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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 (E) PRELIMINARY STUDY OF WATER SUPPLY SYSTEM

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SUPPORTING REPORT E : PRELIMINARY STUDY OF WATER SUPPLY SYSTEMS

TABLE OF CONTENTS

ABBREVIATIONS AND TERMINOLOGY

CHAPTER 1 INTRODUCTION

1.1 Background 1-1
1.2 Composition of Master Plan Report 1-3
1.3 Supporting Report E 1-3

CHAPTER 2 ZONING OF STUDY AREA

2.1 Purpose and Basic Concept 2-1
2.2 Supply Zones / Areas / Blocks 2-1
2.2.1 Supply Zones 2-1
2.2.2 Supply Areas 2-2
2.2.3 Supply Blocks 2-2

CHAPTER 3 GROUNDWATER

3.1 Introduction 3-1
3.2 Strategy for Groundwater Exploitation 3-1
3.2.1 Criteria for Selection of Areas for Proposed Boreholes 3-1
3.2.2 Areas Proposed for New Boreholes 3-1

CHAPTER 4 SURFACE WATER RESOURCES AND WATER BALANCE SIMULATION

4.1 Introduction 4-1
4.1.1 Objectives of the Study 4-1
4.1.2 Study Area 4-1
4.1.3 Description of the Cases Studied 4-1
4.2 Water Resources Yield and Planning Models (WRYM/WRPM) 4-2
4.2.1 Selection of WRYM/WRPM for Simulating the Water Balance 4-2
4.2.2 Terminology 4-3
4.2.3 Basic Concept of the Models 4-4
4.2.4 Existing Use of the Model in the Crocodile and Olifants River 4-4
4.2.5 Water Allocation Rules 4-5
4.2.6 Schematic Representations 4-6
4.2.7 Form of Output 4-6
4.2.8 Data Requirements for the Water Balance 4-6
4.3 Available Runoff Data 4-7
4.3.1 Runoff Data Required for WRYM 4-7

4.3.2 Availability of Runoff Data 4-7
4.4 Available Water Resources 4-7
4.4.1 Surface Water 4-7
4.4.2 Expected Return Flow and Incremental Urban Runoff 4-8
4.5 Water Demands 4-8
4.5.1 Primary Water Demand 4-8
4.5.2 Irrigation Water Demand 4-8
4.5.3 Stock-watering Demand 4-8
4.5.4 Environmental and other Requirements 4-9
4.6 Results of the Water Balance Simulation 4-9
4.6.1 Simulation and Assessment of Case 1 4-9
4.6.2 Simulation and Assessment of Case 2 4-11
4.6.3 Simulation and Assessment of Case 3 4-13
4.6.4 Conclusions 4-14

CHAPTER 5 INFRASTRUCTURE DEVELOPMENT PLANNING

5.1 Assumed Design Standards and Cost Curves 5-1
5.1.1 Storage Dams and Diversion Weirs 5-1
5.1.2 Conveyance Canals 5-2
5.1.3 Water Treatment Works 5-2
5.1.4 Delivery and Distribution Pipelines 5-2
5.1.5 Pumping Stations 5-3
5.1.6 Reservoirs 5-3
5.1.7 Reticulations 5-4
5.1.8 Boreholes 5-4
5.2 General Planning Approach 5-5
5.3 Development Planning for the Western Zone 5-7
5.3.1 Vaalkop North Supply Area 5-7
5.3.2 Vaalkop South Supply Area 5-9
5.3.3 Barnardsvlei Supply Area 5-10
5.3.4 Koster Supply Area 5-12
5.4 Development Planning for the Central Zone 5-13
5.4.1 Brits Supply Area 5-13
5.4.2 Klipvoor Supply Area 5-15
5.4.3 Rand Water Supply Area 5-17
5.4.4 Temba Supply Area 5-18
5.5 Development Planning for the Eastern Zone 5-20
5.5.1 Weltevreden Supply Area 5-20
5.5.2 Bronkhorstspruit Supply Area 5-23
5.6 Cost Estimates 5-25
5.7 Recommendations on Sanitation Options 5-26
5.7.1 Introduction 5-26
5.7.2 Recommended Sanitation Options 5-26
5.8 Environmental Impact 5-27

CHAPTER 6 OUTPUTS FROM INFRASTRUCTURE PLANNING PROCESS

6.1 Costs 6-1
6.2 Programme and Disbursement Schedule 6-1
6.2.1 Short and Medium Term Development Plan 6-1
6.2.2 Long Term Development Plan 6-1
6.2.3 Outline Summary of the Infrastructural Development 6-2
6.3 Management Implications of Technical Solutions 6-2

LIST OF TABLES

Table 2-1 : Zoning of Study Area 2-3
Table 4-1 : Acceptable Return Period and Allowable Distribution of Demand 4-15
Table 4-2 : Probable Drought River Runoff in the Study Area 4-15
Table 4-3 : Projected Return Flow and Urban Runoff in the Crocodile River (2015) 4-16
Table 4-4 : Estimated Current Return Flows and Urban Runoff (1995 base) 4-16
Table 4-5 : Assumed Return Flows and Urban Runoff (Alternative 2 of case 3) 4-16
Table 4-6 : Required Surface Water Amount for Projected Primary Water Demand 4-17
Table 4-7 : Allocation of Primary Demand 4-21
Table 4-8 : Summary of Water Balance for Case 1 (1995 base) 4-22
Table 4-9 : Water Balance for Case 1 (1995 base) 4-23
Table 4-10 : Water Balance for Case 2 (Base Plan) 4-24
Table 4-11 : Summary of Water Balance for Case 2 (Base Plan - 2015 base) 4-25
Table 4-12 : Water Balance for Case 3 Alternative 1 4-26
Table 4-13 : Summary of Water Balance for Case 3 Alternative 1 (2015 base) 4-27
Table 4-14 : Water Balance for Case 3 Alternative 3 4-28
Table 4-15 : Summary of Water Balance for Case 3 Alternative 3 (2015 base) 4-29
Table 4-16 : Water Balance for Case 3 Alternative 2 4-30
Table 4-17 : Summary of Water Balance for Case 3 Alternative 2 (2015) 4-31
Table 5-1 : Summary of Additional Bulk Infrastructure Required for Vaalkop North S/A .. 5-8
Table 5-2 : Summary of Additional Bulk Infrastructure Required for Vaalkop South S/A . 5-10
Table 5-3 : Summary of Additional Bulk Infrastructure Required for Barnardsvlei S/A ... 5-12
Table 5-4 : Summary of Additional Bulk Infrastructure Required for Koster S/A 5-13
Table 5-5 : Summary of Additional Bulk Infrastructure Required for Brits S/A 5-15
Table 5-6 : Summary of Additional Bulk Infrastructure Required for Klipvoor S/A 5-17
Table 5-7 : Summary of Additional Bulk Infrastructure Required for Rand Water S/A 5-18
Table 5-8 : Summary of Additional Bulk Infrastructure Required for Temba S/A 5-19
Table 5-9 : Summary of Additional Bulk Infrastructure Required for Weltevreden S/A ... 5-23
Table 5-10 : Summary of Additional Bulk Infrastructure Required for Bronkhorstspruit S/A 5-25
Table 6-1 : Summary of Costs from Infrastructure Planning - Western Zone 6-4
Table 6-2 : Summary of Costs from Infrastructure Planning - Central Zone 6-5
Table 6-3 : Summary of Costs from Infrastructure Planning - Eastern Zone 6-6
Table 6-4 : Breakdown of Costs for RDP and Higher Level of Service 6-7
Table 6-5 : Proposed Expansion of Water Treatment Works in the Study Area 6-8

LIST OF FIGURES

Figure 4-1 : Schematic Diagram of Crocodile River System 4-32
Figure 4-2 : Schematic Diagram of Olifants River System 4-33
Figure 4-3 : Storage Water Allocation Plan of Case 1 Western Zone (1995 base) 4-34
Figure 4-4 : Storage Water Allocation Plan of Case 1 Central Zone (1995 base) 4-35
Figure 4-5 : Storage Water Allocation Plan of Case 1 Eastern Zone (1995 base) 4-36
Figure 4-6 : Storage Water Allocation Plan of Case 2 (Base Plan) Western Zone (2015 base) 4-37
Figure 4-7 : Storage Water Allocation Plan of Case 2 Central Zone (2015 base) 4-38
Figure 4-8 : Storage Water Allocation Plan of Case 2 Eastern Zone (2015 base) 4-39
Figure 5-1 : Flow Chart for Improvement of Sanitation 5-31

LIST OF APPENDICES

Appendix 1 : Planning Schematics
Appendix 2 : Comparison of Alternative Water Supply Schemes

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

1. INTRODUCTION 1-1

1.1 Background 1-1
1.2 Composition of Master Plan Report 1-3
1.3 Supporting Report E 1-3

CHAPTER 1 INTRODUCTION

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 Capital Investment Plan
H Evaluation of Master Plan and Implementation Plan

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 E

The two supporting reports which relate primarily to the technical part of the Study comprise Supporting Report B, which covers the situational analysis i.e. the existing conditions prevailing in the Study Area; and this report which explains how the raw data from the situational analysis was used to prepare technical proposals to a master plan level of detail.

Chapter 2 explains how the Study Area was broken down into Supply Zones, Areas and Blocks for planning purposes. Chapter 3 briefly addresses groundwater; as the proposed technical solutions are based almost entirely on a surface water supply, this section is brief although the prevailing conditions are explained in Supporting Report B and maps summarising the likely yield and quality are included in the Data Book. The Water Balance Study is described in Chapter 4 when the projected water demands in the Study

Area were assessed against the availability of raw water for primary and non-primary use. The study concluded that no new dams are required within the Study Area at this stage.

In Chapter 5, the infrastructure planning process is explained. Much of the work consisted of preparing schematics which are included in Appendix 1 and may be updated by stakeholders in the future and used as a planning tool. The existing infrastructure in each Supply Area was assessed against the 2015 projected water demand and components with insufficient capacity were identified and the situation was summarised on a schematic. The facilities required to overcome the constraints and also to serve currently unserved areas were then planned and these proposals were also summarised on a spreadsheet. A cost summary sheet for each Supply Area shows the key infrastructure components and a cost estimate. Three alternative water sources were assessed for the currently unserved northern areas in the Central and Eastern Zones. These alternatives are summarised in Appendix 2.

The outputs from the planning process comprised estimated costs, proposals for an implementation programme and other issues with management considerations which need to be considered. These are described in Chapter 6.

CHAPTER 2 : ZONING OF STUDY AREA

2. ZONING OF STUDY AREA
2.1 Purpose and Basic Concept 2-1
2.2 Supply Zones / Areas / Blocks 2-1
2.2.1 Supply Zones 2-1
2.2.2 Supply Areas 2-2
2.2.3 Supply Blocks 2-2

CHAPTER 2 ZONING OF STUDY AREA

2.1 Purpose and Basic Concept

The Study Area was divided into a hierarchy of spatially identified supply areas. From the largest to the smallest division these have been termed Supply Zones, Supply Areas and Supply Blocks. The purpose of these groupings was to serve as a basis for the arrangement of water demands and supply sources, as well as for the management of water supply schemes.

The division of the Study Area that was finally adopted in this Study is shown on the Location Map attached to the Main Report and also in Table 2-1.

2.2 Supply Zones / Areas / Blocks

The criteria that were applied when grouping primary demands and infrastructure into Supply Zones, Supply Areas and Supply Blocks are set out in (1) to (3) below:

2.2.1 Supply Zones

A Supply Zone comprises a grouping of bulk demands that are served by one management unit of Magalies Water, or an expected future management unit of the Board.

Three Supply Zones were selected for this Study; Western, Central and Eastern Supply Zones. These Supply Zones were selected primarily to accord with the natural drainage system of the Study Area. As mentioned elsewhere, the Study Area comprises basically two main river drainage systems. Those are the Olifants River system in the east and the Crocodile River system in the centre and west. Existing water supply infrastructure has, for obvious reasons, been developed around this natural drainage system.

The Western Supply Zone is supplied with water from four sources, ie the Elands and Crocodile Rivers, via Vaalkop Dam, and the Hex River from Bospoort Dam. A large volume of primary water is also imported into the Supply Area at Barnardsvlei by Rand Water (Vaal River System). Primary water from all three of these sources is being consumed in the Greater Rustenburg region and for this reason these sources have been grouped into a single Supply Zone. Koster and Swartsruggens have also been included in this zone. In view of the small water demands in these districts that can be locally sourced, a separate Supply Zone for these districts is not justifiable.

