State of the Environment Report on Water in Namibia

Prepared for the Ministry of Environment and Tourism by
The Water & Environment Team*

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INTER-CONSULT

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Desert Research Foundation
of Namibia

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FOREWORD

Agenda 21, the programme of action for sustainable development that arose from the Rio Conference on Environment and Development (UNCED), recognised the importance of protection of the quality and supply of freshwater resources. The highlighted the conclusions that:

- freshwater resources are an essential component of the Earth’s hydrosphere and an indispensable part of all terrestrial ecosystems,
- water is needed in all aspects of life,
- the widespread scarcity, gradual destruction and aggravated pollution of freshwater resources in many world region, along with the progressive encroachment of incompatible activities, demand integrated water resources planning and management, and
- transboundary water resources and their use are of great importance to riparian States.

These concepts have guided the compilation of this State of the Environment Report on Water in Namibia.

The Water and Environment Team, a joint venture comprising specialists from three Namibian organisations, compiled this State of the Environment Report on Water in Namibia. The core of this team was drawn from Windhoek Consulting Engineers, the Desert Research Foundation of Namibia and Interconsult Namibia (Pty) Ltd. Contributions were also provided by a number of external specialists who collaborated on the final compilation. Minor differences in writing style and approach may therefore be noted between some of the sections.

Public participation in the process was gained through two workshops, the first to assist in the selection of appropriate and useful indicators and the second to discuss the Draft Final Report. In the latter written comments on the Draft were also gathered to facilitate editing and improvements for inclusion into this Final Report. Critical peer-review was carried out prior to finalisation of the Report.

This Report is presented as two volumes:

Volume I: An executive summary followed by an introduction to indicators and a tabulation of each of the Key Indicators identified in the Technical Report

Volume II: The Technical Report in which the water environment is described and indicators of the State of the Water Environment defined.

During the second workshop it became evident that a number of readers looked upon the Draft Final Report as a comprehensive review of the water sector in Namibia and as
such identified certain gaps. It should be noted that although this Report is not intended
to be a comprehensive review it has been necessary to describe most aspects of the
water sector.

This Final Report is one of the first documents in which most aspects of water in
Namibia are presented in a single treatise and, as such it is hoped that readers will find
it a useful reference for the foreseeable future.
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Windhoek, 30 April 1999
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<td>AIC</td>
<td>Average incremental cost</td>
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<tr>
<td>AG</td>
<td>Attorney General</td>
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<td>CBM</td>
<td>Community-based management</td>
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<td>CIDA</td>
<td>Canadian International Development Authority</td>
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<td>CSO</td>
<td>Central Statistics Office</td>
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<tr>
<td>CWC</td>
<td>Constituency Water Committee (formerly Central Water Committee)</td>
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<td>DARD</td>
<td>Department of Agriculture and Rural Development</td>
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<td>DEA</td>
<td>Directorate of Environmental Affairs</td>
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<td>DRFN</td>
<td>Desert Research Foundation of Namibia</td>
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<td>DRM</td>
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<td>Directorate of Rural Water Supply</td>
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<td>DWE</td>
<td>Division of Water Environment</td>
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<tr>
<td>EIA</td>
<td>Environmental impact assessment</td>
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<td>ENWC</td>
<td>Eastern National Water Carrier</td>
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<td>ERS</td>
<td>Ecological Research Section</td>
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<td>EU</td>
<td>European Union</td>
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<td>Food and Agriculture Organisation</td>
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<td>GRN</td>
<td>Government of the Republic of Namibia</td>
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<td>IMC</td>
<td>International Medical Corps</td>
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<tr>
<td>IMP</td>
<td>Integrated management plan</td>
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<tr>
<td>ITCZ</td>
<td>Intertropical Convergence Zone</td>
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<td>IUCN</td>
<td>International Union for the Conservation of Nature and Natural Resources</td>
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<td>LWC</td>
<td>Local water committee</td>
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<tr>
<td>Ma</td>
<td>Millions years old</td>
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<td>MAP</td>
<td>Mean annual precipitation</td>
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<td>Mean annual runoff</td>
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<td>MBEC</td>
<td>Ministry of Basic Education and Culture</td>
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<td>MET</td>
<td>Ministry of Environment and Tourism</td>
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<td>MFMR</td>
<td>Ministry of Fisheries and Marine Resources</td>
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<td>MHSS</td>
<td>Ministry of Health and Social Services</td>
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<tr>
<td>MIS</td>
<td>Management Information System</td>
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<td>MLRR</td>
<td>Ministry of Lands, Resettlement and Rehabilitation</td>
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<tr>
<td>MRLGH</td>
<td>Ministry of Regional and Local Government and Housing</td>
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<tr>
<td>Mm³</td>
<td>Millions of cubic metres</td>
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<tr>
<td>NamPower</td>
<td>Namibian Power Corporation</td>
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<td>NamWater</td>
<td>Namibian Water Corporation</td>
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<td>National Botanical Research Institute</td>
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<td>NDC</td>
<td>Namibian Development Corporation</td>
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<td>NGO</td>
<td>Non-governmental organisation</td>
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<td>NMS</td>
<td>Namibia Meteorological Services</td>
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<td>OKACOM</td>
<td>Permanent Okavango River Basin Commission</td>
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<td>Omdel/OMDEL</td>
<td>Omaruru Delta</td>
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<td>4 Os</td>
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<td>Northern livestock development project</td>
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<td>PED</td>
<td>Price elasticity of demand</td>
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<td>PJTC</td>
<td>Permanent Joint Technical Commission</td>
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<td>PTO</td>
<td>Permission to occupy</td>
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<tr>
<td>RSA</td>
<td>Republic of South Africa</td>
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<td>RWC</td>
<td>Regional Water Committee</td>
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<td>RWEO</td>
<td>Rural water extension officer</td>
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<td>SABRINa</td>
<td>Study of alluvial bed recharge, induced and natural</td>
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<td>SADC</td>
<td>Southern African Development Community</td>
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<td>TDS</td>
<td>Total dissolved solids</td>
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<td>UKTR</td>
<td>United Kingdom Meteorological Office</td>
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<td>UN</td>
<td>United Nations</td>
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<td>United Nations Development Programme</td>
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<td>Unicef</td>
<td>United National Children’s Fund</td>
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<td>USAID</td>
<td>United States Agency for International Development</td>
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<td>VSO</td>
<td>Volunteer Services Overseas</td>
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<td>Acronym</td>
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<td>WASCO</td>
<td>Water and Sanitation Co-ordination Committee</td>
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<td>WASP</td>
<td>Water supply and sanitation sector policy</td>
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<td>WATSAN</td>
<td>Water and Sanitation Forum</td>
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<td>World Meteorological Office</td>
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<td>ZACPLAN</td>
<td>Zambezi Action Plan</td>
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<td>ZERI</td>
<td>Zero Emissions Research Initiative</td>
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1. INTRODUCTION

The Directorate of Environmental Affairs of Namibia's Ministry of Environment and Tourism, with support from the Government of Finland, is undertaking a national programme entitled 'Information and Communication Service for Sustainable Development in Namibia.' The initial steps of this programme will extend over a period of years. A major component of this programme will be the compilation of State of the Environment Reports addressing all important sectors related to the environment. The draft Environmental Management Act mandates annual reports on the State of the Environment to be prepared and communicated.

A State of the Environment Report on Water was selected as the first report to be initiated as part of this national programme. This document represents the first iteration of a State of the Environment Report on Water, planned to be updated on a four to five year basis. This report attempts to identify important components of the water environment in Namibia, as viewed from a broad perspective. Secondly, it provides an overview and brief summary of the state of knowledge concerning these components based on accurate and reliable information. Lastly, indicators have been elaborated to provide a monitoring tool for the state of the environment with respect to a selection of these components originally identified.

Seven chapters, between this introduction and a summary chapter, review existing knowledge concerning the water environment in Namibia. These chapters cover the following components:

- physical and climatic determinants
- surface water
- groundwater
- water supply and demand
- institutional responsibilities, roles and mandates for management of the water sector
- legislative framework, policies and regulations
- neighbouring countries.

Each chapter has a similar structure with an introduction, an overview of the existing information and a final section analysing the situation in Namibia and suggesting ways to monitor change in the state of the environment.

This State of the Environment Report on Water should not be considered an 'atlas of water in Namibia' nor does it purport to provide comprehensive information on water in Namibia. Instead, it is an overview of important components of the water environment, highlighting issues, backed up by available information relevant to economic, environmental and social sustainability of this essential but limited resource. As such, it is designed to provide information for use by decision makers, to identify important issues for possible inclusion in the President's State of the Environment Report to the nation and to provide a tool for monitoring change in the water environment.
1.1 SUSTAINABILITY OF NAMIBIA’S ENVIRONMENT

The term sustainable development is used globally to explain the desires of planners and decision makers to enhance the quality of life experienced by everyone living today without jeopardising the development opportunities and lifestyles of future generations. Sustainable development has three important components:

- making plans for sustainable resource use now and in the future and considering how these plans affect the sustainable use of other resources (economic sustainability).
- protecting and using resources effectively and efficiently (environmental sustainability)
- developing an appropriate social framework for equitable resource use (social sustainability).

Sustainable development in Namibia is hindered by several factors, not the least of which is lack of a Water Act supporting implementation of the Namibian Constitution. Other hindrances to sustainability of development in Namibia, and particularly the water sector, include:

- limitations to economic sustainability:
  - lack of resolution relating to land tenure in communal areas
  - inadequate financial, economic and environmental approach to sustainable use of water
  - lack of definition of criteria for economic sustainability
  - lack of public awareness of the magnitude of the water situation
- limitations to environmental sustainability:
  - absence of approved development plans or land use plans that take water catchments and shared aquifers into consideration
  - limited understanding of services and processes provided by water and wetlands and how to maintain functioning of these systems
  - absence of methodologies to determine the essential ‘environmental reserve’ of a catchment or aquifer
  - comparatively unknown size of the groundwater reserve
  - effects of apparent climate change on surface water resources and groundwater recharge
  - absence of legislation curbing groundwater pollution
- limitations to social sustainability:
  - lack of resolution relating to land tenure in communal areas
  - the rapidly expanding human population and population density of Namibia
  - confused relationships between various authorities dealing directly or indirectly with water
  - underdevelopment, unemployment and illiteracy.

At the same time, there are a number of opportunities to improve the sustainability of Namibia’s development through the water sector.

- opportunities for economic sustainability
  - use of appropriate pricing structures that include environmental and opportunity costs
  - considering water as an economic good
  - creation of development centres in areas with sufficient water resources
- opportunities for environmental sustainability
Figure 1.1: Namibia, Rivers, Roads, Regions and Towns

Namibia’s total surface area of 825,000 km² is divided into 13 regions. With a population density of only two people per square kilometre, it is the most sparsely populated country in sub-Saharan Africa. It is also the most arid. The river systems shown in Figure 1.1 belie the fact that there are no perennial rivers within Namibia’s interior. With a population of approximately 200,000, the capital, Windhoek, is by far the largest settlement, although towns in the Ohangwena and Oshikoto Regions are growing rapidly. The country is served by a paved road network of nearly 6,000 km, the highest per capita in the Southern African Development Community (SADC), but there are many small villages which are not connected to the road network at all.

Data Sources: Office of the Surveyor General; Department of Transport; Windhoek Consulting Engineers.
cross-sectoral planning taking into consideration the 'environmental reserve' and the value of natural processes and services
cross-sectoral planning based on research and long-term, reliable and accurate monitoring of water resources
reuse, recycling and reclamation of water
active water demand management
implementation of the National Drought Policy and Strategy
desalination of sea water to enhance supply
creation of a central institution for research, monitoring and data processing and coordination of water information
opportunities for social sustainability
decentralisation of government functions and enhanced cooperation between sectors on a regional basis
conservancies managing all natural resources in an area
implementation of Water Demand Management throughout Namibia and Community Based Management of water where appropriate
implementation of the Water Supply and Sanitation Sector Policy
increased awareness of appropriate water use and management.

In the long term, sustainable development must recognise the short-term needs as well as the long-term goals and aspirations of individual Namibians and the Namibian government in the context of natural environmental limitations on water supply and availability. Taking advantage of the opportunities provided by the water sector, and minimising the hindrances identified, will represent a major step toward assuring this sustainability.

Sustainability implies long range planning as well as coordinated planning. This is not entirely feasible when the Water Act and land tenure laws remain under discussion a decade after independence. Resolution of these fundamental issues and development of a future-looking population policy urgently need activation. It also follows that, to implement sustainability, water impoundment and abstraction need to be monitored and regulated in a holistic manner. Coordinated planning needs consideration.

1.2 STATE OF THE ENVIRONMENT REPORTING

The State of the Environment Reporting process is designed to increase awareness and understanding of environmental trends and conditions, to provide a foundation for improved decision making at all levels and to facilitate measurement of progress towards sustainability. To this end, a preliminary list of important sectors to be covered by State of the Environment Reports was drawn up in a workshop convened for this purpose in late 1997. At this workshop the participants agreed that freshwater should be the first priority of the sectors to receive attention and for which a State of the Environment Report would be compiled.

The first baseline State of the Environment Reports on the various sectors are expected to identify appropriate, key indicators for long term monitoring of the health and evolving trends of Namibia's environment. It is intended that the reports will be updated regularly to provide a continuous monitoring of all sectors of Namibia's environment. These reports will provide basic information in a comprehensive, easily understood manner, serving as a basis for communication to policy makers, technicians and the general public.
The overall objectives of the national programme entitled 'Information and Communication Service for Sustainable Development in Namibia' are:

1) to provide pertinent information on the health and evolving trends in Namibia's environment to policy makers, scientists, technicians and the general public, and

2) to identify key indicators for long-term monitoring.

The State of the Environment Reports are expected to contribute to the overall programme by providing sector specific, pertinent environmental information and by identifying key indicators. As one of the first State of the Environment Reports, the report on Fresh Water will establish an approach and format for other reports to consider.

1.3 INDICATORS

As described in Section 1.2, the Namibian Government is committed to improving the livelihood of its people and to sustainable use of the Nation’s natural resources. Meeting this challenge requires an understanding of the factors governing the distribution and abundance of national natural resources, the patterns of resource use, and a programme to monitor resource conditions to guide management and policy decisions. Without this adaptive approach to natural resource management, there is little hope for ensuring sustainable resource use and the long-term well-being of Namibia’s citizens.

Without some sort of monitoring and information dissemination network in place, policy makers will continue to be reactive rather than proactive in response to environmental problems. Hence, some means of measuring the status and usage patterns of environmental resources such as water is needed. An indicator, a measure of some variable of interest, whether it be environmental (depth to groundwater table), economic (water cost), or social (per capita incidence of water-borne disease), provides such a means. As the name suggests, indicators are measures which are symptomatic of particular situations. The current numerical value of an indicator may be determined by a simple measurement (i.e. dipping a well to measure the depth to water) or derived from an equation which incorporates measurements of several variables.

1.3.1 WHY DO WE NEED INDICATORS?

The value of indicators to the management of natural resources in Namibia becomes clear when viewed in the context of Namibia's "Information and Communication Service for Sustainable Development in Namibia" program, of which this report is a part. This programme is managed from the Directorate of Environmental Affairs, Ministry of Environment and Tourism and funded by the Government of Finland. If this programme is to be effective, it must:
- determine the status of resources
- discern changes and trends
- provide an understanding of processes
- provide early warning of emerging problems
- measure the effectiveness of environmental policies

The measurement and interpretation of key indicators are central to the success of such a program. Indicators used in a national program for monitoring environmental resources must address the fundamental questions of:

- Is the environment getting better, worse or holding steady?
- Why (what are the causes of change)?
- What can we do about it (do we understand the stressors involved)?

While the measurement and interpretation of indicators is clearly crucial, which ones should we use and how should we use them? Two general types of indicators can be defined: core and developmental. Core indicators are those in which the data collection and evaluation methodologies are well defined, and existing data series provide a historic record in support of future analyses. Developmental indicators are those in which further testing of sampling and evaluation methods is still needed, and historic data series do not exist. Both types of indicators are important components of a long-term monitoring program for Namibia’s water sector. Once selected, the overall health of Namibia’s water sector may be determined through a critical evaluation of indicator scores relative to reference conditions.

1.3.2 DETECTING POLICY-RELEVANT TRENDS

A primary goal of this report is to identify key indicators which are relevant for assessing trends at the national level. These trends may affect policy or be affected by policy at the national, regional or local level. Indicators of trends must have a direct and easily-recognised relationship to socio-economic or environmental well-being, and have the social and political impact to catch the attention of and demand action from policy-makers. The development of appropriate indicators is a key step in addressing questions about the existence or magnitude of trends in natural resources such as water. What constitutes a policy-relevant trend and how can we measure or detect it?

While a trend may be defined as a long-term change in the mean value of a series of measurements, an equally or more important trend may be a shift in the variance. Rainfall patterns provide a key example, wherein a small change in the mean over time could be associated with a significant increase in the variance. The relevant indicator in this case would not be the mean itself, but rather the variance, as an increase in rainfall variability could have an enormous impact on the Namibian economy.

Although the concepts of trend and change are familiar to many, the issues associated with their analysis, and accurate and timely detection, are more subtle. First, the term "trend" is difficult to precisely and objectively define. The term trend describes the continuing directional change in the value of an indicator over time, generally upwards or downwards. Effective trend detection is entirely dependent on the availability of data collected over a period of time in a consistent and reliable manner. Monotonic trends, continual increases or decreases, are commonly detected in the evaluation of long-term data series. Such trends may occur gradually over time, or in abrupt "steps." Step trends may occur in a data series in direct response to a specific event, such as the introduction of a contaminant to a water source, resulting in a sudden change in the variable of interest (Hirsch et al. 1991).
What constitutes long-term, when considering a trend, is subjective and depends upon the dynamics associated with the system under study. A basic understanding of the variability of Namibia's climate only begins to emerge after many decades of study. Long-term data are essential for detecting environmental trends and for putting the present into perspective (Magnuson 1990). Data from a single year, such as rainfall in Khorixas in 1985, reveal little information. Similarly, only a few years of water table measurements from the Kuiseb River aquifer tell us little regarding infrequent recharge events.

In the same way that variation from one year to the next may complicate our recognition of trends, so too may high levels of variation from one site to another during any given year. This spatial variation, which typifies Namibia's natural resources, adds another complexity to our definition of trend. What constitutes the appropriate coverage in a given space, such as a particular region within the country? While groundwater monitoring may be intensive at a single (sentinel) site, we cannot assume that that site is representative of a larger area. Identification of regional trends will probably require more complete data, sampled across a range of sites. Thus our definition of trends must include both change over time as well as change over space in target regions. It should thus be immediately clear that data sets of short duration and limited spatial coverage are not adequate to recognize trends accurately.

1.3.3 HOW OFTEN DO WE MONITOR?

Determining the optimal frequency and distribution of surveys is a key issue in effectively monitoring the status of Namibia's resources. Given the limited resources for monitoring, the longest survey cycle which still meets the needs of early and accurate detection must be identified. The main goal in achieving this optimal frequency is avoiding both unnecessary cost and regulation, while preventing the development of any serious environmental problem. Groundwater dynamics provide a useful example. The depth to the water table is a simple and useful indicator which is responsive to a number of stressors. However, recharge events occur infrequently and are associated with high-magnitude rainfall and surface flows. What is the optimal frequency for measurement? The DWA views abstraction rates which result in a continuous fall over a five year period without recovery during periods of reasonable rain as unsustainable. In such a case, measurement of the water table more frequently than once in five years is necessary.

Costs and logistical challenges associated with the maintenance of a large number of monitoring sites dictate that prioritization of site selection will be necessary - we have neither the time nor money to sample as broadly as we would like. One approach explored within this report is the use of sentinel sites. The sentinel site approach uses a relatively small number of locations which are chosen for intensive study. Each location is selected under the assumption that it is representative of a larger region or class of systems, such as a particular aquifer type or ecosystem. Sentinel sites can be selected for several reasons, including their perceived sensitivity to environmental change and their importance to Namibian society as a whole. Negative changes in sentinel sites may alert us to the urgent need to resample ancillary associated sites to verify long term changes.
1.3.4 MOVING FROM DETECTION TO CAUSATION

Once detected, determining the cause of a trend is important so that appropriate policy changes and management can be instituted. Assigning causality is a key challenge in environmental monitoring programs. While our chosen indicator may be a reliable measure of a given resource, in the absence of any measurements of change in suspected stressors, we may be unable to assign causality and determine whether the trends are “natural” or caused by human activities. Natural resource monitoring programmes commonly emphasize effects-oriented monitoring, which provides a direct measure of a resource (e.g., groundwater storage). However, early detection of changes in resources through stressor-oriented monitoring (e.g., water demand) may be a more effective means of ensuring sustainable resource use. Monitoring changes in stressors is key to successful adaptive management and the prevention of serious resource degradation.

A key challenge associated with natural resource monitoring programs is to isolate the effect of interest from noise introduced by natural spatial and temporal variability. If the size of an impact from a human disturbance is small relative to natural variability, it will be difficult to detect with any degree of confidence (Osenberg et al. 1994). This challenge of distinguishing natural from anthropogenic variability is at the heart of Namibia’s attempts to monitor and ensure the sustainable use and development of its finite water resources. Namibia’s arid climate is highly variable, with large variations in rainfall and river flow between years at any given location. For any data series, the ability to detect trends is a function of three characteristics: (1) the magnitude of the signal, (2) the variance of the data, and (3) the sample size. In an arid country like Namibia, where the variance of water-related data may be very high, one fact is thus readily apparent - only a large change in resource condition is likely to be detected in the absence of a long-term data set.

This issue of separating natural from human-induced change is of particular significance in Namibia, given the high levels of variation, both over space and time, in many resources. Monitoring programs are often piecemeal, intermittent, and short term. They generally have not provided the continuous long-term information about temporal and spatial variation necessary to distinguish natural from human-induced change. This distinction may be best made with a combination of stressor-oriented and effects-oriented monitoring. Ultimately, monitoring trends in both effects and stressors can improve the interpretability of observed changes. The status of an aquifer provides a simple example, in which the effect is a change in the water table in response to multiple stressors, such as changes in water demand (withdrawals) and recharge. In such cases, the choice of appropriate response variables (indicators) is dependent upon our knowledge of the dynamics of the system.

1.3.5 WHAT ARE THE CHARACTERISTICS OF A GOOD INDICATOR?

To be effective, an indicator must be:
- efficient (i.e., easily measured and analyzed using existing data)
- effective (i.e., sensitive to change and clearly linked to causative factors)
- economically and logistically feasible (e.g., already being measured)
- reliable (i.e., accurate and continuous)

A key issue in the development and application of indicators is the feasibility, technical, financial and environmental, of gathering the information required. While an
indicator may have great potential for monitoring policy-relevant trends, the logistical, technical, and economic realities of collecting and analyzing the information required for its determination will dictate its use. While some indicators may have great utility, technical and financial constraints may preclude their use.

1.4 STATE OF THE ENVIRONMENT REPORT – WATER

This State of the Environment Report on Water follows the guidelines set out for State of the Environment Reporting in Namibia as designed by the Ministry of Environment and Tourism, Directorate of Environmental Affairs. Throughout the report, there is a focus on sustainability of the resource, as a component of the hydrological cycle, from environmental, economic and social perspectives. This report provides extensive background material on environment and water covering the physical and climatic determinants of water gain and loss in Namibia, surface water in its several forms, and groundwater in the varied aquifer types found in the country. It then describes the water supply and demand situation, focussing on economics as an information and management tool. The institutional framework for management of water, in terms of its natural availability and use, and the legislative framework are then examined. The final part of the general overview highlights Namibia’s dependency on cooperation with neighbouring countries to sustain equitable use of shared perennial river resources.

Each of these seven central information chapters (Chapters 2 – 8) provides an introduction followed by up-to-date, relevant information on the state of the water environment collated for this report. The last section of each of the seven central information chapters is similar and focuses on environmental health issues related to water.

- First, the relevance to the water sector of the information in the chapter is briefly described. This highlights an important aspect of State of the Environment Reporting, the inclusion of information judged to be relevant, with an explanation of that relevance, rather than an exhaustive overview of existing information.

- Second, an assessment and evaluation of Namibia’s Water Sector with respect to the topic is undertaken. Again, this is approached with a focus on sustainability of the resource and highlights areas where improvement in the Water Sector is indicated. These assessments are not exhaustive, they identify particularly important information for State of the Environment Reporting.

- Third, major themes and concerns for sustainable management and use of water are listed. Again, this is not an exhaustive listing but highlights considerations of particular significance including those that could be addressed by improved management or legislation.

- The fourth sub-section briefly describes a number of potential indicators that can be used to evaluate the health of the water environment. For many of these indicators long-term data are unavailable or too costly or time consuming to collect. Nevertheless, the possibilities are briefly described. We suggest that the importance of these indicators of overall health of the water
environment be recognised and that relevant data collection be continued, expanded or, in some cases, implemented.

- The fifth and last sub-section of each chapter describes key indicators for the water environment.

These key indicators may not be dependent on long-term changes, but may represent a change of state. For example, the key indicator for health of the legislative framework would be the presence of a new Water Act, a document which is either present or absent. In the future, however, implementation of this Water Act may provide indicators for health of the legislative framework, for example, appropriate regulations and their implementation, that could be followed through time, based on appropriate data.

On the other hand, the key indicators of other chapters are based on long-term information routinely collected by the Department of Water Affairs or NamWater, or planned for long-term monitoring by the Directorate of Rural Water Supply. For truly long-term sustainability of the State of the Environment Reporting process, the best indicators would be dependent on information collected by water users and managers directly involved in maintaining the health of the water environment. These highly relevant data could be collated and widely disseminated by the relevant authorities based upon cooperative interpretation of their meaning and significance.

1.5 BACKGROUND TO WATER IN NAMIBIA

The Republic of Namibia, lying along the south-western coast of Africa, is bordered by the Atlantic Ocean to the west, Angola and Zambia to the north, Zimbabwe and Botswana to the east and South Africa to the south. It occupies an area of over 825 000 sq km and hosts a population of approximately 1 700 000 people. It is the most arid country in Africa south of the Sahel. More than 70% of the Namibian population lives within 100 km of the northern perennial rivers. However, the capital city and seat of Government, Windhoek, is located in central Namibia. Less than 18% of the population lives south of Windhoek in more than 40% of the surface area.

As the most arid country in southern Africa, water is the dominant factor constraining social and economic development. Fresh water is essential to meet the basic requirements for sustainable livelihoods and development for all Namibians. But rainfall is highly variable and perennial rivers are only found on the northern and southern borders. Thus, Namibia relies heavily on groundwater and ephemeral rivers to supply domestic, agricultural and industrial users.

About 57% of Namibia’s water comes from groundwater sources, 23% from the border rivers, mainly in the north, and about 20% from impoundments on ephemeral rivers. An estimated 16% of this water is used for domestic purposes, 23% for livestock, 43% for irrigation, 12% for industry and 6% for mining. The volume of water used by natural ecosystems has not been estimated but the varied wetlands including perennial and ephemeral rivers are essential for maintenance of water supply for development and as a habitat for much of Namibia’s biodiversity, including several critically endangered and endangered IUCN red data species.
Potential challenges to these fresh water resources include inadequate protection of the natural systems which provide the water, inefficient and ineffective usage, and rapid growth of water-consuming human and livestock populations. These challenges are exacerbated by positive but exceedingly rapid changes in production and socioeconomic strategies; the latter leading to increasing per capita water consumption, especially in swiftly growing urban areas.

Threats to freshwater resources include overexploitation of alluvial aquifers and damming and overuse of ephemeral river water, especially in the upper regions of catchments. As in most developing countries, freshwater resources are threatened by contamination from human and livestock waste, industrial pollutants, agricultural chemicals and other commercial products. The aridity of Namibia’s environment and the dispersed population may reduce the influence of some of these common threats, but only for the time being. Nevertheless, with increasing agricultural development, especially irrigation and the use of pesticides and fertilisers, and increasing industrial development, especially tanneries, taxidermy, meat and fish processing plants, pollution of groundwater, surface water and the sea is increasing. Industries in Windhoek are polluting ephemeral riverbeds too.

1.5.1 ECONOMY

Namibia had an estimated GDP per capita of N$ 923 (US$ 1,939) in 1997 and is classified by the United Nations as a middle income country. There is, however, a high degree of income inequality. The wealthiest 10% of the households (5.3% of the population) earn more than 50% of all income generated by private households. The average per capita income (adjusted) in the upper income group is N$33 000 per annum, while the comparative figure for the rest is N$1 800 per annum (NPC, 1998). This has significant implications for funding of water supply, water use and the ability of the individual to pay for water.

1.5.2 LAND TENURE

Three major types of land tenure dominate Namibia. Forty-four per cent of the country is privately owned, commercial farmland, supporting an estimated 42 000 people on about 6 000 farms. On most commercial farms, water is drawn from boreholes and small dams. Livestock farming is the main activity on commercial farms. A few farms in the south depend on the Hardap Dam, the Orange River and the Stampriet aquifer for irrigation water. In the north, irrigation is supported by the Grootfontein aquifer but dryland cropping of maize or wheat is most generally practiced.

Forty-one per cent of the country is communal farmland, owned by the State. It supports an estimated 138 000 households. Water is also owned by the State although the Department of Rural Water Supply is currently working on mechanisms to transfer ownership of water infrastructure to communities. Millet farming predominates in the north-central communal areas, while the proportion of sorghum and maize cultivation increases to the east. The communal areas of central and southern Namibia are occupied by livestock farmers, cattle predominating in the east and northwest and goats in the south and west.
Fifteen per cent of Namibia is set aside for conservation, much of which lies in the Namib Desert. Game reserves further north and east focus on wildlife conservation and tourism activities. Water in conservation areas belongs to the State.

1.5.3 POLITICAL REGIONS

Since independence in 1990, Namibia has been divided into 13 regions and 101 constituencies. These regions are similar to but not congruent with the previous magisterial districts, a development that adversely affects usefulness of available long-term data sets. Changes in regional boundaries were made again eight years after independence, further reducing the usefulness of existing data sets. We strongly recommend that future boundary changes recognise the importance of maintaining comparable information about the status of water and other resources.

Political regions were originally designed to provide for approximately the same number of people in each region. As a consequence, some of the northern regions are small and support a dense population. In the south, large regions are sparsely populated while the western part of Namibia supports almost no human habitation outside of the major coastal towns. The result is great regional differences in terms of water sources and water supply systems (Table 1.1).

Table 1.1: Regional distribution of water and water supply systems in Namibia.

<table>
<thead>
<tr>
<th>Name</th>
<th>Area (sq.km.)</th>
<th>Population</th>
<th>Rainfall 90% range (mm)</th>
<th>Main water sources</th>
<th>Main water supply systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caprivi</td>
<td>19 532</td>
<td>90 154</td>
<td>350-570</td>
<td>perennial rivers and groundwater</td>
<td>boreholes, shallow wells, boreholes</td>
</tr>
<tr>
<td>Erongo</td>
<td>63 720</td>
<td>78 470</td>
<td>2-590</td>
<td>groundwater, springs</td>
<td>boreholes (pipelines for coastal towns)</td>
</tr>
<tr>
<td>Hardap</td>
<td>109 888</td>
<td>66 495</td>
<td>2-400</td>
<td>groundwater, dam, ephemeral river</td>
<td>boreholes, pipelines (irrigation schemes)</td>
</tr>
<tr>
<td>Kerea</td>
<td>161 325</td>
<td>61 162</td>
<td>2-350</td>
<td>groundwater</td>
<td>boreholes, pipelines</td>
</tr>
<tr>
<td>Khomas</td>
<td>36 605</td>
<td>167 071</td>
<td>60-590</td>
<td>groundwater, dam, ephemeral rivers</td>
<td>boreholes, pipelines, recycled water</td>
</tr>
<tr>
<td>Kunene</td>
<td>144 255</td>
<td>64 017</td>
<td>2-710</td>
<td>groundwater, perennial river, springs</td>
<td>boreholes, pipelines</td>
</tr>
<tr>
<td>Oshangwena</td>
<td>10 502</td>
<td>179 634</td>
<td>255-970</td>
<td>groundwater</td>
<td>boreholes, shallow wells, pipelines</td>
</tr>
<tr>
<td>Okavango</td>
<td>43 418</td>
<td>116 830</td>
<td>320-870</td>
<td>groundwater, perennial river</td>
<td>boreholes, shallow wells, pipelines</td>
</tr>
<tr>
<td>Omahaka</td>
<td>84 735</td>
<td>52 735</td>
<td>100-710</td>
<td>groundwater</td>
<td>boreholes, pipelines</td>
</tr>
<tr>
<td>Omuattie</td>
<td>13 638</td>
<td>189 019</td>
<td>180-710</td>
<td>perennial river, groundwater</td>
<td>boreholes, pipelines</td>
</tr>
<tr>
<td>Ohana</td>
<td>52 631</td>
<td>134 884</td>
<td>180-710</td>
<td>perennial river, groundwater</td>
<td>boreholes, pipelines</td>
</tr>
<tr>
<td>Oshikoto</td>
<td>28 607</td>
<td>128 745</td>
<td>255-830</td>
<td>perennial river, groundwater</td>
<td>boreholes, pipelines</td>
</tr>
<tr>
<td>Ohikakha</td>
<td>105 328</td>
<td>102 536</td>
<td>180-830</td>
<td>groundwater</td>
<td>boreholes, pipelines</td>
</tr>
</tbody>
</table>

Area and population figures are from 1991; the Delimitation Commission has enlarged Kavango, Ohana, and Oshikoto while reducing the area of Kunene and Caprivi Regions I (C 15 1997). Rainfall range refers to the range of rainfall values expected 90% of the time within the region (Beville et al. 1993). The main water sources and the main water supply systems provided for and used by people are included in the last two columns.
REFERENCES


2. PHYSICAL AND CLIMATIC DETERMINANTS

2.1 INTRODUCTION

When considering the water environment, a useful approach is to start with the "hydrological cycle", which clearly shows how climatic and physical factors interact to determine the nature of the water environment. Figure 2.1 shows the classic picture of the global hydrological cycle.

![Diagram of the global hydrological cycle]

Figure 2.1: The Global Hydrological Cycle

The bulk of the Earth's water is stored on the surface of the globe in the oceans. The effect of the sun's radiation on the oceans is to cause evaporation, the process of water turning from liquid into atmospheric vapour. On average, water vapour remains in the atmosphere for about ten days before condensing to form clouds and eventually precipitation, including rainfall and snow. This precipitation returns directly to storage in the oceans, or it falls on land, becoming surface runoff, or it may infiltrate into the ground. Figure 2.1 shows how the water returns to the atmosphere eventually through evaporation from open surfaces such as lakes or as transpiration from plants.

Source: Hydrology in Practice by E. Shaw; 1994

It is clear from the cycle that changes to climate on a global basis will affect the balance of the cycle. More evaporation resulting from higher temperatures in one place may result in increased rainfall at another point on the globe. Similarly, major changes to land cover may result in increased or decreased runoff or changes in evapotranspiration, resulting in changes in the inputs to the cycle either in terms of quantity or location, or both.
Looking at the situation in arid parts of Namibia, it is clear that the hydrological cycle is distorted and incomplete. Figure 2.2 shows how precipitation, which is the driving factor in any climate, is scarce and irregular. Thus, except as a result of the occasional storm, or of aquifer leakage, there is little runoff.

![Hydrological System Diagram](image)

**Figure 2.2: The Hydrological System in an Arid Environment**

In arid parts of Namibia, the hydrological cycle is distorted and incomplete and is characterised by irregular inputs and in general, continuous outputs. Figure 2.2 shows that precipitation, which is the motive factor in humid climates, is scarce and irregular, whereas evaporation, evapotranspiration, aquifer leakages and especially human abstraction cause regular depletion of resources. Thus, except as a result of the occasional storm, or of aquifer leakage, there is little runoff.

Permanent surface storage is also limited and often only exists as a result of man-made structures. Infiltration rates are influenced not only by the low antecedent moisture conditions, but also by the texture of the surface material and vegetal cover. When flash floods do occur, recharge is comparatively small, with a high proportion of runoff being lost to the sea and atmosphere.

As indicated in Figure 2.2, the hydrological cycle in the arid and semi-arid zone is characterised by irregular inputs and in general, continuous outputs. Under these precarious circumstances, the need to formulate strategies and solutions for environmental sustainability cannot be over-emphasised. The Namibian environment does not have the capacity nor the resilience to regenerate itself once a certain optimum land use is exceeded. By definition, as a developing country, there is a pressure to develop in order to achieve goals of economic and human development, but there is clearly a need to guard against short-term economic gains at the expense of the environment and future generations.
Bearing this in mind, together with the predicted climate change resulting in reduced precipitation with increased variability AND increased population and water demand, it is clear that understanding and following trends in climatic and physical parameters is at the heart of understanding the water environment.

The United Kingdom Meteorological Office (UKMO) transient climate change experiment's "core" climate change scenario (Teer 1996) for the SADC region made certain predictions for Namibia by the 2050s decade. These include an expected increase in Potential Evapotranspiration of 4-8% for central and eastern Namibia, 8-12% for north central Namibia, and 12-16% for the Caprivi. With respect to rainfall, a decrease of up to 5% in Mean Annual Precipitation (MAP) is anticipated, with an increased variability of between 5 and 10%. In addition it was suggested that the length of the rainy season will shorten.

In considering indicators of climate change it may be useful to consider these predictions and to devise indicators which can tell whether these changes are indeed occurring and if so, whether to the predicted extent.

To what degree climate change may affect Namibia and the region is difficult to say with a high level of confidence. According to Tyson (1991),

"In spite of the fact that many future scenarios for climate change are possible, it is generally accepted that overall conditions in the sub-tropical and winter rainfall areas of southern Africa are likely to become hotter and drier by the year 2050. Summer rainfall over the tropical areas of the region may increase. Increased variability is also likely for the first half of the new century. If this general forecast is accurate, the trend towards more frequent and severe droughts in Namibia can be expected to continue."

2.2 PHYSICAL DETERMINANTS

2.2.1 TOPOGRAPHY, GEOLOGY AND SOILS OF NAMIBIA

2.2.1.1 Topography

In broad terms the country may be subdivided into three main topographic regions, namely:

- a narrow coastal plain (0-500m above mean sea level (amsl))
- an eroded escarpment giving way to dissected and rugged topography (500-1500m amsl)
- an extensive interior plateau (1000-1500m amsl)

The Brandberg Mountain, in the western part of Namibia, rises to 2579m amsl, making it the highest point in the country.

The surface topography of the country is shown in Figure 2.3 in which the most prominent mountain ranges and rivers are indicated. The two major desert regions present, the Kalahari and Namib are also shown.
Van der Merwe (1983) compiled a generalised map of the distribution of landscape types in Namibia. From this it was demonstrated that sand dunes or plains dominate more than half of the country.

2.2.1.2 Geology.

The distribution of the main geological units, as given in the 1:2 000 000 map produced by the Geological Survey of Namibia, is illustrated in Figure 2.4. In the broadest terms the geology of Namibia is described from the oldest to youngest formations as follows:

Basement (2 500-300 million years old (Ma))
Igneous and metamorphic formations are exposed in the north-west and extreme south of the country and formed the surface onto which younger sediments were deposited.

Damara Sequence (900-545 Ma)
The Damara comprises sedimentary and metamorphic rocks, which include dolomite, limestone, schist, quartzite, marble, diamicite and phyllite, with some volcanic rocks.
Figure 2.4: Geology of Namibia

This is a simplified representation of surface geology as compiled by the Geological Survey of Namibia. It is interesting to compare this with Figure 4.1, the distribution of Aquifer Types, which has been based on this map.

Data Sources: 1:2 000 000 Geology of Namibia. Map compiled by Geological Survey of Namibia ©1999
Figure 2.5: Dominant Soil Types of Namibia

Generalised view of the dominant soil types found in Namibia.

Data Source: van der Merwe 1983; after Harmse 1978.
Figure 2.3: Surface Elevation of Namibia
This Map shows the overall topography of the country generated from the digital elevation model which has been compiled from a 1x1km grid of satellite measured survey points, contoured in ArcView. Some important mountain ranges and rivers are marked for reference.

Data Source: 1km World DEM, Eros Data Center
A period of intense mountain building (orogenesis) took place after this sequence was deposited and concurrent with this, igneous activity took place, which resulted in the intrusion of certain granites. This period lasted till approximately 470 Ma.

During this latter phase the Nama Group sediments were deposited mainly in the southern part of the country, extending into Botswana. Nama sediments, comprising shale, sandstone, limestone and conglomerate, are exposed in the south-eastern part of the country.

Karoo and Etendeka Groups (310-65 Ma)
In Namibia, the karoo is represented by tillite, shale and sandstone, which are mainly exposed in the southern half of the country. Much of this material was deposited on the eroded surface on top of the Nama Group.

Post karoo volcanic activity resulted in extensive basalt layers capping the sediments and in the emplacement of dolerite dykes and sills into older strata.

Kalahari and Recent (24-0 Ma)
Most of northern and eastern Namibia is covered by a thick blanket of Kalahari sediment, which comprises sand, sandstone, gravel, calcrite and salt pan deposits. This sedimentary pile obscures older strata (collectively termed bedrock) and is in places covered by sand dunes.

2.2.1.3 Soils

Figure 2.5 has been compiled from Harmse (1978) as reproduced in van der Merwe (1983) and provides a generalised view of the dominant soil types present in Namibia. Many combinations and smaller occurrences are concealed in the regional pattern of distribution. In summary, lithosolic, interior arenosolic and poorly developed soil types dominate the pedology of the country. Soils with a high potential for crop production occur in a few areas but irrigation possibilities are limited.

Table 2.2 summarizes the agricultural usefulness of the soils shown in Figure 2.5, together with a brief description of the general characteristics and limitations.
TABLE 2.2: Characteristics of Soil Types shown in Figure 2.5.

<table>
<thead>
<tr>
<th>SOIL TYPE</th>
<th>AGRICULTURAL UTILITY</th>
<th>GENERAL CHARACTERISTICS AND LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fersiallitic</td>
<td>High</td>
<td>Well weathered tropical soils with low water-retaining capacity; potential for irrigation</td>
</tr>
<tr>
<td>Solonetziic and planosolic</td>
<td>Moderate-low</td>
<td>Shallow sands on clay; highly alkaline; periodically wet</td>
</tr>
<tr>
<td>Halomorphic</td>
<td>Low</td>
<td>Danger of salinization; Wetness; Flooding hazard</td>
</tr>
<tr>
<td>Arenosols (Littoral sands)</td>
<td>Low</td>
<td>Low water-retaining capacity; Very sensitive to wind erosion</td>
</tr>
<tr>
<td>Arenosols (Interior sands)</td>
<td>High</td>
<td>Low water-retaining capacity; Sensitive to wind erosion; Potential for irrigation</td>
</tr>
<tr>
<td>Alluvium</td>
<td>High</td>
<td>Danger of salinization; Flooding hazard; Potential for irrigation</td>
</tr>
<tr>
<td>Poorly-developed soils</td>
<td>Low</td>
<td>Shallow; stony; steep</td>
</tr>
<tr>
<td>Lithosols</td>
<td>None</td>
<td>Rocky; Steep mountains and hills</td>
</tr>
</tbody>
</table>

There is a general lack of information on the impacts of soil characteristics on infiltration and runoff (see section 2.4) and a need to look further into these aspects.
2.2.2 MAIN VEGETATION GROUPS

Giess (1971) compiled a vegetation map of Namibia which subdivided the vegetation into three main groups and various vegetation types within each group.

These are summarised as follows:

Deserts –
  Northern Namib,
  Central Namib,
  Southern Namib (*Desert and succulent steppe*),
  Winter rainfall area (*south-west*),
  Saline desert and dwarf shrub savanna fringe.

Savannas –
  Semi desert and savanna transition (*Escarpment zone*),
  Mopane savanna,
  Mountain savanna and karstveld,
  Thornbush savanna (*Tree and shrub savanna*),
  Highland savanna,
  Dwarf shrub savanna,
  Camelthorn savanna (*Central Kalahari*),
  Mixed tree and shrub savanna (*Southern Kalahari*).

Woodlands –
  Tree savanna and woodland (*Northern Kalahari*),
  Riverine woodland.

Figure 2.6 (after Giess, 1971) shows the distribution of the vegetation types in Namibia. Riverine woodland, which comprises narrow stands of trees along some riverbeds, is not depicted due to the small scale of the map.

The reader requiring information on the assemblages characterising the various vegetation types is referred to Giess’s publication, which provides a good overview.
2.3 CLIMATIC DETERMINANTS

2.3.1 PRECIPITATION

2.3.1.1 Introduction

Namibia’s position in the sub-tropics ensures that it is affected by circulation systems prevailing in both the tropics to the north and temperate latitudes to the south. At the same time it is dominated by the high pressure systems that, when averaged, constitute the semi-permanent, subtropical high pressure cells of the general circulation of the southern hemisphere. Effectively, the northern part of Namibia is situated in an area which is traversed by the boundary between two climate systems, the Intertropical Convergence Zone (ITCZ) and the Mid Latitude High Pressure Areas. In addition, the temperate zone includes the far south of Namibia but only at times, since all the zones have northward and southward movement depending on the time of year. The middle of these three zones is one of very little rainfall. The variations in the extent and timing of movement of these zones lead to Namibia’s rainfall patterns, which are characterised by their high temporal and spatial variability. Conventional statistical descriptions such as mean, and even median are often of limited use. Estimates of rainfall characteristics and patterns based on point measurements are problematic due to the huge spatial and temporal variability. It is generally accepted that the accuracy and usefulness of these estimates are directly related to rain gauge density, and the reliability and length of rainfall records.

2.3.1.2 Data Collection

Rainfall (precipitation) data in Namibia are collected by a number of organisations, the most important of which are:

Namibia Meteorological Services (NMS)
Hydrology Division in the Department of Water Affairs (DWA)
Desert Research Foundation of Namibia (DRFN)

In addition to its 20 manned multi-sensor weather stations, the NMS receives daily rainfall data on a monthly or seasonal basis from approximately 380 volunteer observers, although over the years data have been collected and stored for more than 1,000 stations. DWA currently operates 36 autographic rainfall stations that collect data on a continuous (rather than just daily total) basis. There are data for an additional 30 stations which are now closed. Since 1962, the DRFN has collected precipitation data at 40 different locations although many of these were for short periods only. Seven stations remain open of which four record continuous data. The DRFN stations are of particular interest because of the inclusion of several Standard Fog Collectors with data loggers (Henschel, Seely et al. 1998). Although the seven locations at which fog has been collected are all within 50km of Gobabeb, they do cover an area from close to the coast (Rooibank) to as far inland as Ganab. Fog collectors with loggers are still operated at Ganab, Kleinberg, Klipneus, Rooibank, Swartbank and Vogelsfelderberg.
Figure 2.6: Preliminary Vegetation Map of Namibia

Giess has divided the vegetation into 3 main groups, Deserts, Savannas and Woodlands. Further subdivision has given 15 discrete vegetation types of which 14 are shown above. The 15th, Riverine woodland, has not been included, as the areas are too small to show up at this scale.

Quality of data for NMS’s own stations and the majority of its observer stations is good, but there are certainly a number of stations for which data are suspect, either in that the gauges are not always read daily, or that the observer may occasionally be absent. NMS readily acknowledge that there is a serious backlog with respect to the processing of rainfall data, not only of the intensity data which requires a lot of work, but also of daily rainfall data. Data are relatively up-to-date for approximately 100 of the 315 stations currently in operation, but only 30 key stations are completely up-to-date. Almost no rainfall intensity data have been processed for NMS stations for more than a decade. Bearing in mind the investment of time and money that has been made to collect the data, as well as the desperate need for good data as input into various studies, it is worrying that it has not been possible to obtain more useful information from the data.

DWA’s autographic stations are susceptible to instrument failure that can only be detected and rectified during visits to the stations. Processing of the data collected is relatively up-to-date for the majority of stations, although backlogs of greater than three years exist for about 25% of the stations.

The locations of rain gauges registered with NMS are shown in Figure 2.7. All open and closed stations with more than ten years of record have been plotted, since these may be long enough to provide useful data. The map shows clearly that the coastal belt, the entire far north and the north-east are sparsely covered.
Table 2.2 shows how many rain gauges there are, or have been, in all thirteen regions.

Table 2.2: Density of Rain Gauge Network in Namibia

<table>
<thead>
<tr>
<th>Region</th>
<th>Area of Region (km²)</th>
<th>Suggested WMO Gauge Number</th>
<th>Total Rain gauges 310 yrs full yrs</th>
<th>Total open</th>
<th>Opened recently</th>
<th>Total open</th>
<th>Rain gauges per 10 000km² 310 yrs full yrs</th>
<th>Total open</th>
<th>Opened recently</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caprivi</td>
<td>14 126</td>
<td>10</td>
<td>1 2 1 0</td>
<td>1 2 1 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Okavango</td>
<td>46 824</td>
<td>35</td>
<td>10 10 7 0</td>
<td>2 2 1 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kunene</td>
<td>116 329</td>
<td>84</td>
<td>43 45 16 1</td>
<td>3 3 1 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omosatui</td>
<td>25 422</td>
<td>19</td>
<td>7 7 4 0</td>
<td>5 5 3 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oshana</td>
<td>8 646</td>
<td>6</td>
<td>4 4 2 0</td>
<td>8 8 4 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oshikoto</td>
<td>38 432</td>
<td>19</td>
<td>18 19 12 5</td>
<td>6 6 3 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oshangwena</td>
<td>10 644</td>
<td>8</td>
<td>4 4 0 0</td>
<td>4 4 0 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oshoendjupa</td>
<td>105 328</td>
<td>75</td>
<td>143 147 68 5</td>
<td>14 14 6 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Erongo</td>
<td>63 720</td>
<td>48</td>
<td>66 68 27 3</td>
<td>10 11 4 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Komas</td>
<td>36 805</td>
<td>28</td>
<td>103 107 46 3</td>
<td>28 29 12 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Omaheke</td>
<td>84 732</td>
<td>87</td>
<td>56 57 33 4</td>
<td>7 7 4 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardap</td>
<td>109 888</td>
<td>79</td>
<td>108 120 54 3</td>
<td>10 11 5 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Karas</td>
<td>161 325</td>
<td>116</td>
<td>95 99 47 1</td>
<td>6 6 3 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>825 121</td>
<td>698</td>
<td>658 689 315 22</td>
<td>7.9 8.3 3.8 0.02</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes
1 Number of gauges per 10 000km²
2 Only years without any lost record are counted
3 Stations opened in the last 10 years (i.e., since 1988)

For comparison purposes, WMO guidelines indicate a density of 1.25 recording (i.e., continuous recording) and six non-recording precipitation gauging stations per 10 000km². This would imply that a total of 495 non-recording stations and 103 recording stations are required to cover Namibia’s land area. This guideline is sometimes considered unrealistic for arid areas and countries with low populations. Nevertheless, there are undoubtedly areas that do not have adequate rain gauge coverage.

Worst affected regions are the Kunene, Oshangwena, Oshana, Omosatui, Oshikoto, Okavango and Caprivi Regions. More than half of these regions have zero or only one currently operating rain gauge per 10 000km². Even if all rain gauges (including those now closed) with more than ten years of complete data are considered, there are only four per 10 000km² on average for these seven regions. Looking at the situation on a catchment or basin basis, it is evident that very little precipitation data are collected within the Cuvelai Basin, and very little in the headwaters of the northernmost westward flowing rivers. Similarly, very little data are collected for the catchment of streams flowing towards the Okavango Delta.

It is recognised (Agnew and Anderson 1992) that in the arid zone “problems of hydrometry, hydrological analysis and interpretation, and water resource assessment and development are severe”. Indeed the most severe problem is the most basic; what to measure and where to measure it. In its Guide to Hydrological Practices (WMO, 1974) the World Meteorological Organisation defines optimum and minimum data collection networks as follows:

**Optimum Network:**

“By interpolation between values at different stations, it should be possible to determine (with sufficient accuracy for practical purposes) the characteristics of the basic hydrological and meteorological elements anywhere in the country. By characteristic is
meant all quantitative data, averages and extremes that define the statistical distribution of the elements studied”; and

**Minimum Network:**

"Is one which will avoid serious deficiencies in developing, and managing water resources on a scale commensurate with the overall economic development of the country."

For most of the arid zones in the world, the network is either minimum or sub-minimum. If the definition for the minimum network is taken as a goal to achieve, together with the broad guideline of six manually-read and 1.25 recording rain gauges per 10 000km², a useful point of departure has been established for further consideration. Implicit in the definition provided above is an understanding of the purposes for gathering rainfall data and the uses to which they are going to be put. This will make possible a more reasoned analysis of where the serious gaps are. This is discussed briefly in the following paragraphs.

The main applications of rainfall data in Namibia can be summarised as follows, together with an indicative description of the quantity and type of data that may be required:

Understanding and quantifying the water balance (or localised hydrological cycle) on a catchment, regional and national basis. This means that sufficient rainfall data are required to be able to state what the precipitation input is to the water balance.

Detailed data for users dependant on real-time figures. Users such as farmers reliant on irrigation need to look at soil moisture deficit and other related parameters.

Rainfall/runoff modelling. In view of the fact that runoff measurement stations are expensive to erect and maintain, it is necessary to measure rainfall at a number of locations and to estimate the runoff that would be generated by the rainfall.

National and Regional Planning. Information on rainfall helps the planning of drought relief and general strategies.

Estimation of flood lines and design of structures (intensity data are important here).

Ecological and land-use studies

Investigating and monitoring of climate change. With respect to this State of the Environment Study, this is obviously a key application of rainfall data, and is discussed further under 2.5.4.

In considering these applications, it is clear that a limited number of rain gauges are required to cover the country, at least to monitor trends for climate change and, bearing in mind that areas which have apparently little economic importance today, may suddenly become development centres tomorrow. Agnew *et al* (1992) suggests that:

"within the arid zone, the optimum rain gauge network would consist of a relatively sparse distribution of recording and totalising gauges, spread to take into account the major landscape variables and climatic elements. This would be supplemented by a number of dense networks of recording gauges, sited in representative locations. To this would be added, according to logistical possibilities, daily rain gauges.”
A comparison with another arid area similar in population density is interesting. The Sultanate of Oman, which has a surface area of 215 000km$^2$ has a network of 334 open rain gauges. This corresponds to approximately 15.5 per 10 000km$^2$. However, it should be pointed out that almost no data were collected prior to 1973 and that the current relatively healthy state of affairs is the result of a major government initiative and expenditure following the establishment of the Public Authority for Water Resources in 1979.

While a detailed analysis of how and where exactly the data collection network should be improved is beyond the scope of this study, it is important to take note of the fact that any conclusions or indicators based on rainfall data will only be as good as the data from which they are derived. This highlights the need for deriving an indicator which provides feedback on the status of rainfall data collection and processing. This is further discussed in 2.5.4 and 2.5.5.

Both NMS and DWA operate satellite receiving stations for the National Oceanic and Atmospheric Administration (NOAA) satellite data, and NMS are currently attempting to correlate data on cold cloud formation with measured rainfall. This research work is yielding positive results and could ultimately reduce the need for as extensive a rain gauge network as suggested by the WMO.

2.3.1.3 Annual Rainfall

Data collected from the sources mentioned above were analysed and used to draw up Figure 2.8. Figure 2.8 shows isohyets of mean and median annual precipitation for Namibia based on all stations with 10 or more years of record. A total of 315 stations were used amounting to 20 600 station years. An earlier study (Amakali 1992) used data from ± 500 stations and 19 093 station years. The decreasing trend from north-east to south-west is both clear and uniform with only a few anomalies such as the area of high rainfall around Grootfontein and Tsumeb.

The two most predominant features of Namibia’s climate are the scarcity and unpredictability of its rainfall. Namibia’s climate is second in aridity only to the Sahara Desert within Africa (Barnard 1998). Steep gradients characterise the rainfall map from tropical semi-humid (3% of land area) to hyper-arid in the west (12% of land area). Country-wide average rainfall is approximately 272mm.

Examination of Figure 2.8 highlights the problem of relying on “mean” as a measure of the average or normal situation. It is important to realise that the statistical mean is what would be expected every 2.34 years NOT every second year, which is perhaps the common perception of “average”. The median is a measure of what can be expected 50% of the time, or on average, every second year. According to Figure 2.8, the mean rainfall for Keetmanshoop is 155mm and the median is 125mm, or 20% less. For the less arid areas in the north-east, the mean is closer to the median. For example, the mean for the Rundu area is 580mm, and the median 560mm (4% less). In the extremely arid areas the median can be less than half of the mean.

Variability from year to year is high. This becomes even clearer when rainfall variability is examined in more detail.
Figure 2.7: Rainfall Data Collection in Namibia

Although rainfall data are officially collected at more than 400 rain gauge stations, the Namibia Meteorological Services readily acknowledge that there is a serious data processing backlog for many of these stations, especially those which have automatic recorders. Figure 2.7 shows the positions of all open and closed stations with more than ten years of record. Regions with poor rain gauge coverage are the Kunene, Oshigango, Oshana, Omusati, Oshikoto, Okavango and Caprivi Regions. More than half of these regions have none or only one rain gauge currently operating per 10,000 km². Throughout Namibia, the number of rain gauges in operation has been reduced in recent years and is a serious cause for concern.

Data Sources: Namibia Meteorological Services; Hydrology Division, DWA.
Figure 2.8: Long-term Mean and Median Rainfall in Namibia

The "mean" or "average" value has traditionally been used as the key statistic for describing rainfall for an area. In an arid environment, where the statistical distribution of rainfall is skewed, the mean value tends to give a misleading picture. Namibia is no exception, and in the more arid parts of the country it is much more probable to have a year of below average rainfall than one of above average. For this reason, the median value is more often useful since it represents the real "fifty-fifty" value. There is an equal chance of having a rainy season above or below the median value.

Data Sources: Namibia Meteorological Services; Hydrology Division, DWA.
2.3.1.4 Rainfall Variability

For those dependent on rainfall both directly and indirectly, the mean and even median rainfall figures can be misleading. The pattern of rainfall is highly seasonal, being concentrated within a few months, with 90% falling between November and March. This is further compounded by rainfall being highly variable in time and space, both within and between years. This has a direct impact on the growth of vegetation and crops, the movements of people, domestic stock and wildlife, flooding of the rivers and groundwater recharge. The concept of rainfall variability is therefore important. As a measure of variability, Figure 2.9 shows average deviation as a percentage of mean annual precipitation (MAP). Figure 2.10 shows how Namibia compares with the rest of the world. As expected from the preceding discussion of mean and median, variability is highest in the most arid parts of the country. If, as some suggest, variability is one of the things that may increase as a result of climate change, the effect in semi-arid and arid areas could be very severe.
Figure 2.11 shows rainfall variability in a different way by plotting the "drought" rainfall (the annual total which would normally be exceeded four out of every five years or 80% of the time), and the annual total which would only be exceeded one out of five years, or 20% of the time, together with the mean, for seven key stations.

![Rainfall Variability Diagram](image)

**Figure 2.11 : Rainfall Variability (Upper and Lower Percentiles) for Key Locations**

*In the above Figure the top of the blue block represents the upper 20 percentile or a "good" rainfall season, while the bottom of the blue block corresponds to the lower 20 percentile or a "poor" rainfall season. The red spot corresponds to the mean annual rainfall. At Keetmanshoop, where the climate is truly arid, the poor year is much worse than the mean, while the good year is only slightly above the mean.*

This is an interesting way of looking at variability because it gives a good idea of how much annual rainfall can vary within a fairly short time. An event which occurs once in every five years is by no means an extreme event but, for arid parts of the country it can be significantly lower than the mean. The Figure shows, for example, that for Keetmanshoop a poor year would be 75mm and a good year 180mm. The extremes are most pronounced in the more arid areas.

It is also interesting to see how the "good" and "poor" years compare with the mean. For Windhoek, the mean is 361 mm and the "good" and "poor" years 458 and 241 mm, respectively. Thus the poor year is 33% below the mean, while the good year is only 26% above the mean. In Keetmanshoop, the mean is 145mm and the good and poor years 180 and 75mm, or 24% above and 46% below.

Up to this point the description of rainfall in Namibia has been largely limited to annual figures and the variability thereof. It is also important to look at the distribution of rainfall through the year. An annual total of 400mm spread evenly over a four or five month period is very different from 400mm spread over only two months. Figure 2.12 shows the distribution of mean monthly rainfall for stations representing the main climatic regions of Namibia.
Figure 2.9: Variability in Annual Rainfall around Namibia

In arid climates, the difference between a poor rainy season and a good one can be very large. Neither the "mean" nor the "median" gives a good indication of what a poor (but not abnormally poor) rainy season might be like. Rainfall is highly variable in both time and space, both within and between years, and this has a direct impact on the growth of vegetation and crops, the movements of people, domestic stock and wildlife, flooding of rivers and groundwater recharge. A good understanding of the concept of rainfall variability is therefore important. As a measure of variability, Figure 2.9 shows average deviation as a percentage of Mean Annual Precipitation (MAP). Note: Rainfall isohyets shown in Figure 2.9 are as they appear on the 1988 source map. Updated isohyets are provided in Figure 2.8.

Source: Updated Isohyetal Rainfall Map for Namibia Report, 1992, Hydrology Division, DWA.
Figure 2.10: Variability in Annual Rainfall Worldwide

- under 20%
- 20 - 25%
- 25 - 30%
- 30 - 40%
- 40%
Throughout Namibia, the rainfall season is limited to a core period of December to March. The rainy season usually starts earlier in the north and north-east and often goes on into April in the central and southern areas.

The variability within each month is also considerable. Throughout Namibia the rainfall season is limited to a core period of December to March. The rainy season usually starts earlier in the north and north-east and often goes on into April in the central and southern areas.

2.3.1.5 Rainfall Intensity

Another important rainfall parameter is rainfall intensity, defined as the rate at which precipitation falls with respect to time. It is measured using a recording rain gauge, that is one recording time as well as the quantity of rain falling at a point. A number of these gauges are operated in Namibia (20 by NMS office and 36 by Hydrology Division). However, the majority of the data collected have not been processed, because of shortage of staff. This unfortunate state of affairs means that there are a number of stations for which potentially useful and relatively long records exist, but that these data will not be available until the backlogs have been cleared. An effort was made in the late eighties to process data for about 20 stations. Only for Windhoek, however, where the record extends from 1913/14 to 1988/89, is the data series long enough to be of much interest. Figure 2.13 shows the maximum annual intensity figures for different storm durations for Windhoek.
Figure 2.13: Rainfall Intensity for Windhoek

Figure 2.13 shows the heaviest storms which fell in any 15 minute, one hour and 24 hour period for each hydrological season (October to September) between 1913/14 and 1988/89. Rainfall intensity is strongly linked with erosion. Combined with poor vegetation cover, intense rainfall storms can cause large quantities of top soil to be lost. The graph shows, for example, that a storm of around 80mm in a 24 hour period has a return period of approximately one in twenty years. A statistical analysis reveals that no trends either upwards or downwards can be shown with any confidence.

The record indicates that a storm of around 80mm in a 24 hour period has a return period of approximately 1 in 20 years, with 50–60mm having a frequency of approximately seven years. A storm with a 15 minute accumulation of more than 10mm can be expected at least once every year. A statistical analysis reveals that no trends either upwards or downwards can be shown with any confidence. A much longer record or data from a number of stations would be required for statistically significant conclusions to be drawn. Rainfall intensity links strongly with erosion and, combined with poor vegetation cover, intense rainfall storms can cause large quantities of topsoil to be lost. As a parameter that may change with climate change, rainfall intensity is something that needs to be monitored carefully. It would be dangerous to look only at mean precipitation since this could remain steady, but be increasingly comprised of fewer, but heavier rainfall storms.

An understanding of rainfall intensity is important for many other aspects relating to the water sector. For example, it is often the intensity of a storm rather than the quantity which has the greatest effect on runoff, and especially on flood peaks.
2.3.1.6 Fog

The climatological mechanisms of fog are complex (Henschel, Seely et al. 1998) and there are different kinds of fog. Fog is important in the Namib Desert in that it has a precipitation five times higher than that of rain and an even greater reliability (Pietruszka & Seely). Lancaster et al. (1984) described how fog changes from the coast inland. It was shown that fog-day frequency and fog precipitation increased from the coast to a point between 20 and 60km from the coast. After this point both frequency and quantity were found to decline. Figure 2.14, based on data in Henschel illustrates this phenomenon along two transects, one up the Kusib river valley, and one across the nearby gravel plains.

![Fog Precipitation with Distance from the Coast](image)

**Figure 2.14:** Fog Precipitation with Distance from the Coast
Fog-day frequency and precipitation increases from the coast to a point between 20 and 60km from the coast. After this point both frequency and quantity were found to decline in a study by Lancaster et al. (1984).

2.3.2 EVAPORATION

Evaporation, which can be defined as the process in which liquid water is converted into vapour, has been measured at a number of locations around Namibia and adjacent countries since 1951 using either Symons or Class-A evaporimeters. Both of these are essentially water-tight containers with surface areas of approximately one square metre. The fall in depth of the water level in the open pan is taken as equal to evaporation since seepage losses are not possible from a sealed container. The effect of rainfall is taken into account by making measurements at an adjacent rain gauge and adding the rainfall depth to the observed water level drop in the pan. Data quoted for evaporation pans are gross evaporation and the difference between gross and nett evaporation is explained as follows (Crerar 1988):

"If rainfall occurs during the measurement of evaporation the observed depth of water vapourized will be reduced. This observed depth corresponds to nett evaporation. In order to calculate the gross evaporation, the depth of precipitation measured in an adjacent rain gauge must be added to the observed nett evaporation."

