the actual state of the river versus what is acceptable," said Tami Sokutu, deputy Director-General, Water Policy and Resources.

"We will have to categorize major rivers from the cleanest to the most polluted and determine water resource quality objectives for each one. We will then look at who uses the water and what the impact of that water use is. The department will put in place the most effective resource-directed measures, borrowing from the best practices in the world, for example Europe, the US and from the rest of Africa.

"For example, if there are 10 polluters in an area, they will have to ensure among them that they do not exceed the resource quality objectives. We are concerned with the quality of water flowing downstream from these activities and its probable impact on people, animals and the environment.

"A pricing structure is also regulatory, on any water activity the users pay to use the water and then again to discharge waste into water resources.

"To monitor this, we will be establishing catchment management agencies, established by an Act as parastatals and they will have authority to issue licenses for water use, water discharge and will be responsible for the quality of the water in the area.

"Industries have to acknowledge which pollutants they are responsible for, and then take steps to rehabilitate that water. The historical polluters are a big problem - we have old plants and systems in many of our large industries and remediation of pollution originating from these plants is very expensive. But we are pleased to report that industry is willing to work with the department in building modern plants. Where practical they have also come up with solutions to old problems. Some of these are remarkable in the recovery of water previously thought to be beyond reclamation, such as mine water.

"Agriculture has not escaped the new water legislation either. Historically, agriculture has not had to pay for irrigation from boreholes and/or rivers and dams. This is now to be redressed, and water allocations are going to be regulated by the state. Permanent water rights are to be abolished and replaced with temporary allocations for a period not exceeding 40 years, with a possibility of a rolling license.

"Water can no longer be privately owned. It is your borehole, but not your water. However, this does not mean that the state can just walk in and demand water. The water needs of each area will be reviewed first and then steps taken to resolve problems," said Sokutu.

"Catchment areas will have their water user associations to look after their own interests. These have been transformed from the old irrigation boards by broadening the scope of interest to that of all water users. Farming will be encouraged to look at high yield/high value products and subsidies need to be reviewed and time limits imposed.

"The department's vision of 'some for all, forever' and the subsequent legislation has been regarded by many other water scarce countries as an excellent framework through which to ensure that everyone in the country has access to this most precious basic requirement."

Sunday Times, 29 April 1999

10.3 EVALUATION OF REGULATORY CONTROLS FOR PROTECTION OF WATER RESOURCES

Of the three environmental policy instruments – regulatory command-and control instruments, economic instruments, and participatory frameworks – the most historically used and common in SADC states was the command-and-control group of instruments.

Command-and-control-based regulations include direct regulation, monitoring and enforcement systems. This approach employs measurements or standards, such as:

emission, effluent and product standards;
public-health codes; and
land-use regulations designed to manage and protect environmentally sensitive areas and cultural heritage.

Economic instruments employ market values, rely on market developments and price variations to change the behaviour of resource users, including the private sector and those who degrade resources. Economic instruments are described in more detail in chapter 4 of this report, but it may be stated here that these include:

user charges;
pollution charges;
market creation or emission trading charges;
subsidies in the form of tax incentives; and
soft credits.

The strength of the regulatory command-and-control approach is that it affords a reasonable degree of predictability of the results if properly implemented and enforced. But often enforcement is constrained by financial, administrative (coordination) and human resources. Regulatory instruments have the disadvantage of using government structures to manage resources, which can, as in the case of water, come to be regarded as a social good rather than an economic good with economic value. Hence, such frameworks can be economically inefficient and costly. They also do not include consultation and participation by the stakeholders.

The great advantage of the market-based approach is that firms and individuals are given the opportunity to compensate for environmental damage in market price terms. But the weakness of this market approach is that the effects on the environment are not as predictable as those of the regulatory approach, and can enforce efficiency at the cost of equity.

There is now a definite shift in the way the two approaches are applied in the SADC states, with more emphasis on the development and application of economic instruments, and less emphasis on management by government control as it becomes increasingly clear that command-and-control is necessary but not sufficient to manage water resources. Instead, a combination of economic instruments and participatory approaches where local communities in catchments and in towns are empowered to take up the guardianship and stewardship of water resources management, seems to be the emerging trend, as illustrated in case studies in subsequent sections. The important role of the public as the custodians of the water resources has been encouraged by recent trends emphasizing public disclosure of polluting industries and the degree of compliance/non-compliance to pollution control regulations.

10.3.1 Water use and abstraction controls

Instruments for control of water abstraction and use include incentives, penalties and tariffs that closely reflect the cost of providing the water as well as the opportunity cost of committing the resource to the specific use. In developing the incentives and penalties, environmental impacts of water use need to be incorporated and their costs internalized.

In the SADC region, the issuing of permits/licenses for water abstraction and the use of water charges are widely applied measures for control and management of water abstraction. However, the auditing of these measures, in particular the permits/licenses once issued, is limited by institutional capacity. Water charges in most countries are being restructured to reflect partial cost recovery but not the true economic value of the water. The costs and benefits of allocating water to aquatic ecosystems are still inadequately addressed.

Ownership of water in most countries in the region is vested in the state as guardian of all water resources. Private ownership of water existed in South Africa, Namibia and Zimbabwe but is being changed through introduction of new water legislation. Principles of water allocation and rights vary but the general trend is toward securing supply for basic human needs and aquatic ecosystems, and then treating other water uses and requirements on merit. Riparian rights allocations are rapidly being removed in the interest of addressing historical imbalances. Box 10.8 gives examples from a selection of SADC countries.

Principles of water allocation rights in selected SADC member states **Box 10.8**

Malawi
Principles for allocation include the provision of water as a basic need. Provision of water for resource management and aquatic ecosystems are given prominence. A market-based allocation process is being promoted as well as variable allocations in response to droughts and floods.

Mozambique
All significant water abstractions and effluent discharges must be authorized and registered.

South Africa
Water for basic human needs and aquatic ecosystems is guaranteed; other uses are recognized if they are beneficial in the public interest.

Tanzania
Water allocation and water rights at national levels are allocated by the Ministry; in designated river basins, water rights are managed by water offices.

Zimbabwe
Water allocation is being reviewed to address inequitable perpetual allocations and to address imbalances in access to water, especially by poor rural communities.

10.3.1.1 Abstraction permits/licenses

Abstraction permits, licenses, concessions or authorizations provide a mechanism for determining and monitoring the user sector and quantity allocated from the given water source. At the scale of a catchment area, abstraction permits/licenses issued can provide an indication of the total water usage but this is based on the assumption that the permit holders are complying with the provisions of the abstraction permits/licenses. If the assumption is correct then the permitted total abstraction would provide an accurate indication of water available for other subsequent and/or competing uses.

The permits/licenses are issued based on the notion that the state is the guardian of all water resources in the country and therefore determines who should exploit the water and the use thereof – a principle widely adopted in southern African countries (Botswana, Tanzania, South Africa, and Zimbabwe). The permit also provides conditions on the quantity of water which may be utilized and provisions on renewal and revoking of the permit granted. (FAO 1994)

The permit/license can be used as a tool for water-use control and protection of aquatic ecosystems when adequate capacity is available for enforcement. Although environmental flow requirements are not explicitly recognized in permits, these requirements can be accommodated in the same manner as drought and other provisions. Such is the case in South Africa, for example, where the reserve is a water right and all other water users are granted a permit only after the reserve has been determined and set aside. In the case of Lesotho, for example, drought provisions are included through a regulation that provides for the revoking of or variation in permits during times of drought. (Lesotho Water Resources Regulations 1980)

10.3.1.2 Allocation of water for aquatic ecosystem functions

Environmental flow requirements are defined in chapter 5 as the water that is deliberately left in the river or released from a reservoir for maintaining the structure and function of aquatic ecosystems downstream. This excludes water released for diluting pollution or for downstream economic activity.

The accurate determination of environmental flow requirements is a complex process, but one that is essential for environmentally sustainable management and development of water resources in a river basin. In a largely semi-arid region such as southern Africa, the determination of environmental flow requirements poses technical problems because of the non-perennial nature of many rivers, little or no accurate data on flow regimes and a general lack of ecological data.

This makes the determination of ecosystem water requirements difficult to undertake within a reasonable time period. The investment required, in terms of data networks, human resources and expertise still remains an impediment to research on determining data-intensive characteristics of water resources such as ecosystem water requirements.

In South Africa, environmental flow requirements are embodied in the water policy and the environmental policy as "the environmental reserve". The provision of water to meet basic human needs and maintain environmental sustainability is set out as the primary guaranteed component (part of the Reserve) after which other demands may be addressed. Thus the water required for environmental conservation has been elevated to a comparable status to water for basic human needs. This principle provides for

the allocation of water of appropriate quality and quantity to protect the ecosystem as part of the obligation of the state (DWAF 1997). The upcoming water policy in Tanzania has a similar, but a slightly varied stipulation.

The recognition of aquatic ecosystems as legitimate users of water, or in some countries as the actual resource base, is now also reflected in water policies of many SADC countries (for example, Malawi, Zambia and Zimbabwe). However, the legislative framework for monitoring water allocations to aquatic ecosystems often lies with the Environmental Councils/Ministries of Environment, which can be problematic if insufficient capacity exists within those institutions. Moreover, during periods of drought, water supply projects take preference and are often developed at the expense of aquatic ecosystems. Thus, there is need for prior basin-wide determination of environmental flow requirements that take into consideration the influence of prolonged droughts and that are protected by effective legislation and regular auditing. In addition, due to the relatively low levels of understanding and few techniques for determination of environmental flow requirements, there is a need for concerted efforts to sensitize decision-makers on the importance of this component of water resources. Political commitment is necessary to ensure allocation of resources to adequately address the determination and implementation of environmental flow requirements.

10.3.1.3 Economic instruments: Water tariffs, water charges and other fees

Charges are applicable to all uses, including energy, agriculture, industry, mining and domestic use to cover the costs of management, conservation and protection of water resources and this includes both the capital and operating/maintenance costs of:

- assessment, allocation, and permit administration;
- hydrological, water quality, and sediment monitoring;
- catchment protection, and pollution control.

Countries that have adopted water charges include Tanzania (as reflected in Box 10.9), and South Africa, where water charges are used to fund the direct and related costs of water resources management, development and use and may also be used to achieve an equitable and effective allocation of water. In addition, charges may be used to encourage compliance with prescribed standards and water management practices according to the user-pays and polluter-pays principle. (South Africa National Water Act 1998)

Water charges principles in Tanzania **Box 10.9**

In order to realize the objectives of water resources management:

- All water uses will be charged for, especially water used beyond the quantities required for basic human needs necessary to maintain human health, personal hygiene and sanitation.
- Water referred to as the Reserve will be provided free of charge to respect the basic needs for human life and the environment.
- The 'polluter-pays principle' will be introduced on effluent discharges. An economic charge will be related to the environmental damage caused by the discharge, the cost of prevention and treatment to restore the resource to acceptable quality standard.
- A resource and catchment conservation charge will be introduced and an upstreaming mechanism of the accrued resources from the use of the water shall be put in place.
- The level of all the charges will be fixed and reviewed periodically, based on studies and analytical work to be conducted from time to time.
- The pricing strategy will detail the charges to be collected by the government for the right to use water and will clarify the parameters to be taken into account in the calculation of the various charges; the strategy will be part of the legal framework.

Tanzania National Water Resources Management Policy, Draft 1999

Tariffs are applied to consumptive uses of water, such as for domestic, industrial, mining and agricultural uses, and these typically cover the capital and operating/maintenance costs of:

- abstraction (physical works such as intake structures);
- treatment plants;
- storage dams and reservoirs; and
- distribution facilities and systems.

Typically, tariffs are set with specific objectives such as:

- full cost recovery;
- targeted subsidies; and
- opportunity cost pricing.

In the SADC region, water tariffs are used as a tool for managing demand for water, ensuring a degree of cost recovery and promoting investment in water resources development. This notion is well represented in Malawi for example, where the water pricing strategy aims at,

providing incentives for investment in the water sector,
ensuring efficient operation and maintenance,
providing incentives to water users to use water efficiently,
generation of sufficient income to cover costs, and
ensuring financial sustainability. (Country Situation Report 1997)

Effective water tariffs should closely reflect the true cost of abstraction and delivery of water and should be intended to recover the cost of development, treatment, distribution and other capital and operating costs involved in water supply projects. The principle being widely promoted in newly formulated policies in SADC countries, is to reflect the economic value of water through the structure of prices (*eg* rising block tariff system in Botswana in Box 10.10), while fulfilling the social obligation of providing essential quantities free or at lifeline tariffs to poor communities. These principles largely result in cross-subsidization between affluent and poor communities, although there are great disparities in the level of service between the urban affluent communities, and the urban poor, and worst of all, to the rural communities.

Aquatic ecosystems on the other hand, are not adequately factored into the pricing system, as pointed out earlier, in chapter 4. The absence of tools for accurately estimating the opportunity cost of using water for urban supply or hydropower generation as compared to meeting environmental flow requirements results in less water being provided for aquatic ecosystems where the latter competes with supply demands, unless specific provisions are made in policy and law, as in South Africa.

There is need, therefore, to improve awareness and promote a participatory approach to developing incentives and penalties that effectively discourage wastage of water and on the other hand promote water conservation and demand management. Governments need to devise mechanisms through consultation with communities and other stakeholders that seek a balance between the use of economic instruments, the command-and-control tools, and active participation of communities in water-use control.

10.3.2 Water quality management and pollution control

The availability of water alone is not sufficient to indicate its suitability for use. The quality of the water determines the type of use for which it would be suitable or the level of treatment that would be required for it before use. Water quality degradation exacerbates water scarcity as it reduces options for downstream use and increases the cost of treatment. Water quality management is critical in a water scarce region such as southern Africa (see chapter 6 for a complete discussion on the subject).

Water quality management and pollution control is generally the responsibility of Departments of Water Resources throughout the region, although Health and Environmental Departments/Ministries also play an active role in protecting the quality of water. Water quality standards, monitoring and the use of legislation and regulations to manage and protect water quality are the main approaches used in southern Africa and elsewhere.

The primary limitations to effective control relate to the costs of monitoring, the cost of treatment, and the capacity to enforce legislation. Water quality monitoring requires large investments in the network, sampling equipment, testing equipment and data analysis. Human resources capacity and systems for effectively reporting and utilizing available data are also limiting factors in the region. Hence, some countries in the region, such as Tanzania, continue to operate on temporary drinking water quality standards.

Water quality management is even more difficult in the context of regional transboundary waters (such as Lake Victoria), where three countries each have different sets of water quality and effluent standards. This poses great challenges for achieving effec-

Botswana urban water supply tariffs, 1991/92 **Box 10.10**

Band	Monthly Consumption (cu m)	Tariff (pula / cu m)			
		Gaborone & Lobatse	Jwaneng	Francistown	Selebi-Phikwe
1	0-15	0.65	0.55	0.55	0.5
2	15-40	2.60	2.10	2.20	1.28
3	> 40	3.50	2.40	2.50	1.65
4	Raw Bulk	1.00	n/a	0.55	Special tariff

Botswana National Water Master Plan Study 1992

tive pollution control, and requires a unified approach to manage a complex lake ecosystem. Meanwhile, the WHO guidelines provide a useful benchmark for monitoring the quality of drinking water (see chapter 6).

10.3.2.1 Pollution control measures

Water pollution is increasingly reducing the availability of safe water in southern Africa. Such pollution is derived from specific sources (point sources), such as domestic, industrial and mining effluent drains, municipal drains, or from diffuse sources (non-point sources) in the case of agricultural land and contaminated runoff from cities and towns, or slime-dams from mining operations. (See chapter 6 for a more detailed discussion.)

Water pollution issues in Zimbabwe **Box 10.11**

The problem of water pollution has been increasing in magnitude in Zimbabwe, threatening the wellbeing of water resources in the process. The pollution of water resources has been attributed to a number of causes.

- Treatment technology:
- Nutrient removal – Disposal of treated effluent has posed a problem in that technology available for most urban centres, even when working satisfactorily, produces effluent of high phosphate and nitrate levels causing pollution and eutrophication of the receiving waters (Lake Chivero supplying Harare is a well-documented case where this problem has been continuing for the last 30 years). Visible indications of high levels of nutrients, such as proliferation of some aquatic plants associated with eutrophication, are usually noted around the discharge points of treatment plants that discharge their effluent into river systems. Waste stabilization ponds have produced effluent that is not suitable for river or stream discharge because it often does not meet the discharge standards, mainly due to the heavy nutrient load that remains in the effluent.
- Poor maintenance and management – Poor management (*eg* of ponds not being desludged for long periods, or overloaded systems) has often caused treatment technologies to produce poor quality effluent.
- Inadequate controls on industrial effluent – Inadequate pretreatment of industrial wastewater causes problems in treatment facilities resulting in subsequent pollution of receiving waters, thus contributing to unacceptable levels of pollutants in water bodies. The heavy metals from industrial effluent decreases activity of biological systems in municipal sewage treatment works.
- Disposal methods – The method used for effluent disposal relies on the quality of effluent in question. However, regulations regarding the disposal of effluent is not adhered to in some places. According to regulations, effluent from stabilization ponds is not supposed to be discharged into river systems – a practice used at the majority of ponds across the country.