The Central Supply Zone has four primary water sources, ie the Pienaars River (Roodeplaat Dam - Wallmannsthal and Temba water treatment works, and Klipvoor Dam - no existing treatment works), the Apies River (Leeukraal Dam - Kudube WTW), the Crocodile River (Hartbeespoort Dam - Brits WTW) and the Vaal River (imported by Rand Water for supply to the Akasia, Rosslyn, Klip-Kruisfontein, Ga-Rankuwa, Mabopane and Soshanguve areas).

The Eastern Supply Zone has three separate supply sources, all being tributaries of the Olifants River, ie the Bronkhorstspruit (Bronkhorstspruit Dam and water treatment works), the Wilge

River (Premier Mine Dam - Cullinan WTW) and the Elands River (Mkombo Dam - Weltevreden WTW). Water is also imported from the Loskop Dam (Olifants River) for purification at Weltevreden WTW. Proposals have also been approved for the transfer of Vaal River water from the Grootdraai Dam into the Bronkhorstspruit Treatment Works.

The existing water supply infrastructure in the Study Area is described in more detail in Supporting Report B.

2.2.2 Supply Areas

A Supply Area comprises a grouping of bulk demands that are supplied from a common surface water resource or a set of resources, eg dams and/or weirs, but allowing also for imported and exported water.

The Western Supply Zone has been divided into four Supply Areas; the Vaalkop North, Vaalkop South, Barnardsvlei and Koster Supply Areas. The Central Supply Zone was also divided into four Supply Areas; the Brits, Klipvoor, Temba and Rand Water Supply Areas. The Eastern Supply Zone was only divided into two Supply Areas; the Bronkhorstspruit and Weltevreden Supply Areas.

2.2.3 Supply Blocks

Some of the above-mentioned Supply Areas have been further subdivided into a number of Supply Blocks. A Supply Block comprises a grouping of bulk demands that are supplied from a single bulk supply pipeline (with branches if applicable). The bulk supply pipeline either originates from a water treatment works, or is a branch to a pipeline serving an entire service area that originates at such a water treatment works. In conclusion, the Study Area was divided into 28 Supply Blocks as shown in Table 2-1.

Table 2-1 : Zoning of Study Area

SUPPLY ZONE	SUPPLY AREA	SUPPLY BLOCK
WESTERN	1.Vaalkop North	1. Thabazimbi
		2. Mokgalwaneng
		3. Sefikile
		4. Ramokokstad
		5. Saulspoort
		6. Mogwase/Sun City
	2. Vaalkop South	7. Bethanie
		8. Vaalkop Southern/Bospoort
	3. Barnardsvlei	9. Barnardsvlei Western
		10. Barnardsvlei Eastern
	4. Koster	11. Koster
		12. Swartsruggens
CENTRAL	1. Brits	1. Brits
		2. Hartbeespoort
	2. Klipvoor	3. Kipvoor West
		4. Klipvoor East
		5. Moretele North
	3. Rand Water	6. Rand Water
	4. Temba	7. Kudube North
		8. Kudube South
		9. Wallmannsthal
		10. Warmbaths/Nylstroom
EASTERN	1. Weltevreden	1. Bloedfontein
		2. Kameelriver
		3. Mapoch
		4. Walkraal
	2. Bronkhorstspruit	5. Bronkhorstspruit
		6. Cullinan

CHAPTER 3 : GROUNDWATER

3. GROUNDWATER
3.1 Introduction 3-1
3.2 Strategy for Groundwater Exploitation 3-1
3.2.1 Criteria for Selection of Areas for Proposed Boreholes 3-1
3.2.2 Areas Proposed for New Boreholes 3-1

CHAPTER 3 GROUNDWATER

3.1 Introduction

The geohydrology of the Study Area is described in Section 5.12 of Supporting Report B. A consolidated database was constructed from the significant known sources of information and from the information collected, conclusions were reached concerning general trends in groundwater availability, exploitability and quality. The general trends in borehole yield and quality across the Study Area are shown in Figures 5-4 and 5-5 of Supporting Report B and more comprehensive information is shown on maps included in the Data Book.

Supporting Report B describes current estimated levels of use of groundwater and some of the associated problems. These are mainly associated with quality (due to faecal contamination associated with poor sanitation, fluorides from geological sources and nitrtaes from sanitation, agriculture and natural sources), and quantity (the yield as measured by exploitability and accessibility is often inadequate) and generally mitigate against any new major groundwater development except on the extreme south west fringe of the Study Area in the dolomitic aquifer.

3.2 Strategy for Groundwater Exploitation

3.2.1 Criteria for Selection of Areas for Proposed Boreholes

The primary consideration in this regard is the result of the water balance study. Every attempt has been made to meet the future water demand from surface water resources.

For the reasons stated above, potential development of groundwater resources has been further tempered by the consideration of groundwater quality. Groundwater quality is classified by DWAF as Class 0 (ideal) to Class 4 (unacceptable for domestic use or stock-watering without treatment). In this regard it has been considered appropriate to eliminate the supply of Classes 3 and 4 groundwater by the year 2002 and the supply of Class 2 groundwater by the year 2015.

3.2.2 Areas Proposed for New Boreholes

In the towns of Koster and Swartsruggens, a deficit has been projected in 2015 compared with the existing surface water infrastructure capacity. These communities are located too far from Rustenburg for a bulk supply to be provided by MW or Rand Water on an economical basis however the area has been identified as having potential for the development of groundwater to meet the projected shortfall.

No other significant groundwater schemes were identified by the Study. It is anticipated that Thabazimbi TLC will continue to suppliment the bulk water supply from MW with groundwater from the iron ore mine (currently at 1.3 mcm/a), as the cost is favourable. The mine also usus 11.1 mcm/a at present and will continue to do so. Rural areas and some small agricultural

holdings which cannot be economically reticulated with a surface water supply will also continue to be served by groundwater.

The infrastructure development planning proposed for Koster, Swartsruggens and Thabazimbi is described in more detail in Chapter 5.

CHAPTER 4 : SURFACE WATER RESOURCES AND WATER BALANCE SIMULATION

4. SURFACE WATER RESOURCES AND WATER BALANCE SIMULATION

4.1 Introduction 4-1
4.1.1 Objectives of the Study 4-1
4.1.2 Study Area 4-1
4.1.3 Description of the Cases Studied 4-1
4.2 Water Resources Yield and Planning Models (WRYM/WRPM) 4-2
4.2.1 Selection of WRYM/WRPM for Simulating the Water Balance .. 4-2
4.2.2 Terminology 4-3
4.2.3 Basic Concept of the Models 4-4
4.2.4 Existing Use of the Model in the Crocodile and Olifants River ... 4-4
4.2.5 Water Allocation Rules 4-5
4.2.6 Schematic Representations 4-6
4.2.7 Form of Output 4-6
4.2.8 Data Requirements for the Water Balance 4-6
4.3 Available Runoff Data 4-7
4.3.1 Runoff Data Required for WRYM 4-7
4.3.2 Availability of Runoff Data 4-7
4.4 Available Water Resources 4-7
4.4.1 Surface Water 4-7
4.4.2 Expected Return Flow and Incremental Urban Runoff 4-8
4.5 Water Demands 4-8
4.5.1 Primary Water Demand 4-8
4.5.2 Irrigation Water Demand 4-8
4.5.3 Stock-watering Demand 4-8
4.5.4 Environmental and other Requirements 4-9
4.6 Results of the Water Balance Simulation 4-9
4.6.1 Simulation and Assessment of Case 1 4-9
4.6.2 Simulation and Assessment of Case 2 4-11
4.6.3 Simulation and Assessment of Case 3 4-13
4.6.4 Conclusions 4-14

CHAPTER 4 SURFACE WATER RESOURCES AND WATER BALANCE SIMULATION

4.1 Introduction

4.1.1 Objectives of the Study

The objective of the water balance simulation is to assess the availability of surface water resources in the Study Area for meeting the present and expected needs of domestic, industrial and mining user sectors, together referred to as primary water demands, and the large water requirements for irrigated agriculture. Account should also be taken of the water requirement for environmental systems and international commitments in respect of rivers of common interest. The water balance simulation approach is used to assess the present water supply situation from existing infrastructure and to evaluate possible new development proposals where these may be necessary.

4.1.2 Study Area

Since the boundaries of the Study Area do not coincide with natural catchment areas, the Modelled Study Area for this portion of the assignment covered the tertiary catchments of the Crocodile and Olifants river basins as shown in Figure 5-1 of Supporting Report B. In general the Modelled Study Area includes all sub-catchments which affect the Study Area from a water resources perspective. This means that the upper Crocodile River catchment, above Hartbeespoort Dam is in the Modelled Study Area and only certain tributaries of the Olifants River, i.e. the Bronkhorstspruit, Wilge River, Moses River and Elands River, to the east are included.

Although the upper reaches of the Nyl River catchment, part of the Mogalakwena River system, fall within the Study Area in the vicinity of Warmbaths and Nylstroom, the resources of this river are not available for further development because of possible negative impacts on the Nyl River Flood Plain. These sub-catchments are excluded from the Modelled Study Area.

Differences between the boundaries of the Study Area and the Modelled Study Area in the west are not significant. The same comment applies to the western part of the southern boundaries which extend along the Witwatersrand.

4.1.3 Description of the Cases Studied

In order to assess the adequacy of the limited water resouces in the Study Area, the following water balance simulations were carried out to compare water avilability from river runoff and return flows from urban areas, with the water demand (excluding that met from groundwater).

The concept of the water balance simulation as originally conceived is represented by the following three cases:

Case 1: To simulate the water balance between existing available water resources and the water requirements in 1995.

Case 2: To simulate the water balance between existing available water resources and water requirements in the year 2015.

Case 3: To simulate the water balance between existing available water resources plus newly developed water resources and water requirements in the year 2015.

Since the Case 2 study mentioned above indicated that the water requirements in the respective target years can just be met using the existing available water resources infrastructure, three alternative studies were proposed for Case 3 for 2002 and 2015 (instead of the original scenario). These were:

Alternative 1: In the case of water imported from Rand Water remaining at the level supplied in 1995 (42.1 mcm/a for Central Zone and 39.3 mcm/a for Western Zone).

Alternative 2: In the case that the maximum amount of water imported from Rand Water is at the level of the supply capacity of the existing infrastructure (assumed to be 86.9 mcm/a for Central Zone and 39.3 mcm/a for Western Zone), and expected return flow in the year 2015 is decreased to 80% of the return flow originally projected.

Alternative 3: The concept of this alternative is the same as Alternative 1 but with the water allocation modified.

4.2 Water Resources Yield and Planning Models (WRYM/WRPM)

4.2.1 Selection of WRYM/WRPM for Simulating the Water Balance

The WRYM/WRPM were selected to simulate the water balance in the area because:

(1) These sophisticated models are recommended by DWAF for use in complex systems such as those found in the Study Area.

(2) Comprehensive studies of the Crocodile and Olifants systems have recently been made using these models and all data sets are available.

(3) Interpretation of existing simulations would be sufficient to evaluate the availability of surface water in the area with very few costly additional runs being necessary.

(4) Detailed reports on recent studies using these models are available as are detailed descriptions of the model and its operation.

(5) Special modifications have been made to the model to simulate difficult conditions encountered in the Study Area.

The results of recent simulations using the models were interpreted for the purpose of this Study and special runs of the model were used only for confirming findings and demonstrating the performance of specific components of the system.

4.2.2 Terminology

A number of terms which have a specific meaning or can be interpreted to have various meanings must be defined for the purpose of this assignment. Not all terms are defined but the following are of special concern:

(1) Yield - the quantity of water available, usually per year, from a source such as a dam under specific conditions. The relevant conditions usually refer to the security of supply and method of operating the source. In this assignment reference is made to the "historic firm yield" ie the quantity of water that would have been available over the period of record of runoff (usually the period of naturalized runoff sequence) without failure or shortages. In this case a naturalized record 68 years long was used.

The term "system yield" is also used and this refers to the availability of water from each source (or dam) in the system when all components are operated in a specified manner. This definition of yield is more complex in that the security of supply is associated with water allocation rules where each user sector has a specific hierarchy of reductions of supply or restrictions on use in periods of shortage as described in Section 4.2.3.