While nett evaporation may seem the more useful of the two measurements, there are several reasons why it is important to know the gross evaporation in many hydrological
applications. It is important to note, however, that evaporation from an A-pan is higher than from a large open water surface. This is because the water in the small silver A-pan heats up quickly during the day and cools down rapidly at night. It is therefore necessary to apply a reduction factor to the gross A-pan evaporation quoted for a particular location. A study aimed at deriving reduction factors for large open water surfaces was carried out by the Hydrology Division in DWA (Sivertsen 1991). This study concluded that a reduction factor of 0.8 should be used for the months of January through to June, and 0.7 for July to December.

Several evaporation stations (almost exclusively A-pan) are still in operation, run by both the Hydrology Division within DWA and the NMS, although processing is several years behind. To bring the backlog up to date would take several person years. A report compiled in 1988 (Crerar 1988) was the last time that all available data were processed and used to obtain an overview of evaporation in Namibia. Fortunately, due to the fact that annual variations in evaporation are relatively small (very small when compared to fluctuations in rainfall), up-to-date figures are not absolutely necessary for many studies, and the map produced in this study as well as the data on which it is based are sufficient for most applications. However, in view of the fact that the map was drawn up using very limited data for many areas, in particular the north and coastal areas, it would be useful to update this map using the nearly ten years of new data that have been collected but not processed. This is particularly serious for the coastal belt since it is this zone which is likely to differ markedly from other areas of the country. Evaporation figures along the coastal belt will be markedly affected by coastal fog, the strong and hot east winds and the sometimes cold summer temperatures.

The National Evaporation Map, produced in 1988, is shown in Figure 2.15. It should be noted that the figures provided correspond to millimetres of gross A-pan evaporation. If the mean nett evaporation for a large open water surface were to be calculated from this, both a reduction coefficient and the mean annual rainfall would have to be taken into account.

Evaporation rates vary considerably throughout the year. It was found that the distribution through the year varied for different parts of the country (Crerar 1988). The country was divided into four broad climatic zones (shown as A to D) and a monthly distribution fitted for each zone. The derivation of the zone boundaries was somewhat empirical and depended mainly on an analysis of the available data. The zones do, however, fit in with what is known about temperature variations through the year. For example, the very hot summer temperatures and relatively cold wintertime temperatures in the south result in the largest difference between summer and winter evaporation rates.
Figure 2.15: Evaporation Map of Namibia

Evaporation far exceeds precipitation throughout Namibia, and together with evapotranspiration is the country's biggest water "consumer". Evaporation is difficult to measure from open water surfaces such as lakes, because it is not usually possible to distinguish between evaporation and seepage losses. It can be estimated by considering a number of other climatic parameters, but in Namibia evaporation has generally been measured by observing the fall in water depth in a standard water-tight metal pan. This observed evaporation is usually higher than would be expected from a large open water surface such as a dam, and a reduction factor has to be applied. In Figure 2.15, lines of equal annual evaporation in Namibia are shown based on all observed data up to 1997. Estimates for the coastal belt are considered approximate only, based as they are, on very few data. Note: Rainfall isohyets shown in Figure 2.15 are as they appeared on the 1996 source map. Updated isohyets are provided in Figure 2.8.

Source: Evaporation Map for Namibia, 1988, Hydrology Division, DWA.
The monthly variation in mean evaporation for the four zones of the country in which patterns were found to be relatively homogenous are shown in Figure 2.16.

![Figure 2.16: Monthly Distribution of Gross Evaporation for Four Climatic Zones](image)

Evaporation rates vary considerably throughout the year. The distribution through the year varied for different parts of the country. The country was divided into four broad climatic zones (shown as A to D on Figure 2.15) and a monthly distribution fitted for each zone.

While it is not necessary to measure evaporation as intensively as rainfall, the importance of evaporation in Namibia should not be underestimated. At all of Namibia’s major dams, losses through evaporation far outstrip the quantity of water actually drawn off for water supply. Water is also lost through transpiration and seepage, although the amount is unknown.

For an arid country, Namibia has a large number of surface water supply dams, and hence losses to the atmosphere are high. In order to combat evaporation losses, NamWater attempts to transfer water from dams with inefficient basin characteristics to those with more efficient storage characteristics. Water stored in the Omatako Dam, for example, is transferred to the Von Bach Dam as quickly as possible. In addition, when there is an alternate source to the dam, that can be used later, as much water as possible is taken from the dam when it is full and as little as possible from the alternate source, giving the alternate source time to recover. Further details are provided in the discussion on “Conjunctive Use” in Chapter 5.

In any discussion of evaporation, it is necessary also to consider evapotranspiration and potential evaporation. The latter is important for areas of water deficiency, where it is defined as the amount of water which would be evaporated from the soil and transpired from standard vegetation provided there is an adequate amount of water in the soil. Throughout Namibia, potential evaporation exceeds rainfall for the year, with some areas in the south of the country exceeding 2000mm.

2.3.3 OTHER CLIMATIC DETERMINANTS

A number of other climatic determinants are indirectly associated with the water environment and with the climatic determinants already discussed. For example,
evaporation is affected by air temperature, relative humidity, wind, solar radiation and water chemistry. Information and data on these have been taken from Hutchinson (Hutchinson 1993) These are briefly discussed as follows:

Solar Radiation
Although days are obviously longer during the summer months, the presence of clouds at this time of the year, can mean that the hours of sunshine are greater during the winter months. This is especially true of the high rainfall areas. For example in Katima Mulilo August has 10.7 hours of sunshine, while the average for February is only 6.5 hours. By comparison, for Keetmanshoop, January, with 11.7 hrs is the month with the most hours of sunshine and this reduces to 9.6 hours in June.

Average Temperatures
The coastal strip has its own temperature regime, with the possibility of high temperatures at any time of the year. Elsewhere, there is a marked seasonal regime with the highest temperatures occurring just before the wet season in the wetter areas, and during the wet season in the drier areas. A useful summary is provided in Hutchinson (Hutchinson 1993).

Wind
Only at the coast do mean wind speeds exceed three metres per second. In general, in the interior, August, September, October November and December are the windiest months.

Relative Humidity
Relative humidity is the amount of moisture in the air compared to the maximum amount the air could hold at that temperature, expressed as a percentage. A decrease in temperature would increase the relative humidity. For Windhoek, March is the most humid month at 51%, compared to September at 18%. For Rundu, February is the most humid month at 72%, dropping to 33% in September.

2.4 RUNOFF, INFILTRATION AND RECHARGE PROCESSES

2.4.1 INTRODUCTION

Namibia’s ephemeral rivers are “effluent” systems. This means that the groundwater tables are fed by the river, rather than a high water table acting as source for the river, as is the case with “influent” rivers. Only a small proportion of the rain that falls on a particular catchment ends up as flow in the river. The “depth” of rain that becomes runoff is referred to as "unit runoff" and is normally expressed in mm. Figure 2.17 shows very clearly that Namibia is one of the countries falling entirely within a less than 50 mm unit runoff zone.

A Unit Runoff map and report (Chivell and Crerar 1992), based on almost all available data at the time was drawn up for Namibia and confirms these figures. Indeed it shows that many areas of Namibia had unit runoff values close to zero and that the maximum mean annual value was only 25mm for areas of the Fish River catchment. In general, for the ephemeral systems in Namibia, the percentage of MAP that ends up as river flow varies from as little as less than 1% up to around 12.5% for parts of the Fish River catchment. The remainder goes to direct evaporation and evapotranspiration.
Figure 2.17: Unit Runoff Map of the World

Unit Runoff is the depth of rainfall (in mm) which ends up as river flow. In some parts of the tropics, this can be in excess of 1000mm per annum. By comparison, all of Namibia falls within the "less than 50mm" unit runoff zone. In fact, unit runoff in Namibia is rarely more than 10mm to 15mm and in many areas, especially flat sandy areas where almost all rain infiltrates into the sand, unit runoff is virtually zero.

Source: Hydrology and the River Environment, 1994, by H. Neusser
Evapotranspiration is by far the greatest component. Some of the runoff referred to in this percentage also ultimately goes to recharge of alluvial aquifers on its way downstream, and in so doing, the majority of ephemeral river floods ultimately disappear entirely into the sand.
2.4.2 THE PARADOX OF "GOOD RUNOFF" AND "BAD LAND MANAGEMENT"

Attempts at rainfall/runoff modelling for Namibian conditions have been developed over the last 10–15 years and have shown that the influences of anthropogenic factors are complex. Antecedent catchment conditions, that is those factors relating to catchment conditions before a rainfall event, have a very strong influence on runoff and infiltration and hence recharge as well. The concept of "negative serial correlation" is discussed in Chapter 3 and ties in with the concept of the effect of antecedent conditions. In the arid Namibian situation, contrary to the norm observed in more temperate zones, rainfall following long dry periods can produce more runoff than rainfall following a wet period.

Although this is an over-simplification, the idea can be physically explained by the fact that drought periods generally result in poor vegetation growth and overgrazing, and it is this very lack of ground cover that leads to greater overland flow (with higher velocities), increased erosion and sediment transport. This simple fact raises the apparent paradox that above-normal quantities of runoff in the rivers may be as much a sign of poor catchment conditions and land management as of above average rainfall. It will be necessary to bear this in mind when interpreting the meaning and implications of trends in runoff.

Clearly good land management can help and promote good grazing, reducing erosion and soil loss. A reduction in runoff at the gauging stations would seem likely to follow although this may not be the case in the long run for the following reasons.

Initially, a change for the better with respect to good land management should result in a reduction in runoff. However, studies such as SABRINA, the Study of Alluvial Bed Recharge, Induced and Natural (Wheeler, Crerar et al. 1987), have shown that heavily silt-laden floodwaters often fail to yield good recharge because the small silt particles block the pores in the sandy river bed. This may explain why groundwater levels are much lower than they used to be several decades ago in most rivers. Thus it can be assumed that good land management leading to a reduction in silt load will result in increased recharge rates, even with reduced flows in the rivers.

Clearly the complexities of the natural system make it difficult to identify any trends. Even the above illustration would be difficult to prove for lack of sufficient historical data and the indisputable effect of increased water abstraction by farmers or other human users such as mines and agencies responsible for large-scale abstraction.

2.5 OVERVIEW, GUIDELINES AND INDICATORS

2.5.1 RELEVANCE TO THE WATER SECTOR

An accurate understanding of Namibia's climate as well as the interaction between climatic and physical determinants is at the heart of the water environment, especially as these relate to the availability of fresh water resources. The quantity of flow in an ephemeral stream depends on the frequency and intensity of rainfall as well as the condition of the catchment. In turn, infiltration and recharge depend on the quantity of rainfall falling directly on the ground and the quantity of water entering aquifers from
flowing streams and perennial rivers. However, infiltration rates are also related to soil types and levels of silt load in the stream. The latter of these is, in turn, also related to catchment condition, including vegetation cover. An understanding of these processes is essential if planning and management within the water sector is to be carried out in a sustainable manner. A failure to address any of the issues related to knowing and understanding both physical and climatic determinants and their interaction will inevitably result in socio-economic and environmental degradation, at least in the long term.

2.5.2 ASSESSMENT AND EVALUATION OF THE SITUATION IN NAMIBIA

As discussed already, Namibia, as an arid country, has a water sector that is particularly exposed to the vagaries of drought. At the same time, while rainfall is an unreliable and irregular phenomenon, outputs such as evaporation, evapotranspiration and abstraction are continuous.

Water resources have to be managed in such a way that they last through the long periods of drought. Not only does drought mean reduced rainfall, it also generally leads to a shortage of grazing, overgrazing and hence catchment degradation and ultimately the erosion of topsoil. High sediment loads in the rivers result in a reduction of aquifer recharge. Clearly there is a desperate need for a holistic approach to catchment management.

Within the government, parastatal agencies and the private sector, there are a number of organisations responsible for the collection and analysis of the essential data and information discussed in this chapter. Ongoing research is also carried out by these agencies with the aim of achieving the required understanding highlighted in Section 2.5.1 above. This is no easy task as human resources and levels of expertise are often not sufficient for the work to be carried out adequately. The most worrying trend, especially in a developing country such as Namibia with its limited financial resources, is that large sums of money have been spent on collecting equally large amounts of data but that there are often not the required human resources or financial resources to process the data and thus render it useful. As a result it is inevitable that the decisions required to ensure holistic management on an environmentally sustainable basis are based on limited information.

2.5.3 PRIORITISED CONSIDERATIONS FOR SUSTAINABILITY

In view of Namibia’s intrinsic fragility with respect to over exploitation of its water, land and other natural resources, the need to formulate strategies and solutions for environmental sustainability cannot be overemphasised. In this chapter the climate of Namibia has been addressed as an integrated unit, and emphasis has been placed on the need for an understanding of the dynamics involved. A fundamental concern and consideration in this respect is to improve the level of data collection, processing and analysis. Major requirements include:

An improved data collection network for rainfall in many areas, i.e. better distribution and coverage, especially the entire north from west to east and for evaporation data on the coast. Commercial farmers have traditionally collected rainfall data for NMS, and it is necessary to look at expanding this support into the communal farming areas.
useful strategy may be to run a public relations campaign in order to involve the communities in data collection efforts.

Improved data processing to keep up with the data that are being collected, as well as to clear the backlog, which includes a decade or more of rainfall intensity and evaporation data.

The monitoring of climate in order to track and plan for possible climate change.

The monitoring of catchment conditions. It may be feasible to regularly monitor sample areas around the country using satellite imagery. This could be done by calculating the "Normalised Difference Vegetation Index" (NDVI). A detailed discussion of this is not warranted here, but the concept is based on using an index calculated by looking at the amount of vegetation in each element (pixel) on a satellite image. This value can be checked on a regular basis (e.g. annually).

An holistic approach to catchment management and review of legislation that relates to catchment management, highlighting that overgrazing on one farm affects more than just that farmer.

2.5.4 EVALUATION OF POSSIBLE INDICATORS

The purpose of indicators relating to climatic and physical parameters must provide an indication of change in these two main determinant groups. Thus it is necessary to look at indicators of climate change and of change in the physical characteristics of the catchment, basin or larger land area.

In theory, climate change should be relatively straightforward to investigate since it should simply involve the monitoring of climatic parameters such as Mean Annual Precipitation (MAP), rainfall variability and intensity. In practice this is not so straightforward since the normal spatial and temporal variations are so high that they mask long-term changes. The only way around this approach is to use sufficient quantities of data and long records.

As stated in the introduction to this chapter the UKTR's "Core" Climate Change Scenario predicted an expected increase in Potential Evapotranspiration of 4-8% for central and eastern Namibia, 8-12% for north central Namibia, and 12-16% for the Caprivi. With respect to rainfall, a decrease of up to five per cent in MAP is anticipated, and increased variability of between five and ten per cent. Indicators should monitor these predictions where practicable.

In view of the dependence on up-to-date comprehensive data on rainfall and other climatic characteristics, it would seem wise to consider the inclusion of indicators relating to the effectiveness of data collection and processing activities. Table 2.3 summarises possible indicators.
Table 2.3: Possible Indicators of Status of Climatic and Physical Determinants and of Data

<table>
<thead>
<tr>
<th>Definition of Indicator</th>
<th>Data Collection and Calculation</th>
<th>Uses of Indicator</th>
<th>Discussion/Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Average National Mean Annual Precipitation</td>
<td>Either calculated by taking the arithmetic means for a selection of key stations and taking an average of these values. This “average” for Namibia for the year could be plotted and trends examined. Alternative would be to draw up a map of isohyets corresponding to precipitation for the year. The volume of rain under the contours divided by the surface area of the country could be examined for trends</td>
<td>Identifying possible trends in climate change</td>
<td>Use of arithmetic data relies too heavily on a fixed number of stations. If a station closes, like is no longer being compared with like, so trends may become disguised.</td>
</tr>
<tr>
<td>2. Rainfall Variability</td>
<td>Either this is taken to be the coefficient of variation (standard deviation divided by mean) for selected stations or The difference between the 20 percentiles (upper and lower) divided by mean for selected stations</td>
<td>Identifying possible trends in climate change, in consideration of the possibility that climate change may manifest itself as change in variability rather than mean.</td>
<td>General feeling (at the workshop) was that use of the coefficient of variation was a more scientific and better understood approach. A possibility would be to select six to ten key stations and derive an average coefficient for them.</td>
</tr>
<tr>
<td>3. Rainfall Intensity</td>
<td>This is taken to be the depth of precipitation falling at a point over a given period of time, usually from 15 minutes upwards. These data are collected on charts at approximately 50 stations around Namibia. Intensities are calculated during the processing stage.</td>
<td>Identifying possible trends in climate change, in consideration of the possibility that climate change may manifest itself as change in intensity rather than mean.</td>
<td>While rainfall intensity is an important parameter useful data sets are not readily available. Records which are reasonably up to date are very short. Records from older stations, such as Windhoek, have not been processed for at least ten years</td>
</tr>
<tr>
<td>4. Mean Annual Evaporation</td>
<td>This is the gross evaporation as measured using a standard “class-A” evaporation pan</td>
<td>Identifying possible trends in climate change, in consideration of the possibility that warmer climatic conditions may not be</td>
<td>Processed evaporation data are very out of date and are unlikely to be processed in the foreseeable future. In view of the very strong link between evaporation and solar radiation or even just temperature, it is likely that one</td>
</tr>
<tr>
<td>1. Catchment Condition</td>
<td>2. Catchment Condition</td>
<td>3. Catchment Condition</td>
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<td>------------------------</td>
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</tr>
<tr>
<td>Collecting data after the event is not so easy; processing backlogs can always be resolved. However, the problems behind the management decisions are essential data on which the final data can be collected and then not.</td>
<td>This could simply be a count of the number of control stations which are kept open by the national hydrological services.</td>
<td>This could be monitored using a time series of rainfall at the country. Another approach, although indirect, would be to look at the elevation change into schools.</td>
<td></td>
</tr>
</tbody>
</table>
2.5.5 KEY INDICATORS

In view of the stated aim to limit the number of indicators as far as possible, only two key indicators are proposed. While the possibility that variability and intensity may be affected by climate change, and mean annual precipitation not, may be valid, it was felt that it is more important to produce a single straightforward indicator of climate change. Undoubtedly, specialist research studies will, from time to time, look more closely at changes in solar radiation, rainfall intensity and rainfall variability, especially when more suitable processed data are available.

2.5.4.1 Mean Annual Rainfall

The idea is to calculate the average rainfall for the whole country on a year by year basis in order that firstly, the rainfall of the current season can be compared with the average situation, and secondly, to monitor trends. This is to be done by calculating the annual totals as volumes of rain for the whole country and then to divide this volume by Namibia’s surface area. The approach has been discussed in some detail by Hutchinson (Hutchinson and Namibia Meteorological Service 1998), and seems to yield good results. Hutchinson used between 38 and 345 stations, the minimum number in 1938 and the maximum in 1963.

These values derived for Namibia Average Precipitation (NAP) have been used to draw up Figure 2.18. Figure 2.18 uses an easily understandable approach to looking at trends over five, ten, twenty and thirty year periods. The NAP figures have been used to draw in lines showing the running means for these periods. Thus for any year selected, the mean over the previous five, ten, twenty and thirty years can be read off. The long-term mean for Namibia, using all 82 years of data has been calculated at 276mm and is shown as a horizontal black line. Since this is the first State of the Environment Report for water this is taken to be the baseline mean.

The value for the 1996/97 season was 241mm which is 12.7% below the mean.

With respect to long-term trends, it would seem fruitless to look at periods shorter than fifteen to twenty years, in view of the natural variation in rainfall from year to year and the possible existence of cycles (7 and 11 years). Examination of the thirty year running mean shows a downward trend over the three or four years prior to 1995, but not as acutely as the twenty year running mean, which places more emphasis on the recent years of particularly low rainfall.
Figure 2.18: Trends in Mean Volumetric Annual Precipitation for all of Namibia

The figure uses an easily understandable approach to looking at trends over five, ten, twenty and thirty year periods. Lines have been drawn in using the Namibia Average Precipitation (NAP) figures showing the running means for these periods. The effect of only two above average years since 1978 (in 1988/89 and 1996/97) has pulled all of the running means down. Only the thirty year running mean which includes some wet years from the mid-seventies is close to the Long-term mean.

In addition to the indicator value which simply compares the current year’s rainfall with the long-term mean, it has been decided to develop a single figure indicator which can be re-calculated on an annual basis if so desired. This indicator simply states the current status of the twenty year running mean compared with the 1996 baseline long-term mean precipitation for the whole country. The indicator reports the percentage difference by which the 20 year running mean differs from the long-term mean. The value can be either positive or negative. This idea is illustrated in Figure 2.19.
Figure 2.19: Twenty Year Running Mean Precipitation as Percentage of Long-term Mean Precipitation.

Using the twenty year running mean value and comparing it with the baseline (1996/97) long-term mean provides an indicator which is both meaningful and relatively easy to update. It is clear that the indicator value has decreased steadily over the past four years. If this trend were to continue for many years there would be reason to suspect that the long-term mean precipitation had actually decreased. The indicator value for 1995/96 was −11.53% and increased slightly to −11.52% after the 1996/97 season. If climate change were not to have any effect on rainfall, it should be expected that the value will return to zero eventually.

Number of Rainfall Gauging Stations in Operation

As an indicator of to what degree the necessary data are being collected, a useful and simply verified indicator would be the number of rain gauges in operation. While this is not an indication of how much data are being collected on other climatic parameters, rainfall is, for Namibia, the most critical and the most variable climatic parameter. Usefulness of any rainfall parameters, whether mean annual precipitation, rainfall variability or rainfall intensity, depends on whether sufficient good quality data are being collected.

A series of useful rainfall records were compiled as part of an earlier study using Namibia Meteorological Services records updated by this study. Figure 2.20 is based on these records and shows that there were only 315 rainfall stations operating in 1996 down from a maximum of 345 in 1963. This is clearly a very serious situation especially when the findings presented in Table 2.1 showed that there should be between 500 and 600 rain gauges to provide minimum coverage, and that some areas have very few or no rain gauges. The indicator value now stands at 315, and every effort needs to be made to see that this figure rises as quickly as possible, and that the increase in rain gauges is especially evident in the poorly covered areas of the country.
Figure 2.20: Number of Rain Gauges in Operation in Namibia

Sound environmental management is dependant on reliable data. In order to provide sufficient information for accurate analyses, there should be at least 500 – 600 rain gauges operating in Namibia, and these should be placed in such a way to cater for all potential needs. There are currently only 315 gauges in operation, down from a maximum of 345 in 1963. Given the ever-increasing pressure on natural resources, such a downward trend should not be acceptable.
REFERENCES


3. SURFACE WATER

3.1 INTRODUCTION

Namibia’s surface water resources can be divided broadly into two types, those derived from ephemeral (seasonal, non-permanent systems) and those derived from perennial systems. In the former group are included all the wetland areas and man-made storage dams on or associated with the sporadic flows of ephemeral rivers as well as pans, pools and other wetlands derived from local runoff.

With the exception of short lengths of the Okavango and Kwando Rivers in the north-east of Namibia, all the rivers in Namibia’s interior are ephemeral. Ephemeral rivers represent an important lifeline for people throughout the country either directly in the form of surface water, or indirectly from the groundwater sources which they recharge and from the plant and animal resources supported by these wetlands. The perennial rivers along Namibia’s northern borders support many people living in relatively large numbers along their banks or close to them.

Understanding and quantifying surface water and wetland resources, which includes knowing how much water flows in our rivers and the types and productivity of wetland plants and animals, is a difficult task and requires many years of data collection before results can be considered at all meaningful. This is especially true of both ephemeral and perennial rivers in arid and semi-arid climates where flows, like the rainfall from which they are derived, are unpredictable and variable. Various organisations have been responsible for this task over the last 50 years since the first continuous records were kept. Records for water levels in the perennial rivers go back as far as 1943 when water levels of the Zambezi River at Katima Mulilo were first kept, while the first water level recording station on an ephemeral river was opened on the Omaruru River in the same year and is still in operation today.

3.1.1 HYDROLOGY

The majority of river flow data are collected by the Hydrology Division in DWA, although the newly established NamWater is responsible for data collection at Namibia’s major dams and other bulk-water extraction schemes. DWA operates approximately 150 gauging stations throughout the country on both ephemeral and perennial rivers. Figure 3.1 shows Namibia’s ephemeral and perennial rivers together with all continuous recording water level stations (currently operating and closed stations).
Water levels are recorded automatically at these stations and the data are collected at regular intervals, and then converted into flow data at a later stage. In this way an improved quantification and understanding of flow in Namibia's rivers is gradually being achieved.

It is critically important to understand the steps and inherent difficulties involved in collecting water level data and turning it into useful runoff information. The principles for both ephemeral and perennial stations are the same, only the obstacles to be overcome for ephemeral stations are much greater. The most obvious difficulty with ephemeral rivers is the fact that the rivers are dry for most of the time, and when they do flow it is with little or no warning or predictability. A continuous water level hydrograph (water level against time) is recorded automatically usually using a float system linked to a chart recorder, although this system is gradually being replaced by pressure transducers or bubble gauges linked to electronic data loggers. This is the first step of the process and a certain amount of data are usually lost or missed at this point for a number of reasons including:

- Human error in setting up the instrumentation
- Clock/chart transportation problems and
- Sensor/intake problems including blockage of intakes by mud and silt so that they record with questionable accuracy or not at all.

The first two of these problems are reduced through thorough and frequent checking of stations by hydrometric technicians and hydrologists. The third can only be solved by good site selection and good design, although this is not always possible.

Once data have been collected, the volume of flow has to be calculated. The method by which this is achieved is to establish a unique relationship between water level (stage) and velocity (discharge). Establishment of this "rating" is theoretically straightforward but in practice is very difficult to do accurately for ephemeral river stations, especially when there is no control structure present. Essentially, the average velocity of the flow for each level is calculated by taking into account factors such as the type of soil and rock making up the river bed and banks, the slope of the water surface (approximated as the bed slope), the shape of the river cross-section and the straightness of the river. These factors are often not very stable (shifting river beds) and are difficult to measure in practice (water slope when the river is flowing, or “average slope” of the river bed). In order to reduce the error as far as possible, stations are sited where the river bed is stable and if possible, concrete control structures (weirs) are built. These structures, when working properly, provide stable cross-sections and negate the need for water slope measurements.
Figure 3.1: Runoff Gauging Stations on Perennial and Ephemeral Rivers

Understanding and quantifying surface water resources, which effectively means knowing "how much" and "how often" water flows in Namibia's rivers, is a difficult task and requires many years of data collection before results can be considered as at all accurate. Data are collected on a regular basis from permanent water level recording stations all around the country on both perennial and ephemeral rivers, and at dams. These data are processed by the Hydrology Division in the Department of Water Affairs (DWA), and converted into runoff figures which can then be used in a range of water resource studies.

Data Source: Hydrology Division, DWA.
Clearly the establishment of a theoretical rating requires an intensive effort in the field followed by significant office work. Regular surveys are required at all stations which do not have weirs or other control structures, and these should be repeated after each significant flood event, especially when there is evidence that the river cross-section is not entirely stable.

Once theoretical ratings have been established, they need to be checked and verified in the field through a variety of methods all of which depend on being on site during flood events or soon after. The best of these is the current-meter gauging which involves the physical measurement of the velocity of flowing water using a propeller and at the same time the measurement of the river cross-section. This extremely effective and accurate method obviously requires that the field team can get to the gauging station during the short-lived flood event, and that they can wade into the river safely to take the required measurements. This is only possible at low water levels when velocities are around one metre per second or less, and when there is not a danger of floating debris. At some stations, specially constructed hydrometric cableways make it possible to carry out gaugings at higher levels.

It does not take a lot of imagination to appreciate the organisational and logistical difficulties involved in the described process, even when sufficient numbers of suitably qualified and experienced personnel are available. In Namibia, despite repeated efforts which have been made over recent years by the Hydrology Division to create the essential post of “hydrometrist” this has not been successful. As a result, the majority of data is collected by a small number of under-qualified technical assistants who receive occasional training from an already over-stretched staff of hydrologists. This situation has deteriorated, largely due to a lack of skilled technicians and is reflected by a reduction in the number of surveys that have been carried out in recent years.

These problems may be alleviated by an alternative approach to direct flow measurement which in 1997 was started by the Hydrology Division in corporation with the International Atomic Energy Agency to initiate the use of colour dye and isotopes for flow gaugings. The method is based on the principle that the dilution of a tracer, injected in a known quantity at an upstream site and measured by sampling at a downstream site, is inversely proportional to the magnitude of flow. The advantage over conventional methods is that no access to nor direct measurement of the cross-section is required, but the critical assumption is that there is perfect mixing of the tracer at the sampling site. The technique has proven successful on the Kwanza River and will be tested on other rivers. A new project has been started in 1999 to set up an automatic gauging station that would be triggered by the arrival of floods.

Decision-makers often fail to appreciate the value of reliable and accurate hydrological data. The processed runoff data on which they base their decisions are of little use if
they have not been derived from accurate ratings. Considering that the evaluation of surface (and alluvial groundwater) resources depends almost entirely on reliable runoff data it is clear that it would be a grave error not to allocate sufficient resources to data collection, processing and quality control.

Both in Namibia's ephemeral rivers in the interior and in the perennial rivers on the northern border, low flow conditions have prevailed since the beginning of the eighties. This was initially attributed to temporary conditions of lower rainfall, but it has been suggested (Van Langenhove, 1994) that there has perhaps been no return to the higher flows, "also not during later periods with above average rainfall". Special attention has been paid to the discussion of this hypothesis for each of the perennial rivers and the major ephemeral basins.

3.1.2. ECOLOGY

Namibia's wetlands have both economic and ecological importance and can be evaluated in terms of the value of the natural resources associated with them and their ecological functions. Wetland resources are renewable resources that can be used now and in the future, as long as they are used wisely.

The "goods" or "resources" provided by wetlands include water, soil, sediment and nutrients, plants and animals, conservation and tourism, value, navigation and energy, aesthetics and various social values. The "services" provided by wetlands include primary production, flood attenuation, aquifer recharge, water quality improvement, and transport (for example of sediment, nutrients, animals and seeds).

It is necessary to use water and wetland resources in a responsible and sustainable manner. Sustainable use implies management, so it is becoming increasingly important to know how wetlands function. The monitoring of both wetland productivity and the use of their resources is needed for successful management. With the ever-increasing demand for water it is necessary to determine the amounts of water that should be set aside to maintain wetland productivity and ecological functions.

Aquatic ecology data are collected by the Water Environment Division in the Department of Water Affairs (DWA) and by members of the newly formed Wetlands Working Group which is part of the Biodiversity Taskforce run by the Directorate of Environmental Affairs in the Ministry of Environment and Tourism. Aquatic plant specimens are kept at the National Botanical Research Institute and Faunal collections at the National Museum.
3.2 PERENNIAL RIVERS

3.2.1 RUNOFF

3.2.1.1 Introduction

Namibia is bordered on its southern border and much of its northern border by major perennial river systems. In the south, the Orange River runs the entire length of the border to the Atlantic Ocean. This river is heavily regulated in South Africa resulting in much reduced mean annual runoff and maximum flows by the time the river reaches the Namibian border, but increased base flow.

In the north, the main systems are the Kunene River, which flows into the Atlantic Ocean, the Okavango River, which runs along the northern border with Angola for 415 kilometres, before crossing through the Caprivi Strip to the Okavango Delta. Further to the east is the Zambezi River which runs along the Namibian border with Zambia for a hundred kilometres on its long journey to the Indian Ocean. A tributary of the Zambezi River, the Kwando River, flows across the Caprivi Strip supplying water to the Linyanti River and Swamps and then the Chobe Swamp and River before joining the Zambezi on the border with Botswana, Zambia and Zimbabwe. The Hydrology Division within the Department of Water Affairs, has been collecting information, including water level and discharge data on these systems for many years and co-operation with fellow riparian states is usually good with respect to a free exchange of data, usually through “joint river basin commissions”. The quality and usefulness of data is generally much better than for ephemeral rivers and records go back to the 1940s. One of the reasons is that the presence of permanently flowing water makes for relatively stable conditions and permits the verification of ratings and other relevant data. Paragraphs 3.2.1.2 to 3.2.1.5 present an overview of the main perennial systems.

Rivers are longitudinal ecosystems. The plants, animals and people using the water in any given place are obligatory and/or inadvertent samplers of upstream processes and activities. Unlike most other environments, what happens in the catchment many kilometres away will eventually pass all the inhabitants. For the aquatic fauna and flora there is no escape. Fortunately Namibia’s northern rivers, with their exceptionally diverse fauna, continue to retain their natural self-cleaning processes and cycles, such that the water is still classed as excellent and the flood cycles are largely unregulated.

Unlike many other countries in the world, the northern perennial rivers and their associated wetlands have not yet been polluted, enriched, channelled, impounded, drawn off or otherwise regulated or overexploited by man, on a large scale. They are
national assets in their present states and all efforts should be made to manage and
develop these wetlands sustainably as provided for in Namibia's constitution.

3.2.1.2 Zambezi River

Hydrology
The Zambezi River rises in the highlands of Angola and Zambia and flows southwards
until it reaches the Namibian border just north-west of Katima Mulilo. At this stage the
catchment area is 334 000km² and the mean annual runoff in excess of 40 000Mm³.
An important tributary to the Zambezi from the Namibian point of view, is the Kwando
River, although flow from this river has not reached the Zambezi mainstream for about
fifteen years. When there is a flood peak in the Kwando, however, it occurs much later
than that of the Zambezi due to the extensive flood plains and swampy areas in
southern Angola. This delay is especially accentuated when there are consecutive years
of low flows, since the storage capacity of the swampy areas is then at its greatest.
Figure 3.2 shows the entire Zambezi catchment.
Figure 3.2: Zambezi River Basin

The Zambezi River rises in the highlands of Angola and Zambia and flows southwards until it reaches the Namibian border just north-west of Katima Mullo. At this stage the catchment area is already 334,000 km² and the mean annual runoff in excess of 40,000 million cubic metres, more than four times the annual volume of water flowing in the Okavango or Orange Rivers. An important tributary to the Zambezi from the Namibian point of view, is the Kwando River. Despite the fact that this is a sizeable perennial river with a mean annual runoff of more than 1,000 million cubic metres, flow has not reached the Zambezi mainstream for more than fifteen years. When there is a flood peak in the Kwando, it occurs much later than that of the Zambezi due to the extensive flood plains and swampy areas in southern Angola.
Figure 3.3 shows the mean, minimum and maximum hydrographs through the year.

Figure 3.3: Minimum, Maximum and Mean Hydrographs for the Zambezi River

Figure 3.3 shows the mean, minimum and maximum hydrographs based on observed monthly flow volumes since 1943. The figure shows that in good, average and poor runoff years the Zambezi usually peaks in April, and reaches its minimum in October. The volume of water that flowed in April of the highest year on record is nearly 20,000 Mm$^3$, which is more than the total for an entire poor year (as represented by the minimum line).

Although records for the Zambezi River at Katima Mulilo have only been kept since 1943, a correlation with the record for Livingstone in Zambia approximately 100 km downstream has been carried out (Crerar 1985). The extended record for Katima Mulilo is shown in Figure 3.4.
Figure 3.4: Annual Runoff Volumes in the Zambezi River at Katima Mulilo

Figure 3.4 shows clearly that flows in the Zambezi have been generally low since 1980. By contrast the 1950s, 1960s and 1970s were very wet compared to any other period in the record. While the last eighteen years have certainly been well below average, the figure shows clearly that a similarly low period occurred during the early part of this century. Note that the apparently low MAR implied by this graph results from the inclusion of a period of synthetic record prior to 1943 derived from correlation with Livingstone, Zambia.

Of all the perennial rivers, the Zambezi River shows the highest positive inter-seasonal relation between annual flow volumes. This means that years with high and low floods are more likely to be grouped, i.e. a year with high floods is more likely to be followed by a year with above average flows than one with below average flows. This is because of the influence of extensive flood plains which retain moisture and pools between seasons. It is clear that inter-seasonal correlation contributes to an apparent cyclic appearance of data with it being necessary for a particularly big flood year to break the effect of successive dry years. The higher the inter-seasonal correlation the more valid this is. Unfortunately it has not been possible to evaluate a useful inter-seasonal correlation for the Kwando River due to the shortness of the record, but the particularly extensive nature of the swamps and flood plains associated with this relatively small system would probably result in an even higher inter-seasonal correlation coefficient than the 0.51 calculated for the Zambezi. A sufficiently high coefficient could explain how the one or two above average floods which must certainly have taken place in the upper reaches of the Kwando River catchment have been neutralised by preceding successive years of low flow. The need for a longer record for the Kwando River, as well as the implementation of a data collection programme further upstream, is acute.

The Eastern Caprivi stretches from the Kwando River in the west to the point at which the Chobe River joins the Zambezi River in the east. Between these two points, the river is very flat and almost featureless and in times of high flood the different flood plains can be linked. Of the Eastern Caprivi’s 11 600km², approximately 30% is flood plain
(Rawlins 1983) the majority of which are the flood plains of the Zambezi River to the east of Katima Mulilo.

The flat nature of the area plays an important role in determining the complex hydrological regime. Under “normal” conditions (which have not occurred for 15 years), the Kwando River acts as a tributary to the Zambezi River flowing southwards through the Caprivi Strip and then round the southern and western sides of the eastern Caprivi. Between flowing across the Strip and making its confluence with the Zambezi River, the Kwando River supplies water to extensive wetlands, first the floodplains and swamps of the Kwando River itself, then the Linyanti Swamps, Lake Liambezi and finally the Chobe Swamps. Overflow from the Chobe Swamp enters the Chobe River. During the last two decades, the Kwando River has experienced no exceptional floods at all, at least not as far downstream as where it is first gauged within Namibia. Firstly, evaporation from the wetlands systems has meant that the levels in Lake Liambezi dropped to the extent that there was no longer an outflow to supply the Chobe Swamp, and secondly that the Linyanti could no longer supply an overflow into the lake and the lake dried up. After a time, it seems that a stable situation has been reached in which the reduced evaporation (from a much reduced surface area) is equal to the low flow levels in the Kwando River.

As stated, these “normal” condition have not prevailed for more than 15 years. During these times any water that has entered the Chobe Swamp has been backwater from the Zambezi River, and these backwater flows have even extended as far back upstream as the dry Liambezi Lake on two occasions and provided some small inflows. Only a slightly above average flood in the Zambezi River is sufficient to push the backwater back to the Chobe Swamp and even to the Liambezi Lake itself. It should be noted of course that even under normal conditions, the seasonal backwater from the Zambezi occurs (between April and June), and the backwater flow and tributary flow would meet somewhere in the system, making the understanding of the system even more complex.

In discussing the Eastern Caprivi Wetlands the above description of the dynamics of the system should be kept in mind.

The Eastern Caprivi wetlands are normally divided into five parts,

- The Upper Kwando
- The Lower Kwando and Linyanti
- Lake Liambezi
- Chobe Marsh
- Eastern Floodplains (of the Zambezi)
The Upper Kwando meanders over a floodplain up to 5km wide and comprises numerous backwaters and side channels. Its total surface area (open water and marsh vegetation) was estimated in October 1985 (Crerar 1987) at 136.8km².

Water can take up to six months to percolate through the Linyanti swamps which were estimated at having a saturated surface area of 3 827km² in 1985.

Lake Liambezi, which is currently dry, completely overgrown and extensively farmed, had an open saturated area of 406km² in 1985. While the fact that the lake has dried is a clear indication of the severity of the drought over the last two decades, it is important to point out that reports indicate that the lake has filled up and dried up again on a number of occasions over the last century.

It is difficult to judge how serious the drought has been, and how many above average seasons would be required to rectify the situation. Currently the quantity of dead organic material blocking the Linyanti Swamp means that it is no longer possible to navigate the channel further downstream than Nkasa Island. Flow measurements on each side of the blockage have shown that only a small proportion of the flow now reaches the Linyanti River and Swamp.

Ecology
The eastern Caprivi wetlands are an extremely valuable resource to a country as dry as Namibia. Mendlesohn and Roberts (1997) calculated that the open water and floodplains cover a total area of 4 000km².

When the Zambezi floods its banks east of Katima Mulilo, water spills out of the main channel and into the floodplains in Namibia. The flood typically lasts between four to six weeks in March and April. The floodwater follows a network of shallow depressions, deep channels and permanent backwaters south and east across the floodplain and eventually spills out of these and across open grassland. Eventually the water recedes but parts of the eastern floodplain can remain inundated for very long periods and thus support vast beds of papyrus and reeds.

In a recent study carried out by the Department of Water Affairs in Katima Mulilo, the freshwater invertebrate fauna of the main river channels was assessed and effectively used to determine water quality. The water borne vector for Bilharzia, Bulinus spp. snails, are common in the Chobe and Kwando rivers but not in the Zambezi River.

Fish are an important protein source in the eastern Caprivi, with some 82 species recorded from the Zambezi (van der Waal, 1996, Curtis et al 1998). Fish yields estimated in the late 1970s and early 80s, when conditions in the eastern Caprivi were substantially wetter, were as high as 800 tonnes per annum for Lake Liambezi (Van der
Waal, 1990), and an additional 700 – 900 tonnes a year from the Zambezi, Chobe and Kwando Rivers. Recently, reduction in floodplains due to inadequate floods and overfishing are thought to be causing a decline in the fisheries. The floodplains associated with rivers are important in the life cycle of many of these fish species providing habitat, food and breeding grounds. The area holds the richest diversity of bird species in Namibia, largely due to the presence of its extensive wetlands (Schlettwein et al, 1991).

Floodplains throughout the region provide essential dry season grazing to stock and wildlife.

The main threats to the wetlands of eastern Caprivi are reduced flows in the Zambezi and its tributaries, the aquatic weed Salvinia molesta, the increasing use of pesticides, road building activities and overexploitation of wetland resources due to increasing human pressure, whilst future threats include intensive agriculture and pollution. According to Day (1997), the main causes of environmental degradation in the eastern Caprivi wetlands are; overpopulation which leads to ever-increasing use of natural resources, poverty, which means a reliance on natural resources, and the loss of traditional management practices governing the use of those resources. Day (1997) further identifies overgrazing as one of the major threats to the eastern Caprivi wetlands.

One of the main challenges in the eastern Caprivi wetlands has been to control the invasive aquatic weed Salvinia molesta, or Kariba weed. With the introduction of the biological control agent Cyrtobagous salviniae, a weevil specific to Salvinia molesta by the Department of Water Affairs, this threat has been successfully controlled in Namibia (Schlettwein and Bethune 1992, Taylor and Clarke, in press).

DDT is still used routinely by the Ministry of Health and Social Services in Namibia to kill malaria mosquitoes. It is known to concentrate in predatory fish and to be harmful to piscivorous birds. There is a need to monitor the impact of pesticides on wetland fauna in the eastern Caprivi.

The eastern Caprivi is considered to have good potential for irrigation. At present the only irrigation scheme in the eastern Caprivi is near Katima Mulilo where 240ha is used to grow tobacco and maize. There is renewed interest in a large scale 105 000ha sugar estate in an area north-west of Lake Liambezi. The main environmental concerns of large irrigation schemes are the resultant increase in the use of pesticides and fertilizers that causes nutrient rich runoff to flow into the surrounding wetlands, draining of wetlands and floodplains for cultivation, decreasing river flow downstream of abstraction points and an increase in human/wildlife conflicts.
3.2.1.3 Okavango River

Hydrology
As shown in Figure 3.5, the Okavango River drains three countries, Angola, Namibia and Botswana. The river rises in the Angolan highlands as two major tributaries, the Cubango and the Cuito Rivers. While the Cubango (Okavango in Namibia) has a significantly larger catchment area than the Cuito (115 000km² compared with 73 000km² at their confluence), its mean annual runoff (MAR) is only slightly higher.
Figure 3.5: Okavango River Basin

The Okavango River rises in the Angolan highlands as the Cubango River in the west and its main tributary, the Cuito River in the east. Although the Cubango (Okavango or Kavango in Namibia) has a significantly larger catchment area than the Cuito, its mean annual runoff is only slightly higher. The Cubango River flows through rough terrain for about 600 km, until close to the Namibian border where it enters the Kalahari sands zone. The river meanders through a shallow and wide valley, with flood plains of between two and six kilometres wide. The confluence of the Cuito and Okavango Rivers takes place about 300 km after the Cubango River first reaches the Namibian border. The Cuito River rises in an area of slightly higher precipitation and meanders through some vast flood plains in southern Angola. These have the effect of creating a more even flow regime. After crossing the Caprivi Strip the Okavango River enters Botswana. Seventy kilometres further downstream the mainstream starts to divide and the Okavango Delta is formed, with a surface area that varies between approximately 10 000 and 15 000 km².
Mean annual precipitation (MAP) over the headwaters of the Cubango River which are at an elevation of up to 1 700m is between 700 and 1 150mm. The river flows through rough terrain for about 600km, until close to the Namibian border where it enters the Kalahari sands zone. At the border, it turns eastwards and forms the Namibian/Angolan border for the next 415km. At this stage the river meanders through a shallow valley, with flood plains of between two and six kilometres wide. The confluence of the Cuito and Okavango Rivers takes place about 300km after the Cubango River first reaches the Namibian border. The Cuito River rises further to the east than the Cubango River, but mean annual precipitation is of the same order as for the upper Cubango River catchment. However, unlike the Cubango River, the Cuito River meanders through some vast flood plains in southern Angola.

These have the effect of creating a less peaked flow regime. Minimum flows are much higher than those in the Cubango River, and maximum flows are considerably lower. The seasonal peak of the Cuito River is usually several weeks later than that of the Cubango River.

Just downstream of the village of Mukwe, the river swings southwards and crosses the Namibian Caprivi Strip and enters Botswana. Seventy kilometres further downstream the main stream starts to divide and the Okavango Delta is formed, with a surface area, which varies between 10 000 and 15 000km².

Figure 3.6 : Minimum, Maximum and Mean Hydrographs for the Okavango and Cuito Rivers at Rundu and Dirico

*Figure 3.6 shows how the maximum and mean hydrographs for the Okavango at Rundu have much higher flow volumes than those of the Cuito at Dirico. However, flow in the Cuito is more constant throughout the year.*
Figure 3.7: Annual Runoff Volumes in the Okavango and Cuito Rivers

Figure 3.7 shows the contributions of both the Cuito River (red) and the Okavango River (blue) upstream of the confluence. The total height of the column corresponds to the total volume for the year. Volumes in the Cuito River, although usually smaller than those in the Okavango River, are more consistent.

Ecology

Some 95,000 farmers and fishermen live within a 5km strip on the southern bank of the Okavango River. Many of these people are dependent on riverine resources for food, water, building materials, tools, fishing-gear and fodder (Bethune 1991).

Several aquatic plants are eaten by people in Okavango (and Caprivi). These include tubers of water lilies, and water chestnuts, fruits and a variety of nuts. Reeds, sedges, grasses and trees are extensively used for building materials especially for houses, fences both bordering fields and as wells circling villages and individual houses, fishing equipment, boats, sledges and tools. Although many of the materials are obtained from the floodplains and are annually renewable, there is an accelerating trend towards over exploitation of these resources because of population pressure.

Many wetland animals other than fish are eaten, including snails, crabs, frogs, reptiles, birds and as well as the larger mammals. Fish is very important in the daily diets for most people living near the rivers.

3.2.1.4 Kunene River

Hydrology

The Kunene River rises in Southern Angola to the west of the Cubango River, with the headwaters lying at elevations of between 1,700 and 2,000m. The total catchment is 106,500km², of which 14,100km² lies within Namibian territory. Figure 3.8 shows the catchment.
Figure 3.8: Kunene River Basin

The Kunene River rises in Southern Angola to the west of the Cubango River, with the headwaters lying at elevations of between 1700 and 2000m. The total catchment area is 106 500km², of which 14 100km² lies within Namibian territory. Between the source and Matale, a distance of nearly 250km, the main channel is well defined with a number of rapids and steep sections. From Matale to close to the Namibian border, the nature of the river changes drastically as it flows over the much flatter Kalahari sands. From upstream of the Ruacana Falls to the coast, the river drops nearly 1 200m over a distance of approximately 385km, which includes several spectacular waterfalls.
Between the source and Matala, a distance of nearly 250km, the main channel is well defined with a number of rapids and steep sections. From Matala to close to the Namibian border, however, the nature of the river changes drastically as it flows over Kalahari sands with a gentle gradient. Only the eastern bank is at all well-defined, with wide flood plains on the western bank. From upstream of the Ruacana Falls to the coast, a distance of just under 385km, the river drops nearly 1 200m including several spectacular falls. Although there are a number of tributaries in the southern part of the catchment, the major proportion of the runoff is generated from rain falling over the northern highlands between October and March.

The Kunene River catchment lies relatively far to the west, so rainfall is relatively unreliable and variable. There is a large difference between good and poor years of rainfall and hence runoff. The relatively small catchment and steep river bed slope in the upper section also mean that flows run relatively quickly to the coast leaving the river almost dry in the upper reaches by the end of the dry season. With the construction of the Gove Dam as part of the Ruacana hydro-electric scheme, upstream flows should have become more regulated, but this has not really happened due to the fact that the dam has never been operated properly.

Figure 3.9 shows the average, minimum and maximum hydrographs for the Kunene River at Ruacana, while Figure 3.10 shows the total annual runoffs since 1936 (DWA).

![Figure 3.9](image-url)  
**Figure 3.9 : Minimum, Maximum and Mean Hydrographs for the Kunene River**  
*Figure 3.9 shows the extremely variable nature of the Kunene river hydrographs, with the maximum recorded volume for April more than seven times the mean volume. Variability of flow from season to season in the Kunene River is very high hence the reliance on large reservoirs for regulation of flows so that hydro-electric schemes can work efficiently.*
In addition to being used for the generation of electricity at Ruacana, the Kunene also supplies a significant amount of water to Oshakati (via Ogongo), as well as to other places in the Oshana, Ohangwena, and Oshikoto Regions. It is important to note that this demand is at its peak in October, which corresponds to the period of minimum flow in the Kunene. Minimum flow in the Kunene River is low and highly variable, indicating that there is no real base flow.

![Bar chart showing annual runoff volumes in the Kunene River at Ruacana](image)

**Figure 3.10: Annual Runoff Volumes in the Kunene River at Ruacana**

*This series of annual data for the Kunene River shows the enormous variability of flow from year to year with a maximum seasonal volume of 13 000Mm³ and a minimum seasonal volume of only 1 000Mm³. While flows in the last five years have been low, the record shows that these low flows have occurred before.*

**Ecology**

Surprisingly little is known of the ecology of the Kunene River. Few crustacea have been recorded. The freshwater shrimp *Macrobrachium vollenhoveni* reaches its southern limit in the Kunene River (Kensley, 1970), as does the freshwater oyster *Etheria elliptica* (Appleton, 1996). Both these edible species are found nowhere else in Namibia.

The Kunene River has at least 74 fish species, of which at least five are thought to be endemic. Fifty-nine Kunene fish species also occur in the Okavango River, suggesting a previous link between the two catchments (Skelton et al., 1985). The fish resources are little used in the Namibian section of the river.

The Kunene River mouth is of particular ecological interest. It hosts a freshwater wetland on the coast. The mouth has 84 bird species of which 14 are red data birds. It has, in this desert area, the southern-most range of the Nile softshelled turtle *Trionyx triunguis*, breeding populations of crocodiles, the water leguan *Varanus niloticus* and aggregations of green turtles *Chelonia midas* (Simmons 1993).
Figure 3.11: Orange River Basin

The Orange River is the largest river in Africa south of the Zambezi, with a virgin mean annual runoff estimated at between 11 000 and 12 000 Mm$^3$. The total Orange River catchment has a surface area in excess of 1 million km$^2$, and is divided between four countries. Most of the runoff is generated on South African territory, followed by Lesotho and then Namibia. Some of these contributions are highly variable including that from the Fish River in Namibia. Nevertheless, well in excess of 4500 Mm$^3/\text{a}$ is contributed by runoff from Namibian territory. As a result of a major dam building programme and large-scale irrigation projects in South Africa over the last thirty years, the mean annual runoff in the lower reaches of the Orange River has been cut by nearly two thirds. In addition to more than a dozen dams, including three particularly large ones, there are also a number of transfer schemes in operation in South Africa, which bring water to the Vaal River from other parts of the Orange River catchment in order that the Gauteng Region has sufficient water. The most recent and largest of these is the Lesotho Highlands Water Scheme. All this development has had a huge impact on the natural flow in the river further downstream where it forms the border between Namibia and South Africa. The environmental impact has undoubtedly been considerable, both along the length of the Lower Orange River, and at the mouth, which is an important RAMSAR site.
3.2.1.5 Orange River

Hydrology

Figure 3.11 illustrates the catchment of the Orange River. The catchment is spread over four countries, South Africa, Namibia, Botswana and Lesotho. Of these only Botswana does not have any border on the Orange River mainstream.

The Orange River is the largest river in Africa south of the Zambezi with a virgin mean annual runoff estimated at between 11 000 and 12 000 Mm³ (McKenzie, 1996).

The total Orange River catchment has a surface area in excess of one million square kilometres. Most of the runoff is generated on South African territory, followed by Lesotho and then Namibia. Some of these contributions have high variability including contributions from the Fish river. Nevertheless, well in excess of 480 Mm³/annum is contributed by runoff from Namibian territory.

Flow in the lower parts of the Orange River has been much reduced, especially over the last 35 years since the inception of the Orange River Project (ORP) in South Africa. This project was proposed to irrigate thousands of hectares in the Eastern Cape, Northern Cape and Free State areas of South Africa.

In order to operate the ORP scheme there are more than a dozen dams including two particularly large dams with a combined capacity of 8 500 Mm³. In addition there are several dams in the Upper Vaal River which are used for water supply to the Gauteng Province around Johannesburg.

There are also a number of transfer schemes in operation which bring water to the Vaal River from other parts of the Orange River catchment in order to supplement water supply to the Gauteng Province. Such a large number of dams in the middle and upper reaches of the Orange River System as well as these transfers have a huge impact on the natural flow in the river further downstream where the river forms the border between Namibia and South Africa.
The majority of dams in the Orange River have been built in the last 35 years and hence the characteristics of the river in the period before 1970 are very different to those after 1970. Figure 3.12 shows the mean monthly runoff volumes for the periods 1935/36 to 1969/70 and for 1970/71 to 1996/97 at a point just upstream of the confluence with the Fish River.

![Monthly Flow Volumes in The Orange River](image)

**Figure 3.12 : Monthly Flow Volumes in The Orange River**

As a result of the Orange River being heavily regulated in South Africa, and large-scale abstraction taking place, the total flow passing Namibian territory has been reduced by around 50% since 1970. High flow, during November to May, has been reduced significantly, but flow during the low flow months (June to October) has increased.

**Figure 3.13** has been plotted using data from a study carried out for the Department of Water Affairs in South Africa.
The study derived a naturalised (no dams, no regulation, no abstraction) runoff sequence for the Lower Orange River upstream of the Fish River and then modelled a similar sequence assuming the 1995 level of dams development for the whole record back to 1920. The results clearly showed that the dams have had a huge impact on runoff in the lower Orange River. The mean annual runoff has been reduced from approximately 9 600Mm³ to only 3 335Mm³. The environmental impact has undoubtedly been considerable both along the length of the lower Orange and at the mouth, which is an important RAMSAR site. A positive side is the fact that during drought years, when previously flows would have stopped in the lower reaches, there is now a regulated low base flow all the year round making irrigation in the lower reaches of the river feasible.

As far as the lower Orange is concerned there are two ways in which the basic hydrograph has changed. Firstly, regulation of the flow to ensure sufficient water for downstream irrigation schemes as well as to cater for the "environmental" demand at the mouth, means that there is a constant baseflow in the river. Secondly, large scale abstraction combined with heavy regulation has resulted in a much reduced flow during the traditionally high flood months. Mean Annual Runoff at the coast is much reduced. The following results have been observed:

- Negative effects on the Orange River estuary, which is ranked as the sixth most important coastal wetland in South Africa. It is an important resting site on the
migration route of many aquatic bird species. It is also listed as a RAMSAR wetland site of international importance under the RAMSAR Convention.

- The regulation of flow has led to an increased occurrence of reeds, which as in the case of the Fish River downstream of Hardap Dam will increase the risk of inundation of agricultural land.

- Due to the regulation of flows and the need to maintain higher flows in order that the needs of downstream users are met (including ironically the mouth’s environmental needs), the breeding season of the blood-sucking blackfly has been prolonged resulting in higher livestock losses.

- The Orange River is naturally turbid and this is important for the natural control of certain nuisance organisms. New dams, or an increase in the salinity of the water may reduce turbidity.

Efforts are currently being made (through guaranteeing certain minimum flows to the mouth) to re-establish the salt marsh on the southern bank of the Orange River, and to restore the fresh water regime to control salinisation of the Orange River mouth by periodic fresh water flushing by releases of water down the river.

The South African Government has recognised the duty that they have towards protecting the environment associated with the Orange River, which until Namibian independence, was officially all within South Africa. Of interest and comfort to Namibia are certain statements made in the Orange River Re-planning Study, Reconnaissance Phase Report (McKenzie, Roth 1994).

"In order to proceed with the feasibility of the Vaal Augmentation Planning Study, it is necessary to ascertain how much additional water, if any, can be transferred from the Orange River................. The water rights of Namibia and Lesotho will also be taken into account together with the numerous social and environmental demands, both in the Orange River Basin and the adjacent Fish and Sundays River basins in the Eastern Cape."

Ecology
Except for near the mouth, the lower Orange River has no floodplains or backwaters. River regulation has changed the Orange from a formerly seasonal river to a perennial one and this probably accounts for its low invertebrate species richness (Palmer, 1997)

One of the Orange River’s 14 fish species is endemic to the lower river and four to the Orange River system (Hay, 1993) Two of these species, Barbus hospes and Austroglanis sclateri, are listed as rare in the red data book (Skelton, 1987).
The Important coastal wetland at the mouth, which is a registered Ramsar site, supports some 20,000 birds. Thirty-two resident bird species are seasonally joined by 18 palaeartic and six intra-African migrant species.

3.2.2 FLOOD AND DROUGHT FREQUENCY ANALYSIS

Just as runoff in the northern perennial rivers has been affected by drought in recent years, so there has been a high frequency of below average peak flood flows in them. Flood peaks have been consistently below average for almost two decades. Also significant has been the occurrence of close to historical low flows in both the Zambezi and Okavango Rivers in the last few years. Figure 3.14 shows the calculated monthly low flows for different return periods for the Okavango River at Rundu.

Implications of low flows over an extended period are manifold, including that the current perception of flood plains have changed and areas are increasingly seen as areas for human habitation and agricultural activity. This is especially true of the Zambezi flood plains in the Eastern Caprivi. The relatively high flood of 1997/98 caused communication problems and loss of life in that area. Although this was the biggest flood for nearly a decade, it fell well short of the peaks of the late nineteen seventies, which when repeated are likely to be more destructive, resulting in increased loss of life.

![Figure 3.14: Low Flow Analysis for the Okavango River at Rundu](image)

Figure 3.14 is the result of a statistical analysis carried out on observed daily flow data for the Okavango River at Rundu and shows how flows "normally" (once in 2 years) return to approximately 35 m³/s every year in November/December. However the low flow falls below 14 m³/s once in a hundred years. Recent flow gaugings carried out by DWA, suggest that the value may be closer to 9 m³/s.

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It is clear from an examination of Figures 3.4, 3.7 and 3.10 which show the quantity of flow in the northern perennial systems, that since 1982 there has been a general reduction in the flow of all systems. In the Zambezi River the ratio of the average of annual flows after 1982 compared to flows in prior years is less than 0.55 (Van Langenhove) and during 1995 and 1996, the lowest minimum flows, 190m³/s and 140m³/s respectively, were observed since monitoring was started at Katima Mulilo. The eastern flood plains which used to be inundated most years prior to 1981, have only been well flooded two or three times since then. However, when looking at the total record for the Zambezi (i.e. including the synthesized period from 1907/08 up to 1943/44) it is immediately evident that there were years as low in the past, most notably 1914/15. Within Namibia itself in the Caprivi, the Kwando River has shown no significant annual floods since 1982, and the minimum flow has decreased from around 20m³/s to 11m³/s, which is by far the lowest level on record. The impact on the Linyanti Swamp and Lake Liambezi further downstream has been severe. The lake has dried up completely and flow within the Linyanti has been reduced to a trickle.

Although continuous records have been kept for Lake Liambezi only since 1967, observations from time to time have made it possible to deduce that the lake has been dry in the past, some time before the 1950s, probably during the 1920s or early 1930s. This ties in with the long term flow record for the Zambezi River. The lake may serve as a good indicator of the long-term trends in the northern perennial rivers.

The situation in the Okavango River has been largely the same as that of the Zambezi, with historic low flows having been recorded in the last decade. In the Kunene River significant reduction in hydropower generation has been observed resulting from extremely low flows.

The most obvious reason to explain the decline in flows would be a change in general climatic conditions (either temporary or long term, random or with a reason). Evidence from Namibian rainfall is not conclusive (see Chapter 2), although clearly rainfall has also been below average since 1982. Unfortunately, records from within the catchments are very scarce.

Other explanations for the change in regime have been put forward and are related more to possible changes in land use and vegetation and which in turn are related to socio-economic factors. It may be argued that in the upper catchments of the border rivers, there could have been intensified agricultural development, from which less dense vegetation and runoff interception would result, during the 30 or 40 years before the start of armed conflicts in the same area. The most likely explanation may lie somewhere between the climate change explanation and the socio-economic one.
What is clear is that theories implying that the reduction in flows are limited to recent global warming and climate change are not easily proven, especially since similar periods of low flow have occurred in the past as shown by the Zambezi River record and by what has happened in the past at Lake Liambezi.

Only careful monitoring for a number of years will verify whether these trends are continuing or not.

3.2.3 WATER CHEMISTRY AND POLLUTION

As already stated, the water quality of the northern border rivers is generally very good although good data are not always available for all systems. A summary of the chemical water quality for water in the Okavango River, which has been well studied, is provided in Table 3.1

Table 3.1: Water Quality of the Okavango River

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit of Measurement</th>
<th>Mainstream sites</th>
<th>Backwater sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity</td>
<td>(µS/cm)</td>
<td>30 - 45</td>
<td>45 - 205</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>6.8 - 7.2</td>
<td>6.7 - 7.5</td>
</tr>
<tr>
<td>TDS</td>
<td>(mg/l)</td>
<td>25 - 42</td>
<td>30 - 172</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>as CaCO₃ (mg/l)</td>
<td>10 - 20</td>
<td>20 - 95</td>
</tr>
<tr>
<td>Na⁺</td>
<td>(mg/l)</td>
<td>1 - 3</td>
<td>3 - 10</td>
</tr>
<tr>
<td>K⁺</td>
<td>(mg/l)</td>
<td>1 - 2</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>(mg/l)</td>
<td>6 - 16</td>
<td>7 - 46</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>(mg/l)</td>
<td>3 - 8</td>
<td>6 - 22</td>
</tr>
<tr>
<td>SiO₂</td>
<td>(mg/l)</td>
<td>8 - 15</td>
<td>9 - 36</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>(mg/l)</td>
<td>0.5 - 1.0</td>
<td>1.0 - 5.6</td>
</tr>
<tr>
<td>Total N</td>
<td>(mg/l)</td>
<td>0.1 - 1.5</td>
<td>0.1 - 6.2</td>
</tr>
<tr>
<td>PO₄ - P</td>
<td>(mg/l)</td>
<td>0.01 - 0.07</td>
<td>0.02 - 0.15</td>
</tr>
<tr>
<td>Org P sol</td>
<td>(mg/l)</td>
<td>0.01 - 0.10</td>
<td>0.02 - 0.32</td>
</tr>
<tr>
<td>Total P</td>
<td>(mg/l)</td>
<td>0.01 - 0.15</td>
<td>0.04 - 0.37</td>
</tr>
</tbody>
</table>

Chemical concentrations recorded in the Okavango River from samples collected from 35 mainstream sites and 10 backwater sites during a 1984 survey. The water of the Okavango River is typically soft with very low conductivity values. The low values probably have much to do with the very low levels of agricultural activities in the catchment in Angola as well as perhaps the underlying geology.

By contrast with the northern perennial rivers, water quality in the Orange River clearly provides cause for concern, but is to be expected in view of the large number of
abstraction and irrigation schemes upstream as well as large centres of population in South Africa.

Poor water quality combined with the changed flow regime in the Orange River has led to a number of environmental problems which are discussed under wetlands later in this chapter.

Development in the catchments of the Kunene, Kwando and Okavango Rivers in Angola is limited. This is in some part due to the war that has affected these areas badly for almost 30 years, but also because these areas have traditionally been development backwaters in Angola. This is especially true of the Okavango and Kwando River catchments, and even the part of the Zambezi River catchment.

3.2.4 WETLANDS

Wetlands have been defined in a number of different and overlapping ways including “land where an excess of water is the dominant factor determining the nature of soil development and the types of animals and plant communities living at the soil surface spans a continuum of environments, where terrestrial and aquatic systems intergrade.” [Cowardin, 1976 #8] This is an important part of the definition accepted at a Wetland Workshop held in Windhoek in 1988.

The Ramsar convention and the Wetlands Working Group of Namibia use the following definition: “areas of marsh 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 6m.” (Ramsar Convention Bureau 1997).

Most of the perennial rivers on Namibia’s borders support important wetlands, and indeed the wetland associated with the mouth of the Orange River and those of the Okavango River within the Muhango Park have RAMSAR status.

Although Namibia’s largest wetlands are associated with perennial systems, a number are also associated with ephemeral systems. A list of Namibian wetlands is set out in Table 3.2 and Figure 3.15 shows the locations of both ephemeral and perennial wetlands including the main storage dams in Namibia.
Figure 3.15: Location of Wetlands in Namibia

All of Namibia's ephemeral and perennial rivers can be regarded as wetlands, and because Namibia is so arid, its wetlands have considerable ecological, economic and social importance. Figure 3.15 shows the location of Namibia's main wetlands which include pans, vleis, lagoons, hot springs, lakes, swamps and major dams.