IWSD 1998

Water pollution control can be achieved through legislative measures by forbidding the discharge of waste into freshwater, restricting the discharge through penalties and licenses, charging for the discharge of waste, zoning of land uses or through prescription of preventative measures for polluting activities. (FAO 1994) This also requires political will and an effective licensing, monitoring, analysis and enforcement system. (Box 10.11)

Some countries in the region, including Namibia and Zimbabwe, are adopting water quality management strategies which include incentives for water-use minimization, wastewater re-use and water recycling.

10.3.2.2 Water quality standards and objectives

If discharge of wastes into water resources is permitted, then the most commonly used instrument for controlling the quality of waste discharges is the use of effluent discharge standards. These are usually concentration-based limits which apply to effluent discharges at end-of-pipe. Several countries, including Zambia and South Africa, have developed their own effluent discharge standards, which are prescribed by regulation. All dischargers must meet these standards, unless they are permitted a relaxation under certain circumstances.

While uniform effluent discharge standards are administratively simple to apply, they are only as effective as the capacity to enforce them. In addition, they do not take into account total pollutant loads into a water resource from several sources, and it is common to find a situation where many dischargers are releasing effluent into a water body, all are meeting the effluent standards, but water quality in the receiving water body continues to degrade since the water resource cannot assimilate the total load of pollutants.

SOE Zambezi – CEP

A more recent trend is to set receiving water quality objectives, and then determine site-specific or catchment-specific effluent discharge standards which will ensure that objectives are met. The objectives can be prescribed in regulation, or set on a catchment by catchment basis. South Africa has published water quality guidelines to assist in the setting of statutory receiving water quality objectives for surface waters, but other countries who are taking this approach are still utilizing World Health Organization (WHO) or European Union (EU) guidelines.

10.3.2.3 Ambient water quality monitoring

Ambient water quality monitoring establishes the background or upstream quality of water prior to discharge of wastes and therefore determines the suitability of water quality for particular uses, and the capacity of the system to assimilate, dilute or neutralize introduced effluent and wastes. This capacity becomes very limited during periods of prolonged drought and as a result of land degradation and upstream pollution.

Ambient water quality monitoring in the southern African region is often conducted irregularly (on an ad hoc basis to address a crisis, or to meet needs for a new project). It is typically carried out in conjunction with hydrological monitoring programmes. The cost of transportation, proper storage of water samples and chemicals, laboratory facilities and the availability of required human resources all impede the effectiveness of water quality monitoring initiatives.

The implementation of conventional water quality monitoring programmes is not only costly, but there are serious questions about its appropriateness in data-poor, resource-scarce environments such as Sub-Saharan Africa in general and the SADC region in particular. Rapid biomonitoring techniques are emerging as cost-effective alternatives to conventional water quality monitoring programmes, but the legal status of biomonitoring for compliance purposes needs to be clearly established in policy and legislation.

Legislative measures in support of ambient water quality monitoring should be closely linked with effluent discharge monitoring programmes. The issuing of a permit to discharge effluent should also bear a condition for the discharger to monitor and report on ambient water quality conditions both upstream and downstream of their [illegible]

10.3.2.4 Effluent discharge monitoring

Effluent discharge monitoring is typically conducted in areas where wastewater from municipal sewage treatment plants and industrial and mining facilities is discharged. (Box 10.12) Mining operations, urban and informal settlements, manufacturing, and other large industries produce [illegible] quantities of effluent. However, small manufacturing processes such as clothing, food processing, engineering works and paper processing also produce small quantities of highly toxic effluent in the form of heavy metals that require stringent monitoring to ensure compliance with discharge standards and regulations.

The monitoring and control of effluent discharges require close cooperation between the government authority charged with the responsibility and public and private sector industries and municipalities. Control should be approached proactively through the minimization of hazardous effluent, pretreatment prior to release into the natural environment, and awareness campaigns. Industries should be encouraged to monitor and report on their effluent discharge. On the other hand, stringent legislative measures can only be effective if there are equally strong institutional arrangements to ensure compliance. The approach being implemented in Zambia, for example, under the Zambia Water Pollution Control regu-

Sampling and testing of water for effluent in Zimbabwe — **Box 10.12**

Suitable points for taking samples of waste or effluent waters for the purpose of testing any analysis, shall be provided when requested, by the Director of Water Development.

A composite for the analysis for all tests, other than those for temperature, pH and dissolved oxygen, shall be taken by combining individual samples so that a minimum of five samples of equal volume of not less than 500 millilitres each of the waste or effluent water shall be taken, at the point of discharge, at approximately equal intervals of time over a minimum period of four hours within any 24-hour period.

Temperature, pH and dissolved oxygen readings shall be taken on individual samples at time of sampling and all samples shall comply with the prescribed standard for temperature, pH and dissolved oxygen.

Where full laboratory facilities do not exist on the site for determination of dissolved oxygen, the oxygen in the sample may be fixed at the time of sampling by adding sulphuric acid, the permanganate, the oxalate, the manganous sulphate and the alkaline iodide only. The stopper must be replaced and the solution well mixed.

The remaining steps may be carried out later in the laboratory.

FAO 1994

lations of 1993, entails the setting of standards for discharged effluent including physical, bacteriological and chemical content. A license to discharge effluent is issued provided the industry/applicant also monitors and reports the quality of the effluent discharged.

10.3.3 Management of land-use impacts on water resources

A review of the RSAP prepared by the SADC Water Sector reveals that the type and combination of land-use practices in the region impact on water resources management in various ways. Pesticide pollution (*eg* DDT) and fertilizer pollution are major problems in eight SADC countries; deforestation, mainly due to fuelwood cutting, and soil erosion are serious problems in eight countries; and all SADC member countries suffer from overgrazing. Box 10.13 summarizes the impacts of poor land use on water resources.

Chapter 7 on Watershed Degradation and Management discussed the causes of watershed degradation which usually result from land-use practices, and proposed broad watershed management guidelines and recommendations for a sound water policy. The chapter proposed the implementation of integrated land-use management approaches that take into consideration the principles of catchment-based water resources management.

In addition to the broad guidelines and sound water policy, another environmental policy instrument, *ie* property rights, is being applied, especially in countries where there have been inequalities in the past, for clarifying responsibilities, defining and defending property rights in order to promote conservation and management of natural resources such as land and water. SADC countries, for example Zimbabwe, South Africa, and Tanzania, are adopting land and land-use policies and legislation to reform existing rights and or create new and permanent property rights with the objective of having a well-defined tenure system that is secure and will promote incentives for the efficient use, investment and sustainable management of natural resources. A proper understanding of customary/communal systems and land tenure, and the protection of the rights and productivity of poorer groups such as rural women, is necessary to ensure that property rights become an effective policy instrument in land and water management.

Impacts of poor land use on water resources **Box 10.13**

Poor land use can impact on water resources in many ways, including:

- **Altering the hydrology (runoff, infiltration and recharge rates);**
- **Increasing soil erosion, leading to increased sediment transport and deposition, which can effect the hydraulic capacity of rivers and channels and reduce the effective economic life of major investments such as dams;**
- **Degrading water quality by increasing turbidity and sediment load, thus requiring more treatment of water prior to use;**
- **Introducing pollutants which are washed off the land surface into water bodies or leached into groundwater.**

Zoning can be used effectively to control non-point source pollution and as a strategy for protection against flooding, apart from having other benefits for water resources management. Zoning policies allocate land for specific uses, such as farming/agriculture, forestry, residential/urban/settlement, mining, park/conservation area, river source, natural heritage. In relation to water and environmental management, zoning strategies can be used to promote conservation-related activities in sensitive headwater areas or dry regions and focus water intensive activities in areas well endowed in the resource. (Box 10.14)

In southern Africa, zoning for protection of water resources is mainly achieved indirectly through the declaration of parks, conservation areas and heritage areas that coincide with important wetlands, river sources and major lakes, whether artificial or natural. Several joint initiatives between countries, for example, Botswana and South Africa on the Kalahari Gemsbok Park; the proposed international park covering parts of Mozambique, South Africa, and Swaziland; and Lesotho and South Africa along the Drakensberg ranges will go a long way to providing protection for important but fragile catchments.

The challenge for policy and institutional frameworks related to effective land-use management for water and environmental protection; is to define methods for balancing the benefits of downstream socio-economic activities and water uses with upstream development needs. The reverse also applies. An example of the former relates to the need to maintain the rich eco-tourism industry of the Okavango delta, versus possible future needs to utilize the relatively undeveloped headwater regions of the Okavango river in Angola and Namibia.

The Umgeni river catchment area in Kwazulu-Natal is another example. The latter challenge can be exemplified with the cases of most river basins draining into

Zoning for water conservation: Land tenure and water rights in Tanzania **Box 10.14**

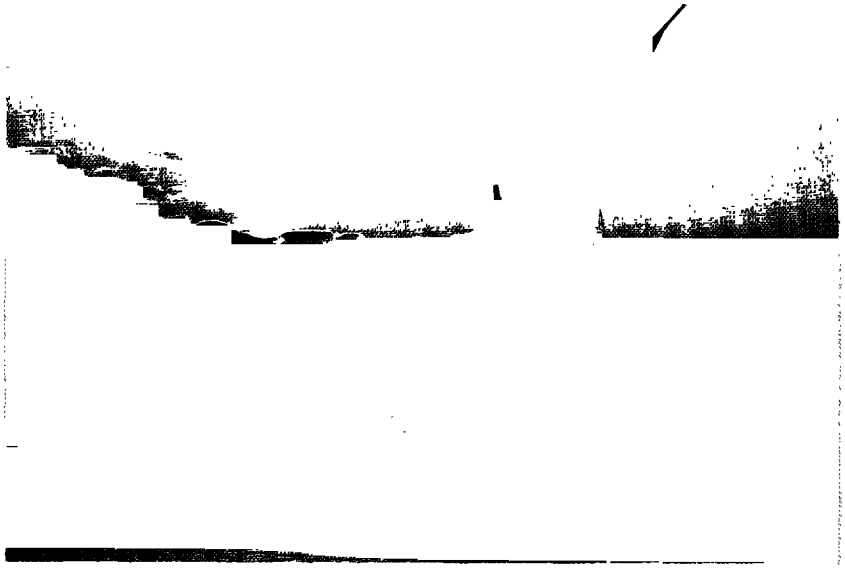
Problem – Issue
The aim of the National Land Policy is to promote and ensure a secure land-tenure system, to encourage the optimal use of land resources, and to facilitate broad-based social and economic development without upsetting or endangering the ecological balance of the environment.

Policy Statement
- Water rights shall only be issued where the applicant has satisfied the respective water management agency that the intended land development will not in any way upset or endanger the ecological balance and the environment;
- No water rights shall be tied to any land, and water rights shall not be awarded with land transfer. Duration of water rights shall not be the same as for land leases;
- Land use in areas close to river courses or water bodies may influence the flow regimes. To avoid this situation, the land areas falling within a one- and five-year flood shall be regarded as falling within a watercourse or water body and shall be regulated by the Water Act.

Problem – Issue
The land policy identifies a tendency over the last 10 years of allocating sensitive areas such as small islands to individuals. This practice has caused destruction to these sensitive areas.

Policy Statement
- Water rights for such areas shall only be issued in accordance to the specified land use;
- Water rights for marginal areas shall only be issued where development has been deemed to be compatible to those areas;
- For restricted or sensitive areas such as National Parks, some wetlands, etc., water abstraction shall only be allowed where other sources are absent.

Tanzania National Water Resources Management Policy draft 1999



D. Martin, APG

Mozambique including the Zambezi, Save and Incomati, where the upper catchments of these rivers have been extensively developed while the lower catchments in Mozambique have little or no development at present.

There is a need therefore to approach land-use management, particularly of international rivers, according to a regional strategy in order to minimize imbalances and also to promote consideration of the ecological requirements of all sections of the catchment in land-use planning. Close co-operation among water and land-use managers and communities is required for awareness creation and participation in land-use management.

10.3.4 Environmental Impact Assessment (EIA)

Environmental Impact Assessment (EIA) is a decision-making tool used for identifying and addressing potential environmental impacts of economic development. King and Brown in Chapter 5 provide an example of the links of EIA to water resources planning and development. A baseline EIA can be undertaken as part of strategic planning to identify options for development of regions and areas under different climatic and geographical conditions or as a tool for managing resources for future development alternatives. At a more operational level EIA is utilized as a planning tool for assessing alternative sites, alternative technologies or combining different approaches in identifying the most suitable development project. The crosscutting nature of an effective EIA at any level potentially provides a platform for seeking consensus on the means and mode of water resources development.

The environmental impacts of large water-supply projects and programmes including dams and reservoirs, diversions, irrigation projects, industrial and municipal abstraction, as well as return flows in the form of municipal sewage, agricultural runoff, industrial effluent and raw sewage, are very significant. The requirement for undertaking EIA for all major water projects is reflected in all recently revised water policies in southern African countries. The Departments/Ministries of Environmental Affairs are usually the custodians of the process and act to oversee the correct application and follow-through of EIA procedures.

10.3.4.1 EIA regulation (national and regional)

The EIA regulations in the SADC region have emerged together with the establishment of the environmental agencies and departments. The main limitations of the EIA process are lack of capacity and the intersectoral coordination required for evaluation of documentation and technical reports as a basis for authorization for project development. The EIA process can be costly, and priorities such as economic development needs, political imperatives, industrial investments and emergency situations such as drought, compromise the effective application of the process. The procedures for addressing transboundary impacts are not clearly defined and present problems as well in co-ordination between countries whose EIA regulations may differ.

In South Africa, the EIA regulations as provided for in the Environmental Conservation Act No.73 of 1989, involve essentially two levels of study, namely scoping followed by full environmental impact assessment, both of which are supported by an elaborate public participation process including public meetings and advertising in local or national media.

Authorization for developing a project is either given at provincial level or at a national level for projects whose impacts are of national interest. This regulation is now being reinforced through the National Environmental Management Act, No 107 of 1998 to incorporate a full spectrum of integrated environmental management principles under which interested and affected parties should be consulted at planning, assessment and implementation stages of projects. Thus EIA should play its proper role as a decision support system for assessing alternatives and highlighting potential environmental aspects of development.

Drawing up of an environmental management plan and monitoring of its implementation by different sectors is strengthened and provided for in legislation. The approach taken for EIA in South Africa presents a benchmark for other countries in the region and its successful implementation, depending on the availability of capacity in the related institutions, will provide a good example of future trends in effective environmental protection and conservation. Lesotho, Malawi, Zambia and Zimbabwe have also developed EIA guidelines and regulations which if successfully implemented will enhance environmental and water resources management in the region.

The regional perspective of EIA in the SADC region depends on the establishment of effective knowledge exchange, information exchange, and dissemination and development of the required policies and institutional frameworks. General awareness of the principles has been achieved through application of the principle at the project level, *eg* on the Lesotho Highlands project where transboundary issues are being addressed.

Regional institutions such as SADC ELMS and the SADC Water Sector need to play a more active role in promoting sectoral, regional or strategic EIA for shared river basins for example as initiated on the Zambezi River Systems Action Plan (ZACPLAN).

10.3.4.2 Weaknesses in application of the EIA procedure

Chapter 1 listed the factors that can undermine the influence of EIAs on project decision-making. In identifying the weaknesses of applying the EIA procedure in the SADC region, it is useful to mention some of the aspects that make it unpopular among proponents of development and difficult to enforce on the part of the responsible authority.

- EIA can require significant amounts of money and time.
- If not scheduled carefully it can result in significant delays in project planning.
- EIA can expose information about the planned project that makes the project unattractive to funding agencies.
- EIA can expose the proposing agency's planning and decision-making processes to scrutiny and evaluation by outsiders.
- The criteria for assessing the importance of environmental impacts are often qualitative and the

procedure for weighing economic benefits against environmental losses are often subjective. (Hirji and Ortolano 1991)

Current practice is that EIA often comes late in the project cycle and is done mainly to identify mitigation options or to "legitimize" the project, whereas if it had come earlier it would have positively influenced the project planning and implementation process.

Hirji and Ortolano (1991) advance five criteria for assessing the effectiveness of EIA procedure:

compliance with rules and regulations;
preparation of adequate EIA documents (including the terms of reference for the EIA);
utilization of appropriate methods in assessing environmental impacts;
influence of environmental information on various aspects of planning and decision-making; and
placement of appropriate weight on environmental impacts relative to economic and technical factors.

Box 10.15 highlights factors that can enhance the role of EIA in project planning and management decision-making.

Key factors to enhance the role of EIA in project decision-making **Box 10.15**

The influence of EIA on project decision-making can be enhanced when:

- The EIA process is started at the earliest stage of the evaluation of a proposed development programme or project.
- The scope of the study provides for broad coverage of the major potential issues and places them in a broader development context.
- The analyses of alternatives is undertaken at an early stage and includes evaluation of development, site, and technical alternatives.
- The economic value of resource degradation is incorporated in the project cost/benefit analysis and decision-making.
- The methods used to predict and forecast the impacts are well selected.
- The study is made available in a timely manner and used effectively by decision-makers and the public in their consideration of the proposed project.
- The mitigation and monitoring plan are realistically designed and can be implemented under local conditions.
- There are arrangements in place to oversee environmental aspects of project implementation.

