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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
THE REPUBLIC OF SOUTH AFRICA

THE STUDY ON THE EXPANSION OF CAPACITY OF MAGALIES WATER IN THE REPUBLIC OF SOUTH AFRICA (PHASE 1)

FINAL REPORT

SUPPORTING REPORT (B)
SITUATIONAL ANALYSIS

DECEMBER 1996

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SUPPORTING REPORT B : GAP ANALYSIS

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ABBREVIATIONS AND TERMINOLOGY

The following abbreviations are used in this report:

AADD	Annual Average Daily Demand
ANC	African National Congress
BLA	Black Local Authorities
BODA	British Overseas Development Agency
CAPEX	Capital Expenditure
CASE	Community Agency for Social Inquiry
CBOs	Community Based Organisations
CDE	Centre for Development and Enterprise
CIP	Capital Investment Plan
CRDC	Community Reconstruction and Development Committee
CRCS	Crocodile River Catchment Study
CSIR	Council for Scientific and Industrial Research
CWSS	Community Water Supply and Sanitation
DAF	Dissolved Air Flotation
DANIDA	Danish International Development Agency
DBSA	Development Bank of Southern Africa
DC	District Council
DCF	Discounted Cash Flow
DFA	Development Facilitation Act
DWAF	Department of Water Affairs and Forestry
ESA	Extended Supply Area of Magalies Water Board as gazetted in April 1996
ESCOM	Electricity Supply Commission
GIS	Geological Information System
GNU	Government of National Unity
GSWCA	Government Subterranean Water Control Area
GWCA	Government Water Control Area
GWS	Government Water Scheme
IB	Irrigation Board

IBS	Irrigation Board Scheme
IDT	Independent Development Trust (NGO)
IFR	Instream Flow Requirements
IMT	Interim Management Team
INR	Institute of National Resources
JICA	Japan International Cooperation Agency (the official agency responsible for the implementation of the technical cooperation programmes of the Government of Japan)
LAPC	Land and Agricultural Policy Centre
LRDC	Local Reconstruction and Development Committee (Local RDP Committee)
LWC	Local Water Committee
MSF	Medicines Sans Frontiers
MEC	Member of Executive Committee
MW	Magalies Water Board
NELF	National Electrification Forum (ESKOM Database)
NGOs	Non-Governmental Organisations
NPV	Nett Present Value
NWP	North West Province
NWWA	North West Water Supply Authority
O&M	Operation and Maintenance
ODA	Official Development Assistance
ODO	Organisation Development Officer
OECF	Overseas Economic Cooperation Fund of Japan
PLP	Presidential Lead Project
PMC	Project Management Committee of the JICA Study
PSC	Project Steering Committee of the JICA Study
PWB	Phalaborwa Water Board
PWG	Project Working Group of the JICA Study
PWSSD	Provincial Water Supply and Sanitation Directorate
PWV	Pretoria Witwatersrand Vereeniging triangle (geographical area)
RBC	Rotating Biological Contactor
RDP	Reconstruction and Development Programme

RSA Republic of South Africa

RSC Regional Service Council
(regional bodies established to facilitate and coordinate service provision across local boundaries. To be replaced by Regional and District Councils)

RWB Rand Water Board

S/W Scope of Works

SAMWU South African Municipal Workers Union

SANCO South African National Civic Organisation

SCOWSAS Standing Committee on Water Supply and Sanitation

SDD Summer Daily Demand

Setplan Settlement Planning Services Consulting Engineers

SGT Self-Governing Territories

SR Service Reservoir

STW Sewage Treatment Work

SWET Sanitation and Water Education and Training Program

TA Tribal Authority

TBVC Transkei, Bophuthatswana, Venda, Ciskei (former ""independant"" homelands)

TDS Total Dissolved Salts

THM Trihalomethanes

TLC Transitional Local Council

TMC Transitional Metropolitan Council

TOR Terms of Reference

TRC Transitional Rural Council

VIDP Ventilated Improved Double Pit toilet (latrine)

VIP Ventilated Improved Pit Latrine

WP White Paper

WRC Water Research Commission

WRYM Water Resources Yield Model

WTW Water Treatment Works

UNITS

c	Cent (100c = R1)
ha	Hectare
kg/c/year	Kilograms per capita per year
kl	Kilolitre
kld	Kilolitres per day
km	Kilometre
km2	Square kilometre
l/c/yr	Litres per capita per year
lcd	Litres per capita per day
m3/c/yr	Cubic metres per capita per year
mcm	Million cubic metres
mcm/a	Million cubic metres per annum
mg/l	Milligrams per litre
Mld	Megalitres per day
R	Rand (R1 = 100c)

CHAPTER 1 : INTRODUCTION

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1.1 Background

In August 1995, the Governments of South Africa and Japan agreed the scope of work for a technical co-operation programme focused on the expansion of the capacity of Magalies Water (MW). The Japan International Cooperation Agency (JICA) is currently undertaking the study in close co-operation with the Department of Water Affairs and Forestry (DWAF) in South Africa. The initiative to expand the capacity of Magalies Water is a direct outcome of South Africa's new Water and Sanitation policy, which is based on the Reconstruction and Development Programme (RDP). In terms of the policy, institutions like Magalies Water will extend bulk supply networks in the longer term, and will assist in stimulating and supporting local level water supply and management institutions in the short to medium term.

The overall framework of the JICA Study is as follows:

PHASE 1 - Formulation of a Master Plan

Stage 1 - Situational Analysis

Stage 2 - Formulation of a Master Plan up to the year 2015 and priority projects to the year 2002

Stage 3 - Recommendations on study methods and terms of reference for Phases 2 and 3

PHASE 2 - Feasibility Study on priority projects

PHASE 3 - Implementation of selected water supply and sanitation pilot initiatives

Against the background of the overall framework described above, the present JICA Study is concerned only with the Phase 1, formulation of an overall and strategic framework / master plan for the appropriately phased, long term, sustainable development of water supply infrastructure and sanitation, including appropriate Second and Third Tier support, in the Study Area. The formulation of a priority project to the year 2002, and an extended programme up to the year 2015 is included in the present JICA Study.

The first Stage of this Phase was a Situational Analysis. The purpose of this was to understand the socio-economic conditions, hydrological and hydrogeological resources, demand for water, supply of water, existence and condition of infrastructure, present standard and coverage of services, environmental conditions, policy implications, capacity and roles of the First, Second and Third Tiers, water supply attitudes and practices at the community level, financial situation, and water tariffs and cost recovery systems.

The second Stage of the Phase is to formulate a Master Plan which includes the Gap Analysis, the Policy / Strategy Recommendation / Plan, the Preliminary Study of Water Supply System (Technical Solution), and the Economic/Financial Analysis of the formulated project(s) under pre-feasibility level including an initial capital investment plan.

The objective of the Gap Analysis was to establish a complete understanding of the Gap between the Current State (institutional, technical and financial) of water infrastructures in the Magalies Water Study Area and the desired future state, as presented in the Water Supply and Sanitation policy. The current state has been determined in the Situational Analysis. The future state is identified through key policy documents such as the White Paper on Water Supply and Sanitation, as well as the needs and expectations of the communities and other consumers in the Study Area.

The objective of the Policy / Strategy Recommendation / Plan was: to facilitate and guide the expansion of Magalies Water through practical recommendations regarding policy and strategy; to identify areas of national policy that support/hinder the expansion of MW, and to propose actions to be taken; to identify areas of policy in specific water sector and related institutions that require attention, and to propose appropriate actions; and to propose strategies to deal with institutional and technical gaps that are likely to hinder the expansion of MW, together with strategies that will facilitate the expansion process.

The objective of the Technical Solution was to quantify the technical requirements to achieve the standards and levels of service identified in the desired future state and bridge the Gap mapped out in the Gap Analysis.

The objective of the Economic/Financial Analysis is to quantify both the cost and the benefit to be incurred by and arising from the project proposals which are to be evaluated from various viewpoints of RSA's national economy and the second and third tiers' entrepreneurial stance. The lessons obtained from a series of analysis will be fed to further Phases 2 and 3 of this Study.

Key to the success of the JICA Study is the support and involvement of the main stakeholders in water supply and sanitation in the Study Area - Magalies Water Board, national and regional offices of DWAF, local authorities, district councils, local and Provincial Government, communities and their representative organisations, and NGOs. To ensure that this involvement occurs the following Institutional arrangements have been put in place:

- The entire JICA Study is managed by a Project Management Committee (PMC), on which sits representatives of Magalies Water, Department of Water Affairs and Forestry and JICA. The PMC sits approximately once a month; and

- Project Working Groups (PWGs) have been established to oversee the activities of the Study Team and the local consultants. Three PWGs were established, which include representatives of key stakeholders, as well as MW, DWAF and JICA.

1.2 Composition of Master Plan Report

The Final Report is composed of an Executive Summary, Main Report, Supporting Reports and a Data Book. Each Supporting Report covers an individual part of the Study and has been prepared to provide detailed information to the more interested or specialist reader. The Supporting Reports are as follows:

A General Affairs
B Situational Analysis
C Gap Analysis
D Policy and Strategy Options
E Preliminary Study of Water Supply System
F Institutional Development Plan
G Economic/Financial Analysis

The Data Book contains primary data and information, and only a limited number of hard copies will be produced which will be held by key stakeholders (such as DWAF and Magalies Water). The contents of the Data Book will be made available in electronic format whenever applicable.

1.3 Supporting Report B

The first stage of the JICA Study involved a detailed situational analysis i.e. a review of the existing conditions prevailing in the Study Area in the Study Area which included institutional and technical aspects as shown in the table. The work was completed mid 1996 and as circumstances in the Study Area are constantly evolving, some of the findings may already have become out of date. Also certain findings have subsequently been developed and are explained in more detail in other parts of the Report. The information from the situational analysis still provides a good overview of circumstances in the area and provided a good basis for the subsequent work therefore it is presented here.

TECHNICAL STUDY	INSTITUTIONAL STUDY
• Background (physical, socio-economic conditions) • Investigation of peripheral areas • Review of policy on Second Tier roles, responsibilities • Water study (infrastructure, demand forecasts) • Profile of Second Tier organisations	• Water study, including issues of policy and cost recovery • Issue scoping with stakeholders • Audit of capacity and readiness in the Third Tier • Case studies of 30 selected communities

Key findings were as follows:

1.3.1 Infrastructure and Resource Issues

(1) Water availability in the Study Area is adequate at present. By 2015 the population of the Study Area will grow from 3.1 million to over 5 million. However the increased demand is expected to be offset by increased return flows.

(2) Water is imported into the Study Area, and the storage capacity of dams is close to the natural mean annual runoff. Water resources are highly interdependent and require integrated planning and development.

(3) There is potential for: improved surface water utilisation (eg. increased use of Klipvoor Dam), more efficient use of water, and reallocation of water resources. To meet growing primary demand, transfer of irrigation quotas (with compensation), to primary users may be required.

(4) Certain existing supplies (especially groundwater), do not meet potable water quality standards desirable for the Study Area.

(5) Water treatment infrastructure is generally in a good condition. There are relatively few sewage treatment plants.

(6) The Study Area is generally characterised by poor availability and predictability of groundwater resources.

1.3.2 Policy Issues

(1) The policy and legal frameworks for water supply and sanitation are still evolving. There is a need for new policy in certain areas, for revision of existing policy, and for more integration.

(2) Policy sees water supply to be a local government responsibility. Interim Second Tier roles must support but not undermine local officials.

1.3.3 Institutional Issues

(1) The merger of Magalies Water and most of the areas of NWWA falling into the Study Area is going ahead. There are many challenges, including subsidy reduction in former NWWA areas, and the effective short and long term deployment of former NWWA staff.

(2) Cost recovery varies among Second and Third tier authorities administering water schemes. Magalies Water has full recovery, but the challenge is to improve recovery elsewhere. Lowest recovery levels are in the former homelands.

(3) Non-payment has two sides. It hinders the phasing out of subsidies, but also causes implementing agencies to shy away from projects in the areas where they are most urgently needed.

(4) Stakeholders in the Magalies expansion see the following challenges ahead: linking the best attributes of MW and NWWA; clarification of short and long term roles for Second and Third Tiers; the cost implications of expanded supply for MW and its customers; the feasibility of achieving RDP targets in the Study Area; and the mobilisation of broader representation on the board of MW.

(5) Capacity among Third Tier organisations is highly varied. Clarity on roles and sources of support is emerging. District Councils have a key strategic and integrative role. Success will depend on capacity, development expertise and ability to mobilise resources at and for the Third Tier level.

(6) Community capacity is diverse. In some cases there is organisation around water, and a readiness to manage local supply. In other places this is absent. Key obstacles (in some places) include limited community participation in water management issues, factors leading to non-payment; weak and conflicting local organisations, unauthorised connections (sometimes supported by local officials), and lack of water knowledge.

I. TECHNICAL STUDY

CHAPTER 2 : BACKGROUND TO THE STUDY

CHAPTER 2 BACKGROUND TO THE STUDY

CHAPTER 2 BACKGROUND STUDY

2.1 Description of the Study Area and Topography

The Study Area is situated between 24°30' S and 26°08' S and 26°28' E and 29°19' E, and extends from the Limpopo River in the north to Gauteng in the south and from the western part of the Limpopo River to the confluence of the Olifants and Elands rivers in the east.

On the western side of the Study Area, the Crocodile River rises on the Witwatersrand, just north of Roodepoort at a height of approximately 1,700 m above sea level. It then flows in a generally north-westerly direction for 280 km, during which it is joined by the Marico River, at just below 900 m above sea level. After the confluence the river becomes the Limpopo River which forms the border of South Africa with Zimbabwe and Botswana.

The watershed in the south, between the Vaal River catchment and the Crocodile River catchment, is formed by the Witwatersrand with the Magalies Mountains situated just to the north. The average slope of the area decreases from south to north.

The Crocodile River flows through the Witfonteinrant and the Vlieëpoort Mountains, which run in an east-westerly direction, in the region of Thabazimbi. The Hoek mountains form the watershed in the north-east between the Crocodile River and the Mogol River. The well known Pilanesberg is in the west of this catchment.

Towards the east, the Waterberge mountains, which are about 1,800 m above sea level, are located between the Crocodile and Mogalakwena Rivers. The Mogalakwena River rises as the Nyl River, just north of Nylstroom, at an altitude of between 1,000 and 1,500 m above sea level. It then flows in an easterly direction through the flat, poorly drained Nylvlei wetland, at approximately 1,100 m above sea level, after which it flows through a wetland. About 45 km north west of Potgietersrus, the Mogalakwena River is joined by one of its main tributaries, the Sterk River, and as it flows northwards it is fed by numerous small tributaries, until it finally flows into the Limpopo River at approximately 600 m above sea level.

The Olifants River Basin is situated south of the Nyl River. Within the Olifants River Basin, both the Wilge and Olifants Rivers rise at a height of between 1,200 m and 1,800 m above sea level. To the east, the Wilge River rises near Devon on the Highveld and then flows in a northerly direction until its confluence with the Olifants River, upstream of Loskop Dam. The major tributaries of the Wilge River are the Bronkhorstspruit, Saalboomspruit, and Grootspruit.

The Olifants River rises to the east of the Wilge River, at an altitude of between 1,200 m and 1,800 m above mean sea level. The Olifants River is joined by the Trichardtspruit, Steenkoolspruit and the Rietspruit, before its confluence with the Klein-Olifants River of which the Keeromspruit and the Rietkuilspruit are the major tributaries. After the confluence of the Olifants River with the Klein-Olifants River, it is joined by the Klipspruit and the Wilge River respectively.

To the north-east, the Olifants-Loskop area is encountered into which the Selons, Bloed and Moses rivers flow. This catchment includes the Springbok Flats area (900 m to 1,200 m above sea level), in the north and the undulating Highveld (1,200 m to 1,800 m above sea level) in the south.

The Elands River rises near Kaztan and is situated to the south-west of the Olifants-Loskop area. The Elands River flows in a northerly direction through hilly country for about 60 km, until it reaches the Rust de Winter Dam where it turns in a westerly direction to its confluence with the Olifants River, just to the south of the Springbok Flats.

2.2 Climate

For the purpose of considering climate, the Study Area has been subdivided into three regions; the western region (Crocodile River Basin), the northern region (Mogalakwena River Basin) and the eastern region (Olifants River Basin). The Study Area is reviewed from west to east for the purposes of this section of the report.

2.2.1 Rainfall

Summer rainfall is predominant in the Study Area. The western region receives most rainfall from November to February, and the northern and eastern regions receive rainfall mainly from October to March.

The mean annual rainfall in the west ranges from 500 mm to 800 mm. In the northern region, the mean annual rainfall decreases from 1,060 mm, at the source of the Nyl River, to 170 mm at the confluence of the Limpopo and Mogalakwena Rivers. On the eastern side of the Study Area, the mean annual rainfall ranges between 500 mm and 800 mm.

There are over 1,000 rainfall stations located within the Study Area however Table 2-1 provides details of six representative stations.

There is an increase in the occurrence of frost from west to east, with the west receiving little frost in winter and the east receiving frost in the low lying areas from May to September.

Hailstorms are common in the eastern region, with typically four to seven incidents occurring annually in any given location.

The annual evaporation rate increases from 1,700 mm in the east to 2,240 mm in the west. The evaporation rate is higher in summer than in winter. Evaporation is measured at 26 stations within the Study Area and Table 2-2 shows average evaporation at three representative stations.

2.2.2 Temperature

Average monthly temperatures range from 8°C to 28°C in the west and 11°C to 27°C in the east. The greatest extremes in temperature are experienced in the western part of the Study Area, where the temperature can fluctuate from -11°C to 40.6°C. Representative average temperatures are reflected in Table 2-3.

2.2.3 Wind

In the north of the Study Area, prevailing winds are light to moderate in a north-easterly direction, and occasionally south-easterly in winter. In the eastern region, the prevailing wind direction is from the south-east. The representative average wind speed is reflected in Table 2-4.

2.3 Environmental Sensitivity

It is necessary to consider the sensitivity of the natural environment to water resources development because of the inter-relationship between these factors within the river ecosystem. Human activities can have major impacts on the ecological system, which in turn can result in changes in the quality and quantity of water available for water users.

There are a number of proclaimed nature reserves and other areas of special conservation importance in the Study Area.

The Magaliesberg Mountain range, from Pretoria to Rustenburg, has been declared an area of special conservation importance in term of the Environmental Conservation Act of 1989, Act 73 of 1989.

The vegetation and wildlife of the Study Area will be briefly discussed below.

2.4 Vegetation

The western region of the Study Area is predominantly bushveld, however the central and northern regions are represented by a variety of veld types, and the eastern region consists of grasslands in the south and savanna in the north.

The western region of the Study Area is predominantly bushveld with the following trees: *Acacia galpinii, Acacia erioloba, Acacia nigrescens, Combretum imbrebe, Spirostachys africana, Scherocarya caffra, Lannea discolor* and *Ficus natalensis.* The other types of vegetation present in this region are Turf Thornveld, (which is also present on the eastern side of the Study Area on the north western banks of the Elands River), Kalahari Thornveld and Sandy Grassveld. Turf Thornveld is a naturally open thornveld, which tends to thicken as a result of poor grazing practices.

Further east, Sour Bushveld is found in the south-western area of the Waterberg mountains, and along the south-western banks of the Nyl River. This veld type consists of an open savanna of tall, straight *Faurea saligna* trees in a tall, tufted, wiry, sour grassveld in the less rocky areas and a dense mixed bushveld in the rugged areas. Sour Bushveld is important for catchment protection and a number of red data species are endemic to it.