Data Sources: Water Environment Division, Hydrology Division, DWA.
## Table 3.2: Wetland Systems Found In Namibia

<table>
<thead>
<tr>
<th>Wetland Type</th>
<th>Characteristics</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RIVERINE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perennial rivers</td>
<td>Rivers that flow throughout the year</td>
<td>Kunene, Okavango, Zambezi + Orange Rivers, Kwando/Linyanti/Chobe system</td>
</tr>
<tr>
<td>Rivers and their associated floodplains and rivermouths</td>
<td>Low lying areas and depressions next to rivers</td>
<td>Okavango and Caprivi floodplains</td>
</tr>
<tr>
<td>River mouths</td>
<td>Predominantly freshwater wetlands which form where rivers meet the sea.</td>
<td>Kunene and Orange river mouths</td>
</tr>
<tr>
<td>Ephemeral rivers/omirambo</td>
<td>Rivers flowing only after heavy rains, sometimes not for several years.</td>
<td>Kulaseb, Nossob, Ugab, Huab rivers</td>
</tr>
<tr>
<td>Oshanas</td>
<td>Seasonal, shallow, inter-inked pans receiving inflow from rainfall and seasonal floods.</td>
<td>Cuvelal drainage area</td>
</tr>
<tr>
<td><strong>LACUSTRINE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floodplain + oxbow lakes</td>
<td>Shallow lakes in depressions or old river courses in floodplain areas.</td>
<td>Lake Liambezi (now dry), small lakes in the Caprivi floodplain area e.g. Lake Lisikili</td>
</tr>
<tr>
<td>Open waters such as lakes, dams and pans</td>
<td>Small, deep, permanently filled sinkholes and caverns.</td>
<td>Ojikoto and Guinas Lake, Algams and Drakensbreath cave</td>
</tr>
<tr>
<td>Sinkhole lakes and caves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pans</td>
<td>Shallow, ephemeral, unvegetated pools in depressions filled by local rainfall or endorheic rivers.</td>
<td>Nyae-nyae pan, Kalahari &quot;panneljeesveld&quot;, Etosha pan, Sossusvlei, Tsodabvlei</td>
</tr>
<tr>
<td>Dams/Impoundments</td>
<td>Man-made lakes formed when rivers are impounded by a dam wall.</td>
<td>Stalo Dams eg. Hardap, Von Bach, Ulushandja and numerous smaller farm dams</td>
</tr>
<tr>
<td><strong>PALUSTRINE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swamps</td>
<td>Well vegetated, wet areas with open standing water associated with perennial rivers.</td>
<td>Linyanti swamp, Okavango Delta in Botswana</td>
</tr>
<tr>
<td>Well-vegetated waters such as marshes, swamps &quot;Vleis&quot;, seeps and springs</td>
<td>Well-vegetated, water logged areas with little visible open water, found alongside perennial rivers.</td>
<td>Confluence of the Okavango + Cuito Rivers</td>
</tr>
<tr>
<td>Vleis or Mulapos</td>
<td>Seasonal or permanent, shallow, vegetated pools dependent on local rainfall or fed by groundwater rising to the surface.</td>
<td>&quot;Tsumkwe&quot; vleis, e.g. Makuri pan</td>
</tr>
<tr>
<td>Seeps and springs</td>
<td>Permanent vegetated pools and streams fed by groundwater</td>
<td>&quot;Damaraland&quot; fountains e.g. Sefontain Karst springs</td>
</tr>
<tr>
<td>Geothermal or hot water springs</td>
<td>Small, permanent pools fed by hot groundwater rising to the surface from great depth.</td>
<td>Ai-Ais, Gross Barmen, Rehoboth, Warmquissle, Klein Winchoek</td>
</tr>
<tr>
<td><strong>ESTUARINE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estuaries</td>
<td>Wetlands at the mouths of perennial rivers subject to both tidal and river inflows.</td>
<td>Kunene River Mouth</td>
</tr>
<tr>
<td><strong>MARINE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inter-tidal mudflats</td>
<td>Shallow coastal areas of mud exposed and flooded by tides.</td>
<td>Walvis Bay salt flats Sandwich Harbour</td>
</tr>
<tr>
<td>Shallow sub-tidal and inter-tidal coastal waters and lagoons</td>
<td>A shallow lake connected with or close to the sea.</td>
<td>Walvis Bay lagoon            Lüderitz lagoon</td>
</tr>
</tbody>
</table>

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3.2.5 LINKS BETWEEN PERENNIAL SURFACE WATER AND GROUNDWATER RESOURCES

As discussed in Chapter 2, Section 2.4, the ephemeral river systems in Namibia are effluent, that is water flowing in them recharges the groundwater. This is not quite the same with the perennial rivers which can be both effluent and influent.

It has been observed (Marques, 1996) that during the flood season in the Okavango River, the high flood level of the river is much higher than the surrounding groundwater table, so there is a nett flow into the ground water and subsequently a small reduction in flow as the river continues downstream. However, it was observed that because the flood recedes relatively quickly, towards the end of the flood the surrounding groundwater table is slightly higher than the water surface of the river, and there is influx of water into the stream (influent system). It seems likely therefore, that a similar trend would be observed for other perennial rivers in Namibia, with the exception perhaps of the Kunene River where groundwater storage to the outside of the main stream is relatively limited.

Springs have a significance far greater than their water production alone might suggest. The wetlands supported by springs in Namibia are usually small in area but are islands of resources for local people and wildlife in ordinarily dry surroundings.

Water is the most obvious resource of springs. In areas where there are no other surface waters such as stock watering points, dams, rivers or boreholes, springs may provide the only water for humans, livestock and wildlife in the dry season. Springs have a limited discharge of water which is balanced by natural replenishment mechanisms. Any attempt to disturb that balance, to increase the flow of water for instance, may result in serious detrimental consequences and even the drying up of the spring.

In Namibia, spring-fed wetlands support a higher level of biodiversity, with large numbers of endemic species including fish and aquatic invertebrates, than surrounding habitats because of their resources.

Springs are often ancient in human terms and are frequently sites of archeological interest.

Springs continue to be threatened by human use. As natural focal points in the landscape, springs and their associated wetland resources increasingly attract human activity and because they are small, spring-fed wetlands are very easily damaged. Detrimental activities at springs can be divided into the following categories.
• **Lowering of local groundwater levels.** Pumping groundwater at rates greater than it is recharged has led to lowering ground water levels in many parts of Namibia. Normally permanent springs can become temporary or dry up altogether.

• **Large-scale water use from springs.** Water for stock watering, irrigation and household use will reduce the size and biodiversity of the associated wetland. Grazing and trampling by livestock can quickly destroy the habitat of small wetlands.

• **Pollution of springs.** Washing, trampling, diesel pump engine leaks, faeces and insecticides easily pollute spring waters because of the small total volume and flow.

• **Alterations to springs.** Damming, covering, dynamiting and draining have often been attempted to improve a spring. These sorts of activities can reduce or stop water flow to spring-fed wetlands or limit access by local wildlife.

• **Developments at springs.** Developments such as tourist lodges, houses, dams, mines, schools, clinics and roads reduce access of wildlife that in Namibia may be dependent on spring water. Spring-fed wetlands may then be further degraded by activities such as the collection of reeds or control of water borne disease vectors. Lights can devastate the populations of aquatic invertebrates.

• **Other uses of springs.** Tourists often camp at springs in remote areas. This may reduce access for wildlife and cause pollution and disturbance. Tourists apparently frequently bath, and even wash their vehicles, in springs at which they are camped. Although one group may only spend a single night at a spring, it is increasingly likely that there will be another group the following night.

All the above activities can reduce the natural resource value of springs and decrease biodiversity in the area. Some of the activities can destroy a spring or make an endemic species extinct.

The Water Ecology Section of DWA has started an inventory of springs and collects data on their fauna, flora and human use.
3.3 EPHEMERAL RIVERS

3.3.1 RUNOFF

3.3.1.1 Introduction

All the internal rivers of Namibia are ephemeral or seasonally flowing rivers. It is convenient to describe them in five main groupings:

- The Westward flowing rivers. These include all the rivers flowing towards the coast and those which disappear in the sands of the Namib desert, and the tributaries of the Kunene in the north.
- Orange River tributaries, most notable of which is the Fish River.
- Molopo River tributaries, which include the Nosob and Auob Rivers.
- Cuvelai System.
- Tributaries of the Okavango River, which include the Omatako River.

These groupings are shown in Figure 3.16.

Collection of reliable ephemeral runoff data is notoriously difficult and has yet to be mastered anywhere in the world. As a result, estimates of runoff volumes and flows are often inaccurate. Estimates of runoff in ephemeral rivers usually depend on indirect methods of measurement such as the measurement of water levels using a water level sensor coupled to a data logger or other automatic recording device. Water level alone is of limited use as an indicator of the quantity of water passing a certain point on a river since it has to be converted into volume or flow. The flow rate for any given level will depend on a number of factors such as the width of the river, the slope of the river and geometry of the river bed. Since the collection of this information is often tedious and time-consuming, and some parameters are not even stable with time, it is sometimes impossible to obtain reliable discharge data.

Ephemeral rivers are a vital source of water in Namibia both as surface water and as groundwater resulting from recharge. Both bulk consumers such as municipalities and mines, and all types of farmers are largely dependant on water in dams or ephemeral flow-recharged aquifers. The best possible quantification of the resource is therefore vital.

Continuous water level data are collected at more than 100 stations on these ephemeral rivers and have been processed for the majority of them.
Many of these data have been carefully utilised in water resource studies when appraising the yield or usefulness of dam and dam sites, aquifer recharge rates, and abstraction schemes. Other studies, broader in nature have also been carried out, looking at basins or regions as a whole. One of these, the Unit Runoff map (Figure 3.17) and Report (Chivell, 1992) is particularly significant in that it attempted to utilise as much as possible of the available runoff data to compile a map showing runoff potential expressed in millimetres per unit area. The map confirmed what was already known, that the relationship between mean annual precipitation and mean annual runoff is a tenuous one. Some areas of low rainfall were shown to have runoff potential up to five times higher than areas with three times higher mean annual precipitation. There are many reasons for this and these have been discussed and evaluated in numerous studies on rainfall/runoff modelling.

The unit runoff map’s isolines taken from the 1992 map are presented in Figure 3.16. The first thing that is clear from the map is that large areas of the country are not covered. This is either because there were simply not sufficient data available (for example the Cuvelai basin) or the areas are of little interest in terms of runoff (the dunes of the Namib desert and the downstream reaches of the Nossob and Omatako River systems).
Paragraphs 3.3.1.2 to 3.3.1.6 briefly discuss the five main ephemeral systems and their catchments.

Ephemeral rivers in Namibia form river corridors of resources that pass through the otherwise dry areas. They provide and maintain the natural resource base on which many rural communities depend. For instance, a single mature *Faidherbia albida* (Anna) tree can produce over 250kg of pods per season (Fagg & Stewart, 1994) and so provides valuable, protein-rich fodder to both stock and wildlife. Ephemeral rivers are as much a linear habitat as are perennial rivers. The resources of water and vegetation found in them provide a habitat for many species that could not survive without them. Because they are linear, the area of habitat is small and so is vulnerable to change.

3.3.1.2 Westward Flowing Rivers

General
With the exception of the Hoarusib River, the largest of the westward flowing rivers, rising on the high plateau, are the Kuiseb, Swakop, Omaruru and Ugab Rivers, with a combined catchment area of 87 100km². Of the westward flowing rivers they are also the catchments which support the largest numbers of people, especially the Swakop River catchment in which are found Windhoek and the towns of Okahandja, Karibib, Usakos and Swakopmund. To the north of these there are also large rivers including the Huab, Hoanib, Hoarusib, Khumib, Uniab and Khoichab Rivers which all flow through to the sea in good years. To the south of the Kuiseb River, the Tsauchab and Tsondab Rivers do not flow to the sea but instead feed large pans and associated groundwater systems in the desert sands of the Namib.

Generally for rivers, the trend is that the mean annual runoff increases from the source downstream. This is quite normal and is due to the fact that there are tributaries joining all the time. However, with the westward flowing rivers in Namibia, a point is reached in the desert or desert fringes where transmission losses exceed additions from tributaries. This “hinge point” represents the point at which the Mean Annual Runoff (MAR) starts to decrease. Figure 3.16 illustrates the Maximum Mean Annual Runoff for each of the major catchments. The values provided for each of the rivers corresponds to the hinge point or maximum MAR. It should be pointed out that for some catchments, such as the Swakop River, the point of maximum MAR has shifted upstream due to the effect of the major Von Bach and Swakoppoort storage dams.

Kuiseb River
The Kuiseb River rises in the Komas Hochland, with the uppermost part of the Kuiseb/Swakop River watershed only about 15 kilometres to the west of Windhoek. Of the four rivers under investigation, the Kuiseb is the most affected by the desert environment, with more than half of the catchment having a unit runoff potential of 1mm or less. The upper part of the catchment is generally farmed as cattle ranches and
Figure 3.16: Ephemeral River Catchments and Main River Basin Divisions

The ephemeral river catchments can be conveniently divided into five main groupings: i) Westward-flowing rivers, ii) Orange River tributaries, iii) Molopo River tributaries, iv) Cuvelai System and v) the Okavango River tributaries. Figure 3.16 shows these main groupings as well as the catchments within them. Also shown is an estimate of the Mean Annual Runoff (MAR) of each river at a point corresponding to the perceived "hinge-point" where MAR is estimated to have reached its maximum value. On rivers with major dams, this point may have shifted upstream from its natural position to the position of the dam itself, as a result of reduced spill.

Data Source: Hydrology Division, DWA.
Figure 3.17: Unit Runoff Map of Namibia

The unit runoff lines taken from the 1992 map show runoff potential expressed in millimetres per unit area. It is interesting that some areas of low rainfall were shown to have relatively high runoff potential. Due to a lack of data, there are large areas which are not covered by the map, but many of these areas have very little runoff potential, including the dunes of the Namib Desert and the downstream reaches of the Nossob and Omatako River systems.

Source: Unit Runoff Map for Namibia, 1992, Hydrology Division, DWA.
there are a large number of farm dams. In addition, the Friedenau Dam, built in 1970, has a capacity of 6.7Mm³, and its 210km² catchment area lies entirely within the 10mm unit runoff zone. Unit runoff values in the Khomas Hochland range from 4mm in the west up to 10mm in the east (Chivell, 1992). In this area soil cover is generally poor and the vegetation is typical highland and thorn bush savannah.

In descending from the plateau, the Kuiseb cuts its way through the spectacular Kuiseb canyon before reaching the desert where tributary additions are rare. The main tributary of the Kuiseb is the Gaub River which has a catchment area of 2 490km² at the confluence.

The desert part of the catchment is divided by this linear oasis with high dunes rising from the left bank (south side) of the river and the flat gravel plains on the right (north side).

**Swakop River**

Of the four catchments under review, the Swakop River has the largest catchment (30 100km²), marginally larger than the Ugab River. The Swakop is probably the most urbanised of the four catchments with the capital city situated in the headwaters, and other smaller towns as well, including Okahandja. Unit runoff values vary from effectively zero near the coast, to as high as 10mm for the rural parts of the catchment. By comparison, the Ugab River has much lower runoff potential in its headwaters. Much of Windhoek's urban runoff is collected in the Goreangab Dam, now highly polluted. This dam lies within the Swakoppoort Dam catchment. The rest of Windhoek’s urban runoff also flows into the Swakoppoort Dam.

Downstream of the Swakoppoort Dam, the majority of runoff originates in the Khomas Hochland to the west of Windhoek, with the Khan River being the most important tributary from this area. The Khan River, the major northern tributary of the Swakop River, has its confluence only about 50km from the coast, and is unaffected by either the Von Bach or Swakoppoort Dams. Runoff in both the Swakop River and Khan tributary is of course, affected by large numbers of farm dams in the upper parts of their catchments.

The presence of two major storage dams, the Von Bach Dam and the Swakoppoort Dam has significantly affected the frequency and magnitude of runoff in the lower reaches of the Swakop River.
Omaruru River
The Omaruru River rises on the north-western and southern flanks of the Etjo mountains, approximately 70km to the north-west of Omaruru Town. Runoff potential within the Etjo mountains is very high for an arid country with unit runoff values of up to 30mm (see Unit Runoff map). The uppermost 1 360km² of catchment has a unit runoff of 15mm or more. The other area of high runoff potential is the Erongo mountains where a major tributary, the Okondeka River, rises. At the confluence of the Okondeka and Omaruru Rivers, the catchment area is 3 810km², but only about 30% of the total catchment area is responsible for the major portion of generated runoff. The Mean Annual Runoff of the Omaruru River reaches its maximum around this point, and steadily declines towards the coast as transmission losses increasingly outstrip contributions from tributaries. From about the hinge-point onwards, the Omaruru River runs in an increasingly deeper gorge until about 50km from the coast. The depth of the gorge gradually lessens again towards the coast and below the Omdel Dam the river flattens out into a wide alluvial plain underlain by a number of deep palaeochannels, which form the Omaruru Delta. These channels have a large storage capacity and are an important water source for water supply to the Central Namib Area.

Ugab River
The Ugab is the most northerly of the four catchments, and the furthest away from the existing centres of development. Despite having a catchment almost the same size (28 400km²) as the Swakop River, runoff potential is considerably less. The Ugab River rises to the east of Outjo in an area with mean annual precipitation in excess of 450mm, but this flat area, much of which is covered by Kalahari sands, does not yield much runoff. The catchment area of the proposed Sebraskop Dam site includes an area of higher runoff potential in its entirety. Little runoff is generated downstream of the Sebraskop Dam site.

3.3.1.3 Orange River Tributaries
The main tributary of the Orange River in Namibia is the Fish River, which, with a catchment area of 80 300km², is the largest of the ephemeral rivers in the country. It includes several major tributaries such as the Löwen River which joins just south-west of Keetmanshoop, and the Konklop River which joins the Fish River near its confluence with the Orange River.

The Fish River rises in the Nauchas Highlands to the south of Rehoboth as a number of important tributaries, which join before the Hardap Dam near Mariental to form a large ephemeral river with a number of permanent pools. The Hardap Dam is the only major dam on the mainstream of the Fish River, the other large dam being the Naute Dam on the Löwen River.
The DWA operates six gauging stations on the mainstream of the Fish River and twelve on the tributaries, so, with the exception of the Konkiep River, the runoff potential is well understood. The runoff potential for the entire Fish River catchment is shown on the Unit Runoff Map in Figure 3.17. (The Konkiep is shown separately)

### 3.3.1.4 Molopo River Tributaries

Although the Molopo River in Botswana (and hence also its Namibian tributaries) is in fact a tributary of the Orange River, it has been shown as a different grouping on Figure 3.16. This is because the main rivers which make up this grouping are so completely different in character to the Fish River and its tributaries. The main tributaries to the Molopo which originate in Namibia are the Nossob and Auob Rivers. There are other tributaries with significant catchments, but which have very limited flow potential. These include the Ollifants River (main tributary to the Auob River), and even the Okanob River, which although a substantial river in its upper reaches, disappears before making its junction with the Auob River. It is important to remember, however, that these rivers make a substantial contribution to recharge of important groundwater resources.

It is decades since the Nossob and Auob Rivers had major floods going all the way through to the Molopo River, although these have happened. In 1973/74 there were major floods and to a lesser extent again in 1984 and 1988 which did not make it.

### 3.3.1.5 Cuvelai System

The Cuvelai or “Oshana” System consists of a collection of ephemeral rivers, shallow pans and wetlands, many of which join together and flow into the Etosha Pan following good rainy seasons. The streams are known as oshanas and originate in Angola, several hundred kilometres north of the border in some cases.

A good quantitative understanding of the hydrology of the Oshana System is lacking and will only be achieved after several consecutive years of additional records are collected and analysed. Current understanding on work carried out by Wipplinger is based on a five year data set collected in the late 1970s and work carried out in the last three or four years following some good floods.

Improved understanding of the Oshana System is essential in view of the fact that the system supports the most densely populated regions of Namibia. Bad land management and over-exploitation of water and other resources (grass and wood) in these areas, as well as in the Angolan headwaters, are exerting increasing pressure on the environment in these areas.

Contrary to the trend in recent years, there was a very large flood in the Cuvelai in 1995. The flood peak was estimated to have had a return period of up to 1 in 30 years...
(Crerar 1995). The flood ("efundja") had an unusually long duration contributing to a total volume of approximately 300Mm³, the highest on record.

Monitoring and quantification of the Cuvelai System is difficult for a number of reasons, not least accessibility during periods of high flood. However, it is clear that a major effort needs to be made to collect and process data to deepen the understanding of the system.

3.3.1.6 Okavango Tributaries

The main "tributary" of the Okavango River in Namibia is the Omatako River. In addition to it, there are many virtually fossil ephemeral rivers which may contribute some flow following high rainfall. The Omatako River is not known to have contributed anything other than local runoff in living memory.

3.3.2 WATER CHEMISTRY AND POLLUTION

In view of the fact that water flowing in the ephemeral rivers has been derived from very recent rainfall, apart from the fact that it is very turbid, the water is generally of a high quality. Due to the speed at which overland flow takes place, there is not usually enough time for surface water flows to take on the chemical characteristics of the soil and rock formations over which the flow passes. Nevertheless, some data have been collected, but not sufficient to analyse trends.

3.3.3 WETLANDS

Namibia’s ephemeral wetlands are shown in Figure 3.15. Although the ephemeral rivers of Namibia have dry, sandy or rocky riverbeds for most of the year, they are conduits for sub-surface flow and contain a number of wetlands, defined here as "shallow, swampy or marshy areas with little or no water flow" (Loutit, 1991). They fall under the general wetland definition of water-logged soil dominated by emergent vegetation (Davies, 1986). This description applies to sections of almost all the westward flowing rivers north of and inclusive of the Kulpis. Further to the south, in the dunes of the Namib desert, a number of streams form dramatic wetlands in the Namib sand seas during years of exceptionally high rainfall.

Many of the ephemeral wetlands are periodically used by man, depending on the availability of water points and grazing. In the past, many people were reliant on the ephemeral rivers and their wetlands for animal foods, hunting and even seasonal fishing. Nowadays, "Wetland utilisation includes communal domestic stock farming, small mining enterprises, small-scale gardening or rural community developments and health or educational schemes. A variety of tourism development schemes, both inland and coastal make use of wetlands for resources and recreation" (Loutit, 1991).
The ecology of Namibia’s ephemeral wetlands is fragile, depending on irregular flows. Near surface groundwater and springs play a vital role in ensuring the survival of many ephemeral habitats all round the country. Over-exploitation of alluvial aquifers, and the building of dams which reduce flow anywhere further downstream, are potentially harmful to aquifers and the wetlands that depend on them.

3.3.4 LINKS BETWEEN EPHEMERAL SURFACE WATER AND GROUNDWATER RESOURCES

In general, ephemeral streams in Namibia act as recharging sources to alluvial aquifers. This is discussed in Chapter 4. The reverse situation in which groundwater acts as a source for ephemeral river flow is limited to a number of springs which are arguably in fact perennial streams.

There are a number of significant springs in the Karst Area, and many of these could be considered ephemeral in that they dry up during periods of drought or following over-exploitation of surrounding groundwater.

In the westward flowing rivers there are also a number of springs usually resulting from the presence of compartments in the alluvium or other geological features. The number of these springs has reduced over the course of several decades largely as a result of over-exploitation of the surrounding groundwater, as well as, of course, drought.

3.4 DAMS / RESERVOIRS

3.4.1 INTRODUCTION

There are many significant surface water storage dams in Namibia despite the high evaporation rates. Namibia’s major dams are shown in Figure 3.18. They are generally for bulk water supply to municipalities and/or mines, but also for supply to irrigation projects. There are also countless small dams used by smaller communities and farmers for human consumption and/or stock watering.
Dams within Namibia can be seen as fulfilling one or more of the following functions:

- Bulk water supply to municipalities.
- Bulk water supply to mines.
- Bulk water supply to irrigation schemes.
- Part of a conjunctive use/transfer scheme.
- Storage prior to artificial recharge of groundwater.
- Stock-watering.
- Small-scale storage for human consumption.
- Recreation – water sports.
- Education.

Details relating to supply and demand from these different types of dams are covered in Chapter 5. This chapter deals more with dams as they fit into surface water as a resource and the effects that they have on the river environment.

3.4.2 NAMIBIA’S MAJOR STORAGE DAMS

Table 3.3: Namibia’s Main Storage Dams

<table>
<thead>
<tr>
<th>Dam Name</th>
<th>River</th>
<th>Full Storage Capacity (Mm³)</th>
<th>Dead Storage Volume (Mm³)</th>
<th>Purpose of Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swakoppoort Dam</td>
<td>Swakop</td>
<td>63,489</td>
<td>1.431</td>
<td>Urban water supply Research</td>
</tr>
<tr>
<td>Von Bach Dam</td>
<td>Swakop</td>
<td>48,560</td>
<td>2.073</td>
<td>Urban water supply Recreation, Research</td>
</tr>
<tr>
<td>Omatako Dam</td>
<td>Omatako</td>
<td>43,399</td>
<td>4.073</td>
<td>Urban water supply Research</td>
</tr>
<tr>
<td>Goreangab Dam</td>
<td>Gammams</td>
<td>3.621</td>
<td>0.010</td>
<td>Recreation, Fishing Education</td>
</tr>
<tr>
<td>Avis Dam</td>
<td>Avis</td>
<td>2.417</td>
<td>0.010</td>
<td>Recreation Education</td>
</tr>
<tr>
<td>Otjivero Main Dam</td>
<td>White Nossob</td>
<td>9.808</td>
<td>0.066</td>
<td>Urban water supply</td>
</tr>
<tr>
<td>Otjivero Silt Dam</td>
<td>White Nossob</td>
<td>7.795</td>
<td>0.096</td>
<td>Urban Water Supply</td>
</tr>
<tr>
<td>Tilda Viljoen Dam</td>
<td>Black Nossob</td>
<td>1.224</td>
<td>0.028</td>
<td>Urban water supply</td>
</tr>
<tr>
<td>Daan Viljoen Dam</td>
<td>Black Nossob</td>
<td>0.429</td>
<td>0.000</td>
<td>Urban water supply</td>
</tr>
<tr>
<td>Hardap Dam</td>
<td>Fish</td>
<td>294.593</td>
<td>4.299</td>
<td>Urban water supply Recreation, Fishing, Stock Watering</td>
</tr>
<tr>
<td>Naute Dam</td>
<td>Löwen</td>
<td>83.520</td>
<td>1.320</td>
<td>Urban water supply Irrigation, Recreation</td>
</tr>
<tr>
<td>Oanob Dam</td>
<td>Oanob</td>
<td>34.505</td>
<td>0.417</td>
<td>Urban water supply</td>
</tr>
</tbody>
</table>
Figure 3.18: Main Surface Water Storage Dams
Despite high rates of evaporation, surface water storage dams are an important water supply source. Most of the water supplied to Windhoek, Okahandja, Mariental, Keetmanshoop, Gobabis and Rehoboth is supplied from dams. The most serious environmental problem associated with dams is the reduced runoff downstream of the dam. In the case of the Canob Dam, the design made allowances for ecological releases to alleviate this problem. Plans for large dams on the Ugab, Omaruru and Fish Rivers (and tributaries) are still tabled for discussion from time to time.

Data Sources: Hydrology Division, DWA.
Figure 4.1: Distribution of Aquifer Types
Map showing distribution of the main environments in which groundwater occurs in Namibia. This is based on a broad grouping of geological units according to hydrogeological properties and the predominant aquifer types present.

Data Source: 1:2 000 000 Geology of Namibia, Map compiled by Geological Survey of Namibia ©1998, DWA Database and Reports.
Figure 4.2: Regional Rest Water Level

A map showing the rest water levels recorded in boreholes drilled throughout Namibia serves as a useful guide to the order of depths to which future drilling may have to be done. It also provides an indication of the accessibility of groundwater.

Data Source: DWA Groundwater Database
Figure 4.3: Groundwater Flow Patterns

The piezometric surface (elevation of the water table above sea level) indicates the general directions of flow of groundwater in Namibia. As can be expected this surface is generally consistent with the topographic surface of the country and groundwater and surface water flow in approximately the same directions.

Data Source: DWA Groundwater Database
<table>
<thead>
<tr>
<th>Dam Name</th>
<th>Town</th>
<th>Area (ha)</th>
<th>Storage (m³)</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dreihuk Dam</td>
<td>Horn</td>
<td>15,493</td>
<td>0.206</td>
<td>Recreation</td>
</tr>
<tr>
<td>Bondels Dam</td>
<td>Bondels</td>
<td>1,103</td>
<td>0.007</td>
<td>Urban water supply</td>
</tr>
<tr>
<td>Olushendja Dam</td>
<td>Cuvela &amp; feeder canal</td>
<td>42,331</td>
<td>4,000.</td>
<td>Urban water supply, Fishing, Balancing dam and emergency water supply to Oshakati</td>
</tr>
<tr>
<td>Friedenau Dam</td>
<td>Kuiseb</td>
<td>6,723</td>
<td>0.391</td>
<td>Recreation</td>
</tr>
<tr>
<td>Omaruru Delta Dam</td>
<td>Omaruru</td>
<td>41,288</td>
<td>5,000</td>
<td>Recharge enhancement, Urban water supply</td>
</tr>
<tr>
<td>Omatjene Dam</td>
<td>Omatjene</td>
<td>5,063</td>
<td>0.200</td>
<td>Urban water supply</td>
</tr>
</tbody>
</table>

For all these dams, with the exception of Omdel Dam (see Chapter 4), the largest "consumer" of water is evaporation. Evaporation losses increase in proportion to the extent of the area of the surface water of the dam. Some dams are sited in relatively deep valleys and do not lose nearly as much water to evaporation as those in wide shallow valleys. The dam with the worst characteristics is the Omatako Dam, and the best, Oanob Dam. If both these dams have the same quantity of water in them, the evaporative losses from the Omatako Dam will be nearly three times higher than from the Oanob Dam.

3.4.3 THE EFFECT OF DAMS ON THE RIVER ENVIRONMENT

3.4.3.1 Introduction

Two aspects merit discussion with respect to the effect of dams on the river environment. Firstly, the effect that large dams have on the river environment downstream of them, and secondly the effect that the numerous "farm" dams have on inflows into the large water supply dams. These aspects are discussed in 3.4.3.2 and 3.4.3.3 with reference to certain case studies in Namibia.

3.4.3.2 Large Water Supply Dams

Namibia's main water dams, although not large by international standards, are very large when compared to the mean annual runoffs of the rivers on which they are constructed. The Von Bach Dam, for example, with a capacity of 50Mm³ is able to store approximately two and a half times the mean annual runoff of the river at that point. It has not spilled since the late seventies largely because of its size, low inflow rates, and the fact that the water is utilised at a fairly rapid rate.

Large dams have a major impact on flows further downstream. A study carried out on a proposed dam (Crerar 1984) on the Omaruru River at the point of maximum runoff,
concluded the following (assuming a dam of capacity one and half times the mean annual runoff):

- Mean Annual Runoff immediately downstream of the dam wall would be reduced from 40.48Mm³/annum to 24.60Mm³/annum.

- The number of years with flow at a point immediately downstream of the dam would be reduced from almost once a year to once every three to four years.

This change in the flow regime clearly has major impacts on the downstream user.

In order to avoid this problem, the idea of allowing a programme of compensatory releases was investigated as part of the design of the Oanob Dam, built in 1990. A study carried out by the Hydrology Division (Van Langenhove, 1989) concluded that under certain circumstances between one and five million cubic metres/annum could be released. A set of curves which combined long-term statistical and short-term operational considerations regarding safety of supply were derived which enable the decision-maker to decide whether there is enough water in the dam to make compensatory releases.

In view of the fact that the assured yield of the Oanob Dam is only 4Mm³/annum it may seem strange that significant compensatory releases can be considered. It must be remembered, however, that most of the water which would be used in a compensatory release programme would be lost to evaporation if not utilised, and only a small proportion towards increasing the safe yield.

3.4.3.3 Small Dams

It has been suggested from time to time, that recent poor inflows to certain of the main water supply dams are in part related to a proliferation of farm dams in their catchments. These dams, although usually small, need to fill up before flow in the tributaries can reach the main stream and flow on towards the dam.

A detailed study on the effect of farm dams in the Omatjenne Dam catchment area on the yield of the Omatjenne Dam (Mostert 1990) identified 64 farms dams in the 840km² Ugab catchment. The total capacity of these dams was estimated at 1.6Mm³. This is sizeable when the volume is compared to the capacity of the Omatjenne Dam (5.063Mm³).

The study concluded that the yield at the 95% assurance level would be 0.675Mm³/annum if there were no dams in the catchment, compared to the current assured yield of zero.
3.4.4 POLICY

For dams with a capacity larger than 20 000m³, approval for construction has to be obtained from the Department of Water Affairs. Part of the approval process includes a technical assessment by the Hydrology Division.

For major dams, full environmental assessment studies are required. These have been carried out as a matter of course since 1988.

A memorandum on the policy for the Approval of farm dams in the catchment of State dams was compiled by the Hydrology Division (Church 1990). The main conclusions were:

- any investigation of the influence of farm dams on the runoff potential of State dams can only attempt to assess the effect of future dams as compared to the present state. Investigation into past effects of the gradual increase in farm dams is not possible for lack of information on previously constructed dams.

- in principle, no further recommendations for the approval of farm dams larger than 20 000m³ in State dam catchments will be forthcoming.

- consideration be given to the introduction of measures in the new Water Act which would enable the state to control or enforce the removal of any unauthorised structure which has been built in a river or streambed in the catchment area of any State Water Scheme

- investigations into the effect of farm dams in the catchment areas of State dams be extended to include all State Water Schemes and communal aquifers.

3.4.5 WATER CHEMISTRY

The potability of water is determined by its aesthetic (taste, smell, turbidity), chemical and bacteriological quality. River water feeding Namibia's dams is generally of excellent quality, requiring only conventional treatment and disinfection.

Table 3.4 summarises the water chemistry of three of Namibia's main dams during the period 1992 to 1996 (Bethune, 1996)
Table 3.4: Water Quality of Three Namibian Dams (1992-1996)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit of Measurement</th>
<th>International Standards</th>
<th>Von Bach Dam</th>
<th>Swakoppoort Dam</th>
<th>Oanob Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity</td>
<td>(µS/cm)</td>
<td></td>
<td>117-315</td>
<td>302-580</td>
<td>141-264</td>
</tr>
<tr>
<td>TDS</td>
<td>(mg/l)</td>
<td></td>
<td>77-209</td>
<td>199-425</td>
<td>93-174</td>
</tr>
<tr>
<td>Total Alkalinity</td>
<td>(mg/l)</td>
<td></td>
<td>57-139</td>
<td>129-215</td>
<td>62-130</td>
</tr>
<tr>
<td>PH</td>
<td></td>
<td></td>
<td>6.9-8.35</td>
<td>6.9-8.8</td>
<td>6.8-8.35</td>
</tr>
<tr>
<td>Cl</td>
<td>(mg/l)</td>
<td></td>
<td>0.5-15.5</td>
<td>18-46.5</td>
<td>0.5-9</td>
</tr>
<tr>
<td>Na</td>
<td>(mg/l)</td>
<td></td>
<td>3-18.5</td>
<td>12.5-64</td>
<td>&lt;1-13</td>
</tr>
<tr>
<td>K</td>
<td>(mg/l)</td>
<td></td>
<td>6-14.5</td>
<td>13-31</td>
<td>5.12.8</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>(mg/l)</td>
<td></td>
<td>&lt;1-20</td>
<td>7-35</td>
<td>0.19-17.5</td>
</tr>
<tr>
<td>Ca</td>
<td>(mg/l)</td>
<td></td>
<td>37-76</td>
<td>53.5-80</td>
<td>45-93.5</td>
</tr>
<tr>
<td>Mg</td>
<td>(mg/l)</td>
<td></td>
<td>12-39</td>
<td>29-59.5</td>
<td>8.9-27</td>
</tr>
<tr>
<td>SiO₂</td>
<td>(mg/l)</td>
<td></td>
<td>&lt;0.5-6.5</td>
<td>&lt;0.5-8</td>
<td>0.5-9</td>
</tr>
</tbody>
</table>

Although water quality changes during the course of the year as a result of inflow and temperature changes, levels of pollution in Namibia's main storage dams are low. The one exception is the Goreangab Dam which is highly polluted and no longer fit for human consumption, even after treatment.

3.5 OVERVIEW, GUIDELINES AND INDICATORS

3.5.1 RELEVANCE TO THE WATER SECTOR

Droughts and limited availability of both surface water and groundwater resources in the interior of Namibia are beyond the control of man. However, this limited availability means that man must be in a position to manage and use the resource judiciously. Part of that management is the planning of how resources can best be used in a way that is environmentally, socially and economically sustainable. Later in this study, approaches in use to manage resources, and to manage demand are discussed, but such planned management can only happen if the resources are known. In the case of surface water it is necessary to know the quantity of flow, the frequency or reliability of the flow, and the quality of the water. In view of the fact that a large percentage of the water supplied comes from surface water sources (dams on ephemeral rivers and perennial rivers), and that much of the supplied ground water is also derived from surface water, a good understanding of the surface water resources is important.
In Chapter 2, the global hydrological cycle was introduced, and subsequently the hydrological cycle or system as it operates in an arid environment. Understanding and quantifying the distorted nature of the hydrological cycle as it operates in Namibia is fundamental to sustainable management of the water resources of this country.

3.5.2 ASSESSMENT AND EVALUATION OF THE SITUATION IN NAMIBIA

Data relating to surface water resources are collected mainly by the Hydrology Division within the DWA. Most data are collected from automatic recorders which have to be visited on a regular basis for servicing and station inspection. The collection, processing and analysis of these data is a time-consuming, demanding and a relatively expensive task, and requires that those involved are suitably trained, motivated and sufficient in numbers.

Current manning levels within the Hydrology Division are unquestionably too low, especially within the technical field, for the work to be carried out effectively.

In Namibia, despite repeated efforts which have been made over recent years by the Hydrology Division to create the essential post of "hydrometrist" this has not been successful. As a result the majority of data is collected by a small number of under-qualified technical assistants who receive occasional training from an already overstretched staff of hydrologists.

It is important that decision-makers are reminded of the value of accurate and reliable hydrological data. Considering that the evaluation of surface (and alluvial groundwater) resources depends almost entirely on reliable runoff data, it is clear that it would be a grave error not to allocate sufficient resources to this fundamental aspect of water resource assessment and evaluation.

3.5.3 PRIORITISED MANAGEMENT CONSIDERATIONS FOR SUSTAINABILITY

The following points are suggested as priorities for management consideration:

- Increased resources are required to ensure that the existing hydrological surface water network can be operated efficiently and that the capture of reliable data can continue.

- More gauging stations and field visits during times of flood are required in the Cuvelai River Basin. This is an important system which has been almost completely ignored in the past. Efforts have already been made by the Hydrology Division to rectify this in recent years.
• Attention needs to be paid to updating the water quality databank to make the data more accessible, and to ensure that frequent sampling for water quality continues at dams and on perennial rivers, and on ephemeral rivers when in flood.

3.5.4 POSSIBLE INDICATORS

A number of possible indicators were presented at an indicators workshop in Windhoek. These are discussed in Table 3.3 It was agreed at the workshop that runoff indicators relating strongly to rainfall and therefore to climate change should not be used since there were too many other factors that played a role.
<table>
<thead>
<tr>
<th>Definition of Indicator</th>
<th>Uses of Indicator</th>
<th>Data Collection and Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mean annual runoff as measured at gauging stations (including dams representing key selected key stations) is calculated.</td>
<td>Long-term mean can be used for indicator of the status of the country's surface water resources. Identification of the country's surface water resources is the first step in the evaluation of trends.</td>
<td>Change in long-term variability is associated with low yield. Since high variability is the basis for the evaluation of the indicator, a potential indicator variability is a potential change in flow regimes of the country's rivers. Can be used as an indicator of the evaluation of trends. Impossible to evaluate the evaluation of trends without very long records.</td>
</tr>
<tr>
<td>2. Runoff variability as defined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Runoff/Precipitation ratio or Runoff/Siltation ratio.</td>
<td>Could be calculated by dividing (mean) annual runoff (for a given area) by (mean) annual precipitation (for the same area) or by dividing (mean) annual runoff by (mean) annual siltation rate for selected storage dams.</td>
<td>Such an indicator would provide an indication of the status or health of the catchment.</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>4. Surface Water Quality. The quality of the surface waters as measured using selected biochemical parameters</td>
<td>Data of selected key ephemeral, perennial rivers and dams to be evaluated</td>
<td>The quality of a river or dam provides a good indication of the status or health of the catchment.</td>
</tr>
</tbody>
</table>
| 5. Status of Surface Water Storage | This could be evaluated by summing the total water stored in the main storage dams at the beginning of the hydrological season (1 October). | This would provide a simple to calculate indicator of the surface water storage reserves in the country | Clearly the total storage in the dams will be dependent on a number of factors that are not easily separated:  
• How much runoff has occurred  
• Decisions made by management on whether to use surface water or groundwater  
• Levels of water demand management. |
At the workshop there was lively discussion on the possibility of using point 3. above as an indicator of catchment health/status, and although it was agreed that there were not sufficient data available to do this, it was a useful idea to consider for the future.

In line with the objective of deriving a very limited set of key indicators it was decided to use only one, which is discussed in more detail in 3.5.5.

3.5.5 KEY INDICATORS

3.5.5.1 Annual Runoff

Runoff is measured at key runoff stations by the Hydrology Division in DWA on a continuous basis. Inflow into the country’s main reservoirs is monitored by NamWater. It is proposed that runoff into key dams and at selected river gauging stations be used to give an indication of whether runoff in the country’s ephemeral and perennial rivers has been above or below average for the season under review.

The Department of Water Affairs produces a weekly dam bulletin which is made available to all interested parties. In compiling these bulletins, inflow is evaluated so these figures are relatively easily available. For the key gauging stations, runoff volumes are available about nine months after the end of the hydrological season.

The proposed key runoff gauging stations have been discussed with the Head: Hydrology, and are summarized in Table 3.4.

The value of the indicator will correspond to the percentage of these selected key stations which record above their mean annual runoff.
Table 3.4: Indicator Stations for Annual Runoff

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Type</th>
<th>River</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ameib</td>
<td>Ephemeral gauging station</td>
<td>Khan</td>
</tr>
<tr>
<td>Etosha</td>
<td>Ephemeral gauging station</td>
<td>Omaruru</td>
</tr>
<tr>
<td>Hardap dam</td>
<td>Dam gauging station</td>
<td>Fish</td>
</tr>
<tr>
<td>Katima Mulilo</td>
<td>Perennial river station</td>
<td>Zambezi</td>
</tr>
<tr>
<td>Mukwe</td>
<td>Perennial river station</td>
<td>Okavango</td>
</tr>
<tr>
<td>Naute Dam</td>
<td>Dam gauging station</td>
<td>Löwen</td>
</tr>
<tr>
<td>Noordoewer</td>
<td>Perennial River Station</td>
<td>Orange</td>
</tr>
<tr>
<td>Oanob Dam</td>
<td>Dam gauging station</td>
<td>Oanob</td>
</tr>
<tr>
<td>Ottero Dam</td>
<td>Dam gauging station</td>
<td>White Nossob</td>
</tr>
<tr>
<td>Ruacana</td>
<td>Perennial river station</td>
<td>Kunene</td>
</tr>
<tr>
<td>Schlesien</td>
<td>Ephemeral gauging station</td>
<td>Kuiseb</td>
</tr>
<tr>
<td>Sesfontein</td>
<td>Ephemeral gauging station</td>
<td>Hoanib</td>
</tr>
<tr>
<td>Swakoppoort dam</td>
<td>Dam gauging station</td>
<td>Swakop</td>
</tr>
<tr>
<td>Vingerklip</td>
<td>Ephemeral gauging station</td>
<td>Ugab</td>
</tr>
<tr>
<td>Von Bach Dam</td>
<td>Dam gauging station</td>
<td>Swakop</td>
</tr>
</tbody>
</table>

Runoff records for many of the above (especially the ephemeral river stations) will be readily available. Data from the key ephemeral stations will normally be processed within six to nine months after the end of the hydrological season.
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Church J. 1990. *Memorandum on the Policy for the Approval of Farm Dams in the Catchment of State Dams*. Hydrology Division, DWA.


Mostert AC. 1990. *The Effect of Farm Dams in the Omatjenne Dam Catchment Area on the Yield of the Omatjenne Dam*. Hydrology Division, DWA. Windhoek.


Schlettwein CHG, and Bethune S. 1992. *Aquatic weeds and their management in Southern Africa: Biological control of Salvinia molesta in the eastern Caprivi*. In: Matiza,


Taylor ED, Clarke NV (In press). *Does Salvinia molesta still pose a threat to biodiversity in Namibia’s eastern Caprivi wetlands? Madoqua*


4. GROUNDWATER

4.1 INTRODUCTION

4.1.1 BACKGROUND

Namibia is an arid country with perennial rivers only on its northern and southern borders. This means that the country is essentially without surface water save for a few ephemeral streams (which flow in response to short duration, intense rainfall events) springs, man-made dams and ephemeral pans. Some of this run-off is held back and stored in dams, which provide temporary water supply on a small scale for farmers and on a larger scale for urban areas, but approximately two thirds of the population relies on groundwater for survival.

In assessing the health of the groundwater sector in Namibia, the usefulness of resources is of fundamental importance. Groundwater usefulness is determined by several factors such as:
- the nature of the water bearing strata
- proximity to consumers
- depth of water from surface (accessibility)
- borehole, well or spring yield
- stored volume of water and replenishment (recharge)
- chemical and bacteriological composition of the water
- susceptibility of the groundwater resource to pollution.

This chapter describes the mode of occurrence of groundwater and examines threats such as contamination and depletion of resources. Indicators, which illustrate trends in the overall health of groundwater in Namibia, are developed after examining the sector in some detail, at the end of the chapter.

4.1.2 DATA AND MAIN DATA SOURCES

Administration and control of groundwater in Namibia is the function of the Geohydrology Division of the DWA. This Division has conducted and commissioned numerous studies of the groundwater of the country and has built up and maintains a vast Groundwater Database. This database provides co-ordinates and some locality information together with certain technical specifications and records for some 42 500 boreholes. Of these records, approximately 32 000 have some useful data whereas the remainder are limited only to information regarding the locality and it remains doubtful that the boreholes were in fact drilled.
In the DWA Groundwater Database boreholes are numbered using two different systems:

- The “borehole number” is a sequential number assigned to boreholes drilled for the Government. A prefix “WW” is used, although some older boreholes might have the prefix G, A or T.
- A single numbering system was introduced that assigned a sequential number to each water point (borehole, well or spring) located in the area covered by a 1:50 000 scale topographical sheet. Each topographical sheet therefore has its own set of “well numbers” starting at 1. The numbering system uses an alphanumerical identification (six digits), combined with the well number as the key field identification to refer to a water point in the database. Thus the 5th water point located on topographical sheet number 1920 AB would be assigned 1920AB5 as its key identifier.

During the early 1980s the CSIR (South Africa) conducted an extensive hydrogeochmical survey of Namibia in which 25 580 samples (including 250 river samples) were taken and analysed for major and minor ions (Huyser, 1982). This investigation survey constituted the most intensive survey ever conducted. Additional data is, however, added to the system on a continuous basis. Maps, which are available from the DWA library, were generated, showing the distribution of the following parameters: F, NO3, SO4 and TDS. These parameters have been incorporated into the Groundwater Database, which can thus be used to provide some indication of water quality at each borehole.

For a network of boreholes throughout the country water levels are monitored by DWA, either manually at regular intervals (e.g. quarterly) or have autographic recorders installed in them. In the past the DWA was also responsible for the collection of abstraction data for State Water Scheme boreholes. This function is now the responsibility of NamWater.

Although there are some groundwater control areas in Namibia, where individuals require DWA approval to drill a borehole and abstract water, much of the country is open to farmers and institutions wishing to drill and use groundwater. The result is that numerous boreholes are drilled for which the DWA is not necessarily provided with data. In groundwater control areas the number of boreholes drilled, the purpose for which they are drilled and the amount of water abstracted, is regulated and more data is therefore given to DWA. Monitoring is normally carried out in groundwater control areas, which provides DWA with a means of checking on the status of reserves and exercising a management role when needed.

Until recently water samples were analysed by the Department of Water Affairs (DWA) free of charge. A large hydrochemical database was thus generated over the years
80 000 analyses) and stored in the form of typed out analysis reports, which are held by DWA. Since the late 1980s the particulars of the samples have been stored in UNIX format. At the same time an attempt was made to add the earlier data to the system beginning with the oldest analyses. To date approximately half of the older analyses have been entered and are available in digital format and users outside DWA or the Namibia Water Corporation (NamWater) can obtain the data in ASCII format.

At present DWA and NamWater are in the process of changing to a new computer system, which will be in place within a few years. At the same time the different datasets, such as hydrochemistry and hydrogeology, are being transferred into more user-friendly programmes, most of which will run under Windows.

In future, water quality data will be available in MS-ACCESS format at DWA and in MS-EXCEL format at NamWater. The analyses processed in the laboratory of NamWater since April 1997 will no longer be given out free of charge to the public. Older data will however, remain free of charge and the DWA is considering making this available to the public via the Internet.

Previously, when samples were handed in for analyses, the particulars of each sample were recorded and reproduced on the analysis report. Unfortunately the particulars were not always given in a standard format, which has made it difficult to use the data in applications such as database queries.

Hydrochemical records regularly have no co-ordinates by which the spatial distribution of determinants may be plotted. It was therefore necessary to link the hydrochemical database to the Groundwater Database to obtain co-ordinates for each of the records. This was achieved by linking either the borehole number or the topographical sheet + well number from the hydrochemistry database to the same field in the Groundwater Database. Where no borehole number was given in the hydrochemistry database, it was not possible to locate the origin of the data and the analysis was thus discarded.

It was possible to link approximately 30 500 hydrochemical analyses for the determinants F, NO₃ (as N), SO₄ and TDS. It was also possible to link between 5 000 and 5 800 analyses for other determinants (Ca, Cl, Conductivity, K, Na, Mg, NO₂ (as N), SiO₂, Ryznar and Langelier Indices, pH, Total Hardness, Phenolphthalein Alkalinity and Total Alkalinity). Between 42 and 160 analyses for metals (Cd, Cr, Cu, Fe, Mn, Pb and Zn) were also linked.

When the data were plotted, a somewhat unequal distribution was shown, with far more data available for commercial farmlands compared to communal farming areas. Additional data has been provided for the communal farming areas by a number of regional groundwater studies conducted since Independence. These data have now been added to the database, which has improved the overall coverage.
4.2 AQUIFER CHARACTERISTICS AND DISTRIBUTION

Groundwater is contained in voids in rocks and sediments. These voids (pore-space), relative to the total volume of rock, define the porosity, and the size of voids and passages between the pore-spaces define the permeability. Strata containing abstractable groundwater, referred to as an aquifer, may vary, as may the nature of the porosity and permeability.

In describing aquifers certain criteria are important for overall classification. These include:

- The nature of the porosity, whether primary (e.g. voids between the individual grains in a sedimentary rock) or secondary (controlled by fractures in otherwise impermeable rock);
- The nature and composition of the host material;
- The level to which water will rise in a borehole (i.e. the piezometric level, or watertable in an unconfined aquifer).

Using these criteria, aquifers occurring in Namibia are classified as follows:

- Bodies of alluvium commonly host groundwater in intergranular pore-spaces and are termed alluvial or sand aquifers. Certain of these aquifers may have limited storage but experience relatively rapid recharge after significant run-off events. In the drier, western parts of Namibia, alluvial aquifers supported by westward flowing ephemeral rivers are an important source of potable water for urban and industrial supply.

- In central southern Africa a large area is covered by semi- to unconsolidated strata of the Kalahari Group. The Kalahari is generally fine to very fine grained and has low primary porosity. Boreholes drilled into Kalahari aquifers are generally low yielding and produce water of variable salinity. Layered fresh and saline waters are present in some places.

- Where bedrock is intrinsically impermeable, groundwater occurrence is limited to zones of secondary permeability formed by fracturing and faulting. In some cases folding of the strata causes movement along bedding planes and other discontinuities and this may also give rise to the development of secondary porosity. Although these are grouped together as fracture aquifers it should be realised that the distinction of various specific aquifer types is possible.

- In dolomite and limestone terrain, fault structure or formation hosted aquifers undergo extensive solution weathering which enlarges the secondary porosity, giving rise to "karst" features. Large volumes of groundwater are stored underground in cavernous, karst aquifers such as those which typify parts of the Otavi Mountains.
Solution weathering occurs along bedding planes, faults and joints, through the percolation of meteoric water containing carbonic acid from dissolution of atmospheric CO₂, which dissolves the carbonate rocks.

- Irrespective of the geological formations involved; there are instances where an aquifer may be capped by impervious strata. Under certain conditions this may lead to confinement of the aquifer. Where the degree of confinement is such that it causes the level of the groundwater to rise sufficiently to flow from the mouth of a borehole, without pumping, the condition is referred to as artesian. Artesian aquifers need to be developed in a special way to prevent leakage and wasting of the resource.

Each of these aquifer types is discussed in more detail below and their overall distribution shown in Figure 4.1.

Figure 4.2 is a plot of the range of depth of water level, from surface, in individual boreholes and is useful for illustrating the general accessibility of groundwater. Shallow water (less than 20m from surface) is accessible to hand dug wells and can be withdrawn by bucket or handpump. Deeper levels will need drilling and powered pumps for exploitation. The data for this plot have been taken from the Groundwater Database.

When describing groundwater in a regional context it is useful to illustrate directions of subsurface flow as depicted by the piezometric surface, Figure 4.3. The piezometric surface was created by plotting and contouring the elevation of the water level measured in individual boreholes and converted to metres above sea level. The data used are from the Groundwater Database and represent water level measurements taken over decades at the time boreholes were drilled. Updated surfaces are only possible for areas where regional studies have been conducted.

4.2.1 ALLUVIAL AQUIFERS

Alluvium filled riverbeds are an important source of groundwater in Namibia, supporting aquifers which are replenished periodically by runoff events. The alluvial aquifers supply water for towns, industries, mines, irrigation and farming activities.
Alluvial aquifers comprise alluvium-filled palaeochannels (ancient, buried river channels), commonly underlying active ephemeral rivers, which hold water in intergranular pore-space. The alluvial material is not always homogeneous but comprises multiple layers of silt, clay, sand, cemented sediment, gravel and boulders. These layers have different hydraulic characteristics, resulting in variable permeability and porosity. Where permeable strata overlie an aquifer, an unconfined (or phreatic) condition exists. Alternatively, where impermeable layers overlie the saturated formations, the aquifer is said to be confined. Gradations between confined and phreatic conditions occur, and where the cover material is semi-permeable, recharge to the aquifer by infiltration may be significantly delayed.

Semi-confinement by silt layers in the upper parts of the alluvium of the Kuiseb River led to a delay of up to 6 months for the infiltration of flood-water to the Swartbank/Roobank aquifer after the 1997 floods (Wessels, 1998).

The storativity value or specific yield of alluvial aquifers in Namibia varies between 6% - 25%, i.e. between 60 - 250 litres of water is available for abstraction for every cubic metre of saturated sediment (J V Consultants, 1993).

Important wellfields which tap alluvial aquifers to supply towns, mines and irrigation farmers are tabulated below:

Table 4.1: Important Wellfields Exploiting Alluvial Aquifers in Namibia

<table>
<thead>
<tr>
<th>WELLFIELD (RIVER)</th>
<th>CONSUMER</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Kuiseb River</td>
<td>Walvis Bay, Rössing Mine, Arandis, Swakopmund</td>
<td>The aquifer has been subdivided into the Roobank and Swartbank Compartments and includes the Kuiseb Delta area known as the Dorop aquifer.</td>
</tr>
<tr>
<td>Omdel (Lower Omaruru River)</td>
<td>Henties Bay, Rössing Mine, Arandis, Swakopmund</td>
<td>This aquifer comprises the alluvial body underlying a 40km stretch of the Omaruru River upstream of the mouth, which is artificially recharged by surface flow into the Omdel Dam.</td>
</tr>
<tr>
<td>Nei-Neis (Omaruru River)</td>
<td>Uis Village and Tin Mine</td>
<td>Prior to closure of mine (September 1990) production was 53 000m³/month. Now 20 000m³/month to town only.</td>
</tr>
<tr>
<td>Omaruru (Omaruru River)</td>
<td>Omaruru: town and irrigation farmers</td>
<td>Total length of aquifer underlying the Omaruru River is 35km. Kranzberg Mine was also supplied from here until it closed in the 1970s.</td>
</tr>
<tr>
<td>Spes-Bona (Khan River)</td>
<td>Karibib</td>
<td>Situated approximately 80km north of Karibib. Boreholes tap the alluvial aquifer as well as fractured bedrock beneath the alluvium.</td>
</tr>
<tr>
<td>Khan-Kranzberg (Khan and Aroab Rivers)</td>
<td>Usakos</td>
<td>Khan River alluvial aquifer situated upstream of the Khan-Aroab confluence. Kranzberg wellfield taps the Aroab River alluvial aquifer.</td>
</tr>
<tr>
<td>Khan River</td>
<td>Rössing Mine</td>
<td>Saline groundwater is abstracted for dust suppression during mining operations.</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| Osona (Swakop and  | Okahandja: town and irrigation farmers     | Production from boreholes in the Okahandja River alluvial aquifer, which extends 15km 
| Okahandja Rivers) |                                           | upstream of the Okahandja-Swakop confluence. The town water supply from von Biber Dam. Abstraction 
|                    |                                           | from boreholes tapping the Swakop alluvial aquifer is used for irrigated market gardening. |
| Rehoboth (Oanob    | Rehoboth                                   | A wellfield exploiting the Oanob River alluvial aquifer supplied water to Rehoboth until mid 
| River)             |                                           | 1990 when supply from the newly constructed Oanob Dam commenced. The dam has effectively cut-off 
|                    |                                           | recharge to the alluvial aquifer, however pumping from the aquifer has also stopped. Studies on artificial recharge from the dam are underway. |
| Koichab Pan        | Lüderitz                                   | Water supply to Lüderitz is provided by a pipeline from the Koichab Pan wellfield some 
|                    |                                           | 100km to the northeast. Production is curtailed at a rate of 82 000m³/ha. Studies indicate the 
|                    |                                           | this water is 5 000 – 7 000 years old (Kehrbarg, 1993) which, coupled to an annual rainfall in the catchment area of 50mm, 
|                    |                                           | suggests that in effect the source is being mined. Groundwater quality has remained unchanged since commencement of pumping April 1969. |

Figure 4.4 shows the distribution of the main, exploited alluvial aquifers in Namib. Other alluvial aquifers, which are not shown, are as follows:

- Currently unused freshwater alluvial aquifers are known to exist along the coastal stretches of certain westward flowing ephemeral rivers;
- along the Hoanib River (e.g. at Sesfontein and Khowarib);
- along the Huab River (e.g. at Eersbegin);
- small scale abstraction is carried out near the mouths of the Uniab and Ugab Rivers;
- along the Fish River (e.g. at Ai-Ais).

4.2.2 KALAHARI AQUIFERS

About one third of the country is covered by aeolian (wind blown) sand, which includes Kalahari Group sediments and deposits of the West Coast and Namib. Kalahari host aquifers underlie areas in the northern and northeastern parts of the country (Figure 4) and include phreatic, confined and artesian aquifers. The artesian condition is described under Section 4.2.5.
The Kalahari Group comprises arenaceous and argillaceous, semi-to fully consolidated sediments, which were deposited into a major continental basin extending to the north and northwest into Angola and eastwards into Botswana. Calcrite and recent sand dunes cap the Kalahari Group, which is in excess of 350m thick in the northern parts of Namibia.

Groundwater is not present everywhere in the Kalahari but where it occurs it is relatively easy to locate by drilling (e.g. throughout most of the Okavango and Caprivi Regions). The sediments form an almost continuous permeable layer from which generally low yields may be abstracted via boreholes. Factors determining yield include variations in aquifer permeability, thickness of saturated sediments and the diameter and design of the borehole or well.

A threefold subdivision of Kalahari aquifers in the western parts of Ohangwena and Oshikoto Regions was proposed (GCS, 1991). This subdivision, which is only applicable in the area covered by the Cuvelai drainage system, comprises the following aquifers:

- **Discontinuous Perched Aquifer**: containing fresh water perched above shallow impermeable layers largely confined to the Cuvelai drainage system from whence recharge is derived. This aquifer is commonly less than 8m below surface and exploited via unlined hand-dug wells and ‘gat-dams’;

- **Main Shallow Aquifer**: where water levels are generally deeper than 8m but still accessible by hand-dug wells. Water quality varies from fresh to brackish, the latter condition interpreted as the result of mixing with saline water from the aquifer below;

- **Deep Aquifers**: tend to be very saline containing relatively ancient water dating from the period in which the sediments were deposited (i.e. connate water). In places potable (drinkable) water has been intersected by boreholes in this deep aquifer but the relationship of this to the generally hypersaline water dominating the aquifer is not fully understood.

In places there is significant confinement of Kalahari aquifers, which results in an artesian to sub-artesian condition. The most noteworthy locality where this occurs is the Namutoni - Oshivelo area where an impermeable clay layer overlies a highly permeable horizon in the Kalahari sediments. Individual borehole yields of above 50m$^3$/h have been recorded from this permeable horizon. It is interesting to note that above the confining horizon is a reliable phreatic aquifer from which boreholes commonly yield 5-10m$^3$/h.

Isolated boreholes also intersect artesian water in Kalahari strata along the Nhoma Omuramba and at Shiguru (near the confluence of the Omatako and Okavango Rivers).
Figure 4.4: Distribution of Strategic Alluvial Aquifers in the Central Areas of Namibia

This map provides detail from Figure 4.1 showing the location of the most important alluvial aquifers supplying State Water Schemes in the central areas of Namibia.

Data Source: DWA Groundwater Database and internal reports
Figure 4.7: Areas Surveyed in the Stompriet Artesian Basin

Areas covered by the DWA survey conducted in the mid- to late 1980's to assess the situation in the artesian basin with respect to management of the resources.

Data Source: DWA internal report, Nawrowski (1989)
4.2.3 FRACTURE AQUIFERS

Fracture aquifers form in hard rock where porosity is developed along interconnecting fissures and other open discontinuities. The nature of the fracture network, density of fractures and the width of individual apertures determines aquifer permeability and storativity (the ability to store or release water).

Dolerite and pegmatite dykes usually intrude along older zones of weakness such as faults and exhibit sharp contacts with the country rock. Such contacts and associated vertical fractures commonly form useful fracture aquifers. Furthermore, dolerite dykes, normally vertical or steep dipping, may act as effective groundwater barriers to groundwater flow through the country rock. In the Karas Region and in the southern parts of the Hardap Region many successful boreholes were drilled along dolerite dyke contacts. Deep circulating ground water, with elevated temperatures, may also be associated with dykes (e.g. Omburu near Omaruru).

When faulting occurs, the rocks may become shattered and broken up (brecciated) in the vicinity of the plane(s) along which movement takes place. In fault zones the groundwater potential is dependent on the nature and extent of brecciation. Approximately 10km east of Tses a production borehole penetrated a south–west striking fault zone on the contact of the Nama Group and Nossob Member (Prince Albert Formation, Ecca Group, Karoo Sequence) sediments yielding 100m³/h. From pumping tests, the storativity of this confined aquifer is relatively high, calculated to be $5.8 \times 10^{-4}$; i.e. 0.6 litres of water per cubic metre of rock.

Litho-stratigraphic contacts may also form fracture aquifers where groundwater commonly moves along bedding planes. In the Khorixas area, groundwater is stored in the permeable phyllite-quartzite and dolomite-phyllite contact zones.

The Otjiwarongo Synclinal Marble Aquifer stretches from Omatjene, 20km west of Otjiwarongo to Okapuka, 50km northeast of Otjiwarongo. Groundwater is confined to solution features, which are developed on the contact zone between the marble and country rock and interconnecting fracture zones. Twenty-one production boreholes on the marble aquifer supply water to Otjiwarongo.

The main aquifers in the Windhoek area are fractured zones in the Auas quartzite. Groundwater flows along bedding planes and fault zones to the abstraction area. Ground water supply from the wellfield is from 49 production boreholes. During dry seasons when the dam levels are low, production from the wellfield is high (1968 = 4.99Mm³; 1996 = 3.9Mm³) and vice versa in good rainfall seasons (1974 = 0.566Mm³; 1997 = 0.868Mm³).
Elevated groundwater temperatures observed in production boreholes and nearly all hot springs in Namibia (Ai-Ais, Gross Barmen and Warmbad in the Karas Region) are related to deep-seated aquifer structures, with deep circulating water along fault zones.

The newly developed wellfield northeast of Gobabis is underlain by fracture-hosted quartzitic basement aquifers. Unsaturated Kalahari sediments of less than 20m overlie these aquifers. On each of 10 boreholes, which intersect fracture hosted aquifers, a 72hr pumping test was carried out at pumping rates of 20 -60m$^3$/h (CBA, 1996b).

Conventional pumping test analysis methods, used on various aquifer studies in Namibia, give storativity values for fractured aquifers in the order of $10^{-3}$ - $10^{-4}$. The groundwater available for abstraction from a fracture-hosted aquifer is thus 0.1 – 1.0 litres per cubic metre of rock.

4.2.4 KARST AQUIFERS

With the generally low rainfall in Namibia true "karstification" does not occur on a large scale in carbonate lithologies. So-called "Karst Aquifers" are in fact partially karstified fracture aquifers, where secondary porosity has been enhanced by solution weathering (Schmidt, 1996). This type of aquifer is, however, distinct and deserves separate description as it is one of the strategic groundwater resources of Namibia.