Hirji and Ibrekk 2001

10.3.5 Policy to support implementation of regulatory controls

Policy and legislative support for the determination of Environmental Flow Requirements (EFR) for both water quantity and water quality, is relatively new in most SADC countries. Although EIA has been mandatory for somewhat longer, the scientific tools for determination of EFR have been developed only within the last 10 years, and very few EFR determinations have been carried out for large projects. Notable examples are the EFR study for the Lesotho Highlands Water Project, the Olifants River Environmental Water Requirements Assessment, and the Sabie River Instream Flow Requirements study (the latter two being entirely within South Africa).

Determination of EFR is only the very first step in the process of achieving sustainable management of water resources. The next, and usually larger, challenge is to actually implement the EFR determination. Few countries have clearly established policy which sets out the links between the EFR determination and the setting of quantitative management objectives for a river basin. There is a need to ensure not only that policy and legislation support the determination of EFR, but also that there is a strong supporting policy framework for undertaking the key steps of translating an EFR determination into water resource management objectives, and then developing an operational strategy or plan for achieving the objectives.

A logical strategy must be developed which sets out not only the quantitative objectives for management of flow and water quality in a river basin, but also a plan for progressively moving towards achievement of these objectives over an agreed time frame, by using the various regulatory controls which are available. This plan, usually referred to as a river basin management plan or catchment management plan, would contain the operational details related to how the water resources in a river basin would be managed and how the impacts of water use and land use would be controlled, in order to ensure the desired balance between utilization and protection of those water resources. Several countries in the region have now made provisions in water legislation for the

development of river-basin management plans which, once agreed upon by stakeholders and approved by the central water resources management agency, become binding on both the regulators and the stakeholders.

In general, once an EFR determination has been completed, one of two situations is likely to arise:

It may become clear that, even once the EFR have been implemented, water resources in the river basin are not fully exploited, and the current situation is sustainable. Then the EFR can be used to set limits on future exploitation and possible impacts of future land uses, in order to ensure that use of water resources in the river basin remains environmentally sustainable. In such a case, the EFR should serve as the baseline for any EIA study in the basin, in order to prevent the cumulative environmental impacts of incremental development from gradually leading to an unsustainable, over-exploited situation.

Alternatively, it will be shown that, once the EFR have been implemented, the water resources in the basin will be or are already over-exploited, probably to a level which is not sustainable, and the management plan will need to address the gradual recovery to a point where the EFR can be achieved. It is this situation which is addressed in more detail below.

10.3.5.1 Implementation of EFR in an over-exploited water resource

Moving from an over-exploited situation in which protection is not explicitly afforded to aquatic ecosystems to a situation where EFR are incorporated into river basin management objectives for environmentally sustainable management, may take considerable time. This is especially true if the current situation is entrenched through the granting of long-term authorizations or rights in perpetuity. Reducing water allocations or discharge permits overnight could lead to severe shocks to the local economy, while legal battles over changes in water-use authorizations and/or rights could be intense and protracted if sufficient attention is not first paid to the enabling policy and legislative environment.

There are three possible approaches to rectifying a situation of over-exploitation in order to enable EFR to be achieved. Each has economic and legal implications, and usually some combination of the three may be required as part of a river basin management plan. The approaches are:

supply-side management;
demand-side management; and
re-allocation of existing water-use authorizations and/or rights.

10.3.5.2 Supply-side management

Supply-side management is an approach in which increasing demands for water or use of water resources are met by finding or developing new sources of supply, within or outside the watershed. For example,

- new storage dams might be constructed to meet rising demands for irrigation water, or to make water available for releases to meet environmental flow requirements;
- inter-basin transfer schemes might be constructed to deliver additional water to a rapidly-growing urban area;
- higher levels of potable water treatment might be employed to counteract the effects of pollution from agricultural, urban or industrial sources.

While supply-side management options are sometimes necessary and may be the only way to meet short term imperatives for economic development or provision of basic water services, they are almost always expensive in monetary terms, technologically demanding to install and maintain, and do not adequately address the protection of environmental sustainability of water resources. This is especially true as the readily accessible and cheaper sources have become exploited.

10.3.5.3 Demand-side management

Demand-side management entails the management of off-stream demands for water and minimization of the impacts of land use and water use on water resources, through a mix of planning, regulatory and economic measures.

The purpose of demand-side management is to make more water available, either to meet growing offstream demands or to provide for environmental flow requirements, without necessarily resorting to expensive and unsustainable structural and technological supply-side interventions. Generally, demand management programmes need to be instituted on three levels in order for an overall demand management strategy to be successful (MacKay *et al* 2002):

- at the watershed planning level, in order to achieve the most efficient and beneficial allocation of water

between major water use sectors such as agriculture, industry and domestic;
at the sectoral level, in order to maximize the productive use of water and minimize unproductive losses in production and/or delivery processes within each water use sector;
at the end-user level, in order to maximize the efficiency and care with which water is used by individual consumers or end-users.

Demand-side management at watershed level

Changes to the flow regime and water quality in a watershed can be caused by a number of factors, which include land-based activities, hydraulic structures in the water resources themselves, and waste discharges on land or directly into water. These effects have been described in detail elsewhere in this chapter.

A comprehensive demand management strategy should include programmes which protect the source waters and address issues such as soil erosion, deforestation, waste management and maintenance of natural vegetation, particularly in the riparian zones of rivers and wetlands.

Other programmes may also include conjunctive use of surface water and groundwater, the use of artificial recharge and groundwater banking. Such programmes would be aimed at improving the quality of water resources; restoring flow patterns, timing and assurance; maintaining the diversity, structure and function of aquatic ecosystems. They can be implemented through regulation (for example requiring landowners to restore riparian land or to install soil erosion works), but are usually more effective if implemented through the use of economic incentives such as grants or tax rebates, or through providing assistance to develop alternatives such as fuelwood plantations in order to reduce the use of natural vegetation for fuelwood.

Strategic environmental assessments could be used to determine water allocations between major water-use sectors, in order to identify the most efficient allocations of water between sectors at the watershed level, taking account of the economic, social and environmental impacts of each sector's use of water. Ideally, land-use activities which reduce runoff or cause changes in flow, such as commercial plantation forestry, should be considered to be water uses as well, and controlled and managed accordingly.

Demand-side management at sector level

Demand management programmes within water user sectors usually address the efficient use of water in production and delivery processes, through water conservation practices or introduction of alternative technologies for production and delivery processes which minimize the use of water. These are usually most effectively implemented through economic measures, including:

bulk water tariffs which are structured so as to encourage [illegible] and minimization of water use;
charges for waste discharges which discourage the generation of large volumes of wastewater;
the use of disincentives such as production taxes on products which are "water-hungry" or on production which leads to significant impacts on water resources, for example in commercial agriculture where excessive or careless use of agro-chemicals leads to these chemicals being leached or washed from the soil and polluting water resources;
re-use of treated wastewater for groundwater recharge or for agriculture;
incentives such as tax rebates or grants for installation of water-efficient technology or successful water conservation programmes.

At a sectoral level, significant water savings can often be effected in the short term and with little additional capital cost, simply through effective management and maintenance of existing water storage and supply infrastructure. For example, in urban areas significant losses of water occur through undetected leaks or leaks which are not quickly repaired, or through illegal connections. Water losses through evaporation and seepage in open reservoirs or canals can be minimized through proper design of storage reservoirs, covering of open water supply canals where possible, and lining of canals and smaller reservoirs. (UNEP 1997)

In the agricultural sector, which is one of the largest water use sectors in the world (Postel 1997), significant water savings can be achieved through,

lining of furrows, canals and reservoirs with clay or plastic;
proper scheduling of irrigation according to soil moisture levels;
changing from high-volume sprinkler or overhead irrigation to drip or microjet irrigation; and
use of recycled wastewater for irrigation of many non-food crops and some edible crops.

Reporting on water conservation and demand management can be made an integral part of environmental or general business reporting for all public sector and parastatal institutions and for bulk water users in the private sector. This will encourage the adoption of water-efficient technologies and water conservation programmes.

Demand-side management at end-user level

Management of water demands at end-user level depends on the creation of a high level of awareness of the value of water, and on the perception that the benefits of utilization of water resources are being equitably shared. A combination of public education programmes and appropriate water pricing is usually necessary in order to encourage water savings by individual consumers. There are also several technological options which can promote water savings, particularly when installed in new housing developments, including,

- low-flush or no-flush toilets and toilet tank displacement devices;
- low-flow shower heads, faucet aerators and pressure reduction devices; and
- dual water systems to facilitate the use of grey water on vegetable and ornamental gardens.

Alternative sources of water

In water-scarce areas, there are several alternative solutions that can be used to augment freshwater supplies.

How much water might a forest collect from fog? **Box 10.16**

Two leading fog collection experts offer the following example of the amount of water a forest might collect (or conversely, lose if the forest is cut) from fog. Assuming a fog-covered watershed with 100,000 trees planted for good exposure in a 500-metre-wide band roughly 10 metres apart, they estimate that each tree can collect around 250 litres per day during the fog season. If the season is half a year, the total water collected in a year is 45 cu m per tree. Assuming also that three-quarters of this water is used directly by the trees or evaporates, around a million cu m is still available for use. This is equivalent to an extra 100 mm of rainfall on 10 sq km in a year.

Collectors should have spaces between them to permit the wind to flow. Studies suggest that lengths of 0.5 to 1 km may be needed for 50 collectors of 12-24 m. Parallel rows of collectors may be built in some locations.

Schemenauer and Cereceda 1992a, in Gleick. 2000

These include:

- rainwater harvesting, whereby each household collects roof water and runoff water in drums, tanks or reservoirs;
- fog harvesting, especially in arid western boundary current regions such as the coast of Namibia;
- aquifer recharge, which reduces evaporation losses from surface water storage and can improve water quality (though should be avoided if there is a risk of pollution of groundwater with persistent toxic substances);
- desalination of sea water, which is still relatively expensive in southern Africa, though it is used in Namibia; and
- use of "virtual water", whereby water-scarce countries import water-hungry products from countries where water is plentiful and relatively cheap rather than producing these products themselves, although this option requires economic and political stability in the region in order to be successful.

10.3.5.4 Reallocation of existing water uses

Sometimes a valid management option for achieving EFR in an over-exploited river basin may be to reallocate existing water uses, either to higher-value uses, to more water-efficient uses, or for meeting EFR.

Reallocation can be effected through a "command and control" approach, by abolishment of prior water use rights and replacement with limited-duration authorizations. This route has been taken in South Africa and Zimbabwe, where new water legislation also effectively decouples water rights from ownership of riparian land and gives the water resources management agency the ability to review or revoke water-use authorizations or licenses and reduce water allocations as and when necessary. With this approach, it is necessary to clearly specify, in legislation and policy, the circumstances under which allocations may be reviewed and whether compensation is payable.

In South Africa, if an existing lawful water use is reviewed and reallocated either for the purposes of meeting the Reserve (the water set aside for basic human needs and aquatic ecosystems) or for redressment of past inequities, then that is considered to be expropriation and compensation by the state may not necessarily be payable. If an existing lawful water use is reallocated, say to another, higher-value use, then compensation may be payable.

Reallocation can also be effected through a voluntary approach, by allowing, and in some cases facilitating, trading of water-use authorizations. This promotes the establishment of a free market in water, which usually leads to water being valued appropriately. However, there are some drawbacks to this approach. It may require the state to "buy back" water allocations for meeting EFR at the market rate, which could be very expensive in an over-exploited river basin where water is already scarce.

Technical problems can arise if trades occur between users who are far removed geographically from one another, although within the same river basin. Again, explicit policy guidance and strict controls are necessary in order for water and effluent trading to support sustainable water resources management. While several countries have introduced legislation which enables trading, the reality is that trading is likely to be very limited due to the lack of capacity to control and audit the process, and the technical challenges involved.

10.4 EVALUATION OF NATIONAL INSTITUTIONS

10.4.1 Environmental agencies

After the Rio Earth Summit, SADC countries started to reorganize the ministries and departments with responsibilities for environmental issues, or created new ones to deal specifically with environment and sustainable development, for example, in Malawi, Mozambique, Namibia, Swaziland, South Africa, Zimbabwe and Lesotho (Box 10.17). These central government structures which have been established deal with policy and legislative formulation, and implementation of environment management and development programmes.

Several countries in the region have, in addition, established central environment agencies such as the National Environment Secretariat in Lesotho, the Swaziland Environment Authority, Tanzania's National Environment Management Council and Zimbabwe's Natural Resources Board. These agencies play three key roles in all of the above countries:

- coordination of environmental programmes and activities;
- formulation of legislation and other legal instruments; and
- implementation of national environmental activities, often in collaboration with non-governmental organizations (NGOs).

These agencies play an increasingly crucial role in preparing and coordinating national participation in and implementation of multilateral environmental agreements, protocols and conventions, and in creating awareness, partnerships and cooperation at national and regional levels in environmental management.

Environmental agencies in the SADC region continue to face various challenges including:

- entrenched sectoral policies, programmes, laws and institutional arrangements, which will need closer inter-ministerial co-ordination, and new and innovative approaches for national development planning and for integration of environment in decision-making in the public and private sector;
- lack of qualified staff, expertise, funds and equipment to implement and enforce many existing national laws and international conventions; and
- the need to de-emphasize command-and-control regulatory approaches to environmental protection and management, and move towards wider use of economic instruments and legal incentives as well as empowerment of local communities in management of the natural resources on which their lives depend.

The challenge is to strengthen and empower the emerging, young environmental agencies established by the recent environmental management policies and laws, and water resources management policies and laws, in order to support and sustain the emerging fundamental shift of government's role from direct implementation to facilitation of implementation by relevant rural and urban local communities.

Box 10.17 shows that, in most SADC countries, several agencies are involved in or have responsibilities for environmental management and protection which are linked to water resources management. There is a need therefore to address conflicts and competition in the roles and responsibilities of agencies, which might hamper progress. For example, in countries where there is a department of environment and an environmental management secretariat or authority or council (as in Tanzania), the roles of the two institutions have to be clearly defined.

10.4.2 Water resources agencies

Water resources agencies throughout the region are responsible for the planning, development, management and monitoring of both surface and ground water. This

National environmental institutions and their responsibilities **Box 10.17**

Country	Institutions	Responsibilities
Angola	Min. of Agriculture and Rural Development	Land husbandry
	Min. of Fisheries and Environment	Marine resources management
	Secretariat for Environment	Policy development and environmental activities
Botswana	National Conservation Strategy Coordinating Agency	Implementation of conservation strategy
	Min. of Local Government, Lands, Housing and Environment	Land management Multi-sectoral environmental issues
	Min. of Commerce and Industry	
	Natural Resources Board	
	Min. of Agriculture	
Lesotho	National Environment Secretariat	Implementation of national environment action plan
	Min. Environment, Gender and Youth Affairs	Coordination and implementation of environment management programmes
	Min. of Natural Resources	Natural resources management Protected area management
Malawi	Min. of Natural Resources and Environment	Policy development, programme implementation
	Min. of Agriculture, Forestry	Natural resources management
Mozambique	Min. for Coordination of Environmental Affairs	Coordination of environmental activities, organizations and programmes
	Min. of Agriculture	Land, wildlife and forest resources management
Namibia	Min. of Environment and Tourism	Coordination of environmental activities and organizations and programmes
	Min. of Lands, Resettlement and Rehabilitation	Land husbandry
	Min. of Fisheries and Marine Resources	Marine resources management
South Africa	Min. of Environmental Affairs and Tourism	Development and coordination of environmental policy
	Dept. of Water Affairs and Forestry	Freshwater and forest resources management
	Dept. of Public Works	Pollution monitoring and control
	Dept. of Agriculture	Land management
	Dept. of Transport	Marine resources management
Swaziland	Swaziland Environment Authority	Development and coordination of environmental policy
	Min. of Tourism, Environment and Communications	Policy development and programme implementation
	Min. of Natural Resources and Energy	Water resources and wildlife management
	Min. of Agriculture and Cooperatives	Land husbandry
	National Trust Commission	National park and monuments
Tanzania	National Environment Management Council	Coordination of environmental bodies and activities
	Div. of Environment (Vice President's Office)	Policy and programme development and implementation
	National Land Use Planning Commission	Land husbandry
	Min. of Tourism, Natural Resources	Natural resources conservation
	Zanzibar Commission for Lands and Env.	Forest, wildlife and marine resources conservation
Zambia	National Environment Council	Coordination of environmental programme
	Min. of Environment and Natural Resources	Natural resources management
Zimbabwe	Min. of Mines, Environment and Tourism	Forests and wildlife management
	Natural Resources Board	Advise on natural resources conservation
	Min. of Agriculture and Water Development	Land and water management

SADC ELMS 1993 (updated 1999)

role encompasses policy formulation, assessment of the available resource, setting up networks for monitoring the resources quantity and quality, and providing global plans for the effective exploitation and conservation of the resource.