(2) Security of supply - an indication of the long term average risk of shortage in supplies expressed as a recurrence interval in years on average probability for example 1:100 years or 0.01 probability. The degree of shortage or restriction (e.g. 20% reduction), must also be specified. Security of supply is generally set as a minimum target and actual availability is generally better than the target.

(3) Naturalised runoff - Naturalised runoff is the best estimate, using available technology, of the runoff sequence (usually on a monthly basis), that would have occurred from a completely natural catchment. In order to arrive at this estimate a rainfall - runoff model (the Pitman model) is calibrated for the period of observed runoff using records at gauging stations taking into account the growth of variables such as afforestation, urbanization, irrigation abstractions, other abstractions and return flow. The naturalised conditions are then extended back in time for as long as rainfall data is available setting all the development variables to zero.

It is important that the modeling process at gauging stations be checked by doing consistency and other evaluations.

(4) Urban runoff - Urban runoff represents the increase in stream flow that is attributable to the hardening of the land surface in urban areas and the consequent decrease in interception, infiltration and evapo-transpiration. The estimate of urban runoff used in the water balance is derived from the rainfall-runoff modeling process where calibration has taken place. No provision is made for growth in urbanization over the planning period to 2015.

(5) Return flow - Return flow is the increase in stream flow resulting from the discharge of treated wastewater at specific points in the river system. This should not be confused with the dispersed accretion of flow components, such as seepage from irrigation and

other uses, which are taken into account in the modeling process. Return flows represent a proportion of the water used, mainly for domestic use and for industry, in severed portions of the catchment area, and are calculated for the main point discharges using an algorithm which can be calibrated where data is available.

4.2.3 Basic Concept of the Models

The WRYM and WRPM are mathematical or numeric models of the river systems which are set up to simulate the behaviour of all components of the system. If recorded or historic hydrological events such as rainfall and runoff are to be repeated the WRYM is used, or if it is required to simulate the behaviour of the system with a large number of statistically similar possible hydrologic conditions the WRPM is used. Both models contain the same basic data on components of the system, such as storage dams, and make it possible to simulate the behaviour of very complex systems with a wide variety of types and sizes of components.

Both models are sophisticated integrated system analysis models and both have the same basic principles in common, but they have distinctly different purposes. The models are in essence a water balance model which can simulate complex water resources systems. Various operating rules can be applied and preference can be given to certain functions by the correct selection of penalty functions. The solution method of both models is an linear/dynamic programming algorithm.

The basic difference in application is that the yield model is essentially a static model that will provide certain yield information if run iteratively, from which operational criteria can be established for the planning model. The planning model is used mainly to run stochastic sequences using growing (changing) demands and set targets for reliability of supply. From the results it will become clear whether the set targets are achieved and if not, what the probability of non-achievement is.

The models are very comprehensive in their abilities and can therefore model very complex systems. The price that is paid for these abilities is the massive amount of input data that is required and the computational effort. An example of this is that a single WRYM run for the Crocodile River model takes just over 4 hours on a Pentium 150 PC.

4.2.4 Existing Use of the Model in the Crocodile and Olifants River

The models have been used recently in assignments commissioned by DWAF for both the Crocodile and Olifants catchments which cover almost the entire Study Area. The only area not covered is the Upper Mogolakwena Catchment around Nylstroom. This area is however not available for the development of surface water due to ecological sensitivity according to a recent decision by the Central Government (see Section 4.1.3). An alternative supply to the Warmbaths/ Nylstroom area has been developed using imported water from Temba WTW via the recently constructed pipeline. This will supplement the existing sources in the area ie Warmbaths Dam and Donkerpoort Dam. Domestic supply to this area is therefore secure.

Due to two rather special situations found in the Crocodile catchment, special extensions have recently been developed for the model. The first is a component to simulate the variations in return flow depending on the climate. It was found during the recent update of the catchment study from the additional data available, that there is a definite correlation between return flow and effective rainfall. This component is now part of the models and has been calibrated for the return flows to the Upper Crocodile catchment. A further extension to the model is the simulation of the groundwater stored in the alluvial deposits found in the Lower Crocodile River. These deposits are recharged during periods of high flow, and the irrigators make use of this by installing shallow boreholes to supplement water from the river during periods of low flow. This can best be described as a dummy dam with a considerable lag attached to it. A calibrated routine has been added to the model to reasonably simulate this phenomena.

4.2.5 Water Allocation Rules

(1) User grouping and security of supply

In the model it is recognized that there are different user sectors which have different requirements regarding security of supply. For example in domestic supply to more affluent communities the total demand is made up of water for drinking purposes, for washing and sanitation and for watering gardens. The latter is non-essential and can be curtailed periodically while drinking water must be supplied at a much higher level of assurance. The approach in the model is to allocate different fractions of the demand to different assurance levels. These are then aggregated over the various sectors to determine the quantities to be supplied at the selected levels of assurance for any given source as shown in Table 4-1.

The interpretation of the table is that, in the case of irrigation for example, 50% of the irrigation can be curtailed at a frequency of 1:20 years. A further 40% ie a total of 90% can be curtailed at a frequency of 1:100 years and that 10% must be available at 1:200 years. The same applies to the other user sectors.

It should be noted that these are pre-set targets. From the output of the planning model it can be established wether these targets have been met and if not, how often the system component has failed to meet such targets.

(2) Penalty structure

A penalty structure is used to optimize operation of the system. By allocating larger penalties to, for example, shortages in urban demand than to shortages in irrigation, urban demand will always be given priority over irrigation demand. The penalty structure can be applied to almost any variable. For example it can be applied to spillages in which case, with a high penalty on spillage the model will try to minimize spillage and keep the dam as empty as possible. This instance can be applied for example where a dam has the function of flood absorption.

(3) Dam operating rules

Dam operating rules are handled differently in the WRYM and the WRPM. In the first case dam operating rules are enforced using the penalty structure. In the WRPM operating rules are determined from information interpreted from the WRYM where various levels of curtailment are introduced in order not to violate the set levels of assurance.

(4) Run-of-river abstraction

In both the Crocodile and Olifants models, the only run-of-river abstractions are for irrigation demand. In most cases the irrigation is calculated for each month taking into account the irrigated area, the crop pattern, the effective rainfall and the efficiency of the method of irrigation practiced for that reach. This is compared to the available runoff for the month and, if available, the water for irrigation is supplied. If insufficient runoff is available only part of the irrigation demand equal to the runoff is supplied.

4.2.6 Schematic Representations

Schematic representations of the models are given in Figures 4-1 and 4-2 for the Crocodile and Olifants models respectively. These are simplified versions of the actual model but serve the purpose of indicating the complexity of the models and showing the constituent nodes and channels.

4.2.7 Form of Output

The output from a model run is sent to a computer file. The content of the file is determined before the run by selecting various output parameters. Usually the selected output comprises variables of particular interest or those for parts of the model where problems are expected. It would be impractical to select all variables as this would create massive output files of many hundreds of mega-bytes. The output files can be scanned for information but this is extremely time consuming. Some post-processing programmes have been developed to aid in the analysis and visualization of results.

4.2.8 Data Requirements for the Water Balance

The data requirements for the WRPM is very extensive. It requires for example, a full length naturalized flow record of monthly values at each nodal point. Files containing monthly urban runoff and return flow are also required where needed. Monthly evaporation and rainfall files are required for each nodal point. There are thirteen control parameter files which include, amongst others, node information, connectivity between nodes, penalty functions, parameters regarding return flow estimates and information regarding irrigation. Results from the WRYM from which the operating rules for the dams are established are also input.

At each abstraction point, the full record of growing monthly demands is required. At points where water for irrigation is abstracted, information regarding irrigated area, crop pattern, application rates and efficiency is required.

4.3. Available Runoff Data

4.3.1 Runoff Data Required for WRYM

Runoff data for the models comprise naturalized (virgin) flow records at each modelled node point. Naturalized runoff being the flow that would occur without any man-made influence as defined in Section 4.2.2. Where node points lie within a single homogeneous catchment, there is a facility to input one set of records and to apportion the correct proportion of the runoff to the various nodes.

4.3.2 Availability of Runoff Data

Naturalized virgin runoff data for all nodes is available for the period October 1920 to September 1989. This was synthetically generated using the Pitman rainfall-runoff model after extensive and reliable calibration during the Olifants and Crocodile River Basin Studies. The Water Resources '90 Study re-evaluated the calibration parameters and found them to be acceptable and as such, they were included in the WR90 publication as the best available. Consideration was given to extending the available records from 1989 to 1994 (5 years) utilising existing model parameters and extended rainfall records. This extension would have required considerable effort collecting, verifying, patching and entering monthly rainfall records from over 300 stations and then running the rainfall-runoff models.

From recent studies, "Water Resources Evaluation for the Proposed Rooipoort Dam on the Olifants River", "Hydrological Analysis of the Hazelmere Dam", and the "Re-evaluation of the Crocodile River Basin", where flow records have been extended, it is clear that no significant change in the statistical parameters of the flow records results. Although the perception exists that the recent drought of the late 1980's and early 1990's was serious, it became clear from the naturalized flows that it was not the most serious drought on record. What made the drought appear serious was the present level of development in the catchments. The effect of this development is however taken into account in the models and therefore no adjustment of virgin or naturalized flow was necessary. Since the primary evaluation was based on the WRPM which uses a stochastic approach, it was decided not to extend the flow records as no change in results was likely.

4.4 Available Water Resources

4.4.1 Surface Water

Utilisation of streamflow in the Study Area has been developed to the extent that large storage dams have been constructed in virtually every main river to regulate the variable runoff to meet increasing water demands.

Within the Study Area, ninety storage dams have been identified as illustrated in Table 4-3 of Supporting Report B. Probable drought flow records for specified points of the Crocodile and Olifants river are shown in the Table 4-3 of this report.

4.4.2 Expected Return Flow and Incremental Urban Runoff

The major contributors to return flows in the Crocodile River basin are the municipal and industrial sectors. Since most of the water for urban water supply is imported from adjacent river systems, these return flows have in the recent past, effectively constituted an inter-basin transfer of water into the basin which has supplemented the natural runoff. In order to evaluate such return flows which represent an important water resource in the basin, DWAF in association with BKS, conducted a study and reported on the "Urban Demands and Return Flows in the Crocodile River Catchment (CRCS)" in August 1990. The conclusion of the study was that the return flow from major sewage treatment works in the Upper Crocodile sub-system will comprise about 59 % of the total quantity of water supplied in urban areas in the target year 2015.

Since the results of the CRCS were originally published, environmental conditions in the river basin have changed slightly so it was necessary to update the conclusions. In June 1996, DWAF in cooperation with BKS, executed a study to determine optimum operating rules for the transfer of water from Hartbeespoort Dam to Vaalkop Dam and to address concern regarding possible over estimation of return flows as well as urban water demand projections. The average return flow ratio, estimated from this further study, was about 53%. In addition, incremental surface runoff due to urbanisation was considered to be about 45 mcm/a in the specified areas.

The summarised return flows and urban runoff for the Crocodile River to be applied in this Study are shown in Table 4-3 and the return flows and runoff from urban areas in 1995 and in 2015 (Case 3 - Alternative 2) are assumed to be as shown in Table 4-4 and Table 4-5 respectively.

4.5 Water Demands

4.5.1 Primary Water Demand

Primary water demand includes provision for domestic use, industry and mining. The basis for projecting future primary water demands is described in Section 4.3 of Supporting Report B.

Since projected primary water demands in Supporting Report B are net values at the outlet from water treatment works, an allowance of 5% for treatment losses and a further allowance for the losses from the water source to the purification works are added to the net values. The primary water demands assumed in the water balance simulation are presented as net values, after deducting the amount of groundwater utilised, in Table 4-6. These estimated primary water demands were allocated according to present supply conditions and the relationship between demand and supply at each location as shown in Table 4-7.

4.5.2 Irrigation Water Demand

The current practices concerning irrigation and the estimated irrigation demand is shown in Section 4-3 of Supporting Report B.

4.5.3 Stock-watering Demand

In the Study Area, there are large areas of grazing land for livestock breeding. The water demand for stock-watering is discussed in Section 5.5.4 of Supporting Report B. and is estimated to be about 8.4 mcm/a.

4.5.4 Environmental and Other Requirements

The applied simulation model is set up to simulate the behaviour of the 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. These are described in Sections 5.10 and 5.11 of Supporting Report B.

Riverine ecosystems and other water requirements for environmental purposes do not enjoy legal recognition under the present legislation and existing water resources development was generally 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 the river, the water balance simulation does not include specific provision for this purpose.