Additional water supplies to the central area of Namibia and western Otjozondjupa Region, via the Eastern National Water Carrier (ENWC), are from groundwater sources in the Grootfontein Karst Area and water pumped from the Kombat Mine for dewatering purposes.

A German–Namibian groundwater exploration project was conducted by the BGR (the German Geological Survey) over the Otavi Mountain Land (OML), occupying the areas north and northwest of the Omambonde and Omatako Omuramba and including parts of the Otavi, Grootfontein and Tsumeb triangle.

Figure 4.5 shows the area modelled by the BGR in relation to the traditionally recognised "Karst Areas I - IV". Together with foreland areas the project covered an area of 12,000 km$^2$ generating numerical models to simulate groundwater behaviour and determine recharge parameters.
Figure 4.5: Groundwater Areas of the Grootfontein-Otavi-Tsumeb Karstland

Areas I-IV are used for management and description of the Karst land by DWA, overlain by the study areas used for the BGR modelling of 1996. Map reference: UTM grid-zone 33K, central meridian 15° E.

Data Source: BGR Project 89.2034.0 Geohydraulical Investigations and Groundwater Modeling of the Otavi Mountain Land, DWA 1996

The aquifers consist of fissures, fractures, major east-west or northeast-southwest trending fault zones and partially karstified dolomite. The dolomitic aquifer is underlain by metamorphic basement rock, which acts as an aquitard (zone of low porosity and permeability).

The main groundwater flow patterns in the Otavi Mountain Land, as depicted by the hydraulic gradient (Figure 4.3) are:

- Eastwards into the Omatako drainage basin,
- North-westwards to the Etosha Pans and the Owambo/Cuvelei Basin.
Outflow from the karst aquifers thus provides a significant contribution to the recharge of Kalahari hosted aquifers.

Aquifer characteristics of the carbonate aquifers of the Otavi Mountain Land are variable, being less favourable with depth where transmissivity declines. This heterogeneous character coupled to very variable recharge, results in reduced potential for groundwater abstraction during times of protracted drought when water levels are already depressed in the karst aquifers.

From the BGR study, a low storage coefficient of 0.005 and a moderate hydraulic conductivity of $10^4$ m/s were derived for the entire area tested (Schmidt, 1996).

Substantial groundwater resources occur in the dolomitic aquifer in the Tsumeb area. Large quantities of water were pumped in the past from the Tsumeb Mine during dewatering operations. This water was used by the mine, municipality of Tsumeb and for irrigation purposes. Mining operations ceased in 1996 and since then no water has been abstracted from the mine. The municipality relies on its own water resources and pumps water from 11 production boreholes with an annual supply of 1.5 - 2.0Mm$^3$. To the north and northeast of Tsumeb and to the west, in the vicinity of the Guinas and Otjikoto lakes (sinkholes or dolines), water is abstracted for irrigation and stock watering by farmers.

4.2.5 ARTESIAN AQUIFERS

A borehole, which derives its water from a confined aquifer, will normally show a rise in water level above the top of the aquifer. The elevation of the rest water level, above sea level, is called the potentiometric level. Where the confining pressure at the top of the confined aquifer is large enough to raise the water level to the surface, groundwater will flow out and the condition is referred to as artesian.

Artesian aquifers are exploited in three main areas (Figure 4.1):

- The Stampriet Artesian Basin, with artesian and sub-artesian conditions in boreholes in the Auob- and Nossob sandstones (Ecca Group).
- An area 30-40km west of Maltahöhe, artesian water occurs in black limestone and sandstone aquifers of the Schwarzerand Subgroup of the Nama Group.
- In the area of Oshivele and Namutoni, the artesian aquifer draws its water from a highly permeable layer in the Kalahari sediments, which is overlain by a confining clay layer. Groundwater from this aquifer may have a high sodium chloride content, which makes it unsuitable for irrigation purposes although it is generally potable.

The Stampriet Artesian Basin (SAB) covers an area of nearly 65 000km$^2$ in the southeastern part of the country (Nawrowski, 1989). Groundwater from the basin is
• The Kalahari Group sediments (conglomerates; silt; clay: sandstone; dune sand and calcrete)
• Fractured country rock along intrusive contacts (basalts and dolerite dykes and sills)
• Upper artesian Auob sandstone (coarse to fine grained, white to dark brown sandstone)
• Lower artesian Nossob sandstone (medium to coarse grained white sandstone)

In October 1955 the Stampriet artesian basin (SAB) was declared a groundwater control area, which means that permits issued by the Department of Water Affairs are required for the drilling of boreholes and the abstraction of artesian groundwater. In order to determine the degree to which permit conditions were complied with, the Department of Water Affairs conducted a survey in the mid to late eighties. The locations of the 3 areas covered by this survey are shown in Figure 4.7.

Table 4.2: Results from the Borehole Survey in the Stampriet Artesian Basin

<table>
<thead>
<tr>
<th></th>
<th>Area 1</th>
<th>Area 2</th>
<th>Area 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveyed Area (km²)</td>
<td>5140</td>
<td>8095</td>
<td>7500</td>
</tr>
<tr>
<td>Farms surveyed</td>
<td>62</td>
<td>117</td>
<td>89</td>
</tr>
<tr>
<td><em>Estimated abstraction (m³/a) for</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>6100 000</td>
<td>230 000</td>
<td>570 000</td>
</tr>
<tr>
<td>Stock watering</td>
<td>300 000</td>
<td>370 000</td>
<td>440 000</td>
</tr>
<tr>
<td>Domestic &amp; Municipal</td>
<td>200 000</td>
<td>700 000</td>
<td>530 000</td>
</tr>
<tr>
<td><em>Estimated abstraction (m³/a) from</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artesian + Sub-artesian aquifers</td>
<td>6200 000</td>
<td>600 000</td>
<td>50 000</td>
</tr>
<tr>
<td>Kalahari aquifer</td>
<td>400 000</td>
<td>700 000</td>
<td>*1 490 000</td>
</tr>
<tr>
<td>Basalt aquifer</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Abstraction estimated for Kalahari + Basalt

As a result of the survey a network of 173 monitoring boreholes was subsequently selected by the Geohydrology Division of the Department of Water Affairs for water level monitoring on a biannual basis.

The objective of this survey was to gather sufficient data and process it in order to evaluate and manage the resources of the Stampriet Artesian Basin. It was recommended that, after 5 to 10 years of monitoring (i.e. in the late 1990s), all the data should be re-evaluated to set parameters for determining the long-term potential of the SAB in terms of recharge, abstraction and natural losses. A large-scale hydrocensus and aquifer modelling programme will commence later this year (1999) with Japanese Aid and the existing monitoring data will be included.
used for large-scale irrigation, stock watering, domestic and municipal use. The southeast flowing ephemeral Auob, Olifants and Nossob Rivers are the only significant surface drainage development in the Basin.

Kalahari sediments exceeding 250m thickness cover large areas of the artesian basin and form a phreatic aquifer in places.

A sequence comprising Nossob sandstone (30m thick), blue shale (60-100m thick) and Auob sandstone (30m thick) (Karoo Sequence), is overlain by an impermeable, blue and yellow shale unit which serves as a confining bed for the underlying water bearing sandstones. Figure 4.6 is a block diagram showing the stratigraphy and conditions in the Stampriet Artesian Basin.

Figure 4.6: Block Diagram of Stampriet Artesian Basin showing Hydrogeological Relationships. (After DWA, 1985)

Nossob sandstone and shale outcrop along the Weissrand, east of Mariental. Groundwater recharge to the sandstone aquifers occurs near the western and northern boundaries of the artesian basin, where the Auob – and Nossob sandstone outcrops and suboutcrops reach their highest topographic elevation.

Groundwater in the Stampriet area exists in 4 different geological environments, namely:
4.2.6 GENERAL GROUNDWATER FLOW DIRECTIONS IN NAMIBIA

Normally, a high degree of correlation exists between groundwater level water contours and surface contours and groundwater flowing from elevated areas (i.e. of recharge) to lower areas, following the general surface drainage systems as is indicated in Figure 4.3.

4.3 STORAGE CAPACITY

In order to estimate the volume of groundwater available for abstraction from a particular aquifer the dimensions of the water bearing body must be known. From this the saturated volume is determined from direct measurement of the thickness of the zone below the water table (i.e. the saturated thickness). Simplistically, the volume of groundwater available is equal to the saturated volume of aquifer, multiplied by the storativity (specific yield for unconfined - or the storage coefficient for confined aquifer conditions). Storativity is a parameter determined by test pumping and it may be necessary to incorporate variations in storativity across the aquifer when performing groundwater volume calculations. The storativity of an aquifer normally decreases with depth.

4.3.1 ALLUVIAL AQUIFERS

Bulk water supplies to Walvis Bay, Swakopmund, Rössing Mine, Arandis, Henties Bay, Lüderitz, Uis, Karibib, Usakos and Omaruru are all provided from alluvial aquifers recharged by westward flowing ephemeral rivers. Calculated stored reserves and average changes in water level of the main alluvial aquifers are summarised in quarterly reports prepared by the Geohydrology Division of NamWater. Recently calculated volumes available for abstraction in the main alluvial aquifers are tabulated below. It must be noted that the values of ‘months of adequate abstraction’ were calculated based on zero recharge.
Table 4.3: Calculated Stored Volumes Available for Groundwater Abstraction

<table>
<thead>
<tr>
<th>Bulkwater Supply Scheme</th>
<th>Consumers</th>
<th>Aquifer</th>
<th>Date calculated</th>
<th>Stored Volume (Mm³)</th>
<th>Months of Adequate Abstraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Koichab Pen</td>
<td>Lüderitz</td>
<td>Koichab Pan Wellfield</td>
<td>Aug 93</td>
<td>150**</td>
<td>245</td>
</tr>
<tr>
<td>Kuiseb</td>
<td>Walvis Bay, Swakopmund, Rössing, Arandis</td>
<td>Rooibank Swartbank</td>
<td>Jun 98</td>
<td>8.09</td>
<td>31.25</td>
</tr>
<tr>
<td>Omdel</td>
<td>Swakopmund, Rössing, Arandis, Henties Bay</td>
<td>Omdel – Omaruru River</td>
<td>Jun 98</td>
<td>53.74</td>
<td>121</td>
</tr>
<tr>
<td>Nei Neis</td>
<td>Uis community</td>
<td>Omaruru River</td>
<td>Jun 98</td>
<td>1.27</td>
<td>49</td>
</tr>
<tr>
<td>Spes Bona</td>
<td>Karibib town</td>
<td>Khan River</td>
<td>Jun 98</td>
<td>0.84</td>
<td>21</td>
</tr>
<tr>
<td>Usakos</td>
<td>Usakos town</td>
<td>Khan River</td>
<td>Jun 98</td>
<td>0.40</td>
<td>3</td>
</tr>
<tr>
<td>Omaruru</td>
<td>Omaruru and Irrigation farmers</td>
<td>Municipal Omaruru River Omburo Omaruru River</td>
<td>Mar 98</td>
<td>0.75</td>
<td>0''</td>
</tr>
</tbody>
</table>


'' Rest water level in Omburo aquifer, below borehole depth. Water source mainly used for irrigation purposes when available.

Figure 4.8 has been inserted to illustrate the nature of variability of stored volume in selected alluvial aquifers in Namibia. From this it can be seen that since 1990 a steady downward trend has been exhibited in the Kuiseb and Omdel aquifers. In the trend exhibited by the graph for Kuiseb, this has been interrupted by the 1996-97 floods, which resulted in significant recharge (32 – 43Mm³). The Omdel trend shows a decline from about 96 – 55Mm³ for the same period. No effect from the 96-97 floods is noted, even though further upstream at Nei Neis and Omaruru, where dramatic increases in stored volume of approximately 1 - 5 Mm³ and 0.25 – 2.5 Mm³ respectively occurred. This is probably due to the completion of the Omdel dam which retained the 1996-97 flood.

The low volume alluvial aquifers, Omaruru, Nei Neis, Usakos and Spes Bona all show high variability with steady depletion of reserves after each recharge event, with pronounced recharge after annual flows in the ephemeral rivers. This influence of below annual mean runoff events is not noticed in the west coast aquifers, Kuiseb and Omdel.
Figure 4.8: Quarterly Volume Calculations for Selected Alluvial Aquifers
Volume calculations which are based on water level monitoring are reported quarterly for the major alluvial aquifer wellfields by NamWater. Data are only available back to 1990 at present but show the high variability displayed in aquifers with limited storage compared with the less dramatic seasonal response shown by the largest aquifers (Kuiseb and Omdel).

Data source: NamWater Geohydrology Division
Case studies carried out on fracture aquifers in various parts of Namibia have produced the following estimates of stored reserves:

Table 4.5: Estimated Stored Reserves for Some Fracture Aquifers in Namibia

<table>
<thead>
<tr>
<th>Project</th>
<th>Consultant</th>
<th>Area</th>
<th>Estimated Stored Reserves (Mm$^3$)</th>
<th>Storativity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater Investigations to Provide Additional Water Supplies to Gobabis (1996b)</td>
<td>Carr Barbour &amp; Associates</td>
<td>Fractured hosted aquifers NE of Gobabis</td>
<td>22</td>
<td>0.002</td>
</tr>
<tr>
<td>A re-assessment of the marble aquifer potential and a critical review of management and operational aspects, 1998</td>
<td>NamWater (Seimons, W)</td>
<td>Otjwarongo Marble aquifer Compartment I – VII</td>
<td>Not calculated</td>
<td>0.0027</td>
</tr>
<tr>
<td>On-going modelling</td>
<td>Windhoek City Council (van der Merwe, pers. comm.)</td>
<td>Windhoek Aquifer</td>
<td>22-25</td>
<td></td>
</tr>
</tbody>
</table>

4.3.4 KARST AQUIFERS

Conclusions regarding the groundwater potential in the Otavi Mountain Land area, derived from various projects, are summarised in the table below:

Table 4.6: Results of Previous Studies of the Karst Area

<table>
<thead>
<tr>
<th>Source</th>
<th>Groundwater Potential Area</th>
<th>Area covered Km$^2$</th>
<th>Saturated thickness (m)</th>
<th>Storativity</th>
<th>Stored reserves Mm$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>BGR Report (1996)</td>
<td>Karst_01</td>
<td>900</td>
<td>150</td>
<td>0.005</td>
<td>675 (1978)</td>
</tr>
<tr>
<td>BGR Report (1996)</td>
<td>Karst_02</td>
<td>1300</td>
<td>150</td>
<td>0.005</td>
<td>315 (1996)</td>
</tr>
<tr>
<td>CAM: Phase 1 (1993)</td>
<td>Dolomitic aquifer AREA I</td>
<td>140 (E = Brandwag)</td>
<td>10</td>
<td>0.005</td>
<td>7.0</td>
</tr>
<tr>
<td>CAM: Phase 1 (1993)</td>
<td>Dolomitic aquifer AREA II</td>
<td>162.5 (Grootfontein)</td>
<td>20</td>
<td>0.005</td>
<td>16.2</td>
</tr>
<tr>
<td>CAM: Phase 1 (1993)</td>
<td>Dolomitic aquifer AREA III</td>
<td>160 (E = Khusib)</td>
<td>16.0</td>
<td>0.005</td>
<td>16.0</td>
</tr>
<tr>
<td>CAM: Phase 1 (1993)</td>
<td>Dolomitic aquifer AREA IV</td>
<td>50 (Abenab)</td>
<td>20</td>
<td>0.005</td>
<td>5.0</td>
</tr>
</tbody>
</table>

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### Table 4.6: Results of Previous Studies of the Karst Area

Based on the results of various projects, the following conclusions are summarized in the table below:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area Covered</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential Area</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2D seismic, 1996</td>
<td></td>
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<tr>
<td>3D seismic, 1997</td>
<td></td>
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<tr>
<td>4D seismic, 1998</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5D seismic, 1999</td>
<td></td>
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</tr>
</tbody>
</table>

#### Table 4.4: KARST Aquifers

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Water Level</th>
<th>Depth (m)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

#### Table 4.5: Estimated Storage Reserves for Some Fracture Aquifers in Namibia

The following estimates of stored reserves:

<table>
<thead>
<tr>
<th>Property</th>
<th>Estimated Storage (m³)</th>
<th>Area Covered</th>
<th>Consultant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Case studies carried out on fracture aquifers in various parts of Namibia have produced...
The BGR study assumed a saturated thickness across the modelled area of 150m. This figure is considered unrealistically high. Monitoring and production boreholes drilled in the AREA 1 - IV, are between 30 and 150m deep, with an average depth of approximately 105 metres below ground level. Rest water levels vary between 15m and 105 metres below ground level. Permeability of the aquifers is seen to decrease with depth. In view of the sharp decline in water levels in recent years, it is more reasonable to base stored reserve calculations on a conservative 10m - 20m saturated thickness, as was used for the above mentioned CAM study.

The estimated sustainable yield (CAM: Phase 1 Report) of the four dolomitic aquifers (AREA I - IV), totals 14.6Mm³/a. Seeger (1990) however gives a qualified, sustainable yield for the carbonate aquifers of only 10Mm³. These two figures are of the same order of magnitude and serve to illustrate that the Karst area should not be considered an infinite source of groundwater.

4.4 RECHARGE OF AQUIFERS

When meteoric water (from rain) infiltrates the ground and percolates down to the saturated zone, to be added to the groundwater, recharge is said to take place. Recharge may be measured as a response of the water table to the addition of water, in millimetres, or the amount of water added to the saturated zone. Assessments of recharge from runoff are greatly dependent on the availability of accurate hydrological data.

In some places, studies have been conducted to establish the processes involved so that sustainable use of aquifers may be achieved. Methods used have included the analysis of isotopes and detailed monitoring of rainfall, run-off and water level response.

4.4.1 ALLUVIAL AQUIFERS

Recharge to alluvial aquifers is provided primarily by flow in ephemeral river channels with a minor contribution from direct infiltration of rainfall. Studies of recharge after runoff have shown that the relationship is seldom a simple one. Annual recharge is not directly proportional to annual runoff for a particular alluvial system. It has been observed that the silt-load left behind by previous runoff events may effectively seal off the underlying alluvium from infiltration. The intensity of individual runoff events has
been seen to play an important role in breaking up this seal and promoting infiltration. High intensity runoff events do not necessarily imply high rainfall years.

After the 1997 floods in the Kuiseb River, recharge to the lower Kuiseb Aquifers resulted in a water level rise of between 0.41m and 2.23m corresponding to approximately 15Mm³ and 5.6Mm³ for the upstream and downstream aquifers respectively.

4.4.2 FRACTURE AQUIFERS

A succession of very good rainfall seasons, i.e. significantly above the mean annual rainfall, is required to recharge an aquifer system measurably. In some parts of an aquifer the water level may react faster to rainfall than in other parts because of the time needed for the infiltrating water to be distributed evenly through the fracture system. Recharge to fractured aquifers may also depend on runoff events in ephemeral rivers where these crosscut fracture aquifer systems (e.g. dykes or fault zones).

![Figure 4.9: Average Change in Water Level in the Otjiwarongo Marble Aquifer (1990-1998)](image)

Data Source: Quarterly Report for April - June 1998 on Status of Major Aquifers and Aquifer management Tasks; Namwater, Geohydrology

Significant ground water recharge to the Otjiwarongo Marble aquifer was from inflow into and seepage from Omatjenné Dam during the 1997/1998 rainy season. This earth dam overlies the marble outcrops of the Omatjenné- Otjiwarongo compartment of the Otjiwarongo Marble Aquifer. An average water level rise of 18m was recorded for the
Figure 4.10: Water Level Monitoring Records for Selected Boreholes in Karst Areas I and II

Data Source: Namwater, Geohydrology

Figure 4.11: Water Level Monitoring Records for Selected Boreholes in Karst Areas III and IV

Data Source: Namwater, Geohydrology
Omatjenne-Otjiwarongo compartment corresponding to a volume of 3.6Mm³ of recharge water. Apart from the recharge from the Omatjenne Dam (Figure 4.9) no significant recharge of ground water from rainfall occurred for the period April 1990- January 1998 (Seimons, 1998).

Saturated Kalahari sediments may also contribute to recharge of underlying fracture-hosted aquifers.

A general figure of 2.5% of annual rainfall recharging fracture aquifers, where soil cover is thin, is found to be appropriate for general use. It was found that recharge is higher where soil cover is thin and decreases with increasing surface cover, as would be expected.

4.4.3 KALAHARI AQUIFERS

Where the rest water level in a phreatic Kalahari aquifer is deeper than 20m it is felt that little, if any, direct recharge from rainfall will take place due to the very fine grain size and correspondingly low permeability of the sediment. Comparing Figures 4.1 and 4.2, an idea is gained of the average rest water level in Kalahari aquifers. From this it is seen that much of the Kalahari has a water rest level of greater than 20m. Consequently it is interpreted that substantial recharge must therefore originate from fracture aquifers in bedrock with which the Kalahari comes into contact. This recharge is slow, possibly taking several hundred years for water to move 100km (Interconsult, 1996).

4.4.4 KARST AQUIFERS

Groundwater recharge to the aquifers underlying the Otavi Mountain Land is dependent on rainfall (intensity, frequency, and duration).

The mean annual rainfall for meteorological stations covering the Karstland, are tabulated below:

Table 4.7: Mean Annual Rainfall for Selected Stations in the Karstland

<table>
<thead>
<tr>
<th>Station</th>
<th>Mean Annual Rainfall (mm)</th>
<th>Good rainfall sequence 1973/74-1977/78(mm/a)</th>
<th>Poor rainfall sequence 1978/79-1996/97(mm/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grootfontein</td>
<td>552</td>
<td>764</td>
<td>481</td>
</tr>
<tr>
<td>Tsumeb</td>
<td>516</td>
<td>No reliable data</td>
<td>448</td>
</tr>
<tr>
<td>Otavi</td>
<td>530</td>
<td>648</td>
<td>459</td>
</tr>
<tr>
<td>Otirukakako</td>
<td>558</td>
<td>852</td>
<td>511</td>
</tr>
<tr>
<td>Toggenburg</td>
<td>596</td>
<td>842</td>
<td>564</td>
</tr>
</tbody>
</table>
Since 1978, when the last effective recharge was recorded, there has been a steady decline in groundwater levels in the Karst land, which is attributed to a period of lower than average rainfall and not to abstraction. Short lived recoveries of the water level are noted in the records for monitoring boreholes following single 'good' rainy seasons such as 1988/89 and 1993/94 as illustrated in Figures 4.10 and 4.11.

Currently large-scale abstraction from the Karst aquifers is carried out at three places, namely:

- The two Berg Aukas boreholes (WW24857, WW21853) which supply water to the Otjituuo area, some 50km east of Grootfontein. Annual production is of the order of 1Mm³.
- Dewatering activities of the Kombat mine, which produce between 4Mm³/a and 5Mm³/a, is distributed via the ENWC and pipelines to the Okakarara area.
- Grootfontein municipality with an annual abstraction of some 3Mm³.

In the past, large-scale abstraction from production boreholes WW25949, WW26664 also took place in the Brandwag area. These boreholes “dried up” in 1992 when the water level reached the pump inlet depth. Boreholes were drilled to 31m and 37.3m respectively. According to the BGR report, the influence of abstraction from farming activities (livestock and domestic), on the regional decline of water level is negligible (Schmidt, 1998).

Recharge conditions for the Otavi Mountain Land as given in the BGR report are as follows:

- 2% recharge of the mean annual rainfall – sequence of above normal rainfall years (as for the 1973/74–1977/78)
- 1% recharge of the mean annual rainfall – single rainy season above mean annual rainfall (1988/89;1993/94)
- 0% recharge of the mean annual rainfall – annual rainfall below the long-term average.

For the past twenty years, annual rainfall has remained below the mean and the regional long-term sustainable recharge to the Karstic aquifers has been zero. Abstraction without any significant regional recharge to the system will result in groundwater mining with serious implications for the environment. Through-flow from the Karst aquifers is considered to be a significant recharge source for the Kalahari aquifers. If a continued decline in water levels occurs in the Karst aquifers this would have a gradual but long-term effect on adjacent Kalahari aquifers. More locally the continued decline in the Karst aquifer would manifest itself in water levels dropping to below the reach of existing boreholes, springs ceasing to flow and the dying out of several species of deep rooted trees.
4.4.5 ARTIFICIAL ENHANCEMENT OF RECHARGE

Artificial recharge through injection boreholes, or settling basins, has become a satisfactory method for recharging the groundwater system using either treated surface runoff or wastewater. Aquifers can thus be used as environments where surplus water can be added, stored and redistributed. Artificial recharge water should be chemically compatible with the existing groundwater composition and the storage strata.

Windhoek
In times of drought the dams supplying Windhoek with freshwater dry up or are severely depleted. The resulting shortfall in water supply has been made up by heavy abstraction from the Windhoek Aquifer system. A series of below average rainfall years may therefore lead to the abstraction of large quantities of groundwater from the aquifer at an unsustainable rate over a relatively short time, with long-term negative effects on the groundwater source. Artificial recharge is presently being tested in an attempt to replenish the Windhoek groundwater resources, which have been heavily pumped over the past few years.

For this artificial recharge test, Windhoek municipality purchases purified surface water (from von Bach Dam) from NamWater. The application of artificial recharge through one injection well started on 12 August 1998. Water is pumped into the aquifer system at constant rate of 60m³/h for approximately 24hrs/day. On site, the purchased water is passed through a column of activated carbon, and chlorinated before entering the borehole. This artificial-recharge experiment is supervised and will be evaluated by the CSIR from South Africa.

Omdel Dam
As early as 1984, the DWA was involved in research into answering the question of why recharge to alluvial aquifers after significant flood events was often very much less than expected. The conclusion reached was that a very fine layer of silty material on the surface of the riverbed impeded water penetration. This certainly occurs in the Omaruru River, and as a result, prior to the construction of the Omdel Dam, large quantities of floodwater would pass over the riverbed into the sea without significantly contributing to recharge. The existing Omaruru Delta has a very large storage capacity with a natural average recharge of 3,5Mm³ per year. In 1987 when the proposal to build the Omdel recharge enhancement dam was tabled, more than double this, 8,5Mm³ per year was being abstracted, clearly a situation which could not continue indefinitely. The proposed project, completed in 1994, was to allow the temporary storage of ephemeral floodwaters in a large reservoir upstream of the aquifer thus ensuring the settling out of the fine suspended sediment. The clean water would then be released in a controlled manner and allowed to infiltrate into the aquifer. A high rate of infiltration
would be ensured due to the absence of silt. The aim would be to transfer the entire contents of the reservoir into the aquifer during the dry season, so that if there were a second good rainy season, there would be available storage space in the reservoir. Figure 4.12 shows a conceptual layout of the scheme as it was built.

Since being commissioned, the Omdel dam has not received major inflows. However, the water released from the lesser flood events which had been stored, has resulted in an immediate rise in the ground water table. The possibility of using the same approach on other westward flowing rivers has been examined (Creser) and could be viable. One drawback, however, of all other sites is the relatively small aquifer storage downstream of the selected dam sites.

Figure 4.12: Conceptual Layout of the Omdel Recharge Enhancement Scheme
In order to ensure that ephemeral river flows are free from silt, and hence to improve infiltration rates and recharge of the aquifer, the floodwaters are trapped in the large Omdel storage dam for several weeks. Once the water is clear it is released over “spreading grounds” where recharge happens quickly.

4.5 WATER CHEMISTRY

For practical reasons the approved National Guidelines for Drinking Water have been divided into three basic groups of determinants, namely:

- Determinants with aesthetic or physical implications,
- Inorganic determinants,
- Bacteriological determinants.

The concentration of and limits for the aesthetic, physical and inorganic determinants define the group into which water will be classified as follows:
• GROUP A: Water with an excellent quality
• GROUP B: Water with good quality
• GROUP C: Water with low health risk
• GROUP D: Water with a higher health risk (water unsuitable for human consumption)

For human consumption, water should ideally be of excellent quality (Group A) or good quality (Group B), however, in practice many of the determinants may fall outside the limits for these groups in the water used. Water classified as having a low health risk (Group C) or high health risk (Group D) is considered unfit for human consumption. Since the limits are defined on the basis of average lifelong consumption, short-term exposure to determinants exceeding their limits is not necessarily critical, except where extremely toxic substances are present.

The group limits and criteria used for inorganic constituents are tabulated below.

Table 4.8: Guidelines for the evaluation of drinking water for human consumption with regard to chemical, physical and bacteriological quality (mg/l, except conductivity: mS/m and pH: dimensionless).

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Group A Excellent</th>
<th>Group B Good</th>
<th>Group C Low Risk</th>
<th>Group D High Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca (as CaCO₃)</td>
<td>&lt; 375</td>
<td>500</td>
<td>1000</td>
<td>&gt; 1000</td>
</tr>
<tr>
<td>Cl</td>
<td>&lt; 250</td>
<td>600</td>
<td>1200</td>
<td>&gt; 1200</td>
</tr>
<tr>
<td>Conductivity</td>
<td>&lt; 150</td>
<td>300</td>
<td>400</td>
<td>&gt; 400</td>
</tr>
<tr>
<td>F</td>
<td>&lt; 1.5</td>
<td>2</td>
<td>3</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>K</td>
<td>&lt; 200</td>
<td>400</td>
<td>800</td>
<td>&gt; 800</td>
</tr>
<tr>
<td>Mg (as CaCO₃)</td>
<td>&lt; 290</td>
<td>420</td>
<td>840</td>
<td>&gt; 840</td>
</tr>
<tr>
<td>Na</td>
<td>&lt; 100</td>
<td>400</td>
<td>800</td>
<td>&gt; 800</td>
</tr>
<tr>
<td>NO₃ (as N)</td>
<td>&lt; 10</td>
<td>20</td>
<td>40</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>pH</td>
<td>6 - 9</td>
<td>5.5 - 6 or 9 - 9.5</td>
<td>4 - 5.5 or 9.5 - 11</td>
<td>&lt; 4 or &gt; 11</td>
</tr>
<tr>
<td>SO₄</td>
<td>&lt; 200</td>
<td>600</td>
<td>1200</td>
<td>&gt; 1200</td>
</tr>
<tr>
<td>TDS</td>
<td>&lt; 1500</td>
<td>2000</td>
<td>3000</td>
<td>&gt; 3000</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>&lt; 300</td>
<td>650</td>
<td>1300</td>
<td>&gt; 1300</td>
</tr>
</tbody>
</table>
Table 4.9: Information Concerning Hydrochemical Determinants
(in respect of Human Consumption):

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Guideline values for calcium are based on taste and household considerations. High calcium concentrations cause scaling problems and excessive soap consumption.</td>
</tr>
<tr>
<td>Chloride</td>
<td>Guideline values for chloride are based on taste considerations. High concentrations give rise to corrosion of metals.</td>
</tr>
<tr>
<td>Colour</td>
<td>Colour in water is generally due to organic compounds together with colloidal iron and/or manganese.</td>
</tr>
<tr>
<td>Conductivity</td>
<td>Conductivity is a function of the total dissolved solids in the water. A conductivity of 300mS/m corresponds to approximately 2 000mg/l total dissolved solids.</td>
</tr>
<tr>
<td>Fluoride</td>
<td>Protracted intake of water with fluoride concentration greater than 2.0mg/l F causes mottling of teeth and from 3 – 6mg/l F skeletal fluorosis can occur.</td>
</tr>
<tr>
<td>Iron</td>
<td>High Iron concentration in water is aesthetically undesirable, gives rise to discoloration, staining and taste problems.</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Magnesium concentrations greater than 420mg/l give rise to an unpleasant taste. Magnesium, in association with sulphate, may have laxative properties, but the human body can adapt to this effect in time.</td>
</tr>
<tr>
<td>Manganese</td>
<td>Colour/staining problems can arise when manganese concentrations exceed 0.05mg/l.</td>
</tr>
<tr>
<td>Nitrate</td>
<td>Water with more than 20mg/l nitrate/nitrite as N, can cause methaemoglobinaemia in babies under 1 year old. The water is non-toxic for older age groups.</td>
</tr>
<tr>
<td>pH</td>
<td>Low levels may cause severe corrosion of metals in the distribution system. High pH levels cause a progressive decrease in the efficiency of the chlorine disinfection process.</td>
</tr>
<tr>
<td>Potassium</td>
<td>Potassium concentrations exceeding 340mg/l give the water an unpleasant taste. High concentrations may also have a laxative effect.</td>
</tr>
<tr>
<td>Sodium</td>
<td>Guideline values for sodium are based on taste considerations. High sodium levels can cause high blood pressure.</td>
</tr>
<tr>
<td>Sulphate</td>
<td>Guideline values for sulphate are based on taste considerations. Water containing high concentrations of sulphate can have a laxative effect, which is enhanced when consumed in combination with magnesium. Metal corrosion and degradation of concrete and asbestos cement may be increased by high sulphate level.</td>
</tr>
<tr>
<td>Total Hardness</td>
<td>Guideline values for total hardness are based on taste and household considerations. Depending on the calcium and magnesium salt combination, high levels can cause scaling. In addition, hard water results in excessive soap consumption and subsequent scum formation.</td>
</tr>
<tr>
<td>Turbidity</td>
<td>If turbidity is the only determinant causing a C or D classification of the water, there is no reason for grave concern as this can be remedied by treating the water. Turbidity affects aesthetic quality of water. The amount of chlorine required for disinfection increases as the turbidity increases.</td>
</tr>
</tbody>
</table>

A series of maps have been plotted (Figures 4.13 - 4.16) using data from the groundwater database maintained by the Department of Water Affairs Geohydrology and Water and Environment Divisions. These plots show the distribution of TDS, F, SO₄, and NO₃ (as N) on a national scale. Consideration was given to generating contoured plots with the data but, as it is not always wise to infer across areas for which no data is available, it was decided to use a coloured symbol indicating the group classification of each determinant in water from each borehole. The result is a map of Namibia showing a coloured dot at the location of each borehole from which an analysis
is present on the database. The legend indicates the group and concentration limits for
the determinant plotted.

Water chemistry relates to residence time as well as to the composition of the material
that the groundwater passes through during infiltration and through-flow. In the river
environment surface deposits of readily soluble material may also be taken into solution
during flow and thus be introduced to the groundwater environment. In a coastal
environment sea water commonly extends into aquifers inland. Due to the higher
density of sea water compared with fresh groundwater originating from inland, an
interface is formed with fresh water overlying saline. This interface is usually a wedge,
which may move sea- or landwards depending on the flow of fresh water to the sea.
Intensive abstraction of fresh water from coastal aquifers may encourage the wedge to
move inland. This phenomenon, known as salt-water intrusion, is a constant threat to
coastal alluvial aquifers.

Where permeability is very low, groundwater moves very slowly through the formation
and as a result the residence time may be long. Groundwater will slowly dissolve salts
from the host formations and, given sufficient time, the dissolved salts may become
concentrated to the extent that the water becomes saline and unpotable. Northwest of
the Etosha Pan extending to the Cuvelai, the sediments are very fine, containing
appreciable amounts of silt and clay. In this environment the groundwater is virtually
motionless, which, combined with the intrinsically high salt content of the formation,
has resulted in exceedingly high salinity of the groundwater.

A large body of alluvial material lies to the immediate north of the Omdel aquifer. It is
interpreted that the ancestral Omaruru River deposited this alluvial material. After the
Omaruru River abandoned its former course, insignificant recharge has resulted in an
increase in groundwater salinity in the alluvial aquifer of the palaeochannel. Abstraction
from the Omdel aquifer must therefore also take cognisance of the potential for
saltwater intrusion from this source as well as from the ocean.

Variations in total dissolved solids (TDS) concentrations across Namibia are shown in
Figure 4.13. High TDS concentrations in parts of the Stampriet Artesian Basin are the
result of very saline water hosted by the overlying shale layers. Many shale layers were
initially deposited in a saltwater regime and solutes have been retained in the pore
spaces, attached to the clay minerals. The shale layers are porous but do not transmit
water easily (i.e. they have low permeability) and water is retained for a long time. The
very wide lateral exposure of the shale layers to the more permeable overlying and
underlying sandstone horizons of the Auob and Nossob, may result in significant
movement of water and solutes from the shale layers into the intercalated aquifers.
Excessive abstraction of groundwater from the sandstone aquifers may lead to a change in the hydrostatic pressure in the aquifers, increasing the contribution from the shale layers and resulting in an overall increase in TDS. A general increase in TDS values is noted towards the southeastern corner of the basin (an area called the "Salt block") which is probably the result of insignificant recharge.

High salinity (TDS) groundwater is also found in other areas but these are often limited in extent and a borehole with saline water can be as little as 10km from an adjacent borehole with fresh water, where both are abstracting from essentially the same geological formation.

The high fluoride concentrations (Figure 4.14) of Class C and D (above 2mg/l) may be the result of groundwater circulation through igneous and sedimentary rocks containing the mineral fluorite (CaF₂). Metamorphic rock, containing amphiboles such as hornblende and some mica, may also contain appreciable fluorine. Apatite commonly holds fluoride and occurs as an accessory mineral in many metamorphic and igneous rocks or as the main constituent of phosphate rock (Hem, 1985). Too much fluoride can harm teeth; causing mottling of tooth enamel which may become brittle. The effects of excessive fluoride intake are particularly visible in children while their permanent teeth are still forming. Ultimately skeletal fluorosis can occur.

High concentrations of sulphate in groundwater are normally related to the oxidation of pyrite and/or of evaporite minerals, CaSO₄ and CaSO₄.2H₂O. In some areas of Namibia this has also been attributed to the proximity of dolerite intrusions, where the dolerite is deeply weathered. Bacterial activity might give increased concentrations of SO₄. Concentrations above 600mg/l (Class C) have a laxative effect on most consumers. Sulphate concentrations above 250mg/l make water aggressive (corrosive) particularly towards asbestos-cement or cement-concrete pipes. Figure 4.15 shows the variation in SO₄ concentrations in groundwater across the country.

Nitrate is the most toxic element commonly present in the ground water of Namibia (Figure 4.16), causing infant mortalities at certain concentration levels. Higher levels cause animal deaths. According to Driscoll (1986), nitrate does not normally originate from minerals in the aquifer but from sources such as certain plants (legumes) which transfer nitrogen to the soil; leaching of decomposing plant material; human and animal waste and nitrate fertilisers to the ground water source. Hoad (1990) suggests that elevated nitrate concentrations originate from the Nama Group sediments. Indeed the widespread incidence of boreholes with high nitrate seen surrounding the Stampilartesian Aquifer is unlikely to be the result of pollution and most probably has its origin in the host Nama sediments or Karoo coals.

Nitrate concentration of Class B standard (> 10mg/l as N or 44mg/l as NO₃) in water may cause fatal blood disorder called methaemoglobinemia ("blue-baby-syndrome") to
Figure 4.13: Distribution of Total Dissolved Solids (TDS) in Groundwater

TDS concentrations give a useful indication of overall salinity of the groundwater and the distribution map highlights certain regions where this may be a problem. Numerous isolated occurrences of high TDS are shown but these may be due to very localised phenomena.

Data Source: DWA Groundwater Database and Hydrochemistry Division Database
Figure 4.14: Distribution of Fluoride (F) in Groundwater

An elevated level of fluoride in groundwater has health implications and it is therefore useful to know the regional distribution of this ion. High fluoride content is commonly associated with specific aquifer host-rock types, such as granite.

Data Source: DWA Groundwater Database and Hydrochemistry Division Database
Figure 4.15: Distribution of Sulphate (SO₄) in Groundwater

An elevated level of sulphate in groundwater has health implications and it is therefore useful to know the regional distribution of this ion. High sulphate content is commonly associated with specific aquifer host-rock types, such as dolerite but may also be the result of pollution.

Data Source: DWA Groundwater Database and Hydrochemistry Division Database
Figure 4.16: Distribution of Nitrate (NO₃) in Groundwater

An elevated level of nitrate in groundwater has health implications and it is therefore useful to know the regional distribution of this ion. High nitrate content is commonly associated with pollution but may be associated with certain rock types such as some Nama Group sediments.

Data Source: DWA Groundwater Database and Hydrochemistry Division Database
infants during their first six months of life. When pregnant women consume water with high nitrate levels it may affect the foetus, causing raised methaemoglobin levels and truncated growth. Nitrate is normally non-toxic to adults, but concentrations in excess of 100mg/l (as N) may cause mucous membrane irritation. Concentrations of 100mg/l (as N) or 440mg/l as NO3 can be fatal to cattle and sheep. Lost milk production and aborted calves are signs of nitrate poisoning.

Groundwater sources supplying Maltahöhe with water have concentrations of nitrate exceeding 20mg/l (as N). This water is abstracted from faults in the Nama Group quartzites and although nitrate is a widespread component of these sediments it is suspected that a significant contribution originates from effluent leaking from the town’s sewage oxidation plant.

In dolomite and marble host rocks, the hardness or the total calcium and magnesium content control the quality of groundwater. In dolomitic aquifers the magnesium values are high, while high calcium content is associated with marble aquifers. Normally waters from these types of aquifers are classified as Class B. Extreme scaling of pipes may occur where the total hardness exceeds 100mg/l (as CaCO3).

4.6 ESTIMATION OF POTENTIAL POLLUTANTS

Groundwater contamination has not been given significant attention until recently, most people in the groundwater industry not realising the extent of pollution and its negative impact on groundwater resources.

Most contaminants (soluble or insoluble) enter aquifers because of inadequate waste disposal practices. Once contamination has occurred in an aquifer it may take a long time, hundreds of years, to clean effectively because the natural decay of pollutants is so slow. It is thus important that all parties involved (scientists, municipalities, town councils, ministries, and others) become involved and aware, so that effective control, monitoring and removal of groundwater pollution hazards can take place.

Pollution potential of groundwater is dependent on the following variables:

- Nature of surface soil – sorption capacity
- Gradient of ground surface
- Characteristics of the underlying fractured or porous formation
- Depth to water table
- Water table gradient
- Thickness of the saturated formation
- Hydraulic conductivity of the aquifer
- Distance to an ephemeral river or flood water
- Distance from a pollution source
- Nature and concentrations of pollutant
All these parameters must be considered in the management, construction or expansion of a wellfield.

Common sources of pollution include but are not limited to the following:
- Oxidation plants
- Overflow from oxidation ponds
- Septic tanks
- Pit latrines
- Graveyards
- Cattle/sheep/goat/poultry yards
- Manure storage piles
- Abattoirs (blood and fat)
- Tanneries and taxidermists
- Municipality waste dumps/landfills
- Industrial waste dumps
- Mine tailings, ore processing plants and other mine effluent disposal
- Buried fuel storage tanks
- Agricultural chemicals
- Pest control

Domestic contaminants include all waterborne waste products of human and animal origin, which may render water unsuitable for human purposes.

Sewage contamination adds nitrate and chloride to groundwater, the latter commonly being the first indication of sewage contamination. High nitrate and chloride concentrations are positive indicators of sewage seepage while "kraal pollution" is indicated by nitrate contamination alone.

Raw domestic sewage disposed or leached into an open system such as the Okavango and Zambezi Rivers may render the water unfit for human consumption, destroy water plants and animals and enrich problem plant populations due to the introduction of nutrients such as phosphates and nitrogen present in the effluent.

Three production boreholes, situated SW of Aroab, were taken out of operation in the early 1980s, due to the pollution by fuel from a nearby petrol storage tank. Drinking water with very low concentrations of petroleum is unpotable. At that stage these boreholes supplied 90m^3/day, or 31% of the daily water demand of the town. Water samples of these boreholes were taken and analysed again in 1989 but the water was still polluted with petroleum and unfit for domestic use. To date, these boreholes are still not in operation and it is assumed that the contamination problem persists.

According to the Department of Water Affairs, 90% of all oxidation plants under control of line ministries (Environment and Tourism, Regional and Local Government and
Housing, and Works, Transport and Communication) are neglected. Along the Okavango River, 70% of all oxidation ponds and septic tanks are in a bad state of repair.

The type of mining practice and the nature of the minerals produced determines the nature of mine effluent. Toxic chemicals such as cyanide and arsenic, used in metal extraction processes, are fatal to man and animals. Fine mine dust deposits may destroy or damage vegetation or may be taken up by run-off and enter surface and groundwater reservoirs. Sulphuric acid water, derived from processing pyrite ore, leached from slimes dams, or sulphur acid used in Uranium production may pollute surface and groundwater sources. Pollution hazard occurs at all mines in Namibia and will hopefully be reduced with impending new legislation (the soon to be promulgated – Environmental Management Act, and an update of the existing Water Act of 1956).

Negligence in renewing wastewater and effluent disposal exemption permits and repairing damaged sewage dam walls and pumps, and unchecked overflows from oxidation ponds dumped on unprotected ground, can cause long-term groundwater pollution with serious health and environmental implications.

4.7 LINKS BETWEEN GROUNDWATER AND SURFACE WATER

As mentioned in Section 4.4.4. groundwater recharge is estimated at 0-2% of the annual rainfall. The thickness and nature of the overburden controls the volume of water that will be added to the groundwater system. The thicker the soil cover and the more clay present the smaller the recharge from rainfall and vice versa.

Recharge from surface water may improve the quality of the groundwater, depending on:

- The amount of surface water added to the groundwater source
- Chemical composition of the ground formation through which the recharge-water is moving.

Conversely, recharge from surface water originating from polluted sources may tend to cause deterioration of groundwater quality.
4.8 SUPPORT OF THE BIOPHYSICAL, SOCIAL AND ECONOMIC ENVIRONMENT

Water levels in alluvial aquifers are generally shallow; less than 10m, and therefore readily accessible to the roots of trees which abound in certain areas. Depression of water levels over protracted periods, due to drought or abstraction, may result in irreversible damage to such vegetation (Ward and Breen, 1983).

Where rock barriers effectively dam up through flow of the groundwater in a body of alluvium, water may be forced to emerge at the surface where ponding may result. Such ponds may persist long after flooding has occurred in the main river channels or may dry up due to reduced through flow. Nevertheless, these ponds are an important source of water for humans and wildlife in some areas. Prolonged drought periods and upstream abstraction may however, cause premature depletion of ponds, which will threaten the livelihood of those who are dependent on the source for survival.

Alluvial aquifers are of fundamental importance to development along the arid Namibian coastline. All ports and towns (with the exception of Oranjemund) along the Namibian coastline depend solely on groundwater from alluvial sources. The economic significance of these aquifers is therefore great and their sustainable use in future years will continue to be of strategic importance.

Treated surface and wastewater can be stored underground in a suitable groundwater system (e.g. sand dams). During peak-demand periods the recharge water can provide adequate water supplies for domestic, agricultural and industrial use at reasonable costs.

This method of recharging aquifers with treated waste and surface water still requires thorough investigation. The application of injection wells in all water-short areas may be the answer to a competent way of providing enough and affordable water to all users.

4.9 OVERVIEW, GUIDELINES AND INDICATORS

4.9.1 RELEVANCE TO THE WATER SECTOR

With most of the country devoid of perennial surface water sources Namibia, relies heavily on groundwater to sustain life. Although, in terms of population numbers it may be said that groundwater supplies approximately two thirds of the national water requirements, in terms of area this is clearly not so. With the exception of those living along the banks of perennial rivers or with access to piped water, most rural
communities are dependent on groundwater. A significant proportion of the country is engaged in pastoral farming and for this the reliance on groundwater is significant.

Very little economic development is possible without securing a water supply capable of sustaining it. In this regard many small mines and other industries have had no other option than establishing a sustainable groundwater supply source for their operations. Most commercial farms are reliant on groundwater for stockwatering and several large irrigation projects use groundwater as their main source of water.

Groundwater in alluvial bodies, perched aquifers, diverse shallow environments and springs is clearly a very important natural resource. The sustainable use and protection of this fundamental resource has clear environmental, economic and social relevance and should be seen as vital to present and future generations in Namibia.

4.9.2 ASSESSMENT AND EVALUATION OF THE SITUATION IN NAMIBIA

In Namibia, groundwater is owned by the State. The Geohydrological Division is the state institution charged with management and control of the resources of the country with respect to abstraction.

Recently, with the formation of NamWater, the former bulk water supply function of the Department of Water Affairs has been removed from direct Government control and management. Bulk water supply has thus gone from public (State) provision to commercial commodity. Bulk abstraction of groundwater will now be managed by a commercially driven organisation. The Department of Water Affairs will retain some responsibility for rural water supply from boreholes and bulk water distribution systems, but this too is gradually being handed over to local water point committees and other regional institutions. Should this process reach its logical conclusion the Groundwater Division at the Department of Water Affairs will have a greatly reduced day to day involvement in water supply activities.

A Groundwater Database is currently maintained by the Department of Water Affairs. This database, whilst providing a good summary of borehole data on a national or regional scale needs systematic checking to improve the overall quality and provide for updating in certain relevant fields. At present, provision is made for monitoring water levels but other fields also need to be updated periodically.

An initiative recently started, is to develop another national groundwater database – the GROWAS project. This project will be a joint Department of Water Affairs – NamWater venture but the overall responsibilities and functions of the two institutions are not clear.
At present there are datasets pertaining to hydrochemistry and waterpoint surveys from regional studies which relate to boreholes but which have not been linked to the Groundwater Database. (This project is the first attempt at linking these disparate datasets to produce comprehensive national coverages of various parameters). It is sincerely hoped that the proposed GROWAS project will address this situation effectively and make data freely available in a useful format.

Abstraction and water level data from NamWater are, as a matter of course, being provided regularly to the Department of Water Affairs for databasing as the ultimate regulation of resource management lies with them. This forms part of the permit conditions.

The initiative started, post independence, of conducting regional investigations which involved waterpoint surveys should be continued until all the communal farming areas have been covered. A different approach should be sought for commercial farms but their boreholes should also be covered at some next stage. This will provide a reliable indication of the water consumed from groundwater sources daily, and give some indication of resource estimates.

4.9.3 CONSIDERATIONS FOR SUSTAINABILITY

Groundwater, although periodically replenished from rainfall, must be considered a finite resource. Wise management and control of this resource is therefore imperative to sustaining the environment and socio-economy of Namibia now and for future generations. This should include:

- management of the volumes abstracted from different aquifers,
- effective legislation regarding water use and pollution,
- control of pollution hazards,
- enhancement of recharge,
- regulation of future groundwater development,
- training in groundwater,
- maintaining effective monitoring networks,
- in depth understanding of the principles and processes involved in groundwater movement, storage and recharge,
- recognition and protection of seeps, springs and geothermal springs in important wetlands (habitats for often endemic aquatic organisms).

4.9.4 EVALUATION OF POSSIBLE INDICATORS

In physical terms the health of the groundwater sector is best described in terms of:

- the volume of water stored and accessible for use;
- the quality of that water in terms of natural chemical composition and in terms of pollutants;
- the amount of recharge which is needed to replace water abstracted or lost through natural processes from aquifers;
- biodiversity in springs and seeps;
- ecological sustainability.

A number of indicators are potentially suitable for monitoring the health of the groundwater sector, as tabulated below.

Table 4.10: Potential Indicators for Monitoring the Health of the Groundwater Sector

<table>
<thead>
<tr>
<th>Definition of Indicator</th>
<th>Data collection and calculation</th>
<th>Uses of indicator</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Ambient Ground Water Quality: changes in natural water chemistry reflect the composition of recharge waters</td>
<td>Regular sampling at sentinel sites</td>
<td>Early warning that an aquifer is becoming saline will make it possible to act in time to prevent ‘loss’ of the resource</td>
<td>Saline intrusion into coastal aquifers is a major threat that must be averted.</td>
</tr>
<tr>
<td>Pollution of Ground Water Resources: pollution, largely anthropogenic, may render groundwater resources unusable</td>
<td>Regular sampling at sentinel sites</td>
<td>Detection of the slightest indication of pollution will make it possible to introduce early mitigations</td>
<td>Pollution of aquifers is a major threat that must be averted and control of potential pollution sources is therefore vital.</td>
</tr>
<tr>
<td>Aquifer Depletion: natural processes and abstraction can lead to the depletion of stored groundwater reserves which will limit the usefulness of an aquifer</td>
<td>Monitoring of stored volumes and abstraction rates</td>
<td>Knowledge of the sustainability of a resource will facilitate the early securing of alternative sources for consumers, or their relocation</td>
<td>Aquifer depletion may occur gradually, over a few decades, and therefore not be detected. If the trend is constantly monitored then this should alert the relevant authorities in time to take appropriate mitigatory action.</td>
</tr>
<tr>
<td>Aquifer Recharge: the amount of water added to an aquifer replacing water previously removed</td>
<td>Measurement of recovery of water levels after rainy season in sentinel locations annually</td>
<td>If recharge volumes are known then these can be used to manage sustainable annual abstraction</td>
<td>Detailed knowledge of aquifers is needed to determine recharge volumes. Unfortunately this is not the case in many non-strategic aquifers and as a basis for management recharge volume can only be used in a limited number of cases.</td>
</tr>
<tr>
<td>Water Levels in Strategic Aquifers:</td>
<td>Measurement of water levels in strategic aquifers</td>
<td>Prediction of shortfalls in supply from strategic aquifers will enable early counter measures to be taken</td>
<td>NamWater closely monitors the volumes of water available for abstraction in strategic aquifers as part of their aquifer management function.</td>
</tr>
</tbody>
</table>
4.9.5 KEY INDICATORS

From an evaluation of the potential indicators given above, a number of key indicators are identified to monitor the health of the groundwater environment in Namibia. These are as follows:

- Pollution of groundwater;
- Water levels measured in non-strategic, regional aquifers;
- Months of adequate abstraction.

4.9.5.1 Pollution of groundwater

Until recently there has been little emphasis on the monitoring and control of pollution of aquifers even though it appeared in the Water Act of 1956. The subject is addressed in the soon to be promulgated Environmental Management Act prepared in draft form by the Ministry of Environment and Tourism.

As stated in section 4.6, pollution monitoring has not been routinely carried out nor controlled until recently and, as a result, there is no baseline data against which to identify trends. It is therefore recommended that more boreholes are identified or drilled for monitoring pollution in certain areas where Pollution of groundwater is considered a real threat, like the ones around the Kombat, Karibib and Rössing mines. Aquifers in this category and which must be monitored include:

- Windhoek aquifer which is under threat from domestic and industrial pollution and the Kupferberg landfill site;
- Between Windhoek and Okahandja, tanneries and taxidermists have for some time disposed of their effluent in a manner that threatens groundwater resources downstream;
- Maltahöhe is apparently threatened by the town sewerage works;
- At Tsumeb, the smelter and mine have emitted toxic and noxious dust, gasses and readily soluble salts over a long period which must have influenced the surrounding environment.

It is recommended that more suitable monitoring sites be selected and that a programme of routine sampling and analysis be carried out. The location of monitoring sites and the determinants to be monitored still need to be identified.

4.9.5.2 Routine monitoring of water levels in the non-strategic, regional aquifers

To date no routine monitoring of water levels in the non-strategic, regional aquifers is conducted. It is proposed that sentinel boreholes are identified in certain aquifers and that these be monitored biannually and be reported on in the planned State of the Environment Report to be presented annually to Cabinet. Aquifers considered important for this purpose include:

- Kalahari aquifer (sentinel boreholes in Caprivi, Omusati, Kavango and Omaheke);
• Fracture aquifer (sentinel boreholes north and west of Gam, west of Opuwo, Kamanjab, Kalkveld, Ovitoto, Ariamsvlei and Tses);
• Alluvial aquifers (sentinel boreholes at Sesfontein, Otjimbingwe);
• Karst and associated fracture aquifers (sentinel boreholes Opuwo and Khorixas-Fransfontein area).

Sentinel boreholes should be situated far from any operating borehole or surface impoundment (that may be leaking) so that the measurements made can be a true reflection of the natural state. It is recommended that a limited field study be carried out to establish sites suitable for this programme. In areas where no existing borehole meets with the requirements set for monitoring, the drilling of a new borehole may be necessary.

4.9.5.3 Months of adequate abstraction in strategic aquifers

The existing monitoring and management practise employed by NamWater will provide the data needed for this indicator. A formal agreement should therefore be entered into between the Ministry of Agriculture, Water and Rural Development and NamWater to ensure that the data are made available for incorporation into the proposed State of Environment reporting procedure.

It is proposed that the calculated ‘months of adequate abstraction’ be monitored and quoted in the reporting as this will relate to changes in the security of supply from each of the aquifers over time.

4.9.5.4 Monitoring of ambient changes in water quality

Groundwater salinity changes may result from a number of causes including excessive abstraction or reduced recharge. Increases in salinity may occur gradually resulting in the groundwater becoming too saline for human consumption. When this occurs, remedial action is costly, slow and not always successful and the use of the aquifer may be lost.

It is proposed that water samples be taken from selected production boreholes in strategic aquifers (Rooibank, Omdel, Windhoek, Tsumeb karst aquifer and Koichab Pan) at the end of the dry season each year (prior to any annual recharge events). This will show the levels of highest salinity reached annually and provide an indication of trends that may be emerging.
REFERENCES


Joint Venture Consultants 1993. CES - Consulting Engineers Salzgitter, Germany. LCE - Lund Consulting Engineers, Windhoek, Namibia


5. WATER SUPPLY AND DEMAND

5.1 INTRODUCTION

Until the turn of the century, water supply and water demand in Namibia were in balance. People settled where water was found on or near the surface throughout the year and moved their livestock between places where water was temporarily available. Since then people have learned to transport water from place to place, to dam ephemeral rivers and to tap groundwater to support domestic, agricultural and industrial activities. Increasingly, water resources were exploited to promote development throughout Namibia, wherever people decided to settle. Often the sites originally selected for settlement were places where water was naturally available, but growing populations of people and livestock, urbanization and increased industrial activities necessitated supplementing the available supplies.

As a result of growing demand, the authorities sought to increase the supply of water where and when it was required. Only late in the century did people begin to recognise that water is the primary limiting factor to development in Namibia and that water supply cannot continue to be expanded indefinitely to meet every imagined demand. The result has been a number of innovative approaches to management of water supply with the ultimate goal of increasing the available supply. More recently, water engineers in Windhoek have been involved in the development of a water demand management system in an attempt to balance the continually increasing demand for water against the limited supplies available.

5.2 WATER SUPPLY

Water supply implies the provision of water in sufficient quantity and of an appropriate quality to meet the requirements of people, their livestock and their associated activities.

A water supply and sanitation policy (WASP) for Namibia was approved in 1993. In terms of this policy, affordable water supply and sanitation services should be made available to all Namibians in order to improve public health and hygiene, reduce the burden of collecting water, promote community based social development, support basic needs for subsistence and promote economic development. Beneficiaries should contribute towards the cost of services at increasing rates for standards of living exceeding the levels required for providing basic needs.

According to the WASP:

- all Namibians should have access to water at a cost the country can afford
- water supply should be managed on good business principles
- private sector and support organisations should be encouraged to participate in the water sector
- there should be community involvement and acceptance of mutual responsibility in decision making and
• use of the country's water resources should respect the principles of environmentally, economically, and socially sustainable development.

In Namibia, water supply is distinguished as:

a) bulk water supply to distributors such as municipalities and other local authorities as well as bulk consumers such as mines and irrigation farming complexes
b) water distribution by second level operators such as the municipalities, local authorities, the Directorate of Rural Water Supply and other bulk consumers mentioned in a) above
c) Private water consumers such as farmers, mine owners and tour operators who develop water supply systems for their own use only.

Namibia has reached the limits of easily accessible water sources and improved management of water supply is becoming a first priority.

Recognising that water resources in Namibia are scarce, the Water Sector and Sanitation Policy (WASP, 1993) stipulates the following priority ranking to the allocation of water where there are competing demands:

First priority: Water for domestic purposes and for livestock watering, for both subsistence and commercial farming

Second priority: Water for economic activities such as mining, industries and irrigation. Priorities for these activities will in each individual case have to be determined by the benefits derived in relation to the overall development objectives and plans for the country.

5.2.1 PRIMARY WATER SOURCES

In Namibia, the primary sources of water supply are perennial rivers, surface and groundwater storage on ephemeral rivers, and groundwater aquifers in various parent rocks. In addition, however, a variety of alternative approaches are being used or have been proposed to augment and enhance water supply. These innovative approaches are dependent on appropriate management of existing supplies, and range from conjunctive use of water sources, the artificial recharge of ground water reserves and the reuse of water, to harvesting of rain and fog water and managing water demand.

A primary source of water, which is a step in the natural water cycle and is located either on the surface or below ground, is termed a Water Resource, and can be defined as a natural source or occurrence of water which is not artificially confined, e.g. river, spring, aquifer.

These contrast with a Water Source that depends on appropriate management for augmentation of the supply and which can be defined as requiring a man made structure to supply water from a Water Resource, e.g. river offtake, dam, borehole, well.

A major problem in the distribution of water in the country is the fact that the major demand centres are located long distances from the primary water sources. This has great bearing on the cost of water supply in Namibia. As an example, the potential of the perennial rivers is huge compared to the sustainable yield from the other sources.
The biggest water demand centre, which is Windhoek and the central area of Namibia, is, however, far removed from any of these rivers and the transfer of water to this area can only be done at great cost. The largest proportion of the rural population in Namibia is concentrated in the north of the country where people do live near perennial rivers. The distribution of water from these sources to the widely spread rural communities, however, results in a high cost of supply.

Although the potential of supply from the perennial rivers is great, the abstraction of water from these sources is subject to negotiation with other basin states. The long term Namibian requirement from the perennial rivers is estimated to be 600Mm³/a.

Figure 5.1 illustrates the current consumption from the different natural resources.

![WATER USE FROM NATURAL RESOURCE](image)

**Figure 5.1**: Current consumption of water from natural resources countrywide

### 5.2.1.1 Groundwater

Groundwater sources supply 51% of Namibia’s current water consumption. Water is abstracted from different types of aquifer as described in Chapter 4 of the report. The major aquifers from which water is abstracted are the following:

- Grootfontein Karst aquifers
- Tsumeb aquifers
- Otjiwarongo marble aquifers
- Omaruru delta alluvial aquifer
- Kuiseb alluvial aquifer
- Windhoek wellfield
- Koichab pan aquifer

The stored reserves and abstraction from these aquifers are given in Table 5.1 below.

**Table 5.1**: Stored reserves and abstraction from major aquifers

<table>
<thead>
<tr>
<th>AQUIFER</th>
<th>STORED RESERVE Mm³</th>
<th>ABSTRACTION Mm³/a</th>
<th>CONSUMER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grootfontein (karst)</td>
<td>1 162</td>
<td>n/a²</td>
<td>Grootfontein, ENWC</td>
</tr>
</tbody>
</table>

1. n/a: Not applicable
2. ENWC: Environment and Natural Resources Commission
5.2.1.2 Perennial rivers

The only perennial rivers available to Namibia are the Kunene, the Okavango, the Kwando-Linyanti-Chobe and the Zambezi on the northern border and the Orange on the southern border. This water must be shared with other basin states and the equitable and beneficial allocation of these international water sources is subject to agreement between the basin states.

5.2.1.3 Ephemeral Rivers

Namibia is an arid country. All the rivers that have their source in the interior of the country are ephemeral. Due to the erratic rainfall conditions, the flow in the ephemeral rivers is irregular and unreliable. The potential of the surface water sources is therefore limited. Various strategies have been implemented to increase the available resources as set out below.

5.2.1.4 Dams

One of the most obvious strategies for increasing the water available from ephemeral rivers is the construction of water retaining structures such as dams. These are discussed in the following paragraphs.

Table 5.2 below lists the dams constructed on ephemeral rivers together with their capacities, mean annual run-offs and 95% assured yields.

Table 5.2: Dams constructed on ephemeral rivers

<table>
<thead>
<tr>
<th>DAM</th>
<th>CAPACITY</th>
<th>MEAN ANNUAL RUN-OFF</th>
<th>95% ASSURED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mm³</td>
<td>Mm³/a</td>
<td>Mm³/a</td>
</tr>
<tr>
<td>Von Bach</td>
<td>47.5</td>
<td>18.27</td>
<td>8.26</td>
</tr>
<tr>
<td>Swakoppoort</td>
<td>67.1</td>
<td>22.14²</td>
<td>7.42</td>
</tr>
<tr>
<td>Omatako</td>
<td>40.7</td>
<td>35.06</td>
<td>4.70</td>
</tr>
<tr>
<td>Hardap</td>
<td>300.2</td>
<td>188.36</td>
<td>50.00</td>
</tr>
<tr>
<td>Oanob</td>
<td>34.1</td>
<td>10.13</td>
<td>4.88</td>
</tr>
<tr>
<td>Neule</td>
<td>83.6</td>
<td>74.01</td>
<td>12.00</td>
</tr>
<tr>
<td>Otjivero</td>
<td>17.4</td>
<td>8.45</td>
<td>1.24</td>
</tr>
<tr>
<td>Omdel</td>
<td>42.0</td>
<td></td>
<td>5.20</td>
</tr>
</tbody>
</table>
Figure 5.2: Assured Yield from Major Storage Dams

Figure 5.2 shows the yield (at 95% assurance level) for Namibia's main storage dams. The yields do not take account of conjunctive use operations which would increase the yield. It is interesting to note how small the yields are in comparison with the sizes of the dams. The 95% assured yield of Namibia's largest dam, Hardap, is only 50Mm³/annum despite a capacity of nearly 300Mm³. Even the yield of the Von Bach Dam, one of Namibia's most efficient with respect to evaporation losses, is barely 10% of its capacity.

Source: Hydrology Division, DWA.
Central Area Dams
The Central Area Dams which supply water to Windhoek, Okahandja, Karibib and other smaller consumers in the central area of the country are the Von Bach, Swakoppoort and Omatako dams. The supply from these dams is operated as a single system in conjunction with the local sources of the Municipality of Windhoek, which are the Windhoek wellfield, the Goreangab dam and the water reclamation works. Because it is possible to draw from these sources conjunctively, it has been possible to increase the available supply from these sources to more than the sum of their individual assured yields. The conjunctive use schemes will be discussed in detail in paragraph 5.2.3 below.