The additional duty of service delivery including provision and maintenance of water supply and sanitation is being gradually removed from water agencies and delegated to autonomous and semi-autonomous institutions, local government/ municipalities and the private sector. This is because of the potential conflict of interest if custodianship of water resources and bulk water supply functions are held within a single institution. There is growing realization of the distinctly different functions of guardianship of the resource and the resource use or utilization function, as reflected in the restructuring of the Water Departments in Namibia, Zambia, Tanzania and Malawi to separate the two functions.

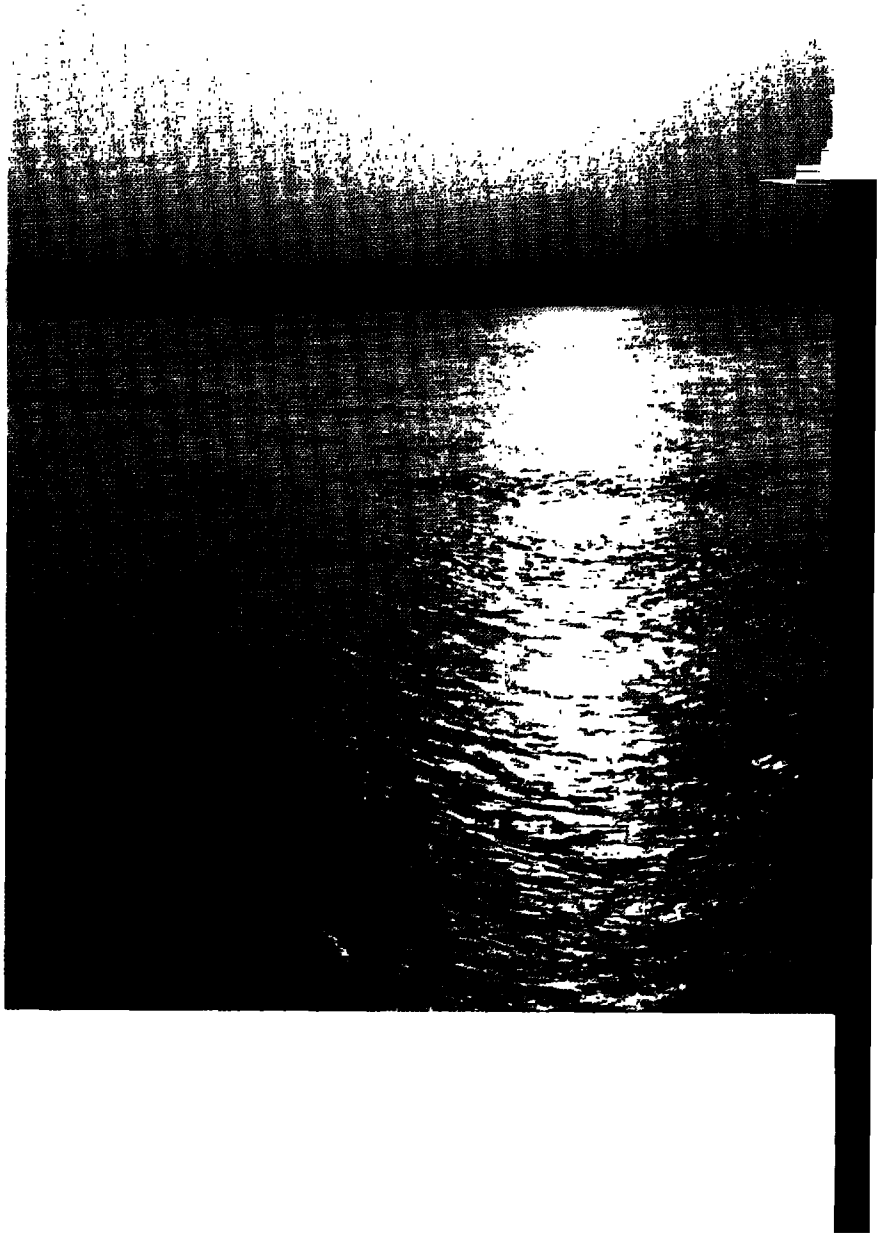
The main focus of water resources agencies is to support the management and protection of water resources in order to ensure that water remains [illegible] for socio-economic development activities. Water is then integrated into the strategic economic policies of the country as natural resource input runs parallel with land resources, which are put to productive use by different sectors of production.

Generally, national institutions are developing policies in line with integrated water resources management principles. However, expertise in water management institutions is still heavily biased towards hydrology and engineering. The latest initiatives to incorporate economics, socio-political issues and environmental disciplines in water resources training will help to alleviate the problem. But there is also need for principles of good water resources management to be incorporated into the other professional fields such as health and agriculture, in order to promote understanding and effective coordination among the sectors.

Most SADC states, and indeed other African countries such as Kenya, Ethiopia and Ghana, are developing water resources management policies and strategies that define and clarify roles and responsibilities of all stakeholders in the sector and establish institutional reforms, as exemplified by the South African National Water Policy and National Water Act, the Tanzania National Water Resources Management Policy, and the Zimbabwe Water Resources Management Strategy. The Zimbabwe Strategy states that "the objectives of the institutional reforms are aimed at:

- defining roles and [illegible] responsibilities of all stakeholders in the sector;
- promoting the involvement of stakeholder institutions in the management of water resources; and
- establishing coordination mechanisms for the efficient management of the sector."

Box 10.18 presents the institutional arrangements put in place in Zimbabwe for the efficient management of



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Institutional arrangements for efficient management of water resources in Zimbabwe Box 10.18

- A national water authority (ZINWA) and a statutory corporation will be formed. The authority will be the apex organization for the management of water resources in Zimbabwe operating on a commercial basis. It is expected that the authority will operate and maintain water works and provide services to other government institutions and catchment councils. The authority has been formed by an act of Parliament through a process of stakeholder consultation. Several meetings and workshops were also held to discuss the formation of this institution. The major functions of the authority will be to advise the minister in the formulation of national policies and standards on water resources management and planning, pollution control, water quality management and protection of the environment.
- Central government, through a smaller and streamlined Department of Water Development, will continue to undertake the statutory and regulatory functions in the sector.
- The local authority institutions, *ie* the urban and rural district councils, will provide potable drinking water in their areas of jurisdiction. The role of these authorities would be to treat and distribute water to the consumers. ZINWA will provide bulk raw water to these institutions for supply to consumers.
- Catchment councils and sub-catchment councils formed under the Water Act will also play a very important role in the management of water. These stakeholder institutions will play a more active role in the allocation of permits for water use, the monitoring of water use, pollution control and enforcement of regulations.
- The catchment outline plan will act as an important tool for coordinating the activities of different sectors within the catchment.
- The private sector will be expected to play a greater role in the development of the sector. Through partnerships with government, the local authority, or on their own, the private sector will be given opportunities in various forms to participate in the sector. The form and nature of participation will differ with the activity.
- The role of rural communities in the maintenance of water facilities will be further strengthened. Through cost recovery the communities increasingly contribute towards the operation and maintenance of water points.

Zimbabwe Water Resources Management Strategy draft 1999

water resources, and is typical of the recent institutional reforms and arrangements that SADC states are making to ensure participatory management of water resources. Through these structures and approaches, the local communities will get a chance to participate in the management of the environment and water resources.

The most significant institutional developments are the adoption of the river catchment as the basic unit for integrated planning and management of water resources in the SADC region, and the legal establishment of catchment management agencies with specified powers and responsibilities (Box 10.19).

The water resources management policies, strategies and laws also assign new roles of water resources management to the various water boards, metropolitan and municipal councils, and water associations.

Functions of catchment management agencies in South Africa Box 10.19

"The initial functions of a catchment agency are:

- to investigate and advise interested persons on the protection, use, development, conservation, management and control of the water resources in its water management area;
- to develop a catchment management strategy;
- to co-ordinate the related activities of water users and of the water management institutions within its water management area;
- to promote co-ordination with the implementation of any applicable development plan established in terms of the Water Services Act, 1997 (Act No. 108 of 1997); and,
- to promote community participation in the protection, use, development, conservation, management and control of the water resources in its water management area."

South Africa National Water Act 1998

10.4.3 Cross sectoral coordination

Cross-sectoral coordination at national levels poses challenges where data and information sharing and consultations are required, for example, in development of water resources management policies and strategies. The coordination and integration of inputs from water-related sectors is usually addressed through formation of committees or similar arrangements with limited duration and scope. It is recommended that the mandate of these structures be extended to cover the implementation of programmes and formulation of legislation, and to address drawbacks identified during the development of policies and strategies.

Similar and parallel cross-sectoral structures should also be established at regional levels, through active, formalized and regular participation of environmental and water resources officials in water sector activities, especially those designed to achieve the goals of integrated water resources management and catchment management. The SADC Water Sector should be tasked to formulate innovative approaches to derive input from users and managers of water from areas outside water departments which can then be integrated to guide programmes and policies at regional level.

Global role players should engage in a dialogue on ecosystems approaches in water resources management, by providing support and by establishing watchdog mechanisms that give feedback on the evolution of the approach globally and promote best practices from southern Africa and elsewhere. The model promoted by the Global Water Partnership (GWP) on integrated water resources management can form a basis for furthering cross-sectoral coordination at the national, regional and global levels.

10.4.4 Public education, awareness and participation

Public participation in policy formulation instills a sense of ownership in the resultant policy and ensures commitment to implementation. Public participation in water resources planning and management is generally still inadequate. Even with promotion of new processes of stakeholder involvement in policy reformulation, it is mainly the urban population and communities or strong and powerful stakeholders such as the electricity companies that manage to participate in and influence the discussion groups.

Awareness about the principles of equitable sharing and allocation of water, sustainable use and principles of wise and economically efficient use of water are only now gaining recognition. Much work needs to be done to improve this situation.

Public awareness of water resources issues, water availability, water quality and links with the environment, are inherited from the interaction between the communities and the land and water as a means of livelihood. The rural poor communities are generally very well informed about the condition of the land and availability of water. However, these communities are not familiar with the policies, management strategies and development initiatives planned by governments, which sometimes lead to conflicts of interest, in particular where large-scale projects are involved, as has happened in the Pangani and Rufiji river basins in Tanzania.

There is need for community education on policies and development strategies for river basins. Communities on the other hand can provide a wealth of information regarding the trends and changes in condition of the catchment as well as suggesting sustainable approaches to water resources management.

10.4.5 Community-based action/programmes

Community-based action in planning, allocation, and monitoring of water use is very important to achieve sustainable utilization of water resources. As mentioned earlier, communities have an intimate relationship with the catchment and their experiences can be integrated into the more scientific approaches to provide strategies for sustainable water resources management and environmental protection. Chapter 9 provides examples of local community-based water resources management initiatives.

Community participation in water resources management is being promoted through revised water policies for example:

In Namibia, the Water and Sanitation Policy (1993) provides for, among other things, the equitable improvement of water supply and sanitation through combined efforts of government and the beneficiaries based on community involvement, community participation and acceptance of mutual responsibility. Water tariffs also reflect the principle of payment by the community as a general rule to cover operation and maintenance costs, taking into consideration the ability of the community to pay. (Country Situation Report 1997)

In Malawi, the government has introduced measures to promote village level responsibility for operation and maintenance for borehole pumps. Similarly in Zambia community participation in groundwater development is strong. In Tanzania, community level functions being promoted include planning water sector activities, implementation of planned activities, operation and maintenance of water schemes.

The National water resources management policies and laws, particularly those of Kenya, South Africa, Tanzania and Zimbabwe, also propose strategies for awareness creation and training of stakeholders, and for mainstreaming gender equality issues in all aspects of water resources management.

Communities need to be empowered to make informed decisions on water management and thus assist government to realize the global goals of strategic planning. Community level participation can be mobilized to deal with emergencies such as floods and extreme droughts. Community participation needs also to be incorporated into policy principles in order to support and promote integrated approaches to water resources management.

10.5 EVALUATION OF REGIONAL INSTITUTIONS

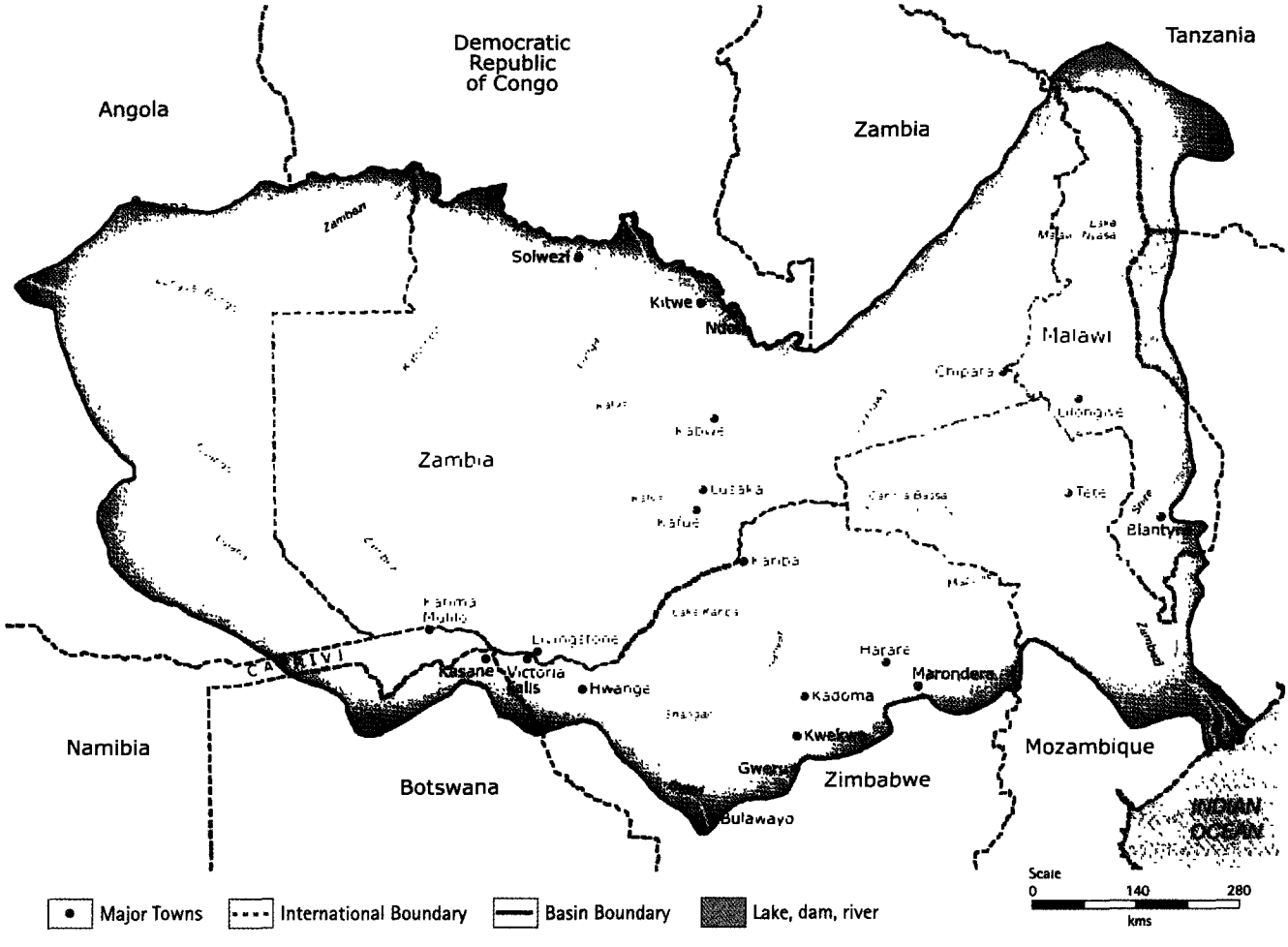
10.5.1 Regional Co-operation — Zambezi, Okavango, Lake Victoria, Lesotho Highlands

The SADC region covers in excess of 9.275 million sq km and 78 percent of this land area falls within the major shared river basins. All the SADC countries excluding the Indian Ocean Islands share at least one river with their neighbours.

At the regional level one of the challenges is in maintaining equitable use/allocation of water especially among neighbouring countries which may be at very different levels of economic development and with wide disparities in information and expertise pertaining to water resources.

Cases where downstream countries are faced with low levels of understanding of their water resources and lack long term plans for their utilization, need to be addressed in order to promote mutual trust, and transparency in development of shared watercourses. These issues are currently being addressed through projects such as the SADC-Hydrological Cycle Observing Systems (HYCOS) which will make data available on water resources quantity, quality and hydrometeorology, seamlessly and in real time, to all member states with the appropriate equipment. However, environmental water requirements tend to be at the tail end of negotiated flows in the absence of relevant data and established institutional frameworks for monitoring of river systems.

Zambezi River Basin **Map 10.1**



Zambezi River Basin Atlas, SADC/DENCONSULT/ZRA, Lusaka 1998

At a different level are complex ecosystems such as Lakes Victoria, Malawi, T[illegible] and Kariba, the Kafue flats and the Okavango delta. Apart from the situation of Lake Victoria, which extends beyond the SADC region and is therefore not entirely bound in terms of policy framework by the Protocol on Shared Watercourses, legislative and institutional frameworks for the management of these complex systems are generally still weak.