To the north-east, Sourish Mixed Bushveld is found along Nyl River flood-plane, as well as on the eastern side of the Study Area, at the confluence of the Olifants and Wilge rivers, where it borders on a negligibly small area of Mixed Bushveld. This veld type occupies an irregular belt on the lower slopes of mountains, between the sour types (both grassveld and bushveld), and the mixed types of the plains and valleys. Like the Sour Bushveld, it is also an open savanna, however the dominant tree type is *Acacia caffra*, within a fairly tall, dense grass veld which is dominated by *Cymbopogon plurinodis, Themeda triandra, Elionurus muticus* and Hyparrhenia.

Further northwards, Mixed Bushveld is present along the lower reaches of the Nyl River and the middle reaches of the Mogalakwena River. Mixed Bushveld contains a mixture of *Terminalia/Dichapetalum* and tends to be quite dense with small trees. It usually occupies sandy plateaux and valley regions.

At the source of the Mogalakwena River, a variety of veld types are present: North East Mountain Sourveld, Springbok Flats Turf Thornveld and Pietersburg Plateau False Grassveld. Springbok Flats Turf Thornveld is a naturally open thornveld, which tends to thicken up when the grass cover is reduced by grazing mismanagement, and Pietersburg Plateau False Grassveld is an open, clumpy Sourish Mixed Bushveld, with *Acacia rehmanniana* as its most common tree.

Arid Sweet Bushveld is present within the middle reaches of the Mogalakwena River and just before the confluence of the Limpopo and Mogalakwena Rivers.

In the far north of the Study Area, at the confluence of the Mogalakwena and Limpopo Rivers, Mopani Veld is present. Mopani Veld is a typically short, fairly dense growth of shrubby *Colophopermum mopane*, which is usually associated with a number of other trees and shrubs within a sparse and tufted grassveld.

Further east Turf Highveld, which is a pure grassveld type, is encountered within the southern region of the Wilge River and the upper reaches of the Olifants River tributaries; Steenkoolspruit and Trichardtspruit. Bankenveld, a false grassveld type, is found in the central regions of the Wilge River catchment (covering a total of 70% of the entire catchment); the majority of the lower Olifants River catchment; the south western part of the Elands River catchment and in the central regions of the Olifants-Loskop area.

In the far eastern region in the vicinity of the Olifants-Loskop area, North Eastern Sandy Highveld is encountered. It is a very dense veld type which is dominated by sour grass species.

2.5 Threatened Plant Species

Threatened plant species are found in the east of the Study Area, where there are usually less than 10 threatened species present, except within the Wilge River catchment, where 20 threatened plant species are found. The number of vulnerable plant species increases in the wetter areas at the confluence of the Wilge River with the Bronkhorstspruit and Olifants rivers.

2.6 Alien Vegetation and Bush Encroachment

The presence of alien plant species has a number of serious ecological implications for both indigenous vegetation and the production potential of the land. The banks of rivers is the habitat which is most affected by the presence of alien plant species. The most significant of these alien plant species are; *Syringa*, the grey poplar (*Populus canescens*) and the giant reed (*Arundo donax*).

In places where *Syringa* is present, it becomes the dominant canopy tree and is a serious threat to indigenous riverine vegetation and the associated fauna.

The grey poplar occurs in dense thickets, which suppress indigenous vegetation, as well as blocking and narrowing river courses.

The giant reed, invades water courses and tends to go largely unnoticed at the expense of the indigenous riparian vegetation.

2.7 Wildlife

2.7.1 Fish

There is no data available for the western part of the Study Area. In the northern and central regions, 26 species of fish are present. Of these, 24 are indigenous and 2 have been introduced. Some of the species found in this region include: *Tilapia rendalli, Tilapia sparmanii, Clarias gariepinus, Labeo cylindricus* and *Barbus trimaculatus*.

Further eastwards, within the Olifants River Basin, there are 61 fish species present. The Olifants River Basin can be subdivided into the Wilge River and its tributaries, the Elands River and its tributaries and the Bloed, Olifants and Moses Rivers and their tributaries. The smallest number of fish species is found in the Wilge River, where only 13 species occur, 4 of which are classified as having the maximum sensitivity to environmental conditions and one (*Barbus argenteus*, which is found in the Bronkhorstspruit), is of special conservation concern. Within the Elands River, 29 fish species are found; 6 of which have maximum sensitivity to environmental conditions and one, namely *Chiloglanis sweirstrai*, is of special conservation concern as a result of it been habitat specific and confined to the fast flowing sections of streams over sandy or pebbly beds. Within the Bloed, Olifants and Moses rivers, 44 fish species are found of which

9 have maximum sensitivity to environmental conditions, and one, *Chiloglanis sweirstrai*, is of special conservation concern.

The fish species which have maximum sensitivity to environmental conditions include, *Barbus trimaculatus, Barbus paludinosus, Tilapia sparmanii, Clarias gariepinus* (which depends on rapids or well-oxygenated water), and *Cyprinus carpio*.

Within the Upper Olifants River, 17 fish species are found, 5 of which have maximum sensitivity to environmental conditions. Of these, only *Austroglanis selateri* has been identified as a threatened species.

2.7.2 Reptiles and Amphibians

In the northern central regions of the Study Area, a variety of rare and vulnerable reptile and amphibian species are found within the Mosdene area.

Further eastwards in the Olifants River Basin, there are no endangered reptile or amphibian species within the Wilge River and Elands River regions. Within both the Upper Olifants River and the Olifants-Loskop Reach, fewer than 5 species of reptiles and amphibians have been classified as being endangered, rare or vulnerable. In the Upper Olifants River region, there has been habitat destruction as a result of the development of agriculture.

There is no data available for the western region of the Study Area.

2.7.3 Mammals

A variety of rare and vulnerable mammal species are found in the northern and central regions of the Study Area. Within the Sterk River region, the rare and vulnerable species which are encountered include Cape hare, bushbabies and leopard.

Eastwards towards the Olifants River Basin, a variety of mammal species are encountered some of which are noted as red data species. A breakdown of the total number of species and red data species present within each region is shown in Table 2-5.
At present, there is no data available for the western region of the Study Area.

The serval, the hippopotamus and the water rat are found within the Wilge River region. These species are of particular importance as a result of their aquatic habitats which are can be affected by either an increase or a decrease in river flow.

There are 34 mammal species found in the Upper Olifants River area. Of these, only the hedgehog, which has been classified as "rare" is a listed Red Data Species,.

2.7.4 Birds

In the northern and central regions of the Study Area over 300 bird species are found. Of these, only 25 are Red Data species. Within the Sterk River catchment, species which are present include the Peregrine falcon, Cape vulture and the black eagle.

Further eastwards towards the Olifants River catchment, it is found that the number of bird species present in each region varies greatly.

The greatest variety of bird species are found near Settlers (350 species), the Loskop Dam (300 species) and the Wilge River (300 species). Elsewhere, the greatest variety of bird species is found near the Elands River (250 - 300 species), and the lowest variety in the Upper Olifants River (50 - 100 species). There are less than 5 Red Data species present in each region, except for the Upper Olifants River, where there are less than 10 Red Data species present.

2.8 Ecological Flow Requirements

Although the need to allocate water resources for maintaining riverine ecosystems is not at present recognised in law, current practise is to take cognisance of the so-called Instream Flow Requirements (IFR), in the planning and design of new water supply schemes. Proposed amendments to South African water law also give prominence to the needs of riverine ecosystems.

Development of the water resources of the country dates back more than 70 years and in some cases no consideration was given to IFR's. As a result, releases from storage dams generally do not include any allowance for ecosystems and the result has been unplanned and uncontrolled environmental impact, usually in a negative sense, sometimes resulting in serious damage which is very costly to put right, if it is possible at all.

Recent serious attempts to assess and take account of IFR's in new water resource development projects include cases where the negative effects of past neglect of IFR's affect the feasibility of new proposals to a degree which makes them non-viable. In extreme cases, capital investment in new storage facilities would be necessary to meet modest environmental management objectives without adding to the availability of water supplies.
Although not yet fully documented, there is strong evidence to show that the need to provide streamflow downstream of existing and proposed storage dams, and to retain streamflow in unregulated rivers, has a significant effect on the quantity of water which can be made available for domestic use or for any other purpose.

2.9 Environmental Laws

Many organisations are actively engaged in, or have responsibilities for planning, management, local administration and data collection of natural resources in the Study Area. The main laws governing these activities are as follows:

Environmental Conservation Act (Act No 73 of 1989): This law pertains to all aspects of development and the environment and basically provides for "the effective protection and controlled utilisation of the environment". It makes provision for:

- the protection of ecological processes, natural systems, natural beauty and the preservation of biotic diversity in the natural environment;

- the promotion of sustained utilisation of species and ecosystems and the effective application and re-use of natural resources; and

- the protection of the environment against disturbance, defacement, poisoning and destruction.

It allows for:

- the protection of the natural environment if it will promote the preservation of ecological processes, natural systems, natural beauty or indigenous species, or biotic diversity in general;

- the declaration of any area as a special Nature Reserve or as a limited development area for the purposes of protection of the environment, land or water resources; and

- the identification of any activity which may detrimentally affect the environment, including water use and disposal, and may require that an Environmental Impact Assessment (EIA) is conducted for any activity identified above.

Although it has the potential to be immensely powerful, a lack of regulations so far makes this Act ineffective. This law was rewritten and published in 1982 as No 100 of 1982: Environmental Conservation Act, 1982. Implemented by the DEA.

Mountain Catchment Areas Act (Act No 63 of 1970) and the Mountain Catchment Areas Amendment Acts (Acts No 41 of 1976 and 76 of 1981):

These acts provide for the "conservation, use, management and control of land situated in mountain catchment areas", and are of particular relevance to water resources management. However, no areas within the Study Area are listed and thus the Act is currently irrelevant to this Study. Implemented by the DEA.

Conservation of Agricultural Resources Act (Act No 43 of 1983):

This act provides for "control over the utilisation of the natural agricultural resources of South Africa to promote soil, water and vegetation conservation and combat weeds and invader species" and is thus important as far as any development which may affect the vegetation and agricultural potential of an area, including water resources, is concerned. Implemented by the Department of Agriculture.

Weeds Act No 42 of 1937 as amended by Acts No 2 of 1939, No 50 of 1952 and No 32 of 1964 and No 74 of 1969:

This Act provides for the eradication of such plants as may be declared to be weeds by proclamation of the State President (formerly the Governor-General). A duty is placed on the occupier or owner of land to eradicate such weeds. Previous to the passing of Act No 50 of 1952 (Section 4), the extirpation of noxious weeds was under the control of the Provincial Councils. The Jointed Cactus Eradication Act, No 52 of 1934, was repealed by the Weeds Amendment Act, No 32 of 1964 and jointed cactus is now dealt with under the Weeds Act.

Water Act, Act 54 of 1956 and amendments:

Relates to the pollution of the environment and is discussed in another section.

These are not the only laws relating to the environment and many laws and bye-laws are at present being rewritten however they serve as a guide to the variety of relevant laws implemented by different Government Departments and illustrate the complexity of environmental law enforcement.

2.10 Environmetal Management

Environmental management is done on a provincial basis and the following is a list of institutions involved in the Study Area:

Gauteng: (Mr S Furrey)

The Director
Nature Conservation
Private Bag X209
PRETORIA
0001

North West Province: (Mr P van Rooyen)

The Director
Environmental Conservation
PO Box 4303
BRITS
0250

Mpumalanga: (Dr G Batchelor)

The Director
Environmental Management
Private Bag 11233
NELSPRUIT
1200

2.11 Geology

2.11.1 Lithology

The lithologies represented in the Study Area comprise a wide variety of sedimentary, igneous and metamorphic rock types. These span a geological history of some 3,500 million years, the oldest being represented by unnamed gneiss and migmatites formed towards the end of the Swazian Erathem and the youngest by Quaternary alluvium, sand and calcrete formed less than 18 million years ago. Other chronological periods of significance are recognised as the following:

(1) Between approximately 2,300 and 2,100 million years ago, during the Vaalian Erathem, when the Chuniespoort, Pretoria and Rooiberg Group rocks as well as the Bushveld Complex were formed;

(2) Around 1,300 million years ago, during the Mokolian Erathem, when the alkaline intrusive Complexes such as Pilanesberg were formed; and

(3) Between 345 and 190 million years ago, during the late Palaeozoic and early Mesozoic Erathems, when the Ecca Group shales, the Clarens and Irrigasie Formation sediments and the Letaba Formation basalt's were formed.

A broad subdivision of the major geological formations is presented in Table 2-6 together with a brief description of the rock types relevant to each and statistics pertaining to their surface extent. Note that the order of their listing from top to bottom mirrors their chronostratigraphic relationship to one another from youngest to oldest.

2.11.2 Structural Geology

The structural geology of the Study Area is characterised by numerous large scale features such as the regionally extensive Bushveld Complex and the smaller ring-like Pilanesberg Complex, an alkaline intrusive. More specific to the groundwater regime, however, are smaller structural features such as linear fault zones and dyke intrusions.

Subsequent to the solidification of rocks emplaced during the final phase of igneous activity associated with the Bushveld Complex, tensional conditions in the earth's crust led to the development of normal faults in the western part of the Study Area. The strike of these features is mainly north-northwest. The Rustenburg fault represents one such structure. Others are recognised in the vicinity of the Crocodile River between Thabazimbi and Brits. The existence of these regional scale features points to the likely existence of many more such, but smaller, features. An inspection of the 1:250,000 and 1:50,000 scale geological maps confirms this. These structures offer preferred targets for the siting of successful water supply boreholes.

Intrusions of syenite and diabase characterise the dyke structures, which are of pre-Karoo age. The Pilanesberg swarm of north-northwest trending dykes are representative of these intrusions. They are characterised by their generally negative magnetic signatures relative to those of the surrounding country rock (Day, 1980). These structures generally constitute important targets for the siting of successful boreholes in the Study Area.

2.11.3 Economic Geology

The economic geology of the Study Area is characterised by a rich assemblage of minerals. According to Coetzee (1976), these range from precious metals (the non-ferrous platinum-group metals, gold, copper and lead), to basic metallic minerals (the ferrous minerals chrome, manganese, iron, molybdenum and nickel), to non-metallic minerals (kaolin, dimension stone, wollastonite, limestone, phosphate, glass sand, fire clay and road-building materials). The mineral wealth of the Study Area is exploited by both larger scale mining operations, centred on the extraction of the more valuable minerals such as the platinum-group metals, chrome and iron ore, and smaller operations such as those producing dimension stone.

2.12 Surface Water Quality

2.12.1 Introduction

South Africa is a water deficient country therefore the Water Act (1956) requires that effluent be treated and returned to the water course from which it was abstracted. As a result of this practise, salination, pollution and eutrophication occur and the quality of many water sources in the Study Area is declining. The urban areas of Pretoria, northern Johannesburg and the surrounding communities are located in the upper catchments of the Crocodile and Olifants river systems which flow through the Study Area and as a result many of the sewage treatment works serving these communities are located just outside or just within the southern fringe of the Study Area and discharge into watercourses which in turn feed most of the large impounding reservoirs therein.

In the peri-urban and rural parts of the Study Area, particularly in the north and east, poor sanitation comprising the use of pit latrines or other low-flow sanitation options is widespread. This has a particularly adverse effect on groundwater quality which is discussed in more detail elsewhere. The use of oxidation ponds without mixers is practiced within the Study Area however strict criteria governing the design and operation of such facilities are intended to prevent any significant impact on groundwater or surface water quality. Current legislation permits the use of such ponds for effluent flows of less than 750 m^3/d.

Mining operations are widespread within the Study Area and the level of treatment of liquid waste from mining operation varies considerably. Such treatment facilities are often designed, constructed and operated by, or under the supervision of, mining engineers rather than specialists in wastewater engineering. However DWAF applies the same effluent quality standards to mining facilities as for other industrial operations and enforcement measures are taken against those causing serious pollution.

2.12.2 Salination

Natural salination of water sources is recognized as a problem internationally in arid and semi-arid regions. This natural problem has been exacerbated by urbanization and industrialization. Water is a scarce resource in South Africa therefore indirect reuse of water is widely practiced and return flows are a vital water resource in the Study Area. There are various degrees of salinity above which water becomes unsuitable for use for potable water supply, industry and agriculture. Although the WHO (1984) drinking water guidelines specify 1,000 mg/l TDS, possible adverse health effects from potable water with high TDS will depend on the concentration of individual constituents. In the case of industry, different sectors will have different maximum values of TDS above which they cannot use the water without further treatment and the level of certain elements will have major economic implications for certain industries such as mineral processing. The problem is compounded when desalination techniques such as ion exchange are used by industry and a concentrated brine waste is generated. It is necessary to establish controls for the safe disposal of such brines to prevent further salination of water sources. For agriculture, the prevailing soil conditions and the crop concerned will determine what level of TDS can be tolerated for irrigation.

Mitigation measures currently used include blending using a second source and the use of the river channel for return flows while water for primary use downstream is carried in a canal (such as the one from Roodeplaat Dam which supplies the water treatment works at Wallmannsthal and Temba).

2.12.3 Pollution Prevention Control Measures

Effluent standards were introduced in South Africa for the first time in the Water Act, 1956. The treatment of any water resulting from industrial use is obligatory and three types of standards are currently applicable:

- General Standard. (applied universally);
- Special Standard, (for specified streams); and
- Special Standard for Phosphorous, (for sensitive catchments).

The requirements apply only to physical and chemical (but not biological), parameters. The pollution prevention policy has been formulated primarily on the polluter pays principle.

In addition to these standards, DWAF has established water quality guidelines for various uses based on the Receiving Water Quality Objective (RWQO) approach to ensure that water remains fit for use by downstream users. This is done by imposing stricter standards than the general requirements where necessary due to local conditions. Catchments studies for the Olifants and Crocodile basins include guidelines for critical parameters.

In the long term, surface water quality in Study Area will continue to deteriorate as the volume of return flows and urban runoff increase, with urbanization and with the expansion of water supply and sewerage systems, while the natural runoff will decrease. The rate of deterioration will largely depend on activities south of the Study Area, which will be the origin of much of the return flows, and will be of great significance to downstream users, particularly for primary use. The development of water quality models as a tool for integrated catchment management is strongly recommended.

The long term trend of deteriorating water quality in the Study Area will have a significant impact on MW as treatment costs and possibly the level of treatment required are likely to increase. The need to use powdered activated carbon will become more frequent and at some point in the future, probably beyond the target date of 2015, it may be necessary to introduce a further stage of treatment such as GAC absorbers.

2.12.4 Eutrophication of Surface Water

Eutrophic water is that which contains sufficient nutrient material (nitrogen and phosphorous in the context of water supply), to support prolific growth of aquatic plants. The problems caused by eutrophication are numerous and are described in detail in "Management of Water Resources of the Republic of South Africa" published by the Department of Water Affairs in 1986.

In the context of the Study Area, these problems include:

- increased treatment cost, (additional process stages, such as microscreens and DAF, and additional chemicals, such as powdered activated carbon, are necessary for effective treatment at water works such as Wallmannsthal, Temba, Kudube, Brits etc.);

- control of algal growth is necessary in irrigation canals (as for the Hartbeesport and Loskop schemes);

- control of algae is necessary in the storage reservoirs to enable recreational activities to continue;

- loss of aesthetic appearance which in turn affects the value of properties located close to water bodies (lake-side homes, leisure related businesses etc.); and

- adverse health impact on fish, livestock, pets and possibly humans.