The Eastern Dams
The Eastern Dams which are the Otjivero Main Dam, the Otjivero Silt Trap Dam, the Daan Viljoen Dam and the Tilda Viljoen Dam all supply water to Gobabis together with a number of borehole schemes. This combined system is also operated as a conjunctive use scheme, which will be discussed later in the report.

Oanob Dam

![Consumption and Potential Supply from Oanob Dam](image)

Current Consumption = 1.9 Mm³/a

Supply Potential = 4.9 Mm³/a (including ecological reserve)

Figure 5.3: Consumption and potential supply from Oanob Dam

The Oanob Dam supplies water to Rehoboth. The 95% assured yield of the dam is 4.9 Mm³/a while the current consumption for domestic purposes is 1.9 Mm³/a. An important forest of camel thorn trees exists downstream of the Oanob Dam, which was fed by flow in the Oanob River. Except in years of exceptional rainfall when the dam spills, this natural forest will be cut off from its source of water. It has been decided in
principle to release 1.6Mm$^3$/a of water from the dam for environmental purposes. The effective 95% assured yield from the Oanob Dam is thus 3.5Mm$^3$/a.

**Hardap Dam**
The Hardap Dam supplies domestic water to Mariental town as well as domestic and irrigation water to the Hardap irrigation scheme. The current consumption is 30.9Mm$^3$/a while the 95% assured yield is 50Mm$^3$/a.

![Consumption and Potential Supply from Hardap Dam](image)

Figure 5.4: Consumption and potential supply from Hardap Dam
Naute Dam
The Naute Dam supports an irrigation project downstream of the dam and also supplies domestic water to Keetmanshoop. The 95% assured yield of the dam is 12.0Mm³/a and the current consumption is 5.0Mm³/a.

![Consumption and Potential Supply from Oanob Dam](image)

*Figure 5.5: Consumption and potential supply from Naute Dam*

Friedenau Dam
The Friedenau Dam was constructed in the late sixties to supply water to the Matchless Mine. The mine has since closed down and water from the dam is now used to supply farmers in the vicinity with water for stock drinking. Consideration has been given to connecting the Friedenau Dam to the Windhoek supply system. However, because of the relatively small 95% assured yield of 0.82Mm³/a and the long pipeline distance of approximately 50km, no firm decision has been taken yet to exercise this option.

Omdel Dam
The Omdel Dam was constructed on the Omaruru River upstream of the river mouth. This dam was constructed solely to augment the ground water reserves found in the alluvial aquifer formed by the palaeo channels of the Omaruru River delta. Water is pumped from this aquifer to supply consumers along the central west coast. Inflow into the Omdel Dam is allowed to stand for a sufficient length of time for the silt and other suspended solids to settle out. The clear water is decanted from the surface and fed, under controlled conditions, into the alluvial aquifer to increase the yield from the borehole scheme. In this way the maximum yield of the dam is utilized. This artificial recharge scheme is discussed in more detail in section 5.2.7.

Dreihuk Dam
The Dreihuk Dam was constructed on the Hom River near Karasburg in the late seventies to supply water to Karasburg town. However, inflow in the period since the dam was completed has been negligible and water is seldom available for supply to Karasburg. Revised calculations of the assured yield of the dam have now estimated this figure to be zero.
Goreangab Dam
Recently there has been considerable urban development in the catchment of the Goreangab Dam, which is constructed on the Gammans River. As a result, the water in the dam has been polluted to the point where it is no longer possible to treat it in a conventional water treatment plant to potable water standards. Water from the dam is therefore treated at Windhoek’s water reclamation plant which treats effluent from the conventional sewage treatment plants to a standard where the water can be recycled into the domestic supply system. The capacity of the current water reclamation plant is too small to treat all the current sewage treatment plant effluent as well as the water available from the Goreangab Dam. The full yield of the dam is therefore not currently utilized. The Windhoek Municipality is, however, currently engaged in increasing the capacity of the current water reclamation plant from 3.65Mm$^3$/a to 7.7Mm$^3$/a by the construction of a new plant.

5.2.2 CONJUNCTIVE USE AND ASSURANCE OF SUPPLY

Conjunctive use of water in Namibia is aimed at reducing evaporative losses of water from the surface of open dams. Surface water, which evaporates quickly, is used first and groundwater, which does not evaporate, can be reserved for use when surface water is not available. This management approach was developed in the mid 70’s and is applied in Namibia wherever water from large surface dams on ephemeral rivers is supplemented by water from groundwater aquifers (Heyns et al. 1998).

An example of the implementation of the strategy is the system for water supply to Windhoek.

5.2.2.1 Conjunctive use for supply to Windhoek

Windhoek obtains its water supply from the following sources:

- local boreholes
- the Goreangab dam on the outskirts of the town
- a water reclamation plant
- the re-use of purified sewage effluent for parks, sports fields and gardens
- three major state dams – Von Bach, Swakoppoort and Omakato Dams located 70, 110 and 180km distant from the city
- links to a ground water source 400km north of Windhoek.

Future plans for the expansion of the conjunctive use principle include the possible construction of a pipeline which will link the Eastern National Water Carrier at Grootfontein with the Okavango River, 250km to the north.

By operating these varied water sources on an integrated basis, the assured safe yield of the combined sources can be significantly increased and the total available supply can amount to more than the sum of the individual safe yields from the sources separately. The dams, which continually lose water to evaporation, can therefore be more effectively used in this way. Each dam has a ratio of surface area to stored volume. It follows, therefore, that the dam with smallest surface area to stored volume ratio will lose relatively less water to evaporation. Thus if the dams can be operated conjunctively and water is transferred between dams such that there is always the

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smallest surface area to stored volume ratio within the system, evaporation will be reduced and the system yield will be increased. The system efficiency can be increased even further by taking surface water and storing it in confined ground water compartments as is currently being done in the Windhoek aquifer.

The comparison of potential evaporation from the three central dams provided in Table 5.3 below illustrates the different losses from evaporation for each of the dams.

Table 5.3: Comparison of potential evaporation from the three central dams at full supply level

<table>
<thead>
<tr>
<th>DAM</th>
<th>EVAPORATION Mm³/a</th>
<th>RATIO: Area / Volume¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>von Bach</td>
<td>9</td>
<td>0.11</td>
</tr>
<tr>
<td>Swakoppoort</td>
<td>17</td>
<td>0.12</td>
</tr>
<tr>
<td>Omatako</td>
<td>23</td>
<td>0.31</td>
</tr>
</tbody>
</table>

¹Surface area at full supply capacity (km²) divided by Active (or abstractable) storage capacity (Mm³)

During 1997, the production of water from the three major dams was 15.7Mm³ while the loss from evaporation was 35.5Mm³. It is estimated that up to one third of this evaporative loss could be prevented by using the reservoirs to artificially recharge the underground aquifer as part of the conjunctive use management programme (van der Merwe 1998).

For the three dams supplying Windhoek it has been estimated that the yield from the conjunctive use of the three-dam system can increase the yield of the system by 44% above that of the individual yields of the dams calculated in isolation.

Table 5.4 below illustrates the benefits that can be achieved by operating the system in an integrated way.

Table 5.4: Comparison of yields for integrated system operation: ¹From DWA Report – August 1986

<table>
<thead>
<tr>
<th></th>
<th>Combined 3 dams</th>
<th>Sum: 3 dams in Isolation</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% Assured yield (Mm³/a)</td>
<td>19.7</td>
<td>13.7</td>
</tr>
</tbody>
</table>

Within the current system there is no one component which can be regarded as an assured source, as all the sources are reliant on variable rainfall for their recharge. However, if the Okavango River, with its assured supply, is introduced as a component of the system, the other sources can be utilised at a higher yield (but lower individual assurance), thus increasing the yield from the individual sources. Operated together with the Okavango River, the three central dams can supply a long-term safe yield which is 2.3 times greater than the sum of the yields calculated for the individual dams.

5.2.2.2 Conjunctive use for supply to Gobabis

Gobabis is supplied with water from the two Otjivero dams on the White Nossob River, the Daan and Tida Viljoen Dams on the Black Nossob River and boreholes which abstract water from two different aquifers. The surface water storage is operated along
the same principles as the three central dams supplying Windhoek, namely that water is transferred using operating rules which ensure the least amount of evaporation for the greatest volume of water in storage. Although the Tilda Viljoen Dam, which is an off-the-river storage dam, does not contribute any run-off, it plays an important part in this system. It is used as emergency storage at Gobabis for water transferred from the Otjivero dam. It is also used to store water impounded by the Daan Viljoen Dam, which has a relatively small capacity with high losses.

The yield from the Otjivero Dams (excluding Daan Viljoen) is estimated at 1.24Mm³/a while the current consumption from these sources is 0.55Mm³/a.

5.2.3 UNCONVENTIONAL SOURCES

Conventional sources of water include surface water collected in dams, groundwater and water abstracted from the perennial border rivers. Unconventional water sources refer to water supplied through means other than the traditional supply augmentation. Examples are:

- re-use of water
- water reclamation
- artificial groundwater recharge
- fog harvesting
- rain harvesting.

The increasing cost of conventional bulk water supply investments has led to the search for more attractive and practical unconventional sources of additional water supplies. Technological advancements have also been very important in making alternative investments more appealing. This is particularly the case when considering the reclamation of waste water. Furthermore, the environmental and political costs associated with conventional water sources, e.g. the Okavango River, have also emphasised the need for alternative sources of water.

Lastly, the inexorable move towards more realistic full financial cost pricing of water will make recycling and re-use of water more viable for private agents such as domestic consumers, manufacturing and agriculture.

There are different types of water re-use. They are addressed as follows.

5.2.3.1 Indirect Water Re-use

Treated wastewater released into the environment for downstream use can be considered as indirect re-use of water. This use has important connotations for both economic activities and the maintenance of environmental stream-flow requirements in regions of water scarcity.

In Namibia the re-use of water through the release of water into watercourses is limited. This is mainly because of the lack of water treatment facilities in most urban centres outside Windhoek, and the huge losses of water that occur through evaporation in Namibia as a whole. In addition, the ephemeral nature of Namibia's inland rivers reduces the assimilative capacity of these watercourses. In most places wastewater is routed to evaporation ponds rather than treated for re-use. In Windhoek, however, some effluent is discharged into the ephemeral watercourses after being purified (van der Merwe, 1998).
5.2.3.2 Direct Water Re-use

Direct water re-use refers to the on-site treatment of wastewater and the distribution thereof for consumption. This can be done on a private basis, within homes or factories financed individually, or on a centralized basis. The wastewater can be treated to different degrees of quality depending upon the intended use. Lower quality treated waste water can be used for watering public parks, private gardens etc., but high quality potable water is required for domestic consumption.

Figure 5.6 shows the flows of water supply and the level of re-use of water in Windhoek.
Figure 5.6. The Re-use of Water in Windhoek
5.2.3.3 On-site Re-use of Industrial Effluent

It has become economically viable for certain industries in Windhoek and elsewhere to invest in the on-site re-use of effluent. For example, Namibia Breweries had a dual pipe system incorporated in the design of the factory. This system allows the use of wash water from the sand filters for cleaning purposes. This brewery has various other water saving devices contained in their integrated approach to water management. The specific consumption of water is 4 litres of water for each litre of beer. This compares with between 5.5 and 8.5 in South Africa and between 5 and 7 in Europe.

The meat companies in Windhoek are looking into the possibility of re-using their own effluent on site for cleaning purposes. Furthermore the Zero Emissions Research Initiative (ZERI) is being investigated by a number of different companies. This initiative endeavors to re-use wastes of all types for productive, value adding processes.

5.2.3.4 On-site Re-use of Domestic Effluent

Water that has been used for washing and cleaning is termed grey water. Sixty percent of the total effluent flow in Windhoek can be classified as grey water, which if re-used, could reduce clean water consumption by up to 30%. Grey water can be used to flush toilets and water gardens for instance.

It is estimated that as much as 35% of total water consumption in high income areas in Windhoek is used for gardens. It is also estimated that, in conjunction with rain water harvesting, a 50% saving of water could be achieved in these areas.

5.2.3.5 Re-use Through a Dual Pipe System

A dual pipe system allows the supply of two different types of water within a distribution network. One pipe system can be used to supply fresh potable water whilst the other can be used to supply lower quality or semi-purified water. The water is used for different purposes depending on the quality of the water supplied. The cost of the water will vary according to the quality, allowing consumers to make savings with respect to their water consumption pattern, whilst water supply agencies can save on costs through reduced demand for high quality potable water.

In 1997, a total of 1.14Mm³ of water was used for the irrigation of sports fields, parks, cemetery gardens and nurseries in Windhoek. This water was supplied through a second pipe system used for the transport of semi-purified water.

Installing a dual pipe system to every domestic consumer would be an expensive operation. However considerable cost and water savings are made as a result of the existing dual pipe system for irrigation in Windhoek. It has been estimated that the water supplied in this manner for irrigation in Windhoek is 60% cheaper than potable water and 23% cheaper then the bulk water supply tariff paid to NamWater (van der Merwe, 1997). Dual pipe systems also exist in Walvis Bay, Otjiwarongo, Swakopmund, and Tsumeb.

5.2.3.6 Reclamation of Wastewater for Direct Potable Use

Water reclamation for direct potable re-use is practised when water is reclaimed and blended with good quality water from other sources.
In Windhoek the reclamation of sewerage effluent for potable water use was pioneered in 1968. The system in Windhoek has been upgraded several times since then and now can supply a maximum of 3.65Mm$^3$/a, or approximately 20% of the total demand of Windhoek. The cost of this water is estimated to be in the order of N$2.35/m$^3$, which compares favourably to the bulk water tariff of N$3.17/m$^3.

The Windhoek water reclamation project is based on the premise that successful reclamation can only be achieved when three equally important elements are controlled:

- diversion of industrial and other potentially toxic wastewater from the main wastewater stream
- wastewater treatment to produce an effluent of adequate and consistent quality and,
- proper effluent treatment to produce acceptable potable water.

These three requirements are controlled by systematic regulation of water pre-treatment quality and the use of a series of multiple chlorination and maturation pond phases to remove pathogens.

The capacity of the plant is to be extended and the projected cost of this water is N$2.50/m$^3. The capacity is expected to increase to 7.7Mm$^3$/a. This will represent a useful and relatively cheap source of water to the city of Windhoek which is expected to be on line by the year 2000.

The use of reclaimed water for artificial groundwater recharge is also being considered as discussed in section 5.2.3.10.

5.2.3.7 Desalination

The sea is a potential source of water in Namibia, however, the high mineral content must be reduced to make it potable. Similarly, there are a number of saline underground aquifers located in Namibia that could be desalinated and used for domestic supply. Two desalination techniques are available:

- reverse osmosis by use of membrane technology. Although considerable water recovery is possible the technique requires a large amount of energy and the technology is not accessible on a small scale. A further problem is the life of the membranes when used for enzyme-rich waters.

- distillation by use of heat, evaporation and condensation. This technique can be used at the household level using solar energy.

Distillation can also be done using compression, evaporation and condensation. This approach is not easily accomplished on a small scale.

Constraints on desalination include the high capital costs of the plant, the cost of energy to drive the process and operating costs. The sea off the west coast of Namibia, the source of water, has a high organic and nutrient content from the Benguela Current and requires pre-treatment of the intake water. Furthermore, the increasing point pollution by the Walvis Bay harbour, despite the dilution, may also hinder the effectiveness of desalination (DWA). Some saline groundwater sources can be distilled with very simple apparatus, producing several litres per day, suitable for an individual
household or small village. As the supply of potable water diminishes in relation to increasing population and concomitant demand in Namibia, desalination will increase in importance. This process may provide the main coastal water supply in the future (Heyns et al 1998).

The important coastal towns of Walvis Bay and Swakopmund are located in the central west coast area of Namibia. Also situated here is the Rössing Uranium Mine, which is economically very important to the country. This area currently obtains its water from the alluvial aquifers of the Omaruru and Kuiseb rivers. These two sources have a limited sustainable yield and in particular the lower Kuiseb River supports a great deal of woody vegetation, which is dependent on ground water from the aquifer to survive. For many years now concern has been expressed about the dangers of over abstraction from these aquifers and the declining water table in the area. NamWater has conducted a feasibility study for the desalination of seawater which, if introduced, will establish a sustainable water supply to the west coast area as it will supplement the sustainable yield of the current ground water reserves.

The feasibility study referred to recommended the implementation of a seawater desalination scheme. The decision to implement the project has been made and tenderers for a turnkey project have been pre-qualified.

Desalination is a long term source of supply. However, the process is expensive, the main demand centre of Windhoek is far away and water will have to be pumped to a great height, requiring huge amounts of energy. Desalination of sea water is thus not considered as a feasible alternative for Windhoek for the present.

5.2.3.8 Fog Harvesting

Fog water harvesting is used in Chile to support towns of several hundred people. With a similar climate but differing topography, fog could be considered as a supplementary water source for households situated on Namibia's coast. Experimenting with standard fog collectors to evaluate the potential for fog water collection along the Kuiseb valley in the central Namib, a maximum of 14.5P/m² screen/fog event and an annual mean of 3.5P/m² screen/fog event have been recorded (Henschel et al 1998). Furthermore, fog water production is currently being evaluated using screens of 48m² at two villages situated at differing distances inland from the coast.

5.2.3.9 Water Harvesting

Water harvesting techniques, which are of particular interest to arid and semi-arid climates, include four broad categories:

- rain water harvesting
- runoff water harvesting
- flood water harvesting
- subsurface water harvesting.

These are all discussed in further detail below and special attention has been paid to rainwater harvesting which is relevant to Namibia.
Rain water harvesting
Rain water harvesting refers to the process by which rainfall is harvested almost immediately after falling. Because Namibia’s water usually falls in intense bursts during a short season, rainwater harvesting is not commonly used. The main technique for rainwater harvesting is roof catchment. The rainfall is collected from gutter downpipes into a storage tank. Major limitations of using roof runoff water are cost, the capacity of storage tanks and the necessity of storing the water safely for later use. Rain water harvesting is used all over the world, including Namibia, although not as often as might have been expected.

Rainwater harvesting has been used in Namibia for most of the current century, although there are no data of the amount of water it contributes to the overall supply or to the water used by individual households. The storage capacity of domestic tanks is usually in the range of 1m³ or less and households may have up to four storage tanks per plot. Most roof runoff water is used for ornamental gardens in urban areas. A study carried out by DWA (1996) investigated the potential for subsidizing rain harvesting from roof catchments in Namibia with special reference to the Windhoek Urban Area.

Potentially available rainwater can be calculated by multiplying the rainfall depth by the horizontally projected roof area and by a runoff coefficient (approximately 0.8). For an average size dwelling in Windhoek this corresponds to just under 30 cubic metres per year, although this is often considered optimistic because it assumes that there is sufficient storage for the total amount. Another problem is that even if sufficient storage can be made available for the average rainfall year it is not normally possible to cater for all rain falling in above average years. Clearly the long-term rainfall volume caught will be reduced. The conclusion reached in the 1996 study was that a 100 square metre roof would only have a reliable yield of 8.7m³ per year, and not nearly 30m³.

The feasibility of rain harvesting in financial terms has been shown to be low. Assuming the best case scenarios, and that galvanized rainwater tanks are purchased on interest-free loans, the unit cost per cubic metre (N$//cubic metre) would be N$18.74 for northern Namibia, N$19.12 for Central Namibia and N$31.23 in the South. Clearly large subsidies would be required to make the installation of large tanks worthwhile. The conclusion reached for Windhoek was that the unit cost of water would be far higher than envisaged for alternative sources such as the upgrading of the Windhoek reclamation works, and that subsidization of households to buy storage tanks could not be justified.

While this is true, rainwater harvesting techniques in areas where other water supplies are not available, or where the distances to existing supply sources are far, means that the installation of water tanks may be viable.

Runoff water harvesting
This can be seen in two main categories, runoff harvesting for short-term storage or “runoff farming” and long-term storage. Runoff farming refers to the process of constructing bunds, ditches, loops and micro-catchments in order to trap and/or divert runoff for short periods and to use for arable farming. The details of these practices are more related to agriculture and are therefore not discussed in detail here.
Long-term storage techniques are often used for stock water or irrigation, and while none of these techniques are used in Namibia they are worthy of consideration under appropriate conditions:

**Rock catchments**

This technique uses naturally occurring, exposed and almost impermeable rock surfaces for the collection of rainwater. Rainwater falling on these surfaces is channeled by low walls and captured at the lowest point and drained into a reservoir. Examples of this system can be found in Kenya, and the idea has been investigated in Namibia (Webster) where the bare granite monoliths in the western desert areas could be suitable sites.

**Ground catchments**

In this approach, large areas of ground are bush-cleared and the ground compacted to achieve an appropriate degree of impermeability. If necessary, a network of channels can be used to deliver the runoff to a reservoir. Such catchments have been used successfully in Australia, Lesotho and Somalia and could be investigated for Namibia.

**Djabaas**

This is the Kenyan name for the structures which prevail on the islands and along the coast of Kenya, and also on some Greek Islands including Corfu. The principle simply involves building an impermeable surface (usually out of concrete) on a suitably shaped piece of ground and collecting the water in a (usually) covered reservoir. These are not used in Namibia but bear consideration.

**Flood water harvesting**

Flood water harvesting can also be seen in terms of short and long-term storage. Short-term storage methods are used mainly for the irrigation of crops, and are not really used in Namibia. Long-term storage refers to the conventional storage of flood water in dams as already discussed in Section 3.4.

**Subsurface water harvesting**

There are two main types of subsurface water harvesting. They are:

- **Sub-surface Dams**
  These are sub-surface vertical dams, which are built down to bedrock in alluvial aquifers, and subsequently trap sub-surface flow in the aquifer. This technique has been used successfully in Tanzania, Kenya and Morocco and could represent a useful approach to be followed in Namibia.

- **Sand Storage Dams**
  The first sand storage dams were built in Namibia in the first half of the twentieth century and have sometimes been quite successful. The idea is to build a low dam wall across the ephemeral stream with the intention of checking the flow of sand-laden water. With the reduction of flow velocity, the sand particles are deposited behind the wall while the fines are transported further downstream. As the level of the "sand reservoir" rises so also is the wall raised periodically until a large reservoir of sand, free from fines is built up. Although the volume of water stored is much less (often 80% less) than in
a conventional surface water dam because water can only be stored in the spaces between the sand particles, evaporation losses are minimal.

Sand-filled dams are immune to silting, a further advantage over open storage dams which have particularly short lives in arid regions. A number of successful sand storage dams have been built in Namibia, especially in the central area. A recent study carried out by DWA (concluded 1992) on a proposed sand storage dam on the Okatemb River in the Kunene Region concluded that the stored volume of sand would have to be very large (2 500 000m³) to supply the required volume of water, and that it would take 100 years to raise the wall to the required height. Notwithstanding this conclusion, it would appear that sand-storage dams could be useful in Namibia. The viability of a sand storage dam can be increased when used in conjunction with an alluvial aquifer or when sited over a preferential recharge area such as a marble band. Figure 5.7 illustrates a typical sand storage dam built over a preferential recharge zone.

![Diagram of sand storage dam](image)

**Figure 5.7 : Typical Example of a Sand-storage Dam**

*The successful construction of a sand storage dam unfortunately takes many years, since successive heightening of the wall happens only as the dam fills up with sand. While the water can only be stored in the spaces between the sand grains, evaporation losses are very small and the dam is immune to silting up. Sand-storage dams may be particularly suited to the situation when the user needs to withdraw relatively small quantities from an ephemeral river with a large catchment. In this case the dams can be built up quite quickly.*

*Source: Water Storage in Sand-filled Dams by H. B. Saubermann; 1966*
5.2.3.10 Artificial Groundwater Recharge

Artificial recharge is an important part of Namibia’s approach to water management. The Omdel dam on the lower Omururu River has already been discussed in Chapter 4 from the technical point of view.

It is used to increase the natural recharge to the Omdel aquifer from which water is pumped out to supply Henties Bay, Swakopmund, Arandis and the Rössing Uranium Mine, thus contributing significantly to water supply on Namibia’s west coast. Construction of this dam and associated infrastructure was only completed in 1993 and the dam has received only small inflows since then. Nevertheless recharge to the aquifer has been up to expectations.

More recently, water engineers of Windhoek have initiated artificial recharge of the secondary fractured rock aquifer serving the town. It is estimated that the underground storage capacity of the Windhoek Aquifer is in the order of 15 – 25Mm³ and that a minimum annual recharge at a rate of 6 – 10Mm³ will be possible. This would augment the natural recharge rate of five years, observed after high abstraction during periods of drought. In 1998, 100 000m³ of water supplied by NamWater was treated through Granular Activated Carbon and injected into a production borehole over a period of 2 months. To date, no negative effects have been detected, while some of the surrounding boreholes are recovering at four times their natural recovery rate (van der Merwe 1998). A similar approach could be used to store excess reclaimed water.

5.2.3.11 Summary

The use of unconventional sources of water such as those outlined above has certain advantages over the conventional supply augmentation strategies. Firstly, in the case of Windhoek, it can be seen that the water that currently comes from the reclamation plant can be supplied at lower cost than that supplied by the bulk water supplier. The re-use of water in semi-purified form, for gardens and for public sports fields and cemeteries can reduce the demands for potable water for a given area. In general the semi-purified water is cheaper to supply than the potable water, although questions remain as to the economic viability of dual pipe systems for each and every domestic consumer.

The re-use of water in this way has allowed the consumption of conventional surface and groundwater sources to remain at 1987 levels in 1997, despite the population having almost doubled. Total consumption has remained approximately constant at 1989 levels.

Furthermore, the re-use of water will reduce the demands upon the conventional sources of water, i.e. surface water collected in dams, abstraction directly from the border perennial rivers and abstraction from groundwater resources. This will mean that the environmental and political costs associated with the abstraction of water from these conventional sources will be reduced in the short-term. It is possible that the extended re-use of water may preclude the need for further supply augmentation should the overall demands for water be stable over time. At the very least it will be possible to achieve the same benefits that water supply affords to consumers from a smaller amount of water abstracted from these conventional sources. In the long-term this makes economic sense and, if we consider the controversy surrounding the proposed Okavango River abstraction, it could also make political sense.
5.3 WATER DEMANDS

Having discussed water sources and resources, this section addresses the current water use patterns, i.e. who is using water and from where it is supplied. Water use or water consumption is defined as the actual quantity of water consumed by a consumer or at a Water Demand Centre (WDC).

Water demand, on the other hand, is the quantity of water required to meet the needs of a WDC or other consumer. In economics, water demand is considered strictly as a price quantity relationship. If either the yield from a Water Resource, or the supply capacity of the Water Infrastructure cannot meet the Water Demand, water consumption will be less than the demand.

Businesses, industrial enterprises, institutions, public offices and residential consumers all share available water. In Walvis Bay 51% of water supplied is used for residential purposes while for Windhoek and Otjiwarongo the figures are 65% and 77% respectively. In general, less than 1% of water supplied to a town with full water reticulation and water borne sewage is used for drinking and cooking. About half of the water goes to gardens, food processing such as beer, soft drinks, meat and fish, manufacturing products and the building and construction industries.

5.3.1 CURRENT WATER DEMAND BY SECTOR

In an arid country such as Namibia where water is scarce and water resources costly to develop, it is important to prioritize the use of water by the various sectors of the economy. This prioritization cannot only consider the economic outputs of each sector per m³ of water consumed, but also has to consider the basic needs of humans and stock as well as take into account numerous socio-economic aspects. As previously mentioned, the first priority is water for domestic purposes and livestock watering for both subsistence and commercial farming. The second priority is water for economic activities such as mining, industries and irrigation. Priorities for these activities will in each individual case have to be determined by their respective value in relation to the overall development objectives and plans for the country.

Table 5.5: Water consumption by sector (1996)

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>WATER CONSUMED PER ANNUM</th>
<th>% OF TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban – all inclusive</td>
<td>67.9</td>
<td>24.2</td>
</tr>
<tr>
<td>Rural domestic</td>
<td>13.1</td>
<td>4.7</td>
</tr>
<tr>
<td>Wildlife and Tourism</td>
<td>0.7</td>
<td>0.25</td>
</tr>
<tr>
<td>Mines</td>
<td>20.0</td>
<td>7.1</td>
</tr>
<tr>
<td>Livestock</td>
<td>42.2</td>
<td>15.0</td>
</tr>
<tr>
<td>Irrigation</td>
<td>137.0</td>
<td>48.75</td>
</tr>
<tr>
<td>TOTAL</td>
<td>280.9</td>
<td>100</td>
</tr>
</tbody>
</table>
5.3.1.1 Urban Water Usage

Urban residential water usage varies from one income group to another. Water is considered by economists to be a "normal" good with a positive income elasticity of demand, i.e. the demand for water increases with income. This relationship has been observed in Windhoek where the income elasticity of demand has been calculated to be 0.83. This means that with every 100% increase in income, water demand increases by 83%\(^1\). Table 5.6 shows how per capita usage varies from one income group to another in Windhoek.

Table 5.6: Water consumption pattern of Windhoek (1996/97)

<table>
<thead>
<tr>
<th>CONSUMPTION GROUP</th>
<th>POPULATION</th>
<th>UNIT CONSUMPTION l/c/d</th>
<th>WATER CONSUMPTION Mm(^3)/a</th>
</tr>
</thead>
<tbody>
<tr>
<td>Squatters</td>
<td>35 250</td>
<td>20</td>
<td>0.26</td>
</tr>
<tr>
<td>Low income</td>
<td>85 590</td>
<td>80</td>
<td>2.88</td>
</tr>
<tr>
<td>Middle income</td>
<td>58 400</td>
<td>140</td>
<td>3.09</td>
</tr>
<tr>
<td>High income</td>
<td>17 650</td>
<td>309</td>
<td>2.09</td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
<td></td>
<td>3.35</td>
</tr>
<tr>
<td>Industrial</td>
<td></td>
<td></td>
<td>0.99</td>
</tr>
<tr>
<td>Distribution losses</td>
<td></td>
<td></td>
<td>1.36</td>
</tr>
<tr>
<td>TOTAL</td>
<td>181566</td>
<td></td>
<td>13.74</td>
</tr>
</tbody>
</table>

It can be seen that the lowest income water users are estimated to consume approximately 20 litres per capita per day, less than the 25-30 litres per capita per day recommended by the WHO. In Windhoek the middle income group is the main water consumer, consuming over 3Mm\(^3\)/a out of a total of 13.74Mm\(^3\)/a, while the high income groups drop to 2.09 Mm\(^3\)/a.

There are commercial and industrial water users that occur in urban areas also. Including their water consumption raises the per capita water consumption of urban areas to around 300l/c/d on average.

Table 5.7: Per capita consumption in major urban centres

<table>
<thead>
<tr>
<th>TYPE OF CONSUMPTION</th>
<th>PER CAPITA CONSUMPTION – l/c/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban domestic</td>
<td>156</td>
</tr>
<tr>
<td>All urban uses</td>
<td>286</td>
</tr>
</tbody>
</table>

Table 5.8: Per capita consumption countrywide

<table>
<thead>
<tr>
<th>TYPE OF CONSUMPTION</th>
<th>PER CAPITA CONSUMPTION – l/c/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban domestic</td>
<td>200</td>
</tr>
<tr>
<td>Rural</td>
<td>30</td>
</tr>
<tr>
<td>Domestic: urban and rural</td>
<td>76</td>
</tr>
<tr>
<td>Non-domestic: mines, agriculture and industry</td>
<td>393</td>
</tr>
<tr>
<td>All inclusive unit demand</td>
<td>469</td>
</tr>
</tbody>
</table>

\(^1\) The Windhoek Case Study of the Namibia Water Demand Management Study 1998/99.
5.3.1.2 Agricultural

Water supply for agriculture can be divided into two components. The first is for stock drinking which is considered to have a first priority rating. The second is for irrigation, which only enjoys a second priority as defined in paragraph 5.2.

Large scale irrigation is only practised along the perennial rivers and at major dams where surplus water is available.

5.3.1.3 Rural

Responsibility for rural water supply rests with the Directorate of Rural Water Supply in the Department of Water Affairs. Since independence in 1991 huge strides have been made in the field of rural water supply.

Where good quality groundwater is available, the rural water supply schemes are based on groundwater abstraction. However, where only poor quality groundwater is found in specific areas and also where the water demand is higher than the groundwater potential in a given area, schemes utilising piped water are used. The standards currently in use for the design of piped water schemes are defined in terms of the Water Sector and Sanitation Policy and are as follows:

- Per capita consumption: 25 litres per day
- Consumption of 1 Large Stock Unit (LSU): 45 litres per day
- Consumption of 1 Small Stock Unit (SSU): 12 litres per day
- Consumption per day pupil: 15 litres per day
- 1 000 litres per day per clinic or 30 litres per day per out patient
- maximum walking distance to a water point: 2.5km
- Population growth to be estimated at 3% growth per annum
- For cattle, the water demand must allow only for the number of cattle that can be sustained by the area under consideration. The current guideline is 10ha per LSU depending upon the project area.
- Cattle drinking troughs to be based on one trough per 200 cattle
- The maximum allowable walking distance for cattle is 7.5km.

The communities must be involved in all aspects of planning and implementation of water schemes.

5.3.1.4 Mining

Mines are responsible for their own water supply. Where water is supplied under agreement by NamWater, the mine must pay the economic tariff for the water supplied which is based upon full cost recovery of both capital and operations costs. Mines are encouraged to re-use water as far as possible.

5.3.1.5 Environmental

Other than the Constitution of the Republic of Namibia, none of the legislation or policies in place acknowledges the 'ecological reserve'. This term applies to the amount of water which is necessary to maintain the processes and services that are provided by water to maintain the health of the natural aquatic ecosystem. The ecological reserve thus represents an important component of the sustainable water supply system, while
at the same time requiring a portion of the water that might be otherwise used, albeit unsustainably in the longer term.

Nowhere has the ecological reserve been thoroughly assessed in Namibia. In the Lower Kunene Hydropower Feasibility Study, an ecological flow of the perennial Kunene was estimated to be 20m/s. When the offtake from the perennial Okavango River was being considered during the feasibility study for the Rundu-Grootfontein Link Project, some components of the ecological reserve were briefly considered such as: water for floodplain inundation, water to support the Okavango Delta, water for fish, reeds and other products used by people along the river, and water to support the woody riverine vegetation. The conclusion was that a 10% (of MAR) continuous offtake would not have serious impact on the delta region or other components of the riverine environment.

On some of the ephemeral rivers of western Namibia, withdrawal from ecological reserve has obviously exceeded sustainability. The Huab River in its middle reaches in the communal lands shows evidence of wetlands drying up and large trees previously used for fodder have died off. This is probably related to the several large farm dams (>20,000 m³) located upstream on commercial farms. Similarly, on the Swakop River, the two large dams which supply Windhoek have lowered the water table at Otjimbingwe where winter wheat can no longer be grown in the river bed and many large fodder trees have died off along its course in the Namib-Naukluft Park.

In South Africa, authorities are currently attempting to establish the ecological reserve of the Olifants River, a river flowing westward through an arid, winter rainfall environment. Participatory methods are being used to allow all Interested and Affected Parties, including those who represent the environment, to present their case and contribute toward the decision. The South African Water Act prominently includes the environment as one of the recognised users of water with rights to maintain its share.

5.3.1.6 Summary of Sectoral Demands
Figure 5.8: Water demand by sector

In Figure 5.8 above the use of water as a percentage of the total current consumption per sector in Namibia is illustrated.

5.3.1.7 Unaccounted for Water

Unaccounted for water is water that is ‘lost’ in the distribution system between when it leaves the bulk water supplying authority and when it reaches the consumer. The term is normally applied to urban reticulation systems. Leaks, inaccurate meters, illegal connections and administrative errors all contribute to the losses.

According to audited annual financial statements of the Windhoek Municipality, these measures have resulted in low levels of unaccounted for water during the past three years (1994/95: 9.09%; 1995/96: 12.09%; 1996/97: 10.04%) (van der Merwe 1998).

Much higher levels of unaccounted-for-water are found in Khorixas where the amount is estimated at 58% of the water pumped into the town’s reservoir (WDM Study 1999) and at more than 80% for the Grootfontein army base. For the urban centres of Namibia as a whole, Table 5.9 shows the current estimates of unaccounted for water.
Table 5.9: Unaccounted for Water in Urban Centres.

<table>
<thead>
<tr>
<th>Local Authority Area</th>
<th>Total Water Production (m³ 1996/97)</th>
<th>Unaccounted for water %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arandis</td>
<td>561 345</td>
<td>35.0+</td>
</tr>
<tr>
<td>Gobabis</td>
<td>480 933</td>
<td>7.7</td>
</tr>
<tr>
<td>Grootfontein</td>
<td>2 887 587</td>
<td>20.9</td>
</tr>
<tr>
<td>Henties Bay</td>
<td>359 669</td>
<td>9.0</td>
</tr>
<tr>
<td>Karasburg</td>
<td>228 197</td>
<td>18.0</td>
</tr>
<tr>
<td>Karibib</td>
<td>246 624</td>
<td>n/a</td>
</tr>
<tr>
<td>Katima Mulilo</td>
<td>2 224 980</td>
<td>35.0+</td>
</tr>
<tr>
<td>Kestmanshoop</td>
<td>1 653 419</td>
<td>17.0</td>
</tr>
<tr>
<td>Khorixas</td>
<td>1 102 985</td>
<td>58.0</td>
</tr>
<tr>
<td>Luderitz</td>
<td>834 009</td>
<td>22.0</td>
</tr>
<tr>
<td>Mariental</td>
<td>627 488</td>
<td>9.4</td>
</tr>
<tr>
<td>Okahandja</td>
<td>1 124 861</td>
<td>16.0</td>
</tr>
<tr>
<td>Omaruru</td>
<td>656 251</td>
<td>7.0</td>
</tr>
<tr>
<td>Ondangwa</td>
<td>870 147</td>
<td>35.0+</td>
</tr>
<tr>
<td>Ongwediva</td>
<td>1 125 878</td>
<td>35.0+</td>
</tr>
<tr>
<td>Opuwo</td>
<td>640 363</td>
<td>47</td>
</tr>
<tr>
<td>Oshakati</td>
<td>1 773 799</td>
<td>35.0+</td>
</tr>
<tr>
<td>Otjiwarongo</td>
<td>1 551 167</td>
<td>7.5</td>
</tr>
<tr>
<td>Otjo</td>
<td>639 012</td>
<td>7.7</td>
</tr>
<tr>
<td>Rehobot</td>
<td>1 904 374</td>
<td>35.0+</td>
</tr>
<tr>
<td>Rundu</td>
<td>1 516 622</td>
<td>38.0</td>
</tr>
<tr>
<td>Swakopmund</td>
<td>2 793 197</td>
<td>12.0</td>
</tr>
<tr>
<td>Tsuneh</td>
<td>1 041 603</td>
<td>15.0</td>
</tr>
<tr>
<td>Usakos</td>
<td>123 925</td>
<td>31.1</td>
</tr>
<tr>
<td>Walvis Bay</td>
<td>4 515 087</td>
<td>14.5</td>
</tr>
<tr>
<td>Windhoek</td>
<td>13 741 731</td>
<td>10.0</td>
</tr>
</tbody>
</table>

*35+ represents a rough estimate of the situation based on information from Namibia's Water Demand Management Country Study.*
5.3.2 WATER DEMAND BY SECTOR AND SOURCE

To bring together the demand and supply sides of the water equation it is illustrative to show water demands by economic sectors and also by source. The best estimates of this breakdown have been compiled by the Natural Resource Accounting programme of the Directorate of Environmental Affairs.

Table 5.10: Use of Water by Sector and Source. (1993, in millions of m³)

<table>
<thead>
<tr>
<th>All Sources</th>
<th>Groundwater</th>
<th>Perennial Rivers</th>
<th>Ephemeral Rivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>Bulk Rural</td>
<td>Total Bulk Rural</td>
<td>Total Bulk Rural</td>
</tr>
<tr>
<td>Agriculture</td>
<td>146.1</td>
<td>35.2 111.1</td>
<td>69.1 5.6 63.4</td>
</tr>
<tr>
<td>Livestock</td>
<td>39.1</td>
<td>7.5 31.6</td>
<td>36.5 5.6 30.8</td>
</tr>
<tr>
<td>Crops</td>
<td>107.1</td>
<td>27.7 79.5</td>
<td>32.6 0 32.6</td>
</tr>
</tbody>
</table>

| Mining      | 21.7 4.4 17.3 | 20.3 3.0 17.3 | 0.9 0.9 0         | 0.5 0.5 0 |
| Diamonds    | 13.6 0 13.6   | 13.6 0 13.6    | 0 0 0             | 0 0 0 |
| Other Mining| 8.1 4.4 3.7   | 6.7 3.0 3.7    | 0.9 0.9 0         | 0.5 0.5 0 |

| M'facturing | 5.0 5.0 0     | 3.5 3.5 0      | 0.2 0.2 0         | 1.3 1.3 0 |
| Fish Proc.  | 0.7 0.7 0     | 0.7 0.7 0      | 0 0 0             | 0 0 0 |
| Other       | 4.3 4.3 0     | 2.8 2.8 0      | 0.2 0.2 0         | 1.3 1.3 0 |

| Service     | 5.2 5.0 0.2   | 3.6 3.4 0      | 0.2 0.2 0         | 1.5 1.4 0.1 |

| Households  | 44.7 34.7 10.0 | 28.2 22.6 5.7  | 5.3 1.7 3.6       | 11.2 10.4 0.7 |
| Rural       | 10.0 0 10.0    | 5.7 0 5.7      | 3.6 0 3.6         | 0.7 0 0.7    |
| Urban       | 34.7 34.7 0    | 22.6 22.6 0    | 1.7 1.7 0         | 10.4 10.4 0  |
| Government  | 2.3 2.3 0      | 1.5 1.5 0      | 0.1 0.1 0         | 0.7 0.7 0    |

<table>
<thead>
<tr>
<th>All Sources</th>
<th>Groundwater</th>
<th>Perennial Rivers</th>
<th>Ephemeral Rivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>Bulk Rural</td>
<td>Total Bulk Rural</td>
<td>Total Bulk Rural</td>
</tr>
<tr>
<td>TOTAL</td>
<td>225.1</td>
<td>86.6 138.5</td>
<td>126.2 39.6 86.6</td>
</tr>
</tbody>
</table>

Note: All Sources = 3 (Groundwater) + (Perennial Rivers) + (Ephemeral Rivers)
5.4 THE ECONOMICS OF WATER SUPPLY

5.4.1 VALUE ADDED AND WATER USE

Value added shows the contribution of an economic sector to Gross Domestic Product (GDP). Value added per \( m^3 \) relates this contribution to water usage. Value added per \( m^3 \) of water is a useful concept for considering the economic benefits derived from the use of water in different sectors of the economy. Calculations based on an analysis of the National Accounts for 1996 (G.M. Lange, 1996) revealed the data shown in Table 5.11.

Table 5.11: Value added per cubic metre of water by sector 1996

<table>
<thead>
<tr>
<th>Economic Sector</th>
<th>Value added (millions of N$)</th>
<th>Water use 1996 (millions of cubic metres)</th>
<th>Value added per cubic metre of water 1996 (N$/m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>1,029</td>
<td>142.9</td>
<td>7.2</td>
</tr>
<tr>
<td>Commercial</td>
<td>650</td>
<td>92.9</td>
<td>7.0</td>
</tr>
<tr>
<td>Subsistence</td>
<td>379</td>
<td>50.0</td>
<td>7.6</td>
</tr>
<tr>
<td>Mining</td>
<td>1,654</td>
<td>25.2</td>
<td>65.6</td>
</tr>
<tr>
<td>Diamond mining</td>
<td>1,189</td>
<td>13.6</td>
<td>86.0</td>
</tr>
<tr>
<td>Other mining</td>
<td>485</td>
<td>11.6</td>
<td>41.8</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>1,552</td>
<td>5.3</td>
<td>292.8</td>
</tr>
<tr>
<td>Fish processing</td>
<td>364</td>
<td>0.5</td>
<td>708.0</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>1,198</td>
<td>4.8</td>
<td>249.6</td>
</tr>
<tr>
<td>Services</td>
<td>3,215</td>
<td>5.5</td>
<td>574.5</td>
</tr>
<tr>
<td>Hotels and Restaurants</td>
<td>226</td>
<td>1.2</td>
<td>166.3</td>
</tr>
<tr>
<td>Transportation</td>
<td>252</td>
<td>0.8</td>
<td>315.0</td>
</tr>
<tr>
<td>Other services</td>
<td>2737</td>
<td>3.5</td>
<td>782.0</td>
</tr>
<tr>
<td>Whole economy</td>
<td>11,796</td>
<td>231.2</td>
<td>51.0</td>
</tr>
</tbody>
</table>

Value Added per \( m^3 \) acts as a useful guideline for determining the most economically beneficial use of scarce water resources through the knowledge of the opportunity costs of water use.

The opportunity cost of water use is defined as the forgone economic benefit that occurs due to the use of water in one sector instead of another. For example, if \( 1m^3 \) of water is used in mining rather than manufacturing, N$65.6 of value added accrues to the Namibian economy rather than N$282.9. The foregone benefit of this trade-off is the difference between the two, N$217.3. In a scenario in which different potential users are competing for the same water, knowledge of the value of water in the different potential uses is a useful guide to national development policy in the face of scarce water.

The following section attempts to provide some analysis of why certain sectors have very high value added per cubic metre of water.
5.4.1.1 Agriculture

Agriculture is a major user of water for two reasons. Firstly, irrigation uses vast quantities of water for very little value added. Total irrigation use in 1998 was about 36.45Mm³. Although value added for this sector is not available, an estimate of total revenues (value-added plus non wage costs) indicates a total value of output of N$14m for 1993. Even with no costs apart from wages, and information from different years, this would indicate a value added of less than N$0.5 per cubic metre of water. Secondly, livestock are major users of water, using about 18 cubic metres per head per year. Although this is a major use, it appears likely from the figures quoted above that water is currently still affordable for the livestock sub-sector.

5.4.1.2 Mining

Mining is a major user of water. Major users are Rosh Pinah, Rössing, Otjihase, Navachab and Namib Lead. As indicated by the figures, all types of mining are able to pay water costs unless the cost of water rises enormously beyond present levels.

5.4.1.3 Manufacturing

Small quantities of water are used in various manufacturing processes and again it appears that as a whole, water will continue to be affordable.

5.4.1.4 Services

Hotels and restaurants appear to be relatively water intensive compared to the rest of this sector, probably due to irrigation of gardens at many of the establishments. However, their high value added per cubic metre means that users will be able to pay the future cost of supply.

5.4.1.5 Households

Although household output is not explicitly measured in the national accounts, the value of water to households can be very high. These values include reduced illness, reduced time spent collecting water and higher ability to work. Although no studies have been explicitly done for Namibia, the values derived are expected to be quite high, since the "lifeline" supply needed for health (e.g. drinking, washing and cooking) is very low (about 5-6 cubic metres a year) and its value is very high. However as households start using water for secondary uses, such as washing cars or watering gardens, the value drops.

5.4.2 WATER PRICING

This section gives a brief overview of the principles and the importance of water pricing. The current approach to water pricing in Namibia and the extent to which water supply is currently subsidised are then addressed.

5.4.2.1 The Importance of Water Pricing

The current wisdom in the field of water management is that water should be treated as an "economic good". This message was stated clearly as the outcome of the Dublin Conference of 1992 and reiterated by the World Bank. There have been different

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interpretations of this statement, however discussion has centred upon treating water as a normal good for which users are willing to pay. In terms of the theory, water consumers will use water until the “marginal benefits” (the benefit of the last unit consumed) equal the “marginal cost” (the cost of the last unit consumed). Since the cost of water to consumers is largely governed by its price, pricing and the factors that should influence the price for water have been the main areas of discussion on this subject.

There are three main inter-linking reasons for approaching the allocation of water from the pricing perspective. These are:

- Financial cost recovery
- Economic efficiency
- Sustainability

Each of these aspects has different implications for pricing policy. We address them in turn.

5.4.2.2 Financial Cost Recovery

Financial cost recovery refers to the process of recouping all the costs involved in supplying water from those who consume it i.e. capital, operation and maintenance costs. If water is supplied from public organizations, financial cost recovery will be important from the point of view of government finance. Treating water as an economic good, for which people are willing to pay, enables the government to use formerly used funds for other worthwhile causes such as education and health, which are often less predisposed to direct cost recovery\(^3\). The drain on public finance will be reduced. For a private firm financial cost recovery is imperative for the sustainability of the company and the supply of water of a given quality. In both cases financial cost recovery can be achieved in a number of ways. For example:

- flat rates (fixed charges for unlimited water supply),
- connection fees,
- volumetric tariffs,
- taxation (government).

All these pricing policies can recoup all the costs incurred in supplying water. However, from an economic point of view these pricing mechanisms do not have the effects required for the achievement of economic efficiency in water consumption.

5.4.2.3 Economic Efficiency.

Economic efficiency in water consumption is achieved when consumers demand water until the marginal benefit obtained from water consumption is equal to the marginal cost of supply. The cost of consumption of marginal units of water is only reflected by a tariff for water which relates to specific units consumed, i.e. volumetric pricing. If a consumer pays a flat rate for water consumption, i.e. a single lump sum payment for unlimited water use, marginal units of consumption are effectively costless. This will lead to a situation where water will be used where marginal benefits are low, i.e. low

\(^3\) J Briscoe, “Water as an Economic Good: The Idea and What It Means in Practice”.

\(^4\) i.e. charging the users directly rather than through taxation.
value uses of water are encouraged. In a country in which water is often a constraint to economic activity it is important to discourage relatively low value uses of water. It is therefore important to price water volumetrically, at marginal cost, to ensure water is allocated in a way that achieves economic efficiency. In this sense the price of water is the allocation mechanism.

5.4.2.4 Sustainability

Here we take sustainability to mean continuity in water supply of a given quality over time. With respect to water it is worth highlighting three types of sustainability:

- Financial
- Institutional
- Environmental

The treatment of water as an economic good and the pricing thereof has implications for each of these aspects of sustainability. Conversely, these factors also influence the pricing of water.

We have already addressed the effect of pricing upon the financial, and by extension, the institutional sustainability of water supply organizations. Covering costs will ensure that the water service is maintained and help maintain the institutions that supply water\(^5\). However, environmental/ecological sustainability is not guaranteed by financial cost recovery or volumetric marginal cost pricing which reflect only financial costs.

5.4.2.5 Environmental Costs and Sustainability

For the price of water to truly reflect the social costs of supply, costs external to those incurred by the water supply agency need to be included. Environmental degradation, loss of habitat and ecosystem, and other such external costs need to be included in the tariff for water if economic efficiency is to be truly achieved. This raises three issues:

- How do we measure the environmental costs?
- How do we ensure that these costs are internalized by the water supply agency?
- How do we ensure sustainability?

Environmental economics has a large array of tools at its disposal for the measurement of environmental costs. For example, if water usage from a river affects downstream tourism potential through reduction of wildlife, it may be possible to look at these changes to give value to the environmental quality changes. If for example the extraction of 10Mm\(^3\)/a from a watercourse causes a loss of tourist revenue of N\$10m/a, the average loss per m\(^3\) is N\$1\(^6\). Another example refers to changes in the quality of water supply as a result of over-use and/or pollution. Environmental costs can be proxied by the increased costs associated with returning water, for drinking or for environmental demands, to its original quality.

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\(^5\) This says nothing about the efficiency of these institutions however.

\(^6\) For true economic efficiency the marginal costs/damage should be charged. This example is an average damage, i.e. we should charge the damage that the last unit of water consumption causes for true economic efficiency.
In terms of pricing, per unit taxation equal to the (marginal) damage that each unit of water used causes, would yield economic efficiency and force suppliers and consumers to take into account the environmental damage. From the above example N$1/m³ should be added to the water tariff (See footnote 6). This is one form of regulation which will internalize the external costs of water supply.

We need to be aware that ecosystems/environmental goods such as watercourses and groundwater are often subject to “threshold” effects (P. Dasgupta and K-G Maler). This means that environmental damage may not be linearly related to e.g. water usage. At some level of usage environmental costs may become very large, or damage may be irreversible such that the unit taxation may not be an adequate mode of regulation. An example of this may be aquifer depletion, where at a certain threshold of abstraction the aquifer may collapse, become intruded by salt water or cease to provide key water supplies to local vegetation. In such a situation other regulatory policies may be required to ensure the sustainable use of water sources. These may include:

- Quotas for abstraction
- Fines for over use
- Limitations on technologies

Each would determine water use within the thresholds determined by environmental linkages.

Our definition of sustainability is not guaranteed by the use of economic pricing. Economic efficiency is guaranteed by these methods but the two concepts are not necessarily compatible. Indeed sustainability, depending on the definition, is not an economic concept but rather a concept of intergenerational equity. For example, under certain circumstances economics may say it is optimal to mine an aquifer or pollute a watercourse, where the benefits outweigh the costs. These actions may not be considered sustainable by our definition of sustainability. For sustainability to be achieved in water resource usage other rules may need to be applied. There are many definitions of sustainability, and in each case economics can tell us the best way for it to be achieved.

The demand curve for water is also a determinant of the efficient price. It should be recognised that full knowledge of the demand curve is required for optimal pricing to occur as described. Here we discuss two noteworthy aspects which affect the demand curve:

- Social Benefits (Water as a “merit” good)
- Opportunity Costs

5.4.2.6 Water as a “Merit” Good

External economic effects can be both positive and negative. A “merit” good is a good which harbours wider social benefits than might be reflected by the benefits that accrue purely to individuals. Education is considered to be a merit good since a well educated

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7 Economic efficiency may not achieve sustainability, indeed economic efficiency might not always advocate sustainability. It may be economically efficient to mine an aquifer for example, however this is not necessarily a “sustainable” practice.
society will harbour wider social benefits than the benefits that occur privately to educated individuals: reduction in crime, innovative population etc. In the same way, clean water supply is often considered to be a merit good. The reduction of water related diseases as a result of clean water supply confers wider social benefits upon society than those that accrue to individuals alone, for example:

- a healthier workforce may be more productive,
- medical costs to society are reduced.

In cases of education and water it is speculated that the whole economic benefit is greater than the sum of benefits to private individuals. This seems a reasonable assumption, and economic theory states that merit goods justify some sort of subsidization since the market in which private individuals make their preferences known, will not reflect the wider significance of the provision of the good.

However, there is some debate as to the extent to which water fulfills the role of a merit good. It is clear that some level of water consumption is required for survival and various guidelines are stipulated for this required daily consumption: The World Health Organization recommends between 25 and 30 litres per capita per day. As such it could be stated that these minimum levels of water consumption should be encouraged through subsidization. The question arises when we consider the use of water for other purposes, over and above the minimum level seen as required for health. It would be hard to argue that water for golf courses and swimming pools should be available at a subsidized rate as a basic right for human existence. In essence, depending on the quantities supplied to individuals, water can either be a merit good or an ordinary private good.

5.4.2.7 Opportunity Costs

Where water is scarce and there are many competing demands for water, it is important that water is used in its most productive uses. Pricing in terms of costs of supply may not evoke such an allocation, since water may be scarce and many consumers may demand water at the current marginal cost. In this scenario some indication of the foregone benefits, the opportunity cost, of allocating to one user rather than another, needs to be reflected in the price for water in order to allocate water to the most productive uses. One way in which to achieve such an allocation would be to hold an auction for water, where allocations are made to the highest bidders. Allowing the trade of water rights between users may also evoke this outcome. Calculating the value of water in different uses would also allow a social planner to make decisions about this allocation.

5.4.2.8 Summary

Pricing is a crucial allocation mechanism for any economic good. Water is no exception. In terms of economic efficiency all of the costs and benefits associated with water demand and supply should influence the price. The optimal price should include consideration of:

- Financial Costs
- Environmental Costs
- Opportunity Costs
- Social Benefits

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In practice, Namibia is taking its first steps towards recovering financial costs of water supply in both rural and bulk supply. Environmental costs and opportunity costs exist but they are a long way from being incorporated into workable tariffs. In practice, only the bulk water supplier, NamWater, and local authorities are charging volumetric tariffs.

5.4.3 THE CURRENT COSTS OF WATER SUPPLY

5.4.3.1 Bulk Water.

The current costs of bulk water supply in Namibia vary from region to region. As a national weighted average, the cost of a m³ of water is N$2.41. The regional variations are shown in Table 5.12.

<table>
<thead>
<tr>
<th>WATER REGION</th>
<th>Weighted Regional Full Cost Tariffs (N$/m³)</th>
<th>Total Cost (N$ millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brandberg</td>
<td>2.74</td>
<td>14.3</td>
</tr>
<tr>
<td>Cuvelai</td>
<td>3.55</td>
<td>21.7</td>
</tr>
<tr>
<td>Hardap</td>
<td>2.29</td>
<td>11.6</td>
</tr>
<tr>
<td>Karas</td>
<td>2.30</td>
<td>8.8</td>
</tr>
<tr>
<td>Kavango</td>
<td>1.43</td>
<td>9.5</td>
</tr>
<tr>
<td>Khomas</td>
<td>2.62</td>
<td>30.9</td>
</tr>
<tr>
<td>Kunene</td>
<td>4.67</td>
<td>23.7</td>
</tr>
<tr>
<td>Namib</td>
<td>1.93</td>
<td>18.3</td>
</tr>
<tr>
<td>Omaheke</td>
<td>7.54</td>
<td>8.6</td>
</tr>
<tr>
<td>Waterberg</td>
<td>2.52</td>
<td>10.2</td>
</tr>
<tr>
<td>NAMIBIA</td>
<td>Average 2.41 Total</td>
<td>157.5</td>
</tr>
</tbody>
</table>

SOURCE: Government Gazette no 1883, and NamWater Finance Division correspondence.

The above tariffs reflect the current full cost tariff, where full cost refers to the capital, operations and maintenance costs that are incurred in supplying water. The cost varies considerably by region mainly due to the capital intensity. The total annual cost of water supply, estimated from these weighted tariffs and the water consumption associated with each region, is N$157.5 million

NamWater must recoup all these costs in order to become financially self-sufficient. There is debate, however, as to what constitutes “full cost” when the capital components are old and nearing the end of their lives, whilst in other regions new investments are being determined. The way in which NamWater has decided to account for old and new capital in the tariff is as follows.

For existing infrastructure:

- Old capital, such as existing dams and pipelines is depreciated over 25 years based on the historical value of the capital at the time of construction. The “book value” of capital is used which excludes adjustments for inflation.

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8 Consumption taken for the 1997/98 period.
9 Straight-line depreciation assumed. Capital built in 1970 is valued at 1970’s prices for example.
• Existing operations and maintenance costs are included in the tariff. This includes chemicals, overheads, repairs and other costs.

The above charges compensate the depreciation and contribute to the future replacement of existing infrastructure.

For new investments:

• The full financial cost of new investments is incorporated in the tariff. This includes capital valued at current prices and the full interest payments over the weighted average lifetime of the scheme.

• The operations and maintenance costs are again included.

At the time of writing it is uncertain whether a two part tariff (a fixed part and a volumetric part) or a pure volumetric tariff is to be used. The former model is recommended as it allocates the cost to specific components of the operating environment.

5.4.3.2 Urban Water

Water is supplied to urban areas by the Local Authorities; municipalities, village councils and town councils. NamWater supplies water in bulk to the urban centres and it is the responsibility of the Local Authorities to supply water to consumers. The costs of reticulation will vary from one urban centre to another depending upon a variety of factors including:

• Population/Demography
• Geography
• Type of water supply (e.g. in house, yard pipe or communal standpipe)

The cost of reticulation in each urban centre is currently unknown. The tariffs do not in general reflect precise knowledge of these costs. This is reflected in the arbitrary 10% mark-up over the NamWater tariff that is employed by many Local Authorities. The expenditures that are made on water related services are not specifically accounted for in the budget of the Ministry of Regional and Local Government and Housing and as such it is impossible to put a precise figure on Urban water costs over and above the NamWater costs. This is an issue that requires further investigation if water sector management is to become a reality.

5.4.3.3. Rural Water

The Ministry of Agriculture and Rural Development has the responsibility for supplying water to the communal areas of Namibia. This responsibility falls more specifically on the Directorate of Rural Water Supply (DRWS). The cost of supplying water to these areas can be represented by the budget of the DRWS. See Table 5.13.
Table 5.13. The Operational Budget of the Directorate of Rural Water Supply (N$ millions)\textsuperscript{10}

<table>
<thead>
<tr>
<th>Division</th>
<th>1997/8</th>
<th>1998/9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural Water Supply North</td>
<td>19.2</td>
<td>17.5</td>
</tr>
<tr>
<td>Rural Water Supply South</td>
<td>17.2</td>
<td>14.2</td>
</tr>
<tr>
<td>Rural Development</td>
<td>8.5</td>
<td>20.9</td>
</tr>
<tr>
<td>Total</td>
<td>44.9</td>
<td>52.8</td>
</tr>
</tbody>
</table>

The total capital budget for the DRWS amounts to N$75m for 1997/8 (appropriated) and N$35m for 1998/99 (estimated). With the move towards community based management, certain parts of the operations budget will be reduced as communities begin to bear the costs themselves. Other parts of the DRWS budget will increase as a result of:

- Training programs for Water Point Committees
- Training of rural extension officers
- Investment in improvements in access to water (new boreholes/water points etc)

This indicates that the cost of water supply to rural communities will increase initially as investments in human and man-made capital are made, whilst thereafter reductions in the operational budget may be witnessed.

The cost of individual water supply systems for rural areas is shown in Table 5.14. The costs will vary with the depth of the groundwater. These estimates are for a borehole of 100m depth.


<table>
<thead>
<tr>
<th>System</th>
<th>Annual Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel engine</td>
<td>11400</td>
</tr>
<tr>
<td>Hand pump</td>
<td>1900</td>
</tr>
<tr>
<td>Solar pump</td>
<td>3600</td>
</tr>
<tr>
<td>Windmill</td>
<td>4360</td>
</tr>
</tbody>
</table>


Ultimately the costs will be borne by the Water Point Committees (WPC) once community based management is established. In addition to the financial costs of water supply there will be travel and salary costs incurred by the communities managing the water points when contributions are taken to the bank, spare parts are purchased etc. The total costs vary by region due the differing types and numbers of water points in each region. Table 5.15 shows the total costs, including travel, for the rural water supply regions.

\textsuperscript{10} Estimated from the budget of DRWS and the "Estimate of Revenue and Expenditure for the Financial Year Ending March 1999".
Table 5.15. The Regional Costs to Communities of Water Supply (1996).

<table>
<thead>
<tr>
<th>Region</th>
<th>Water # Points</th>
<th>Total O + M Costs (N$ '000's)</th>
<th>Travel Costs (N$ '000's)</th>
<th>TOTAL (N$ '000's)</th>
<th>Cost per Water Point (N$ '000's)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caprivi</td>
<td>370</td>
<td>751</td>
<td>74</td>
<td>825</td>
<td>2.23</td>
</tr>
<tr>
<td>Cuvelai</td>
<td>1 200</td>
<td>8 928</td>
<td>240</td>
<td>9166</td>
<td>7.64</td>
</tr>
<tr>
<td>Erongo</td>
<td>280</td>
<td>2 320</td>
<td>56</td>
<td>2976</td>
<td>8.49</td>
</tr>
<tr>
<td>Hardap</td>
<td>330</td>
<td>1 668</td>
<td>68</td>
<td>1734</td>
<td>5.25</td>
</tr>
<tr>
<td>Karas</td>
<td>450</td>
<td>2 034</td>
<td>90</td>
<td>2124</td>
<td>4.72</td>
</tr>
<tr>
<td>Kunene N</td>
<td>340</td>
<td>2 557</td>
<td>68</td>
<td>2625</td>
<td>7.72</td>
</tr>
<tr>
<td>Kunene S</td>
<td>550</td>
<td>4 570</td>
<td>110</td>
<td>4685</td>
<td>8.51</td>
</tr>
<tr>
<td>Omaheke</td>
<td>470</td>
<td>5 210</td>
<td>94</td>
<td>5304</td>
<td>11.29</td>
</tr>
<tr>
<td>Okavango</td>
<td>880</td>
<td>6 899</td>
<td>170</td>
<td>7039</td>
<td>8.28</td>
</tr>
<tr>
<td>Otjozondjupa</td>
<td>260</td>
<td>3 142</td>
<td>52</td>
<td>3194</td>
<td>12.28</td>
</tr>
<tr>
<td>TOTAL</td>
<td>5 100</td>
<td>38 049</td>
<td>1 020</td>
<td>39 067</td>
<td>AVE 7.66</td>
</tr>
</tbody>
</table>


The total cost to all communities in Namibia of operations and maintenance of water points amounts to N\$39 million, ranging from N\$9m in the Cuvelai to N\$825 000 in the Caprivi. There are different constraints in the different regions shown partly by different costs for the average water point in each of the regions ranging from N\$12 000 in Otjozondjupa to about N\$2 000 per water point in the Caprivi. The ease with which the ownership of water points can be transferred to communities will be partly determined by the burden of costs in the different regions. It should be noted that these costs are only the operations and maintenance costs. Capital costs would need to be considered for full cost recovery.

5.4.4. THE EXTENT OF SUBSIDISATION.

5.4.4.1 Bulk Water.

NamWater has a policy of full cost recovery, required by legislation of the NamWater Act (Act 12 of 1977). This entails applying tariffs for recovering capital, operations and maintenance costs from water consumers by the year 2000. Tariffs have not historically reflected the costs of supply and as such in 1996 a policy to raise tariffs by 20% per annum for 5 years was implemented, however this policy neglects several factors:

- Demand may fall as a result of increases in water prices.
- Revenue will change as a result of this demand response (either up or down)
- Some of the bulk water supply points require greater than 20% per annum increases over the next 5 years in order to achieve cost recovery.
- Variations in inflation rates and especially the costs of fuels might seriously affect the pricing structure

The Government also agreed to pay a direct subsidy to NamWater in the interim period until full cost recovery has been achieved. This subsidy has been paid only partially.