The provisions of the Protocol on Shared Watercourses seek to promote equitable and sustainable management and development of international waters in the region but the underpinning institutional frameworks and legislative requirements at the national, bilateral and multilateral levels will be the main determining factors for its success. Adequate information regarding the resource base, environmental flow requirements and the levels of pollution and other environmental threats have to be determined as part of baseline information for effective management of the systems and to be integrated into [illegible] agreements governing shared watercourses. Thus the interpretation of the Protocol to include and explicitly outline these issues has to be expedited in light of the threats to the water resources.

Against this background, regional cooperation on water resources management and planning poses a significant challenge, and the SADC countries have risen to the challenge through several forms of cooperation and political commitment on joint water and related initiatives over the years. The support of donors and other cooperating partners in strengthening the transboundary water development initiatives and cooperation on water resources management also contributes to the implementation of some best practices and experiences from around the world.

In the Zambezi river basin, wide cooperation is being initiated through the ZACPLAN whose main objective is to promote sustainable utilization of the water resources of the entire basin. However, this programme, which has been in existence for almost 15 years, has not borne tangible results, mainly due to poor institutional settings and lack of budget provisions for individual projects.

The success of ZACPLAN will only be realized when an institutional framework with a mandate over the whole basin and political backing of the basin states has been adopted. The bilateral agreements between basin states (*eg* Zambezi River Authority) and the major projects on the basin (*eg* Cahora Bassa) need to be adequately integrated into the management strategy adopted by the basin states. The ZACBASE with its data and resources needs to be operationalised by linking it to real-time data sources and utilized to provide alternative large-scale development and management scenarios for the basin.

The establishment of the Permanent Okavango River Basin Water Commission (by Angola, Botswana and Namibia) in 1994 is a proactive approach needed for sustainable development of this ecologically important inland river basin. The ecological survival of the Okavango delta, a World Heritage site, depends entirely on wise development of the river basin by the three basin states. There is currently little development of water resources in the Okavango river basin and this would be the best time for a detailed assessment of ecosystem water requirements in order to guide future plans for utilization of the resources in the basin.

The Lesotho Highlands Water Project, based on the 1986 treaty signed by the governments of Lesotho and RSA, is an example of cooperation on technical-operational, legal-institutional and political levels. The technical cooperation including sharing of data, information and research studies, and collaboration is witnessed through the Orange River Re-planning Study, initiated in 1994 to address sustainable development of the water resources of the entire basin.

The study has served to strengthen the basis for sharing the water resources of the basin and highlights the environmental constraints and opportunities within which to operate the system, factors which were not clear at

DWAF, South Africa

SADC countries have risen to the [illegible] of managing shared water resources [illegible] several forms of cooperation and political commitment on joint water and related initiatives, such as the Lesotho H[illegible] Water Project.

inception of the project, and which are likely to pose future challenges to meet provisions of new water policies in the two countries. The political and institutional framework is being catered for within the SADC structures as well as through multilateral cooperation among the basin states. The affected countries (Botswana, Lesotho, Namibia and South Africa) are consulting on the formation of a basin wide commission.

10.5.2 Regional environmental mandates

The SADC ELMS is mandated to coordinate the development and implementation of all environment management issues including policies, strategies and action programmes. In approving the SADC Policy and Strategy for Environment and Sustainable Development in 1996, the SADC Council of Ministers stated that ELMS must assume a new "watch-dog" role to ensure that economic growth and development strategies are consistent with SADC's environmental objective, as well as principles of equity and priority to the poor.

This new role entails the development of environmental standards, guidelines and regulations to be adopted and enforced by all member states; developing and harmonizing regional positions in negotiations in international environmental conventions, protocols and other agreements, and assisting member states to develop national action programmes for implementing such agreements; intersectoral coordination and close collaboration with all the SADC Sectors to ensure that their programmes and activities integrate environmental management concerns for sustainable development.

Inter-sectoral coordination is necessary particularly with sectors related to agriculture, energy, forestry, wildlife, water, mining, industry, trade, and livestock development, whose activities impact on the environment more directly.

The SADC Water Sector is mandated to coordinate the development and implementation of policies, strategies and programmes in all aspects of water resources development and management, at the national and regional level, and with emphasis on transboundary watercourses. The Coordination Unit of the Sector has elaborated the *Regional Strategic Action Plan for Integrated Water Resources Development and Management in the SADC Countries 1999 – 2004*, the major objective of which is "to develop a comprehensive and integrated approach to water resources management and development. Such an objective is to be accomplished through commitment to:

- attaining a much stronger human and institutional capacity to formulate laws, policies and norms which allow water resources to be used cost-effectively as economic and social goods; and
- ensuring the more efficient use of existing and planned infrastructure projects which harness water's potential in an environmentally and economically sustainable manner." (SADC WSCU 1998)

The seven strategic objectives, with detailed immediate results, identified in the Strategic Action Plan are:

- improve legal and regulatory framework at the national and regional level;
- improve national and transboundary river basin management, planning and coordination;
- strengthen linkages among macro-economic, social and environmental policies;
- improve information acquisition, management and dissemination;
- support awareness building, education and training;
- promote public participation; and,
- invest in infrastructure. (SADC WSCU 1998)

Projects being developed and implemented from these objectives will adopt an integrated approach to include environmental concerns. There is still a need to develop and agree on an integrated water resources management policy that provides for ecosystem requirements and conservation of the fragile ecological water resource base. This will be achieved through intersectoral coordination and participation of relevant SADC sectors as stakeholders in water resources policy formulation.

The Regional Protocol on Shared Watercourses also embodies elements of integrated water resources management and calls on member states to:

- develop close cooperation for judicious and coordinated utilization of the shared watercourse systems in the SADC region;
- coordinate environmentally sound development of shared watercourse systems in order to support socio-economic development;
- hold regional conventions on equitable utilization and management of the resources of shared watercourse systems; and
- consolidate other agreements in the SADC region regarding the common utilization of certain water course systems.

In October 1999, SADC Ministers of Environment directed SADC ELMS to develop, in the usual consultative

manner, a SADC Protocol on the Environment. This protocol will enable the region to have a legally binding agreement on the "green", "blue", and "brown" environmental issues as well as on socio-economic issues such as trade, and international obligations as they affect the environment and sustainable development in the region.

Regional mandates are clearly defined and specific to the different SADC sectors, but are of necessity complementary. Stakeholder participation and the highly consultative process demanded by SADC ensures intersectoral coordination and harmonious development of regional agreements on sustainable environmental management.

10.6 ELEMENTS OF ENVIRONMENTALLY SOUND WATER RESOURCES MANAGEMENT POLICY

The analysis in this chapter has revealed that a wide range of national and regional environmental management policy and institutional reforms are taking place in the SADC region. At the national level, new water policies, laws, strategies and master plans are being prepared. Environmental management agencies and river basin and catchment agencies are being established. There is also a fundamental shift in national policy and institutional reforms towards integrated water resources management approaches emphasizing economic efficiency, environmental sustainability and social equity. At regional level, the *Regional Strategic Action Plan for Integrated Water Resources Development and Management in SADC countries, 1999 – 2004* provides the basis for designing various water resources management projects.

However, reviews in preceding chapters have identified challenges, weaknesses and key environmental issues that need to be addressed to make the emerging trends effective. One of the key challenges is to agree (at SADC level) on the definition of environmental sustainability and the criteria for its integration into the policies, legislation, planning and management of water resources. Chapters 3 to 8 in this report have made various suggestions on how to integrate environmental sustainability into water resources management, and the challenge will be for the relevant SADC policy-making bodies to endorse the recommendations and provide specific guidelines on how to implement them.

The sequence of developing environmental policy and institutional frameworks should be such that an over-arching and comprehensive environmental management policy should be developed first, then the sectoral water policy, and finally the legislation to give effect to the implementation of the sectoral policy. This approach will avoid conflicts between environmental and water laws.

It is important that policy and legal frameworks should be developed in a highly consultative, multidisciplinary and intersectoral manner involving all stakeholders to ensure harmonious implementation. Customary laws and traditional knowledge and technologies which have successfully been used in managing natural resources should be incorporated into water resources statutes.

Current trends in SADC member states indicate that by the year 2025 most countries should have developed comprehensive and enforceable water resources management policies and legislative frameworks. Similarly, the SADC Water Sector's Regional Strategic Action Plan has identified 31 projects, with priority to the development of legal and institutional frameworks for the management of shared river basins.

For policy, legislative and institutional frameworks to be effective, they have to empower and involve the local communities. In this regard, stakeholders have to be identified and assisted to participate fully in the process of developing the frameworks. Integrated catchment or watershed or river basin management approaches, that confer through policy and legislation, ownership and management roles to well-informed local communities will help to ensure the conservation and protection of the ecological water resource base, especially where large diffused populations in many rural areas rely directly on water resources for their subsistence.

To facilitate effective stakeholder participation, public awareness and education on the important links between environment and water resources should be carried out as a continuous process and should encourage early exposure of children, the youth and rural populations to water resources management issues. Sensitization of politicians and policy-makers to obtain their commitment is another aspect to be incorporated in policy and legislative frameworks. The role of women in natural

resources management in general and in water resources in particular should be incorporated and strengthened through policy and legislation. The policy and legislation should also create a conducive environment for private sector participation in water resources management, as emphasis has shifted to the use of market and economic instruments for water resources management.

Policies and legislation should promote capacity-building and strengthening of environmental and water institutions, including the training of experts in environment and water management, and in the specialized areas as recommended in chapters 3 through 8. The roles and responsibilities of central government agencies, catchment management agencies, and other participatory institutions and bodies including private sector and rural and urban local communities, need to be clearly defined both in policy and in law.

Policy and legislation should include explicit guidance on river health classification criteria and this would provide a clear basis for translating EFR determinations into quantitative, preferably statutory management objectives which can then be incorporated into river basin management planning.

Watershed degradation should be dealt with through specific measures [illegible] and legislation) that protect water resources through national and regional conservation strategies. However, experience has shown that using catchment areas and river basins as units of water resources planning and management with the appropriate community participation is the most effective approach (refer also to Chapter 9). Land-use zoning laws and regulations should be strengthened and strictly enforced to minimize impacts on water resources.

To manage and control water pollution (refer to Chapter 6), the following issues need to be considered: harmonization of national policies; instituting community-based and private sector monitoring programmes; applying the polluter-pays-principle; encouraging low or zero pollution through economic incentives and strict enforcement of EIA application; sharing nationally and regionally information, data and networking on pollution issues and control measures; using local expertise in developing regulation and strategy.

Water weed control should include measures to ensure better fertilizer management techniques; preventing weed invasion through awareness and better watershed management especially by local community involvement; making environmental impact assessment (EIA) mandatory; promoting economic use of weeds.

EIA is a vitally important tool in the SADC region for strengthening the environmental aspects of water resources management, but is weak and needs national policies and legislation to make it strong and effective. Chapters 3 to 8 have all recommended that EIA be made mandatory in integrated water resources management. All countries need to develop and adopt EIA regulations and establish guidelines and standards, as well as harmonize procedures; develop implementation capacity through tailored training programmes; and adhere to strict enforcement of EIA. Specific and directed measures need to be undertaken to effectively implement EIA provisions.

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A FRAMEWORK FOR MAINSTREAMING THE ENVIRONMENT IN WATER RESOURCES MANAGEMENT

Rafik Hirji, Paul Maro and Heather Mackay

CONTENTS

A FRAMEWORK FOR MAINSTREAMING THE ENVIRONMENT IN WATER RESOURCES MANAGEMENT

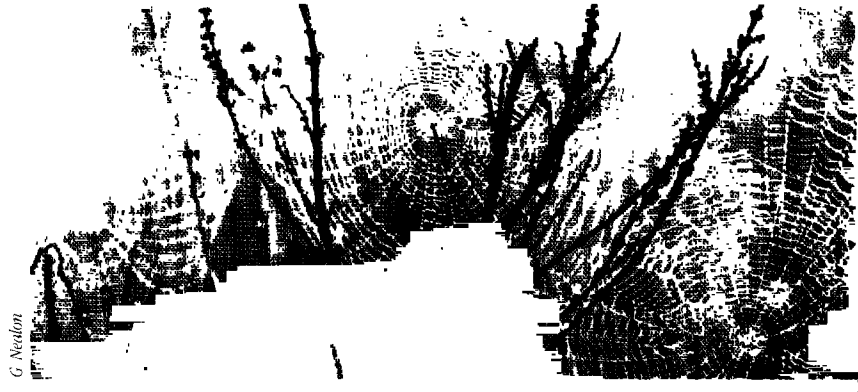
11.1 INTRODUCTION

Water is an essential and limited resource in the Southern African Development Community (SADC), as seen in preceding chapters, and it is scarce in a number of local areas, basins and countries in the region. Water resources in the region are also vulnerable due to:

- high variability of the climate, which is compounded by global climate change; and
- degradation and depletion of water resources by people due to many factors including,
  - inefficient water use;
  - inadequate water allocation mechanisms;
  - increasing water pollution;
  - increasing watershed degradation;
  - encroachment into wetlands by development and other land uses;
  - losses of aquatic biodiversity;
  - proliferation of aquatic weeds; and
  - introduction of alien species.

The depletion and degradation of water resources worsens poverty and is compounded by poverty, and in some cases by conflict, as well as by:

- weak policy, legal and institutional frameworks that do not provide for management of water resources in an integrated manner, or do not offer adequate practical and legal opportunities for communities to participate in the project planning and management decision-making process and to resume their traditional role as active custodians of nature and natural resources; and
- the presence of numerous international water bodies, which complicates the sharing and management of the water resources as a result of the complexity of arrangements and treaties made between peoples and states, but which also offers an opportunity to advance regional integration through joint custodianship and unity of purpose.



G. Nealon

Water resources in the region are vulnerable to climate variability and human activities.

The ongoing water sector reforms in the region provide a unique opportunity for discussing emerging water resources management challenges and for promoting the management of water resources in an integrated manner; in particular, the specific aspects related to the integration of environmentally sustainable principles and practices.

The challenges associated with this integration are significant (Box 11.1), but initial indications suggest that the importance of the water/environment interface is increasingly being recognized. There is a need, however, to elevate the discourse and there is broad support for ongoing efforts to ensure that environmental sustainability becomes one of the primary objectives in any regional, national, basin or local water resources strategy, programme or project. This will ensure that the benefits of water resources development investments, as well as the benefits from natural aquatic ecosystems, will continue to be enjoyed into the future.

Key challenges in the integration of environmental sustainability criteria into water resources management **Box 11.1**

- The concept of sustainable water resources management is poorly understood.
- Environmental sustainability criteria for the water sector are absent.
- Economic analysis of the environmental and social costs and benefits of water resources development and management is inadequate.
- The environmental impact assessment process is generally ineffective due to weak implementation.
- Consultations and representation in the EIA process and in water resources management decision-making are inadequate.
- Current water policies are not environmentally sustainable.
- Environmental regulations for international waters are inadequate.
- Capacity to carry out complex environmental and socio-economic analyses is limited.
- Representation of water users in water management institutions and participation of water users in water resources planning and management decision-making is inadequate.
- Regulatory frameworks for water resources management are generally weak.
- Capacity to manage lakes and other aquatic ecosystems is limited.
- Public sector water and energy utilities are generally not perceived to be providing people with equitable access to the basic services that are considered to be benefits of sustainable water resource utilization.

The concept of water management adopted by SADC seeks to integrate the planning, development and traditional management of water resources across all use sectors through an integrated process which promotes the coordinated development and management of water, land and related resources in an equitable manner without compromising the sustainability of vital ecosystems. The concept of Integrated Water Resources Management (IWRM) is a holistic management philosophy that fully recognizes:

all natural (biophysical) aspects of the surface and groundwater resource systems, including variation in time and space;

all sectors of the economy that depend on water and hence the complete suite of inputs and outputs related to water, including waste water;

relevant national objectives and constraints, including social, legal, institutional, financial and environmental objectives and constraints; and,

the complexity of spatial resources distribution and competing demands such as upstream-downstream interactions, inter-basin transfers and shared watercourses.

In recognizing that everyone should benefit from the natural resources of the region, and that 15 of the region's watercourses are shared by two or more countries, a policy framework (SADC Protocol) was negotiated, and came into force in 1998. In 2000 the protocol was revised in line with new trends in the management of shared resources and to strengthen the original protocol.

The Protocol on Shared Watercourses in the Southern African Development Community and the Regional Strategic Action Plan (RSAP) for Integrated Water Resources Development and Management in the SADC Countries (1999-2004) provide a framework for the region to successfully meet the challenge of developing a comprehensive and integrated approach to water resources development and management. In addition to the protocol, most countries in the region are undergoing major reforms to strengthen national water resources management policies, laws and institutions and are building their capacity to be able to meet the emerging water resources management challenges. Such an objective is to be accomplished through a commitment to:

attaining much stronger human and institutional capacity to formulate laws, policies and norms which allow water resources to be used cost effectively as an economic and social good, and

ensuring the more efficient use of existing and planned infrastructure projects which harness water's potential in an environmentally and economically sustainable manner.

Awareness-building around IWRM in the context of the RSAP and the SADC Protocol on Shared Watercourses has been identified as an essential element in advancing and sustaining IWRM at national, basin and regional levels.