It is estimated that 80 to 90% of nutrients in water sources originate from point sources. Therefore, in order to control nutrient levels in an effort to reduce eutrophication, the South African Government introduced a phosphate standard of 1.0 mg/l soluble orthophosphate as P for effluents discharged in seven critically sensitive catchments. The standard was introduced in 1980 and full implementation was required by 1985. Two of these seven critically sensitive areas fall within the Study Area: the Pienaars and Crocodile rivers upstream of their confluence and the Olifants River upstream of Loskop Dam. Together these catchments comprise more than half of the Study Area.

Although there is not consensus amongst limnologists concerning the nutrient concentrations above which eutrophication takes place, it is informative to assume some such levels in order to assess the vulnerability of stored water in the Study Area to eutrophication. General features of a eutrophic lake and of an origotrophic lake were described by Okada (JICA Text) and levels of nutrients above which eutrophic characteristics are exhibited were greater than 0.2 mg/l for total nitrogen and greater than 0.02 mg/l for total phosphorous.

Table 2-7 shows data from the DWAF database which was reviewed for the purpose of analyzing the surface water quality within the Study Area. The values which exceed the above levels of nitrogen and phosphorous are underlined.

Although the parameters reviewed (nitrate/nitrite and phosphate concentrations) do not fully represent the total nitrogen and total phosphorous concentrations, the analysis below does indicate reservoirs where eutrophication is likely to occur.

The table indicates that based on average nitrate/nitrite and phosphate concentrations the nitrogen and phosphorous levels exceed or are approaching the nutrient levels required for eutrophication to take place at many locations. Algae does cause problems at many of the water treatment works.

2.12.5 Existing Surface Water Quality

In order to make an assessment of the conditions prevailing in the rivers and raw water reservoirs within the Study Area, use was made of information from the water quality database of DWAF. Representative points were selected from all of the survey stations within the Study Area. The locations selected included all impounding reservoirs, intermediate stations, when available, located on the watercourses between such reservoirs, and such additional points as were necessary to provide an overall picture of water quality in the major rivers. Recent data was analyzed statistically and the results are summarized in Tables 2-8 and 2-9. The detailed data obtained from DWAF is included in Part C of the Data Book

It should be noted that the period and frequency of sampling was not necessarily the same at all stations. This is especially true of the rivers, some of which are also subject to considerable flow variation. Unfortunately for some stations no flow data is available for correlation with water quality. The absence of data for metals for most stations, especially iron and aluminium, is unfortunate as the levels of these parameters is important in assessing treatment process suitability.

In addition to the information obtained from DWAF, sampling and analysis was carried out under the supervision of the Study Team to investigate the quality of water being consumed, water treatment works performance and the quality of potential new raw water sources within the Study Area. The sampling was carried out in two stages and the reports are included in Part E of the Data Book.

2.12.6 Suitability of Surface Water for Treatment

In order to derive possible raw water quality criteria for treatability of water for domestic use, a technique proposed in a paper published in 1988 by the Hydrological Research Institute of DWAF, "Water Quality Objectives for Raw Water for Potable Use" (PL Kempster and HR Van Vliet), was used which proposes the following three relationships to relate raw water quality to the water quality standards recommended in SABS 241-1984 "Specification for Water for Domestic Supplies". The approach seeks to take into account the variability of raw water quality and the effectiveness of the treatment process for each parameter. The relationships proposed are:

$P_{50} = R_{ec} \times f$
$P_{90} = M_{al} \times f$
$P_{100} = C_l \times f$

where P_{50} is the 50% non exceedence percentile, P_{90} the 90% non exceedence percentile, P_{100} the 100% limit, f is a purification removal correction factor determined for each parameter and R_{ec} the Recommended limit in SABS 241, M_{al} the Maximum allowable limit in SABS 241 and C_l the "Crisis limit" proposed in the NIWR criteria ("Proposed aesthetic / physical and inorganic drinking water criteria for the Republic of South Africa", Kempster and Smith, 1985), as there is no equivalent criteria in SABS 241. Table 2-10 below is reproduced from the 1988 paper and shows the above levels for each parameter. The data obtained from DWAF and summarised in Tables 2-8 and 2-9 was assessed with respect to the values shown in Table 2-10.

In the main, the data indicates that water quality is suitable for conventional treatment. It must be noted however that the parameters considered are limited and some key parameters are not included as data was not available from the database (e.g. iron, manganese, total phosphorous, total nitrogen etc.).

With respect to impounded water, exceedance of the above values was mainly with respect to

TDS which exceeded the P_{50} level at Roodekopjes Dam, Bospoort Dam and Leeukral Dam. At Olifantsnek the P_{90} level for pH was also marginally exceeded. The TDS levels which are in excess of the P_{50} level by about 10% all fall well within the WHO recommended level of 1,000 mg/l and do not present a problem.

A similar trend can be seen in the rivers with TDS levels in excess of the P_{50} figure in the Crocodile River at Crocodilepoort, Vaalkop and Hardekoolbult. The P_{50}, P_{90}, and P_{100} levels for nitrates and nitrites are exceeded in the Crocodile River at Kalkheuwal.

Although not in exceedance of the guideline levels in the above table, the level of fluorides in the Moses River at Uitspanning and in the Elands River at Weltevreden, (both in the extreme north-east of the Study Area), and in Vaalkop Dam sometimes exceed the recommended limit of 1.0 mg/l hence care must be taken to ensure that if this water is treated, that the level of fluorides present in the raw water is reduced.

2.13 Water Quality Standards

The South African Water Quality Guidelines (1993) published by DWAF govern water quality and will comprise eight volumes as shown below.

Volume 1: Domestic Use
Volume 2: Recreational Use
Volume 3: Industrial Use
Volume 4: Agricultural Use
Volume 5: Natural Environment
Volume 6: Integrated Manual
Volume 7: Estuarine
Volume 8: Coastal and Marine Environment

Only volumes 1 to 4 have been published to date; the first five will relate to inland surface water and groundwater. A revision of Volume 1 which relates to domestic use is due to be issued shortly. It must be noted that compliance with these Guidelines is not mandatory and cannot be enforced nor does non-compliance warrant punitive measures. The 1993 edition of Volume 1: Domestic Use, was based on South African Standards 241-1984 "Specification for Water for Domestic Supplies" where applicable, and reference was also made to standards used in other countries. SABS 241 specifies a "Recommended Maximum Limit" and a "Maximum Allowable Limit" for various physical, chemical and bacteriological parameters.

The parameters included in Volume 1 of the Guidelines differ from those in SABS 241; some parameters are included in the Guidelines but not included in SABS 241 and vise versa. For each parameter information is given on:

- the occurrence of the substance in the natural environment
- standards used in other countries
- background information
- inter-dependence with other constituents and properties
- interpretation of measurements.

For a series of different ranges of concentrations, the possible health effects and treatment options are described for each substance and a target guideline range is indicated.

In the event that the Water Quality Guidelines do not refer to a particular constituent, then it is recommended that reference be made to the drinking water quality criteria of the Department of National Health and Population Development (Aucamp and Vivier, 1990). In these criteria, three levels are specified for each constituent of which the two most onerous, "Maximum Level for No Risk" and "Maximum Level for Insignificant Risk", are broadly the same as the Recommended Limit and Maximum Allowable Limit specified in SABS 241.

In Table 2-11 the guideline levels in SABS 241 and Volume 1, the Water Quality Guidelines and the Department of National Health and Population Development criteria are shown for comparison purposes with WHO, Japanese and EU water quality standards.

Table 2-1: Monthly Average Rainfall for Representative Rainfall Stations

Station No	Station	Period of Records	Monthly Average Rainfall (mm)												
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
0591 538	Marblehall	1938 - 1996	85	75	49	38	8	5	1	4	17	44	89	105	520
0515 412	Witbank	1956 - 1996	140	89	85	42	12	6	4	8	25	86	126	111	734
0589 503A	Warmbaths	1941 - 1996	120	84	74	37	7	6	2	5	16	58	101	124	510
0513 285	Pretoria	1916 - 1996	136	75	82	51	13	7	3	6	22	71	98	110	674
0548 165	Pilanesberg	1915 - 1986	78	71	58	38	6	12	3	5	25	57	61	105	414
0511 524	Rustenburg	1918 - 1996	144	103	95	56	11	4	2	8	24	58	100	114	719

Table 2-2: Average Evaporation

Average Evaporation (mm)													
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Warmbaths	229	187	186	143	134	111	127	175	229	252	232	105	2,250
Pretoria	195	175	161	114	98	74	83	120	152	200	181	105	1,746
Pilanesberg	265	241	202	174	156	118	131	175	219	256	276	124	2,497

Table 2-3: Average Temperatures

Average Temperature (°C)												
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Marblehall	25.4	25.0	23.7	20.2	16.2	12.7	12.8	15.7	20.1	22.6	23.5	24.8
Warmbaths	23.5	23.0	21.5	18.7	15.2	12.0	12.1	15.1	19.1	21.4	22.2	23.0
Pretoria	23.0	22.6	21.5	18.2	14.9	11.8	12.0	14.9	18.6	20.4	21.4	22.4
Pilanesberg	25.3	24.5	23.2	19.7	15.9	12.2	12.2	15.7	19.5	22.2	23.5	24.4

Table 2-4: Representative Average Wind Speed

Average Wind Speed (m/s)												
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Warmbaths	3.1	2.6	2.7	2.6	2.5	2.5	2.6	2.9	3.3	3.6	3.3	3.1
Pretoria	2.9	2.6	2.4	2.4	2.4	2.6	2.6	3.2	3.3	3.3	2.9	2.8
Pilanesberg	2.9	3.2	3.1	3.0	2.7	3.2	3.2	3.8	3.7	3.6	3.8	3.4

Table 2-5: Mammal Species Present Within the Olifants River Basin

Region	Total No of Species	Total No of Red Data Species	Vulnerable	Rare	Indeterminate
Wilge River	44	9	3	5	1
Elands River	63	14	4	8	2
Bloed, Olifants and Moses Rivers	57	5	3	2	-

Table 2-6: Distribution of the Major Geological Formations

Major Geological Formations / Rock Type	Surface Extent	
	Area (km^2)	Percentage of Total
1. Quaternary Sediments (alluvium, sand, calcrete)	903	3
2. Letaba Formation (basalt)	496	2
3. Irrigasie / Clarens Formations (sandstone, siltstone, mudstone)	2,160	8
4. Ecca Group (shale)	1,468	5
5. Dwyka Tillite Formation (tillite, diamictite)	475	2
6. Basic Intrusive Rocks and Alkaline Complexes (foyaite, syenite)	2,939	11
7. Waterberg Group (sandstone)	730	3
8. Lebowa Granite Suite (hornblende and biotite granites)	4,694	17
9. Bushveld Complex (gabbro, norite, anorthosite)	5,200	19
10. Rooiberg Group (porphyritic and amygdaloidal rhyolite)	1,449	5
11. Pretoria Group (quartzite, shale)	6,122	22
12. Chunlespoort Group (dolomite, chert, quartzite)	664	2
13. Unnamed Swazian Rocks (gneiss, migmatite)	20	1
Total	27,320	100

Table 2-7: Vulnerability of Raw Water Storage Reservoirs to Eutrophication

Name of Raw Water Storage Reservoir	Average Concentration (mg/l)		Water Treatment Works Using Raw Water
	NO_3/NO_2 as N	Ortho-PO_4 as P	
Bon Accord Dam on Apies River	0.47	0.024	
Hartbeespoort Dam on Crocodile River	1.80	0.029	Brits WTW
Rietvlei Dam on Hennops River	0.79	1.101	
Roodeplaat Dam on Pienaars River	0.83	0.263	Wallmannsthal, Temba WTW
Lindleysoort Dam on Elands River	0.39	0.033	
Koster Dam on Koster River	0.11	0.025	Koster WTW
Klipvoor Dam on Pienaars River	0.08	0.331	
Roodekopjes Dam on Crocodile River	0.14	0.037	
Bospoort Dam on Hex River	0.16	0.214	Bospoort WTW
Warmbath Dam on Buffels Spruit	0.08	0.028	
Vaalkop Dam on Elands River	0.22	0.028	Vaalkop WTW
Leukraal Dam on Apies River	3.08	1.358	Kudube WTW
Buffelspoort Dam on Sterkstroom River	0.05	0.014	
Olifantsnek Dam on Hex River	0.17	0.039	
Swartsruggens Dam on Elands River	0.34	0.040	Swartsruggens WTW
Loskop Dam on Olifants River	0.07	0.032	
Rust de Winter Dam on Elands River	0.14	0.018	(Weltervreden WTW)
Rhenosterkop Dam on Elands River	0.15	0.013	Weltervreden WTW
Bronkhorstpruit Dam on Bronkhorstpruit	0.12	0.019	Bronkhorstpruit WTW, (Cullinan WTW)

Table 2.8: Water Quality in Dams in the Study Area

Station Number	Hydro Stations		Elec Cond (mS/m)	Total Diss Salts (mg/l)	pH	Na Diss (mg/l)	Mg Diss (mg/l)	Ca Diss (mg/l)	F Diss (mg/l)	Cl Diss (mg/l)	NO_3/NO_2 as N (mg/l)	SO_4 Diss (mg/l)	Ortho PO_4 as P (mg/l)	TAL as $CaCO_3$ (mg/l)	Si Diss (mg/l)	K Diss (mg/l)	NH_4 as N (mg/l)
A2R001Q01	Hartbeespoort Dam on Crocodile River	Average	49.6	337	8.5	43	14	29	0.5	47	1.80	69	0.029	96	2.0	9.7	0.09
		50%	48.2	340	8.5	43	14	28	0.6	47	2.18	68	0.027	94	1.4	9.8	0.06
		90%	54.8	371	9.0	49	15	36	0.7	51	2.64	74	0.044	108	3.7	10.4	0.20
		Max	59.8	395	9.7	51	20	45	0.7	59	2.76	83	0.056	164	4.0	11.1	0.23
		Min	44.6	283	7.9	33	13	19	0.4	33	0.43	56	0.009	66	<0.4	5.3	<0.04
A2R002Q01	Bon Accord Dam on Apies River	Average	47.8	342	8.3	29	17	38	0.4	31	0.47	49	0.024	140	3.2	5.2	0.05
		50%	46.8	346	8.4	29	17	36	0.4	27	0.44	46	0.025	142	3.9	5.0	0.04
		90%	60.2	435	8.6	40	21	49	0.6	46	1.07	61	0.034	171	4.5	6.9	0.09
		Max	61.5	443	8.8	41	22	49	0.8	54	1.25	64	0.038	177	5.0	7.0	0.10
		Min	34.4	242	7.7	17	11	27	0.2	17	<0.04	34	<0.005	105	<0.4	3.9	<0.04
A2R003Q01	Olifantsnek Dam on Hex River	Average	18.4	142	8.0	5	10	22	0.2	5	0.17	9	0.039	71	6.3	3.9	0.11
		50%	15.1	110	7.4	4	9	12	0.2	3	0.04	6	0.029	67	6.1	2.8	0.06
		90%	28.9	214	9.7	8	15	23	0.3	8	0.47	11	0.061	102	7.0	5.2	0.24
		Max	35.7	285	10.4	9	20	155	0.4	9	0.62	40	0.183	138	7.1	13.4	0.32
		Min	11.0	88	6.9	2	5	8	0.1	<3	<0.04	<4	0.007	43	5.6	1.9	<0.04
A2R004Q01	Rietvlei Dam on Hennops River	Average	52.8	384	8.5	56	11	30	0.4	38	0.79	68	1.101	134	4.5	14.7	0.83
		50%	52.2	385	8.4	55	11	30	0.4	37	0.99	69	1.254	133	4.6	10.8	0.80
		90%	56.8	406	9.0	61	11	33	0.6	43	1.44	75	1.519	138	5.3	11.4	1.14
		Max	66.1	413	9.2	66	12	33	0.8	45	1.53	86	1.556	141	6.6	14.7	1.25
		Min	46.7	353	8.1	48	10	28	0.2	33	<0.04	55	0.170	118	3.4	9.8	<0.04
A2R005Q01	Buffelspoort Dam on Sterkstroom River	Average	8.6	48	7.3	2	3	4	0.1	8	0.05	6	0.014	18	3.9	2.7	0.06
		50%	6.7	44	7.3	2	3	4	0.1	6	0.04	6	0.012	18	3.8	1.4	0.04
		90%	10.6	75	7.6	2	4	4	0.2	17	0.06	9	0.021	23	4.9	7.5	0.09
		Max	66.1	97	8.0	5	4	13	0.3	26	0.13	13	0.037	48	5.4	13.2	0.22
		Min	4.9	28	6.7	<2	2	3	<0.1	<3	<0.04	<4	<0.005	6	2.6	1.0	<0.04
A2R006Q01	Bospoort Dam on Hex River	Average	74.5	516	8.8	88	22	31	0.4	108	0.16	85	0.214	137	1.7	14.2	0.21
		50%	75.3	526	8.9	94	23	30	0.3	116	0.06	87	0.229	132	1.7	14.5	0.07
		90%	86.6	585	9.2	104	25	37	0.5	123	0.39	111	0.401	164	2.8	16.7	0.36
		Max	100.8	785	9.5	119	40	52	0.7	174	1.53	123	0.707	237	3.7	17.8	4.67
		Min	49.1	354	7.8	52	13	21	0.2	61	<0.04	36	0.006	96	<0.4	9.3	<0.04
A2R007Q01	Lindley's Poort Dam on Elands River	Average	17.7	139	8.1	7	9	13	0.3	6	0.39	17	0.033	67	4.6	4.8	0.05
		50%	18.3	142	8.1	6	9	13	0.3	6	0.39	17	0.031	69	4.6	4.7	0.04
		90%	21.0	168	8.3	8	10	16	0.5	7	0.60	21	0.046	80	5.2	5.7	0.07
		Max	22.2	173	8.3	15	11	18	0.6	8	0.65	25	0.099	86	5.7	6.0	0.15
		Min	7.8	71	7.7	3	3	6	0.2	<3	0.06	10	0.011	30	3.8	2.7	<0.04