All of the rivers in the Study Area are of interest to one or more neighboring states and would be 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 and the 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 and that new development proposals would be discussed with neighboring states before implementation.

4.6 Results of the Water Balance Simulation

4.6.1 Simulation and Assessment of Case 1

In the present situation the existing water resources infrastructure can easily cope with the primary water demand at the postulated level of assurance. For irrigation there are cases where the irrigation falls below the postulated levels of assurance but these have been previously selected and accepted by the relevant irrigators. Examples include irrigators from Olifantsnek Dam and from Swartsruggens Dam.

The major influence on the high levels of supply is the significant quantity of return flows into the area. For the present conditions this amounts to some 120 mcm/a in the Upper Crocodile and 89.5 mcm/a in the Pienaars and Apies catchments. Table 4-8 and Table 4-9 indicate the demands and actual supply for each source of supply. These figures are average annual values. The storage water allocation to existing reservoirs by Service Zone is illustrated in Figure 4-3, Figure 4-4 and Figure 4-5 for Case 1. In Part I of the Data Book graphical representations are given for a number of selected sites and parameters. These include traces of the storage state and supply levels at selected points. Also included are the transfers between Hartbeespoort Dam and Vaalkop Dam.

The results of the comprehensive assessment of the Case 1 simulation are discussed as follows:

(1) Crocodile River basin

(a) Upper Crocodile

Primary water demand in 1995 was relatively low at 15 mcm/a which can be met with no risk of failure from Hartbeespoort dam. A significant amount of irrigation is supplied from this sub-catchment with 64.9 mcm/a being drawn from run-of-river flow, mainly from the Magalies river. Since the Magalies River is fed from a strong dolomitic aquifer, the security of supply is about 70 % of the water demand. Most of the water used from the storage in this sub-catchment is supplied to GWS irrigation areas with a demand of 136.6 mcm/a.

Since the river runoff to Hartbeespoort Dam consists of natural river runoff and return flow comprising of treated water from the urban area of Grater Johannesburg, a very high security of supply is assured.

Buffelspoort dam is subject to regular and significant shortages because more land has been scheduled than can be supplied with assurance. Farmers plant cash crops and use the water beneficially when it is available. Irrigators using the river runoff between Hartbeespoort Dam and the Roodekoppjes Dam enjoy a high level of security and their demand of 29.4 mcm/a is almost fully met.

The overall situation in the Upper Crocodile River for 1995 is that the primary demands can be met with no deficit. In addition, a surplus of 63.5 mcm/a is available at Hartbeespoort Dam of which up to 32.5 mcm/a is exported to the Elands river system at Vaalkop Dam.

(b) Pienaars River:

This river system comprises two main storage dams at Roodeplaat and Klipvoor and two minor dams at Bon Accord and Leeukraal. These units operate as a system and benefit from significant return flows upstream of Roodeplaat and upstream of Leeukraal.

Primary water requirements in 1995 of 30.5 mcm/a at Roodeplaat and Leeukraal dams are fully supplied. Irrigation demand on Roodeplaat Dam, Bon Accord Dam and Klipvoor Dam, which totals 82.4 mcm/a, can be met with a rather high security of supply, and 75 % of the run-of-river user demand of 39.9 mcm/a is met.

(c) Elands River:

The Elands River system comprises a number of small dams and a major dam at Vaalkop. This system is augmented by transfers from Hartbeespoort Dam and importation from Rand Water. The primary water demands are mainly supplied from Vaalkop Dam with 30.5 mcm/a and also from the Bospoort Dam where 1.9 mcm/a is available; 1.0 mcm/a from Koster Dam is sufficient.

Irrigation from the Olifantsnek, Koster and Lindleyspoort Dams, with a total demand of 25.6 mcm/a, is subject to shortages (about 16.1 mcm/a or 63 %), within the target security criteria while 2.7 mcm/a is supplied from Vaalkop Dam at high security for irrigation.

Only 32 % of the run-of-river irrigation demand of 16.7 mcm/a upstream of Vaalkop Dam can be met, but shortages will reduce as return flows gradually increase.

(d) Lower Crocodile River

About 72 % of the total irrigation demand of 63.0 mcm/a in the Lower Crocodile is supplied.

(2) Olifants River basin

(a) Bronkhorstspruit

Tributaries of the Olifants River supply the eastern part of the Study Area. Bronkhorstspruit Dam on the Bronkhorstspruit River is an important source which can fully supply primary demands of 14.2 mcm/a for 1995 and 0.7 mcm/a for irrigation. The Premier Mine Dam on the Wilge River can fully supply the 5.0 mcm/a primary demand at Cullinan.

(b) Elands in the Olifants River system

There are two Dams on the Elands River, namely Rust de Winter and Mkombo (Rhenosterkop). The former is intended for irrigation use while the latter was able to supply only 1.7 mcm/a in 1995 due to drought conditions. The supply from Mkombo is augmented by importation s of 9.5 mcm/a from Loskop Dam. Of the total run-of-river irrigation demand of 9.1 mcm/a, approximately 7.3 mcm/a can be supplied from the Elands River.

(c) Summary

In 1995, the Crocodile River system can meet all primary and irrigation requirements at a high or very good level of security. This situation requires transfers from Hartbeespoort Dam to Vaalkop Dam and the importation of 39.3 mcm/a to the Elands catchment and 42.1 mcm/a to the Pienaars River catchment.

Local resources in the Olifants river tributaries utilize existing augmentation from Loskop Dam to meet 1995 water requirement.

4.6.2 Simulation and Assessment of Case 2

Case 2 represents the base case in the target year 2015 and it is assumed that the existing primary water supply from Rand Water to the Study Area will increase in the future, but only up to the capacity of the existing infrastructure, and that any demand exceeding this capacity will be met using local water resources.

The outputs from the simulation for Case 2 are tabulated in Table 4-10 and summarised in Table 4-11, and the water allocation plans on existing and already programmed water source facilities are illustrated in Figure 4-6, Figure 4-7 and Figure 4-8.

The results of the comprehensive assessment of the Case 2 simulation are summarised as follows;

(1) Environmental change of water resources:

As a general trend of the Case 2 study, it can be noted that the incremental return flow from the Crocodile River sub-catchment is about 97.4 mcm/a or 44 % of the 1995 level. The impact of this, therefore, will contribute greatly to improve the water resources availability in the Study Area.

In parallel with the effective utilization of the return flows from treated effluent of urban water users, it is necessary to closely monitor the water quality of such return flows which must be maintained at an acceptable level for subsequent primary use of the water.

The assumed irrigation water requirement does not change between 1995 and the target year 2015. The differences between Case 1 and Case 2 therefore, represent the balance of incremental primary water demands, increasing available water resources from increased return flows and imported water from Rand Water, the incremental amount of which is about 44.8 mcm/a (126.2 - 81.4).

(2) Major differences between Case 1 and Case 2

(a) Crocodile River basin

i) Upper Crocodile

Both primary and irrigation water demands can be met from water resources available within the basin except for water abstracted from run-of-river for irrigation purposes. Other matters are similar to the results of Case 1.

ii) Pienaars River

There is no deficit in either the primary or irrigation sector (except for the irrigation supply from run-of-river upstream of Klipvoor Dam), mainly due to contributions from incremental urban return flow.

iii) Elands River

The primary water demand is supplied mainly from Vaalkop Dam which must be supplemented by transfers from Hartbeespoort Dam where 42.1 mcm/a of surplus water is available. On the other hand, shortages of water for irrigation follow the same trend as for Case 1.

iv) Lower Crocodile:

There is no substantial improvement compared to Case 1.

(b) Olifants River basin

The incremental water demand for the primary sector is about 46.4 mcm/a. To supplement water resources for Bronkhorstspruit WTW beyond the year 2000, an import up to a maximum amount of 15.0 mcm/a from Grootdraai Dam has been approved under the Kwandebele Augmentation programme. As a result of the simulation, about 10 mcm/a (37.5 - 27.4) of surplus water is available for primary water supply in the Kwandebele area.

(3) Summary of Case 2

Due to the expected significant increase in return flows in the Upper Crocodile and Pienaars river systems, the primary demand is fully supplied and the irrigation water supply is also improved. In fact irrigation is supplied at a much higher level than is normally the case in South Africa. In the Olifants River tributaries, the primary demands can also be fully met with the incorporation of the already approved importation from Grootdraai Dam on the Vaal River.

The details of reservoir operation and water supply security for Case 2 at five major Dams, Hartbeespoort, Roodekoppjies, Vaalkop, Roodeplaat and Klipvoor are illustrated in Part I of the Data Book.

4.6.3 Simulation and Assessment of Case 3

(1) Case 3 - Alternatives 1 and 3

For Case 3, alternative scenarios were analysed for 2015 based on the base case, i.e. Case 2. Only changes in the Western Zone and Central Zone were modelled. In the Eastern Zone, only infrastructure alternatives were considered and these are reported in Chapter 5. It was assumed that the present level of water importation by Rand Water would not increase. In Alternative 1 it was assumed that any shortfall in the Western Zone would be supplied from Vaalkop Dam and shortages in the Central Zone would be distributed between Hartbeespoort, Roodeplaat and Leeukraal dams.

The results for this scenario indicated shortages in the irrigation supply at Hartbeespoort and Roodekopjes dams. Furthermore, since short term shortages in the irrigation supply are, in any case expected around 2000, this option is not considered feasible. The allocation of shortages was then changed in Alternative 2 so that 25% is supplied from Hartbeespoort Dam and 75% from Roodeplaat/ Leeukraal. Shortages at Hartbeespoort Dam are minimal but the level of irrigation supply at Vaalkop Dam reached a level similar to the 1995 scenario. The exact distribution of allocation should be optimized but, from a subjective evaluation of the results, it is likely to be a 30/70 split. This would still not adversely affect irrigation at Hartbeespoort Dam while the supply at Vaalkop would be somewhat increased resulting in an improvement on the present situation. The demand and supply are summarized in Table 4-12 and 4-13 for Alternative 1 and Tables 4-14 and 4-15 for Alternative 3 and graphical representations are attached in Part I of the Data Book as for the first two Cases.

(2) Case 3 - Alternative 2

In Alternative 2 of Case 3, it is assumed that the Rand Water supply would be limited to the extent of the capacity of the present infrastructure i.e. 39.3 mcm/a in the Western Zone and 86.9 mcm/a in the Central Zone. In addition, it is assumed that return flows to the catchment will only be 80% of the present estimates. From the results of Alternatives 1 and 3 it is clear that no additional demand can be placed on Hartbeespoort Dam in the short term. The expected shortages in the Rand Water Supply Area in the Central Zone were therefore allocated to Leeukraal while the shortage in the Western Zone was again allocated to Klipvoor.

The results indicate that the primary demands can all be met but that there would be a reduction in irrigation supply compared to Case 2. This is still, however, at a slightly higher level than at present (Case 1). Results showing the demand and supply are given in Tables 4-16 and 4-17 and graphical representations are shown in Part I of the Data Book.

4.6.4 Conclusions

In conclusion it was found that the primary demand could always be met from the existing water resources infrastructure. This should, in reality, have been expected since the penalty structure imposed on the model gives much higher preference to primary supply than irrigation supply. Shortages in the primary supply would only occur if there was a complete failure in irrigation supply.

Due to the increasing level of return flows the supply level to irrigation in 2015 is significantly improved in the most probable scenario. Even assuming onerous limitations on either the Rand Water supply or the assumed level of return flows, the irrigation sector will be no worse off than at present.

Water resources utilization in the Study Area is amongst the most developed in the country. It is concluded that the availability of water resources for supply of primary and irrigation water in the Study Area is at a sufficiently high level when the expected return flows from the treated effluent of urban users reaches a certain level, and the operation of each storage on dam is properly managed.