This technical report, therefore, also addresses the aspects of information provision, awareness-building and knowledge-sharing among the peoples of the region so they are able to take informed decisions together that will see the SADC region move away from regarding IWRM as a concept to IWRM being an integral practice.

The report recognizes the importance of engaging the parliaments, local government and communities, as well as the judiciary, private sector, media, universities, research institutions and think tanks.

The report also internalizes gender perspectives through acknowledging the key role played by women in the usage of water resources in this region, the impor-

tance of involving women as key stakeholders in the conception, formulation and implementation of initiatives, and the role that women, men and youth should play in the management of these resources.

The implementation of the RSAP and the Protocol on Shared Watercourses can also benefit by incorporating the key messages from recent global events such as the World Water Vision and the Report of the World Commission on Dams. This technical report:

1 underscores the central message from these global fora that,
effective development and effective management of water resources are essential for sustainable growth and poverty reduction in the SADC region, and sustainable water resources management requires finding a balance between the needs of the people and the protection of the natural resource base, so that water resources can continue to provide benefits for improving people's livelihoods and quality of life, reducing poverty and fostering economic growth into the future.

2 provides a well-defined operational context for mainstreaming the relevant management elements for achieving the necessary degree of protection of the water resources.

In the SADC region, the imperative for ensuring that the primary resource base remains secure and protected is not only clear but is a regional priority, given the limited endowment of water resources and the economies and social systems that are highly dependent on the timely availability of water.

Considerable attention has been or is being placed on promoting cooperative mechanisms for managing shared watercourses and for developing the capacity for natural disaster prevention and preparedness. However, inadequate attention has been given to needs for addressing the land-use and water-use practices that are degrading and depleting the water resources. This report recommends the development of a policy, legal and institutional framework and capacity for managing the uncertainty associated with human-induced degradation of water resulting from unsustainable land and water use practices.

This final chapter provides the framework of actions for mainstreaming environmental sustainability criteria in water-resources planning and management decision-making. Box 11.2 highlights the multiple dimensions of the IWRM challenges.

The IWRM challenge has multiple dimensions Box 11.2

- Challenges related to uncertain climate require responses that can improve prediction and forecasting capabilities, and adaptation and mitigation measures to manage climate variability and climate change, including the need for drought management strategies, new storage facilities, flood control, etc.
- Challenges related to growing population, increasing demand and low level of supply coverage require responses that encourage improved use efficiency, expansion of services, management of water utilities, demand-responsive approaches for community supplies.
- Challenges related to growing degradation of water resources require actions that support wise use of water, allocation of water for environmental uses, demand management, protection of sources and the resource base (including watersheds, recharge areas, wetlands, etc. through control of land use, land use policies, zoning, etc.), management of waste discharges from point and non-point sources, and management of invasive weeds on the basis of decentralized management at the basin or catchment levels.
- Challenges related to the management of transboundary rivers, lakes, aquifers and wetlands require innovative responses that are based on joint and cooperative actions to find mutually beneficial solutions to allocation issues, water management concerns (such as flood management) and the management of aquatic ecosystems.

11.2 KEY LESSONS EMERGING FROM PRECEDING CHAPTERS

Previous chapters have shown the severity of present and emerging threats to sustainability of water resources in the SADC region, and have highlighted the magnitude of the challenges facing the region in moving towards sustainable water resources management and equitable distribution of the costs and benefits of the development and utilization of water resources. The thematic reviews in each chapter of the current situation in the region and discussions of emerging future options at the policy, regulatory and operational levels provide several important lessons for SADC countries, which are consolidated below.

Sustainable water resources management is underpinned by good information.

The scarcity of reliable quantitative information for water resources management is one of the major weaknesses for most SADC countries. Integration of environmental sustainability issues into water resources planning, development and management requires that cost-effective, long-term monitoring programmes be established to collect information on aspects such as:

water availability;
water quality;
present and future water and land uses;
projected demands on water resources;
state of the aquatic environment;
local knowledge and indigenous knowledge systems;
macro-economic trends which affect demographics and hence water demand;
the status of water resources, in terms of both biophysical factors and ecological health; and
indicators of economic wellbeing which allow assessment of the degree to which environmentally sustainable utilization of water resources is generating socio-economic benefits for communities.

- **Awareness should be generated of the need to quantify the value of all goods and services provided by water resources, not just water.**

All stakeholders including those who make policy and decisions at all levels need to be sensitive to the range of goods and services provided by water resources apart from just water, and that the maintenance and utilization of these goods and services depend to a large extent on the protection and maintenance of healthy, functional aquatic ecosystems. Planners and water users should identify and quantify the economic values of such goods and services, and make this information widely accessible. The emphasis on the ecological and biophysical dimensions must be complemented by the socio-economic considerations of impacted people and communities. As a matter of course, these economic values should be included in full cost-benefit analyses which address environmental, social and economic costs and benefits of water resources development and management decisions in an integrated manner.

- **Biodiversity of aquatic ecosystems is critical to ensuring the sustainability of water resources utilization.**

If water resources, and the many goods and services which they provide, are to be managed as renewable resources, then restoration and maintenance of the natural biodiversity of aquatic ecosystems is vitally important in ensuring that water resources retain their resilience and ability to recover from the pressures of utilization. Policy and regulatory frameworks and watershed management strategies must recognize the biodiversity of aquatic ecosystems as a key criterion in sustainable water resources management.

- **The water requirements of aquatic ecosystems should be given clear status in law, policy and planning processes.**

The provision of sufficient water of adequate quality, delivered in as close to a natural flow regime as possible, underpins the protection of aquatic ecosystems, which in turn ensures the sustainability of water resources. In order for the water requirements of aquatic ecosystems to be assured, explicit and clear status should be afforded to these water requirements in water policy and law, and there should be clear indications given of how they will be addressed in decisions on water allocations. Environmental policy and law should specify that the water requirements of aquatic ecosystems be addressed in the earliest planning stages of water resources development projects and water resources management and allocation decisions. Determinations of the water requirements of aquatic ecosystems should be based on the principle of maintaining an adequate level of natural ecological processes and functions to sustain the provision of the various goods and services that are valued or relied upon by communities. To support this, a river health classification system needs to be established.

- **Sectoral policy, regulatory and planning frameworks related to watershed management should be harmonized and consolidated.**

The links and cause-effect relationships between land-use and water resources should be explicitly recognized in policy and regulatory frameworks. This may require that sectoral policies, such as those addressing agriculture and livestock, energy, mining, industrial development, water resources management, services provision and environmental protection and management, be reviewed, harmonized and possibly consolidated in order to promote integrated management of land and water resources at a watershed level.

The use of Strategic Environmental Assessment (SEA) approaches should be promoted and followed when planning and setting objectives for land and water resources management. Institutional structures and mechanisms may need to be concurrently reviewed and reformed in order to implement integrated watershed management strategies.

- **Meaningful representation of user groups in water management institutions and participation of communities in planning and decision-making is essential.**

Water resources institutions such as river basin authorities must be representative of the multiple water-user interests in the basin. Planning and decision-making processes related to development, allocation and utilization of water resources must be broadened from a narrow technical exercise to also integrate effective participation of water-user groups, including private sector and communities impacted by such decisions. The processes should be community-driven, and should address the short-term and long-term socio-economic needs of these communities.

Community and user participation in the planning and management decision-making processes helps to ensure that the distribution of costs and benefits of water resources development, allocation and management is equitable. If stakeholders perceive the distribution of costs and benefits to be unfair, they are unlikely to change the ways in which they use and impact upon water resources.

- **Preventive management is more cost-effective than rehabilitation or remediation.**

The long-term costs of rehabilitation or remediation of degraded water resources, and restoration of the goods and services provided by these resources, usually far outweigh the short-term economic benefits of over-exploitation, whether through over-abstraction, pollution or poor land-use management. The precautionary principle should be applied in decisions regarding development and allocation of water resources, or those regarding control and management of land-based activities which cause degradation of water resources. Preventive management strategies should also include and promote demand-side management approaches, over supply-side interventions.

- **Successful control of invasive and nuisance species requires commitment to holistic, long-term management strategies.**

The control of invasive and nuisance species, particularly aquatic weeds, requires the development and implementation of holistic long-term strategies if it is to be both successful and cost-effective. Preventive management remains the most efficient way of dealing with the problem of invasive species, but once they are present in a water resource, short-term controls such as mechanical and chemical methods must be balanced with longer term approaches such as biological controls and with long-term commitment to integrated control programmes. Collaboration between neighbouring countries and those sharing water resources is essential, and control programmes should be designed and implemented jointly by all countries in shared water resources.

- **Environmental sustainability criteria should be incorporated into strengthened regulatory frameworks and effective implementation promoted.**

Regulatory frameworks for water resources management should be strengthened, particularly where related to the assessment and mitigation of environmental impacts on water resources (Box 11.3). Environmental sustainability criteria should be incorporated into regulatory frameworks, utilizing regulatory tools that are:

flexible, *ie* they can take account of the needs of different socio-economic development situations and different biophysical and ecological characteristics of water resources;

relatively simple to administer and enforce, so that implementation can be effective even if capacity and expertise are limited at the community level;

Typical water quality management and pollution control objectives — Box 11.3

Water quality management and pollution control measures are instituted typically for meeting the following types of objectives:

Protect human health against pollution. This is to ensure that health requirements are met, that maximum limits for the concentration of pollutants in the environment and in products are set in light of human health criteria and taking into account the concepts of the basic protection level and no effect level.

Safeguard the natural environment. This is to ensure that ecological requirements are met and other needs are taken into account which are based on criteria applicable to the species or the ecological systems in question. The basic-protection level and the no-effect level must be taken into account.

Restore, preserve and improve the quality of human life. This is to maintain an agreeable and attractive environment in which human potential is well-rooted and which nourishes the human spirit. Social and cultural requirements constitute an essential factor in deriving water quality and pollution control objectives.

appropriate, *ie* tailored to suit southern African aquatic ecosystems rather than imported from northern temperate countries with no modification; based on the use of economic instruments such as charges, incentives and penalties, in order to promote self-regulation and encourage minimization of impacts on water resources.

Existing expertise and capacity in the region can be mobilized through establishment and facilitation of effective knowledge-sharing networks.

Expertise and capacity for sustainable water resources management is severely limited in southern Africa, especially in the public sector. This is a critical weakness, since it is primarily public sector organizations such as government agencies and river and lakes basin authorities which are responsible for the various aspects of water resources management. Communication between the different countries is often slow and ineffective, and sharing of knowledge between professionals and water resource managers at the operational level is frequently constrained due to bureaucratic processes. At the national and regional levels, innovative strategies are needed in order to overcome existing barriers to sharing of knowledge, experience and expertise.

11.3 A FRAMEWORK FOR ACTION

The previous chapters have outlined some of the important ways that poverty and economic development are inextricably linked to environmental sustainability, and in particular to water resources sustainability. The primary focus of SADC is to promote economic growth, to alleviate poverty and to foster regional cooperation. In that regard the sustainability and sustainable utilization of the water resource systems are not ends in themselves, but essential components of the welfare and security of people and their livelihoods, especially the poor wherever they may live.

This section proposes a framework for action for achieving the broad objectives of systematically mainstreaming environmental sustainability objectives in (Box 11.4) water resources planning, development programmes and investments.

Environmental sustainability criteria for water management — **Box 11.4**

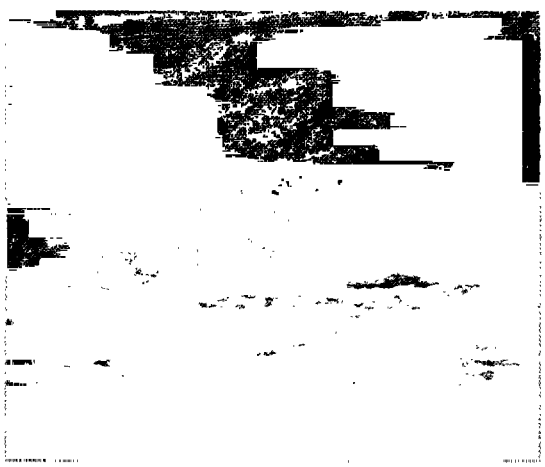
- A minimum water requirement to be guaranteed to all people to maintain human health.
- Sufficient water to be guaranteed to restore and maintain the health of ecosystems. Specific amounts will vary depending on climatic and other conditions. Setting and implementing the environmental flow requirements will require flexible and dynamic management.
- Data on water resources availability, use, and quality to be collected and made accessible to all parties.
- Water quality to be maintained to meet certain minimum standards. These standards will vary depending on the location and how the water is to be used.
- Human actions should not impair the long-term renewability of freshwater stocks and flows.
- Institutional mechanisms to be set up to prevent and resolve conflicts over water.

Gleick *et al* 1999 (see References chapter 2)

1 Adopt a clear framework for environmentally sustainable water resources development and management.

- Action SADC

Sustainable water use is defined as the use of water that supports the ability of human society to endure and flourish into the indefinite future without undermining the integrity of the hydrological cycle or the ecological systems that depend on it. SADC should develop an



L. Basto

The Pungwe river is one of 15 shared watercourses in SADC.

accepted framework which incorporates a limited set of outcomes (with explicit goals and criteria) to express this concept of sustainability, and make it operationally useful in assessing where present policies and plans may lead or are leading or in deciding among alternative strategies.

For successful implementation, any framework for sustainability of water resources needs to include:

- policy and legal instruments which clearly establish the status of aquatic ecosystems;
- tools for setting quantitative objectives for protection of water resources (quantity and quality of water required for aquatic ecosystems);
- a river health classification index;
- regulatory tools for controlling and auditing direct water use such as abstraction and discharge in order to ensure that protection objectives are met (includes environmental flow requirements, effluent standards, water quality objectives, EIA, licensing procedures);
- regulatory tools for controlling and auditing people's behaviour and use of land and water, in order to ensure that protection objectives for aquatic ecosystems are met (land use practices, water conservation and demand management practices);
- appropriately designed monitoring networks and information management systems which provide the necessary information to support sustainable management of water resources.

- Action Member States

Countries should actively engage in the preparation of a SADC framework for environmentally sustainable water resources development and management, which they can adopt and use at national level to critically measure other sectoral policies and plans (*eg* agricultural, economic, environmental and water policies) in terms of their contribution to or impact on the sustainability of water resources.

2 Broaden economic evaluation methods at project and programme planning levels.

- Action SADC

An improved understanding of the economic values of all the goods and services provided by aquatic ecosystems, (not just water), should be promoted by SADC, particularly at the levels of policy, planning and decision-making, but also engaging other stakeholders.

International water resources projects in shared river basins should, as a matter of course, incorporate full socio-economic analysis of environmental costs and benefits as part of the options analyses at the planning stage.

- Action Member States

There is a need to broaden the currently used, project economic evaluation methods to incorporate the benefits of environmental management and socio-economic implications of the degradation of water resources and aquatic ecosystems in order to improve and inform project decision-making. This is because of the growing recognition that economic and environmental objectives are compatible rather than conflicting.

Sharing of water for environmental and other uses may seem like a zero sum game, but it is not a win-lose situation. Experience has shown that if downstream fisheries, agricultural productivity and groundwater recharge functions, and the storage nutrient cycling functions and water cleansing functions played by wetlands are not protected, the overall economy suffers.

Countries should incorporate, into regulatory procedures such as EIA and into planning processes for land-use and water-resources development, full socio-economic and cultural analysis of costs and benefits related to all goods and services provided by aquatic ecosystems.

3 Strengthen the role of planning tools such as the Environmental Impact Assessment (EIA) and Strategic Environment Assessment (SEA) in project planning and decision-making.

- Action SADC

EIA is a limited planning tool at the basin level. Here, Strategic Environmental Assessments are more useful for assessing options and planning decisions, since EIA is project-focused and reactive instead of proactive. The value of Strategic Environmental Assessments as planning tools related to sustainable resource management should be highlighted more strongly.

- Action Member States

Countries should strengthen their planning tools, particularly the implementation of the EIA process, and encourage and broaden the emerging tools such as SEA; and work towards strengthening the contribution of EIA to

project decision-making. Countries without EIA policies and legislation should adopt these, while countries with EIA policies and legislation can improve the effectiveness of EIA implementation. Box 10.15 (in chapter 10) described the factors that enhance the role of EIAs in project decision-making.

Mainstreaming is consistent with a changing focus and orientation from a "do no harm" to "promote improved development" that should be adopted in EIA policies at a country level. This calls for improving EIA effectiveness in project planning and management decision-making, and addressing factors that undermine the influence of EIAs in project decision-making. In addition, the following elements should be considered:

- Introducing and encouraging the use of Strategic Environmental Assessment as a strategic planning tool for sustainable water resources management.
- Expanding the use of Sectoral Environmental Assessments and Regional Environmental Assessments;
- Increasing the emphasis on basin-wide understanding of the ecosystem's functions, values and requirements, and how community livelihoods depend on and influence them, before decisions on development options are made;
- Valuing ecosystem, social and health issues as an integral part of project and river basin development, and giving priority to the avoidance of impacts, in accordance with a precautionary approach;
- Selecting project options that avoid significant impacts on threatened and endangered species. When impacts cannot be avoided, appropriate mitigation measures and viable compensation measures must be put in place;
- Ensuring that project affected stakeholders are consulted in a timely manner and that their views are incorporated in the final project design.