Table 2.8: Water Quality in Dams in the Study Area

Station Number	Hydro Stations		Elec Cond (mS/m)	Total Diss Salts (mg/l)	pH	Na Diss (mg/l)	Mg Diss (mg/l)	Ca Diss (mg/l)	F Diss (mg/l)	Cl Diss (mg/l)	NO_3/NO_2 as N (mg/l)	SO_4 Diss (mg/l)	Ortho PO_4 as P (mg/l)	TAL as $CaCO_3$ (mg/l)	Si Diss (mg/l)	K Diss (mg/l)	NH_4 as N (mg/l)
A2R008Q01	Warmbad Dam on Buffels Spruit	Average	7.3	55	7.5	4	2	4	0.3	5	0.08	6	0.028	35	5.3	3.1	0.08
		50%	7.4	53	7.4	4	2	4	0.3	5	0.04	5	0.017	25	5.4	2.8	0.04
		90%	7.7	63	7.7	5	3	5	0.4	6	0.10	8	0.033	30	5.6	3.8	0.16
		Max	7.8	64	7.8	5	3	5	0.6	6	0.37	10	0.199	222	5.7	3.9	0.24
		Min	6.5	48	7.2	3	2	3	0.1	3	0.04	4	0.005	20	4.6	2.5	0.04
A2R009Q01	Roodeplaat Dam on Pienaars River	Average	49.2	344	8.5	47	13	27	0.4	48	0.83	40	0.263	127	1.5	8.9	0.32
		50%	49.6	344	8.4	47	13	27	0.3	48	0.79	40	0.276	124	1.3	8.9	0.22
		90%	49.6	344	8.4	47	13	27	0.3	48	0.79	40	0.276	124	1.3	8.9	0.22
		Max	58.2	387	9.6	54	15	34	0.6	56	2.11	49	0.514	163	3.2	9.6	1.48
		Min	43.1	299	7.2	42	11	22	0.3	41	<0.04	29	0.066	106	0.5	8.0	<0.04
A2R011Q01	Koster dam on Koster River	Average	21.2	169	8.2	7	11	16	0.4	6	0.11	13	0.025	90	3.5	4.3	0.05
		50%	21.4	171	8.3	7	11	16	0.4	6	0.08	12	0.021	90	4.0	4.3	0.04
		90%	23.1	185	8.4	9	13	18	0.5	8	0.19	20	0.037	99	4.6	4.8	0.06
		Max	23.7	194	8.5	10	14	19	0.6	9	0.45	26	0.141	105	6.4	5.0	0.33
		Min	6.7	50	7.3	3	2	4	0.2	4	<0.04	5	0.008	24	1.6	0.3	<0.04
A2R012Q01	Klipvoor Dam on Pienaars River	Average	61.7	456	8.7	64	18	34	0.6	62	0.08	66	0.331	162	3.1	11.7	0.52
		50%	61.1	466	8.7	64	18	33	0.6	64	0.04	67	0.316	160	3.6	11.4	0.04
		90%	70.4	492	9.0	79	21	39	0.8	74	0.14	77	0.452	180	5.4	13.3	0.57
		Max	79.6	558	9.1	82	21	43	0.8	81	0.38	78	1.033	198	5.7	15.8	8.47
		Min	47.6	376	8.1	47	15	28	0.5	46	<0.04	49	0.113	137	<0.4	9.8	<0.04
A2R013Q01	Swartruggens Dam on Elands River	Average	13.7	92	7.1	5	7	9	0.2	8	0.34	6	0.040	44	3.3	2.6	0.11
		50%	13.6	96	7.1	4	7	9	0.2	8	0.28	6	0.022	46	3.8	2.4	0.10
		90%	16.4	106	7.6	6	9	11	0.2	9	0.70	11	0.076	53	5.2	3.5	0.18
		Max	24.9	178	8.0	11	14	18	0.3	17	0.87	14	0.210	92	5.7	6.4	0.35
		Min	8.8	44	6.4	3	4	5	<0.1	4	<0.04	<4	<0.005	14	<0.4	1.9	<0.04
A2R014Q01	Vaalkop Dam on Elands River	Average	58.9	420	8.2	54	22	35	0.9	54	0.22	74	0.028	142	3.3	7.6	0.10
		50%	52.3	380	8.2	47	20	34	0.9	45	0.20	63	0.023	140	3.3	7.6	0.09
		90%	83.0	608	8.5	85	31	50	1.1	93	0.28	125	0.042	180	3.7	9.0	0.15
		Max	88.3	678	8.6	98	36	52	1.2	105	0.70	140	0.155	197	4.7	9.6	0.27
		Min	36.2	255	7.5	26	12	21	0.6	22	0.05	31	<0.005	103	2.5	6.2	<0.04
A2R015Q01	Roodekopjes Dam on Crocodile River	Average	77.0	543	8.5	72	29	44	0.6	82	0.14	109	0.037	162	3.7	9.0	0.06
		50%	77.2	550	8.5	73	30	45	0.6	83	0.12	108	0.020	162	3.4	9.0	0.05
		90%	81.5	584	8.6	76	32	55	0.7	92	0.25	117	0.031	185	5.4	9.7	0.09
		Max	87.8	615	8.7	78	34	55	0.8	99	0.50	124	0.260	187	8.0	9.8	0.18
		Min	65.2	460	8.3	63	21	34	0.4	62	<0.04	95	<0.005	133	<0.4	7.9	<0.04

Table 2.8: Water Quality in Dams in the Study Area

Station Number	Hydro Stations		Elec Cond (mS/m)	Total Diss Salts (mg/l)	pH	Na Diss (mg/l)	Mg Diss (mg/l)	Ca Diss (mg/l)	F Diss (mg/l)	Cl Diss (mg/l)	NO_3/NO_2 as N (mg/l)	SO_4 Diss (mg/l)	Ortho PO_4 as P (mg/l)	TAL as $CaCO_3$ (mg/l)	Si Diss (mg/l)	K Diss (mg/l)	NH_4 as N (mg/l)
A2R016Q01	Leeukraal Dam on Apies River	Average	72.6	541	8.6	81	18	45	0.5	73	3.08	77	1.358	177	6.3	12.9	0.11
		50%	73.9	555	8.5	86	18	45	0.5	76	3.14	78	1.339	178	6.6	13.8	0.07
		90%	82.9	600	9.1	94	20	51	0.6	84	5.10	85	2.067	196	8.1	14.9	0.24
		Max	88.7	672	9.4	105	22	54	0.7	90	5.53	104	2.451	233	8.7	15.7	0.78
		Min	56.1	380	7.9	43	15	36	0.2	44	0.10	57	0.311	127	1.9	1.2	<0.04
B2R001Q01	Bronkhorstpruit Dam on Bronkhorstspruit	Average	31.3	233	8.2	14	17	20	0.4	11	0.12	18	0.019	121	1.4	5.5	0.06
		50%	30.7	231	8.3	13	17	20	0.3	11	0.06	17	0.016	120	1.4	5.4	0.05
		90%	33.3	249	8.6	14	18	21	0.4	13	0.28	22	0.033	129	2.1	5.9	0.08
		Max	41.9	274	8.7	19	20	23	0.5	14	0.34	24	0.047	140	2.3	6.8	0.21
		Min	26.4	192	7.0	10	14	17	0.2	9	<0.04	13	0.005	98	0.7	4.7	<0.04
B3R001Q01	Rust de Winter on Elands River	Average	17.7	122	7.6	13	5	9	0.5	12	0.14	13	0.018	52	5.3	6.6	0.06
		50%	17.4	120	7.6	13	5	9	0.4	12	0.08	10	0.012	51	5.4	6.4	0.06
		90%	19.0	135	7.9	15	6	11	0.8	14	0.31	27	0.036	65	7.7	9.2	0.10
		Max	20.3	150	8.2	20	6	11	3.3	16	0.48	32	0.100	72	10.0	10.3	0.11
		Min	15.9	104	6.8	10	4	6	<0.1	7	<0.04	<4	<0.005	28	1.5	1.9	<0.04
B3R002Q01	Loskop Dam on Olifants River	Average	30.8	194	7.9	21	10	19	0.4	13	0.07	81	0.032	37	2.8	4.5	0.05
		50%	30.5	193	7.9	21	10	19	0.4	14	0.04	81	0.015	36	2.8	4.5	0.04
		90%	34.1	223	8.1	25	10	22	0.5	15	0.13	99	0.030	42	3.3	4.9	0.07
		Max	37.7	234	8.4	27	12	22	0.7	18	0.22	108	0.590	47	3.4	5.4	0.08
		Min	26.6	160	7.4	15	8	9	0.2	7	<0.04	60	<0.005	29	1.4	4.0	<0.04
B3R005Q01	Rhenosterkop Dam on Elands River	Average	29.6	216	7.9	26	8	19	1.2	19	0.15	8	0.013	106	4.8	6.8	0.10
		50%	30.0	216	8.0	25	8	20	1.2	18	0.11	7	0.010	107	4.6	7.0	0.06
		90%	36.0	259	8.3	38	9	22	1.5	30	0.31	12	0.023	129	7.0	7.7	0.17
		Max	39.2	300	8.5	43	11	26	2.2	35	0.61	30	0.094	147	11.3	8.1	0.75
		Min	9.3	70	5.5	6	3	6	0.1	5	<0.04	<4	<0.005	32	0.5	3.2	<0.04

Table 2.9: Water Quality in Rivers in the Study Area

Station Number	Hydro Stations		Elec Cond (mS/m)	Total Diss Salts (mg/l)	pH	Na Diss (mg/l)	Mg Diss (mg/l)	Ca Diss (mg/l)	F Diss (mg/l)	Cl Diss (mg/l)	NO_3/NO_2 as N (mg/l)	SO_4 Diss (mg/l)	Ortho PO_4 as P (mg/l)	TAL as $CaCO_3$ (mg/l)	Si Diss (mg/l)	K Diss (mg/l)	NH_4 as N (mg/l)
A2H006Q01	Pienaars River at Klipdrift	Average	53.9	387	8.3	51	17	30	0.6	53	0.21	35	0.057	153	2.8	7.9	0.05
		50%	54.6	386	8.3	51	17	31	0.6	54	0.13	36	0.044	156	3.1	7.6	0.04
		90%	61.7	446	8.5	58	21	37	0.9	62	0.52	42	0.090	190	4.3	9.0	0.07
		Max	73.6	516	8.8	70	26	43	1.0	71	0.73	64	0.444	227	5.2	14.1	0.23
		Min	24.9	192	7.8	23	9	13	0.3	23	<0.04	21	0.016	18	<0.4	5.9	<0.04
A2H012Q01	Crocodile River at Kalkheuwel	Average	58.5	407	8.2	48	14	42	0.5	52	7.87	70	0.380	109	5.9	10.4	0.31
		50%	60.1	421	8.2	51	14	44	0.5	54	8.26	69	0.366	111	6.0	10.5	0.06
		90%	66.5	461	8.4	59	17	48	0.7	62	9.63	83	0.508	134	7.3	12.3	1.16
		Max	68.9	488	8.6	62	18	53	1.0	66	12.99	91	0.899	138	7.7	12.6	1.97
		Min	27.4	190	7.8	16	7	22	0.3	18	0.33	35	0.144	49	0.8	6.0	<0.04
A2H021Q01	Pienaars River at Buffelspoort	Average	59.6	433	8.4	64	15	34	0.6	60	0.58	59	0.411	152	3.6	10.8	0.08
		50%	61.6	442	8.4	66	17	35	0.6	61	0.47	61	0.399	155	3.5	10.9	0.05
		90%	68.7	493	8.6	79	19	39	0.7	72	1.46	70	0.548	174	4.6	12.0	0.17
		Max	83.5	573	9.1	89	19	40	0.8	90	2.04	82	0.710	191	6.8	13.2	0.25
		Min	28.1	214	7.7	27	4	18	0.4	24	<0.04	20	0.193	89	2.1	8.2	<0.04
A2H025Q01	Crocodile River at Hardekoolbult	Average	70.9	504	8.2	72	22	41	0.7	83	0.30	71	0.097	168	3.7	10.5	0.07
		50%	71.1	516	8.2	74	22	42	0.7	84	0.27	69	0.062	173	3.8	10.3	0.05
		90%	80.7	569	8.6	80	26	47	0.7	97	0.58	90	0.209	183	5.5	12.2	0.15
		Max	93.1	583	8.7	91	28	48	0.8	98	0.63	100	0.311	188	6.1	14.1	0.21
		Min	50.1	390	7.6	51	16	29	0.4	59	<0.04	50	0.020	133	1.8	8.0	<0.04
A2H032Q01	Selons River at Modeil	Average	14.3	61	7.1	4	4	6	0.4	9	0.44	9	0.081	25	5.7	3.2	0.30
		50%	8.5	59	7.4	4	4	6	0.3	9	0.38	7	0.046	24	5.6	2.7	0.12
		90%	14.1	94	8.2	5	5	8	0.5	10	0.70	16	0.138	39	6.7	5.3	0.55
		Max	77.0	95	8.8	6	5	9	0.5	10	0.76	20	0.279	42	6.9	6.5	1.47
		Min	5.8	7	5.7	3	3	3	0.3	6	0.13	<4	0.033	12	4.6	1.5	0.06
A2H048Q01	Crocodile River at Crocodile Poort / Thaba Moya	Average	78.9	575	8.2	61	34	50	0.5	79	1.75	104	0.184	186	7.7	7.8	0.07
		50%	81.3	611	8.2	63	36	54	0.5	84	1.51	108	0.178	199	7.6	7.9	0.05
		90%	88.7	645	8.5	68	40	57	0.6	91	2.80	118	0.246	211	9.7	9.0	0.08
		Max	99.9	679	8.9	76	44	58	0.7	103	3.10	126	0.349	217	10.5	9.6	0.54
		Min	52.0	378	7.8	37	18	33	0.3	46	0.38	73	0.083	124	0.2	6.1	<0.04
A2H059Q01	Crocodile River at Vaalkop/Atlanta	Average	98.9	691	8.3	96	37	56	0.6	126	0.30	119	0.026	213	6.0	7.6	0.06
		50%	97.0	696	8.3	93	37	55	0.6	120	0.23	122	0.018	208	6.0	7.6	0.04
		90%	124.4	872	8.4	123	46	71	0.8	184	0.65	139	0.033	243	8.0	8.2	0.06
		Max	136.0	947	8.9	130	58	79	1.0	190	0.89	155	0.233	288	9.0	9.8	0.58
		Min	74.3	66	8.1	75	27	42	0.3	87	<0.04	85	0.009	179	3.0	6.2	<0.04

Table 2.9: Water Quality in Rivers in the Study Area

Station Number	Hydro Stations		Elec Cond (mS/m)	Total Diss Salts (mg/l)	pH	Na Diss (mg/l)	Mg Diss (mg/l)	Ca Diss (mg/l)	F Diss (mg/l)	Cl Diss (mg/l)	NO_3/NO_2 as N (mg/l)	SO_4 Diss (mg/l)	Ortho PO_4 as P (mg/l)	TAL as $CaCO_3$ (mg/l)	Si Diss (mg/l)	K Diss (mg/l)	NH_4 as N (mg/l)
A2H096Q01	Lindleys Poort Dam on Elands River - Right Canal	Average	18.9	137	8.1	5	9	14	0.3	5	0.39	14	0.028	70	5.0	3.7	0.06
		50%	19.8	139	8.0	5	9	14	0.2	4	0.28	13	0.029	73	5.1	3.7	0.05
		90%	23.4	163	8.4	6	11	17	0.4	6	0.83	22	0.034	90	5.7	4.1	0.09
		Max	24.3	176	8.6	7	12	19	0.5	8	1.05	23	0.042	96	5.9	4.7	0.11
		Min	10.6	79	7.6	3	5	7	0.1	<3	0.14	9	0.014	35	4.0	2.5	<0.04
B2H015Q01	Wilge River at Zusterstroom	Average	17.8	118	7.8	9	5	14	0.3	7	0.05	34	0.017	36	3.6	3.6	<0.04
		50%	17.8	114	7.8	9	5	13	0.3	8	0.05	34	0.015	35	3.6	3.4	<0.04
		90%	24.8	164	8.0	10	7	21	0.5	9	0.08	53	0.031	49	4.2	4.2	<0.04
		Max	25.7	178	8.1	11	9	29	0.6	11	0.11	77	0.054	54	4.7	6.9	0.06
		Min	8.5	74	7.4	5	3	6	0.1	5	<0.04	14	0.007	24	2.2	3.1	<0.04
B3H007Q01	Moses River at Uitspanning / Dennilton	Average	17.6	139	7.9	19	4	9	1.0	9	0.10	11	0.021	67	5.0	5.2	<0.04
		50%	17.0	138	7.9	19	3	8	1.0	9	0.05	10	0.018	66	4.9	4.9	<0.04
		90%	23.9	178	8.2	26	5	13	1.3	12	0.28	15	0.037	90	6.8	6.2	0.04
		Max	28.8	221	8.3	34	13	20	1.5	20	0.46	24	0.114	111	8.3	9.7	0.14
		Min	7.9	63	7.3	8	1	3	0.4	5	<0.04	<4	<0.005	19	2.4	2.2	<0.04
B3H008Q01	Elands Riverat Weltervreden	Average	23.0	166	7.3	14	7	19	0.9	13	0.18	6	0.029	85	6.6	5.2	0.06
		50%	22.4	155	7.3	13	6	19	0.8	12	0.09	4	0.027	78	6.4	5.2	0.05
		90%	30.7	230	7.6	18	11	27	1.1	18	0.47	10	0.053	123	8.8	6.2	0.10
		Max	45.9	266	8.1	23	13	31	1.4	27	0.82	22	0.100	141	12.5	7.6	0.41
		Min	9.6	89	6.7	7	4	6	0.5	6	<0.04	<4	<0.005	43	3.1	3.4	<0.04

Table 2-10: Value of Parameters for Assessing Raw Water Quality

Determinant	f	P_{50}	P_{90}	P_{100}
Turbidity	NS[a]	NS	NS	NS
Colour	NS	NS	NS	NS
Taste	NS	NS	NS	NS
Odour (ON)	2	2	10	NS
pH	-	6 to 9	5.5 to 9.5	4 to 11
Conductivity (mS/m)	1	70	300	400
TDS (mg/l)	1	500	2000	2700
Total Hardness (mg/l Ca CO_3)	1	20 to 300	650	1300
Magnesium (mg/l)	1	70	100	200
Sodium (mg/l)	1	100	400	800
Sulphate(mg/l)	1	200	600	1200
Nitrite / Nitrate (mg/l)	1 (var.)	6	10[c] (8[d])	20[c] (10[d])
Fluoride(mg/l)	1	1	1.5	3
Arsenic(mg/l)	1	0.1	0.3	0.6
Cadmium(mg/l)	1[e](2)[g]	0.01[e](0.02[g].)	0.02[e] (0.04)[g]	0.04[e] (0.08)[g]
Copper(mg/l)	1	0.5	1.0	2.0
Cyanide(mg/l)	1	0.2	0.3	0.6
Iron(mg/l)	5	0.5	5	10
Lead (mg/l)	3	0.15	0.3	0.6
Manganese (mg/l)	2	0.1	2.0	4.0
Mercury (mg/l)	1	0.05	0.010	0.020
Phenols (mg/l)	2	0.010	0.020	0.080
Selenium (mg/l)	2	0.040	0.10	0.20
Coliforms	NS	NS	NS	NS
Aluminium	NS	NS	NS	NS
Ammonia (mg/l N)	1	1	2	4
Calcium	NS	NS	NS	NS

Source: "Water Quality Objectives for Raw Water for Potable Use", DWAF Hydrological Research Institute, PL Kempster and HR Van Vliet (1988)

Notes:

a = Not specified

b = odour number

c = small community users

d = large community users

e = acidic pH waters

g = alkaline pH or turbid waters

Table 2.11: Comparison of Water Quality Standards

Parameter	WHO (1993)	Republic of South Africa SABS 241 (1984)		RSA Water Quality Guidelines (1993)	Republic of South Africa Proposed Criteria of Department of National Health and Population Developmen		Japan Water Quality Standards (Dec 1993)	EC Directive (1980)
	Recommended	Recommended Limit	Max. Allowable Limit	Recomm. Limit	Max. Limit for No Risk	Max. Limit for Insignificant Risk		MAC
Physical characteristics								
Colour (TCU)	15	20	NS		20	-	5	20
Taste & Odour (TON)		Not objectionable	Not objectionable	1	1	5	No abnormalities	3 @ 25°C
Hydrogen-sulphide (mg/l)	0.05							undetectable
pH	< 8.0 (PS)	6.0 - 9.0	5.5 - 9.5	6.0 - 9.0	6.0 - 9.0	5.5 - 9.5	5.8 - 8.6	9.5 max.
Temperature (°C)					< 25	< 30		25°C
Turbidity	5 NTU	1 NTU	5 NTU	1 NTU	1 NTU	5 NTU	2 mg/l	4 JTU
Total Dissolved Solids (mg/l)	1,000	(450) from conductivity					500	1,500 (a)
Conductivity (mS/m)		70	300	70	70	300		
Total Hardness ($CaCO_3$)		20 - 300	NS - 650	< 100 where possible	20 - 300	650		
Hardness (Ca)								min 60 mg/l (b)
Hardness (Ca / Mg)							300	
Dissolved Organic Carbon				5	5	10		