The extent of cost recovery can be monitored by looking at the annual gazetted proposed and existing tariffs for NamWater's 200+ bulk water supply schemes, and obtaining a weighted average of the ratio of current tariff to full cost recovery tariff. These figures have been calculated since 1995/6.
Table 5.16. Weighted Average of NamWater Tariffs and Full Cost Recovery Tariffs.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tariff</td>
<td>N$1.20</td>
<td>N$1.50</td>
<td>N$1.63</td>
<td>N$2.26</td>
<td>N$2.47</td>
</tr>
<tr>
<td>Full Cost Tariff*</td>
<td>N$2.36</td>
<td>N$2.36</td>
<td>N$2.96</td>
<td>N$2.41</td>
<td>N$2.65</td>
</tr>
<tr>
<td>% Cost Recovery</td>
<td>51%</td>
<td>64%</td>
<td>55%</td>
<td>94%</td>
<td>93%</td>
</tr>
</tbody>
</table>

SOURCE: Government Gazette no. 1883, and NamWater Finance Division correspondence.

* As mentioned before, the definition of full cost has changed over the years. Table 5.17 uses the weighted average tariffs derived from the Gazetted tariff schedule for 1997/8, 1996/7 and 1995/6. For 1998/99 and 1999/2000 the tariffs have been quoted from the finance division at NamWater, with that for 1999/2000 being a 10% increase on N$2.41 for 1998/99.

The ratio is showing an increase, meaning that current tariffs are approaching full cost recovery levels. However, the percentage of cost recovery is dependent upon the definition of full cost. It can be seen that the level of the full cost recovery tariff has changed over the years, partly because of increasing real costs and more recently because of the changing methodology in calculating full costs. This has meant that varying degrees of cost recovery have been achieved over the time period shown. The tariff calculation is due to change this year (1999) and the full cost recovery tariff reduced to N$1.96/m³. This implies cost recovery will be achieved this year.

Furthermore, regional variations are lost in looking at national averages. Table 5.17 shows how the extent of cost recovery varies from one region to another, implying cross-subsidization.

Table 5.17. Regional Cost Recovery Ratio

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Brandberg</td>
<td>79%</td>
<td>86%</td>
</tr>
<tr>
<td>Cuvelai</td>
<td>78%</td>
<td>87%</td>
</tr>
<tr>
<td>Hardap</td>
<td>95%</td>
<td>102%</td>
</tr>
<tr>
<td>Karas</td>
<td>98%</td>
<td>106%</td>
</tr>
<tr>
<td>Khomas</td>
<td>91%</td>
<td>97%</td>
</tr>
<tr>
<td>Kunene</td>
<td>53%</td>
<td>60%</td>
</tr>
<tr>
<td>Namib</td>
<td>111%</td>
<td>123%</td>
</tr>
<tr>
<td>Okavango</td>
<td>121%</td>
<td>129%</td>
</tr>
<tr>
<td>Omaheke</td>
<td>35%</td>
<td>43%</td>
</tr>
<tr>
<td>Waterberg</td>
<td>93%</td>
<td>102%</td>
</tr>
</tbody>
</table>

Of all the regions, Omaheke performs the worst and Okavango the best in terms of cost recovery tariffs. However, until the ratio of tariff to full cost is greater than or equal to one, water consumers are being implicitly subsidized.

It is also clear that a degree of cross subsidization is occurring between regions. On average however, (Table 5.16) NamWater is still making a loss although current changes in the tariff may mean that NamWater will break even within the next few years.
5.4.4.2 Urban

Urban water is generally supplied by the Local Authorities; Regional, Town and Village Councils and Municipalities. It is the Local Authorities that have the responsibility to set tariffs for water. For full cost recovery the tariff for water must include the reticulation costs (operations and maintenance) and the capital costs. These costs are largely unknown for the urban centres of Namibia, however Local Authorities often have arbitrary approaches to tariff setting and water accounting e.g. a 10% mark-up on the NamWater tariff, indicating that direct cost recovery for water is not considered. Furthermore, non-payment by Local Authorities is common and usually as a result of non-payment/non-collection of water bills from consumers. Often the Ministry of Regional and Local Government and Housing finances unpaid bills. The cost of this intervention is currently unquantified, but can be considered as a subsidy.

The larger municipalities, Windhoek, Swakopmund and Walvis Bay for example, are more diligent in their water accounting practices. Separate and distinct accounts for water exist and water is charged at the cost recovery price.

5.4.4.3 Rural

The extent of subsidisation of Rural Water Supply is difficult to quantify since volumetric charging for water is not commonplace. Due to the lack of cost recovery at present, the costs of Rural Water Supply, shown in 5.4.3.3, essentially represent the extent of subsidization.

The move towards cost recovery in the rural sector will be a difficult process to monitor in terms of the financial accounts. It would be erroneous to take the budget as a whole and expect a reduction over time, since capital expenditures, training and extension workers are all likely to increase with the movement towards Community Based Management of the water points. There may be parts of the budget that may see reductions over time; for example maintenance expenses, materials and supplies and perhaps travel expenses, all of which are distinct items on the budget of RWS north and south. However, this will not tell us about the quality of the service.

The progress of RWS in achieving cost recovery could be assessed by monitoring percent of bills paid regularly. However, it is perhaps best approached from the institutional side by monitoring the number of Water Point Committees that are established and trained, whilst at the same time monitoring access to water supply. This will be a better indicator of the success of RWS in achieving its targets. Access to water supply in rural areas is one of the key targets of RWS. The target is that 80% of the rural population should have access to improved water sources by 2007. Access is defined as being within 2.5km of an improved water source. The current state of affairs and the progress is shown in Table 5.18

Table 5.18. Access to Improved Water Supply in Rural Areas.

<table>
<thead>
<tr>
<th>Year</th>
<th>1990</th>
<th>1996</th>
<th>1998</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
<td>62%</td>
<td>65%</td>
</tr>
</tbody>
</table>

The subsidisation of RWS should be seen in the light of the National Development target of improving access to water supply for the rural communities.

5.5 WATER DEMAND MANAGEMENT\textsuperscript{11}.

Water Demand Management is a fundamental part of an integrated approach to sustainable management of the water sector. The purpose of Water Demand Management (WDM) is to ensure that water is used in the most efficient way by instigating policies which affect the demand for water. WDM attempts to obtain the greatest service to the end user from the smallest quantities of water. As such it is an alternative method of increasing the supply of water to traditional supply augmentation strategies. Supply is effectively increased through increasing the services to end users from a given quantity of water. In light of the growing demands in Namibia, due to growth and change in the structure of population and environmental constraints, and the expense of the previously favoured supply augmentation, attention is now focused on WDM to ensure that greatest benefits are derived from limited resources.

WDM can be implemented in a variety of ways with different policy tools being successful in a variety of contexts. These policy tools include market mechanisms such as price changes, non-market mechanisms such as the application of standards and quotas, and fines on water use and direct intervention such as repairs to leaks, reduction of unaccounted for water, promotion of water efficient technologies, moral suasion and legislative changes.

5.5.1 WATER DEMAND MANAGEMENT IN NAMIBIA.

Of all the urban centres in Namibia, only Windhoek Municipality has a proclaimed water demand management policy. The best example of the implementation of a coherent and integrated water demand management program is consequently to be found in the capital. The constituent parts of this program are as follows:

5.5.1.1 Market Mechanisms

Pricing water in accordance with the economic principles in 5.4.2 will affect demand. The increasing “block tariff” system of volumetric charges is applied in Windhoek. This means that larger quantities of water consumed are charged at progressively higher volumetric prices. The current tariff situation in Windhoek is presented in Table 5.19.

Table 5.19: The Block Water Tariffs in Windhoek (June 1998).

\begin{center}
\begin{tabular}{|c|c|}
\hline
Water Consumption & Tariff (N\textdollar/m\textsuperscript{3}) \\
(m\textsuperscript{3}/month) & \\
\hline
0-6 & 2.65 \\
7-15 & 3.70 \\
16-36 & 4.75 \\
37-45 & 6.25 \\
45+ & 8.15 \\
\hline
\end{tabular}
\end{center}

\textsuperscript{11} This chapter has been adapted from the Water Demand Management Namibia Country Study, Windhoek Case Study by Ben van der Merwe, 1998.
The bulk water full cost recovery tariff for water supplied to Windhoek at present is N$3.17/m³. It can be seen that there is some cross-subsidization occurring between different consumption blocks, and consequently between different consumers. This results in a baseline tariff that encourages the consumption of the first 6m³ of water. This is in line with economic theory, which states that the water consumption up to certain levels is a merit good, i.e. there are social benefits to the consumption of water related to health effects, and thus water consumption in these small amounts should be encouraged. This is also an equitable policy since it addresses the skewed distribution of income in Windhoek by allowing water supplied at a low price for lower, generally poorer consumers, to be subsidized by the larger, generally richer, consumers. The tariff also punishes progressively higher levels of consumption and acts as a limiting mechanism for water consumption.

Changes in the block tariff structure in 1992/93 and again in 1996/7 have had a significant effect on the level of water consumption, despite the continual growth in population. The cut-off point for the punitive tariff is thought to be one of the main factors affecting water consumption.

Windhoek is not the only town in Namibia to have proclaimed increasing block tariffs for water. Tsumeb, Walvis Bay and Swakopmund also apply this system with varying degrees of success. In Tsumeb, for example, it appears that the structure of the block tariff has encouraged greater consumption levels. This is as a result of the cut-off points for each tariff increment and illustrates the need for a proper analysis into the scheduling of the tariffs prior to their introduction.

5.5.1.2 The Effect on Revenues

The effect that real price changes will have on the revenues obtained from the sale of water will depend upon the price elasticity of demand (PED) for water. PED is calculated as shown below.

\[
\text{PED}^{13} = \frac{\% \text{ change in quantity}}{\% \text{ change in price}}.
\]

If the PED is between 0 and 1 (what is known as inelastic demand) then revenues will be increased as a result of a price increase. If the PED is greater than 1 (elastic demand) revenues will be reduced. It is important for the water supply agency to have some knowledge of the PED when instigating price changes.

5.5.1.3 Non-Market Mechanisms

These include quotas on water use and fines for over use. Fines for over use occur in Windhoek, however quotas on water use do not exist. Quotas for water use do exist for boreholes in groundwater control areas and for abstraction from the perennial rivers in Namibia. Limits are set for the allowable abstraction from a particular source and this limit is stipulated in the abstraction permit. In general there are no fines for over use and the monitoring of water sources, especially boreholes, is lacking.

---

12 Merit goods afford wider benefits to society, which means that the market price may cause under-consumption of the good since it would ignore these effects. The quantity of water consumption that can be considered a merit good is unknown but is implicitly assumed to be up to 6m³/a in Windhoek.

13 This number will be negative for most goods since demand and price changes are in opposite directions.
5.5.1.4 Direct Intervention

The following components of the Windhoek Municipality WDM strategy can be considered as Direct Intervention.

Policy:
The policies that have been approved and implemented in Windhoek include:

- **Maximum Re-use of water:**
  - Semi-purified effluent is used for irrigation of sports fields, this has replaced 1.1Mm³/a of potable water demand.
  - The Goreangab reclamation works can provide up to 3.65Mm³/a of potable water. This is to be upgraded to 7.5Mm³/a.
  - Grey water re-use is encouraged in private premises.

- **Plot Sizes:**
  - Plot sizes for new residential developments have been reduced. Evidence suggests that household consumption of water is strongly correlated to plot size.
  - Higher density housing is encouraged in existing developments.

- **Urbanisation:**
  - Guidelines have been developed to efficiently supply water to the growing urban population.

- **Reduction of Municipal Water Use:**
  - Municipal water use, for public gardens and the like has been reduced by 50%.

- **Wet Industries:**
  - Guidelines are given to wet industries on a continuous basis for the efficient use of water.
  - New wet industries will have to implement plans to re-use water.

Legislation:
New water supply regulations were promulgated for Windhoek in 1996. They specifically addressed the issue of water conservation. The requirements of the regulations are as follows:

- **Water Efficient Equipment:** From 16 December 1996 the following measures are compulsory:
  - Metering taps must be used in all hostels.
  - Taps outside non-residential buildings must be self closing or lockable.
  - Toilet cisterns must be 6/3/ litre dual flush units.
  - Automatic flushing devices are prohibited.
  - Retrofitting of inefficient devices must occur within 3 years.

- **Groundwater:**
  - Abstraction from private boreholes is to be monitored and groundwater levels to be controlled.

- **Gardens:**
  - Watering may not be done between the hours of 10.00 and 16.00, i.e. times of high evaporation.

- **Swimming Pools:**
  - Swimming pools must be covered when not in use.

- **Prevention of Pollution:**
  - Regular testing of underground fuel tanks is mandatory. All tanks are registered.
Technical Measures:
Certain technical measures have been introduced as part of the legislation approved in 1996. These technical measures include:

- Lowering of Unaccounted for Water:
  - Leakage detection is carried out on a continual basis.
  - Repair programs are in place.
  - Water audits are undertaken.
  - Proper management of meters is underway.
  - A systematic pipe replacement program is underway.

- Efficient Ways of Watering Gardens.
  - Proper irrigation systems are used for municipal gardens.
  - Advice is given by the Municipal officials on efficient watering methods and where these systems can be obtained.

- Artificial Recharge of the Windhoek Aquifer.
  - It is foreseen that that full-scale re-charge of the Windhoek aquifer will be implemented as from May 1999 subject to availability of water.

- Rainwater Harvesting.
  - Rainwater harvesting is undertaken on a small scale by the residents in and around Windhoek.

Public Campaigns and Awareness:
Public campaigns are an essential component to WDM. National awareness campaigns have been undertaken since 1992 in tandem with the annual world water day. Windhoek has its own awareness programme. Without the participation of the public the success of these programmes will be limited. In Windhoek awareness has been heightened in the following way:

- Education Programs:
  - Lectures in schools and other institutions of learning on the subject of water management.
  - Radio and television appearances.
  - Advertisement in the local Media.
  - Pamphlets on water saving ideas both inside and outside the house distributed with bills.

- Consumer Advisory Service.
  - Advice on all water related issues including reduction of water losses and pressure reduction.
  - Information on how to detect leaks in premises is supplied.

- Advice on Efficient Gardening Methods.
  - Advice on suitable shrubs and trees for Windhoek.
  - Advice on efficient garden watering practices.

- Community Empowerment in formerly neglected areas.
  - A programme to train community based plumbers was initiated for proper maintenance of water installations on private residential plots.
  - Training of gardeners was identified as an important task, which should still be addressed.

It is the combination of these measures, implemented in an integrated manner, that has achieved considerable success in dampening down demands for water from conventional sources. Indeed as one can see from Figure 5.9, the level of water
consumption from conventional sources (surface and borehole) in Windhoek was the same in 1997 as in 1987, despite the population nearly doubling.

Figure 5.9: Water Production in Windhoek from Different Sources Including Irrigation

5.5.2 WATER DEMAND MANAGEMENT POTENTIAL

Given the definition of WDM above, and the economic, managerial, technical and legal components associated with it, a brief appraisal of the potential for WDM to be implemented throughout Namibia is possible. The IUCN Water Demand Management Namibia Country Study investigated the extent and awareness of WDM in different sectors of the economy.

5.5.2.1 Urban Areas

Windhoek is the only urban centre to have a distinct Water Demand Management policy. It was found that as a result of this factor, and the combination of institutional weaknesses and low levels of water awareness, significant water savings could be made through the implementation of an integrated approach to water demand management. The main problems noted were:

- High levels of unaccounted for water.
- Low levels of maintenance.
- Ineffactual tariff setting.
- Non-payment of water bills.
Worst case examples were Opuno and Khorixas, both of which suffered high levels of unaccounted for water, low quality and deteriorating infrastructure and flat rate charges for water. The amount of unaccounted for water shown in Table 5.20 amounts to a loss in revenue for the local government of around N$1,351,428 in Khorixas and N$524,132 in Opuno in terms of what must be paid to NamWater. Since these towns add a 10% increment to the NamWater tariff, the losses in revenue to the local authority is actually greater. These are rough estimates based on the consumption figures in Table 5.20, but they show at least the order of magnitude of the financial losses that occur as a result of both failing infrastructure and poor tariff setting.

Table 5.20: Underestimate of Consumption and Unaccounted for Water

<table>
<thead>
<tr>
<th>Town</th>
<th>Consumption (m³)</th>
<th>Unaccounted for Water</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Municipal Estimate</td>
<td>NamWater</td>
<td>m³</td>
</tr>
<tr>
<td>Khorixas</td>
<td>465,519</td>
<td>1,102,985</td>
<td>637,466</td>
</tr>
<tr>
<td>Opuno</td>
<td>376,980</td>
<td>640,383</td>
<td>263,383</td>
</tr>
</tbody>
</table>

Many urban centres have old and/or deteriorating, badly maintained reticulation systems, often inadequate to cater for growing urbanisation. One WDM intervention would be to replace these reticulation systems, reduce unaccounted for water and supply more people with the same quantity of water.

5.5.2.2 Urban Commerce

The best case examples of water demand management techniques implemented by the urban commercial and industrial sectors are situated in Windhoek. For example Namibia Breweries has one of the lowest specific water consumption levels (i.e. litres of water used to produce one litre of beer) in the world, at four litres. This is as a result of the integrated approach to water used in the design of the factory, the incentives to save water that arise from the tariffs structure and the high level of awareness in Windhoek. In the other urban centres of Namibia few WDM practices were noted in the industries questioned, although the inexorable move towards full financial cost pricing has made most private agents more aware of the need to use water more efficiently.

5.5.2.3 Rural Water Supply

Historically, supply of water to rural areas has been undertaken through a sense of social justice and as such the government did not recover the costs of water supply. The movement towards Community Based Management (CBM) of rural water points has been instigated to encourage water users to become responsible for their water supply by taking responsibility for recovering the financial costs of supplying water, including maintenance and management of the system. This is to be achieved through the creation of Water Point Committee’s (WPC’s). The combination of this strategy, including awareness campaigns and training means that the efficiency of water use will be increased and therefore the same or better services will be provided with reduced amounts of water. Furthermore, given the fragility of the ground water resource base upon which many rural consumers depend in some areas, and the need for maintenance

14 For Khorixas the Municipal estimate is based on the flat rate of assumed consumption, multiplied by the number of houses in the town assumed to be consuming. The large consumers are also included. For Opuno the same structure of usage as in Khorixas is used for residential consumption with a detailed estimate of the main consumers added on.
free operation of water points, appropriate technologies are used to reduce water wastage and to reduce maintenance costs. This is the rural interpretation of WDM.

The issue of Water Demand Management in Rural Water Supply has not been specifically addressed in policy for very good reasons. Recent studies have shown that in rural areas the national mean per capita daily water consumption is 9.91l. The median is approximately 8.31l. In Namibia the acceptable minimum water consumption required for good health is stated to be 25l per capita per day (WHO). The capacity of boreholes is planned by Directorate of Rural Water Supply (DRWS) using 15l per capita per day as a rule of thumb, 45l per day for a large livestock unit and 15l for small livestock units. It can be seen that the average daily consumption is less than that recommended for good health, thus to look towards rural domestic consumption as a potential area for water demand management policy, seems illogical.

However, since livestock are larger users of water, individuals in the DRWS have stated that this is an area that is receiving attention. It has been suggested that a fee per head of cattle may be one management technique.

The issue of groundwater depletion and the wider social effects that this might have are highly relevant to rural water supply, most of which comes from boreholes.

5.5.2.4 Mining

On the whole, the mining industry is fairly diligent when it comes to the management of water for industrial purposes. This diligence arises for a number of reasons including:

- The large amount of water used by the individual mines.
- The high proportion of costs that fresh water supply makes up.
- The need for precise inputs of water in the mining processes.
- The proximity of certain mines to alternative inputs like seawater.
- The proven financial benefits of alternatives like recycling.
- Environmental obligations (e.g. ISO 14000/1, mining laws, laws in the country of origin of the parent company).

Table 5.21: Breakdown of Water Sources at Rossing Mine*.

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>1977 (Mm³/a)</th>
<th>1977 (%)</th>
<th>1997 (Mm³/a)</th>
<th>1997 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater (NamWater)</td>
<td>9.5</td>
<td>100</td>
<td>2.6</td>
<td>27.66%</td>
</tr>
<tr>
<td>Recycled</td>
<td>0</td>
<td>0</td>
<td>6.5</td>
<td>69.15%</td>
</tr>
<tr>
<td>Brackish</td>
<td>0</td>
<td>0</td>
<td>0.3</td>
<td>3.19%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>9.5</td>
<td></td>
<td>9.4</td>
<td></td>
</tr>
</tbody>
</table>

* These figures are based on information contained in a booklet called "the Story of Water at Rossing Uranium Mine". These are estimates based on a graph therein.

It has become viable for some mines to take unilateral action to save water. Examples include Rossing and Navachab mines, both of which are fairly large and sophisticated and can seemingly exploit economies of scale in water saving techniques, such as large scale recycling (see Tables 5.21 and 5.22). In smaller industries, e.g. meat processing and small scale bottling plants, there are often no financial incentives for unilateral water saving investments. Water costs make up a small percentage of total costs, and
the amounts of water used are small in comparison. Therefore, any innovation to the existing plant will often require considerable change and achieve only relatively small cost savings in water. Mines it seems are confronted by economies of scale when it comes to water saving strategies due to the sheer amount of water they use\(^{15}\).

Table 5.20: Water Reclamation at Navachab Gold Mine.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NamWater</td>
<td>95555</td>
<td>95681</td>
<td>109668</td>
<td>86306</td>
<td>118466</td>
</tr>
<tr>
<td>Borehole+</td>
<td>52000</td>
<td>63000</td>
<td>54000</td>
<td>45000</td>
<td>54000</td>
</tr>
<tr>
<td>Sub-Total</td>
<td>100555</td>
<td>101081</td>
<td>115068</td>
<td>91705</td>
<td>124867</td>
</tr>
<tr>
<td>Reclamation++</td>
<td>583651</td>
<td>589360</td>
<td>634022</td>
<td>530178</td>
<td>784884</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1593207</td>
<td>1595199</td>
<td>1657417</td>
<td>1447241</td>
<td>2033551</td>
</tr>
<tr>
<td>Reclamation %</td>
<td>35.5%</td>
<td>35.5%</td>
<td>35.5%</td>
<td>38.6%</td>
<td>38.6%</td>
</tr>
</tbody>
</table>

* Shaded areas are estimates based on the 1998 water abstraction.
** Shaded areas are estimates based on the % of reclaimed water in 1997.

However, there are considerable savings possible in many of the mines addressed. Obvious examples include Oranjemund and Rosh Pinah mines where, although certain water management practices are undertaken in the mining processes themselves, the practices undertaken in the towns associated with the mine leave much to be desired. Namdeb provides water to the citizens of Oranjemund at no charge. Water is paid for through the general taxation in the town and as such the marginal costs of water usage to the residents are zero. This leads to huge figures of water consumption of up to 16m\(^3\) per household per day. In Windhoek it is found that the consumption averages about 200 litres per person per day. If the average household has 6 persons, this leads to a consumption of 1.2m\(^3\) per household per day, 13 times less\(^{16}\).

Indeed, if the per household consumption in Oranjemund and Rosh Pinah were reduced to the levels attained on average in Windhoek, approximately 1/10 of the water would be required. This would mean savings in the order of 6MM\(^3\)/a, and 0.6MM\(^3\)/a for Oranjemund and Rosh Pinah respectively. Considering that both obtain their water from the Orange River, this quantity of water represents a significant proportion of the 40-50MM\(^3\)/a proposed as Namibia's entitlement from the Orange River.

5.5.2.5 Summary

It can be seen from the discussion above that there exists considerable potential for Water Demand Management to be implemented in the different sectors of water consumption. The costs of these practices, if comparable to Windhoek, would mean that water savings would be a much cheaper option than augmenting supply.

5.6 FUTURE WATER DEMANDS

At present many water sources in Namibia are close to being fully exploited or even over exploited. Groundwater is being mined in some areas where abstraction is greater

\(^{15}\) It should be recognised that the water costs to mines are also very often only a small percentage of costs. Their absolute value is high however, and the net benefits from WDM are also high in an absolute sense.

\(^{16}\) This number of people per household could be an overestimation.
than recharge, e.g. the Khoichab pan near Luderitz. In other areas, for example the Stampriet aquifer, little is known about the potential sustainable yield. As for surface water (perennial and ephemeral) there are two distinct problems. Firstly the current infrastructure is being used to full capacity in some areas such as in Windhoek and the Central Namib region. Secondly, where water is available, for example at the Hardap Dam or along the perennial rivers, few distinct development options exist. Inversely many of the urban and industrial centres are far from where water is abundant and relatively cheap. For example Windhoek, Swakopmund, Walvis Bay and Luderitz are approaching the limits of current water supply possibilities. Investments will be required in the future, should demand increase as projected, and the alternatives are expensive for each of these urban centres. Although it would be ideal to have demand predictions for all the regions of the country, at present only the central areas of Namibia have been studied in detail.

5.6.1 FUTURE WATER DEMANDS FOR NAMIBIA

Water demand estimates and information on water resource potential are used to draw up a master water plan for a country. In Namibia, a water scheme using local water sources is normally planned for a 15 year planning horizon. A water scheme using regional water sources is planned for a twenty year period, while the planning horizon for a national water scheme linked to internationally shared rivers is 30 years. A rural water supply scheme has a five to ten year planning horizon, depending on the size and growth potential of the community.

5.6.1.1 Future Demands by Source

Table 5.23 shows the predicted water demands by sector and source in 2020.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Perennial Rivers</th>
<th>Ephemeral Rivers</th>
<th>Groundwater</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>19</td>
<td>100</td>
<td>21</td>
<td>30</td>
</tr>
<tr>
<td>Livestock</td>
<td>4</td>
<td>10</td>
<td>Farm dams only</td>
<td>63</td>
</tr>
<tr>
<td>Mining</td>
<td>7</td>
<td>25</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Irrigation</td>
<td>77</td>
<td>180</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>TOTAL</td>
<td>107</td>
<td>315</td>
<td>53</td>
<td>85</td>
</tr>
</tbody>
</table>
5.6.1.2 Future Demands by Sector

The predicted future demand by sector is shown in Figure 5.10\textsuperscript{17}.

![Graph: Future Demands by Sector](image)

Figure 5.10: Estimated Future Water Demand per Sector.

5.6.1.3 Urban

The future growth in urban domestic water demand is driven by population and income growth. Factors such as Water Demand Management and increasing prices as a result of cost recovery may help to curb growth somewhat.

Manufacturing usage generally occurs in urban areas. Very little is known about manufacturing use trends at present, since most manufacturers obtain their water from municipalities and information has not been extracted. Although manufacturing is not a major user of water at present (about 2% of total use) the rapid growth that will occur in this sector if Namibia’s development strategies (which focus on increasing value added in manufacturing) are successful, may make it a major user of water in the future. In this sense pollution and wastewater disposal will become more of an issue in the future as well.

Urban demands are expected to have grown from 67Mm\textsuperscript{3}/a in 1996, to 109Mm\textsuperscript{3}/a in 2012.

5.6.1.4 Agriculture

Growth of the agricultural use of water by livestock is expected to fall off in the medium term as herd size levels off after recovery from previous droughts and adjusts to the grazing available. On commercial farms the switch from livestock to game farming will contribute to this reduction. The demands of livestock as a whole are expected to rise at a rate of 1% from 37Mm\textsuperscript{3}/a in 1996.

\textsuperscript{17} The prediction is taken from the DWA planning report of 1998 entitled “Water Demand of Namibia”.

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Irrigation currently uses a large proportion of total water. Water use by irrigation is overwhelmingly along the Okavango River and growth is probably dependent on continued subsidies for large irrigation projects run by institutions like NDC. In these cases demand for water is easily under the control of the government. However, there are significant new investments planned along the Orange River by both government and the private sector. Demands for water for other projects could result in similar increases along the other perennial rivers in future. Ultimately irrigation water demand is governed by the existence of suitable land and the prices of crops, as well as government policy. Any increases may come in large lumps as indicated in Figure 5.10.

Agricultural demands are predicted to increase from 202Mm$^3$/a in 1996 to 284Mm$^3$/a in 2012.

5.6.1.5 Mining

Existing mines are not expected to increase their water demands significantly. It is not possible to predict requirements for new mines. In the very long term, many mines may shut down due to the expense of obtaining the furthest reaches of minerals, or due to a reduction in the price of the ores. Conversely, water demand may increase if mineral prices rise. Developments such as the Skorpion mine will increase water usage in this sector. The Haib copper mine remains a potential investment for the future. These two developments represent the largest potential increase in water demand, requiring 0.8Mm$^3$/a and up to 60Mm$^3$/a respectively from the Orange River. Skorpion mine will also use groundwater, as do many mines, which is not recorded here.

Water requirements in the mining sector are predicted to increase from 18Mm$^3$/a in 1996 in line with future developments and closures. In Figure 5.10 an increase to around 30Mm$^3$/a in 2012 is shown.

5.6.1.6 Rural

Rural water usage has several components. Domestic usage is expected to increase from the 1996 level of 13Mm$^3$/a to 21Mm$^3$/a in 2012, at a rate of 3% per annum. These estimates are based on an assumed consumption of 30 litres per day and estimated population growth of 3% per annum. It is domestic rural water use that is reflected in Figure 5.10.

Other rural uses include livestock and irrigation. These are included in the agricultural prediction of Figure 5.10. However, it is worth noting that livestock use for the communal areas is estimated as being 21Mm$^3$/a in 1996 and subject to 1% growth, constrained by carrying capacity. This includes cattle, sheep, goats, pigs and poultry.

5.6.1.7 Tourism

Although minor at present, tourism demands are expected to increase in the future at a rate of 5%. Tourism is one of the fastest growing economic sectors in Namibia. This will have additional effects on the rest of the economy. In the short to medium term, tourism is expected to grow at about 10% a year.

Tourism demand is expected to increase from 0.74Mm$^3$/a in 1996, to 1.6Mm$^3$/a in 2012.
5.6.1.8 Total

In total, the Namibian water demands are expected to increase from the current level of 302Mm³/a to approximately 450Mm³/a in 2012. This represents an average growth rate of 2.2%\(^{18}\). At this rate of growth the domestic water resources will be fully used by 2017. The predictions are heavily dependent on the assumptions made about future irrigation potential, this being one of the major components of total water use. The total domestic assured yield in Namibia has been quoted as being 500Mm³/a (Day 1998).

5.6.2 FUTURE DEMANDS FOR THE CENTRAL AREAS OF NAMIBIA

Most economic activity in regd to manufacturing and the service sectors takes place in the Central Area of Namibia. Windhoek is also situated in the area and, due to its geographical position, is supplied with water from a variety of different sources. Current existing developed sources are almost fully utilized and emergency measures have been investigated focusing largely on water from the Okavango River. For this reason this area has been the focus of the Central Areas Water Master Plan (CAWMP) of 1993 and 1995 and the Okavango Pipeline Feasibility study of 1997. In each study sectoral demand projections were made in order to estimate the time at which consumption of water would use all of the currently developed sources, and hence when new developments must take place. The demand projections were extrapolated into the future using assumptions about the main drivers of demand, population growth and economic growth. The implied growth rates have been used to extrapolate the demand projections into the future. The comparison of the three projections can be seen in Figure 5.11.

CAWMP 1993 represents phase 1, CAWMP 1995 represents the interim phase. The projections shown here represent the middle/medium projections contained in each\(^{19}\). STUDY refers to the Okavango Pipeline Feasibility study projections. WDM represents a hypothetical Water Demand Management effect. The assumed effect is one of a growth rate reduced by 25% compared to that implied in the STUDY scenario. This is a plausible effect of Water Demand Management.

In referring to the demand growth in each sector, reference is made to the Okavango Pipeline Feasibility Study of 1997. This is the latest projection, starting in 1995/6.

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\(^{18}\) Assuming exponential growth.

\(^{19}\) Each study had a low, medium and high prediction.
Figure 5.11. Comparison of Water Demand Projections.

5.6.2.1 Urban

The urban water demand growth rate was based on expected population growth in urban centres which was based on the population estimates of the local authorities or the 1991 census. The towns included in the Okavango Feasibility Study were Windhoek, Okahandja, Karibib, Otjiwarongo, Otavi, Tsumeb, Grootfontein, and a number of minor urban centres. The population growth in these urban centres has been at a rate of approximately 5% per annum, ranging from about 2.65% in Tsumeb to 7% in Otjiwarongo. Windhoek has been assumed to grow at a rate of 4.35%. This projection contains a WDM effect based on assumed gains that could be made in Windhoek, Okahandja, Otjiwarongo, Grootfontein and Tsumeb. The commercial, industrial and residential water demands are all considered urban. An initial demand of 27Mm³/a is assumed to grow at a rate reflecting the assumptions for each urban centre.
Also included in the STUDY demand projection are government centres: Omatjenne experimental farm, Osona Military Base and Windhoek International Airport. Small rural villages and small consumers were also included. Their combined initial water demand amounts to 0.9Mm³/a, and is assumed to grow at a rate of 4% pa.

5.6.2.2 Agriculture

The agricultural sector in the projection includes irrigation and stock watering. Irrigation is limited to Kombat mine, water abstraction permit holders in the central areas, other commercial farming and Oshikoto and Guinas lakes. An initial demand of 2.25Mm³/a is assumed to grow at a rate of 4% per annum. Stock watering is constrained in the long-run by the carrying capacity of the land. There has been little growth in this sector. As such an initial demand of 2Mm³/a is assumed to grow at 0.5%.

5.6.2.3 Mining

The mines included in the water demand projection are Tsumeb, Kombat, Okaruso, Navachab and Otjihase. An initial demand of 3.5Mm³/a is assumed to grow at a rate of 1% per annum.

5.6.2.4 Wildlife and Tourism

The water consumption of the resorts in the central areas has remained largely constant over time. However, a growth rate of 2% pa is assumed reflecting the general growth in the tourist industry in Namibia. An initial demand of 0.153Mm³/a is used.

5.6.2.5 Summary

The WDM effect takes into account the reduced consumption that has occurred in Windhoek. Consumption was reduced by approximately 3.5Mm³, from nearly 18Mm³ in 1996 to approximately 14Mm³ in 1997/8. The WDM projection also reduces the rate at which demand grows from 2.3% pa to 1.9% pa. This reflects the potential for water demand management to change the pattern of demand through economic, technical, legislative and public awareness techniques in all sectors. As such, the effect on growth is a speculative projection. For the WDM scenario an initial total demand of 38Mm³ and a growth rate of 1.92% pa, is assumed. This compares with the STUDY scenario which assumes an initial demand of approximately 41Mm³ and an average growth rate of 2.3%²⁰.

5.6.3 DISCUSSION OF DEMAND PROJECTIONS.

5.6.3.1 Omitted factors.

Figure 5.11 is a useful explanatory tool for the understanding of the shortcomings of demand projections such as those for Namibia in section 5.6.1, and the central areas. It can be seen from Figure 5.11 that there has been a wide disparity between the water demand projections made in different reports for the central areas of Namibia. Each report tells us something different about the time at which new water infrastructure may become necessary. For example, given that currently available water resources in

²⁰ The growth rates were extrapolated exponentially.
may become necessary. For example, given that currently available water resources in
the central areas are said to be 52Mm³/a, the CAWMP 1993 predicted full utilization of
these resources by 1990/1, the CAWMP 1995 by 1997/8, and the STUDY by 2006/7.
It is obvious that certain factors have been overlooked in the projection methodology
since even today, water supply is maintained to an increased population in the central
areas from the same level of water resource development. The predictions of the two
CAWMP reports have already been proven wrong.

The omissions of the CAMWP reports included:

- The effects of Water Demand Management in Windhoek.

- The general effects of increasing prices as a result of cost recovery policies. (e.g.
  the use of more efficient technologies, recycling, and consumer demand response)

- The effects of unpredictable droughts.

- Other economic factors.

The Okavango Feasibility Study included the estimated effects of the implementation of
WDM techniques such as block tariff structures, water efficient technologies and
general awareness campaigns. However, the effects of price increases on demand
resulting from cost recovery were not included in the STUDY projection. Furthermore
the effects of the increased cost of developing water resources, such as the Okavango
pipeline or groundwater, which would ultimately be reflected in the price to consumers,
were not included. The absence of price responses makes the STUDY demand
projection “price constrained”. The WDM projection is also price constrained in this
sense, although it attempts to account for the dynamic effect of other WDM
techniques. Including estimations of the Price Elasticity of Demand in future projections
may increase their accuracy.

Other economic factors should be considered. For example, in response to price
increases/cost recovery, industries and residential consumers may be encouraged to
invest further in water saving devices and hence a greater efficiency in water usage will
result. The use of recycling will also allow some consumers to re-use more water than
they consume from primary water resources.

Furthermore, demands for water vary with income. As such, if a country or a region has
significantly increasing income levels, these should be incorporated in the demand
projection. Dynamic effects such as these are often ignored.

There are constraints to water demand growth in particular sectors. For example, in the
agricultural sector there are constraints to the extent of irrigable land and the carrying
capacity of the land for cattle. It is not inconceivable that similar constraints exist in
other sectors of the economy. These constraints are not directly included in projections
such as those in Figure 5.11 or section 5.6.1. Constraints such as these are
incompatible with constant growth assumptions, which have been used in the STUDY
and WDM projections and the CAWMP studies.
5.6.3.2 Summary

It is clear that predicting the future is a difficult task. Projections such as those in Figure 5.11 have been extrapolated on the basis of an assumed constant rate of growth and particular restrictive assumptions about water requirements. Recent history has shown us that constant growth in demand is not necessarily a useful assumption and occurrences such as droughts (or good rainfall) and policy changes (e.g. cost recovery and WDM) cause discontinuities. As a result, projections that project far into the future should be treated with caution.

However, certain policies, such as cost recovery, can be assumed to be constant and their effects can be incorporated, in this case through the use of estimates of price elasticity of demand. Income elasticity of demand (the responsiveness of demand to income changes) is also a factor worth consideration. Furthermore, constraints to demand growth should also be identified. All of these factors will contribute to a more accurate prediction of the future.

Lastly, it is important to consider the spatial element to water supply. Predictions which omit the fact that the future demands in some sectors are constrained by the cost of augmenting that supply in the areas in which these sectors expand, will fail to represent the economic reality that water is not a free good and marginal demands are likely to be more costly. Some sectors will not be willing to pay such costs, and although water is physically available in groundwater reserves, perennial rivers and ephemeral rivers, the cost of the water will restrict demand.

5.7 THE COST OF FUTURE WATER SUPPLY OPTIONS

5.7.1 THE FUTURE COST OF WATER FOR WINDHOEK

Windhoek’s growth over the past century has led to a shift in water supply from local sources such as springs, boreholes and dams such as Avis to sources further afield, initially Von Bach and Swakoppoort and now the Karst aquifer of the Grootfontein, Otavi, Tsumeb area. A combination of population growth and highly subsidised water prices have led to rapidly growing demands. In addition to Windhoek’s growth itself there are also demands from other towns, mining, livestock and along the Okavango river (one potential source of supply) irrigated agriculture.

The frequency with which drought years have been experienced over the past decade, has prompted research into the most cost effective emergency water supply for Windhoek. The growing water demands of the central areas of Namibia mean that the future non-emergency supply options for Windhoek are of utmost concern, as the water consumption will exceed the available supply in the near future. Here the unit costs of each water supply option are compared and a descriptive analysis of the issues particular to each option are discussed.

Windhoek is the most important population, commercial and administrative centre in Namibia. In terms of the water supply and demand issues that have been illustrated above, Windhoek displays several characteristics that make it representative of the problems that Namibia as a whole faces. These factors include:
• Rising water consumption: on account of population and income growth as illustrated in the demand prediction above.

• Present capacity almost fully used.

• Increasing marginal costs of water supply.

To illustrate the comparative cost of the different water supply options, values for Windhoek have been listed in Table 5.24.

Table 5.24: Comparative Analysis of the Unit Costs of Water Supply Options for Windhoek (1998).

<table>
<thead>
<tr>
<th>Potential Water Supply Options</th>
<th>Potential Volume of water Assumed per Year (Mm³/s)</th>
<th>Unit Cost, N$/m³ at Windhoek</th>
<th>International Agreement Status</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Supply</td>
<td>15</td>
<td>3.17</td>
<td>None required</td>
<td></td>
</tr>
<tr>
<td>Okavango</td>
<td>17</td>
<td>6.25</td>
<td>None</td>
<td>Environmental and Political consequences</td>
</tr>
<tr>
<td>Kunene (option 1)</td>
<td>30</td>
<td>7.85</td>
<td>Agreement with Angola. 6m³/s, or 190Mm³/a.</td>
<td>Very variable flow, demand in the Kuveli affects the availability.</td>
</tr>
<tr>
<td>Kunene (option 2)</td>
<td>190</td>
<td>10.36</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Tsumeb Aquifers</td>
<td>20</td>
<td>6.40</td>
<td>None</td>
<td>Investigation into the sustainable yield required.</td>
</tr>
</tbody>
</table>

5.7.1.1 The Tariff Calculation

The comparative costs of the different water supply options for Windhoek have been listed in Table 5.24. Each source has a different potential water supply capacity, however the cost comparisons have been made on the basis of supplying the amount of water considered adequate for emergency supply in 1999 as was addressed in the Rundu-Grootfontein link of the Eastern National Water Carrier (ENWC) Feasibility Study.

All the tariffs shown are based on an Average Incremental Cost (AIC) calculation which is an approximation to the Long-Run Marginal Costs of water supply. The discount rate used was 10%, representing the real opportunity cost of capital as used for project appraisal. The tariffs represent the full financial cost recovery tariff, provided that the discount rate is at least equal to the real financial costs, and the water assumed to be supplied is all sold. The amount of water used to appraise the unit costs for each project is equivalent in each case. The “total increment added” to the system is used in each case, as was used in the Rundu-Grootfontein Link of the ENWC Feasibility Study.

Subsequently, there is an assumption that all water is supplied from an emergency situation to the three-dam system, and that available water increases gradually over time as a result. This is not unreasonable for most options. However, in the case of the Okavango, Kunene and Tsumeb aquifer supply options, an increment of N$1.63 is added to the pure AIC for the schemes. This reflects the operations and maintenance
costs of supplying through ENWC and the three-dam system\textsuperscript{21}. The tariffs therefore reflect the bulk water cost. This tariff has not been added to the desalination\textsuperscript{22} or the Hardap options since they do not enter the ENWC at Grootfontein, as is the case in the other options. There are likely to be further infrastructure costs in Windhoek should the Hardap option be realised, since it is likely that storage facilities will be required. The same could be true of the desalination option should water be pumped directly to Windhoek. These potential investments are not represented in the tariffs above.

In conclusion, although the tariffs are comparable in so much as each option has been treated similarly in terms of the tariff calculation and the amounts of water to be supplied, beneath comparability lie some unrealistic assumptions about the practicalities of the various options, described in the following sections. However, the comparison is illustrative of the relative differences in the costs involved in different water supply options compared to one another and the existing NamWater cost recovery tariff of N$3.17/m\textsuperscript{3}.

The tariffs are solely financial cost recovery tariffs and are exclusive of environmental costs. Furthermore, the options need to be appraised in terms of the characteristics peculiar to each.

5.7.1.2 The Kunene River.

The current agreement between Angola and Namibia states that Namibia is entitled to extract half the natural flow at the point of extraction up to a maximum of 6m\textsuperscript{3}/s (190Mm\textsuperscript{3}/a). The point of extraction is the Calueque Dam from which, at present, the limit of the pumping capacity is a maximum of 3.5m\textsuperscript{3}/s. The agreement only refers to this point of extraction and does not preclude further extraction occurring between Ruacana and the mouth of the Kunene. Current extraction supplies the central northern region with water.

The option of transferring water from the Kunene River was considered in the light of the options for an emergency supply for the city of Windhoek\textsuperscript{23}. The need for an emergency supply arose after several very dry years (92/93 and 95/96) left Windhoek in short supply of water.

Two options have been investigated with regard to the Kunene. Option 1: pumping water to Grootfontein from the existing canal that runs from Calueque to Oshakati. Option 2: pumping the water directly from Calueque to Grootfontein, from where it would enter the ENWC for Windhoek. The capital cost of the two options has been calculated at N$1058m and N$1493m (1998 prices) respectively under the assumptions that the same amount of water is to be extracted in each option as was assumed for the Rundu to Grootfontein supply, i.e. 17.28Mm\textsuperscript{3}/a\textsuperscript{24}.

\textsuperscript{21} N$1.63 is N$1.35 in 1998 prices. This addition was made in the Rundu-Grootfontein pipeline study for bulk water O&M costs.

\textsuperscript{22} The desalination option has been included in the unconventional supply options consistent with the previous definitions.

\textsuperscript{23} In the Okavango River to Grootfontein Link of the Eastern National Water Carrier.

\textsuperscript{24} The shortfall in supply in the 1998/99 "likely" case in the feasibility study, without supply from the three dam system.
The capital costs of Option 1 are less; the pipeline required being 150kms shorter, 6 pumping stations instead of 7 and associated reductions in operation and maintenance costs. The capacity of the canal at Oshakati is 1.2m³/s (nearly 38Mm³/a). This is less than the 3.5m³/s (110Mm³/a) pumping potential at Calueque firstly due to oftakes between Olushandja Dam and Oshakati so that the required capacity is less, and secondly because of the capacity of the canal after the "bifurcation" at the border with Angola.

Currently the Kunene River supplies the Central Northern Area of Namibia and mainly the Cuvelai Basin. In 1996/7 the bulk water demands for the Cuvelai region were 6.6Mm³/a. Since 1984/85 the average growth rate in this demand has been 4.7% per annum. In the last 5 years the growth rate has been close to 9% per annum. Taking the consumption figure of 6.6Mm³, this leaves excess capacity at Oshakati of approximately 30Mm³/a. If we take a growth rate in the regional water demands at the long-run average of 5% it would take 35 years, until 2033, for demands to reach the capacity of 1.2m³/s (38Mm³/a). However, if 17.28Mm³/a were required in the future to supply the demands in Windhoek, in a drought situation for example, the capacity of the pipeline at Oshakati would be reached within 23 years, 2021. So Option 1, obtaining an emergency supply from Oshakati, can only be considered as a short-term supply option, since the demands of the Cuvelai will take up the remaining capacity. Option 2 will be more expensive but will supply over the longer term. The unit costs of water from the two Kunene options and the Okavango option may be seen in Table 5.25.

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25 The capacity of the pipeline from Calueque to the border is 6m³/s. The bifurcation divides this capacity between that required for Oshakati and the Cuvelai Drainage Basin and that which was designed to flow into the formerly proposed "Western National Water Carrier". The WNWC was never built but the bifurcation still exists.

26 These growth figures should be read in light of wide fluctuations in the amount of water registered year on year by NamWater. The recent increases could be due in part to the taking over and metering of illegal connections which were often 95% of connections along certain parts of the pipeline infrastructure.

27 It is reasonable to take the bulk water demand of the whole Cuvelai at this point since much of the remaining water supply to the north, north east, south and south east of Oshakati is supplied by pipelines from this point.

28 The figure of 17.28Mm³/a was derived in the Rundu to Grootfontein Feasibility study as the shortfall of supply compared to predicted 1998/99 demand in a situation where the three dam system is completely empty.
Table 5.25: The Comparative Costs of the Two Kunene Water Supply Options

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Capital Costs (MN$)</th>
<th>Average Incremental Cost of Water (N$/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oshakati-Grootfontein</td>
<td></td>
<td>7.85</td>
</tr>
<tr>
<td>Calqueque-Grootfontein</td>
<td></td>
<td>10.36</td>
</tr>
<tr>
<td>Rundu-Grootfontein</td>
<td></td>
<td>6.25</td>
</tr>
</tbody>
</table>

* Note that in the feasibility study this tariff refers to the bulk water tariff. The tariff in Windhoek includes the transport and reticulation costs. Furthermore this tariff has been calculated erroneously in the study. The equivalent tariff in the study, in 1998 prices, is N$6.08. The tariff in Table 5.25 is correct.

The mean annual run-off (MAR) at Ruacana is 5 500Mm³/a (160m³/s), the same average annual flow is recorded at the river mouth. Further upstream at Matala the MAR is recorded as 4 700Mm³/a (149m³/s) and further upstream again the MAR is 1 700Mm³/a (54m³/s).

The MAR of 5 500Mm³/a (160m³/s) should be viewed in the context of large natural seasonal variations of flow in the currently unregulated river. Records show that during the early part of this century the flow occasionally dropped to as little as 1m³/s at Ruacana. Due to the existence of the Calqueque and Gove Dams the fluctuations upstream of Ruacana have diminished somewhat. However because of the non-functioning of the Gove Dam and the incomplete nature of Calqueque, the fluctuations at Ruacana are still pronounced. The average of the low flows at Ruacana is 50m³/s for the three driest months of August, September and October. These would be the months during which emergency supply for Windhoek might be required.

The flow of water pumped from the Kunene into the Oshakati canal and the Itaka canal to the south, is backed up by the Olushandja dam which has a storage capacity of 42.3Mm³. The dam was built to act as an emergency supply should access to the Kunene be impossible. Similarly a pipeline from Ruacana with a capacity of 0.6m³/s was built to carry water into the Olushandja dam in times of extreme emergency. Water from Ruacana is reserved for human consumption. The security given by the Olushandja dam and the Ruacana pipeline can only last for a year due to high evaporation losses.

The unit cost of Kunene option 1 is N$1.60/m³ more than the unit cost estimation for the Rundu to Grootfontein pipeline scheme. The AIC for bulk water supply was estimated to be N$3.68/m³ whilst the supply from Kunene Option 2 works out at around N$5.14/m³, both at a 10% discount rate. However, doubts about the increasingly low flows of the Kunene in recent years (as little as 1m³/s at times) and the

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23 The AIC calculation has been undertaken assuming a time horizon of 35 years. After 23 years option 2 will be able to supply less water due to demands in the Cuvelai region, however the systems analysis in the Rundu to Grootfontein feasibility study assumes that 17.28Mm³/y are pumped in the first year and 5.68Mm³/y thereafter. This assumption means that with the given growth rate of water demands in the Cuvelai the supply to Windhoek will only be constrained in 2032. The water quantity used in the study and for this calculation is the “total secured water” and this is assumed to be the same if water is taken from the Okavango or the Kunene options 1 and 2.

30 It must be recognised that the calculations above are Average Incremental Cost calculations which take into account the incidence in time of water supply and the capital and operations and maintenance costs.
dependence upon Angola that such a supply might create, means that the security of water from the Kunene would be very fragile under certain circumstances. Reliance on Angola may also become a problem for the Okavango River depending upon the future development of the upstream Okavango River Basin.

Furthermore, the hydro-electric capability of the lower Kunene river means that water extracted upstream of the proposed site has an opportunity cost of electricity generation as well as the environmental costs.

5.7.1.3. The Okavango.

The mean annual runoff as measured at Rundu is 5 000Mm³/a. The lowest monthly flow recorded at Rundu is 11.1m³/s. The maximum flow recorded at Rundu is 909m³/s. Again the Okavango is subject to wide annual variation in the flow of water. Currently Namibia’s riparian demands from the Okavango River have been estimated at approximately 20Mm³/a. There are no agreements between the basin states which specify the allowable extraction rate, however a tripartite commission, OKACOM, has been established with the purpose of managing the river basin as a whole.

The issues associated with pumping water from the Okavango are well documented. Political ramifications spawned by concern for the environmental consequences of such water extraction could be potentially costly for Namibia. This is true of both the regional and the international community. Regionally, Namibia will go against the desires of its neighbour Botswana, should it decide to extract water from the Okavango. At the very least, issues of compensation for the effects of lost or reduced water downstream will arise. Similarly the reaction of the international community to issues of environmental concern will cause wider political costs. One only needs to look at the reaction of the international community to Botswana’s intention to irrigate on a large scale in or near the Okavango Delta, or the decision by the French to test nuclear weapons in the South Pacific, to see evidence of this.

5.7.1.4 Okavango vs Kunene

Similar questions about the reliability of the source could be leveled at the Rundu to Grootfontein link of the ENWC. The source of the Okavango is in Angola thus the flow will still be affected by developments there. However, equivalent developments in the upper reaches of the Okavango would take a smaller percentage of the flow at Rundu than would be the case at Calueque as the variability of the Okavango is much less than that of the Kunene. The lowest recorded flow of the Okavango is approximately 11m³/s, whilst the lowest recorded flow of the Kunene is less than 1m³/s. Similarly, the source of the Okavango is in a higher rainfall area than that of the Kunene. This means that equivalent developments of irrigation on the Okavango would require less water from the river due to the higher rainfall in that region.

If an emergency water supply was taken from the Kunene, the supply would cost more and be less secure than if water were taken from the Okavango. Furthermore, extraction of water from the Kunene is likely to have a negative environmental effect on the lower reaches of the river. If an emergency water supply was taken from the Okavango, it would cause environmental damage downstream and represent opportunity costs. The overall costs of these two options require further evaluation, although the Kunene appears, to date, to be the better option.
5.7.1.5 Tsumeb Aquifers.

These aquifers were also investigated as part of the Rundu to Grootfontein link of the ENWC feasibility study. The capital costs used are taken from this study but inflated to 1998 prices. The groundwater option is very appealing for reasons other than the competitiveness of the unit cost calculated in Table 5.25.

The use of the Tsumeb aquifer as a source of water for the growing demands of Windhoek will mean that the uncertainties associated with abstraction from the Okavango River will be eliminated. These uncertainties include the environmental and political costs that may prevail. Although the Tsumeb aquifers do not require international negotiations on abstraction levels, there are important issues that must be addressed with respect to this source of water.

At present the water from these aquifers has only been partially tapped. Current abstraction is used to supply the town of Tsumeb and private boreholes in that area. Total use is approximately 24Mm³/a. There is likely to be a question of property rights with respect to tapping the water from this source and transporting it to Windhoek. In fact, although the water resources do belong to the government which has the power to transfer water, there is likely to be resistance to the proposals from the users in the Tsumeb area. The same could be said of the Grootfontein aquifers, although they are not specifically addressed here.

The sustainability of supply and the possibility that there are strong environmental linkages to the level of groundwater in the aquifer are also issues that need to be considered when comparing the costs of the different options. It is likely that if there are environmental costs to this water, they will occur within the confines of Namibia, rather than outside the country as in the case of the Okavango. In this respect Namibia will internalise these costs and may have a greater incentive to mitigate against them.

5.7.1.6 Hardap.

In light of the above arguments, the option of pumping water from Hardap Dam seems worth further investigation. Excluding the premium for bulk water operations and maintenance, transferring water from Hardap is financially the cheapest option. Furthermore, the Hardap option has various other advantages over the other supply augmentation options. The environmental costs associated with this option are only those associated with restricting the flow of the Fish River into the Orange River. Since the water from Hardap is currently used for irrigation, it could be that the flow to the Orange River would not be further reduced as a result of transferring the water to Windhoek instead. This of course would have to be investigated.

This strategy does not directly require permission from other countries since the water originates from within Namibia. However, a minimum environmental flow has been established for the Orange River to which the Fish River contributes. It is possible that the water extracted may have a considerable opportunity cost at some stage in the future. At present the agreed environmental flow of the Orange River is in the region of 300Mm³/a registered at the river mouth. This flow is maintained by releases of water from the dams in South Africa which often has some economic benefit to South Africa as a result of hydropower generation. However, often this water is simply released to maintain the environmental flow without any economic benefits accruing and at considerable opportunity cost to South Africa. It is possible that in the future Namibia
could trade its contribution to the Fish River with South Africa by maintaining the environmental flow to the Orange River through releases from Hardap.

Currently the opportunity costs of the water from Hardap dam revolve around the environmental aspects mentioned above and the irrigation schemes that are currently operating there. Whether or not the strategy of transferring water from Hardap to Windhoek is economically desirable depends upon whether or not the water is more valuable in Windhoek than in Hardap. If it were the case that the current users, and the multiple economic effects reliant on these users, could be more than completely compensated by the users in Windhoek, this would indicate that the strategy was economically desirable. One way to instigate this trade of water may be the creation of water rights at Hardap based on current users allowing individuals to decide between using the water for their own productive purposes or selling it to the bulk water supplier. Ultimately, if the benefits in Windhoek were sufficient, a trade would occur.

There are various problems that arise from this situation.

- Politically speaking giving water use rights to the current users of water in Hardap would be impractical.
- There is no mechanism available to ensure that the benefits that accrue to these users from the sale of their water rights, feed through into the economy in the way that, for example, wages would have. Therefore there may be some inequitable outcomes.
- The institutional arrangements required for the efficient monitoring and trading of permits, are extensive and often unwieldy\(^{31}\).

The problems with extracting water from Hardap include:

- Water levels fluctuate with those of the three dam system. Whenever a drought hits the three dams it is also likely to hit Hardap dam. This adds an element of insecurity of supply\(^{32}\).
- The irrigation schemes at Hardap would be subject to a reduction in the available water. This will be resisted by the stakeholders.

Clearly there are many implications of supplying water to Windhoek from Hardap Dam. A thorough investigation of the proposals would be required before a decision is taken. This is true of all the options considered.

5.7.2. THE COSTS OF UNCONVENTIONAL WATER SUPPLY OPTIONS\(^{33}\).

Unconventional water supply has been discussed in section 5.2.3. Here we give the projected costs of these sources as a comparison to the conventional supply costs.

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\(^{31}\) There are examples from around the world where successful trades of water rights occur and benefits from this type of transfer are registered.

\(^{32}\) Although Hardap dam is reckoned to have a 95% assured yield of approximately 50Mm\(^3\)/a, this takes into account the uncertainty in supply.

\(^{33}\) This draws heavily on the work of Ben van der Merwe: Windhoek case study of the Water Demand Management Namibia Country Study, and “Strategies for Water Re-use”.

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The increasing expense of conventional bulk water supply augmentation investments has made unconventional sources a more practical and economic alternative source of additional water. Technological advancements have also been very important in making these investments practically more appealing. This is particularly the case when considering reclamation of water. Furthermore the environmental and political costs associated with conventional water sources, e.g. the Okavango River, have highlighted the need for alternative sources of water.

Table 5.26. Unconventional Supply Sources. 

<table>
<thead>
<tr>
<th>Existing Supply Sources</th>
<th>Potential Volume of water Assumed per Year (Mm³/a)</th>
<th>Unit Cost, N$/m³ at Windhoek</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Supply</td>
<td>15</td>
<td>3.17</td>
<td></td>
</tr>
<tr>
<td>Goreangab ext</td>
<td>3.65 (7.5 in future)</td>
<td>2.50</td>
<td>Environmental costs are low</td>
</tr>
<tr>
<td>Desalination</td>
<td>50</td>
<td>19.65</td>
<td>Expensive</td>
</tr>
<tr>
<td>Artificial Recharge</td>
<td>4.8</td>
<td>1.25</td>
<td>Testing still occurring. Supply from reduction in Evaporation.</td>
</tr>
<tr>
<td>Boreholes</td>
<td>2.3</td>
<td>1.15</td>
<td>Subject to recharge</td>
</tr>
<tr>
<td>Purified Effluent</td>
<td>1.14</td>
<td>1.57</td>
<td>Environmental costs are low</td>
</tr>
</tbody>
</table>

5.7.2.1 Reclamation of Wastewater for Direct Potable Use (Goreangab Reclamation Works and Extension).

The practicalities of this unconventional water source are discussed in paragraph 5.2.3.6.

5.7.2.2 Desalination

At nearly N$20/m³, desalination is by far the most expensive option considered above. Although largely benign in terms of the opportunity costs of the water used, desalination is an energy intensive option for two reasons. Firstly the reverse osmosis technique considered here requires considerable amounts of energy to function. The study entitled "Water supply to the central Namib area of Namibia" states that 1MW will be required in the year 2000, rising to 2.3MW in 2005 and 4.6 in 2015. This only refers to four units producing in total 20 700m³/day or 7.3Mm³/a. The required capacity for this analysis is nearly 2.5 times this amount of the 17Mm³/a emergency supply and presumably would require equivalently more electricity. Secondly, pumping the water to Windhoek, against a pumping head of over 2 400m would require an additional 1.5-2MW. In total approximately 7MW of power would be required, more than currently demanded by Swakopmund.

Intensive energy use has environmental consequences. Furthermore, infrastructure will ultimately have to be built to supply the joint electricity demands of desalination and the coastal areas. It is also likely that there will be significant environmental costs associated with a pipeline of over 300kms from the coast to Windhoek.

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34 The tariffs shown here are not equivalent to the conventional tariffs in Table 5.25. They do not use the same assumptions with respect to the quantity of water supplied. They have been supplied by Ben van der Merwe, City of Windhoek Case Study of the Namibia WDM study.

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5.7.2.3 Artificial Groundwater Recharge.

The water engineers of Windhoek have initiated a pilot project for the artificial recharge of the secondary fractured rock aquifer serving the town. It is estimated that the underground storage capacity of the Windhoek Aquifer is in the order of 15 – 25 Mm$^3$ and that a minimum annual recharge at a rate of 6 – 10 Mm$^3$ will be possible. In 1998, 100 000 m$^3$ of water supplied by NamWater was treated through Granular Activated Carbon and injected into a production borehole over a period of 2 months. To date, no negative effects have been detected while some of the surrounding boreholes are recovering at four times their natural recovery rate (van der Merwe 1998). A similar approach could be used to store excess reclaimed water.

It is clear that the option of artificial groundwater recharge is a cheap and efficient use of water. There is likely to be greater scope for the use of this technique in Namibia and in the Windhoek area.

5.7.2.4 Boreholes.

The Municipal boreholes provide the cheapest water to Windhoek. Their use is monitored for sustainability and excessive pumping has been reserved for times of drought. It is these boreholes that are being recharged artificially. Essentially the boreholes will only represent a long-term source as long as the losses from evaporation can be reduced through the artificial recharge. This cheap water is not in limitless supply therefore, but used conjunctively with other sources will enable efficient management of existing supplies.

5.7.2.5 Purified Effluent.

Purified effluent is used for irrigation of sports fields, public gardens and cemeteries. The use of this water rather than potable water means that demands on potable water are reduced. This essentially releases potable water for consumption elsewhere. 1.14 Mm$^3$/a of purified effluent are used in this way, implicitly supplying 1.14 Mm$^3$/a of potable water to the city of Windhoek. Again this is a cheap source of water, but in the long-run this source is limited since there are only so many parks and fields that require irrigation, and only a few more that can be converted to purified effluent irrigation. The saving is one-off in this respect. Furthermore a minimum sewerage flow is required for the current reticulation system.

Further savings could perhaps be made by the use of this water in private gardens through domestic dual pipe systems. However, the cost of this strategy is unavailable here.

5.7.2.6 The Costs of Water Demand Management.

Water demand management represents a wide range of inter-linking policies intended to reduce the amount of water people use in obtaining the services they require from water. The strategies used by the Windhoek municipality have been documented elsewhere. It is useful however to compare the unit costs of these policies to the other water supply techniques.

The water demand management programs of the municipality of Windhoek are financed by a levy on the income from water. At present this levy represents less than 1% of the
total income from water, and is the equivalent of N$0.042/m³. Estimates of the amount of water that are saved as a result of WDM are given in Table 5.27.

Table 5.27: Predicted Water Demand in Windhoek, With and Without WDM.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No WDM (Mm³/a)</td>
<td>21.1</td>
<td>26.7</td>
<td>34.6</td>
<td>44.4</td>
<td>57.1</td>
</tr>
<tr>
<td>WDM (Mm³/a)</td>
<td>17.9</td>
<td>20.7</td>
<td>24.1</td>
<td>27.9</td>
<td>32.3</td>
</tr>
<tr>
<td>Savings (Mm³/a)</td>
<td>3.2</td>
<td>6</td>
<td>10.5</td>
<td>16.5</td>
<td>24.8</td>
</tr>
</tbody>
</table>

Given that the savings shown for 1995, 3.2Mm³, have been achieved at a cost of N$0.042/m³ of total consumption, the total cost of these savings is N$750 000. The unit cost of this saving is approximately N$0.24/m³. Indeed if the prediction shown in Table 5.27 is correct, the Average Incremental Cost of this strategy is N$0.11/m³. This compares favourably to other supply options and the NamWater cost recovery tariff for Windhoek of N$3.17/m³.

The long term capability of WDM strategies to ensure water services to the growing demands in Windhoek is questionable. What is likely, however, is that the combination of WDM and the eventual supply augmentation that will be necessary, if current demands continue to rise, will be a more efficient water supply investment than supply augmentation alone.

5.8 VIRTUAL WATER

5.8.1 DEFINITION OF VIRTUAL WATER

Virtual water can be thought of in two ways:

1. It can be the water that is embedded in the imported products such as industrial goods, foodstuffs and electrical goods. The water used in manufacturing these goods in their country of origin can be quantified precisely and called virtual water. For example, the amount of water contained in imported products varies according to the water use intensity. 1kg of rice contains 1-2m³ of virtual water, hydropower, although non consumptive, contains 4m³ per Kwh (at 100m head difference), thermal power contains 3 litres per Kwh due to evaporation, wheat and maize contain 2.6m³ per kg. The virtual water in this sense refers to the water that was used in the country of the product's origin.

   OR

2. Virtual water can represent water that would have been required to produce the goods in Namibia were they not imported. If goods are imported, domestic water is saved and freed for use in the production of other potentially higher value goods.

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35 This includes the investments in the recycling plant at Goreangab, but excludes any cost savings that are made from the reduced level of consumption. It also excludes the reduction in the unit cost of water as a result of the delays in the need for supply augmentation. The unit cost is calculated assuming that the cost of WDM is N$0.042/m³ for total consumption occurring each year. It has been stated that the reduction in water consumption could be an underestimate. Ben van der Merwe pers. comm.
This refers only to goods that could readily be produced in Namibia. Quantifying virtual water in this second sense is based on hypothetical scenarios.