4 Accord clear status, determine and give effect to water requirements for aquatic ecosystems and basic human needs.

- Action SADC

Effective environmental and water resources management requires that water property rights are clearly defined to protect the interests of various stakeholders. Changing water property rights has relevance to poverty and social stratification and affects the efficiency of water use and its allocation. It is important to protect the services provided by water resources, which depend on the quantity, quality, and assurance of water, and which are needed to protect basic human needs and the structure and functions of ecosystems so as to secure ecologically sustainable development and use. SADC WSCU and SADC ELMS should support countries to develop the legal frameworks at national level for environmental management of water resources. This is important for both national and international water allocation systems. SADC should review the Protocol on Shared Watercourses to ensure that it makes adequate provision for the status and determination of water requirements of aquatic ecosystems and basic human needs. SADC should also support the efforts of member states to undertake studies to determine the quantity and quality of water required for aquatic ecosystems and basic human needs.

- Action Member States

Countries should review, reform and harmonize water and environmental policy and legal frameworks to clearly establish the status of water quantity and water quality allocations for aquatic ecosystems and basic human needs. Countries should establish locally driven, inclusive processes to determine water requirements for aquatic ecosystems and basic human needs; and should ensure that environmental flow assessments are integral components of impact assessment, including provision for monitoring to allow potential revisions of flow requirements at specific intervals.

For example, environmental flows can and should be released from major dams and hydraulic structures, but equal attention needs to be given to the issue of controlling run-of-river abstraction. The provision of environmental flows and the control and auditing of water abstraction are much more difficult in unregulated rivers, but must be addressed if aquatic ecosystems are to be fully protected.

5 Mainstream environmental issues in water resources planning, development and management.

- Action SADC

SADC should support countries' efforts to build national and local government agencies responsible for environ-

mental protection of water resources, to develop EIA policies, procedures, and regulations. There is a reliance in the region on sector-oriented water policies, which rely on the command-and-control approach, are difficult to implement and coordinate, and do not properly integrate environmental quality objectives. Instead of building a unity of purpose, these have the opposite effect, creating scattered and competing interests.

SADC should support water policy reforms that integrate all water-related sub-sectors, including environmental uses of water and should espouse the use of the following appropriate instruments:

- economic (*eg* pricing, tariffs, demand management, and subsidies, etc.);
- regulatory (*eg* laws and regulations) and participatory (*eg* user representation, and transparency);
- participatory planning and decision-making, education, awareness, consultations, etc.; and
- social and cultural engagement (*eg* recognizing and respecting local and indigenous knowledge, attracting local expertise, and working in partnership with community leadership in locally driven processes).

- Action Member States

Countries should mainstream (*ie* ensure the systematic and timely integration of) environmental quality objectives in water resources investments, planning, development and management decision-making in water resources infrastructure projects and policy reforms. For most water development projects it would be possible to balance development objectives with the objectives of conservation of aquatic ecosystem functions and services if they are addressed in the early stages of planning, provided that there is a commitment by the member states and project proponents to these objectives. To achieve this, new policy provisions and procedures will be needed; and in addition, rigorous attention to the implementation of existing policies and procedures will be needed.

The water supply and sanitation, rural and energy sub-sector boards should be encouraged to develop explicit procedures for addressing the sector-specific environmental issues in a structured manner. Specific training and capacity-building programmes should also be encouraged, to focus on the establishment of an environmental regulatory framework to complement and support the reforms related to privatization.

6 Move from restorative to preventive management.

- Action SADC

Given that freshwater is a vital but diminishing resource, it is essential that SADC assists governments and the private sector to undertake planning and management for the development and protection of water resources and the conservation of the associated freshwater ecosystems and habitats. The costs of preventing resource degradation are small compared to remediation and rehabilitation. A major challenge for freshwater resources is to increase the level of effort for preventive measures, while maintaining support for remedial interventions in degraded areas. SADC can promote operations for preventive and restorative measures that enhance the environmental management of water resources, in particular lakes and reservoirs, either as freestanding projects or as components of projects.

- Action Member States

Governments should in a similar manner, assist the other stakeholders at a national level, such as in private sectors and communities, to undertake the protection of water resources and the conservation of the associated freshwater ecosystems and habitats, and strengthen [illegible] that the costs of preventing resource degradation are small compared to remediation and rehabilitation.

A major challenge for freshwater resources management at national levels is to increase the local efforts for preventive measures while maintaining support for remedial interventions in degraded areas.

There will be a need to consider the design of monitoring networks based on the "pressure-state-response" approach, which measures:

- the pressures on the aquatic environment, including driving forces such as climate, flow, water quality, water and land use;
- the resulting state of the aquatic environment, in terms of ecosystem health, quality and flow of ecosystem goods and services, and
- the response of the people who directly and indirectly utilise and rely on water resources, in terms of their social and economic well-being.

7 Move to integrated water quality management, set clear water quality objectives and implement programmes for achieving these objectives.

- Action SADC

Integrated water quality management is the planning, organization, direction and monitoring of all aspects that have an effect on the quality (physical, chemical, biological, bacteriological, etc.) of the water resources, incorporating and balancing the different requirements of relevant water users and water functions in order to enhance efficient and sustainable use of the resource.

To assure a consolidated and coordinated approach to water quality management, SADC should promote a Water Quality Management Strategy. The Strategy would support a region-wide exchange of knowledge and experience in water quality management that would be reflected in policies, best practices, programmes and individual operations.

SADC should promote a step-by-step approach to attain clearly defined water quality objectives, taking into account the current water quality, current and potential new water uses in the catchment area, available technical and financial means for pollution prevention, control and reduction, as well as the urgency of control measures. These objectives, which represent the result of a balance between what is desirable from an environmental point of view and what is feasible from a technical and economic point of view, should be regarded as a policy goal for client countries to be attained within a certain period of time.

- Action Member States

Member states should develop and implement integrated water quality management strategies, which incorporate the setting of policy goals and measurable objectives for water quality and pollution control, and which recognise the need to mobilise all levels of society to ensure that land and water use is managed so as to minimise the impacts on the quality of water resources.

8 Strengthen environmental management capacity related to water resources management.

- Action SADC

The need for skilled and experienced staff in the region is fundamental. While the SADC region has some highly experienced water-resources professionals with the relevant environmental management training and skills, there is still a lack of some key professionals (such as freshwater ecologists, limnologists, environmental economists, experts in water law, EIA practitioners, environmental information systems experts, water institutional issues specialists and groundwater specialists). Also, the depth of operationally relevant experience is limited. There is a need to encourage greater interaction among regional staff, improve sharing of experiences, establish regional advisory services, provide specific training, mentor young staff members, improve the peer review systems, and more effectively draw upon region-wide experience.

SADC should undertake a careful review of the human resources needs and skills mix needed to address the environmental management challenges related to water resources management in the region. This should complement the ongoing restructuring and capacity-building initiatives of SADC to address the traditional areas of water resources management.

- Action Member States

Countries should take cognizance of the proposed SADC review of the skills needed to support environmentally sustainable water resources management. At a national level, there is a need to increase both the numbers of environmental staff who understand and can communicate the aquatic ecosystem issues and the numbers of water resources specialists who understand the real substance of the environmental concerns as well as staff who can quantify the value of potential or actual losses associated with resource and ecosystem degradation.

9 Work in structured partnerships to address and eliminate the causes of watershed degradation.

Over the years most governments in southern Africa have realised the need to eliminate the causes of watershed degradation. This is reflected by the various national conservation strategies and national environmental action plans that have been formulated by most countries. In some cases these policies have not been genuinely implemented. Most of the approaches adopted for watershed management have been driven by one or a few government ministries, *eg* Ministry of Agriculture or

Natural Resources. Other government agencies that are responsible for other natural resources such as water, vegetation and roads have often been treated as interested observers. In addition, users of natural resources within a watershed such as peasant farmers tend to be told what is best for them in terms of watershed management without any meaningful input into the identification of the problems and formulation of solutions. This approach is ineffective with regard to watershed management. Therefore a sound water policy should integrate horizontally and vertically the efforts of various government agencies and those of local communities in order to combat watershed degradation.

There is a need to establish structured partnerships at all levels and involve representation of all stakeholders. This integrated approach is applicable at the regional, national, watershed, and local levels.

Photobank, Harare

SADC is accumulating [illegible] knowledge on issues of [illegible] and should take a strong leadership role in [illegible] sharing of knowledge and expertise

- Action SADC

SADC sectors should ensure that their initiatives take cognisance of the linkages between elements of a watershed in order to combat degradation. For example, initiatives aimed at improving food security at the regional level should incorporate the need to manage soil loss, vegetation clearance for the purpose of increasing cultivated lands, and use of inorganic fertilizers; all of which have the potential to cause watershed degradation.

10 Facilitate and support knowledge-sharing.

- Action SADC

SADC should take a strong lead in facilitating the sharing of knowledge and experiences. SADC is accumulating significant information and knowledge on the issues of environmental sustainability. Efforts to consolidate and share this knowledge should be reinforced. SADC and its partners should play an instrumental role in facilitating knowledge-sharing, through the development and implementation of innovative strategies and partnerships which ensure that knowledge is disseminated at appropriate levels to the people who most need it in support of their everyday work.

- Action Member States

Countries should support SADC efforts to facilitate knowledge-sharing, and remove bureaucratic and organizational barriers that prevent easy, rapid access to relevant knowledge. A structured programme of knowledge-sharing should have clear objectives and use innovative knowledge products to get knowledge and information to people at various levels, from government ministers, to technical professionals, to water users and the public. Seminars are probably one of the least effective ways to transfer knowledge since they usually involve small groups of like-minded professionals who seldom communicate further than their immediate circle. Transfer of expertise at the technical or professional level can be facilitated for example through exchange visits, joint projects, electronic access, and active involvement in professional societies.

11 Develop and implement a broad awareness and communication strategy.

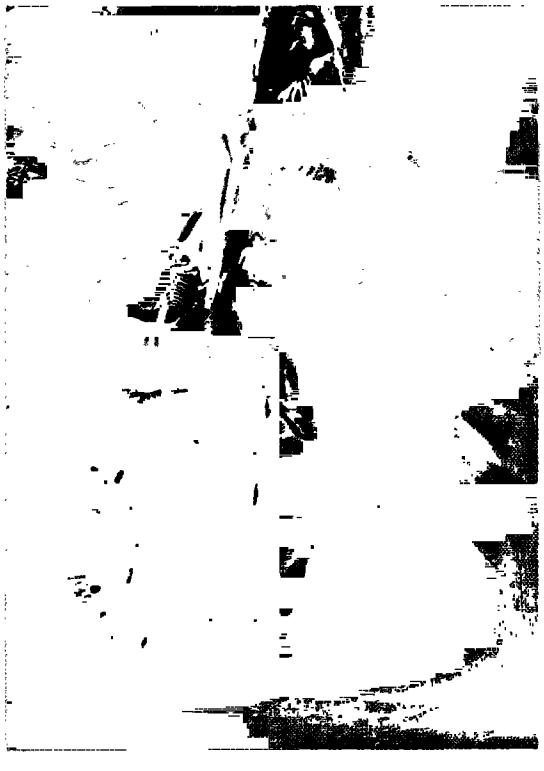
- Action SADC (and Member States)

The communications strategy should be a long-term programme of SADC, its partners and member states promot-

ing a regional and national forum with the objective of developing an informed group of policy-makers and public/private user groups.

A communications strategy should be developed and implemented with the objective of informing, educating and engaging public and private users and communities in a dialogue to improve understanding and share perspectives about the important water resources management issues in the region and about the roles, responsibilities and obligations of both water users – individual, collective, and commercial – as well as regulatory authorities – catchment boards, water apportionment boards, river basin development authorities, lake management authorities, and specific water-using departments or ministries – in specific aspects of water-resources management. This strategy will also translate and interpret into common language, differing aspects of the ongoing water sector reforms in the region.

The communications strategy should be developed at the regional level by SADC and its partners and at the national level by member states, and should be based on developing specific messages for targeted audiences such as policy-makers, decision-makers and technical specialists, users from all sectors, community groups and the general public. This can engage different media (print, radio, TV, newsletters, workshops, policy briefs, factsheets, posters, and other fora) to inform and engage the public in a dialogue and debate about the management of an important, but increasingly scarce resource that is under severe stress. It should also disseminate information on alternative options for utilizing water more efficiently in the various sectors, highlighting the different activities and costs associated with the management of water. The communications strategy should address a wide range of water management issues, challenges and options, guided by the SADC ELMS and SADC WSCU national focal points and their representatives, and developed with a team of regional experts working actively on water resources management issues.



L. Basto

12 Encourage water conservation and demand management initiatives.

- Action SADC (and Member States)

For a water-scarce region, water conservation must remain a key element of the water policy reform process. SADC and member states should promote reforms that encourage water conservation in all water supply and sanitation projects through a wide variety of tools, such as better average cost pricing and introduction of block tariffs, long run marginal cost pricing as incentives for recycling, rationing and restrictions, land zoning and improved technology.

Conservation should also be actively encouraged and promoted in agricultural water use, industrial water use, mining water use and energy water use through public awareness and education programmes, technological innovations, and economic and regulatory instruments.

13 Encourage public participation in water resource management.

- Action Member States, officials and communities

This will have action at all levels including the community. The competence of the local community should be respected even if they use different terminology; others should get to know and use it too. Capacity-building and formal training should be instituted for promising young members of the community, with bonding so they return and teach others for a fixed period (3-5 years). Communities should take seriously the partnerships with national or regional agencies and techni-

cal experts, and try to teach them something about the local resources and how they are used, by the community and by ecosystems, and about local indigenous knowledge systems, not only for water but for the components of integrated water resources management. Communities should be prepared to contribute through funds or in kind or by labour (including participation in committees and decision-making bodies).

14 Promote additional studies in key areas.

- **Water pollution and health impacts.** It is reasonable to assume a relationship between ambient water quality and health, especially for those areas without a modern water supply system. However, the relationship is complex, given the many ways in which people can obtain water and/or avoid the worst impacts of pollution. Methods are being developed to provide macro-level estimates of the health impacts of different interventions, to inform decisions on investment programmes. The value and future direction of such efforts need to be assessed.

- **Reuse of effluent.** It is clear that reuse or recycling of lower quality water, including treated effluents, will be an increasingly important component of overall water resources management. A range of technical options are available but there often remain a number of institutional, behavioral or cost obstacles to be overcome before reuse becomes widespread. Work on this issue should be supported and opportunities for implementation should be identified.

- **Basin studies.** Encourage basin studies similar to those undertaken on the Zambezi basin under ZACPLAN or on the Limpopo basin for the SADC Water Sector, that is, the rapid collection, cataloguing and analysis of all available socio-economic and sector-specific information relevant to mainstreaming the environment in water resources management.

- **Water quality.** SADC should also initiate studies to derive regional numerical water quality criteria for protection and management of water resources, which are suited to southern African bio-geographical conditions rather than being imported directly from northern temperate zones.

11.4 CONCLUSION

This technical report has provided an overview of the conceptual issues related to *Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa*, and a frank assessment of the problems and solutions. It offers a challenge for the people of the SADC region and their representatives, planners and decision-makers, on the importance of developing and managing water resources wisely and carefully, and holding them sacred as they are essential to our survival.

This report fills an important knowledge gap on relevant issues, bringing together a number of related topics in one volume, and shares best practices from the SADC region. It provides a framework for defining the complex and elusive concept of environmental sustainability in water resources management, and for mainstreaming that concept in operational terms in water resources policies and institutional reforms, and in the decision-making for water resources planning and development. It paves the way for developing sound, sensible and sustainable water resources projects and management systems for meeting the SADC region's priority goals of economic growth and poverty alleviation.

In a water-scarce region, the importance of aquatic ecosystems, watersheds and aquifer recharge areas as sources of surface and ground water that should be protected and maintained in a healthy condition is not yet fully appreciated by decision-makers and other stakeholders. Nor has adequate attention been placed on using water wisely and efficiently. The huge economic costs associated with watershed degradation, water pollution or invasion of aquatic weeds are not fully realized. These are caused by many factors including loss of soil cover, nutrients and agricultural productivity, altered hydrology, deteriorated water quality, reduced economic life of storage dams, and damaged water infrastructure due to sediment transport and deposition. Often, these costs are not accurately quantified due to inadequate data, and therefore, the significance of associated economic losses is not appreciated.

A sound water resources policy should aim to raise an awareness among stakeholders about these relationships, and facilitate the development of institutions which manage water resources at the basin level so as to manage the upstream and downstream linkages. These institutions should create opportunities for users of resources occur-

ring within a basin or watershed to participate in making decisions concerning the sustainable management of these resources.

The integrated approach to water resources management is at the basin, national and transboundary levels where the emphasis is on linkages between water and the resource base, land and water resources, sectors, and relationships between upstream and downstream activities, between people of different countries and social strata, and between people and their natural environment.