Table 2.11: Comparison of Water Quality Standards

Parameter	WHO (1993)	Republic of South Africa SABS 241 (1984)		RSA Water Quality Guidelines (1993)	Republic of South Africa Proposed Criteria of Department of National Health and Population Developmen		Japan Water Quality Standards (Dec 1993)	EC Directive (1980)
	Recommended	Recommended Limit	Max. Allowable Limit	Recomm. Limit	Max. Limit for No Risk	Max. Limit for Insignificant Risk		MAC
Substances undesirable in excess (to prevent colour, taste, corrosion, etc.). All concentrations are in mg/l.								
Alkalinity ($CaCO_3$)								
Alkalinity (HCO_3)								min 30 (b)
Aluminium (Al)	0.2			0.15	0.15	0.5	0.2	0.2
Ammonia (NH_3)	1.5							
Ammonia (NH_4)								0.5
Ammonia (N)					1	2		
Calcium (Ca)					150	200		
Chloride (Cl^-)	250	250	600		250	600	200	
Copper (Cu)	1 (see also below)				0.5	1	1	3 (GL) (c)
Iron (Fe)	0.3	0.1	1.0	0.1	0.1	1	0.3	0.2
Magnesium (Mg)		70	100		70	100		50
Manganese (Mn)	0.10 (see also below)	0.05	1	0.05	0.05	1	0.05	0.05
Phenols (C_6H_5OH)		0.005	0.01				0.005	0.0005
Phosphorous								5 P_2O_5
Potassium (K)					200	400		12
Silver (Ag)					0.02	0.05		0.01 (e)
Sodium (Na)	200	100	400		100	400	200	150
Sulphate (SO_4)	250	200	600		200	600		250
Zinc (Zn)	3	1	5		1	5	1	5 (GL) (c)

Table 2.11: Comparison of Water Quality Standards

Parameter	WHO (1993)	Republic of South Africa SABS 241 (1984)		RSA Water Quality Guidelines (1993)	Republic of South Africa Proposed Criteria of Department of National Health and Population Developmen		Japan Water Quality Standards (Dec 1993)	EC Directive (1980)
	Recommended	Recommended Limit	Max. Allowable Limit	Recomm. Limit	Max. Limit for No Risk	Max. Limit for Insignificant Risk		MAC
Inorganic substances of health significance. All concentrations are in mg/l.								
Arsenic (As)	0.01 (P)	0.1	0.3		0.1	0.3	0.01	0.05
Cadmium (Cd)	0.003	0.01	0.02		0.01	0.02	0.01	0.005
Copper (Cu)	2 (P)	0.5	1		0.5	1		no MAC (see above)
Cyanide (CN)	0.07	0.20	0.30		0.20	0.30		0.05
Fluoride (F)	1.5 (d)	1.0	1.5	1.0	1.0	1.5	0.8	0.7 @ 25 - 30° C
Lead (Pb)	0.01	0.05	0.1		0.05	0.1	0.05	0.05 in running water (g)
Manganese (Mn)	0.5 (P(c))	0.05	1	0.05	0.05	1	0.01	0.05
Mercury (Hg)	0.001	0.005	0.01	0.005	0.005	0.01	0.0005	0.001
Nitrate (NO_3)	50 NO_3 (f)							50 NO_3
Nitrite (NO_2)	3 NO_2 (f)							0.1 NO_2
Nitrite/Nitrate (N)		6	10	6	6	10	10	
Selenium (Se)	0.01	0.02	0.05		0.02	0.05	0.01	0.01

Table 2.11: Comparison of Water Quality Standards

Parameter	WHO (1993)	Republic of South Africa SABS 241 (1984)		RSA Water Quality Guidelines (1993)	Republic of South Africa Proposed Criteria of Department of National Health and Population Developmen		Japan Water Quality Standards (Dec 1993)	EC Directive (1980)
	Recommended	Recommended Limit	Max. Allowable Limit	Recomm. Limit	Max. Limit for No Risk	Max. Limit for Insignificant Risk		MAC
Standards for Chlorophyll and Bacterial Quality								
Chlorophyll a concentration				5				
Total Coliforms	0 per 100 ml (h)	Nil	5		0	5	Nil	0 per 100 ml (h)
Fecal Coliforms	0 per 100 ml	Nil	Nil	0 / 100 ml	0	1		0 per 100 ml
Standard Plate Count		100	NS		< 100	< 1,000		
Coliphage				< 1 / 100 ml	0	10		
Enteric Viruses				< 1 $TCID_{50}$ / 10 l	0	1		
Protozoan Parasites				< 1 Gardia cyst / 10 l				

Notes:

GL Guide Level (EC not mandatory)

MAC Maximum Admissible Concentration (EC mandatory)

NS Not Specified

(PS) Performance Standard for filtered water before disinfection.

(P) Provisional

(a) After drying at 180°C

(b) For softened water

(c) After water standing in pipes for 12 hours; 0.1 ex works

(d) Value must depend on climate and local conditions

(e) Level for manganese is 0.5 for toxicity effect but 0.1 to avoid deposition problems

(f) The sum of the concentrations of nitrite and nitrate to their respective GV'S should not exceed 1

(g) EC directive not clear. UK standard applies both to running water and water left standing in pipe

(h) In 95% of samples in the case of large supplies, throughout the preceding 12 months

CHAPTER 3 : SOCIO-ECONOMIC CONDITIONS

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3.1 Introduction

In order to serve as a basis for population estimates and future service levels, and thus primary water demand, a desk top overview of socio-economic conditions in the Study Area was conducted. Given the recent integration of previously independent Bophuthatswana districts with the areas formerly administered by South Africa, the databases used differ from area to area. While every effort was made to achieve direct comparison of these statistics, this was not always possible with respect to either the level of detail, data classification or availability.

Socio-economic data was collected by magisterial district for the 20 districts which are located in the 4 provinces covered by the Study Area as shown in Table 3-1.

3.2 Data Sources and Methodology

Questionnaires were prepared and sent to all local authorities, district councils and government departments; the response was so poor however, despite follow up, that this method was abandoned and direct data collection from published sources was resorted to. Known sources were networked in order to obtain copies of all source documents / computer files. Data was then captured on Excel spreadsheets and re-arranged into a reporting format.

Details of the data sources utilised are as follows:

3.2.1 Central Statistics Services Census Data

(1) Previous RSA administered areas and previous KwaNdebele administered areas.

1980 and 1991 census reports which give population per magisterial district, and only classified population as urban and non-urban for selected larger towns.

(2) Previously Bophuthatswana administered areas :

1985 - 1991 Bophuthatswana census reports which give separate data per village for most villages.

3.2.2 Saldru Report by University of Cape Town on Poverty

Gives poverty indicators based on specific case studies.

3.2.3 Bureau for Market Research

Reports on household income and expenditure based on selected case studies.

3.2.4 Development Bank of South Africa (DBSA)

The DBSA survey reports on population, water supply, sanitation and income.

3.2.5 Escom NELF Database

The database includes information on population, water supply, sanitation and income.

3.2.6 Centre for Development Enterprise

Demographic models for 1995 are available.

3.2.7 Department of National Health and Population Development

The Department has 1994 reports on sanitation and subsistence facilities.

3.2.8 Setplan

Setplan have produced various planning reports for studies in the Study Area.

3.2.9 Map Sources

EVN Consultants GIS maps.
Chief Director Surveys and Mapping 1:50 000 and 1:250 000 scale maps.

3.2.10 Aerial Photography

1:50,000 aerial photography (1995) was accessed in order to update village, footprints.

3.3 Major Socio-Economic Indicators

3.3.1 Population

(1) Introduction

Since 1990 South Africa has seen unprecedented demographic shifts in the population arising from migration away from rural areas and rapid migration into the urban centres and surrounding peri-urban areas. The JICA Study Area, located immediately adjacent to the PWV area (which is the economic heartland of the country), has been directly impacted by these changes. Some studies indicate that population growth rates in recent years have been as high as 26 % per annum in some peri-urban settlements.

In the Urban Development Strategy and the Rural Development Strategy published in the Government Gazette in November 1995 it was forecast that 75 % of the national population will be urbanized by the year 2020 (compared to the present level of 38 %). DBSA also views that the movement of population to metropolitan and other urban areas can be expected to continue, and that the rural population will probably not increase and may even significantly decrease.

For the JICA Study it is envisaged that whilst movement of the rural population from outside the Study Area to Soshanguve, Wonderboom, Brits, Moretele 1 and Odi 1 will continue, less significant numbers of the rural population living within the Study Area will move out to the PWV and to other urban areas. The overall growth rate of the population in the Study Area will therefore remain slightly higher than the national natural growth rate which is 2.3 %.

(2) Population baseline data

For the purpose of the population projection, data from existing information sources was collected and captured in a database. To obtain Study Area wide settlement specific population data, the following sources were referenced :

(a) 1991 Census of South Africa and Bophuthatswana
(b) 1993 NELF database
(c) 1994 DBSA database
(d) 1995 CDE database

Although ad-hoc settlement specific population studies have been undertaken in the Study Area, they are insufficient to build-up an overall picture for the Study Area.

As the NELF, DBSA and CDE databases were all constructed from 1991 census statistics, the 1991 census data was also adopted for the JICA Study as the best available Study Area wide settlement specific population baseline data.

(3) Consolidated database of population

From the above information sources, a consolidated database of comparative statistics by settlement was compiled (see Part A-1 of the Databook) for cross-reference purposes. Data was collected by magisterial district for the twenty districts in the Study Area, which are located in four provinces, namely North-West, Mpumalanga, Gauteng and Northern.

3.3.2 Household Size

Part B-1 of the Databook was prepared from the CSS1991 publication to reflect household size distribution according to race group and magisterial district (urban and non-urban).

Average household size per magisterial district (urban and non-urban) is reflected in Table Part B-2 of the Databook calculated from 1991 population size (Part A-1) and number of households (Part B-1).

Part B-2 of the Databook reflects the expected patterns as follows :

1) White and Indian households in formal urban areas have the lowest household sizes with 3.2 to 4.0 and 3.5 to 5.0 respectively;

2) Black villages in peri-urban and rural areas have the highest household sizes of 6.0 to 7.8.

3) Given the disparities between race groups an average figure is of little use.

No single source of data provides statistics of the number of persons per dwelling for the whole Study Area. The Southern Odi-Moretele Development Appraisal by Setplan summarised in Table 3-2 however gives both the number of persons per household and per family which can reasonably be assumed to be representative of the Study Area:

3.3.3 Income and Expenditure

Part B-3 of the Databook reflects the per capita income distribution by race and gender per magisterial district and is split urban / non-urban.

The data in Part B-4 of the Databook shows the average disposable income for 12 of the 20 magisterial districts according to race. No data was available from either Saldru, BMR or IPR for specific villages or districts at household level. Household level expenditure patterns and discernible incomes will require primary research.

Only Part B-3 of the Databook, which gives per capita income for each racial group per magisterial district serves some use in assessing affordability. The graph shown in Figure 3-1 depicts an assessment of four typical income distribution profiles. This graph reflects the disparity in income between the:

1) Predominantly white urban employed Wonderboom category, with high percentages in the higher income levels.

2) The subsistence rural population of rural Mankwe, with nobody in the higher income category.

3) The increased income by virtue of commuting and migrant labour for urban Moutse, with a high percentage in the middle categories representing formal employment.

4) The relatively high income of formal black townships such as reflected by Soshanguve.

Possibly the best indicator of income expenditure patterns reflecting the bulk of the population are contained in the Southern Odi-Moretele Development Appraisal report by Setplan, dated July 1991, which states the following.

"Households in Southern Odi-Moretele appear to be comparatively well off in terms of the amount of household income. Median household income of R1,160 to R1,900 exceeded the Household Effective Income indicated by the University of Port Elizabeth as a reasonable income to ensure subsistence. Further, a considerable proportion of income is retained as savings. Generally, the Proclaimed Towns emerge as wealthier enclaves, and the Apies West Bank emerges as a poorer area."

3.3.4 Health

Two sources of information were used to reflect health conditions in the Study Area, namely:

(1) Part B-5 of the Databook which reflects the number of health care facilities (clinics, mobile clinics, health care centres and hospitals per magisterial district for those portions of the North-West and Mpumalanga Provinces that fall within the Study Area.

For the Mpumalanga facilities, the table also reflects the availability of water and sanitation services to each family. As can be seen from the data, numerous clinics have an inadequate water supply, and a significant number of clinics are serviced by pit latrine only which has obvious adverse health implications.

(2) The Southern Odi-Moretele Development Appraisal by Setplan, dated 1991, Chapter 2.2 "Health Care Services", reflects the district health-care situation in a typical large portion of the Study Area. Relevant facts from this report are as follows :

a) Bed occupancy at GaRankuwa Hospital averaged 122% with up to 213% in certain wards while Jubilee Hospital in Temba reported a 95% average.

b) Of the 30 clinics in the Moretele area :

1) 17 had no running water supply;
2) 21 had no electricity supply;
3) 13 had no telephone connection or two way radio;
4) 23 relied totally on pit latrine sanitation.

c) Regarding the health status of the community the report reflected the following :

1) The six most important diseases in the Moretele region were :

i.) Tuberculosis (related to malnutrition)
ii.) Hypertension
iii.) Diabetes
iv.) Paraffin Poisoning
v.) Typhoid (related to poor drinking water)
vi.) Cancer of the cervix

2) The five most common cases treated at the Odi hospital are :

i.) Dermatology
ii.) Tuberculosis
iii.) Alcoholism
iv.) Paraffin poisoning
v.) Measles

According to the Secretary of the Odi Hospital at the time of the survey, an outbreak of typhoid was near epidemic status. In Odi the occurrence of malnutrition was not common.

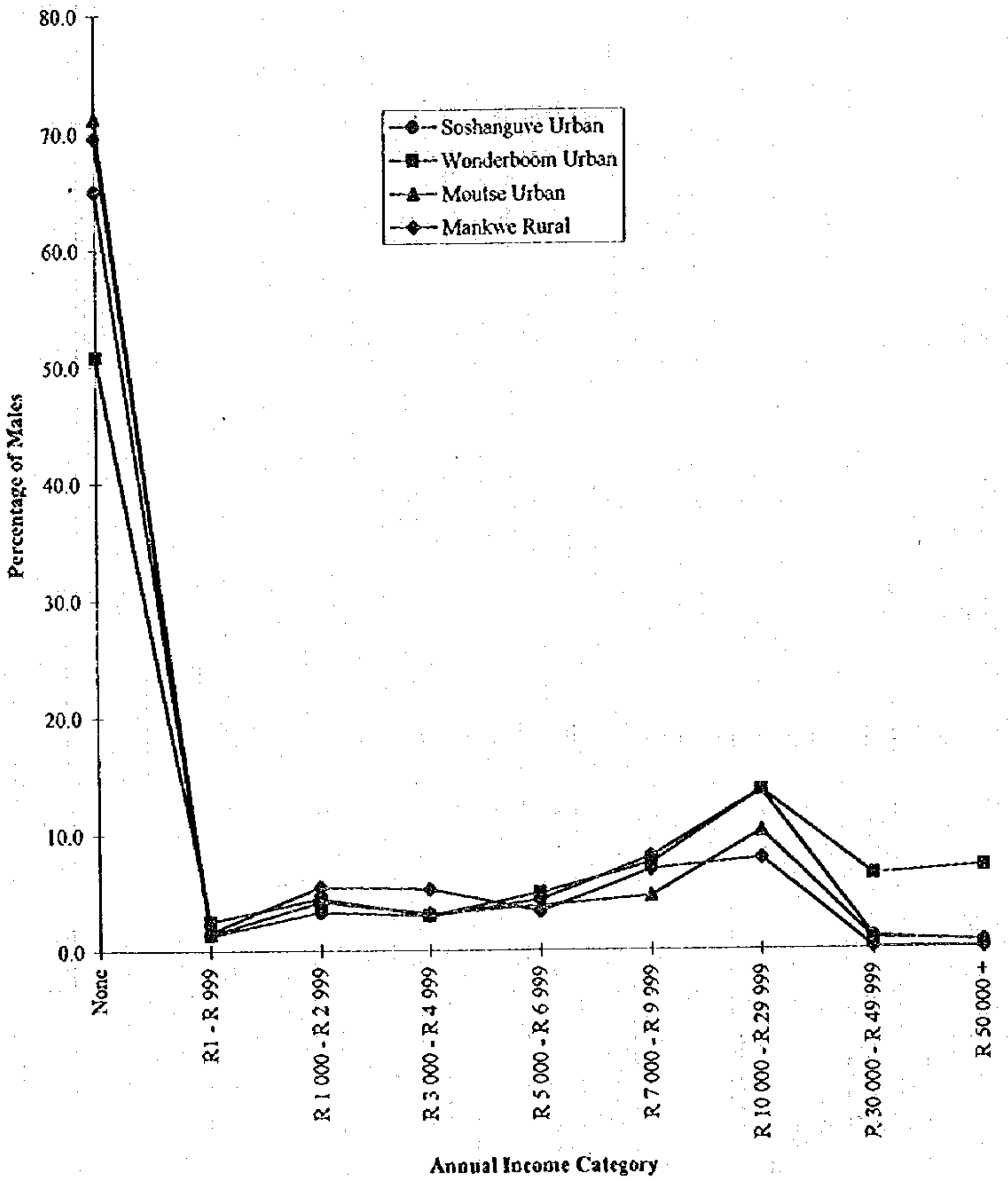
Table 3-1 Summary of Magisterial Districts in the Study Area

Magesterial District	Previous Government	Current Provincial System
Koster	RSA	North-West Province
Swartruggens	RSA	North-West Province
Rustenburg	RSA	North-West Province
Brits	RSA	North-West Province
Odi	Bophuthatswana	North-West Province
Moretele 1	Bophuthatswana	North-West Province
Bafokeng	Bophuthatswana	North-West Province
Mankwe	Bophuthatswana	North-West Province
Bronkhorstspruit	RSA	Gauteng
Cullinan	RSA	Gauteng
Soshanguve	RSA	Gauteng
Wonderboom	RSA	Gauteng
Part of Thabazimbi	RSA	Northern Province
Part of Warmbad	RSA	Northern Province
Part of Waterberg	RSA	Northern Province
Moretele 2	Bophuthatswana	Mpumalanga
Mbibana	KwaNdebele	Mpumalanga
Mdutijana	KwaNdebele	Mpumalanga
Mkobola	KwaNdebele	Mpumalanga
Moutse	KwaNdebele	Mpumalanga

Table 3-2 : Average Number of People per Dwelling

Communities	Average Number of People per Household	Average Number of People per Dwelling
Proclaimed Towns	5.7	5.7
Central Areas	6.5	6.8
Odi Villages	6.2	7.7
Winterveld	5.8	7.4
Apies East Bank	5.9	5.9
Apies West Bank	5.5	5.6

Figure 3-1 : Male Income by District



CHAPTER 4 : WATER DEMAND PROJECTION

CHAPTER 4 WATER DEMAND PROJECTION

CHAPTER 4 WATER DEMAND PROJECTION

4.1 Introduction

In order to serve as the basis for the preliminary planning for water supply systems (Supporting Report E) the population and economic growth dynamics, for the different regions were investigated and interpreted and then extrapolated to predict future population figures. These figures were used to predict water demands for the years 2002 and 2015.