Table 4-1 : Acceptable Return Period and Allowable Distribution of Demand

User Sector	Distribution of Demand (%)		
	Low Priority (1:20 year)	Medium Priority (1:100 year)	High Priority (1:200 year)
Irrigation	50	40	10
Urban & Industrial	20	30	50
Mining	0	30	70
Curtailment Level	0 - 1	1 - 2	2 - 3

Table 4-2 : Probable Drought River Runoff in the Study Area

River System	Point (Dam)	Catchment (km^2)	Naturalised River Runoff (mcm/a)				
			MAR	1:10	1:20	1:50	1:100
1 Olifants River	(1) Upstream of Bronkhorstspruit	1,260	47.4	14.2	11.9	10.4	9.5
	(2) Between (1) and Premier Dam	1,604	55.1	16.5	13.8	12.1	11.0
	(3) Upstream of Mkombo Dam	3,723	54.8	10.4	5.1	4.1	3.5
Total		6,587	157.3	41.1	30.8	26.6	24.0
2 Crocodile River Pienaars River	(1) Upstream Bon Accord Dam	390	25.0	12.3	11.2	10.2	7.5
	(2) Upstream Roodeplaat Dam	682	33.0	13.2	11.6	10.6	9.9
	(3) Between (1), (2) and Klipvoor Dam	6,577	80.7	12.8	9.7	8.1	7.2
Sub-Total		7,649	138.7	38.3	32.5	28.9	24.6
Upper Crocodile River	(4) Upstream of Hartbeespoort Dam	4,107	177.3	73.8	59.5	52.1	46.2
	(5) Between (4) and Roodekopies Dam	2,016	11.6	1.9	1.4	1.1	1.0
Sub-Total		6,123	188.9	75.7	60.9	53.2	47.2
Elands River	(6) Upstream of Bospoort Dam	1,078	24.4	3.5	2.8	2.4	2.1
	(7) Upstream of Koster Dam	284	6.7	0.9	0.7	0.6	0.5
	(8) Between (6), (7) and Vaalkop Dam	4,859	81.8	12.6	9.7	8.1	7.2
Sub-Total		6,221	112.9	17.0	13.2	11.1	9.8
Lower Crocodile River	(9) Bierspruit confluence	7,015	102.7	7.8	5.6	4.4	4.0
Sub-Total		7,015	102.7	7.8	5.6	4.4	4.0
Total		20,789	543.2	138.8	112.2	97.6	85.6

Table 4-3 : Projected Return Flow and Urban Runoff in the Crocodile River (2015)

River Section	Return Flow (mcm/a)	Urban Runoff (mcm/a)	Total (mcm/a)	Naturalised RR* (mcm/a)
Pienaars to Klipvoor	178.9	15.7	194.6	138.7
Upper Crocodile	207.6	29.3	236.9	177.3
Hartbeespoort to Roodekoppies	2.4	0.0	2.4	72.3
Elands to Vaalkop	22.0	0.0	22.0	112.9
Total	410.9	45.0	455.9	501.2

* Note: Naturalised river runoff indicates mean annual runoff (MAR)

Table 4-4 : Estimated Current Return Flows and Urban Runoff (1995 base)

River Section	Return Flow (mcm/a)	Urban Runoff (mcm/a)	Total (mcm/a)	Naturalised RR* (mcm/a)
Pienaars to Klipvoor	89.5	15.7	105.2	138.7
Upper Crocodile	120.0	29.3	149.3	177.3
Hartbeespoort to Roodekoppies	1.7	0.0	1.7	72.3
Elands to Vaalkop	11.0	0.0	11.0	112.9
Total	222.2	45.0	267.2	501.2

* Note: Naturalised river runoff indicates mean annual runoff (MAR)

Table 4-5 : Assumed Return Flows and Urban Runoff (Alternative 2 of Case 3)

River Section	Return Flow (mcm/a)	Urban Runoff (mcm/a)	Total (mcm/a)	Naturalised RR* (mcm/a)
Pienaars to Klipvoor	141.1	15.7	156.8	138.7
Upper Crocodile	166.3	29.3	195.6	177.3
Hartbeespoort to Roodekoppies	1.2	0.0	1.2	72.3
Elands to Vaalkop	11.0	0.0	11.0	112.9
Total	319.6	45.0	364.6	501.2

* Note: Naturalised river runoff indicates mean annual runoff (MAR)

Table 4 -6 : Required Surface Water Amount for Projected Primary Water Demand

Area / Block	1995			2002			2015		
	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)
(1) EASTERN SUPPLY ZONE									
Bronkhorstspruit / Kwandebele									
Moutse 1 & 3	1.813	0.000	1.813	3.175	0.000	3.175	3.088	0.000	3.088
Mbibana	1.171	0.140	1.031	2.051	0.160	1.891	1.994	0.000	1.994
Mdutjana	2.391	0.000	2.391	4.745	0.000	4.745	5.819	0.000	5.819
Kwamhlanga	7.206	0.000	7.206	8.046	0.000	8.046	9.867	0.000	9.867
Ekangala	8.567	0.000	8.567	9.818	0.000	9.818	12.650	0.000	12.650
Moretele 2	1.236	1.236	0.000	1.218	1.218	0.000	2.105	0.000	2.105
Bronkhorstspruit	2.697	0.510	2.187	3.060	0.538	2.522	4.150	0.596	3.554
Total	**25.081**	**1.890**	**23.195**	**32.113**	**1.916**	**30.197**	**39.673**	**0.596**	**39.077**
Water losses (10%)	-	-	2.320	-	-	3.020	-	-	3.908
Area Total	**27.405**	**1.890**	**25.515**	**35.133**	**1.916**	**33.217**	**43.581**	**0.596**	**42.985**
Cullinan									
Cullinan	5.020	0.430	4.590	5.438	0.453	4.985	6.339	0.502	5.837
Total	**5.020**	**0.430**	**4.590**	**5.438**	**0.453**	**4.985**	**6.339**	**0.502**	**5.837**
Water losses (10%)	-	-	0.459	-	-	0.499	-	-	0.584
Area Total	**5.479**	**0.430**	**5.049**	**5.937**	**0.453**	**5.484**	**6.923**	**0.502**	**6.421**
Zone Total	**32.884**	**2.320**	**30.564**	**41.069**	**2.369**	**38.700**	**50.503**	**1.098**	**49.405**

Table 4 -6 : Required Surface Water Amount for Projected Primary Water Demand

Area / Block	1995			2002			2015		
	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)
(2) CENTRAL SUPPLY ZONE									
Roodeplaat									
Wallmannsthal	2.464	0.000	2.464	2.909	0.000	2.909	3.434	0.000	3.434
Moretele I	20.459	0.000	20.459	25.038	0.000	25.038	35.389	0.000	35.389
Moretele I North	0.451	0.451	0.000	0.445	0.445	0.000	0.432	0.000	0.432
Warmbaths/Nylstroom	5.894	1.099	4.795	6.146	1.162	4.984	6.668	1.290	5.378
Total	**29.268**	**1.550**	**27.718**	**34.538**	**1.607**	**32.931**	**45.923**	**1.290**	**44.633**
Water losses (10%)	-	-	2.772	-	-	3.293	-	-	4.463
Area Total	**32.040**	**1.550**	**30.490**	**37.831**	**1.607**	**36.224**	**50.386**	**1.290**	**49.096**
Hartebeestpoort									
Brits	10.607	0.200	10.407	14.573	0.320	14.253	20.879	0.000	20.879
Schoemansville	3.263	0.000	3.263	3.853	0.000	3.853	5.244	0.000	5.244
Total	**13.870**	**0.200**	**13.670**	**18.426**	**0.320**	**18.106**	**26.123**	**0.000**	**26.123**
Water losses (10%)	-	-	1.367	-	-	1.811	-	-	2.612
Area Total	**15.237**	**0.200**	**15.037**	**20.237**	**0.320**	**19.917**	**28.735**	**0.000**	**28.735**
Klipvoor									
Klipvoor	1.818	1.818	0.000	1.795	1.380	0.415	1.746	0.000	1.746
Water losses (10%)	-	-	0.000	-	-	0.042	-	-	0.175
Area Total	**1.818**	**1.818**	**0.000**	**1.837**	**1.380**	**0.457**	**1.921**	**0.000**	**1.921**
Mabopane/Soshanguve	49.796	0.696	49.100	67.896	0.000	67.896	107.033	0.000	107.033
Zone Total	**98.891**	**4.264**	**94.627**	**127.800**	**3.307**	**124.493**	**188.075**	**1.290**	**186.785**

Table 4 -6 : Required Surface Water Amount for Projected Primary Water Demand

Area / Block	1995			2002			2015		
	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)
(3) WESTERN SUPPLY ZONE									
Vaalkop North									
Thabazimbi	22.421	12.410	10.011	22.698	12.410	10.288	23.292	12.410	10.882
Mokgalwaneng	5.286	0.070	5.216	5.333	0.010	5.323	5.444	0.000	5.444
Sefikile	0.106	0.050	0.056	0.155	0.050	0.105	0.165	0.000	0.165
Ramakokostad	0.173	0.170	0.003	0.183	0.050	0.133	0.203	0.000	0.203
Saulspoort	4.090	0.290	3.800	8.739	0.270	8.469	9.149	0.000	9.149
Mogwase/Sun City	7.649	0.200	7.449	8.556	0.420	8.136	10.276	0.000	10.276
Bethanie	1.221	0.000	1.221	1.615	0.000	1.615	2.138	0.000	2.138
Total	40.946	13.190	27.756	47.279	13.210	34.069	50.667	12.410	38.257
Water losses (10%)	-	-	2.776	-	-	3.407	-	-	3.826
Area Total	43.722	13.190	30.532	50.686	13.210	37.476	54.493	12.410	42.083
Koster									
Koster	1.077	0.410	0.667	1.154	0.430	0.724	1.320	0.480	0.840
Swartsruggens	0.458	0.180	0.278	0.485	0.190	0.295	0.542	0.210	0.332
Total	1.535	0.590	0.945	1.639	0.620	1.019	1.862	0.690	1.172
Water losses (10%)	-	-	0.095	-	-	0.102	-	-	0.117
Area-Total	1.630	0.590	1.040	1.741	0.620	1.121	1.979	0.690	1.289
Rustenburg Bapong									
Tlaseng	0.187	0.070	0.187	0.378	0.150	0.378	0.482	0.000	0.482
Paardekraal	9.841	0.000	9.841	12.157	0.000	12.157	14.257	0.000	14.257
Total	10.028	0.070	10.028	12.535	0.150	12.535	14.739	0.000	14.739
Water losses (10%)	-	-	1.003	-	-	1.254	-	-	1.474
Sub-Total (2 Blocks)	11.101	0.070	11.031	13.939	0.150	13.789	16.213	0.000	16.213
Rand Water									
Phokeng	15.795	0.000	15.795	16.799	0.000	16.799	18.650	0.000	18.650
Rustenburg/Thlabane	10.677	0.000	10.677	11.791	0.000	11.791	14.464	0.000	14.464
Bapong	11.809	0.000	11.809	13.996	0.000	13.996	15.531	0.000	15.531
Sub-Total (3 Blocks)	38.281	0.000	38.281	42.586	0.000	42.586	48.645	0.000	48.645
Area Total	49.382	0.070	49.312	56.525	0.150	56.375	64.858	0.000	64.858
Zone Total	94.733	13.850	80.883	108.951	13.980	94.971	121.330	13.100	108.230

Table 4 -6 : Required Surface Water Amount for Projected Primary Water Demand

Area / Block	1995			2002			2015		
	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)	Total (mcm)	Ground-water (mcm)	Surface Water (mcm)
(4) GRAND-TOTAL									
Eastern	32.884	2.320	30.564	41.069	2.369	38.700	50.503	1.098	49.405
Central	98.891	4.264	94.627	127.800	3.307	124.493	188.075	1.290	186.785
Western	94.733	13.850	80.883	108.951	13.980	94.971	121.330	13.100	108.230
Total	226.507	20.434	206.073	277.821	19.656	258.165	359.908	15.488	344.420
(5) BREAKDOWN OF SURFACE WATER									
Eastern	30.564	30.564	0.000	38.700	38.700	0.000	49.405	49.405	0.000
Central	94.627	45.527	49.100	124.493	56.597	67.896	186.785	79.752	107.033
Western	80.883	42.602	38.281	94.971	52.385	42.586	108.230	59.585	48.645
Total	206.073	118.692	87.381	258.165	147.683	110.482	344.420	188.742	155.678

Table 4-7 : Allocation of Primary Demand

Demand Centre	Source	1995 Demand (mcm/a)	2015 Demand (mcm/a)
Brits, Schoemansville	Hartbeespoort	15.0	28.7
Wallmannsthal, Moretele, Moretele North, Warmbaths, Nylstroom	Roodeplaat / Leeukraal	30.5	49.1
Klipvoor	Klipvoor	2.0	1.9
Mabopane, Soshanguve	Rand Water	43.6	107.0
Thabazimbi, Mokgalwaneng, Sefikile, Ramokokstad, Bethanie, Rustenburg North	Vaalkop	30.5	42.1
Rustenburg, Phokeng, Bapong	Bospoort / Rand Water	1.9 / 39.3	1.9 / 39.3
Koster	Koster	1.0	1.3
Bronkhorstspruit, Ekangala, Ekandustria, part Tweefontein	Bronkhorstspruit, Grootdraai import	14.2	16.1 , 4.9
Remainder of Kwandebele	Mkombo, Loskop Import	1.7 / 9.5	12.5 / 9.5
Cullinan	Premier Mine	5.0	6.4