This report has discussed selected examples of different types of challenges, tools and frameworks required for an integrated plan for water resources development and management activities and practices, and their impact on the socio-economic life of the people and environmental resources. Lessons have been drawn and recommendations made for the institutionalization of these lessons in water resources management policies and practices in order to enhance the social acceptability and environmental sustainability of the investments.

The challenges include the determination of water for environmental uses, water pollution control and watershed degradation, aquatic weed management, and water and environmental policy reforms and community-based water resources management.

T Dai [illegible] World

The development and management of water resources should be based on a participatory approach, involving users, planners and [illegible] at all levels, to facilitate sustainable development – that is, [illegible] the needs of present generations without compromising the ability of future generations to meet their own needs." [illegible] *21)*

Decisions by governments, developers and other water resources managers require input of the primary stakeholders, such as communities who are either affected by or benefit from water resources management activities. Consequently, the management of water resources is becoming increasingly reliant on both the participation and cooperation of the local communities.

Community-based management of water resources is not a recent nor an externally inspired activity in southern Africa. On the contrary, communities in southern Africa have, for a very long time, been managing their water resources in a manner that is being suggested in the Dublin and Rio statements. In many parts of the region, water has been managed by the communities although the management practices have differed from place to place, reflecting the different physical endowment of water, cultural values and socio-political organizations of the concerned communities. It should be noted, however, that, although there has been a long tradition of communities being involved in the management of land and water resources in this region, during the colonial period and after independence many countries have experienced a systematic shift towards the centralization of water management activities. Centralized management of water resources has, in general, yielded limited positive results but many negative effects on resource management. Thus, the re-emergence of interest marks a shift back from the centralized management to participatory approach which aims at involving stakeholders and communities in the whole process of water resources planning, development and management.

In addition, for the SADC region, the perception of "community" has been shifted from the traditional view of villagers or urban dwellers living together, to also include the private sector, governments, the inter-governmental body SADC, and the cooperating partners, among others. There now exists an active community for regional development, and emerging communities of stakeholders at basin level for the development and management of transboundary resources.

Finally, it is significant that southern Africa has a vision for sustainable development as embodied in the SADC Treaty, as well as in the SADC Policy and Strategy for Environment and Sustainable Development of 1996. The policy shift towards a participatory and integrated management approach in water resources management is facilitated primarily by the SADC Protocol on Shared Watercourses, supported by the Regional Strategic Action Plan (RSAP) for Integrated Water Resources Development and Management in the SADC Countries (1999-2004).

The overall SADC objective is "the attainment of an integrated regional economy on the basis of balance, equity and mutual benefit for all Member States." Water, by virtue of being a largely shared and transboundary resource, is a key driver for an integrated and prosperous region, and for sustaining regional development.

Annex 1

GLOSSARY

Aa

Absolute resource scarcity – Situation in which there are not enough actual or affordable supplies of a resource to meet present or future demand.
Acacia woodland – A type of dry savanna characterized by thorny shrubs or trees of the *Acacia* species.
Agroforestry – Planting trees and crops together.
Algae – Plants which have chlorophyll and have no stems, roots or leaves and live in water or in moist conditions.
Algal bloom – Rapid growth of certain algal constituents of plankton in and on a body of water.
Alien – Also known as exotic, introduced or non-native, and refers to any organism that enters an ecosystem beyond its normal range through deliberate or inadvertent introduction by humans. Includes genetically modified organisms.
Alluvial fans – A mass of sediment deposited at some point along a stream course at which there is a sharp decrease in gradient. Essentially, a fan is the terrestrial equivalent of a river delta formation.
Anaerobic conditions – Situation without oxygen.
Anoxia – The absence of oxygen, which is necessary to sustain most life.
Anoxic water – Water with a deficiency or absence of oxygen.
Aquatic weed – A plant dependent on an aquatic habitat, with either emergent, submerged or floating leaves, which causes harm or is a nuisance to the natural environment or to people and their environment, *ie* an undesirable aquatic plant, usually introduced and invasive.
Aquaculture – Farming with aquatic plants or animals, *eg* fish farming, or algal cultures.
Aquifers – Porous layers of sand, gravel, or bedrock able to store groundwater.

Bb

Basin – A large, low-lying area drained by a stream or river system. See also watershed, catchment, drainage basin.
Biogas – Gas fuel produced from decomposing organic matter, usually methane gas.
Biochemical oxygen demand – A measure of the quantity of oxygen used in the biochemical oxidation of compounds containing carbon and nitrogen in a specified time, at a specified temperature, and under specific conditions.
Biological diversity – The variability within species, between species and of ecosystems.
Biological oxygen demand – Amount of dissolved oxygen needed by aerobic decomposers to break down the organic material in a given volume of water at a certain temperature over a specified time period.
Biological Weed Control – Control method that uses natural enemies to control weed growth.
Biota (of a river) – Plants and animals that live in or are directly dependent on a river.
Biotechnology – Application of science and engineering in the direct or indirect use of living organisms or parts of products of living organisms in their normal or modified forms.
Borehole – Hole, drilled vertically or at an inclination into the ground and usually fitted with a mechanical or motorized pump to draw water from the ground.

Cc

Catchment area – An area that receives or "catches" the rain that flows into a particular river. See also watershed.
Chemical weed control – Control method that uses herbicides to remove weeds.

Climate Change – A change in the sum total of the weather experienced in an area over years which is attributed directly or indirectly to human activity and alters the composition of the global atmosphere in addition to climate variability observed over comparable time periods.
Coliform bacteria – A group of bacteria predominantly inhabiting the intestinal tracts of humans and other warm-blooded animals, but also occasionally found elsewhere.
Complementary legislation – Laws that are in agreement with other laws and regulations so as to ensure efficient and effective control throughout an area.
Consumptive use – Use of natural resources which involves changing them from their natural state through various forms of harvesting.
Contact herbicide – A plant poison that affects parts of the plant that are reached by the spray.
Contingent valuation technologies – A method for giving value to a product by eliciting information about preferences for that product by asking individuals questions about how much they value it. This value can then be used to estimate expected revenue from use or sale of the good.
Convention – Agreement made by nations over particular issues that are for the benefit of all.

Dd

Dambo – A ciChewa term to describe a shallow, seasonally or permanently waterlogged, grass-covered depression (known in other southern African languages as *mbuga*, *molapo*, *naka*, *bani* or *vlei*).
Deforestation – indiscriminate removal of trees from a forested area without adequate replanting.
Desertification – Land degradation processes occurring in dry sub-humid areas as a result of various factors, including climatic variations and human activities. It is a process of conversion of agriculturally productive land to a desert, usually as a result of overgrazing, depletion of organic matter in the soil, overuse of groundwater, changing patterns in precipitation, etc.
Disease vector – An organism which causes or transmits a disease. For example, malaria-carrying mosquitoes.
Drainage basin – See river basin, watershed, catchment.
Drought – Continuous absence of precipitation during the period when it is normally expected to occur. All other definitions of drought are related to the effect or impact of below average rainfall on agriculture, hence the terms agricultural drought, hydrological drought, etc.
Dry savanna – Semi-arid area with widely-spaced trees, often *Acacia* species, sometimes with touching crowns, but a light canopy that allows grass to grow beneath.

Ee

Ecology – Study of natural environment and of relations of organisms to each other and to their surroundings.
Ecosystem – All the living organisms and the physical environment in an area as well as the processes which link them together.
Eco-tourism – Tourism that focuses on nature-related, non-consumptive activities or experiences such bird watching.
Effluent – Liquid waste material that is a by-product of human activities such as liquid industrial discharge or sewage.
El Nino – The warming of eastern and central Pacific Ocean waters which bring about changes in global weather patterns by affecting air and ocean temperatures, and is associated with below average rainfall in southern Africa.
Endemism – Uniqueness of a species to a particular geographic region.
Emergent plants – Plants rooted in shallow water with aerial stems, leaves and flowers.
Entomology – The scientific study of insects.
Environmental audit – A formal method of inspection used to assess the impact of activities of an organisation, facility, or commercial enterprise on the environment.
Environmental degradation – Depletion or destruction of potentially renewable resources such as soil, grassland, forest or wildlife, by using it at a faster rate than it is naturally replenished.
Environmental Flow Assessment – The process of determining water that should purposefully be left in a river or released from an impoundment in order to maintain a river in desired condition.
Environmental Flow Requirements – The water that is deliberately left in the river or released from a reservoir for maintaining the structure and function of aquatic ecosystems downstream.
Environmental Impact Assessment – Critical appraisal of the likely ecological effects of a proposed project, activity or policy, both positive and negative.
Environmental refugee – Person unable to pursue his/her livelihood due to unfavourable environmental changes, *eg* fishermen in bays covered by aquatic weed mats.

Environmental weed control – Weed control method that manipulates the habitat in which weeds grow so as to suppress their growth through the reduction in nutrient inputs.
Estuary – Part of the river where it meets the sea, characterised by a mixture of sea water and freshwater.
Eutrophication – Process of over-fertilization of a body of water by nutrients that produce more organic matter than the self purification reactions can overcome.
Evapotranspiration – The loss of water to the atmosphere from an area as a result of a combination of evaporation from the soil and transpiration from plants.
Extinction – The total loss of a species from the earth due to natural or human-induced causes.

Ff

Floodplain – Area adjacent to a river or lake, which is seasonally flooded when water levels rise due to high rainfall
Flow regime – The volume and distribution of water that flows down a river in a particular period.
Fluorosis – A disease that results from the ingestion of fluorine in amounts that substantially exceed bodily requirements.
Free-floating plant – An aquatic plant which is not rooted but floats freely on the surface of water.
Fynbos – A South African name for the sclerrophyllous vegetation, similar to chaparral, which occurs in South Africa.

Gg

Geomorphology – Land forms and their attributes such as rivers, mountains and valleys.
Genetically modified organism – Organisms whose genetic make-up has been altered by the insertion or deletion of small fragments of deoxyribonucleic acid (DNA) to create or enhance desirable characteristics from the same or another species.
Groundwater recharge – Replacement of water, usually through rainwater percolating into the ground, to replenish water lost from the groundwater through abstraction, evaporation or transpiration.
Gully – Small, narrow valley cut especially by heavy rain and usually growing in years of above average rainfall, particularly after a period of drought when the plant cover has died.

Hh

Habitat – Place or type of site where plant, animal or microorganism populations normally occur.
Helminth – A worm, which is usually parasitic.
Helsinki Rules – A basis for international agreements related to water management, which states that each basin state has the right to a reasonable and equitable share of water in the basin, and that the maximum benefit should be achieved with minimum disadvantage to other states.
Herbicide – Chemical used to kill or severely damage plants.
Humidity – Mass of water contained in a unit volume of air.
Hydroelectric power – Electricity generated by water power. This is usually achieved by damming rivers and running the water under pressure through turbines.
Hydrology – Science dealing with the properties of water and its occurrence in space and time.

Ii

Impoundment – A water body formed behind a dam wall or weir.
Inundated – Flooded.
Indigenous Knowledge System – The development over many generations, through a traditional way of life of an in-depth knowledge of an ecosystem or ecosystems by local people.
Integrated Catchment Management – Resource management that uses the river catchment to define the area to be managed and ideally integrates the views and demands of all affected parties and seeks the best long-term, environmentally sustainable use of the resources.
Integrated weed control – Combination of control methods best suited to control a particular weed infestation. Usually combines mechanical, environmental, chemical and biological methods.
International watercourse – A river, stream or canal that is shared by two or more countries.
Inter-Tropical Convergence Zone – A zone of intense rain cloud development oscillating between the tropics created when the southeast trade winds meet with the northeast monsoon.
Invasive plant – A plant which, once introduced, is able to spread unaided into new ecosystems where it may cause problems.

Kk

Karoo – Shrubby, semi-desert landscape, named after the karoo region in South Africa.

Ll

Lacustrine – Of lake.
Lagoon – A salt-water lake separated from the sea by a sand bank or coral reef or a small freshwater lake near a large lake or river.
Landfill – Tipping of waste into holes in the ground.
Land tenure – The type of land ownership system.
Leachate – The solution formed when water percolates through a permeable medium. In some cases the leachate may be toxic or carry bacteria.
Leaching – A process by which a substance is washed out of the soil by water passing through it.
Littoral zones – Areas comprising the shoreline of lakes, estuaries or other water bodies, which may be inundated either occasionally or seasonally.

Mm

Macrophytes – Large water plants.
Mangrove – Tropical forest or shrub growing in shore mud with many tangled roots above ground.
Marine – Of the sea or ocean.
Marsh – A permanently or seasonally saturated wetland area and the plants growing on it.
Mechanical control – Method for control of aquatic weeds using manual or mechanical means to remove weeds from a water body.
Methane – A greenhouse gas emitted to the atmosphere from sources such as decomposing waste.
Microcystis aeruginosa – A blue-green algae that grows naturally in many surface waters.
Miombo woodland – A common type of moist savanna woodland.
Monsoon – Seasonal winds usually associated with rainfall.
Morphology – Shape and structure of a watercourse.

Nn

Non-consumptive use – Use of water which does not involve abstraction or reduction in the quantity of water in a water body.
Non-point-source – Source of pollution in which pollutants originate from over a wide area or from a number of small inputs rather than from distinct, identifiable sources.
Nutrient-limited – When certain chemicals essential to growth are not available in adequate concentrations for maximum growth.
Natural enemy – Organisms living, breeding or feeding on a plant in their natural environment which by their activities may damage and restrict growth of the plant.

Oo

Osmoregulation processes – The process whereby an organism maintains control over its internal osmotic pressure irrespective of variations in the environment.

Pp

Pelagic – In marine ecology, applied to the organisms that inhabit open water.
Photosynthesis – A biological process by which plants take in carbon dioxide and release oxygen.
Phreatophytes – Water-loving plants.
Point-source – A source that is distinct and identifiable, for example smoke-stakes and outflow pipes from industrial plants and municipal sewage treatment plants.
Pollution – The contamination of land, air or water with any substance that reduces their ability to support life.
Potable – Drinkable
Precipitation – Water which falls from clouds to the ground as rain, snow, dew, fog, frost, hail, mist, sleet, etc.
Protected area – An area set aside by law for the preservation of given aspects of cultural and natural heritage.

Rr

Rainfall variability – Pattern of rainfall where the amount of rain and where it falls differ widely from year to year.
Ramsar Convention – The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. There are presently 131 Contracting parties to the convention, with 1,177 wetland sites, totaling 102.1 million ha, designated for inclusion in the Ramsar List of Wetlands of International importance.
Reservoir – A large natural or artificial collection of water forming a small lake especially used as a source of water supply.

Riparian – Of or on a river bank; sharing a river basin.
Riverine – Of river, floodplain or swamp.

Ss

Savanna – Arid to semi-arid area with a mix of grass, trees and shrubs, the proportions of each varying with rainfall, soil type and other physical factors.
Sedimentation – Deposition of river-borne sediments in a lake or dam.
Sedges – Grass-like plants growing in marshes or near water.
Semi-arid – Areas where the mean annual rainfall is between 250 and 600 mm, usually seasonal and variable, and where potential evaporation is high.
Sheet erosion – Removal of the most productive top layer of the soil by runoff washing evenly over the land surface.
Siltation – The deposition of sediments by water in a river channel or reservoir.
Soil degradation – Declining productivity of soils resulting from a combination of physical factors such as drought, management factors such as cultivation, and socio-economic factors such as inequitable distribution of land.
Sustainable development – Term used by the World Commission on Environment and Development to denote development which meets the needs of the present without compromising the ability of future generations to meet their own needs – development that does not require a continuous input from outside to sustain itself.
Systemic herbicide – Plant poison that is translocated within plants and so kills the entire plant.
Swamp – Area of waterlogged ground and the plants that grow on it.

Tt

Tradable pollution permits – A free market solution to problems caused by the negative impacts of pollution in which a country is allocated a "pollution quota", and is free to sell a portion of that quota which it is not able to meet.
Tropical cyclone – An intense tropical storm with high winds and heavy rainfall, revolving clockwise round a low pressure area.
Turbidity – The degree to which water is opaque or muddy.

Uu

Upstream – The direction which is opposite to the flow of a river, towards the source.

Vv

Vegetative reproduction – The ability of some plants to reproduce from their fragments.

Ww

Water cycle – A natural and continuous process in which water changes from one state (*eg* atmospheric) to another (*eg* groundwater), and is redistributed in the landscape.
Water-logged – State of water saturation in the soil. catchment, river basin, and drainage basin.
Water-logging – Natural flooding and over-irrigation which brings groundwater levels to the surface, displacing the air in the soil, with corresponding changes in soil processes and an accumulation of toxic substances which impede plant growth.
Watershed – An area from which all surface runoff flows through a common point. Related terms are catchment, basin.
Weed – A plant growing at a place and/or time where it is considered undesirable.
Weevil – Type of a small beetle with a hard shell. The beetle feeds on grain, nuts and other seeds, and destroys crops.
Wetland – Land that has the water table at, near, or above the land surface. It is also land that is saturated for a long enough time to promote aquatic processes and various kinds of biological activity adapted to the wet environment.
Wildlife – Animals and plants that are not domestic.

Annex 2

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