The second definition of virtual water is more important in Namibia’s context, which brings to light the possibility of saving water through imports of water intensive products, whilst reserving domestic water use for higher value activities. This definition of virtual water is used in this report.

5.8.1.1 Virtual Water in Basic Grains

Table 5.28 shows that Namibia imports on average 100 thousand tons of grain every year in order to satisfy demands. Were this grain to be grown with surety in Namibia 300Mm$^3$/a of water would be required for irrigation. Therefore, grain imports can be considered as imports of 300Mm$^3$/a of virtual water to Namibia, water which does not impinge on domestic water resources and is now largely free for use in other sectors.

Table 5.28: Cereal production, imports and utilization, 1991/92 to 1996/97 (in '000 tons)\(^\text{36}\).

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Production 91/92</th>
<th>Production 92/93</th>
<th>Production 93/94</th>
<th>Production 94/95</th>
<th>Production 95/96</th>
<th>Production 96/97</th>
<th>6 Year Ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIZE</td>
<td>Production</td>
<td>Imports</td>
<td>Utilization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>12.8</td>
<td>26.2</td>
<td>43.6</td>
<td>13.1</td>
<td>18.1</td>
<td>27.6</td>
<td></td>
</tr>
<tr>
<td>WHEAT</td>
<td>Production</td>
<td>Imports</td>
<td>Utilization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.9</td>
<td>3.1</td>
<td>5.7</td>
<td>6.3</td>
<td>2.8</td>
<td>4.1</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>MAHANGU</td>
<td>Production</td>
<td>Imports</td>
<td>Utilization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46.0</td>
<td>15.0</td>
<td>36.7</td>
<td>59.1</td>
<td>37.1</td>
<td>56.6</td>
<td>41.8</td>
<td></td>
</tr>
<tr>
<td>SORGHUM</td>
<td>Production</td>
<td>Imports</td>
<td>Utilization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.7</td>
<td>2.2</td>
<td>7.0</td>
<td>10.0</td>
<td>4.0</td>
<td>8.0</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>Production</td>
<td>Imports</td>
<td>Utilization</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>115.6</td>
<td>33.1</td>
<td>75.5</td>
<td>119.0</td>
<td>57.0</td>
<td>86.8</td>
<td>81.2</td>
<td></td>
</tr>
<tr>
<td>Utilization *</td>
<td>158.8</td>
<td>180.4</td>
<td>183.6</td>
<td>198.3</td>
<td>186.4</td>
<td>233.5</td>
<td>191.8</td>
</tr>
</tbody>
</table>

\* Utilization is different to the sum of Production and Imports due to storage.

The notion of virtual water was first considered in the Middle East. Due to high economic and population growth and extreme water scarcity, policies were adopted to import basic foodstuffs rather than produce them domestically. Hence, instead of supplying the increasing food demands from domestic sources, water was reallocated to the commercial/urban sector whilst foodstuffs were supplied from the world markets. The growth of this commercial sector created the foreign exchange necessary to pay for the foreign imports.

It is clear that the idea of virtual water is closely related to the economic theory of comparative advantage which states that countries should be open to trade and

\(^{36}\) Taken from "Food Security or Self Sufficiency for Namibia? A Background and a Review of the Economic Policy Implications", Discussion Paper No.1 Division of Planning, Department of Agriculture, Water and Rural Development, Windhoek.
specialize in the production of goods in which they have a comparative resource cost advantage. Namibia faces a similar situation to the Middle East in terms of aridity and population growth. Namibia is water scarce with domestic water available at approximately 475m$^3$ per capita per annum which is comparable to some of the driest countries in the world e.g. Jordan at 300m$^3$/capita/annum$^{37}$. By other criteria, Namibia is a “water stressed” country having less than 2000m$^3$/capita/annum (Falkenmark 1989). Namibia also faces a high rate of population growth: an average of around 3% per annum.

Therefore, it is necessary that, in determining economic policies, some consideration is given to the water intensity of economic activities, the domestic economic contribution of these activities and the comparative cost of imports. It seems likely that Namibia, being the most arid sub-Saharan African country, will not have a comparative advantage in producing “wet” goods. Currently stated policy seems to go against this logic.

5.8.1.2 Food Self-Sufficiency

The notion of self-sufficiency in basic grains has been documented in both the first National Development Plan (NDP1 1995-2000) and the Water Sector and Sanitation Policy (WASP 1993). The WASP states the irrigation sector should:

“improve sustainable national food self-sufficiency and security”

NDP1 further states that the immediate objectives of the agricultural sector are to:

“improve levels of household food security nationally with an ultimate goal of achieving food self-sufficiency”

These views reflect a desire at the time of Independence to achieve self-sufficiency as a means of increasing food security and establishing continued growth and development in the rural/agricultural sector. More recently the notion of self-sufficiency has been documented in a slightly different way. The National Agricultural Plan (NAP 1995) states:

“the government will pursue food self-sufficiency objectives only to the extent that it is financially rewarding and economically viable to do so”

It is clear that food self-sufficiency is still considered by government to be a desirable way in which to achieve national food security (secure access to food) which gives priority to domestic production. Food self-sufficiency would use domestic water resources rather than virtual water and potentially crowd out other water users. The lowest value use of water in Namibia is in agriculture and especially irrigation. Section 5.4 shows that the value added for agriculture as a whole is lower than that of all other economic sectors, meaning that lower contributions to GDP can be expected by prioritizing irrigation of low value crops. The concept of virtual water is highly relevant when considering this water intensive, low value sector in relation to the policy of food self-sufficiency.

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$^{37}$ This is calculated on the basis of a population of 1.6m, domestic water supplies of 500Mm$^3$/a, 50Mm$^3$/a from the Orange River, 20Mm$^3$/a from the Okavango (current demands) and 190Mm$^3$/a (3m$^3$/s) from the Kunene.
5.8.1.3 Water Requirements for Food Self-Sufficiency

There are natural resource constraints to pursuing a policy of food self-sufficiency. Table 5.29 shows the water requirements for food self-sufficiency.

Table 5.29. Cereal Imports and Water Requirements for Self-Sufficiency.

<table>
<thead>
<tr>
<th>Commodities</th>
<th>91/92</th>
<th>92/93</th>
<th>93/94</th>
<th>94/95</th>
<th>95/96</th>
<th>96/97</th>
<th>6 year ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIZE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports ('000 tons)</td>
<td>31.2</td>
<td>137.8</td>
<td>69.8</td>
<td>38.8</td>
<td>89.7</td>
<td>93.7</td>
<td>76.8</td>
</tr>
<tr>
<td>Water (Mm³/a)</td>
<td>83.2</td>
<td>367.5</td>
<td>186.1</td>
<td>103.5</td>
<td>239.2</td>
<td>249.9</td>
<td>204.8</td>
</tr>
<tr>
<td>WHEAT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports ('000 tons)</td>
<td>27.0</td>
<td>34.5</td>
<td>49.5</td>
<td>37.8</td>
<td>56.8</td>
<td>28.6</td>
<td>39.0</td>
</tr>
<tr>
<td>Water (Mm³/a)</td>
<td>72.0</td>
<td>92.0</td>
<td>132</td>
<td>100.8</td>
<td>151.5</td>
<td>76.3</td>
<td>104.2</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imports</td>
<td>58.2</td>
<td>172.3</td>
<td>119.3</td>
<td>76.6</td>
<td>146.5</td>
<td>122.3</td>
<td>115.8</td>
</tr>
<tr>
<td>Water (Mm³/a)</td>
<td>155.2</td>
<td>459.5</td>
<td>318.1</td>
<td>204.3</td>
<td>390.7</td>
<td>326.1</td>
<td>309.0</td>
</tr>
</tbody>
</table>

These estimates represent a 6 year average. Given population growth of 3% per annum, and the subsequent growth in the demand for basic grains and water that this implies, it is clear that if self-sufficiency in basic grains is achieved, demands for water and land will increase significantly. By the year 2015 over 500Mm³/a and by the year 2030 over 800Mm³/a of water will be required under these assumptions. This assumes that present domestic production also increases at 3% per year. Should this domestic production remain constant over the time horizon used, the water requirements will be 654 Mm³/a and 1 140Mm³/a for years 2015 and 2030 respectively. These predictions are shown in Table 5.30. Obviously predictions so far into the future are uncertain.

Table 5.30: Predictions of Grain Imports, Land and Water Requirements for Self-Sufficiency.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>2015</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grain ('000 tons)</td>
<td>Land ('000 ha)</td>
</tr>
<tr>
<td>Maize</td>
<td>130.80</td>
<td>21.8</td>
</tr>
<tr>
<td>Wheat</td>
<td>66.45</td>
<td>11.075</td>
</tr>
<tr>
<td>Total</td>
<td>197.26</td>
<td>32.875</td>
</tr>
</tbody>
</table>

The amount of water required to allow self-sufficiency in basic grains at present is more than Namibia used in 1996, estimated at 250Mm³ (Day, 1997). The average water requirement added to the consumption of water in Namibia represent more than the estimated safe yield of Namibia's domestic water sources. Domestic water sources are made up of approximately 200Mm³/a from surface water sources and 300Mm³/a from groundwater, depending upon the rainfall in a given year (Heyns P, 1991). This means that to pursue self-sufficiency in basic grains requires full development of Namibia's domestic water resources and water from the perennial border rivers. Water from the

38 This represents growth with respect to population. It ignores potential income effects which could be either positive or negative. Growth in overall grain "utilisation" has averaged 11% over the past six years. So growth in natural resource demands could be greater than suggested by table 5.29
border rivers is subject to an agreement from relevant basin states in line with the appropriate international protocols and agreements on international watercourses.

Water is not the only physical constraint to food self-sufficiency. It has been estimated that there are 25 500ha of irrigable land in Namibia. Currently 6 000ha are being irrigated. Table 5.30 shows how the available irrigable land is also a binding constraint to food self-sufficiency.

5.8.1.4 Costs of Water Supply and the Value of Virtual Water

The cost of water supply will also be a restrictive component to the policy of self-sufficiency. The prime land for irrigation expansion is in along the banks of the perennial rivers. However, it has been shown that a significant amount of Namibia’s internal water resources will be required to expand irrigation to the extent necessary for self-sufficiency. The movement of this water to areas suitable for irrigation will require investments in infrastructure for this purpose. Given the low value of the crops that would be grown, and the unviable nature of present government irrigation schemes, it is questionable whether irrigation of basic grains would economically justify investment in such infrastructure. It would be necessary for the government to invest in such infrastructure since only high value crops can be commercially viable under large scale irrigation in Namibia. Other economic uses for funds: education and health, for instance, suffer as a result.

It should be noted that not all the virtual water is necessarily available for use in other sectors for these reasons. However, higher value uses for water are more likely to make investments in water supply economically viable, whilst virtual water frees water that is crowded out by such low value uses as irrigation of basic grains.

5.8.1.5 Economic Considerations

Water demands will make self-sufficiency unsustainable in the future, since this will require complete devotion of Namibia’s domestic annual water resources, and a significant tranche from the perennial rivers in the near future. In the long-term this policy would require the transferral of water from all other productive and domestic uses in favour of basic grain production. There are severe natural resource constraints to the pursuit of a policy of self-sufficiency in basic grains. In these terms the policy is unsustainable. Furthermore, the implications of moving water away from other productive uses, including domestic usage at the extreme end of the resource constraint, mean that the policy will also be inequitable and uneconomic.

Commercial irrigated agriculture currently accounts for 44% of the total water consumption in Namibia. In 1993 the agricultural sector as a whole contributed 5.2% of Namibia’s total output and 7.5% of the total value-added (see Section 5.4). When compared to other productive uses of water such as the mining sector, manufacturing and fisheries, agriculture yields a very low value-added. This implies that the movement of water away from other productive uses, which will be required in the future, should self-sufficiency in basic grains pursued, will also be economically damaging to Namibia. By this measure all other sectors are more productive with their water.

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39 Etunda for example.
40 Remembering that in some places irrigation is the only possible use for available water.
The question for Namibia now becomes: how is food security to be achieved given the limits of natural resources to sustain domestic production and the economic damage self-sufficiency will entail?

Given that water is the primary limiting factor, it becomes pertinent to look at ways in which Namibia can overcome its water limitations.

5.8.1.6 Virtual Water and Food Security

The issues of food security and food self-sufficiency are highly related to the issue of virtual water. Given that in the long term water will be a binding constraint to pursuing self-sufficiency, policy may look towards virtual water to ensure food security for the nation, whilst promoting other economic uses for Namibia's own water resources.

Namibia appears not to have a distinct advantage over South Africa in the production of wet goods and less so an advantage in the production of low value crops meant for domestic consumption. As an indication of this it has been estimated that one ton of maize costs N$800 to produce in South Africa and between N$1 200 and N$1 400 in Namibia (Heyns et al. 1998).

One manner in which the natural resource constraints, which bind a policy of self-sufficiency in basic grains, can be circumvented is through the import of virtual water in the form of imported grain from other countries, mainly South Africa. This represents a trade in virtual water as occurs globally when wet goods are traded and imported to dry countries, as is the case in Israel. The theory is that domestically produced goods are traded for the foodstuffs, specialization occurs according to comparative advantage, and countries gain through increased economic growth. The global trade in Virtual Water allows wet goods to be produced in countries that are most apt to produce them.

Food security can be achieved in this way since incomes can be augmented and entitlements to food increased. Self-sufficiency may not achieve food security since the gains from trade will not be exploited and economic access may not be increased to the same extent. Furthermore, once the natural resource constraints are met self-sufficiency becomes impossible.

5.8.2 WATER AND GOVERNMENT POLICY

The discussion about virtual water and food self-sufficiency brings to light the need for coherence in the over-riding objectives of government with the policies that are being advocated in the water sector itself. Economic pricing, other water demand management policies, decentralisation and community based management, regulation and monitoring are all being advocated by commentators in the water sector. However, if in developing other economic and social policies, social targets such as unemployment, food security and poverty and other constraints that exist, are not carefully considered in respect of the water sector, the benefits of sound water management policies may be negated or at least severely reduced.

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41 There is no reason why this cannot be considered as an import of virtual quality land as well.
5.9 OVERVIEW

The sustainable development of Namibia is dependent on a sustainable water supply. Due to the increasing demand for water, additional supply from the traditional water sources is becoming increasingly expensive and less accessible. Alternative sources and particularly alternative management approaches are being developed to ensure the supply, and manage the demand for water, and these alternative approaches will become more important in the future. All Namibians must recognise the limitations imposed by water for sustainable development of Namibia and turn these constraints into useful opportunities.

There are several major issues with respect to the water sector in Namibia:

- traditional sources of water are either diminishing beyond the point of being accessible for development or are very expensive to develop. Alternative approaches to water supply must be undertaken by authorities and accepted by water users. Such alternative approaches, some already being used on a small scale, include conjunctive use, the use of unconventional water, artificial recharge and the desalination of water.

- water demand management has been implemented very successfully by Windhoek water engineers. These practices should be investigated and implemented throughout the country where feasible.

- the economics of water supply and demand is a powerful tool to guide planning of water development, but economics has not been fully incorporated into the planning process to date. Full cost recovery, including environmental and economic externalities and opportunity costs, in addition to capital charges and operation and maintenance costs, should be the basis for decision making and pricing. Small scale cross-subsidies to assure a "life-line" amount of water should be the only exception to the principle of fuel cost recovery.

- the demand of the ecological reserve is not currently considered in the provision of water supply and must be taken into account in every water development with a view to ensuring sustainability in water use. Rehabilitation of the ecological reserve, where appropriate, should be considered as the reserve is an important provider of services and processes.

- using a holistic approach to water supply and demand, as well as the use to which it is put, is an essential component of sustainable development not currently applied.

- efficiency and effectiveness of water use is not currently a primary objective of providers or users of water, although it should be to ensure sustainability of water supply.
5.9.1 PRIORITISED MAJOR REQUIREMENTS, CONCERNS, THEMES, STRATEGIES AND MANAGEMENT CONSIDERATIONS FOR SUSTAINABILITY

The first priority for Namibia in terms of its water supply is to apply a more holistic approach to supply as well as demand and use. Table 5.31 provides an overview of important concerns and themes to be addressed.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental principles</td>
<td>Overall goals for social, economical and environmental sustainability of water supply and use</td>
</tr>
<tr>
<td></td>
<td>Prioritised entitlements for water use with special reference to the environment</td>
</tr>
<tr>
<td></td>
<td>Water as an economic and social good</td>
</tr>
<tr>
<td></td>
<td>Recognition of the importance and value of wetlands</td>
</tr>
<tr>
<td></td>
<td>Consideration of water underlying all development plans</td>
</tr>
<tr>
<td></td>
<td>Consideration of water in Namibia's population policy</td>
</tr>
<tr>
<td></td>
<td>Linkage of water supply and sanitation</td>
</tr>
<tr>
<td>Water supply from traditional sources</td>
<td>Appropriate and innovative management of existing supplies, e.g. conjunctive use</td>
</tr>
<tr>
<td></td>
<td>Reduction of unaccounted-for water losses</td>
</tr>
<tr>
<td></td>
<td>Pollution prevention</td>
</tr>
<tr>
<td></td>
<td>Establishment of an environmental reserve</td>
</tr>
<tr>
<td></td>
<td>Dependence on shared water from perennial rivers</td>
</tr>
<tr>
<td></td>
<td>Management of catchments and basins within Namibia and shared with neighbours</td>
</tr>
<tr>
<td>Water supply from unconventional sources</td>
<td>Optimal use of recycled, reused and reclaimed water</td>
</tr>
<tr>
<td></td>
<td>Enhanced desalination techniques</td>
</tr>
<tr>
<td></td>
<td>Enhanced use of artificial recharge</td>
</tr>
<tr>
<td>Economics of water supply and use</td>
<td>Recognition of the use of virtual water for decision making</td>
</tr>
<tr>
<td></td>
<td>Utilisation of economic evaluation as a planning tool</td>
</tr>
<tr>
<td></td>
<td>Assessment of &quot;value added&quot; for use as planning tool</td>
</tr>
<tr>
<td>Financial policy</td>
<td>Use block tariffs as tool to manage demand</td>
</tr>
<tr>
<td></td>
<td>Full cost recovery as goal for tariff levels</td>
</tr>
<tr>
<td></td>
<td>Development of pricing strategy to accommodate subsidies for 'life line' water supply</td>
</tr>
<tr>
<td>Use of water</td>
<td>Increased awareness and implementation of efficient and effective use of water</td>
</tr>
<tr>
<td></td>
<td>Utilisation of economic considerations for planning</td>
</tr>
<tr>
<td></td>
<td>Consumptive vs non-consumptive use</td>
</tr>
<tr>
<td>Water demand</td>
<td>Expanded Water Demand Management practices, policies and awareness</td>
</tr>
<tr>
<td></td>
<td>Acknowledgement of environmental reserve</td>
</tr>
<tr>
<td>Management of water</td>
<td>Every Namibian is a water manager</td>
</tr>
<tr>
<td></td>
<td>Management of water demand, not just supply</td>
</tr>
<tr>
<td></td>
<td>Management to support efficient and effective use</td>
</tr>
<tr>
<td></td>
<td>Management to enhance sustainability</td>
</tr>
<tr>
<td>Information</td>
<td>Monitoring systems</td>
</tr>
<tr>
<td></td>
<td>Information management systems</td>
</tr>
<tr>
<td></td>
<td>Information coordination and dissemination</td>
</tr>
<tr>
<td></td>
<td>Cost of water well publicised</td>
</tr>
</tbody>
</table>
5.10 KEY INDICATORS

5.10.1 POTENTIAL SECONDARY INDICATORS

Key indicators for water supply and demand have been developed and are presented in paragraph 5.10.2. Table 5.32 below lists other potential indicators that can be considered and for which data should be collected.

Table 5.32: Potential indicators of development of water supply, demand and use

<table>
<thead>
<tr>
<th>Definition of indicator</th>
<th>Data collection and calculation</th>
<th>Uses of indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per cent use of water resource: Quantity of water consumed from a specific water source as a percentage of its sustainable yield</td>
<td>Major water sources to be identified. Present annual consumption figures collected from supply authorities. Sustainable yield figures from previous studies.</td>
<td>For identification of sources nearing maximum sustainable use. To assist planning of future projects and supplementation schemes. To inform water managers of status of sources.</td>
</tr>
<tr>
<td>Percentage of population within specified distance of safe drinking water: Percentage of consumers within 2km, 2-5km, &gt;5km of safe drinking water.</td>
<td>Estimates of population for rural areas. Compare with operational boreholes and rural pipeline networks on regional basis. [Could use array of sentinel sites]</td>
<td>To assist CWCs in future planning of rural water supply. To establish priorities for future funding. To inform water managers of status of provision.</td>
</tr>
<tr>
<td>Per capita consumption: Per capita consumption of all water on a national and regional basis, differentiating between rural and urban</td>
<td>Total water consumption figures collected from supply authorities, and population figures from census, updates and other studies.</td>
<td>Measure of: accessibility to safe water; socio-economic state; effectiveness of demand management; to assess sustainability.</td>
</tr>
<tr>
<td>Consumption per sector: Percentage of total water consumption used by: people, animals, irrigation, industries, mining</td>
<td>National and regional data collected from supply authorities and existing studies.</td>
<td>Potential to assess value added per sector. Measure of socio-economic status of regions. Identify areas for policy adjustment.</td>
</tr>
<tr>
<td>Actual Demand/ Projected Demand Ratio: Actual growth in consumption of water divided by projected demand for each major demand centre</td>
<td>Actual consumption figures collected from supply authorities, and compared with earlier projections made at the planning stage.</td>
<td>To support demand management programmes. To assist in updating estimates of life expectancy/ sustainable use of water sources. As warning to planners to adjust demand predictions.</td>
</tr>
<tr>
<td>Reclaimed Water/ Total Water Consumed Ratio: Volume of water reused and reclaimed as a ratio of the total volume of water consumed. National figure, and figures for major demand centres.</td>
<td>Water reclamation and water consumption figures from supply authorities</td>
<td>An indicator of how effectively an available water resource is being used. A measure of effectiveness of demand management programmes.</td>
</tr>
<tr>
<td>Unaccounted-for water: Total quantity of bulk water produced and delivered into a reservoir before distribution/ losses due to pipe breakages, ineffective measurement and leakages</td>
<td>Data collected from bulk water supply agencies, municipalities and other suppliers.</td>
<td>Measure of maintenance efficiency, condition of distribution networks and effectiveness of accounting systems. Measure of effectiveness of demand management programmes.</td>
</tr>
<tr>
<td>Subsidised water: Volume of water subsidised (partly and entirely) / total water consumed; by sector.</td>
<td>Data collected from bulk water supply agencies, municipalities and other suppliers.</td>
<td>Measure of socio-economic status and progress towards national goal of cost recovery for water supply.</td>
</tr>
<tr>
<td>Mean water cost vs per capita GNP: mean cost of water/ per capita GNP</td>
<td>Data from NamWater and Bank of Namibia</td>
<td>Provide indication of cost of water to nation; Basis for information dissemination</td>
</tr>
<tr>
<td>Value added by sector: value added per cubic metre of water used for specific sectors</td>
<td>Data from National Accounts project of MET;</td>
<td>Indication of the effective use of water on a national basis.</td>
</tr>
<tr>
<td>Area of irrigated cropland: number of hectares under irrigation from various sources</td>
<td>Data from MAWRD, NDC</td>
<td>Degree to which water is used for ineffective purposes</td>
</tr>
<tr>
<td>Proportion of water from unconventional sources: proportion of water from desalination; proportion of water conserved by conjunctive use and by artificial recharge</td>
<td>Data collected from bulk water supply agencies, municipalities and other suppliers, as relevant</td>
<td>Measure of innovative use and conservation of limited resource</td>
</tr>
<tr>
<td>Water self sufficiency: the proportion of Namibia’s total annual water consumption derived from sources originating outside of the country/ total consumption</td>
<td>Consumption from external sources (border perennial rivers) from bulk water supplier and estimates for direct domestic use</td>
<td>Measure of dependence upon external water sources as an indicator of availability of water</td>
</tr>
</tbody>
</table>

### 5.10.2 KEY INDICATORS

The key indicators for the health of Namibia’s water supply are shown below.

Water consumed as a percentage of the potential of supply from each of the water resource types, namely ephemeral, perennial, ground and unconventional. These are presented in Table 5.33 below.

#### Table 5.33: Percentage use of water per resource type

<table>
<thead>
<tr>
<th>RESOURCE TYPE</th>
<th>CURRENT CONSUMPTION Mm³/a</th>
<th>POTENTIAL YIELD Mm³/a</th>
<th>INDICATOR(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater</td>
<td>136</td>
<td>300</td>
<td>45.3</td>
</tr>
<tr>
<td>Ephemeral rivers</td>
<td>53</td>
<td>200</td>
<td>26.5</td>
</tr>
<tr>
<td>Unconventional</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Perennial rivers</td>
<td>107</td>
<td>600(^2)</td>
<td>17.8</td>
</tr>
</tbody>
</table>

\(^1\) (Current consumption / Potential yield) \times 100  
\(^2\) Estimated long term requirement

Given the importance of efficient usage of limited water resources in Namibia, and the strong influence that proper pricing has on efficiency, the extent of cost recovery is also seen as a crucial indicator. This is most readily available for the bulk water supply sector at present but it is recommended that equivalent indicators be developed for Local Authorities and Rural Water Supply in the future. The weighted NamWater tariff is shown in Table 5.16 in section 5.4.4.1. The regional variations are shown in Table 5.17 of the same section. These are explained further in the key indicators section.

Unaccounted for water is also considered to be a key indicator of the efficiency and effectiveness of urban water management. This is found in section 5.3.1.7 in Table 5.9.
The value added per m³ of water used is also considered to be a key indicator. This indicates the current value of water in different sectors of the economy and can aid the formulation of efficient and economically sound development policies. This is found in section 5.4.1, in Table 5.11.
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6. INSTITUTIONAL RESPONSIBILITIES, ROLES AND MANDATES FOR MANAGEMENT OF THE WATER SECTOR

6.1 INTRODUCTION

Water is an essential resource affecting all aspects of life in Namibia. Because water appears to 'come from God' and exist as a free commodity on one hand, and to be a scarce and costly commodity on the other, its use and management have evolved considerably over the past century. At the turn of the century, people and their livestock used any available source of water, be it wells, springs, flowing surface water or shallow underground water. Some specific water points were controlled by individuals or groups of people and battles were fought over access to water. With population growth, the changing political situation and the introduction of technology, uses and management of water have changed (Stern and Lau 1990).

Today a wide range of institutions are responsible for different aspects of water supply, management and use (Heyns et al. (eds.) 1998). These institutions range from dedicated Government departments and parastatal institutions through municipalities and Water Point Committees to private organisations and individuals. Their activities are guided by a variety of legislation, policies and regulations that, nevertheless, still do not address all aspects of water management. Finding and exploiting sufficient water to supply an increasing demand has been the main focus of water management until the present decade. Only recently have concepts such as Integrated Water Resource Management, Water Demand Management, Adaptive Management and recognition of the ecological requirements, services and processes of natural water ecosystems been recognised in Namibia, following global awareness and concern for water as a limited resource (e.g. van der Merwe (ed.) 1999). The institutional response has not yet been adequate to address all these growing concerns for water as a limited and essential resource in arid Namibia.

6.2 CENTRAL GOVERNMENT AND RELATED PARASTATALS

The Constitution of the Republic of Namibia claims State ownership and responsibilities for all water not otherwise owned (Constitution 1990). As a consequence, the Government is responsible for overall management of the water sector although some responsibility may be accepted by the institutions it designates. Responsibilities for water range from identification of water sources, development of water sources, purification of water and bulk distribution to distribution reticulation, quality control and assessment, conservation and protection of the resource, and research and monitoring (Heyns et al. (eds.). 1998).
6.2.1 MINISTRY OF AGRICULTURE, WATER AND RURAL DEVELOPMENT

The Ministry of Agriculture, Water and Rural Development promotes and facilitates sustainable development of agriculture, including rural development, and water in Namibia. The Department of Water Affairs, *inter alia*, administers the Water Act, promulgates regulations, is responsible for equitable and reasonable allocation of water, controls water pollution, undertakes research and monitoring of water resources and implements water resource management. To date, water supply rather than management or conservation of the resource itself has been the primary focus of the Department of Water Affairs although the DWA, in the process of supplying water, has initiated and implemented conjunctive use, integrated use and systems use as management tools (Heyns et al. (eds.) 1998).

The Directorate of Rural Water Supply, through its Division of Rural Water Development, is responsible for rural water supply infrastructure and planning. Two divisions of Rural Water Supply, one each for the north and the south of the country, implement community based management and will address cost recovery. This Directorate was established in 1993 in response to the Water Supply and Sanitation Sector Policy, and is in a process of continuous change (DWA 1993). Its overall goal is to support a system of community based management of water supply while directly assuring that the resource itself is used in a sustainable manner. Communities will own water supply infrastructure, by means of a Permission to Occupy (PTO). They will operate and maintain this infrastructure on a cost recovery basis. This will be implemented over a ten year period commencing in August 1997.

To that end, the Directorate of Rural Water Supply has initiated a Management Information System (MIS) that is designed for implementation in all rural water supply regions. The MIS is already installed in Caprivi, Karas, Kavango, Kunene South and Omaheke Regions. The MIS includes information on infrastructure: equipment and structures, including source details: diameter of pipes, depth of boreholes, yield and quality of water and information on community based management: number of water point committees and their effectiveness.

The Directorate of Resource Management is responsible for assessing the water resource potential of Namibia and for long-term strategic planning. Its Division of Law Administration is responsible for administration of the Water Act and for issuing of permits, for the abstraction of water from boreholes in the Underground Water Control Areas, for the withdrawal of water from rivers in excess of that required to irrigate one hectare of land, and for the construction of dams of a capacity larger than 20 000 cubic metres. In respect of the discharge of waste water, control is exercised by issuing exemption permits from the Division of Law Administration after investigation by the Pollution Control Section of the Division of Water Environment and in consultation with the Ministry of Health and Social Services or Ministry of Mines and Energy. The Directorate of Law Administration does not have its own relevant data base, making it difficult to collate data related to water abstraction or effluent disposal by permit holders.

Surface water resources fall under the Divisions of Hydrology and Water Environment and groundwater resources fall under the Division of Geohydrology. Each of these divisions maintains its own relevant data base. A Division of Planning addresses long-term strategic
planning while the Division of Water Environment addresses environmental management, pollution control, water quality and ecological research (limnology, river surveys, biomonitoring, aquatic weed control).

The Directorate of Resource Management maintains a system of permitting. For use of surface water, as described above, an investigation and report is required from a departmental hydrologist and for use of groundwater from a departmental geohydrologist. The opinion of the Ecological Research Section is usually sought too. If the resource allows, permits are issued, usually valid for five years, and may be extended. An annual programme of inspection has been set up but is dependent on limited personnel and funding.

The National Botanical Research Institute in MAWRD collects and curates all wetland and aquatic plants. The Ecological Research Section of DWA coordinates the National Water Awareness Campaign and is responsible for all aspects of Environmental Education related to water.

Recently (1998), the Ministry of Agriculture, Water and Rural Development has instituted the Namibian Water Resource Management Review to review the entire water sector.

6.2.2 NAMWATER

NamWater is the commercialised institution responsible for supply of bulk water to municipalities, the Directorate of Rural Water Supply and other authorities. Although supplying water directly to the Directorate of Rural Water Supply for further distribution to rural communities, it currently has no formal agreements with this Directorate. Established by the Namibian Water Corporation Act No 12 of 1997, NamWater has taken over the responsibility for bulk water supply from the Department of Water Affairs and is continuing services as previously supplied. However, formal agreements and written relationships among the various parties detailing responsibilities, roles and mandates for NamWater have not been elaborated. NamWater has also taken over responsibility for some of the data gathering and updating of the data bases for water supply infrastructure previously handled by the DWA. There appears to be dissatisfaction by DWA with this arrangement and concern related to continued access to the data and to whether NamWater will collect the appropriate and necessary data to adequately manage the resource.

This Ministry has the dual responsibility for assuring the national interests in sustainable use and development of water while devolving control of water supply to the lowest appropriate level. This has implications for institutional structure and personnel as highly skilled water engineers are needed, who may not be totally familiar with community based management principles and activities, as well as community mobilisers and others not necessarily familiar with the overall water situation in their area or in Namibia.

6.2.3 MINISTRY OF WORKS, TRANSPORT AND COMMUNICATION

Shortly after Independence, the Ministry of Works, Transport and Communication constructed a large number of additional schools, clinics, border posts and police stations in remote areas. These required dedicated water supply systems due to their isolation. The
Department of Works carried out the necessary exploitation and implementation but is finding these supply systems impossible to maintain on behalf of the Ministry of Basic Education and Culture, the Ministry of Lands, Resettlement and Rehabilitation, the Ministry of Regional and Local Government and Housing, the Ministry of Health and Social Services, and the Ministry of Defense. NamWater and the Directorate of Rural Water Supply are expected to take over full operation including investigations, assessment, development, exploitation, management and operation. Funding is, however, a problem.

The Weather Bureau in the Directorate of Planning and Transport Management maintains a network of weather stations with rain gauges and evaporation measurement sites throughout Namibia. As illustrated in Chapter 2, this network is inadequate for Namibia's current needs for planning information.

6.2.4 MINISTRY OF ENVIRONMENT AND TOURISM

With respect to water, the Ministry of Environment and Tourism has several important functions. The Ministry of Environment and Tourism is responsible for coordinating environmental assessments in Namibia. The Environmental Assessment Policy, approved by Cabinet in 1994, requires assessments of all projects, programmes, plans and policies. Draft legislation in the form of the Environmental Management Act is currently being prepared to support the role of the Ministry to coordinate, oversee and enforce implementation of Environmental Assessments where warranted.

Namibia is signatory to four important environmental conventions that relate to water, directly or indirectly, for which the Ministry of Environment and Tourism has been assigned national responsibility. To this end, the Ministry, through the Directorate of Environmental Affairs, implements programmes to address Namibia's responsibilities under the conventions.

- The United Nations Convention on Biological Diversity is concerned with the conservation and sustainable use of biological diversity including conservation of genetic materials, species, habitats and ecosystems. All species, habitats and ecosystems affected by or affecting water are of interest to this convention. The recently published country study on biodiversity includes a chapter on terrestrial and freshwater ecosystems (Barnard ed.) 1998).

- The United Nations Convention on Wetlands of International Importance, especially as Waterfowl Habitat, is known as the 'Ramsar Convention' after the town in Iran where it was signed in 1971. This convention provides the framework for international cooperation for the conservation of wetlands. Four sites have been designated as 'Ramsar Sites' in Namibia: The Orange River Mouth (a joint site with South Africa), the Walvis Bay Lagoon, Sandwich Harbour and Etosha Pan; 13 additional sites have been identified. In global terms, wetlands are estimated to be the most valuable ecosystems in the world, valued at over US$ 10 000 per hectare.

- Namibia is a signatory to the United Nations Convention to Combat Desertification as one of those countries experiencing serious drought and/or desertification, particularly in Africa. Through ratification in 1997, Namibia has pledged to combat desertification and
mitigate the effects of drought through rehabilitation, conservation and sustainable management of land and water resources contributing to improved productivity of the land and improved living conditions, particularly at the community level. Desertification is defined as land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities (Wolters ed.) 1994.

- Namibia is a signatory to the United Nations Framework Convention on Climate Change. The Namibian Parliament ratified that convention in 1996, pledging to help stabilise the greenhouse gas concentrations in the atmosphere to prevent interference with the earth’s climate system. As a small, developing country Namibia contributes little to the accumulation of greenhouse gases, however, but is affected by what other countries throughout the world are contributing. Preparation for adaptation to the impacts of climate change, including impacts on water, should be Namibia’s major focus in this regard (Blackie, du Plessis, Tarr 1999).

The Ministry of Environment and Tourism employs a ‘wetlands biologist’ responsible for water supply and wetlands in all parks and for overseeing the implementation of the MET wetland policy.

The Ministry of Environment and Tourism is responsible for water supply to tourist camps and parks.

6.2.5 MINISTRY OF HEALTH AND SOCIAL SERVICES

The Ministry of Health and Social Services (MHSS) has a statutory responsibility to promote and protect the health of the people of Namibia. This includes a monitoring function with respect to the chemical, biological and biochemical quality of water supplied for human consumption. In performing this function, the MHSS obtains information concerning a range of diseases from laboratories covering all regions of Namibia. Two laboratories run by NamWater, one in Windhoek and one in Oshakati, report to MHSS as well as to the Department of Water Affairs and the Ministry of Regional and Local Government and Housing. Chemical quality guidelines relate to 34 chemical substances, and bacteriological guidelines are related to four bacteriological indicators. The Ministry of Health and Social Services has four directorates of Regional Health and Social Services that monitor potability of drinking water in smaller towns and villages that do not provide their own monitoring services. There is no dedicated monitoring system for water borne and water related diseases. No water quality monitoring is carried out for rural water supply in rural communities.

The Ministry of Health and Social Services also has jurisdiction over sanitation. This presents a problematic situation as sanitation components relate closely to water management and pollution control. The MHSS holds the finances and posts for management of sanitation but has asked the DRWS to accept responsibility in the rural areas (H. Koch, pers. comm.). DRWS will only be able to assume this responsibility if resources are made available and the post structure is enlarged. The conflict between sanitation and water management is common in developing countries and requires attention now in Namibia. The Ministry of Health and Social Services is responsible for water supply to hospitals and clinics.
6.2.6 MINISTRY OF REGIONAL AND LOCAL GOVERNMENT AND HOUSING

In Namibia, local authorities are autonomous entities responsible for the delivery of municipal services such as water, sanitation, sewage and electricity. Although juristic bodies, the Ministry of Regional and Local Government and Housing has no role or mandate to fulfil with respect to water and sanitation in local authority areas except for conducting such services under an agency agreement with those local authorities which do not have the capacity, human or other resources, to maintain a suitable service in their areas of jurisdiction. The mentioned role or mandate is further subject to the policies laid down by the respective councils. Thus, the Directorate of Town and Village Administration is responsible for support to Town and Village Councils and Settlement Areas with respect to water reticulation services and waste water disposal facilities. Decentralisation of rural water supply will be a first priority of the decentralisation process championed by this Ministry.

6.2.7 MINISTRY OF LANDS, RESETTLEMENT AND REHABILITATION

The Ministry of Lands, Resettlement and Rehabilitation is responsible for resettlement of farm workers and other people onto government land, particularly commercial farms. This Ministry is responsible for establishment, operation and maintenance of small water schemes not linked to the formal water supply infrastructure. To date, they have expected water supply services from the Directorate of Rural Water Supply on an ongoing basis. Responsibility for planning, providing and maintaining water on resettlement farms has not been adequately determined by the two Ministries. Similarly, advance land use planning, including water supply, for these resettlement farms has not taken place.

6.2.8 MINISTRY OF FISHERIES AND MARINE RESOURCES

The Ministry of Fisheries and Marine Resources is responsible for research, monitoring and management of freshwater fish resources in Namibia. This Ministry operates a Freshwater Fish Research Institute at Hardap Dam. The designated responsibilities of the MFMR do not appear to present any conflicts among institutions responsible for freshwater management.

6.2.9 MINISTRY OF MINES AND ENERGY

The Ministry of Mines and Energy is responsible for power supply in Namibia, including that derived from hydropower. This Ministry has assumed responsibility for the Ruacana Hydropower Scheme, developed by the Department of Water Affairs in 1964, and has been instrumental in the feasibility study of the Epupa Hydropower Scheme.

The Ministry of Mines and Energy is consulted regarding issuing permits for disposal of effluent by large mines.

6.2.10 NAMPOWER

NamPower is responsible for development of electricity supply infrastructure and for power generation and distribution on a commercial basis. In this role it is interested in the development of hydropower, as well as other power sources, in Namibia.
6.2.11 MINISTRY OF BASIC EDUCATION AND CULTURE

The National Museum of Namibia is a component of the Ministry of Basic Education and Culture. The aim of the National Museum is ‘to preserve, understand and explain the national heritage of Namibia’. It achieves this overall aim by:
- collecting and documenting relevant, representative objects, zoological specimens and information
- curating the collections
- undertaking research to account for the natural and cultural heritage of Namibia
- promoting Museum resources through public displays and activities and providing access to collections and loans for the scientific community
- disseminating knowledge.

A collection manual for ‘aquatic invertebrates and terrestrial invertebrates other than insects, arachnids and myriapods’ has been compiled. This manual covers: collection sphere, collecting premises, collecting procedures and accessioning of material. The National Museum has a web site on Internet where the number of aquatic and semi-aquatic specimens can be obtained.

A post for a wetland biologist exists but is currently vacant.

The University of Namibia and the Polytechnic of Namibia have faculties which cover aspects of the water sector: Biology, Agriculture and Nature Conservation.

The Wetlands Working Group of Namibia represents active aquatic ecologists in government and higher education institutions: DWA, MET, MRMR, MBEC (museum), MAWRD (herbarium), University of Namibia and Polytechnic of Namibia. They address wetland policy, inventories and classification and promote coordination, awareness and exchange of information.

The Ministry of Basic Education and Culture is responsible for water supply to schools and school hostels.

6.2.12 MINISTRY OF HOME AFFAIRS

The Ministry of Home Affairs is responsible for water supply to police posts, military bases and border posts.

6.3 REGIONAL GOVERNMENT/ LOCAL AUTHORITIES/ COMMUNITIES

Population centres may obtain their water requirements from the bulk supplier or develop and manage their own water sources, or a combination of the two.

6.3.1 MUNICIPALITIES AND LARGER CENTRES

Larger centres, currently including Gobabis, Grootfontein, Karibib, Keetmanshoop, Mariental, Otjiwarongo, Swakopmund, Tsumeb, Walvis Bay and Windhoek, have Municipalities that take responsibility for purchase of water from the bulk supplier, monitor
bacteriological quality of drinking water supply and are responsible for water reticulation and sewage disposal. Otjiwarongo, Swakopmund, Tsumeb, Walvis Bay and Windhoek also recycle water for further use. Windhoek also manages its own boreholes and reclams domestic sewage to potable standard for domestic use.

All Local Authorities, under the Local Authorities Act No 23 of 1992, are responsible for:
- supplying water to the residents in their area for household, business or industrial purposes
- providing, maintaining and operating a system of sewage and drainage for the benefit of the residents in their area
- providing, maintaining and operating services to such residents for the removal, destruction or disposal of night soil, rubbish, slopwater, garden and stable litter, derelict vehicles, dead animals and all other kinds of refuse or otherwise offensive or unhealthy matter.

6.3.2 COMMUNITIES

The Directorate of Rural Water Supply is responsible for assuring adequate water supply to small rural communities. Their activities are guided by the Water and Sanitation Sector Policy (WASP) which was approved by Cabinet in 1993 (DWA 1993). In response, the Directorate of Rural Water Supply has developed Strategy Papers on the following topics (DWA 1994):
- Ownership of rural water supply schemes and individual water points
- Introduction of payment for the service of water supply
- Sector coordination
- Legal status of water committees
- Monitoring and evaluation system
- Relationship between the Water Point Committee, the Local Water Point Committee, the Central Water Committee and the Department of Water Affairs
- Implementation of rural water supply schemes
- Operation and maintenance of rural water supply equipment

Rural communities, through their Water Point Committees, are expected to become responsible for their own water points, and their finance, and to assure cost recovery of maintenance and operational costs of this water supply in the future. Ownership of supply facilities has legal implications that are currently being investigated. The concept of cost recovery and local management of funds has been approved by Cabinet and is expected to be implemented over a ten year period. The modus operandi is currently in question, however, as the Ministry of Regional and Local Government and Housing wants the payments for water to be paid to that Ministry rather than making rural communities responsible for their own resources.
6.5 MISSING INSTITUTIONS

Although legislation in the form of the Water Research Act No 34 of 1971 (refer to Chapter 7) provides for relevant research through the establishment of a water research commission and fund, no appropriate institution has been created in Namibia. Instead, various departments, divisions and sections within the DWA, and recently NamWater, have established and manage their own research and monitoring schemes and associated databases. A limited degree of cooperation takes place as some of these data bases are shared between users within the sector.

Namibia could benefit from a well-directed and coordinated water research programme that draws input from the water corporation, water authorities, the University and Polytechnic, NGOs, the private sector and others to address country-specific issues of water management and supply.

To effectively design and coordinate an integrated water research programme, a central body, for example a National Water Research Institute, should be established. This body could coordinate and prioritise, but not dictate, research needs; could establish a central fund and help source additional funds for research; could facilitate but not execute research projects and could serve as a central information source. Components of a National Water Research Institute could include:

- central repository of grey (unpublished reports) literature and other relevant literature for use by all researchers in Namibia
- forum for prioritisation, coordination and information exchange among research projects and researchers on all levels, national and international
- forum for setting standards and harmonising data acquisition, archiving, manipulation and use
- data base management when suitable capacity is established
- establish research training priorities, coordinate training opportunities and serve as a repository for information concerning training nationally and internationally with respect to water research
- contribute to awareness creation through facilitation of the popularisation and dissemination of research results to decision makers and all water users and managers.

Much research and awareness creation has taken place in Namibia for many years and a National Water Research Institute could build on and consolidate the efforts of the many existing and potential players in this field.
6.4 THE PRIVATE SECTOR

6.4.1 COMMERCIAL FARMERS

Commercial farmers are entirely responsible for their own water provision and management and for waste water management. They were expected to provide a record of boreholes drilled to the Department of Water Affairs before receiving a subsidy on the water work. There is no provision for sustainable use of groundwater aquifers other than in groundwater control areas or those measures which farmers implement in their own self interest.

When constructing dams of greater than 20 000 m³ capacity, anyone, including commercial farmers, requires the permission of the Department of Water Affairs. The construction of dams is inspected by the Division of Hydrology. Further inspections are carried out infrequently depending on the availability of personnel and resources. For dams of less than 20 000 cubic metres, permits are issued by the Directorate of Extension and Engineering of the Department of Agriculture and Rural Development, and inspections are carried out by that Directorate. The involvement of two different departments within the Ministry of Agriculture, Water and Rural Development is problematic and would appear to prevent holistic planning.

6.4.2 MINING COMPANIES

Mining companies either provide for their own water needs independently of the Department of Water Affairs or they purchase bulk water, at cost, from NamWater. Mines are also responsible for their own waste water disposal management, as permitted by the DWA. DWA controls water use and waste water disposal only in groundwater control areas. There is no provision for sustainable use of water other than the economic incentive of reducing water use to reduce costs.

6.4.3 LODGES AND CONCESSIONS

Lodges and concessions, similar to commercial farmers, are entirely responsible for their own water provision and management and for waste water management. DWA controls water use and waste water disposal only in groundwater control areas. There is no provision for sustainable use of water other than that which owners or managers implement in their own self interest. Some lodges and concessions are motivated by their ‘green’ interests or those of their clients, to implement appropriate water management and use policies.

6.4.4 ALL INDIVIDUALS

All individuals using water are managing water to a degree. Individual managers are often unaware of their role as water managers and therefore often do not contribute to the sustainable management and use of water. In some instances, economic incentives guide individual water managers and users. Education is a second important component in encouraging sustainable management and use by individuals.

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222
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</tbody>
</table>

A significant contribution of Donor Agencies to the water sector has been the introduction of the process of Environmental (Impact) Assessments and their application to many of the water supply development projects. Of the 57 Environmental Assessments carried out in Namibia since 1980, only four refer to water projects (J-J Dohogne, pers. comm.). It appears that this first compilation is incomplete, however, and 16 known Environmental Assessments related to water are included in Table 6.3 below. In addition, other Environmental Assessments, e.g. for roads, have taken impacts on water resources into consideration, but are not listed below. An indication of the proportion of all projects for which Environmental Assessments are undertaken is not readily available but this number is thought to be increasing.

Table 6.3: Environmental assessments related to water supply and development.
(Dohogne pers. comm., EEAN pers. comm.)
<table>
<thead>
<tr>
<th>Rehabilitation of water points</th>
<th>1996</th>
<th>Africa/Namibia</th>
<th>USAID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capriv Rural Water Supply: Katima Mullo and Kongola</td>
<td>DWA</td>
<td>Kreditanstalt für Wiederaufbau</td>
<td></td>
</tr>
<tr>
<td>Khan River aquifer recharge</td>
<td>1997</td>
<td>Rössing Uranium</td>
<td>Rössing Uranium</td>
</tr>
<tr>
<td>Okavango-ENWC water carrier</td>
<td>1997</td>
<td>MAWRD, DWA</td>
<td>DWA</td>
</tr>
<tr>
<td>Upgrading of Lüderitz Water Supply</td>
<td>1997</td>
<td>NamWater</td>
<td>Spanish Association for International Cooperation</td>
</tr>
<tr>
<td>Abenab Mine Water Source</td>
<td>1997</td>
<td>DWA/ Namwater</td>
<td>Norway</td>
</tr>
<tr>
<td>Feasibility for Water Supply to Oshivelo-Ondolo Area</td>
<td>1999</td>
<td>MAWRD, DWA</td>
<td>Italy</td>
</tr>
</tbody>
</table>

6.7 MECHANISMS FOR RESOLVING CONFLICTS

Mechanisms for resolving conflicts should be based on the presence of fora for coordination, consultation and conflict resolution amongst all interested and affected parties in the water sector and between the water sector and other relevant sectors. These fora can and do range from the international to the local level. Fora for the resolution of conflicts among or between management institutions may be the same fora used to resolve conflicts arising among or between institutions concerning legislation, policy and regulations. One of the major conflicts to overcome within the water sector is avoiding further politicisation of water supply and water demand.

At the international level, Namibia is a signatory to a number of commissions and committees related to the water sector. Most are mentioned in Chapter 8 and will not be repeated here. At the national level, a number of bodies have been planned although few are currently in operation (Table 6.4) (Tarr and Blackie unpublished 1998).

Table 6.4: National bodies for coordination of sustainable development including water.

<table>
<thead>
<tr>
<th>Institution</th>
<th>Functions</th>
<th>In operation 1998</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water and Sanitation Coordination Committee (Wasco)</td>
<td>Permanent Secretary level coordination of water policies and objectives</td>
<td>No</td>
</tr>
<tr>
<td>Water and Sanitation Forum (Watsan)</td>
<td>Discuss and coordinate project-level activities</td>
<td>?*</td>
</tr>
<tr>
<td>Sustainable Development Commission</td>
<td>Coordinate policies and promote integration of government policies and objectives.</td>
<td>No</td>
</tr>
<tr>
<td>Council of Traditional Leaders</td>
<td>Advise President on control and use of communal land</td>
<td>Yes</td>
</tr>
<tr>
<td>Land Reform Advisory Commission</td>
<td>Advice to Minister of MLRR</td>
<td>?*</td>
</tr>
<tr>
<td>Forestry Council</td>
<td>Advice to Minister of MET</td>
<td>?*</td>
</tr>
</tbody>
</table>
At the regional and local level, the Directorate of Rural Water Supply has been instrumental in establishing several levels of water committees (DWA 1994). The DRWS is currently working on harmonising local water committees with the community development committees of the Ministry of Regional and Local Government and Housing. However, there is a plethora of coordinating committees and the potential exists for conflicting planning and recommendations to arise from different institutions. Mechanisms for conflict resolution on this level are not yet clarified although a hierarchical order of responsibility and authority is slowly becoming defined.

In addition to the regional and local level institutions that have been established from the national level (Table 6.5), any number of regional and local initiatives have arisen. These include, for example, the Northern Namibia Forestry Committee and similar coordinating institutions that are currently growing in strength. These relevant institutions, many of which directly or indirectly affect the water sector, are not listed in this report.

Table 6.5: Regional and local level institutions. The model illustrated for water committees is currently considered flexible and it is modified in situ for particular circumstances, for example, boreholes and pipelines.

<table>
<thead>
<tr>
<th>Committee designation</th>
<th>Membership</th>
<th>Responsibilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional Water Committees (RWC), formerly Central Water Committee (CWC)</td>
<td>Members representative of a region including: elected councilors, traditional leaders, representatives of local water committees.</td>
<td>To stimulate development of rural water supply schemes. To coordinate activities of LWCs. To prioritise water development options.</td>
</tr>
<tr>
<td>Constituency Water Committees (CWC)</td>
<td>??</td>
<td>??</td>
</tr>
<tr>
<td>Local Water Committees (LWC) (work closely with Rural Water Extension Officers)</td>
<td>Traditional leaders, elected community representatives, representatives of water point committees</td>
<td>To coordinate activities of WPCs in a particular area (one water supply scheme or a natural grouping of water points). To represent interests of WPCs effectively to outside world.</td>
</tr>
<tr>
<td>Water Committees Point WPC</td>
<td>Elected by Water Point Associations using one water point.</td>
<td>Operate and maintain water point and collect contributions from users.</td>
</tr>
</tbody>
</table>

Related regional and local institutions for resource management initiated from national level

<table>
<thead>
<tr>
<th>Regional Councils</th>
<th>Elected</th>
<th>General planning in rural areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional authorities</td>
<td>Customary law and elections ratified by Minister of RLGH</td>
<td>Customary grant land allocation and advisory powers</td>
</tr>
<tr>
<td>Regional Land Boards</td>
<td>Appointees</td>
<td>Land allocation</td>
</tr>
<tr>
<td>Regional Development Committees</td>
<td>?</td>
<td>Guide and coordinate regional development</td>
</tr>
<tr>
<td>Wildlife Councils</td>
<td>Governor and appointees</td>
<td>Wildlife and tourism management</td>
</tr>
<tr>
<td>Conservancies</td>
<td>Elected</td>
<td>Wildlife and tourism management</td>
</tr>
<tr>
<td>Inland Fisheries Advisory Board</td>
<td>Governor and appointees</td>
<td>Inland fisheries management</td>
</tr>
<tr>
<td>Community forest management body</td>
<td>Representatives of community</td>
<td>Management of natural resources in a forest</td>
</tr>
<tr>
<td>Community forest reserves</td>
<td>Elected</td>
<td>Forest management</td>
</tr>
</tbody>
</table>
6.8 OVERVIEW, GUIDELINES AND INDICATORS

6.8.1 RELEVANCE TO WATER SECTOR

While the goal of economic, social and environmental sustainability in the development of Namibia is embodied in the Constitution, institutional responsibilities, roles and mandates are not fully in line with this goal nor do they adequately cover all components of water management necessary to reach this goal. The Namibian water sector requires appropriate institutions and holistic management of limited and essential water to ensure their sustainable development. Attention to alignment, overlap and complementarity among institutions, their responsibilities, roles and mandates is essential. Moreover, these responsibilities, roles and mandates must include not only water supply, for individuals, communities, farmers, towns and industry, but also the conservation, protection, planning and sustainable development, and use of water as a limited but essential national resource.

6.8.2 ASSESSMENT AND EVALUATION OF THE SITUATION IN NAMIBIA

Namibia possesses the basic institutional structure to continue, for a limited period, to supply water to its population using its current approach. It does not, however, have the necessary institutional framework to guarantee long-term social, economic or environmental sustainability of this water supply, its management or use as mandated by the Constitution. Effectiveness of the ‘higher level’ management institutions is hampered by their neglect and the consequent poor performance of the ‘lower level’ community-based management institutions. Effectiveness of management institutions is also hampered by their lack of a cross-sectoral approach to policy harmonisation, planning and implementation of essential service provision. The spreading of responsibilities among different institutions also leads to the situation that no one feels responsible and decisions are referred from one institution to the next. Politicisation of water supply and demand also hinders the effectiveness of the water sector.

In terms of the institutional framework for water management, five components require priority and serious attention. These are:

- the concept that every Namibian is a water manager, which must be fostered at all levels. This will require the education and appropriate training of ‘formal’ water managers as well as every other water user in Namibia. Formal institutions as described in the sections above are not the only managers with responsibilities for the water sector, something which they and all Namibians should recognise.

- all institutions managing water must recognise that water is a common resource. Water managed by one institution has a relationship to water available for management and use elsewhere. Shared aquifers and shared ephemeral rivers are two common water sources requiring management in a holistic manner, by formal institutions and individual water managers.
management of water implicitly or explicitly incorporates the concept of the economic value of water. While the full cost of water, including especially its sustainable use value, may not always be recoverable, recognition and consideration of its value should guide every management decision. All water users, that is all Namibians, should be aware of the cost of water and avoid the conclusion that water is freely provided by government and/or God.

management of water is not just the supply of water to meet demand. Integrated Water Resource Management, including Water Demand Management and management of water-borne sanitation, requires a holistic approach. Currently, Namibia’s water management institutions are not taking a holistic approach to water management and alignment of personnel, roles, responsibilities and mandates among and within institutions is necessary.

natural water systems provide a variety of services and processes that are only now becoming fully recognised globally. In Namibia, this concept has not yet been incorporated into the roles, responsibilities and mandates of the major water management institutions. Attention to this approach is essential to ensure sustainability of the water sector.

lack of and need for Regional Water Supply Development Plans for bulk supply and rural supply must be addressed. The absence of these plans is contributing to the politicising of water supply and water demand to the detriment of sustainability of the water sector.

6.8.3 PRIORITISED CONSIDERATIONS FOR SUSTAINABILITY

The overall goal of the water sector is to contribute to social, economic and environmental sustainability in Namibia. While these words are often heard, the main focus remains on the water supply per se. Institutional responsibilities, roles and mandates for management of the water sector currently support this supply bias while ignoring integrated management of the water resource. Moreover, integrated development in cooperation with other sectors is given low priority as these other sectors also focus on the supply side rather than upon the efficient and effective use and management of essential services. The following table (Table 6.6) highlights some of the main themes and concerns to be addressed with respect to institutions and management.
### Table 6.6: Aspects requiring attention in terms of institutions and management

<table>
<thead>
<tr>
<th>Theme</th>
<th>Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fundamental principles</strong></td>
<td>Establish overall goals for social, economic and environmental sustainability in Namibia, including the water sector</td>
</tr>
<tr>
<td></td>
<td>Establish harmonised institutional responsibilities for water with special reference to the environment</td>
</tr>
<tr>
<td></td>
<td>Integrated Water Resource Management, including sanitation, on all institutional levels</td>
</tr>
<tr>
<td></td>
<td>Efficient and effective use of water</td>
</tr>
<tr>
<td><strong>Use of water</strong></td>
<td>Lawful uses and institutions responsible for oversight</td>
</tr>
<tr>
<td></td>
<td>Controlled activities and institutions responsible for control</td>
</tr>
<tr>
<td></td>
<td>Institutional responsibilities for efficient and effective use of water</td>
</tr>
<tr>
<td></td>
<td>Harmonisation and coordination of roles among institutions with respect to oversight and control</td>
</tr>
<tr>
<td><strong>Protection of water</strong></td>
<td>Responsibility for and management of environmental reserve</td>
</tr>
<tr>
<td></td>
<td>Responsibility for and management of pollution prevention</td>
</tr>
<tr>
<td></td>
<td>Institutional responsibility for and implementation of emergency responses</td>
</tr>
<tr>
<td></td>
<td>Harmonisation and coordination of roles among institutions with respect to protection of water</td>
</tr>
<tr>
<td></td>
<td>Protection of wetlands</td>
</tr>
<tr>
<td><strong>Management of water</strong></td>
<td>Harmonisation of institutional management and oversight</td>
</tr>
<tr>
<td></td>
<td>Responsibilities for integrated water resource management</td>
</tr>
<tr>
<td></td>
<td>Including catchment management, groundwater management, shared water management and demand management</td>
</tr>
<tr>
<td></td>
<td>Human resource development for water management</td>
</tr>
<tr>
<td></td>
<td>Active water demand management</td>
</tr>
<tr>
<td><strong>Information</strong></td>
<td>Harmonisation of responsibilities for monitoring systems</td>
</tr>
<tr>
<td></td>
<td>Improvement of network for monitoring and long-term data collection</td>
</tr>
<tr>
<td></td>
<td>Assumption of institutional responsibilities for information management systems</td>
</tr>
<tr>
<td></td>
<td>Harmonisation of responsibilities for and management of Information coordination and dissemination</td>
</tr>
<tr>
<td></td>
<td>Identification of information and research needs for sustainable water development and use</td>
</tr>
<tr>
<td><strong>Finances and financial management</strong></td>
<td>Harmonisation of institutional responsibility for and implementation of cost recovery policy and pricing strategies</td>
</tr>
<tr>
<td></td>
<td>Harmonisation of cost recovery policy and pricing strategies for water and other essential services</td>
</tr>
<tr>
<td></td>
<td>Financial sustainability of institutional structures responsible for water</td>
</tr>
</tbody>
</table>

### 6.8.4 EVALUATION OF POSSIBLE INDICATORS

Ready made indicators of institutional status in terms of responsibilities, roles and mandates for management of the water sector have not been identified. There is little cooperation between relevant institutions so indicators that provide an overall assessment must be established (Table 6.7).
Table 6.7: Potential indicators of institutional status in terms of responsibilities, roles and mandates for management of the water sector

<table>
<thead>
<tr>
<th>Definition of Indicator</th>
<th>Data Collection and Calculation</th>
<th>Uses of Indicator</th>
<th>Discussion/Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutional roles, responsibilities, mandates and gaps for management of the environmental/ ecosystem reserve</td>
<td>No existing data base Would require identification of requirements and analysis of existing and planned management strategies by all relevant institutions; updated at intervals</td>
<td>Provide an indication of the degree to which the environmental/ ecosystem reserve is being recognised and managed</td>
<td>It is likely that this indicator will only become useful after a new Water Act has been promulgated and regulations established.</td>
</tr>
<tr>
<td>Institutional roles, responsibilities, mandates and gaps for control of water use and water pollution</td>
<td>No existing data base Would require identification of requirements and analysis of control strategies, permits issued and inspections undertaken; update at intervals</td>
<td>Provides an indication of the degree to which water use and pollution of water sources are controlled</td>
<td>This indicator will become more important as population and water demand increase.</td>
</tr>
<tr>
<td>Institutional strategies that refer to water management in terms of social, economic and environmental sustainability, that refer to Integrated Water Resource Management and that recognise water as an economic good, a common resource and a provider of services and processes</td>
<td>No existing data Would require analysis of strategies of all relevant institutions; update at intervals</td>
<td>Provides an indication of degree to which sustainability is being incorporated into ethos and operation of relevant water sector institutions</td>
<td>Components of this indicator could be addressed separately, as and when information sources are identified.</td>
</tr>
<tr>
<td>Institutional roles, responsibilities and mandates for management of water resources, catchments, groundwater, shared water</td>
<td>Little existing information Would require listing of requirements and analysis of existing and planned management strategies of all relevant institutions; update at intervals</td>
<td>Provides an indication of the degree to which management requirements are recognised and implemented for these components</td>
<td>This indicator could support the government policy of decentralisation currently being implemented.</td>
</tr>
<tr>
<td>Proportion of water management funded by donors/ GRN</td>
<td>No synthesised data Would require analysis and annual update of proportion of funding from these sources</td>
<td>Provides an indication of sustainability of water sector</td>
<td>Increasingly important as donor aid diminishes</td>
</tr>
<tr>
<td>Multi-sectoral cooperation in water management</td>
<td>No existing data List of multi/ inter-sectoral fora addressing water management</td>
<td>Provides an indication of degree of multi/ inter-sectoral cooperation in water management</td>
<td>Essential in terms of integrated management</td>
</tr>
<tr>
<td>Multi-sectoral planning for water development and management</td>
<td>No existing data Checklist of institutions consulted during planning phase of new water developments; as</td>
<td>Provides an indication of degree of multi-sectoral planning and management interaction</td>
<td>This indicator would be supported by the Environmental Management Act</td>
</tr>
<tr>
<td>Institutional responsibility for monitoring of water resource, supply and use</td>
<td>No existing collated data DWA to develop a checklist of parameters for measurement, institutions responsible, and state of monitoring data bases; to be updated annually</td>
<td>Provides an indication of state of monitoring of water resource, supply and use by institution(s)</td>
<td>Information from monitoring and evaluation of water resources and their use are essential to all relevant agencies.</td>
</tr>
<tr>
<td>Proportion of tariffs recovered from consumer groups</td>
<td>Data available from local authorities (quality may require improvement) MIS system of DRWS should include these data</td>
<td>Provides an indication of the degree to which this issue is being addressed</td>
<td></td>
</tr>
<tr>
<td>Number of rural water management committees</td>
<td>Data to be available from DRWS in future Calculate as proportion for region, supply source, user group and other identified and relevant categories</td>
<td>Provides an indication of the level of water management in rural areas by non-formal institutions</td>
<td>Performance of committees should be included in the indicator as MIS develops.</td>
</tr>
<tr>
<td>Performance of water committees</td>
<td>Data available from MIS of DRWS in form of complaints to DWA</td>
<td>Would indicate if committee structures are successful in their responsibilities</td>
<td>Effectiveness of committees would add more than just number of committees</td>
</tr>
<tr>
<td>Performance of extension personnel</td>
<td>Data available from MIS of DRWS in form of complaints to DWA</td>
<td>Provides an indication of performance level</td>
<td>A weak link in the rural water supply system.</td>
</tr>
<tr>
<td>Number of voluntary water audits</td>
<td>No existing data DWA to develop list of water users for which water audits would be appropriate, e.g. local authorities, rural pipeline schemes, factories Annual review of audits taking place</td>
<td>Provides an indication of level of awareness of and effort expended in appropriate water management</td>
<td>Could become basis for mandatory water audits for large consumers.</td>
</tr>
<tr>
<td>EAs/ EIAs for water supply</td>
<td>MET/DEA maintains register of all new or renovated water supply plans &amp; projects for which EIAs being done</td>
<td>Provides an indication of level of institutional recognition of sustainability of water supply in Namibia</td>
<td>This indicator will be supported by the Environmental Management Act</td>
</tr>
<tr>
<td>Integrated Water Resource Management</td>
<td>No existing data Would require development of auditing system for the water sector and allied essential services</td>
<td>Provides an indication of sustainability of water use and development</td>
<td>Requires a clear definition of IWRM and criteria for its implementation in differing situations</td>
</tr>
</tbody>
</table>

Comment: None of these indicators is satisfactory. It is recommended that an initial analysis be undertaken of these potential indicators and simple measures identified and prepared for long-term monitoring.
6.8.5 KEY INDICATORS

6.8.5.1 Integrated Water Resource Management in Urban Centres

A key indicator to measure institutional effectiveness in urban areas is the level of awareness and the level of implementation of components of Integrated Water Resource Management (IWRM) and in particular Water Demand Management (WDM) amongst water managers. During 1998, the Windhoek Municipality and the Department of Water Affairs undertook a study of Water Demand Management in urban centres in Namibia. Although not covering all urban areas, the study provides an overview of the level of awareness of IWRM throughout Namibia.