Table 4-8 : Summary of Water Balance of Case 1 (1995 base)

Water Resource	Primary Water (mcm/a)		Irrigation Water (mcm/a)			
	Requirement	Supply	Requirement		Supply	
	Storage Dam	Storage Dam	Storage Dam	River	Storage Dam	River
1. Local Water						
- Upper Crocodile	15.0	15.0	136.6	64.9	131.6	45.0
- Pienaars	32.5	32.5	82.4	39.9	73.9	30.1
- Elands	33.4	33.0	28.3	16.7	18.8	5.3
- Lower Crocodile	0.0	0.0	0.0	63.0	0.0	45.4
- Bronkhorstspruit	19.2	19.2	0.7	0.0	0.6	0.0
- Elands (Olifants)	1.7 + 9.5	1.7 + 9.5 *	0.0	9.1	0.0	7.3
Sub-Total	111.3	110.9	248.0	193.6	224.9	133.1
2. Rand Water	81.4	81.4	-	-	-	-
Sub-Total	81.4	81.4	-	-	-	-
Grand Total	192.7	192.3	248.0	193.6	224.9	133.1

Note) * Imported water from Loskop dam

Table 4-9 : Water Balance for Case 1 (1995 base)

	Water Resource	Pimary Water (mcm/a)		Irrigation Water (mcm/a)			
		Requirement	Supply	Requirement		Supply	
		Storage Dam	Storage Dam	Storage Dam	River	Storage Dam	River
1.	**Crocodile River Basin**						
	1.1 Upper Crocodile						
	Hartbeespoort	15.0	15.0	100.6	64.9	97.0	45.0
	Buffelspoort	0	0	6.6	0	6.6	0
	Roodekoppjes	0	0	29.4	0	28.0	0
	Sub-Total	15.0	15.0	136.6	64.9	131.6	45.0
	1.2 Pienaars						
	Roodeplaat/Leeukraal	30.5	30.5	6.7	13.5	6.6	13.0
	Bon Accord	0	0	11.5	0	11.5	0
	Warmbaths	0	0	2.2	0.8	1.9	0.7
	Klipvoor	2.0	2.0	62.0	25.6	53.9	16.4
	Sub-Total	32.5	32.5	82.4	39.9	73.9	30.1
	1.3 Elands						
	Bospoort	1.9	1.9	0	0	0	0
	Olifantsnek	0	0	14.3	0	7.7	0
	Koster	1.0	0.6	2.9	0	0.9	0
	Lindleyspoort	0	0	8.4	0	7.5	0
	Vaalkop	30.5	30.5	2.7	16.7	2.7	5.3
	Sub-Total	33.4	33.0	28.3	16.7	18.8	5.3
	1.4 Lower Crocodile	0	0	0	63.0	0	45.4
	Sub-Total	0	0	0	63.0	0	45.4
	Total	80.9	80.5	247.3	184.5	224.3	125.8
2.	**Upper Olifants River Basin**						
	2.1 Bronkhortspruit						
	Bronkhorstspruit	14.2	14.2	0.7	0.0	0.6	0.0
	Grootdraai import						
	Premier Mine	5.0	5.0	0.0	0.0	0.0	0.0
	Sub Total	19.2	19.2	0.7	0.0	0.6	0.0
	2.2 Elands of Upper Olifants						
	Rust de Winter	0.0	0.0	0.0	6.5	0.0	5.2
	Mkombo	1.7	1.7	0.0	0.0	0.0	0.0
	Moses	0.0	0.0	0.0	2.6	0.0	2.1
	Loskop import	9.5	9.5	0.0	0.0	0.0	0.0
	Sub Total	11.2	11.2	0.0	9.1	0.0	7.3
	Total	30.4	30.4	0.7	9.1	0.6	7.3
	Grand Total	111.3	110.9	248.0	193.6	229.9	133.1
3	**Rand Water**						
	3.1 Central Zone	42.1	42.1	-	-	-	-
	3.2 Western Zone	39.3	39.3	-	-	-	-
	Total	81.4	81.4	0.0	0.0	0.0	0.0

Table 4-10 : Water Balance for Case 2 (Base Plan - 2015 base)

Water Resource		Pimary Water (mcm/a)		Irrigation Water (mcm/a)			
		Requirement	Supply	Requirement		Supply	
		Storage Dam	Storage Dam	Storage Dam	River	Storage Dam	River
1.	**Crocodile River Basin**						
	1.1 Upper Crocodile						
	Hartbeespoort	28.7	28.7	100.6	64.9	100.6	53.0
	Buffelspoort	0.0	0.0	6.6	0.0	6.6	0.0
	Roodekoppjes	0.0	0.0	29.4	0.0	24.9	0.0
	Sub-Total	28.7	28.7	136.6	64.9	136.6	53.0
	1.2 Pienaars						
	Roodeplaat/Leeukraal	49.1+20.1	49.1+20.1*	6.7	13.5	6.7	13.5
	Bon Accord	0.0	0.0	11.5	0.0	11.5	0.0
	Warmbaths	0.0	0.0	2.2	0.8	2.2	0.7
	Klipvoor	1.9	1.9	62.0	25.6	58.1	18.8
	Sub-Total	71.1	71.1	82.4	39.9	78.5	33.0
	1.3 Elands						
	Bospoort	1.9	1.9	0.0	0.0	0.0	0.0
	Olifantsnek	0.0	0.0	14.3	0.0	7.7	0.0
	Koster	1.3	0.6	2.9	0.0	0.9	0.0
	Lindleyspoort	0.0	0.0	8.4	0.0	7.5	0.0
	Vaalkop	42.1+22.4	42.1+22.4*	2.7	16.7	2.7	5.6
	Sub-Total	67.7	67.0	28.3	16.7	18.8	5.6
	1.4 Lower Crocodile	0.0	0.0	0.0	63.0	0.0	47.1
	Sub-Total	0.0	0.0	0.0	63.0	0.0	47.1
	Total	167.5	166.8	247.3	184.5	233.9	138.7
2.	**Upper Olifants River Basin**						
	2.1 Bronkhortspruit						
	Bronkhorstspruit	16.1	16.1	0.7	0.0	0.6	0.0
	Grootdraai import	4.9	4.9	0.0	0.0	0.0	0.0
	Premier Mine	6.4	6.4	0.0	0.0	0.0	0.0
	Sub Total	27.4	27.4	0.7	0.0	0.6	0.0
	2.2 Elands of Upper Olifants						
	Rust de Winter	0.0	0.0	0.0	6.5	0.0	5.2
	Mkombo	12.5	12.5	0.0	0.0	0.0	0.0
	Moses	0.0	0.0	0.0	2.6	0.0	2.1
	Loskop import	9.5	9.5	0.0	0.0	0.0	0.0
	Sub Total	22.0	22.0	0.0	9.1	0.0	7.3
	Total	49.4	49.4	0.7	9.1	0.6	7.3
	Grand Total	216.9	216.2	248.0	193.6	234.5	146.0
3	**Rand Water**						
	3.1 Central Zone	86.9	86.9	-	-	-	-
	3.2 Western Zone	39.3	39.3	-	-	-	-
	Total	126.2	126.2	0.0	0.0	0.0	0.0

Note) * Imported water to the Rand Water Supply Area

Table 4-11 : Summary of Water Balance of Case 2 (Base Plan - 2015 base)

Water Resource	Primary Water (mcm/a)		Irrigation Water (mcm/a)			
	Requirement	Supply	Requirement		Supply	
	Storage Dam	Storage Dam	Storage Dam	River	Storage Dam	River
1. Local Water						
- Upper Crocodile	28.7	28.7	136.6	64.9	136.6	53.0
Pienaars	71.1	71.1	82.4	39.9	78.5	33.0
Elands	67.7	67.0	28.3	16.7	18.8	5.6
- Lower Crocodile	0.0	0.0	0.0	63.0	0.0	47.1
Bronkhorstspruit	22.5+4.9	22.5+4.9*	0.7	0.0	0.6	0.0
Elands (Olifants)	12.5+9.5	12.5+9.5*	0.0	9.1	0.0	7.3
Sub-Total	216.9	216.2	248.0	193.6	234.5	146.0
2. Rand Water	126.2	126.2	-	-	-	-
Grand Total	343.1	342.4	248.0	193.6	234.5	146.0

Note) * Imported water from Grootdraai and Loskop dams.

Table 4-12 : Water Balance for Case 3 - Alternative 1

	Water Resource	Pimary Water (mcm/a)		Irrigation Water (mcm/a)			
		Requirement	Supply	Requirement		Supply	
		Storage Dam	Storage Dam	Storage Dam	River	Storage Dam	River
1.	**Crocodile River Basin**						
	1.1 Upper Crocodile						
	Hartbeespoort	28.7+32.4	28.7+32.4*	100.6	64.9	97.0	53.0
	Buffelspoort	0.0	0.0	6.6	0.0	6.6	0.0
	Roodekoppjes	0.0	0.0	29.4	0.0	28.0	0.0
	Sub-Total	61.1	61.1	136.6	64.9	121.6	53.0
	1.2 Pienaars						
	Roodeplaat/Leeukraal	49.1+32.5	49.1+32.5*	6.7	13.5	6.7	13.5
	Bon Accord	0.0	0.0	11.5	0.0	11.5	0.0
	Warmbaths	0.0	0.0	2.2	0.8	2.2	0.7
	Klipvoor	1.9	1.9	62.0	25.6	61.6	18.8
	Sub-Total	83.5	83.5	82.4	39.9	82.0	33.0
	1.3 Elands						
	Bospoort	1.9	1.9	0.0	0.0	0.0	0.0
	Olifantsnek	0.0	0.0	14.3	0.0	7.7	0.0
	Koster	1.3	0.6	2.9	0.0	0.9	0.0
	Lindleyspoort	0.0	0.0	8.4	0.0	7.5	0.0
	Vaalkop	42.1+12.7+9.7*	42.1+12.7+9.7*	2.7	16.7	2.7	5.3
	Sub-Total	67.7	67.0	28.3	16.7	18.8	5.3
	1.4 Lower Crocodile	0.0	0.0	0.0	63.0	0.0	48.4
	Sub-Total	0.0	0.0	0.0	63.0	0.0	48.4
	Total	212.3	211.6	247.3	184.5	222.4	139.7
2.	**Upper Olifants River Basin**	212.3	211.6	247.3	184.5	222.4	139.7
	2.1 Bronkhortspruit						
	Bronkhorstspruit	16.1	16.1	0.7	0.0	0.6	0.0
	Grootdraai import	4.9	4.9	0.0	0.0	0.0	0.0
	Premier Mine	6.4	6.4	0.0	0.0	0.0	0.0
	Sub Total	27.4	27.4	0.7	0.0	0.6	0.0
	2.2 Elands of Upper Olifants						
	Rust de Winter	0.0	0.0	0.0	6.5	0.0	5.2
	Mkombo	12.5	12.5	0.0	0.0	0.0	0.0
	Moses	0.0	0.0	0.0	2.6	0.0	2.1
	Loskop import	9.5	9.5	0.0	0.0	0.0	0.0
	Sub Total	22.0	22.0	0.0	9.1	0.0	7.3
	Total	49.4	49.4	0.7	9.1	0.6	7.3
	Grand Total	261.7	261.0	248.0	193.6	223.0	147.0
3	**Rand Water**						
	3.1 Central Zone	42.1	42.1	-	-	-	-
	3.2 Western Zone	39.3	39.3	-	-	-	-
	Total	81.4	81.4	0.0	0.0	0.0	0.0

Note) * Imported water to the Rand Water Supply Area

Table 4-13 : Summary of Water Balance for Case 3 - Alternative 1 (2015 base)

Water Resource	Primary Water (mcm/a)		Irrigation Water (mcm/a)			
	Requirement	Supply	Requirement		Supply	
	Storage Dam	Storage Dam	Storage Dam	River	Storage Dam	River
1. Local Water						
- Upper Crocodile	61.1	61.1	136.6	64.9	121.6	53.0
Pienaars	83.5	83.5	82.4	39.9	82.0	33.0
Elands	67.7	67.0	28.3	16.7	18.8	5.3
- Lower Crocodile	0.0	0.0	0.0	63.0	0.0	48.4
Bronkhorstspruit	22.5+4.9	22.5+4.9*	0.7	0.0	0.6	7.3
Elands (Olifants)	12.5+9.5	12.5+9.5*	0.7	9.1	0.6	7.3
Sub-Total	261.7	261.0	248.0	193.6	223.0	147.0
2. Rand Water	81.4	81.4	-	-	-	-
Grand Total	343.1	342.4	248.0	193.6	223.0	147.0

Note) * Imported water from Grootdraai and Loskop dams.