The lifting of boundaries in the new democratic South Africa in the period from 1992 to 1995 resulted in abnormal growth in certain urban or peri urban areas and in declining or stagnant population in other dormitory towns which came to being as part of the past government policy. Growth from 1995 will be determined mainly by socio-economic factors, such as the availability of job opportunities and infrastructure.

The socio-economic conditions in towns and villages will in turn be determined by the availability of employment, with the result that the ability to pay for water will be the highest in the areas that will grow most.

4.2 Population Projection

The collection of population baseline data and socio-economic conditions are described in detail in Chapter 3.

4.2.1 1995 Population

Since it is impractical in a macro study to derive population growth variables for each and every settlement, the Study Area was divided into seven socio-economic/physiographic zones comprising areas which display similar development characteristics. For each of these seven zones, settlement conditions and recent dynamics were explored as the basis for deriving growth rates to update the baseline population to obtain a best estimate of the 1995 population (see Part A-2 of the Databook for the estimated 1995 population).

Population growth rates were determined, using a combination of the following:

a) historical growth rate
b) migration trends:
 - access to employment opportunities,
 - changed administrative / political boundaries,
 - changed land access,
c) resource base
d) physical and economic planning undertaken by First, Second and Third Tier institutions

An overview of the growth scenarios adopted for each zone is as follows:

(1) Mpumalanga (Moutse 1 and 3, Moretele 2, Mdutjana, Mkobola, Mbibana, Kwamhlanga)

The peripheral rural districts of Mbibana, Moretele 2, and Moutse 1 and 3 are seen as having stagnated since 1990 with no real growth assumed. Ekangala, Kwamhlanga and Mdutjana are seen as having experienced minor growth of 1.8 % per annum. These eastern districts, given their dormitory function and the absence of a local economic base, are seen as areas characterized by outward migration with the natural population growth assumed to have been absorbed elsewhere.

(2) Bronkhorstspruit - Cullinan

The rural areas of the districts of Bronkhorstspruit and Cullinan are assumed to have undergone similar settlement dynamics with the exception of the towns of Bronkhorstspruit and Cullinan where the townships are seen as having undergone rapid growth given their location in Gauteng. The urban areas in these centres are assumed to have accommodated the natural population growth with no real change in migration patterns.

(3) Nylstroom - Warmbaths - Waterberg

The rural areas of Warmbaths and Waterberg are seen as having experienced an outward migration. The townships of Warmbaths and Nylstroom, however, are assumed to have accommodated a rapid influx during the past 5 years. The urban population in these towns is assumed to have stagnated in recent years.

(4) Brits - Odi 1 - Moretele 1 - Wonderboom - Soshanguve

The districts of Soshanguve, Wonderboom, Brits, Moretele 1 and Odi 1, which surround Metropolitan Pretoria, are seen as districts which have attracted a significant population influx in recent years while the outlying rural areas are assumed to have stagnated with natural population growth absorbed elsewhere. The agricultural zone north of Pretoria and the urban communities of the towns are assumed to have grown at their natural population growth rate only. The peri-urban villages, however, and the townships associated with the former RSA towns are seen as having experienced a rapid influx in recent years, thus recent growth rates of up to 20 % per annum have been assumed in these areas. The Klip-Kruisfontein area has developed from scratch during the past 5 years.

(5) Mankwe - Bafokeng - Odi 2 - Rustenburg

These Districts are assumed to have experienced similar dynamics to those outlined above, but the scale of influx is assumed to be less than that which has taken place around Pretoria. Rustenburg and its environs has been the centre of urbanization pressures. In contrast, the outlying rural areas of Mankwe are seen as having stagnated in recent years with only natural population growth assumed to have taken place.

(6) Swartruggens - Koster

In these Districts, a rapid influx to the townships has been assumed with slight outward migration from the established urban communities and rural areas.

(7) Thabazimbi

The rural areas of Thabazimbi District are assumed to have stagnated in recent years whereas the mining areas are assumed to have accommodated an influx although at a more modest rate than that experienced around Rustenburg.

4.2.2 2015 Population

Based on consultation with local officials, (see Part A-3 of the Databook for a list of officials interviewed), and a review of development planning documents relevant to the Study Area and its immediate surroundings, (see Part A-4 of the Databook for a list of reports referenced), future growth scenarios were developed with associated population growth rates up to the year 2015. For the forthcoming 20 years, the following growth scenarios are foreseen for the Study Area :

(1) The primary population growth will take place in Pretoria - Ga-rankuwa, Mabopane and Temba areas. Infrastructure and institutional structures which are well established coupled with job opportunities underlie this axis. There is an active planning policy to reinforce this development by bringing infill planning in Soshanguve North, Soshanguve South and Klip-Kruisfontein areas to strengthen the Pretoria - Mabopane connection. Growth rates of between 2.4 % and 3.5 % have been estimated for this area. It is estimated that existing urban areas such as Pretoria will grow at about 1.5 %. As a balance to this, the core area of the Bon Accord - Rooiwal - Roodeplaat will be reserved for agriculture given the good prevailing soil and climatic conditions.

(2) A secondary growth area is that of Rustenburg. Growth in the Rustenburg area is characterized by large scale developments north east of the town extending around Kana with a growth axis establishing up to Monakato - Mogwase - Northam - Thabazimbi with good potential for a further large platinum mine to come on-stream in the near future just east of Northam. This axis also shows three westward extensions: i) Rustenburg - Phokeng in the south; ii) Monnakato - Airport - Sun City in the centre and iii) Saulspoort - Northern Pilanesberg in the north. As a growth spine the area is well founded on the following factors which reinforce its sustainability :

a) the regional function of Rustenburg;

b) the platinum mining industry;

c) the chrome mining industry;

d) the connection to the iron mine at Thabazimbi and supportive lime mines west of Northam; and

e) the tourist industry of the Pilanesberg and the link to Botswana and the Madikwe game reserve.

Growth rates of between 2.4 % and 4.0 % are expected in this area with a growth of 1.0 % in the traditional urban areas.

In addition, the mining axis and strong agricultural axis linking Brits to Rustenburg has shown recent signs of being supported by further urban development in the Bapong - Majakaneng area which will form a node to support the Southern Odi dormitory villages to the north (Bethanie - Berseba, Makolokwe, etc.). Growth rates of between 2.4 % and 3.4 % have been estimated for this region.

(3) The densely settled areas of Moutse and Kwamhlanga do not possess the underlying sustainable growth factors found in the above two areas. Kwamhlanga is an inheritance of the former Kwandebele homeland capital policy and now functions simply as a dormitory commuter centre for Pretoria, (26,000 commuters/day), and Witbank. This function is, however, considered to be unsustainable as the Government is likely to discontinue its current practise of subsidising the cost of commuter bus services in these areas in the future.

The Moutse village group, although originally initiated as a labour support area to the adjacent Loskop irrigation scheme, has now totally outgrown its original function. While it serves as a dormitory area with commuting to Pretoria and Witbank/Middelburg, it remains poorly placed and represents the biggest future unknown in the Study Area. It is assumed in this Study that growth in the Moutse Group settlements has stagnated with growth largely absorbed by outward migration to the new settlement areas within the Gauteng Core and Witbank - Middelburg periphery, with the remnant population stagnating as a large cluster of dormitory communities. Growth rates of between 0 % and 1.8 % have been estimated for this area.

It is considered in this Study that a significant outward migration from these areas will be absorbed by a Pretoria East Node (east of Mamelodi), and rapid establishment and growth similar to that seen at Klip-Kruisfontein will take place. It is assumed that this node will accommodate a population of about 250,000 people by 2015 through an average annual growth rate of 15%. Thus, if the Pretoria East Node does not happen, these areas (Moutse and Kwamhlanga), may grow at a maximum annual rate of 2.4% (see Part A-5 of the Data Book for the Eastern Zone population projection based on this high growth scenario)..

(4) The dormitory villages of the following areas will merely retain their present status relying on commuting or migrant labour income with a declining subsistence agricultural base :

a) area west of the Pilanesberg;

b) northern and central Odi 1 and Moretele 1; and

c) Moretele 2

(5) Growth prospects are poor for the Swartruggens - Marico - Koster area with only small scale diamond mining showing any new promise in the short term and Zeerust dominating the future Trans Kalahari link spin off. While small scale production of shale, manganese and fluorite is undertaken, the large mining houses are known to have begun Witwatersrand related gold prospecting drilling in the area but to date no positive announcements of any plans have been made.

(6) The rural area east of Pretoria and north of Bronkhorstspruit, (ie: Cullinan - Rust de Winter), is likely to remain an extensive agricultural area with Bronkhorstspruit struggling to compete with the attraction of the coal mining and iron and steel industries in the industrial Witbank/Middelburg area.

In line with the above spatial growth scenarios the current population estimates for the Study Area have been projected to the year 2015 with rates of inward migration lower than those assumed for the 1991 - 1995 period, (see Part A-2 of the Databook for the projected 2015 population).

4.3 Water Demand

4.3.1 Primary Water Requirement

(1) Domestic water demand

No reliable primary statistics of household income and expenditure exist from which affordability of level of water supply can be directly addressed. Findings of previous village water supply schemes and studies in the Study Area were used to assess water demand profiles in typical villages.

Communities in the Study Area were categorized according to the following basic criteria:

a) established urban towns fully serviced with little or no informal infill;

b) formal towns with informal infill;

c) peri-urban villages with influx growth;

d) villages with bus route commuter links; and

e) distant, subsistence level villages with negative or no growth.

Based on the findings of previous studies, actual water demand was estimated using a ratio of house connections, metered yard taps and street taps for each of the above categories.

a) 100 % house connections for traditional towns fully serviced with little or no informal infill- classified as Urban High;

b) 75 % house connections, 15 % yard taps and 10 % street taps for formal towns with informal infill - classified as Urban Low;

c) 75 % house connections, 15 % yard taps and 10 % street taps for peri-urban villages with influx growth - classified as Rural High;

d) 20 % house connections, 60 % yard taps and 20 % street taps for villages with bus route commuter connections - classified as Rural Medium; and

e) 5 % house connections, 15 % yard connections and 80 % street taps for distant subsistent villages with negative or no growth - classified as Rural Low.

It was also found from previous studies that:

a) for peri-urban/rural areas, the per-capita water demand associated with each level of service, (exclusive of system leakage losses), is as follows:
House connection : 120 lcd
Yard tap : 70 lcd
Street tap : 30 lcd

b) for formal towns with informal infill the per-capita water use for house connections could be as high as 230 lcd;

c) for established urban areas the per-capita water use for house connections is much higher than 230 lcd and varies from place to place.

Using the above community and level-of-service classifications and the per-capita water demands, Table 4-1 was prepared summarising the different levels of services.

Table 4-1: Projected Mixes of Levels of Service

Classification of Community	Level of Service	% of House Connections (Water Consumption per Capita)	% of Yard Taps (Water Consumption per Capita)	% of Street Taps (Water Consumption per Capita)
Urban	High	100 (Actual)	0	0
	Low	75 (230 lcd)	15 (70 lcd)	10 (30 lcd)
Rural	High	75 (120 lcd)	15 (70 lcd)	10 (30 lcd)
	Medium	20 (120 lcd)	60 (70lcd)	20 (30 lcd)
	Low	5 (120 lcd)	15 (70 lcd)	80 (30 lcd)

(2) Non-domestic water demand

(a) Industrial, commercial and institutional water demands in urban areas

In established urban areas, a significant portion of water is used for industrial, commercial and institutional purposes. In a detailed study of water use in Rustenburg, industrial demand was found to comprise about 20 % of that for domestic use, with commercial and institutional elements comprising 15 % and 10

% respectively. Where separate figures were not available, the split has been assumed to be as indicated above.

(b) Water demands for mines and other special industrial and commercial Centres

Water demands for mines and other special industrial and commercial centres were studied on an actual consumption basis; where such large consumers are currently being supplied by water boards, demand figures were obtained directly from MW or RW.

(3) Water losses

It was assumed that the water supply system will be upgraded in the future and so a reduction in system leakage losses from the system will be achieved. An allowance of 20 % for system leakage losses (outlet of water treatment works to end consumers), was added to the primary water demand estimated for the year 1995 and this was assumed to decrease to 18.25 % by the year 2002 and to 15 % by the year 2015. Other components of unaccounted-for water, such as losses due to meter malfunctioning, meter under-registration and illegal connections constitute a portion of water consumed and are therefore already included in the per capita consumption figures. Another separate allowance of 5% was added to allow for purification losses and, wherever necessary, a further allowance was added to allow for raw water transfer losses. The gross primary water demand so established was used in the water balance simulation.

(4) Zoning of the Study Area and rearrangement of projected population and primary water demand

The Study Area was divided into three supply zones, ten supply areas and twenty eight supply blocks as shown on the Location Map, with a view to allocating the projected primary demands to individual treatment plants in the Study Area, and to the associated surface water resources. The projected population and primary water demand were then totalled for each supply block, supply area and supply zone. The factors which were taken into consideration in determining supply zone, area and block boundaries are set out in Chapter 2 of Supporting Report E.

The population and primary water demand projected for the years 1995, 2002 and 2015 for each supply block, supply area and supply zone are compiled in Appendix 1 and the same information is summarized in Table 4-2 and Table 4-3. Table 4-4 presents details of the non-domestic primary water demand estimated for the years 1995, 2002 and 2015 for each supply block, supply area and supply zone. Both domestic and overall per-capita primary water demands for the years 1995, 2002 and 2015 and the growth rates of population for the years are summarised for each of the three supply zones in Table 4-5.

Figure 4-1 shows the total population of the Study Area projected for the years 1995, 2002 and 2015, with a breakdown according to service mix and level of service. Figures 4-3, 4-5 and 4-7 provide the same information for each of the three supply zones.

Figure 4-2 shows the total primary water demand for the Study Area projected for the years 1995, 2002 and 2015 with a breakdown according to water use category. Figures 4-4, 4-6 and 4-8 provide the same information for each of the three supply zones.

4.3.2 Non-Primary Water Requirement

(1) Irrigation demand

a) In general, the irrigation water requirement can be estimated taking into account the consumptive use of each crop to be planted, the total area of the crops to be irrigated, effective rainfall during the irrigation period, and the comprehensive irrigation efficiency.

b) Typical cropping patterns for the Study Area are summarised as shown in Table 4-6.

Table 4-6 : Typical Cropping Patterns

Hartebeespoort Dam Area		Roodeplaat Dam Area		Roodeplaat R-O-R Area	
Crop	**Share (%)**	**Crop**	**Share (%)**	**Crop**	**Share (%)**
Vegetables	40	Maize	32	Pastures	40
Wheat	40	Vegetables	31	Vegetables	30
Tobacco	10	Cotton	24	Peanut	15
Maize, Cotton	10	Lucerne	13	Deciduous fruit	15

c) Consumptive use: Water requirements of representative crops are tabulated in Table 4-7.

Table 4-7 : Consumptive Use for Various Crops

Crop	Consumptive Use (mm / year)	Crop	Consumptive use (mm /year)
Wheat	580	Lucerne	1,620
Tobacco	550	Groundnuts	610
Maize	800	Tomato	660
Cotton	750	Onion	390
Citrus	1,560	Soybean	700

d) The effective rainfall to be considered varies depending on the rainfall pattern in the area and the cropping season; the effective rainfall is assumed to be about 70 to 80 % of the actual rainfall during the cropping season.

e) In general, the comprehensive irrigation efficiency can be estimated based on the ratio of application efficiency, conveyance efficiency of the canal and operational efficiency. Comprehensive irrigation efficiencies depend therefore largely on irrigation methods. Average efficiencies adopted vary from 60 to 80 %.

f) Total irrigation water requirements within the Study Area were established and are shown in Table 4-8.

Table 4-8 : Total Irrigation Water Requirement

River System	Irrigable Area (ha)	Requirement (mcm/a)	Water Resources (mcm/a)	
			Reservoir	Run-of-river
Crocodile River Basin				
Upper Crocodile	30,949	201.5	136.6	64.9
Elands	6,806	45.0	28.3	16.7
Pienaars	13,839	122.3	82.4	39.9
Lower Crocodile	6,699	63.0	0.0	63.0
Sub-total	**58,293**	**431.8**	**247.3**	**184.5**
Olifants River Basin				
Upper Olifants	1,080	9.8	0.7	9.1
Sub-total	**1,080**	**9.8**	**0.7**	**9.1**
Total	59,373	441.6	248.0	193.6

Note: The irrigable area in the Study Area supplied indirectly is excluded from the above table.

g) Irrigation demands by local area were allocated to individual water resources: storage water and river flow, as shown in Table 4-9

It should be noted that the figures indicated above represent an average which was calculated when the area was declared, and are based on likely values for cropping patterns, average rainfall, evaporation etc. The total irrigation water requirements used in the water balance model are calculated on a monthly basis depending on that months rainfall, evaporation and on the cropping pattern of the irrigated area in question.

(2) Stock-watering demand

In the Study Area, there are large areas of grazing land for livestock breeding. A large stock unit has a water demand equivalent to one head of cattle, six sheep or goats, twelve pigs or one hundred chickens. The average daily water requirement for a representative large stock unit is about 50 litres per day.

The total population of equivalent large stock units in the Study Area is about 458,000. The total estimated present stock-watering requirements is thus about 8.4 mcm/a. Since livestock is part of the survival strategy of otherwise impoverished communities in rural areas, and since stock-keeping plays an important role in the tribal culture, stock-watering requirements cannot be ignored in the assessment of rural water needs for water demand purposes. The demand has been assumed to remain at the current estimated level of supply.

(3) Environmental and other requirements

The Water Resources Yield Model was set up to simulate the behaviour of the river and storage system, when required to satisfy a specific set of water demands for primary use and irrigation. Other important water requirements are for sustaining in-stream ecosystems, and for satisfying international river flow commitments.

Riverine ecosystems and other water requirements for environmental purposes do not enjoy legal recognition under the present legislation; existing water resources development has generally been planned without specific provision being made for this aspect. Consequently the actual in-stream flow requirements of the rivers in the Study Area are not quantified.

Since environmental water requirements are generally non-consumptive, and a significant portion of irrigation water requirements are abstracted directly from run-of-river, the water balance simulation described in Supporting Report E does not include specific provision for this purpose.

All of the rivers in the Study Area are of interest to one or more neighbouring states, and are thus subject to international rules for best joint utilisation as originally codified in the 1966 Helsinki Rules. Although discussions on the development of international rivers have taken place between RSA its co-basin states, the river regime required at state boundaries has not been quantified. A simplified assumption was made that the residual flow in rivers, including flow to sustain ecological systems, would satisfy inter-state obligations; it was further assumed that new development proposals would be discussed with neighbouring states before implementation.