The information is not collected on an ongoing basis but could easily be incorporated into a regular survey by the Association of Local Authorities in Namibia or by NamWater, the bulk supplier to most of these urban centres. This information could be gathered at the same time as an assessment for the Chapter 5 Indicator on unaccounted-for-water is made.

Past Performance

The questionnaire survey of various urban areas undertaken in 1998 provided the following information concerning water demand management. The first three components of the table: Metre Replacement Programme, Pipe Replacement Programme and Use of Purified Effluent reflect the presence of active steps to reduce water loss and improve water efficiency. The last three components of the table: Water Regulations Promulgated, Community Awareness Programme and awareness by the authorities of the WASP Policy reflect awareness of the need for Integrated Water Resource Management and Water Demand Management even if it is not being implemented.

Table 6.8: Water Demand Management in Urban Areas

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gobabis</td>
<td>NamWater</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Grootfontein</td>
<td>Boreholes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Henties Bay</td>
<td>NamWater</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Karasburg</td>
<td>NamWater</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Karibib</td>
<td>NamWater</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Keetmanshoop</td>
<td>NamWater/Boreholes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Khomaskas</td>
<td>NamWater</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Luderitz</td>
<td>NamWater</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Mariental</td>
<td>NamWater/Boreholes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Okahandja</td>
<td>NamWater/Boreholes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Omaruru</td>
<td>Boreholes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Opuwo</td>
<td>NamWater</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>-----------</td>
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<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Oranjemund</td>
<td>Boreholes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Otavi</td>
<td>NamWater</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Otjiwarongo</td>
<td>NamWater</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Ovitjio</td>
<td>Boreholes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Rehoboth</td>
<td>NamWater</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Rundu</td>
<td>NamWater</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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</tr>
<tr>
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<td>NamWater</td>
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<td>Yes</td>
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<td>Tsumeb</td>
<td>Boreholes</td>
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<td>Yes</td>
<td>Yes</td>
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<td>NamWater/</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<td>NamWater/</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
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<td></td>
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</table>


Pipe Repl. Prog. = Pipe Replacement Programme
Met. Repl. Prog. = Meter Replacement Programme
Water Reg. = Water Supply Regulations
Comm. Aware. = Community Awareness Programme

6.8.5.2 Effectiveness of Community Based Management

One major goal of the Directorate of Rural Water Supply is to hand over ownership to community water points to the communities themselves for operation and maintenance. To this end, Water Point Associations, Water Point Committees, Water Pipeline Committees and similar institutions are being established and trained in the necessary functions. A measure of success of this process would be a low level of assistance being required from the Directorate of Rural Water Supply by the community.

The Directorate of Rural Water Supply is in the process of establishing a Management Information System (MIS) on a regional basis. MIS in five regions have been implemented to date. An important addition to this MIS, as suggested by the Deputy Director of Rural Water Supply, would be a record of the number of times a community calls Rural Water Supply personnel to assist with repairs or maintenance that the community has been trained to do itself. This record could be analysed in a number of ways, for example, to facilitate assessment of the dependence of individual communities, the effectiveness of sections of Rural Water Supply or the effectiveness of particular technical solutions in a region. It could also be interpreted as a measure of the effectiveness of the training programme of DRWS.
## Table 6.9

### STATE OF THE ENVIRONMENT: REPORT ON WATER IN NAMIBIA

**INSTITUTIONAL RESPONSIBILITIES, ROLES, AND MANDATES AND RELEVANT LEGISLATION FOR MANAGEMENT OF THE WATER SECTOR**

<table>
<thead>
<tr>
<th>Surface Water</th>
<th>Identification, Exploitation, Purification and Bulk Distribution</th>
<th>Conservation and Protection</th>
<th>Quality Control</th>
<th>Reticulation</th>
<th>Remarks</th>
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<tr>
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<td>Reticulation by Department of Water Affairs, Rural Water Supply in rural areas only</td>
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Amendments:  
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7 LEGISLATIVE FRAMEWORK, POLICIES AND REGULATIONS

7.1 INTRODUCTION

The legislative, policy and regulation framework directly pertaining to water in Namibia is limited. Currently, the Constitution of the Republic of Namibia, the Water Act 54 of 1956 and the Namibia Water Corporation Act 12 of 1997, together with relevant Amendments and Regulations constitute the primary framework for management of water in Namibia. There are, however, a number of other pieces of legislation and regulations that pertain, directly or indirectly, to management and use of water.

The Directorate of Environmental Affairs of the Ministry of Environment and Tourism has prepared a comprehensive Index of Environmental Legislation in Namibia (Figuera 1996a). Much of the earlier legislation in this index, although it has major implications for water management and use, and even some of the more recent, pertinent legislation, does not mention water directly. Nevertheless, almost all of the index is of relevance to water and the list is included in Annexure 7.1.

7.2 LEGISLATION PERTAINING TO THE WATER SECTOR AND WATER RESOURCES, INCLUDING MISSING LEGISLATION

7.2.1 THE CONSTITUTION OF THE REPUBLIC OF NAMIBIA

The Constitution of the Republic of Namibia serves as the main pillar of the legal foundation for water in Namibia as well as providing for sustainable use of all natural resources (M Figuera in Möwe Bay Fishing Port Feasibility Study 1998). Article 95 of the Constitution of the Republic of Namibia states that:

"the State shall actively promote and maintain the welfare of the people by adopting ... policies aimed at ... maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and utilisation of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future ..."

Article 100 in Chapter 11 of the Constitution of the Republic of Namibia states that:

"Land, water and natural resources below and above the surface of the land and in the continental shelf and within the territorial waters and the exclusive economic zone of Namibia shall belong to the State if they are not otherwise lawfully owned."

The Constitution, with the Water Act 54 of 1956, the Namibia Water Corporation Act 12 of 1997, the regulations promulgated in terms of these two acts and the Water Supply and Sanitation Sector Policy provide the main legal and administrative framework for the water sector in Namibia (Heyns et al. 1998). The two main specific acts governing management and use of water in Namibia are summarised below (modified from Figuera 1998b). As sustainability has only been a consideration for the past decade or so, only the Namibian Water Corporation Act 12 of 1997 mentions
sustainable use of water with planned exceptions to sustainable use requiring specific Ministerial approval and publication in the Government Gazette.

7.2.2 THE WATER ACT 54 OF 1956 AND THE NAMIBIA WATER CORPORATION ACT 12 OF 1997

The Water Act 54 of 1956
The Water Act 54 of 1956 ("the Act") makes provision, inter alia, for the control, conservation and use of water for domestic, agricultural, urban and industrial purposes, for the control in certain respects of the use of sea water for certain purposes and for the control of certain activities on or in water in certain areas.

Only certain of the provisions of this Act are however applicable to Namibia. Sections 4 – 7 and 9A and B govern the control and use of private and public water, sections 21 – 23 and 26 govern the pollution of water, sections 27, 28(1) and 30 govern the control and use of subterranean water and sections 56 and 57(1) govern the construction and control of government water works.

Fresh water is defined in section 1 of the Act as:
"any water flowing or found in or derived from the bed of a public stream, whether visible or not."

"Public stream" is defined in section 1 as:
"a natural stream of water which flows in a known and defined channel, whether or not such channel is dry during any period of the year and whether or not its conformation has been changed by artificial means, if the water in it is capable of common use for irrigation on two or more pieces of land riparian to it which are the subject of separate original grants ... and also on Crown land which is riparian to such stream; provided that a stream which fulfils the foregoing conditions in part only of its course is deemed to be a public stream as regards that part only."

There is no right of ownership in public water and its control and use is regulated and provided for in the Act. Section 9B of the Act limits the quantity of public water that may be impounded from a public stream to 20 000 cubic metres. The prohibition in this section is directed at water works capable of impounding more than the stated limit. A waterwork is defined in the Act as:

"(a) a canal, channel, well, reservoir, protecting wall, embankment, weir, dam, borehole, pumping installation, pipeline, sluice gate, filter, sedimentation tank, road, telephone line or other work constructed, erected or used for or in connection with the impounding, storage, passage, drainage, control or abstraction of water, or the development of water power, including the generation, transmission and supply of electricity, or the filtration or purification of water sewage, effluent or waste, or the protection of public streams against erosion or siltation, or flood control, or the protection of any water work or irrigated land, other use of water for any purpose, or the conservation of rain water;"
(b) land occupied for or in connection with the impounding, storage, passage, drainage, control, abstraction, filtration, purification, development of power (including generation of electricity), or any other use of water, and includes any area occupied or required or held for the purpose of being irrigated or for flood control purposes;

(c) gauge posts, measuring weirs and any other appliances erected or used by the department or an irrigation board or water board."

A person who wishes to construct, alter or enlarge a water work capable of impounding more than 20,000 cubic metres must obtain a permit from Cabinet. In addition, the applicant is required to table letters from downstream owners indicating that they do not object to the construction.

Although there is no limit on the number of dams of less than 20,000 cubic metres that may be constructed by an individual, the plans for such dams must be prepared by the personnel of the Division of Engineering and Extension services of the Ministry of Agriculture, Water and Rural Development. As part of the design of the dams, an hydrological assessment (but not an environmental assessment) is carried out to ensure that not too many dams are constructed in one catchment area. This system is currently not implemented because of lack of trained personnel and funding, and a focus away from the commercial farmlands where many of these dams are constructed in upper reaches of catchments.

In the case of underground water Cabinet has, however, the power to convey and supply any subterranean water which has been or is to be abstracted or obtained in any manner whatsoever by the State to any person for use on any land for any purpose whether such water has been or is abstracted or obtained on land belonging to the government or on other land (section 30A).

Although use of water for industrial purposes does not require a permit, a person using water for industrial purposes is obliged to purify or otherwise treat the water used and any effluent produced by such use before it is discharged, in accordance with requirements which the Minister of Agriculture, Water and Rural Development may from time to time prescribe by notice in the Gazette or by special permit. The requirements in question are contained in regulations, a copy of which is annexed to this report marked “Annexure 7.1”.

After compliance with the requirements of purification the purified water and effluent must, in a manner and subject to any requirements which may be prescribed by regulation, be discharged

“(a) if the water was derived from a public stream, into that public stream at the place where the water was abstracted or at such place as the Minister of Agriculture, Water and Rural Development may indicate; and
(b) if the water was sea water, into the sea at the place where such water was abstracted from the sea or at such place as the Minister of Agriculture, Water and Rural Development may indicate (section 21(1)(b))."

The user of water for industrial purposes must furnish the Department of Water Affairs in writing with those particulars regarding the use and disposal of purified or treated water as may be prescribed by regulation (section 21(1)(c)). The Minister of Agriculture, Water and Rural Development may either by notice in writing to a person, or by notice in the Gazette exempt a person or a class of persons, on conditions which he or she may specify, from any or all of the aforesaid provisions (section 21(4)(a)). Any person prejudiced by such an exemption may apply to the Minister of Agriculture, Water and Rural Development and the person in whose favour the exemption was granted, to object against the continuation of the exemption or any matter in connection with the exemption. The Water Court may confirm or withdraw the exemption or withdraw or amend any condition to which it may be subject (section 21(4)(c)). The Minister of Agriculture, Water and Rural Development may at any time withdraw an exemption or render the continued validity of the exemption subject to such conditions as he or she may determine (section 21(4)(e)).

The Minister of Agriculture, Water and Rural Development is empowered by section 56 of the Act to construct government water works out of moneys provided by parliament and the rights and privileges of ownership in such water works are vested in the State (section 56(4)). The control of such water work and the power to regulate or prohibit the extraction of water therefrom are vested in the Minister (section 56(5)). The Minister is empowered to supply or distribute water from a government water work to any person for any purpose approved by the Minister (section 56(3)).

The Act does not mention desalination of sea water as a source of bulk water supply. Finally, a critical limitation of the Act is that it does not recognise ecosystem water needs. It does empower the Minister to do so, however, the Minister has not yet addressed this issue.

Dating to 1956, it is not surprising that the Act does not address the interdependence of the environment and water nor sustainable use of or protection of water resources. Principle flaws include:
- a major focus on development of the resource and little or no emphasis on its protection, conservation, management or sustainability
- lack of a holistic approach to water resource management
- failure to recognise the hydrological cycle as an indivisible continuum, hence classification of water such as normal and surplus flow, surface and groundwater.
Namibia Water Corporation Act 12 of 1997

The Water Act 54 of 1956 empowered the Minister to draft the Namibia Water Corporation Act 12 of 1997 and appointed the Department of Water Affairs to do so. This Act, although providing primarily for the establishment of the Namibia Water Corporation Limited ("the Corporation"), provides, in addition, for a more efficient use and control of water resources.

In terms of section 5 of this Act the Corporation is established to:
"carry out efficiently and in the best interest of the Republic of Namibia, inter alia, the primary business of bulk water supply to customers, in sufficient quantities, of a quality suitable for the customers' purposes, and by cost effective environmentally sound and sustainable means...."

Section 6 provides that notwithstanding any provisions of the Water Act to the contrary, it shall be a function of the Corporation to supply water to customers within and outside the borders of the Republic of Namibia. Section 7.2 states that the Minister must approve any supply to consumers outside the borders of the Republic of Namibia.

In carrying out its objective and performing its functions under this Act, the Corporation is required, in terms of section 11 to "utilise the water resources available to it on a long-term sustainable basis." The Corporation is further obliged in the performance of its functions, to take:
"appropriate steps to conserve and protect the environment from damage, destruction or degradation, and in particular to protect -
(a) the fauna and flora;
(b) geological and physiographical features of special interest; and
(c) buildings, structures and other objects of architectural, archeological or historic interest."

Accordingly, notwithstanding the lack of environmental protection provisions in the Water Act, the Corporation will be obliged, in supplying water to Namibia, to ensure that water is utilised on a long-term sustainable basis and further to take adequate steps to ensure that the supply of water does not result in damage, destruction or degradation of the environment.

Although a recent Act (1997) and incorporating the concept of sustainable use of water resources, the Act does not create a monitoring mechanism to ensure sustainable use nor provide environmental protection standards to be met by the Corporation. Moreover, DWA does not have oversight powers over the Corporation in this regard.

7.2.3 OTHER LEGISLATION OF PRIMARY RELEVANCE

Other legislation of particular interest to the water sector, although derived from various diverse sectors, is briefly summarised in the following paragraphs (Jacobson et al. 1995; Figuera 1998). This listing illustrates the need for a holistic approach, among various sectors related to sustainable development, which is partly addressed by the draft Environmental Management Act.
The Public Health Act No 36 of 1919 focuses on the quality of water supplied to public users. This act is the basis for the responsibility of the Ministry of Health and Social Services to promote and protect the health of the people of Namibia. This act is currently being revised and is expected to go before Parliament in 1999.

The Soil Conservation Act No 76 of 1969 makes provision for controlling and preventing soil erosion and for the conservation, protection and improvement of the soil, vegetation and sources and resources of the nation's water supplies. This Act gives broad powers to the State but is not applicable in communal farmlands.

The Minerals Prospecting and Mining Act No 33 of 1992 has several references to adequate protection of the environment including water.

The Water Research Act No 34 of 1971 provides for research in connection with 'water affairs' through establishment of a water research commission and fund. Neither has been established in Namibia to date.

The Forest Act No 72 of 1988 and the Preservation of Trees and Forests Ordinance No 37 of 1952 are about to be superseded by the new draft Forestry Act. This new act will afford protection to 'any living tree, bush or shrub within 100m of any river, stream or water-course' which will protect riverine vegetation and in turn, conserve the soil and water. In theory this is intended to include the protection of the water source, so as to conserve the riverine vegetation. In practice, the position could be very different, particularly in ephemeral rivers, as witnessed by the situation where river sand, not covered by the Act, is removed from ephemeral river beds leaving huge trees growing from islands of soil high above the excavation. It is not clear how this Act would protect riverine vegetation from alteration of the river course or water flow and whether this Act could partly address the need for an 'ecosystem reserve'.

The Nature Conservation Ordinance No 4 of 1975 affords protection to various wetlands located within National Parks but has no power to enforce an environmental water reserve for wetlands within National Parks by regulating upstream hydrological alterations. This legislation has been amended to enable the development of conservancies in rural areas of Namibia which should contribute to improved management of rural water sources for tourism and wildlife, although in this legislation communities have no control over rangeland or water sources per se. This limitation should be addressed in future legislation.

The draft Environmental Management Act provides for a set of environmental management principles to be applied by all Government Institutions and private persons in planning and implementing developments likely to have a significant effect on the environment and further gives legislative effect to the Cabinet Policy of Environmental Assessments in Namibia. In terms of this proposed legislation, environmental impact assessments will be required in respect of all plans, policies or programmes which may have a significant effect on the environment and all activities listed in Schedule 1 to the proposed legislation.

The Mountain Catchment Areas Act 63 of 1970 is designed to assure the highest possible quality and quantity of water on a dependable basis from the mountainous regions of upper catchment areas.
7.2.4 MISSING LEGISLATION

The most striking absence of legislation in Namibia refers to the absence of a new, holistic Water Act. Namibia is still using parts of the Water Act No 54 of 1956 that was drafted in South Africa more than 40 years ago. A major limitation of the existing Act, and one that places it at odds with Namibia's Constitution, is that it does not recognise the natural environment as a user of water nor as a provider of essential goods, processes and services. Moreover, it does not stipulate the sustainable use of water resources in terms of social, economic or environmental sustainability.

New legislation with respect to water should ensure 'locus standi' rights to the public so they can contribute to preventing public trust to be violated. New legislation should also guarantee consultation with DWA and MET before any agency undertakes any development that might have an impact on water resource availability and, in association, the environment, thereby augmenting the draft Environmental Management Act.

Appropriate legislation to support devolution of components of rural water supply to communities is sorely needed (e.g. Corbett 1997). This legislation would focus on community ownership of individual water points and be harmonised with other legislation concerning communal lands, much of which is also missing. Legislation emanating from the Ministry of Lands, Resettlement and Rehabilitation and the Ministry of Regional and Local Government and Housing are of particular note.

Legislation covering all aspects of sanitation and legislation covering pollution are two major gaps that require attention and synthesis.

Other legislation, existing or currently being promulgated, is frequently missing explicit reference to water conservation, holistic management and sustainable use in terms of social, economic and environmental sustainability. All legislation should be reviewed and relevant additions, to ensure holistic, sustainable management, incorporated where appropriate.

7.3 REGULATIONS PERTAINING TO THE WATER SECTOR AND WATER RESOURCES, INCLUDING MISSING REGULATIONS

Various regulations, strategies and guidelines concerning use and management of water have been developed and used, many only recently. They have been drawn up by various agencies including Department of Water Affairs, Ministry of Regional and Local Government and Housing and the Ministry of Health and Social Services. Again, few address social, economic and environmental sustainability issues important for sustainable management and use of the resource.

The water sector operates with surprisingly few formal regulations, dependent on skilled, committed and experienced staff for management and implementation of the regulations. Only two, on pollution from industrial effluents (Reg. No. 553 of 5 April 1962) and on subterranean water control areas (Reg. No. 1278 of 23 July 1971) regularly guide water management. Additionally, a further 11 listed below are formally promulgated.
• RSA Proclamation 1277 of 1971 (establishment of an Advisory Water Board)
• Regulation 287 of 1976 (Prevention of Water Pollution by Mines)
• General Notice 5 of 1978 (revision of rates and charges)
• AG Government Notice 52 of 1979 (revision of rates and charges)
• AG Government Notice 62 of 1980 (revision of rates and charges)
• AG Government Notice 80 of 1981 (revision of rates and charges)
• AG Government Notice 128 of 1984 (revision of rates and charges)
• General Notice 132 of 1986 (revision of rates and charges)
• Government Notice 10 of 1988 (revision of rates and charges)
• AG Government Notice 12 of 1980 (delegation of powers)
• Government Notice 167 of 1987 (delegation of powers)

Local authorities, designated as municipalities and referred to in Schedule 1 of the Local Authorities Act. No 23 of 1982, have their own regulations which may differ from local authority to local authority. The Ministry of Regional and Local Government and Housing has provided two model regulations. These are:
- Model Water Supply Regulations promulgated under Government Notice of 1996 dated 1 April 1996, and

As part of its Water Demand Management project the City of Windhoek promulgated a number of additional water regulations specifically to address conservation of water. These regulations are summarised in Table 7.1.

Table 7.1: Regulations promulgated by the City of Windhoek to support Water Demand Management

<table>
<thead>
<tr>
<th>Regulation target</th>
<th>Details of regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undue water consumption of private properties</td>
<td>Wastage of water on private property can be addressed immediately. Windhoek is the only city in Southern Africa that has a Water Control Officer in its employ.</td>
</tr>
<tr>
<td>Water efficient equipment</td>
<td>Metering taps must be used in hostels&lt;br&gt;Taps outside non-residential buildings must be self-closing or lockable&lt;br&gt;Toilet cisterns must be 6/3 litre dual flush units&lt;br&gt;Automatic flushing devices are prohibited. Retrofitting of inefficient devices is compulsory within three years</td>
</tr>
<tr>
<td>Groundwater</td>
<td>Groundwater abstraction from private boreholes and groundwater levels are controlled</td>
</tr>
<tr>
<td>Gardens</td>
<td>Watering may only be done in periods of low evaporation</td>
</tr>
<tr>
<td>Swimming pools</td>
<td>Swimming pools must be covered when not in use</td>
</tr>
</tbody>
</table>

A number of guidelines have been drawn up and are used to guide the management of water in the absence of more formal regulations.

DWA developed ‘guidelines for the evaluation of drinking-water for human consumption with regard to chemical, physical and bacteriological quality’ that have been approved by Government and adopted by NamWater.

The Division of Water Environment, of the Ministry of Agriculture, Water and Rural Development, has developed a set of guidelines for ‘Environmental Assessments for New Boreholes’.
Missing regulations are numerous and should support existing and planned regulation.

7.4 POLICIES PERTAINING TO THE WATER SECTOR AND WATER RESOURCES, INCLUDING MISSING POLICIES

7.4.1 EXISTING NATIONAL AND LOCAL POLICIES

The Water Supply and Sanitation Sector Policy (WASP) represents the only radically new set of guidelines to have been drafted since independence for the water sector (DWA 1993). In terms of policies, the Water Supply and Sanitation Sector Policy (WASP) is the most important instrument supporting non-bulk water management in Namibia. The WASP document states that the provision of improved water supply should:

- contribute toward improved public health
- reduce the burden of collecting water
- promote community based social development, with special note of the role of women
- support basic needs
- stimulate economic growth.

Overall, the operative strategy would be to promote development of reliable and accessible sources of safe water with sufficient capacity on a sustainable basis to serve all homesteads and settlements at an affordable cost.

According to the WASP document, provision of improved sanitation should:

- contribute towards improved health
- ensure a hygienic environment
- protect water sources from pollution
- promote conservation of water
- stimulate economic development

Overall, the operative strategy would be to ensure the safe and affordable disposal of all human and other obnoxious wastes, including sewage and industrial effluent.

- Using the WASP document as a departure point, the Directorate of Rural Water Supply has developed a number of Strategy Papers to guide the implementation of the policy objectives allocated by the WASP. These Strategy Papers, approved by the Permanent Secretary of the Ministry of Agriculture, Water and Rural Development, address a number of topics:
  - Ownership of rural water supply schemes and individual water points (Strategy Paper S1)
  - Introduction of payment for the service of water supply (Strategy Paper S2)
  - Sector coordination (Strategy Paper S3)
  - Legal status of water committees (Strategy Paper S4)
  - Monitoring and evaluation system (Strategy Paper S5)
  - Relationship between the Water Point Committee, the Local Water Committee, the Central Water Committee and the Department of Water Affairs (Strategy Paper S6)
  - Implementation of rural water supply schemes (Strategy Paper S7)
  - Operation and maintenance of the rural water supply equipment (Strategy Paper S8)
Other supporting water management instruments include the Environmental Assessment Policy. This policy was approved by Cabinet in 1994 and provides the framework for environmental assessments to be undertaken in respect of large water supply schemes and other developments that require large amounts of water. It is also applied to rural water supply schemes, including new boreholes when these lead to opening up of new grazing land.

The Fisheries White Paper of 1997 describes Government's policy toward the management, use and conservation of fresh water fish.

The Wetland Policy of 1994 of the Ministry of Environment and Tourism encourages the rational and integrated planning of wetland systems based upon the preservation of the biotic diversity, maintenance of the life support systems and sustainable use.

A National Wetlands Policy, in line with RAMSAR requirements, is being drafted by the Wetlands Working Group of Namibia.

The National Drought Policy and Strategy, approved by Cabinet in 1998, focuses on preparation for and mitigation of effects of drought thereby encouraging the appropriate management and sustainable use of water, particularly those sources developed for and used by livestock. This Policy has also led to the differentiation of grazing and water droughts which require different responses from the water sector.

The Decentralisation Policy identifies rural water supply as the immediate priority for decentralisation.

A number of other national policies and pending legislation impinge directly on the water environment, e.g. that of agriculture, communal lands and decentralisation, even though they do not refer directly to water development or management.

In addition to Municipal Water Regulations, the Municipality of Windhoek has a Water Demand Management Policy and implementation strategy that covers technical issues, policy matters, legislation and a public campaign (Table 7.2). This policy has succeeded in decreasing the water demand per capita in Windhoek in the last decade in parallel with a 43% increase of population. As a result, the nett consumption of water in Windhoek in 1998 is less than it was a decade earlier. Similar policy should be adopted as far as possible in other urban areas, and adapted for use throughout Namibia.
### Table 7.2: Elements of policy enacted by the City of Windhoek to support Water Demand Management

<table>
<thead>
<tr>
<th>Policy element</th>
<th>Details of policy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block tariff system</td>
<td>A permanent block tariff system, to reflect the real cost of water and to curb excessive water use, was implemented</td>
</tr>
<tr>
<td>Maximum reuse of water</td>
<td>Semi-purified effluent used for irrigation</td>
</tr>
<tr>
<td></td>
<td>Water reclaimed to potable standard</td>
</tr>
<tr>
<td></td>
<td>Grey water used on private premises</td>
</tr>
<tr>
<td>Erf sizes</td>
<td>Erf sizes in new developments are reduced</td>
</tr>
<tr>
<td></td>
<td>Higher density housing allowed in existing urban areas</td>
</tr>
<tr>
<td>Urbanisation</td>
<td>Guidelines developed</td>
</tr>
<tr>
<td>Operational water supply practices</td>
<td>Consumption on municipal gardens reduced by up to 50%</td>
</tr>
<tr>
<td>Wet industries</td>
<td>Guidelines given to wet industries for efficient use of water, on a continuous basis</td>
</tr>
<tr>
<td></td>
<td>New wet industries will have to reuse water</td>
</tr>
</tbody>
</table>

Again, the above listing of existing national and local, sectoral policies illustrates the need for a holistic approach to natural resources and their sustainable management and use.

#### 7.4.2 INTERNATIONAL POLICIES AND AGREEMENTS

On an international level, Namibia acceded to the UN Convention on Wetlands of International Importance, known as Ramsar, in 1995, pledging to promote the conservation of wetlands. Four wetlands, the Orange River Mouth, Etosha Pan, the Walvis Bay Lagoon and Sandwich Harbour have been designated under the Ramsar convention.

Namibia is a member of several technical river basin organisations and is involved with several regional water management arrangements. These are summarised in Chapter 8.

#### 7.4.3 MISSING POLICIES

The Constitution of the Republic of Namibia focuses attention on sustainable use of natural resources, yet there are few policies relating to water, directly or indirectly, that focus on its use in terms of economic, social or environmental sustainability. All policies relating to water should emphasise this aspect, whereas most currently do not.

Clearly missing is a Groundwater Protection Policy focused on sustainable development and use of this resource. As a first step, groundwater throughout Namibia should be subjected to a set of guidelines concerning sustainable use and management and information concerning sustainability of current aquifer use and management, should be gathered. The policy should require environmental assessments for any project that has an effect on the hydrological cycle, including recharge.

Although Namibia is involved in a number of international agreements concerning development and use of international, perennial river basins, there is no policy addressing management and use of shared (between different land uses and land users) ephemeral river basins falling entirely within Namibia. Such an Ephemeral River Catchment Policy should address the rights of all users, upstream and downstream, including the environment, and how all these rights would be accommodated in a
sustainable manner. This policy could be modeled after the Helsinki Rules with due consideration for the ephemeral nature of the rivers and that they are located within one country but used by a variety of interests (e.g. Jacobson et al. 1995).

A clear Communal Land Policy that addresses integrated consideration of sustainable natural resource management and use, with particular reference to water, grazing and fencing is currently missing. Various policies touch on the subjects but none are holistic in their approach or focus on economic, environmental or even social sustainability of water development and use in communal lands.

A Communal Water Policy is required which addresses devolution of ownership of water points to local communities, while not excluding the potential for holistic and sustainable management of regional aquifers or other water sources. This policy must be integrated with other policies and legislation related to sustainable development and use of water and other natural resources. In time, policies addressing private and state owned resources should be amalgamated and the nation’s natural resources be holistically treated as national assets.

A Pollution Control Policy would augment other policies existing or called for. Water Quality Guidelines should be upgraded to national standards and address the quality of both drinking water and effluent.

All new or revised policies relating to the water sector, directly or indirectly, should address economic, social and environmental sustainability of the use and management of the resource. As missing or inadequate policies are developed or revised, the following checklist of issues should be addressed in the context of water:
- consideration of effective legislation and institutional framework
- attention to sustainable resource use and management
- planning and management that is integrated with other sectors and holistic in approach
- participation by all interested and affected parties, including rural communities and women
- environmental education, awareness and empowerment of all affected
- adequate information gathering, management and dissemination
- attention to international implications and cooperation

A National Water Demand Policy would be an essential component of a White Paper on water and could contribute to the design of a new Water Act.

7.5 MECHANISMS FOR RESOLVING CONFLICTS

Mechanisms for resolving conflicts over legislation, policies and regulations should be based on the presence of fora for coordination, consultation and conflict resolution amongst all interested and affected parties in the water sector and between the water sector and other relevant sectors. These fora can and do range from the international to the local level. Fora for the resolution of conflicts among or between management institutions may be the same fora used to resolve conflicts arising among or between institutions concerning legislation, policy and regulations. Similarly, cross sectoral conflicts such as those between industry and social requirements for water or between social and environmental requirements for water would be facilitated by the presence of appropriate fora for conflict resolution.
A crucial component of conflict resolution is having relevant and comprehensive information available to be able to judge if legislation, policies or regulations are being complied with and are effective. The Department of Water Affairs (DWA), Directorate of Resource Management, is responsible for maintaining a variety of data bases concerning surface and groundwater in Namibia. Many of these data bases have been transferred to NamWater in the past two years and are now operated jointly. Provision has been made in the legislation for the DWA to request and be given existing data from NamWater but there is no provision for DWA to request NamWater to collect new categories or types of data in addition to those already being collected. It is also not clear if there will be a charge to DWA for use of these data. Moreover, there is also no provision for DWA to request analyses of the data from NamWater. This leaves a wide gap in the potential to collect new and relevant data, the possibility of those data related to income generation for NamWater being given priority and opens up the possibility of a bias in the types of information being gathered. The water quality laboratory and its records have also been given over to NamWater. Moreover, a number of private consultants work with or add to the data bases held by NamWater and the DWA. Currently there is no provision for the coordination or harmonisation of existing data held by the various bodies or for collection of new data (Table 7.5).
<table>
<thead>
<tr>
<th>Category of information</th>
<th>Responsible bodies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial and ephemeral surface water resources</td>
<td>MAWRD: DWA: DRM, Division of Hydrology</td>
</tr>
<tr>
<td></td>
<td>NamWater: Division of Water Environment, Ecological Research Section (DWE, ERS)</td>
</tr>
<tr>
<td>Groundwater resources</td>
<td>MAWRD: DWA: DRM, Division of Geohydrology</td>
</tr>
<tr>
<td></td>
<td>NamWater:</td>
</tr>
<tr>
<td>Pollution control and ecological research</td>
<td>MAWRD: DWA: DRM, DWE, ERS</td>
</tr>
<tr>
<td>Community management and cost recovery; rural water supply</td>
<td>MAWRD: DWA: DRWS, Division of Rural Water Supply - north and south.</td>
</tr>
<tr>
<td>Farm dam records</td>
<td>MAWRD: DARD: Directorate of Extension and Engineering Services, Division of Agricultural Engineering</td>
</tr>
<tr>
<td>Potability of drinking water in smaller towns and villages</td>
<td>Ministry of Health and Social Services; Directorates of Regional Health and Social Services</td>
</tr>
<tr>
<td>Town and village reticulation, sewage, cost recovery</td>
<td>Ministry of Regional and Local Government and Housing: Directorate of Town and Village Administration</td>
</tr>
<tr>
<td>Water Demand Management</td>
<td>Municipality of Windhoek; DWA, DWE, ERS</td>
</tr>
<tr>
<td>Potability and bacteriological quality of drinking water; reticulation, sewage and cost recovery</td>
<td>Municipalities of larger centres; NamWater, DWA: Division of Water Environment</td>
</tr>
<tr>
<td>Hydropower</td>
<td>Ministry of Mines and Energy &amp; NamPower; Ecological Research Section of DWE/DWA</td>
</tr>
<tr>
<td>Aquatic and riparian plants</td>
<td>MAWRD: DARD: Directorate of Agricultural Research and Training, National Botanical Research Institute; DWA: Division of Water Environment, Ecological Research Section</td>
</tr>
<tr>
<td>Freshwater fish, amphibians and invertebrates; collections, research and monitoring</td>
<td>Ministry of Basic Education and Culture: National Museum of Namibia; DWA, DWE, ERS; MET</td>
</tr>
<tr>
<td>Freshwater fish resources; monitoring and management</td>
<td>Ministry of Fisheries and Marine Resources; Freshwater Fish Research Institute</td>
</tr>
<tr>
<td>Rainfall and other weather data</td>
<td>Ministry of Works, Transport and Communication: Department of Transport; Weather Bureau; DWA</td>
</tr>
<tr>
<td>Wetlands</td>
<td>MET; DRM; DWA: DWE, ERS</td>
</tr>
<tr>
<td>Influence of climate change, desertification and effect on biodiversity</td>
<td>MET; Directorate of Environmental Affairs; DWA: DWE, ERS</td>
</tr>
</tbody>
</table>

DARD: Department of Agriculture and Rural Development
DEES: Directorate of Extension and Engineering Services
DRM: Directorate Resource Management (DWA & MET)
DRWS: Directorate of Rural Water Supply
DWA: Department of Water Affairs
DWE: Division of Water Environment
ERS: Ecological Research Section (DRM, DWA)
MAWRD: Ministry of Agriculture, Water and Rural Development
MET: Ministry of Environment and Tourism
In response to the WASP and its implementation, the Directorate of Rural Water Supply has instituted a Management Information System (MIS) on a regional basis. The data being incorporated into the system are summarised in Table 7.6. Two regions, Kunene and Kavango, have had all data for the past two years incorporated into a computerised system established at the regional offices.

Table 7.6 Components of Management Information System of DRWS. For all of these examples of components, the status quo and the targets for implementation are indicated.

<table>
<thead>
<tr>
<th>Main heading</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>Total number of water points</td>
</tr>
<tr>
<td></td>
<td>Number of new water points established</td>
</tr>
<tr>
<td></td>
<td>Number of rehabilitated water points</td>
</tr>
<tr>
<td>Community Based Management</td>
<td>WP Committees established</td>
</tr>
<tr>
<td></td>
<td>WP Caretakers trained</td>
</tr>
<tr>
<td></td>
<td>WP Committees fully trained</td>
</tr>
<tr>
<td></td>
<td>Local Water Committees established</td>
</tr>
</tbody>
</table>

7.6 OVERVIEW, GUIDELINES AND INDICATORS

7.6.1 RELEVANCE TO WATER SECTOR

The water sector is dependent on the identification of appropriate goals for sustainable development of Namibia, both within the sector and for the country in general. While the goal of economic, social and environmental sustainability in the development of Namibia is embodied in the Constitution of the Republic of Namibia, there is little legislation, policy or regulation framework to support this goal. Attention to missing legislation, policies and regulation is of particular importance to the water sector in terms of its sustainable development and use.

Of particular importance is to balance the national interests in economic, social and environmental sustainability with those of individuals owning water points. Current regulations limit the amount of water used from boreholes for irrigation to one hectare of land without a permit. Similar regulations need to be formulated for pipeline water and taps that will be owned by rural communities to balance use and development.

7.6.2 ASSESSMENT AND EVALUATION OF THE SITUATION IN NAMIBIA

Namibia possesses some of the basic legislation, policies and regulation to continue to supply water to its population using its current approach, for a limited period. It does not, however, have the necessary framework to assure the long-term social, economic or environmental sustainability of this water supply and its management or use as is mandated by the Constitution of the Republic of Namibia.

In terms of the legislative, policy and regulatory framework, three considerations could be identified as being of high priority. These are:
- the Constitution of the Republic of Namibia exempts water from being owned by the state if it is ‘otherwise lawfully owned’. This framework for the ownership of water should be reviewed as it precludes, in some instances, sustainable management of
individual aquifers. It is also possible that the current approach precludes use of scarce, potentially shared water resources for the best economic outcome in Namibia. This should be reviewed for commercial and communal farming and other areas.

- ownership of rural water supply facilities by communities is receiving attention. This should be considered in conjunction with consideration of other legislation referring to ownership and management of common property natural resources.

- the existing Water Act does not recognise the natural environment as a user of water nor as a provider of essential goods, services and processes. This should be reviewed as it is in direct conflict with Namibia’s Constitution. Included in this component should be the establishment of the ‘water reserve’ essential for each system.

7.6.3 PRIORITISED CONSIDERATIONS FOR SUSTAINABILITY

The first priority for Namibia in terms of improving its framework conditions is to establish a White Paper on water and then a new Water Act. This must address a number of considerations for overall sustainability. Table 7.7 provides an overview of important concerns and themes to be addressed. In addition, enforcement of existing legislation which contributes to sustainability should be a high priority.

Table 7.7: Aspects requiring attention in terms of legislation and policy

<table>
<thead>
<tr>
<th>Theme</th>
<th>Concerns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental principles</td>
<td>- Establish overall goals for social, economic and environmental sustainability</td>
</tr>
<tr>
<td></td>
<td>- Establish prioritised entitlements for water use with special reference to the natural environment</td>
</tr>
<tr>
<td></td>
<td>- Enforce agreed upon principles and instruments for water regulation and management</td>
</tr>
<tr>
<td>Use of water</td>
<td>- Lawful uses</td>
</tr>
<tr>
<td></td>
<td>- Controlled activities</td>
</tr>
<tr>
<td>Protection of water</td>
<td>- Establish an environmental reserve</td>
</tr>
<tr>
<td></td>
<td>- Pollution prevention, monitoring &amp; river health programme</td>
</tr>
<tr>
<td></td>
<td>- Emergency responses</td>
</tr>
<tr>
<td></td>
<td>- Research and monitoring</td>
</tr>
<tr>
<td>Management of water</td>
<td>- Strategies for water resource management</td>
</tr>
<tr>
<td></td>
<td>- Strategies for catchment management</td>
</tr>
<tr>
<td></td>
<td>- Strategies for groundwater management</td>
</tr>
<tr>
<td></td>
<td>- Strategies for shared water management</td>
</tr>
<tr>
<td></td>
<td>- Institutions for water management including research and monitoring and the funding therefor</td>
</tr>
<tr>
<td>Information</td>
<td>- Monitoring systems</td>
</tr>
<tr>
<td></td>
<td>- Information management systems</td>
</tr>
<tr>
<td></td>
<td>- Information coordination and dissemination</td>
</tr>
<tr>
<td></td>
<td>- Research</td>
</tr>
<tr>
<td></td>
<td>- Research fund</td>
</tr>
<tr>
<td>Water court</td>
<td>- Establishment and operations</td>
</tr>
<tr>
<td>Financial management</td>
<td>- Cost recovery policy</td>
</tr>
<tr>
<td></td>
<td>- Pricing strategies</td>
</tr>
</tbody>
</table>
7.6.4 EVALUATION OF POSSIBLE INDICATORS

Indicators of the legislation, policies and regulations relating to water must be able to indicate change and a trend in the framework conditions. Information for appropriate indicators is not currently available. The following table (Table 7.8) provides suggestions for possible indicators that could be developed. The MIS of DRWS provides the best vehicle for regular and comprehensive collection of relevant information for some of the proposed indicators. Others could be developed by carrying out an initial analysis followed by annual monitoring of the sector.
<table>
<thead>
<tr>
<th>Definition of Indicator</th>
<th>Data Collection and Calculation</th>
<th>Uses of Indicator</th>
<th>Discussion/Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legislation, policies and regulations that refer to water management and use in terms of social, economic and ecosystem sustainability</td>
<td>No existing data base Would require analysis of existing and planned legislation, policies and regulations</td>
<td>Provide an indication of recognition by decision makers of the constitutional requirements for sustainability and potential for enforcement</td>
<td>The legislation, policies and regulations may address sustainable use of water but not be enforced.</td>
</tr>
<tr>
<td>Number of chapters of NDP considering water</td>
<td>No existing data base Would require analysis</td>
<td>Provide an indication of level of awareness and commitment of decision makers</td>
<td>As above, may recognise sustainability but ignore enforcement.</td>
</tr>
<tr>
<td>Number of policies with no legislative or regulatory backup</td>
<td>No existing data base Would require analysis</td>
<td>Provide an indication of the level of commitment of decision makers</td>
<td>As above, may offer commitment but not followed through.</td>
</tr>
</tbody>
</table>

Comment: These three indicators allow for a limited amount of change. Although there is no existing data base, these three indicators could provide a useful tool for monitoring awareness and commitment to sustainable water development and use in Namibia.

| Number of laws and regulations not enforced | No existing data base Would require information collection and analysis | Degree of effectiveness of framework legislation, policies and regulations | Very difficult to measure; a surrogate indicator may be found. |
| Number of unresolved conflicts: bulk suppliers and consumers within one catchment vandalism and theft | Little existing data base MIS of Rural Water Supply could be a source of data | Provide an indication of effectiveness of overall framework conditions and level of understanding by users and management. | Indicator could reflect on understanding of framework or could reflect on framework itself. Could be used in conjunction with other indicators. |

Comment: These two indicators require information not usually collected. If worked into the MIS system of DRWS, valuable information could emerge.
7.6.5 KEY INDICATORS

The key indicator for progress in the legislative framework of the water sector would be the presence of a White Paper on Water and a new Water Act that include allocation of water to an environmental reserve. Although the range of values for this indicator is limited, it is, however, felt that these two documents are the key to sustainability of water development and use in Namibia.

When the White Paper has been developed and a new Water Act is in place, other indicators will become relevant. First should be legislation relating to ownership of rural water supply facilities by communities. This too has a limited range of values as an indicator. Thereafter, if information is being collected for some of the potential indicators suggested in Table 7.8, one, or several of these indicators in combination, could become a key indicator. It is recommended that the follow-up key indicators would encompass, in particular, the presence of regulatory backup to legislation and the degree of enforcement of these regulations.

REFERENCES


8. NEIGHBOURING COUNTRIES

8.1 INTRODUCTION

Shared resources in the Namibian context relate mainly to surface water resources, and more specifically to the border perennial rivers and the ephemeral Cuvelai System. Groundwater flow in eastern Namibia, as illustrated in Figure 4.3, is generally in an easterly direction. From the Stampiliet Basin, flow is towards the south-east through the Nama Group host strata towards Botswana and South Africa. In northern Omaheke and eastern Otjozondjupa Regions groundwater drains towards the Okavango Swamps of Botswana. No attempt has been made to quantify this flow and it has not been raised as an issue of "shared resources".

The main shared perennial resources are the Kunene, Zambezi (including Kwando/Linyanti/Chobe System), the Okavango and the Orange Rivers. The sources of all of these systems lie upstream of Namibia, so Namibia is dependent on activities in the upstream riparian states. In the cases of the Okavango and Zambezi Rivers, however, there are riparian states downstream to whom Namibia has a responsibility.

The Cuvelai System is an important lifeline for a large rural population in the Ohangwena, Oshana, Oshikoto and Omusati Regions in northern Namibia.

8.2 SHARED RESOURCES

8.2.1 ZAMBEZI RIVER

With the exception of Katima Mulilo where water is abstracted directly from the river and some small irrigation schemes to the east of Katima Mulilo, water abstraction directly from the Zambezi River is limited to a few tourist lodges and communal settlements. Because of the large size of the Zambezi flood plains, few people live permanently close to the Zambezi River main stream. Direct abstraction from the river is tiny in comparison with the mean annual runoff of just over 40 000 Mm³.

Much of the water consumed by local inhabitants comes from boreholes sunk some distance from the mainstream or from sources associated with the Kwando/Linyanti/Chobe River system. There are a number of regional state water schemes on the Kwando and on the Linyanti (at Kongola, Linyanti, and Chinchimane). Although quantities consumed are small, the recent low flow in the Kwando has led to intakes drying up and general problems with water supply.
Although Namibia, as a riparian state, is represented on the Zambezi Action Plan Commission (ZACPLAN), which is in the process of evaluating the resources of the Zambezi with a view to a management plan, no formal discussions have taken place between Namibia and other riparian states with respect to allocations of water.

8.2.2 OKAVANGO RIVER

There are a number of bulk water abstraction points on the Okavango River, for irrigation schemes and for settlements, the largest of which is Rundu. In addition, the majority of the population in the region lives close to the Okavango River and takes water directly from it. Bulk water abstraction from the river, and transfer to the Central Area via the Eastern National Water Carrier is planned at some stage in the future. However, although there is a Joint Commission (OKACOM) in place for the Okavango River Basin, no bulk water allocations have been agreed upon for each country as yet. OKACOM is currently busy preparing to carry out a Basin-wide environmental and socio-economic survey and analysis.

8.2.3 KUNENE RIVER

The Kunene River is an important supply source for the relatively densely populated central northern areas of Namibia. Water is piped from the Calueque dam near Ruacana, or from Ruacana itself via Ogongo to Oshakati and other parts of the Oshana, Omusati, Ohangwena and Oshikoto Regions. Following discussions with Angola, Namibia has access to an agreed allocation of 190Mm³/annum which is more than double current consumption.

8.2.4 ORANGE RIVER

In addition to the demands already discussed in chapter 5, it needs to be emphasised that there is a very important environmental demand at the mouth of the Orange River. The objectives of meeting this demand are:

- Re-establishment of the salt marsh on the southern bank of the Orange River Mouth by controlled inundation,

- Restoration of the fresh water regime to control salinisation of the Orange River Mouth system by periodic fresh water flushing by releases of water down the river.

The required environmental demand has been calculated at 244Mm³/annum which is made up of 20Mm³/month (7.65m³/s) for October to July inclusive, a low flow of 4Mm³/month (1.9m³/s) during August, and a freshwater flush of 40Mm³ (19.1m³/s) in September. These criteria should be met 95% of the time.
Namibia and South Africa are still negotiating over what should be the guaranteed allocation to Namibia, although a provisional agreement has been reached on the allocation to Namibia of just over 207Mm³/annum. While this is considerably more than Namibia is using at present, there are possible long-term mining developments that could make major demands on the water.

8.2.5 CUVELAI SYSTEM

The ephemeral and variable nature of the Cuvelai System is such that an allocation agreement would be unrealistic. At present, levels of development and even levels of population density in Angola are low, so there is not a significant human impact affecting quantity or quality of flow generated in the headwaters.

It is clear however, that if any dams or control structures of the kind that have already been investigated for erection in Namibia were to be constructed in Angola, the impact on those dependent on annual floods in the catchment in Namibia would be severe (Van Langenhove 1995).

8.3 SHARED RESPONSIBILITIES

8.3.1 GENERAL

It is accepted both world-wide and within the SADC region that there is a need for responsible use of shared water and other resources. There are indeed a number of conventions, United Nations and regional protocols that are relevant to the water sector and in particular, transboundary systems. These include the following:

- Bio-diversity Protocol
- Convention on Climate Change
- Convention on Desertification
- Convention on Ozone Depletion
- RAMSAR Convention
- UN General Assembly Resolution 51/229: Convention on the law of the non-navigational uses of international watercourses
- SADC Protocol on Shared Watercourse Systems
- Helsinki Rules of the International Law Association

With the exception of the UN Resolution 51/229, the Government of the Republic of Namibia has ratified all of these protocols and/or conventions. This is an important commitment to environmental sustainability that cannot be taken lightly.

In addition, Namibia has entered into various agreements with its riparian neighbours and these are summarised in Table 8.1 and briefly discussed in 8.3.2 to 8.3.6.
Table 8.1: Agreements Covering Regional Water Management

<table>
<thead>
<tr>
<th>Name of agreement</th>
<th>Countries involved</th>
<th>Water systems</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent Joint Technical Commission (PJTC)</td>
<td>Angola, Namibia</td>
<td>Kunene River</td>
<td>Sustainable development and management focus</td>
</tr>
<tr>
<td>Joint Permanent Water Commission (JPWC)</td>
<td>Botswana, Namibia</td>
<td>Kwando/Linyanti/Chobe</td>
<td>Sustainable development and management focus</td>
</tr>
<tr>
<td>Permanent Okavango River Basin Commission (Okacom)</td>
<td>Angola, Botswana, Namibia</td>
<td>Okavango River Basin</td>
<td>Sustainable development focus</td>
</tr>
<tr>
<td>Permanent Water Commission</td>
<td>South Africa, Namibia</td>
<td>Orange River</td>
<td>Sustainable development and management focus</td>
</tr>
<tr>
<td>Treaty on the Vioolsdriift and Noordoewer Joint</td>
<td>South Africa, Namibia</td>
<td>Orange River</td>
<td>Joint Irrigation Authority</td>
</tr>
<tr>
<td>Irrigation Scheme</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SADC Protocol on Shared Watercourse Systems</td>
<td>SADC member states</td>
<td>All shared water course systems</td>
<td>Sustainable development and management focus</td>
</tr>
<tr>
<td>Zambezi River Action Plan</td>
<td>Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia, Zimbabwe</td>
<td>Zambezi River</td>
<td>Cooperation with SADC Water Sector Coordinating Unit</td>
</tr>
<tr>
<td>Draft multilateral water commissions on Orange and</td>
<td>Basin states</td>
<td>Zambezi and Orange Rivers</td>
<td>Under discussion</td>
</tr>
<tr>
<td>Zambezi Rivers</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8.3.2 ZAMBEZI RIVER

As a riparian state, Namibia has been part of ZACPLAN, the Zambezi Action Plan group since independence. The aim of this grouping has ultimately been to model the system and to arrive at an action or management plan for the Basin. Progress has been slow, hampered probably by the large number of riparian states. As yet no full co-operation agreement is in place.

Namibia has been co-operating and working together with Botswana at a technical level on the Kwando/Linyanti/Chobe tributary to the Zambezi since the early 1980s when work concentrated around control of aquatic weeds. In 1991 a Joint Permanent Water Commission was established between Botswana and Namibia. In October of that year a joint investigation of the Kwando River through to its confluence with the Zambezi was carried out and followed up in June 1992 with a jointly written proposal on future joint Namibia/Botswana Co-operation.
8.3.3 OKAVANGO RIVER

The Joint Permanent Water Commission referred to in the previous paragraph applied also to co-operation on the Okavango River. Indeed Namibia and Botswana have been co-operating at a technical level on the Okavango River since 1984. The 1994 OKACOM Agreement between Angola, Namibia and Botswana established a permanent Commission of all three Basin States. The later-signed 1995 SADC Protocol on Shared Watercourse Systems and the 1997 UN Convention on the law of the non-navigational uses of international watercourses provides a supporting framework for the agreement. Under the OKACOM Agreement, the riparian countries are working toward the implementation of an Integrated Management Plan (IMP) for the Basin. Preparatory work for this study, funded by the Global Environmental Facility has been completed and there is a realistic chance that the Commission will receive major funding to support a large-scale Basin-wide environmental analysis which will lead into the Integrated Management Plan. Work should begin on this in 1999.

8.3.4 KUNENE RIVER

In 1969, South Africa and Portugal as the colonial powers in Namibia and Angola respectively, established the Permanent Joint Technical Commission (PJTC) to deal with matters relating to the Kunene River. In 1991, the two independent governments of Namibia and Angola cemented this co-operation by ratifying the 1969 Agreement on the Kunene River and indeed the 1969 "Master Plan of the Kunene River" was accepted as a general official guideline for development of the river. It was, however, agreed that this plan was mainly technical and focussed little on environmental matters. The PJTC has been very active, not least because of the Epupa Dam Hydro-electric Scheme feasibility study.

8.3.5 ORANGE RIVER

Namibia and South Africa established the Orange River Joint Commission in 1994, shortly before the border between the two countries was moved from the northern bank of the river to the centre of the river. Since this time the two countries have worked together frequently both at a technical level on joint flow gauging exercises, and at a political level to agree on an allocation for Namibia. A provisional allocation of 207Mm³/annum has been discussed, but agreement may still be some way off.

South Africa has recently completed a re-planning study for the Orange River Basin (McKenzie, Little et al. 1996). One of the aims was to critically assess the original planning of the Lesotho Highlands Water Project. In the project document the following was stated:

"In order to proceed with the feasibility of the Vaal Augmentation Planning Study, it is necessary to ascertain how much additional water, if any, can be transferred from the
Orange River. The purpose of the Orange River Replanning Study (ORRS) is to evaluate the water resource developments that have already taken place in the Orange River Basin, to investigate options for increased resource utilisation and to determine the extent of the surplus water resources. The study will then focus on how the available resources should be allocated. The water rights of Namibia and Lesotho will also be taken into account together with the numerous social and environmental demands, both in the Orange River Basin and the adjacent Fish Sundays River Basins in the Eastern Cape.

And

"... and does not suggest that the Namibian or Lesotho requirements will be adversely influenced in any way by possible future developments. The whole issue of international sharing of water will be considered separately due to the importance of this to the countries involved. All legal and legitimate water demands (rights) of Namibia and Lesotho will be taken into account before the remaining resources are considered by South Africa for further development."

8.3.6 CUVELAI SYSTEM

While an agreement between Namibia and Angola on allocation of water from the Cuvelai System would be unrealistic in view of the unreliable nature of flows, technical co-operation leading into a permanent Basin Commission would clearly be advisable.

8.4 CO-OPERATION AND CONFLICTS

The levels of co-operation currently existing between Namibia and its riparian neighbours are generally good. On all rivers there are co-operation agreements in place. On the Kunene River there is an allocation agreement in place, and on the Orange River a provisional agreement has been discussed. However, there are no formal or informal agreements in place on the utilisation of water from the Okavango, the Kwando/Linyanti/Chobe or the Zambezi Rivers. Until the riparian states achieve a clear understanding on allocation coupled with an acceptable Basin management plan, the potential for disagreement and conflict can not be ignored.

8.5 OVERVIEW, GUIDELINES AND INDICATORS

8.5.1 RELEVANCE TO THE WATER SECTOR

Namibia’s dependence on shared water is considerable and therefore the importance of good co-operation with riparian neighbours should not be under-estimated. The work of joint commissions needs to be supported at the highest level, but at the same time the technical and scientific groundwork for proper understanding of transboundary water
resources needs to be allowed to proceed unhindered by political pressures. Only in this way can integrated management strategies be successful.

8.5.2 ASSESSMENT AND EVALUATION OF THE SITUATION IN NAMIBIA

In a relatively short time, the authorities in Namibia have succeeded in making considerable progress. Almost all the relevant international protocols and conventions designed to protect the environment have been ratified, and reasonably effective and active Joint Co-operation bodies set up with all the riparian states. Only on the Cuvelai Basin is there no formal agreement to co-operate in place.

8.5.3 PRIORITIZED CONSIDERATIONS FOR SUSTAINABILITY

The approach adopted by the Permanent Okavango River Commission in carrying out the work necessary to draw up an Integrated Management Plan could serve as a model for other Basins. The following guidelines are suggested as general aims:

- Full open sharing of all data combined with a joint data collection programme to avoid unnecessary duplication of effort between riparian states.
- Combined data verification and collection exercises between riparian states.
- Regular technical and managerial meetings between members of the Joint Commissions.
- Holistic approach to data collection and analysis. Avoid concentrating on the river only.
- Carrying out of necessary studies to achieve understanding of all environmental and socio-economic aspects of the Basin.
- Drawing up of an Integrated Management Plan.
- Agreement on Allocations.
- Consultations with local residents and their involvement in the planning and implementation.

8.5.4 KEY INDICATORS

8.5.4.1 Introduction

One key indicator is proposed, providing an indication of the level of agreement and co-operation obtained with fellow riparian states.

8.5.4.2 Agreement and Co-operation with Riparian States

Assuming that there is potential for co-operation agreements on six systems, the Zambezi, the Kwanza/Linyanti/Chobe as a separate unit, Okavango, Kunene, Cuvelai and Orange river systems, and for allocation agreements on five of them, a points system for the derivation of an indicator is suggested. Table 8.1 provides a simple way
of calculating an indicator of "Level of Agreement and Co-operation with Riparian States."

Table 8.2: Indicator of Level of Agreement and Co-operation with Riparian States.

<table>
<thead>
<tr>
<th>System</th>
<th>Co-operation Agreement (2 points)</th>
<th>Provisional Allocation (1 point)</th>
<th>Firm Allocation (3 points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zambezi</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kwando/Linyanti/Chobe</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Okavango</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kunene</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Orange</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cuvelai</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

The indicator score currently stands at 15 out of 27, or 50%. The target is 100%.
REFERENCES


# GLOSSARY OF TERMS

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthropogenic</td>
<td>Caused by the activities of humans.</td>
</tr>
<tr>
<td>Arid</td>
<td>An area where mean annual rainfall is less than 250mm; rainfall is seasonal and variable, and where evaporation far exceeds rainfall.</td>
</tr>
<tr>
<td>Artificial Recharge</td>
<td>The enhancement of the natural process by which an aquifer is refilled with water, from the surface.</td>
</tr>
<tr>
<td>Average Incremental Costs</td>
<td>A unit cost, taking into account the unit costs of marginal investments and their chronological incidence in time.</td>
</tr>
<tr>
<td>Base flow</td>
<td>This is the minimum flow in the river when floods have subsided.</td>
</tr>
<tr>
<td>Bed slope</td>
<td>The gradient of the riverbed of a river measured along the direction of the potential (or in the case of a flowing river) existing flow.</td>
</tr>
<tr>
<td>Block Tariff</td>
<td>A tariff schedule which has different volumetric prices for different volumes of water consumption. E.g. the first 10m$^3$ may cost N$1/m^3$, the next 10m$^3$ may cost N$2/m^3$.</td>
</tr>
<tr>
<td>Bulk water supply</td>
<td>The supply of water in large quantities, usually to a consumer such as a municipality, a mine or an industrial complex, for further distribution.</td>
</tr>
<tr>
<td>Catchment</td>
<td>The area from which runoff flows into a river. Catchments are separated from each other by higher ground such as mountains or ridges.</td>
</tr>
</tbody>
</table>
Channel
The deepest part of the river through which the main volume of water flows.

Climate change
The alteration in climate (more or less rain, hotter or colder) that happens over very long periods of time, and which has been linked to ozone depletion and an increase in greenhouse gasses.

Coefficient of storage/storativity
The volume of water an aquifer releases from or takes into storage, per unit surface area of the aquifer per unit change in head. (This is a dimensionless coefficient – m³/m²/m).

Control structures
In the context of discharge measurement these are any structures built across a river to stabilize the channel bottom so that discharge can be accurately measured. NB Control structures would be defined otherwise in the context of water supply.

Dual Pipe System
Where two networks of pipes exist for the transport of different quality water.

Economic Efficiency
The use of resources such that economic net benefits are maximised. Refers to efficient production, consumption and allocation of resources.

Ephemeral
Lasting for only a short time. When applied to water, describing a river that only flows for a few days each year after localised rainfall.

Evaporation
Water loss to vapour that takes place from open surface water.

Evapotranspiration
Evaporation from an open water surface plus transpiration from vegetation.

Flood frequency
How often floods of a certain size can be expected.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow</td>
<td>The quantity of water passing a point in a given time. Usually expressed as cubic metres per second or litres per second.</td>
</tr>
<tr>
<td>Hydrograph</td>
<td>A graph representing river flow against time.</td>
</tr>
<tr>
<td>Igneous rocks</td>
<td>Rocks produced by volcanic or magmatic agency.</td>
</tr>
<tr>
<td>Indicator</td>
<td>A measure of the status of a factor, e.g. water, that assists with discerning changes and trends, provides an understanding of processes, provides an early warning of emerging problems and measures the effectiveness of policies</td>
</tr>
<tr>
<td>Infiltration rate</td>
<td>How rapidly water moves into a particular soil type.</td>
</tr>
<tr>
<td>Inter-seasonal correlation</td>
<td>The correlation between data from successive seasons.</td>
</tr>
<tr>
<td>Isohyetes</td>
<td>A line drawn on a map joining together points of equal rainfall values.</td>
</tr>
<tr>
<td>Merit Good</td>
<td>A good which confers benefits to society in consumption over and above the benefits to the individual.</td>
</tr>
<tr>
<td>Metamorphic rocks</td>
<td>Sedimentary or igneous rocks that have been transformed by natural agents (e.g. heat and pressure).</td>
</tr>
<tr>
<td>Opportunity Costs</td>
<td>The cost of forgone economic opportunities.</td>
</tr>
<tr>
<td>Perennial</td>
<td>When applied to water, refers to a river that has water flow all year round</td>
</tr>
<tr>
<td>Piezometric surface</td>
<td>An imaginary surface representing the total head of groundwater in a confined aquifer that is defined by the level to which the water will rise in a well.</td>
</tr>
<tr>
<td>Pollution of groundwater</td>
<td>Where the concentration contaminant levels limit or restrict the potential use of groundwater – (Driscoll p890)</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Precipitation</td>
<td>In Namibia, this refers to rainfall, hail, dew and fog, although snow is also water which falls (or &quot;precipitates&quot;).</td>
</tr>
<tr>
<td>Price Elasticity of Demand</td>
<td>The responsiveness of demand (e.g. for water) to changes in price.</td>
</tr>
<tr>
<td>Recharge</td>
<td>The addition of water to the zone of saturation; also the amount of water added</td>
</tr>
<tr>
<td>Rest or static water level</td>
<td>The level of water in a well (borehole) that is not being affected by withdrawal of groundwater.</td>
</tr>
<tr>
<td>Return interval</td>
<td>How often a particular event can be statistically expected to happen again.</td>
</tr>
<tr>
<td>Return period</td>
<td>Length of time over which a particular event can be expected to happen again.</td>
</tr>
<tr>
<td>Saturated thickness</td>
<td>The thickness of saturated material in an aquifer.</td>
</tr>
<tr>
<td>Sedimentary rocks</td>
<td>Rocks which are formed from water-borne or wind born sediments.</td>
</tr>
<tr>
<td>Sentenial Sites</td>
<td>Representative sites selected for monitoring phenomena over a widespread region.</td>
</tr>
<tr>
<td>Specific yield</td>
<td>The ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity to the volume of that mass. This ratio is stated as a percentage.</td>
</tr>
<tr>
<td>Storm duration</td>
<td>The length (in time) of a rainfall event.</td>
</tr>
<tr>
<td>Sustainability, environmental</td>
<td>The non-wasteful use of natural resources for appropriate reasons that does not jeopardise the availability of these resources for use by future generations or does not adversely affect the natural functioning of water resources</td>
</tr>
</tbody>
</table>
Sustainability, social

The social framework which empowers self-control over resources, at the individual and national level; goals include population stability, poverty alleviation and empowerment of women.

Transmissivity

The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. Measured in m³/d through a vertical section 1 m wide extending the full-saturated thickness of the aquifer under a hydraulic gradient of 1.

Unaccounted for Water

The difference between the water put into a system and the water that is measured within the system. Leakage, inaccurate meters, illegal connections and administrative errors contribute to unaccounted for water.

Value-added

The contribution of an economic activity to Gross Domestic Product (GDP).

Virtual Water

Water embedded in imported products, in some cases freeing domestic water for production of other goods rather than domestic production of potential imports.

Water Resource:

A natural source or occurrence of water which is not artificially confined, e.g. river, spring, aquifer.

Water Consumption:

The actual quantity of water consumed at a Water Demand Centre or by any other consumer.

Water Demand Centre:

A community, village, town or region identified as using water from any source.

Water Demand Management

The implementation of policies which influence the consumer-demand for water and the demands on primary sources of water.
Water Demand: The quantity of water required to meet the needs of a Water Demand Centre or other consumer. If either the yield from the Water Resource, or the supply capacity of the Water Infrastructure cannot meet the Water Demand, water consumption will be less than the demand.

Water Infrastructure: Facilities and equipment used to abstract, purify, store or convey water from a Water Source to the point of consumption.

Water Supply Capacity: The capacity of the installed Water Infrastructure to supply water to a Demand Centre.