Table 4-14 : Water Balance for Case 3 - Alternative 3

	Water Resource	Pimary Water (mcm/a)		Irrigation Water (mcm/a)			
		Requirement	Supply	Requirement		Supply	
		Storage Dam	Storage Dam	Storage Dam	River	Storage Dam	River
1.	**Crocodile River Basin**						
	1.1 Upper Crocodile						
	Hartbeespoort	28.7+16.2	28.7+16.2*	100.6	64.9	100.6	53.0
	Buffelspoort	0.0	0.0	6.6	0.0	6.6	0.0
	Roodekoppjes	0.0	0.0	29.4	0.0	29.4	0.0
	Sub-Total	44.9	44.9	136.6	64.9	136.6	53.0
	1.2 Pienaars						
	Roodeplaat/Leeukraal	49.1+48.7	49.1+48.7	6.7	13.5	6.7	13.5
	Bon Accord	0.0	0.0	11.5	0.0	11.5	0.0
	Warmbaths	0.0	0.0	2.2	0.8	2.2	0.7
	Klipvoor	1.9	1.9	62.0	25.6	56.9	18.8
	Sub-Total	99.7	99.7	82.4	39.9	77.3	33.0
	1.3 Elands						
	Bospoort	1.9	1.9	0.0	0.0	0.0	0.0
	Olifantsnek	0.0	0.0	14.3	0.0	7.7	0.0
	Koster	1.3	0.6	2.9	0.0	0.9	0.0
	Lindleyspoort	0.0	0.0	8.4	0.0	7.5	0.0
	Vaalkop	42.1+12.7+9.7	42.1+12.7+9.7*	2.7	16.7	2.7	5.3
	Sub-Total	67.7	67.0	28.3	16.7	18.8	5.3
	1.4 Lower Crocodile	0.0	0.0	0.0	63.0	0.0	48.4
	Sub-Total	0.0	0.0	0.0	63.0	0.0	48.4
	Total	212.3	211.6	247.3	184.5	232.7	139.7
2.	**Upper Olifants River Basin**						
	2.1 Bronkhortspruit						
	Bronkhorstspruit	16.1	16.1	0.7	0.0	0.6	0.0
	Grootdraai import	4.9	4.9	0.0	0.0	0.0	0.0
	Premier Mine	6.4	6.4	0.0	0.0	0.0	0.0
	Sub Total	27.4	27.4	0.7	0.0	0.6	0.0
	2.2 Elands of Upper Olifants						
	Rust de Winter	0.0	0.0	0.0	6.5	0.0	5.2
	Mkombo	12.5	12.5	0.0	0.0	0.0	0.0
	Moses	0.0	0.0	0.0	2.6	0.0	2.1
	Loskop import	9.5	9.5	0.0	0.0	0.0	0.0
	Sub Total	22.0	22.0	0.0	9.1	0.0	7.3
	Total	49.4	49.4	0.7	9.1	0.6	7.3
	Grand Total	261.7	261.0	248.0	193.6	233.3	147.0
3	**Rand Water**						
	3.1 Central Zone	42.1	42.1	-	-	-	-
	3.2 Western Zone	39.3	39.3	-	-	-	-
	Total	81.4	81.4	0.0	0.0	0.0	0.0

Note) * Imported water to the Rand Water Supply Area

Table 4-15 : Summary of Water Balance for Case 3 - Alternative 3 (2015 base)

Water Resource	Primary Water (mcm/a)		Irrigation Water (mcm/a)			
	Requirement	Supply	Requirement		Supply	
	Storage Dam	Storage Dam	Storage Dam	River	Storage Dam	River
1. Local Water						
- Upper Crocodile	44.9	44.9	136.6	64.9	136.6	53.0
Pienaars	99.7	99.7	82.4	39.9	77.3	33.0
Elands	67.7	67.0	28.3	16.7	18.8	5.3
- Lower Crocodile	0.0	0.0	0.0	63.0	0.0	48.4
Bronkhorstspruit	22.5+4.9	22.5+4.9*	0.7	0.0	0.6	0.0
Elands (Olifants)	12.5+9.5	12.5+9.5*	0.0	9.1	0.0	7.3
Sub-Total	261.7	261.0	248.0	193.6	233.3	147.0
2. Rand Water	81.4	81.4	-	-	-	-
Grand Total	343.1	342.4	248.0	193.6	233.3	147.0

Note) * Imported water from Grootdraai and Loskop dams.

Table 4-16 : Water Balance for Case 3 - Alternative 2

	Water Resource	Pimary Water (mcm/a)		Irrigation Water (mcm/a)			
		Requirement	Supply	Requirement		Supply	
		Storage Dam	Storage Dam	Storage Dam	River	Storage Dam	River
1.	Crocodile River Basin						
	1.1 Upper Crocodile						
	Hartbeespoort	28.7	28.7	100.6	64.9	100.6	53.0
	Buffelspoort	0.0	0.0	6.6	0.0	6.6	0.0
	Roodekoppjes	0.0	0.0	29.4	0.0	29.4	0.0
	Sub-Total	28.7	28.7	136.6	64.9	136.6	53.0
	1.2 Pienaars						
	Roodeplaat/Leeukraal	49.1+20.1	49.1+20.1*	6.7	13.5	6.7	13.5
	Bon Accord	0.0	0.0	11.5	0.0	11.5	0.0
	Warmbaths	0.0	0.0	2.2	0.8	2.2	0.7
	Klipvoor	1.9	1.9	62.0	25.6	54.6	18.8
	Sub-Total	71.1	71.1	82.4	39.9	75.0	33.0
	1.3 Elands						
	Bospoort	1.9	1.9	0.0	0.0	0.0	0.0
	Olifantsnek	0.0	0.0	14.3	0.0	7.7	0.0
	Koster	1.3	0.6	2.9	0.0	0.9	0.0
	Lindleyspoort	0.0	0.0	8.4	0.0	7.5	0.0
	Vaalkop	42.1+12.7+9.7	421.1+12.7+9.7*	2.7	16.7	2.7	5.3
	Sub-Total	67.7	67.0	28.3	16.7	18.8	5.3
	1.4 Lower Crocodile	0.0	0.0	0.0	63.0	0.0	46.6
	Sub-Total	0.0	0.0	0.0	63.0	0.0	46.6
	Total	167.5	166.8	247.3	184.5	230.4	137.9
2.	Upper Olifants River Basin						
	2.1 Bronkhortspruit						
	Bronkhorstspruit	16.1	16.1	0.7	0.0	0.6	0.0
	Grootdraai import	4.9	4.9	0.0	0.0	0.0	0.0
	Premier Mine	6.4	6.4	0.0	0.0	0.0	0.0
	Sub Total	27.4	27.4	0.7	0.0	0.6	0.0
	2.2 Elands of Upper Olifants						
	Rust de Winter	0.0	0.0	0.0	6.5	0.0	5.2
	Mkombo	12.5	12.5	0.0	0.0	0.0	0.0
	Moses	0.0	0.0	0.0	2.6	0.0	2.1
	Loskop import	9.5	9.5	0.0	0.0	0.0	0.0
	Sub Total	22.0	22.0	0.0	9.1	0.0	7.3
	Total	49.4	49.4	0.7	9.1	0.6	7.3
	Grand Total	216.9	216.2	248.0	193.6	231.0	145.2
3	Rand Water						
	3.1 Central Zone	86.9	86.9	-	-	-	-
	3.2 Western Zone	39.3	39.3	-	-	-	-
	Total	126.2	126.2	0.0	0.0	0.0	0.0

Note) * Imported water to the Rand Water Supply Area

Table 4-17 : Summary of Water Balance for Case 3 - Alternative 2 (2015 base)

Water Resource	Primary Water (mcm/a)		Irrigation Water (mcm/a)			
	Requirement	Supply	Requirement		Supply	
	Storage Dam	Storage Dam	Storage Dam	River	Storage Dam	River
1. Local Water						
- Upper Crocodile	28.7	28.7	136.6	64.9	136.6	53.0
Pienaars	71.1	71.1	82.4	39.9	75.0	33.0
Elands	67.7	67.0	28.3	16.7	18.8	5.3
- Lower Crocodile	0.0	0.0	0.0	63.0	0.0	46.6
Bronkhorstspruit	27.4	27.4	0.7	0.0	0.6	0.0
Elands (Olifants)	22.0	22.0	0.0	9.1	0.6	7.3
Sub-Total	216.9	216.2	248.0	193.6	231.6	145.2
2. Rand Water	126.2	126.2	-	-	-	-
Grand Total	343.1	342.4	248.0	193.6	231.6	145.2

Note) * Imported water from Grootdraai and Loskop dams.