Table 4-2 : Summary of Projected Population

SUPPLY ZONE	SUPPLY AREA	SUPPLY BLOCK	POPULATION																	
			1995						2002						2015					
			UH	UL	RH	RM	RL	TOTAL	UH	UL	RH	RM	RL	TOTAL	UH	UL	RH	RM	RL	TOTAL
WESTERN	VAALKOP NORTH	THABAZIMBI	10,355	0	0	2,923	37,523	50,801	12,407	0	0	2,075	40,230	54,712	14,482	0	0	2,685	45,785	62,952
		MOKGALWANENG	0	0	0	0	3,969	3,969	0	0	0	0	3,969	3,969	0	0	0	0	3,969	3,969
		SEFIKILE	2,399	0	0	3,061	10,923	16,383	2,911	0	0	7,155	7,713	17,779	4,168	0	0	9,234	7,713	21,115
		RAMOKOKSTAD	0	0	0	0	9,770	9,770	0	0	0	0	10,475	10,475	0	0	0	0	11,920	11,920
		SAULSPOORT	0	0	0	12,550	53,350	65,900	0	0	0	45,565	27,132	72,697	0	0	0	59,812	28,954	88,766
		MOGWASE/SUN CITY	0	649	0	20,952	21,382	42,983	0	649	0	50,416	0	51,065	0	649	0	69,911	0	70,560
		SUB-TOTAL	12,754	649	0	39,486	136,917	189,806	15,318	649	0	105,211	89,519	210,697	18,650	649	0	141,642	98,341	259,282
	VAALKOP SOUTH	BETHANIE	0	0	22,205	0	15,238	37,443	0	0	26,215	17,989	0	44,204	0	0	35,682	24,488	0	60,170
		VAALKOP SOUTHERN/BO	21,629	39,409	87,970	0	0	149,008	27,518	108,809	49,431	0	0	185,758	37,456	157,377	50,246	0	0	245,079
		SUB-TOTAL	21,629	39,409	110,175	0	15,238	186,451	27,518	108,809	75,646	17,989	0	229,962	37,456	157,377	85,928	24,488	0	305,249
	BARNARDSVLEI	BARNARDSVLEI WESTER	36,828	0	77,455	2,191	97,948	214,422	39,485	0	104,012	105,530	0	249,027	44,937	0	171,076	121,356	0	337,369
		BARNARDSVLEI EASTER	0	10,463	14,157	0	12,000	36,620	0	13,222	16,714	15,791	0	45,727	0	20,421	22,750	26,293	0	69,464
		SUB-TOTAL	36,828	10,463	91,612	2,191	109,948	251,042	39,485	13,222	120,726	121,321	0	294,754	44,937	20,421	193,826	147,649	0	406,833
	KOSTER	KOSTER	1,738	0	9,581	0	22,905	34,224	1,738	0	11,006	0	24,557	37,301	1,738	0	14,237	0	27,948	43,923
		SWARTRUGGENS	1,006	0	3,080	0	10,241	14,327	1,006	0	3,538	0	10,980	15,524	1,006	0	4,577	0	12,496	18,079
		SUB-TOTAL	2,744	0	12,661	0	33,146	48,551	2,744	0	14,544	0	35,537	52,825	2,744	0	18,814	0	40,444	62,002
	TOTAL		73,955	50,521	214,448	41,677	295,249	675,850	85,065	122,680	210,916	244,521	125,056	788,238	103,787	178,447	298,568	313,779	138,785	1,033,366
CENTRAL	BRITS	BRITS	46,463	0	0	0	96,399	142,862	57,443	0	0	105,444	3,175	166,062	85,390	0	0	135,827	3,710	224,927
		HARTBEESPOORT	7,450	0	0	0	0	7,450	8,796	0	0	0	0	8,796	11,972	0	0	0	0	11,972
		SUB-TOTAL	53,913	0	0	0	96,399	150,312	66,239	0	0	105,444	3,175	174,858	97,362	0	0	135,827	3,710	236,899
	KLIPVOOR	KLIPVOOR WEST	0	499	0	0	9,198	9,697	0	499	0	0	9,198	9,697	0	499	0	0	9,198	9,697
		KLIPVOOR EAST	0	0	0	0	28,789	28,789	0	0	0	293	28,496	28,789	0	0	0	293	28,496	28,789
		MORETELE NORTH	0	0	0	0	15,830	15,830	0	0	0	0	15,830	15,830	0	0	0	0	15,830	15,830
		SUB-TOTAL	0	499	0	0	53,817	54,316	0	499	0	293	53,524	54,316	0	499	0	293	53,524	54,316
	RAND WATER	RAND WATER	19,481	164	508,428	38,253	370,994	937,320	23,157	164	706,418	498,131	0	1,227,870	31,922	164	1,242,161	794,341	0	2,068,588
		SUB-TOTAL	19,481	164	508,428	38,253	370,994	937,320	23,157	164	706,418	498,131	0	1,227,870	31,922	164	1,242,161	794,341	0	2,068,588
	TEMBA	KUDUBE NORTH	0	60,377	0	139,370	887	200,634	0	77,194	0	165,389	0	242,583	0	119,127	0	229,523	0	348,650
		KUDUBE SOUTH	0	137	0	208,752	2,461	211,350	0	137	0	259,060	2,461	261,658	0	137	0	388,279	2,461	390,877
		WALLMANNSTHAL	0	6,000	0	0	0	6,000	0	7,084	0	0	0	7,084	0	9,642	0	0	0	9,642
		WARMBAD/NYLSTROOM	12,287	148	0	33,934	61,995	108,364	12,287	148	0	37,662	66,467	116,564	12,287	148	0	45,705	75,646	133,786
		SUB-TOTAL	12,287	66,662	0	382,056	65,343	526,348	12,287	84,563	0	462,111	68,928	627,889	12,287	129,054	0	663,507	78,107	882,955
	TOTAL		85,681	67,325	508,428	420,309	586,553	1,668,296	101,683	85,226	706,418	1,065,979	125,627	2,084,933	141,571	129,717	1,242,161	1,593,968	135,341	3,242,758
EASTERN	WELTEVREDEN	BLOEDFONTEIN	0	0	0	0	159,120	159,120	0	0	0	159,328	0	159,328	0	0	0	159,791	0	159,791
		KAMEELRIVIER	0	0	0	0	41,381	41,381	0	0	0	43,416	0	43,416	0	0	0	47,941	0	47,941
		MAPOCH	0	0	0	0	16,254	16,254	0	0	0	18,416	0	18,416	0	0	0	23,223	0	23,223
		WALKRAAL	0	0	0	122,547	179,825	302,372	0	0	0	331,896	863	332,759	0	0	0	400,321	0	400,321
		SUB-TOTAL	0	0	0	122,547	396,580	519,127	0	0	0	553,056	863	553,919	0	0	0	631,276	0	631,276
	BRONKHORSTSPRUIT	BRONKHORSTSPRUIT	12,000	0	0	189,061	809	201,870	13,784	0	0	216,723	0	230,507	17,831	0	0	277,746	0	295,577
		CULLINAN	9,085	0	0	16,500	24,187	49,772	10,725	0	0	21,713	25,931	58,369	14,600	0	0	36,154	29,512	80,266
		SUB-TOTAL	21,085	0	0	205,561	24,996	251,642	24,509	0	0	238,436	25,931	288,876	32,431	0	0	313,900	29,512	375,843
	TOTAL		21,085	0	0	328,108	421,576	770,769	24,509	0	0	791,492	26,794	842,795	32,431	0	0	945,176	29,512	1,007,119
GRAND-TOTAL			180,721	117,846	722,876	790,094	1,303,378	3,114,915	211,257	207,906	917,334	2,101,992	277,477	3,715,966	277,789	308,164	1,540,729	2,852,923	303,638	5,283,243

Note: 1) UH: Urban High, UL: Urban Low, RH: Rural High, RM: Rural Medium, RL:Rural Low

Table 4-3 : Summary of Projected Primary Water Demand

SUPPLY ZONE	SUPPLY AREA	SUPPLY BLOCK	PRIMARY WATER DEMAND (MCM/a)																	
			1995						2002						2015					
			DOM	IND	COM	INS	MIN	TOTAL	DOM	IND	COM	INS	MIN	TOTAL	DOM	IND	COM	INS	MIN	TOTAL
WESTERN	VAALKOP NORTH	THABAZIMBI	2.912	0.345	0.252	0.168	18.412	22.089	3.258	0.370	0.271	0.180	20.322	24.401	3.936	0.421	0.308	0.205	23.871	28.741
		MOKGALWANENG	0.071	0.225	0	0	0	0.296	0.070	0.338	0	0	0	0.408	0.067	0.548	0	0	0	0.615
		SEFIKILE	0.534	0	0	0	5.074	5.608	0.646	0	0	0	5.633	6.279	0.812	0	0	0	6.670	7.482
		RAMOKOKSTAD	0.174	0	0	0	0	0.174	0.183	0	0	0	0	0.183	0.201	0	0	0	0	0.201
		SAULSPOORT	1.341	0	0	0	2.497	3.838	1.892	0	0	0	2.592	4.484	2.300	0	0	0	2.592	4.892
		MOGWASE/SUN CITY	1.092	3.719	2.920	0	0	7.731	1.618	3.987	3.263	0	0	8.868	2.163	4.537	4.011	0	0	10.711
		SUB-TOTAL	6.124	4.289	3.172	0.168	25.983	39.736	7.667	4.695	3.534	0.180	28.547	44.623	9.479	5.506	4.319	0.205	33.133	52.642
	VAALKOP SOUTH	BETHANIE	1.277	0	0	0	0	1.277	1.729	0	0	0	0	1.729	2.290	0	0	0	0	2.290
		VAALKOP SOUTHERN/BOSPO	10.107	0.436	0.327	0.218	2.896	13.984	14.406	1.023	0.410	0.273	2.896	19.008	18.818	1.818	0.542	0.362	2.896	24.436
		SUB-TOTAL	11.384	0.436	0.327	0.218	2.896	15.261	16.135	1.023	0.410	0.273	2.896	20.737	21.108	1.818	0.542	0.362	2.896	26.726
	BARNARDSVLEI	BARNARDSVLEI WESTERN	9.1	1.676	0.557	0.371	8.314	20.018	11.92	2.099	0.588	0.392	9.063	24.062	15.511	3.347	0.651	0.434	9.063	29.006
		BARNARDSVLEI EASTERN	1.706	0	0	0	8.305	10.011	2.298	0	0	0	8.997	11.295	3.378	0	0	0	9.775	13.153
		SUB-TOTAL	10.806	1.676	0.557	0.371	16.619	30.029	14.218	2.099	0.588	0.392	18.06	35.357	18.889	3.347	0.651	0.434	18.838	42.159
	KOSTER	KOSTER	1.019	0	0.04	0.02	0	1.079	1.095	0	0.04	0.02	0	1.155	1.267	0	0.04	0.02	0	1.327
		SWARTRUGGENS	0.421	0	0.03	0.01	0	0.461	0.448	0	0.02	0.01	0	0.478	0.506	0	0.02	0.01	0	0.536
		SUB-TOTAL	1.44	0	0.07	0.03	0	1.54	1.543	0	0.06	0.03	0	1.633	1.773	0	0.06	0.03	0	1.863
	TOTAL	TOTAL	29.754	6.401	4.126	0.787	45.498	86.566	39.563	7.817	4.592	0.875	49.503	102.35	51.249	10.671	5.572	1.031	54.867	123.390
CENTRAL	BRITS	BRITS	8.26	1.286	0.436	0.291	0	10.273	11.416	1.636	0.696	0.464	0	14.212	16.12	2.558	1.141	0.867	0	20.686
		HARTBEESPOORT	3.263	0	0	0	0	3.263	3.853	0	0	0	0	3.853	5.244	0	0	0	0	5.244
		SUB-TOTAL	11.523	1.286	0.436	0.291	0	13.536	15.269	1.636	0.696	0.464	0	18.065	21.364	2.558	1.141	0.867	0	25.93
	KLIPVOOR	KLIPVOOR WEST	0.202	0	0	0	0	0.202	0.201	0	0	0	0	0.201	0.196	0	0	0	0	0.196
		KLIPVOOR EAST	0.512	0	0	0	0	0.512	0.509	0	0	0	0	0.509	0.494	0	0	0	0	0.494
		MORETELE NORTH	0.281	0	0	0	0	0.281	0.276	0	0	0	0	0.276	0.268	0	0	0	0	0.268
		SUB-TOTAL	0.995	0	0	0	0	0.995	0.986	0	0	0	0	0.986	0.958	0	0	0	0	0.958
	RAND WATER	RAND WATER	34.277	9.92	0	0	0	44.197	49.587	12.036	0	0	0	61.623	81.479	17.28	0	0	0	98.759
		SUB-TOTAL	34.277	9.92	0	0	0	44.197	49.587	12.036	0	0	0	61.623	81.479	17.28	0	0	0	98.759
	TEMBA	KUDUBE NORTH	9.675	3.701	0.5	0	0	13.876	11.846	4.709	0.5	0	0	17.055	17.259	5.991	0.5	0	0	23.75
		KUDUBE SOUTH	6.642	0	0	0	0	6.642	8.106	0	0	0	0	8.106	11.79	0	0	0	0	11.79
		WALLMANNSTHAL	2.464	0	0	0	0	2.464	2.909	0	0	0	0	2.909	3.434	0	0	0	0	3.434
		WARMBAD/NYLSTROOM	4.231	0.41	1.046	0.205	0	5.892	4.365	0.433	1.12	0.202	0	6.12	4.644	0.447	1.318	0.196	0	6.605
		SUB-TOTAL	23.012	4.111	1.546	0.205	0	28.874	27.226	5.142	1.62	0.202	0	34.19	37.127	6.438	1.818	0.196	0	45.579
	TOTAL	TOTAL	69.807	15.317	1.982	0.496	0	87.602	93.068	18.814	2.316	0.666	0	114.864	140.928	26.276	2.959	1.063	0	171.226
EASTERN	WELTEVREDEN	BLOEDFONTEIN	2.860	0	0	0	0	2.860	3.839	0	0	0	0	3.839	4.755	0	0	0	0	4.755
		KAMEELRIVIER	0.735	0	0	0	0	0.735	1.350	0	0	0	0	1.35	1.45	0	0	0	0	1.45
		MAPOCH	0.288	0	0	0	0	0.288	0.573	0	0	0	0	0.573	0.701	0	0	0	0	0.701
		WALKRAAL	6.412	0	0	0	0	6.412	10.331	0	0	0	0	10.331	12.101	0	0	0	0	12.101
		SUB-TOTAL	10.295	0	0	0	0	10.295	16.093	0	0	0	0	16.093	19.007	0	0	0	0	19.007
	BRONKHORSTSPRUI	BRONKHORSTSPRUIT	6.693	3.614	0.192	0.128	0	10.627	7.577	3.66	0.226	0.151	0	11.614	9.738	3.748	0.293	0.195	0	13.974
		CULLINAN	1.769	0.089	0.107	0.071	1.11	3.146	2.092	0.105	0.126	0.083	1.11	3.516	2.897	0.143	0.171	0.114	1.11	4.435
		SUB-TOTAL	8.462	3.703	0.299	0.199	1.11	13.773	9.669	3.765	0.352	0.234	1.11	15.13	12.635	3.891	0.464	0.309	1.11	18.409
	TOTAL	TOTAL	18.757	3.703	0.299	0.199	1.11	24.068	25.762	3.765	0.352	0.234	1.11	31.223	31.642	3.891	0.464	0.309	1.11	37.416
GRAND-TOTAL		GRAND-TOTAL	118.318	25.421	6.407	1.482	46.608	198.236	158.393	30.396	7.26	1.775	50.613	248.437	223.819	40.838	8.995	2.403	55.977	332.032

Notes : 1) Primary water demand shown in the table includes system leakage losses (1995: 20 %, 2002: 18.25 %, 2015: 15 %),but excludes losses at the purification plant and from the raw water source to the purification plant.

Table 4-4 : Summary of Non-domestic Primary Water Demand

SUPPLY ZONE	SUPPLY AREA	SUPPLY BLOCK	NAME	DEMAND CATEGOR	WATER DEMAND (MCM/A) 1995	2002	2015
WESTERN	VAALKOP NORTH	THABAZIMBI	AMANDELBULT PLATINUM	MIN	3.28	3.665	4.38
			THABAZIMBI IRON MINE	MIN	11.096	11.096	11.096
			NORTHAM PLATINUM	MIN	2.815	4.129	6.57
			URBAN INDUSTRIAL	IND	0.345	0.37	0.421
			URBAN COMMERCIAL	COM	0.252	0.271	0.308
			URBAN INSTITUTIONAL	INS	0.168	0.180	0.205
			RHINO ANDULASITE	MIN	1.221	1.432	1.825
		MOKGALWANENG	PPC	IND	0.225	0.338	0.548
		SEFIKILE	RPM SWARTKLIP	MIN	4.974	5.533	6.57
			UNION MINE	MIN	0.100	0.100	0.100
		SAULSPOORT	BATLHAKO CHROME	MIN	1.095	1.095	1.095
			RUIGHOEK CHROME	MIN	0.201	0.201	0.201
			MAKGOPE CHROME	MIN	1.000	1.095	1.095
			ROODERAND FERROCHROM	MIN	0.201	0.201	0.201
		MOGWASE/SUN CIT	MOGWASE INDUSTRIAL	IND	3.719	3.987	4.537
			SUN CITY RESORT	COM	2.920	3.263	4.011
	VAALKOP SOUTH	VAALKOP SOUTHE BOSPOORT	RUSTENBURG NEW INDUST	IND	0	0.477	1.095
			IMPALA PLATINUM MINE	MIN	1.825	1.825	1.825
			URBAN INDUSTRIAL	IND	0.436	0.546	0.723
			URBAN COMMERCIAL	COM	0.327	0.41	0.542
			URBAN INSTITUTIONAL	INS	0.218	0.273	0.362
			RPM	MIN	1.071	1.071	1.071
	BARNARDSVLEI	BARNARDSVLEI WESTERN	URBAN INDUSTRIAL	IND	0.742	0.784	0.868
			URBAN COMMERCIAL	COM	0.557	0.588	0.651
			URBAN INSTITUTIONAL	INS	0.371	0.392	0.434
			IMPALA PLATINUM MINE	MIN	4.353	4.353	-4.353
			VOGELSTRUISNEK PLATINU	MIN	0.3	0.3	0.3
			RUSTENBURG PLATINUM MI	MIN	1.924	1.924	1.924
			KAREE MINE	MIN	1.737	2.486	2.486
			RAINBOW CHICKENS	IND	0.934	1.315	2.479
		BARNARDSVLEI EASTERN	WESTERN PLATINUM MINE	MIN	8.305	8.997	9.775
	KOSTER	KOSTER	URBAN COMMERCIAL	COM	0.04	0.04	0.04
			URBAN INSTITUTIONAL	INS	0.02	0.02	0.02
		SWARTRUGGENS	URBAN COMMERCIAL	COM	0.03	0.02	0.02
			URBAN INSTITUTIONAL	INS	0.01	0.01	0.01
	WESTERN ZONE TOTAL			IND	6.401	7.817	10.671
				COM	4.126	4.592	5.572
				INS	0.787	0.875	1.031
				MIN	45.498	49.503	54.867
				TOTAL	56.812	62.787	72.141
CENTRAL	BRITS	BRITS	URBAN INDUSTRIAL	IND	1.286	1.636	2.558
			URBAN COMMERCIAL	COM	0.436	0.696	1.141
			URBAN INSTITUTIONAL	INS	0.291	0.464	0.867
	RAND WATER	RAND WATER	ROSSLYN INDUSTRIA	IND	7	8.321	11.47
			GA-RANKUWA INDUSTRIA	IND	2.92	3.715	5.81
	TEMBA	KUDUBE NORTH	BABALEGI INDUSTRIAL	IND	3.701	4.709	5.991
			CAROUSEL	COM	0.5	0.5	0.5
		WARMBAD/NYLSTR	URBAN INDUSTRIAL	IND	0.41	0.433	0.447
			URBAN COMMERCIAL	COM	1.046	1.12	1.318
			URBAN INSTITUTIONAL	INS	0.205	0.202	0.196
	CENTRAL ZONE TOTAL			IND	15.317	18.814	26.276
				COM	1.982	2.316	2.959
				INS	0.496	0.666	1.063
				MIN	0	0	0
				TOTAL	17.795	21.796	30.298
EASTERN	BRONKHORSTPRUI	BRONKHORSTPRUI	EKANDUSTRIA	IND	3.358	3.358	3.358
			URBAN INDUSTRIAL	IND	0.256	0.302	0.390
			URBAN COMMERCIAL	COM	0.192	0.226	0.293
			URBAN INSTITUTIONAL	INS	0.128	0.151	0.195
		CULLINAN	URBAN INDUSTRIAL	IND	0.089	0.105	0.143
			URBAN COMMERCIAL	COM	0.107	0.126	0.171
			URBAN INSTITUTIONAL	INS	0.071	0.083	0.114
			PREMIER MINE	MIN	1.11	1.11	1.11
	EASTERN ZONE TOTAL			IND	3.703	3.765	3.891
				COM	0.299	0.352	0.464
				INS	0.199	0.234	0.309
				MIN	1.11	1.11	1.11
				TOTAL	5.311	5.461	5.774
STUDY AREA TOTAL				IND	25.421	30.396	40.838
				COM	6.407	7.26	8.995
				INS	1.482	1.775	2.403
				MIN	46.608	50.613	55.977
				TOTAL	79.918	90.044	108.213

Note: IND:Industrial, COM: Commercial, INS: Institutional, MIN: Mining

Table 4-5 : Projected Per-Capita Water Demands and Growth Rates

ZONE		WESTERN					CENTRAL					EASTERN					STUDY AREA				
YEAR & ANNUAL AVERAGE GROWTH RATE		1995	G.R.(%)	2002	G.R.(%)	2015	1995	G.R.(%)	2002	G.R.(%)	2015	1995	G.R.(%)	2002	G.R.(%)	2015	1995	G.R.(%)	2002	G.R.(%)	2015
POPULATION		675,850	2.22	788,238	2.10	1,033,366	1,668,296	3.24	2,084,933	3.46	3,242,758	770,769	1.28	842,795	1.38	1,007,119	3,114,915	2.55	3,715,966	2.74	5,283,243
	DOMESTIC	81,518	4.15	108,392	2.01	140,408	191,252	4.19	254,981	3.24	386,104	51,389	4.64	70,581	1.59	86,690	324,159	4.26	433,954	2.70	613,202
	INDUSTRIAL	17,537	2.90	21,416	2.42	29,236	41,964	2.98	51,545	2.60	71,989	10,145	0.24	10,315	0.25	10,660	69,646	2.59	83,276	2.30	111,885
WATER DEMAND	COMMERCIAL	11,304	1.54	12,581	1.50	15,266	5,430	2.25	6,345	1.90	8,107	819	2.36	964	2.15	1,271	17,553	1.80	19,890	1.66	24,644
(kld)	INSTITUTIONAL	2,156	1.53	2,397	1.27	2,825	1,359	4.30	1,825	3.66	2,912	545	2.34	641	2.17	847	4,060	2.61	4,863	2.36	6,584
	MINING	124,652	1.21	135,625	0.79	150,321	0	0	0	0	0	3,041	0	3,041	0	3,041	127,693	1.18	138,666	0.78	153,362
	TOTAL	237,167	2.42	280,411	1.45	338,056	240,005	3.95	314,696	3.12	469,112	65,939	3.79	85,542	1.40	102,509	543,111	3.28	680,649	2.26	909,677
PER-CAPITA DEMAND	DOMESTIC	121	1.90	138	-0.11	136	115	0.85	122	-0.19	119	67	3.28	84	0.18	86	104	1.70	117	-0.07	116
(lcd)	OVERALL	351	0.20	356	-0.66	327	144	0.68	151	-0.31	145	86	2.32	101	0.08	102	174	0.72	183	-0.48	172

Note : Water demand shown in the table includes system leakage losses (1995: 20%, 2002: 18.25 %, 2015: 15%), but excludes losses at the purification plant and from the raw water source to the purification plant.

Table 4-9 : Irrigation Demand Allocation by Local Area

Area	Source	Annual Demand (mcm/a)
Upstream of Hartbeespoort	Run-of-river	57.2
Hartbeespoort	Harbeespoort	100.6
Buffelspoort	Buffelspoort	6.6
Roodekopjes	Roodekopjes	29.4
Upstream of Roodekopjes	Run-of-river	7.7
Upstream Roodeplaat	Run-of-River	13.5
Roodeplaat	Roodeplaat	6.7
Bon Accord	Bon Accord	11.5
Upstream Warmbad	Run-of-river	0.8
Warmbad	Warmbad Dam	2.2
Upstream Klipvoor	Run-of-river	25.6
Klipvoor	Klipvoor Dam	62.0
Olifantsnek	Olifantsnek Dam	14.3
Koster	Koster Dam	2.9
Lindleyspoort	Lindleyspoort Dam	8.4
Upstream of Vaalkop	Run-of-river	16.7
Vaalkop	Vaalkop Dam	2.7
Lower Crocodile	Run-of-river/Ground water	63.0
Bronkhorstspruit	Bronkhorstspruit Dam	0.7
Upstream Rust de Winter	Run-of-river	6.5
Moses River	Run-of river	2.6

Figure 4-1 Projected Population by Level of Service (Study Area)

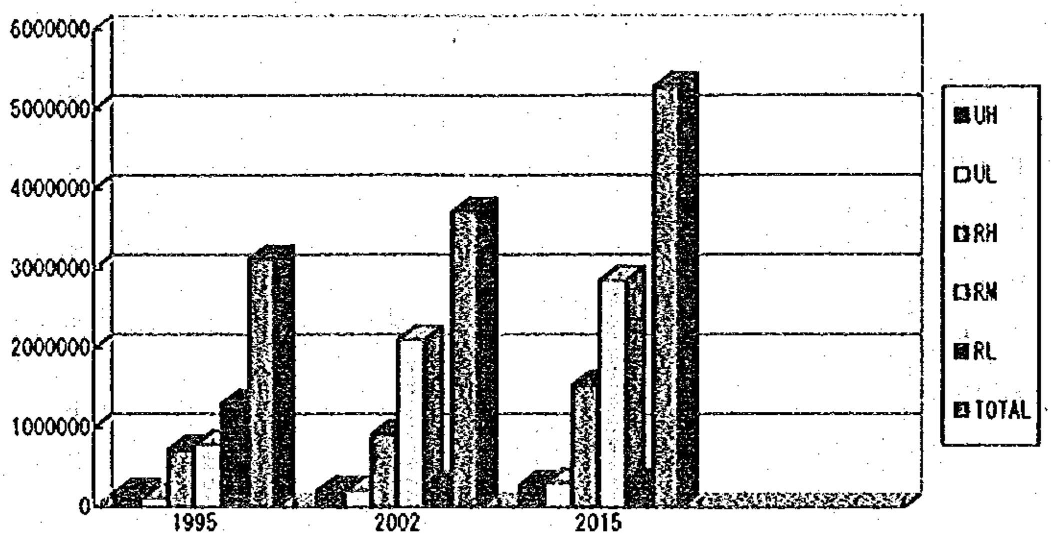


Figure 4-2 Projected Primary Water Demand by Use Category (Study Area)

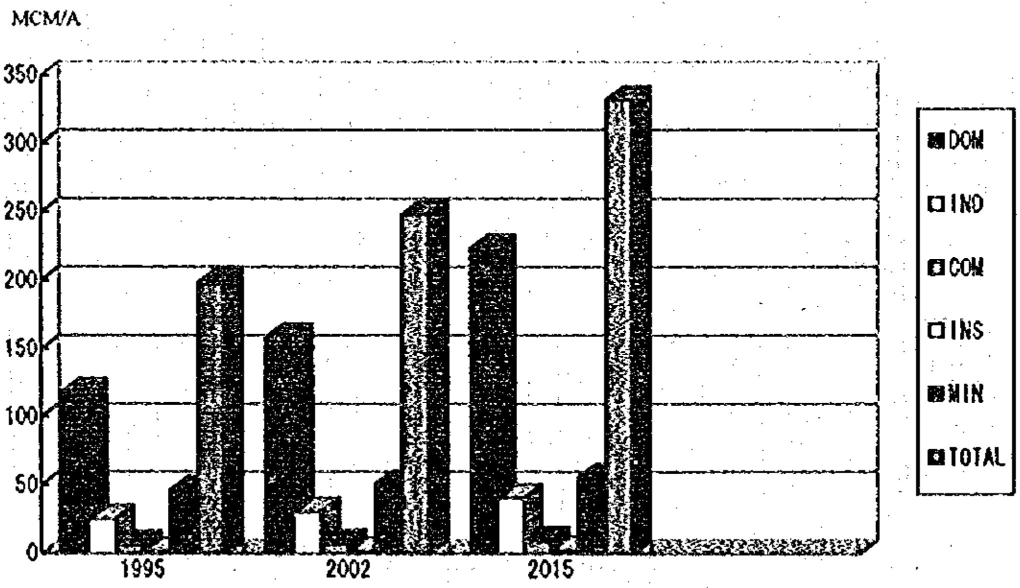


Figure 4-3 Projected Population by Level of Service (Western Zone)

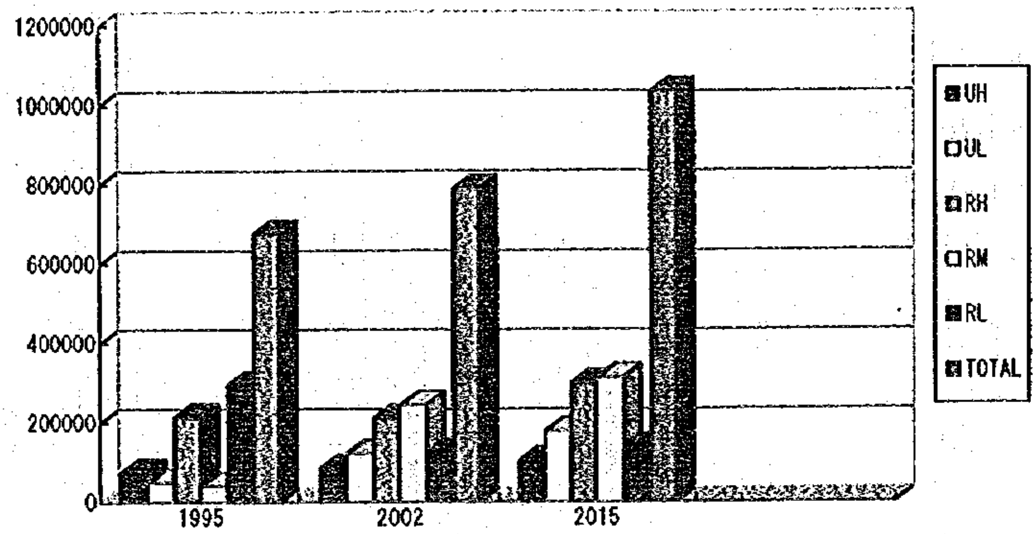


Figure 4-4 Projected Primary Water Demand by Use Category(Western Zone)

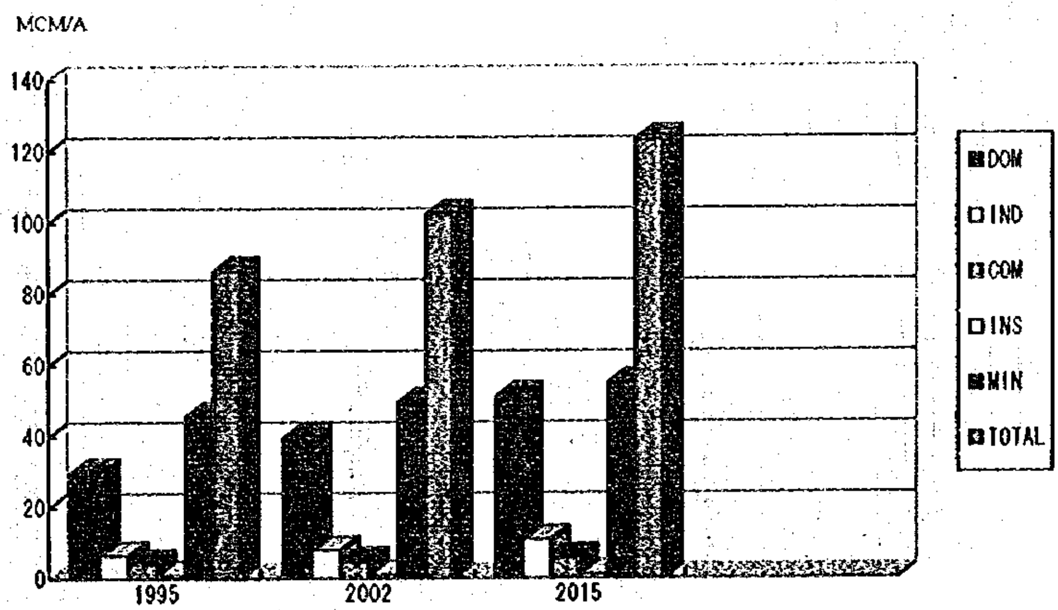


Figure 4-5 Projected Population by Level of Service (Central Zone)

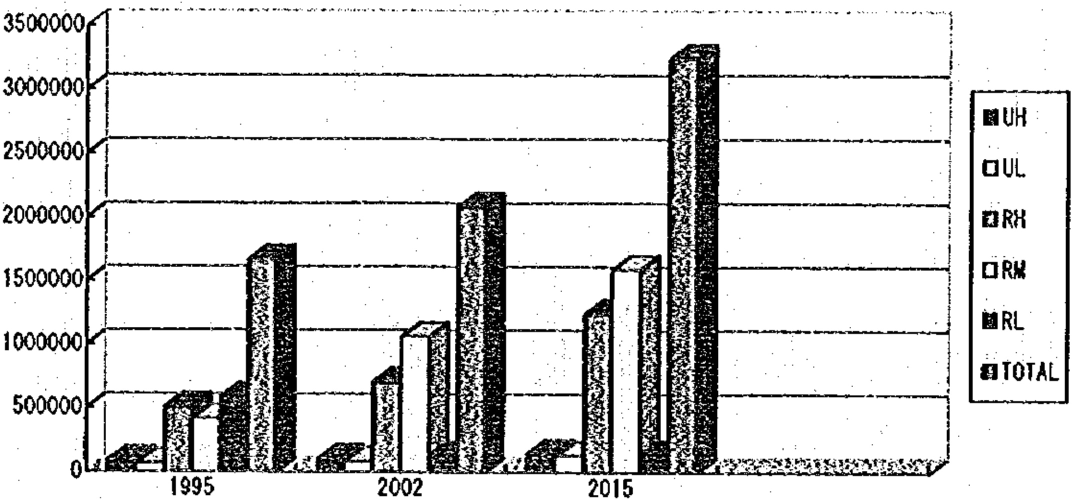


Figure 4-6 Projected Primary Water Demand by Use Category (Central Zone)

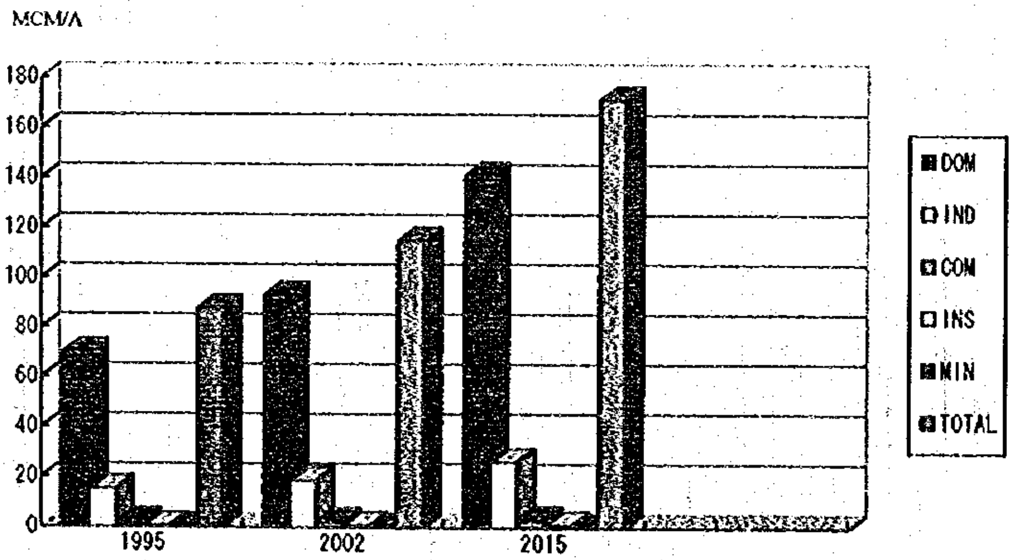


Figure 4-7 Projected Population by Level of Service (Eastern Zone)

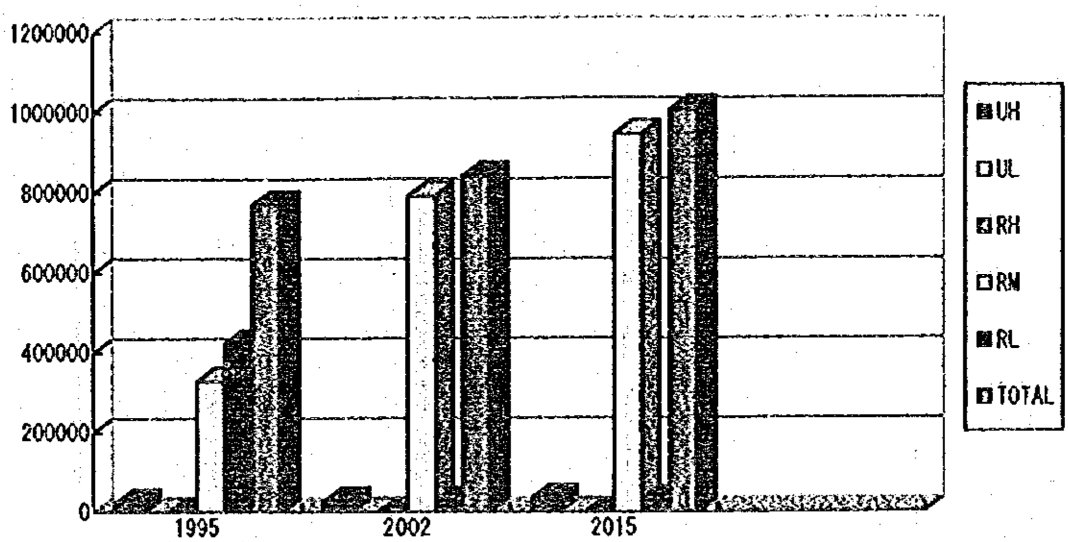


Figure 4-8 Projected Primary Water Demand by Use Category (Eastern Zone)