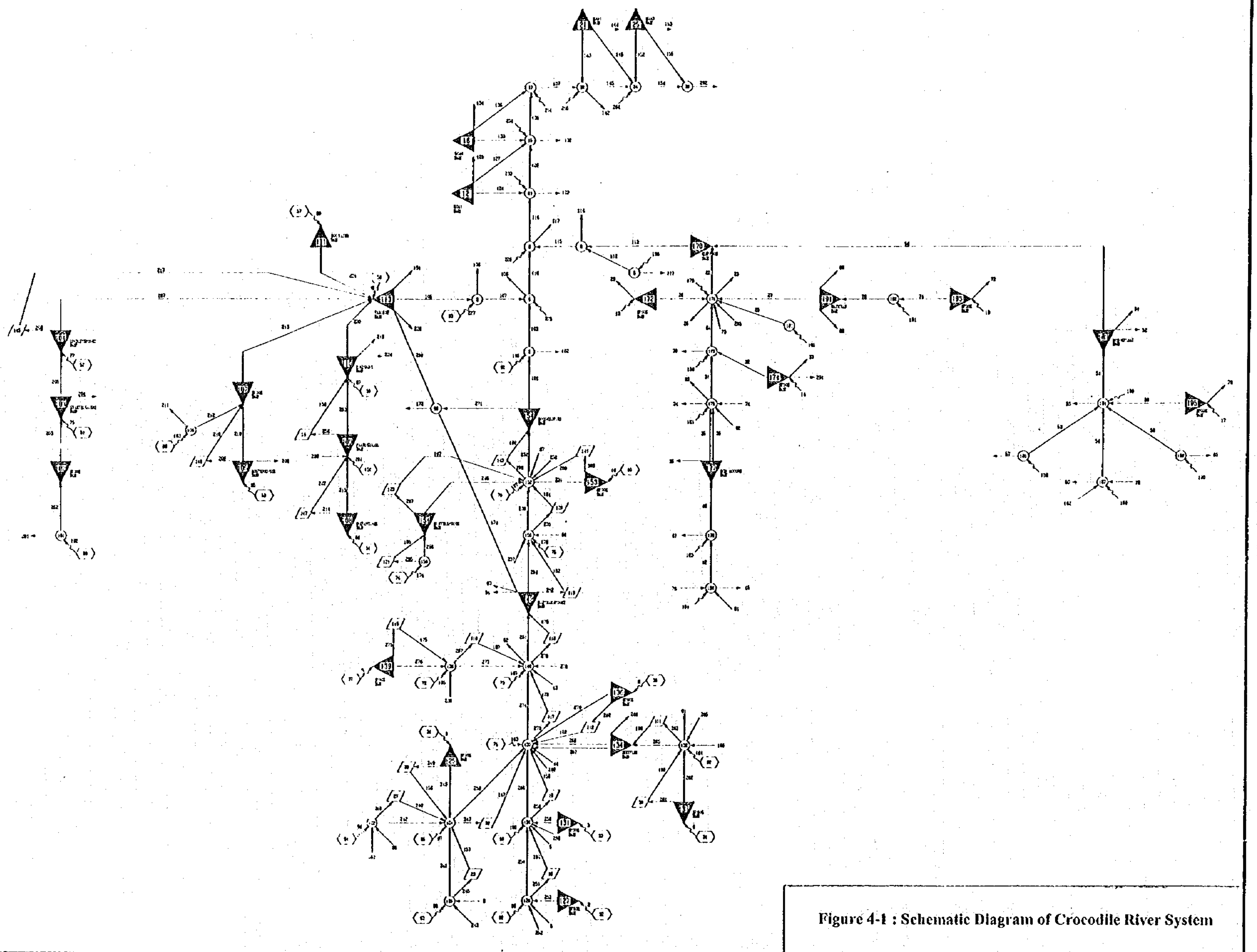


Figure 4-1 : Schematic Diagram of Crocodile River System

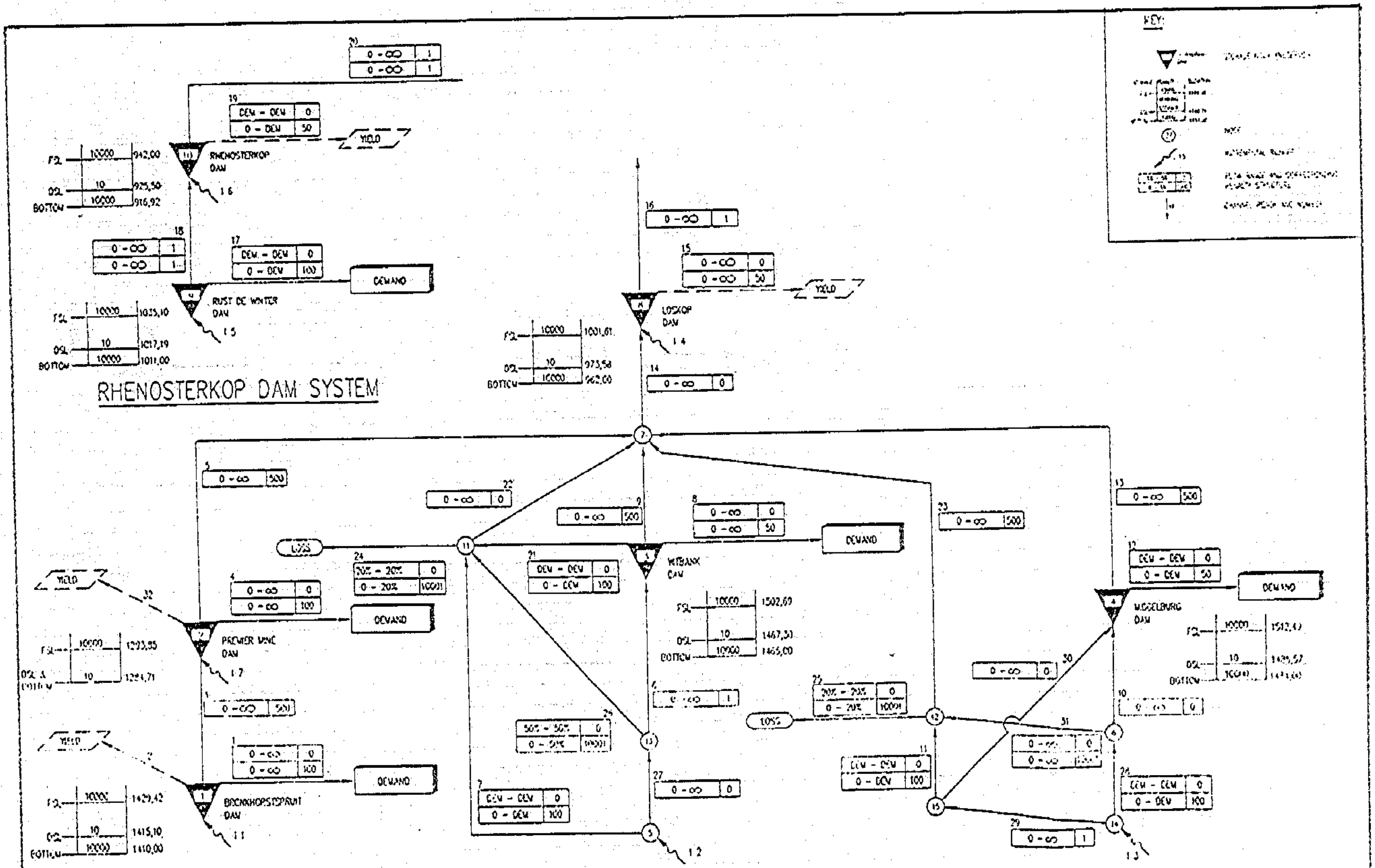
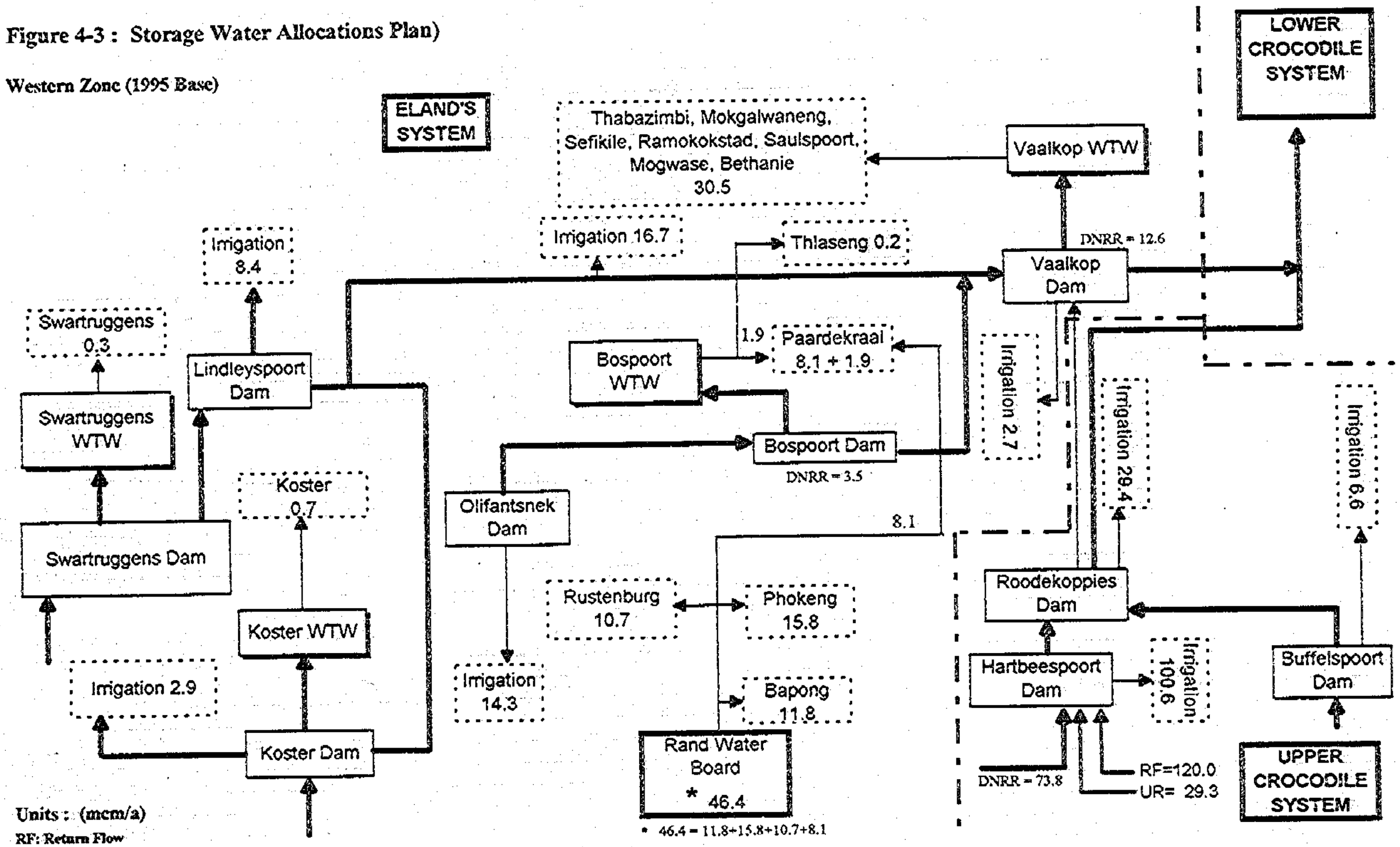


Figure 4-2 : Schematic Diagram of Olifants River System

Figure 4-3 : Storage Water Allocations Plan)

Western Zone (1995 Base)



Units : (mcm/a)
RF: Return Flow
UR: Urban Runoff
Note : DNRR indicates Drought Naturalised River Runoff at one in ten year return period.

Figure 4-4 : Storage Water Allocation

Central Zone (1995 Base)

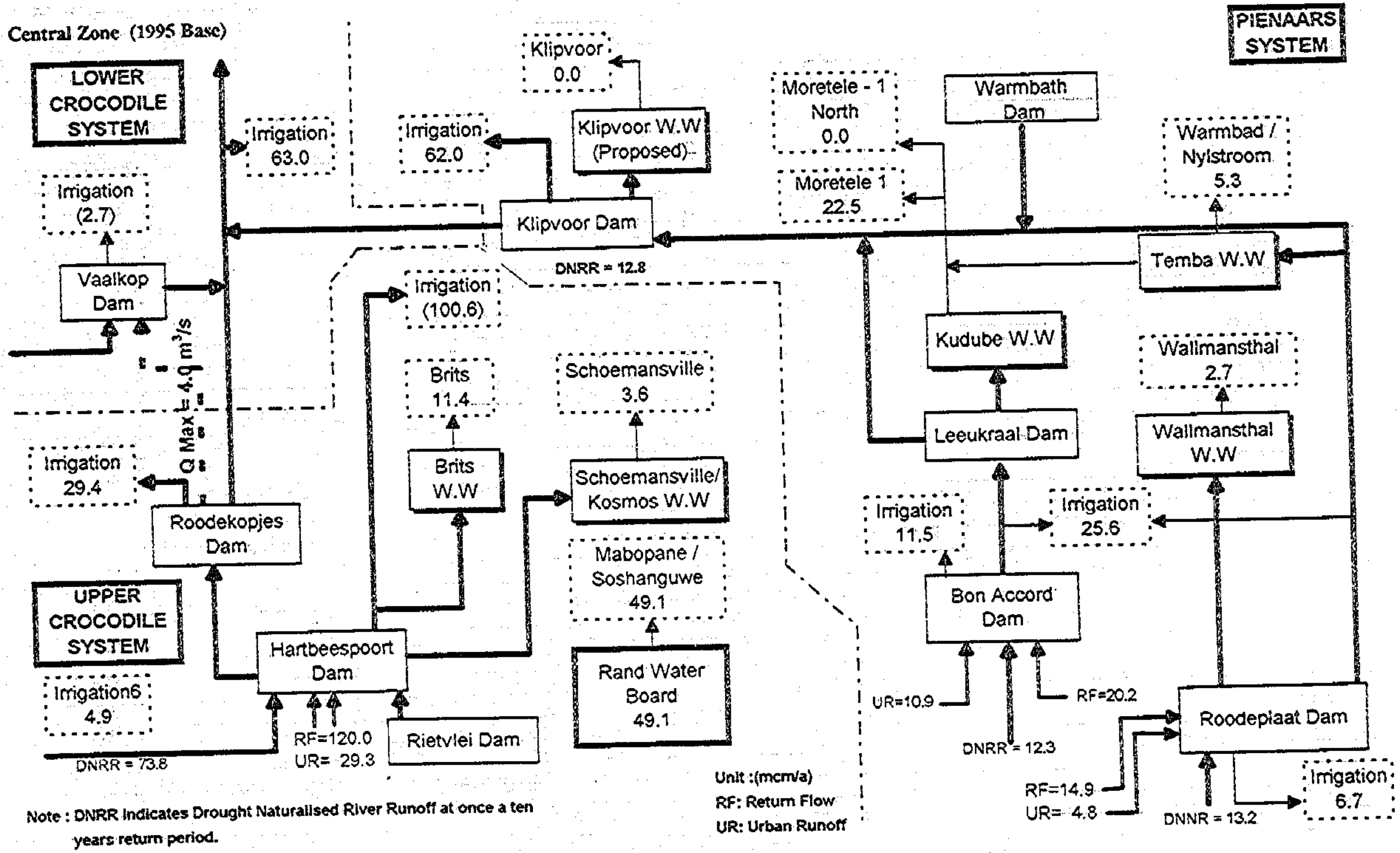
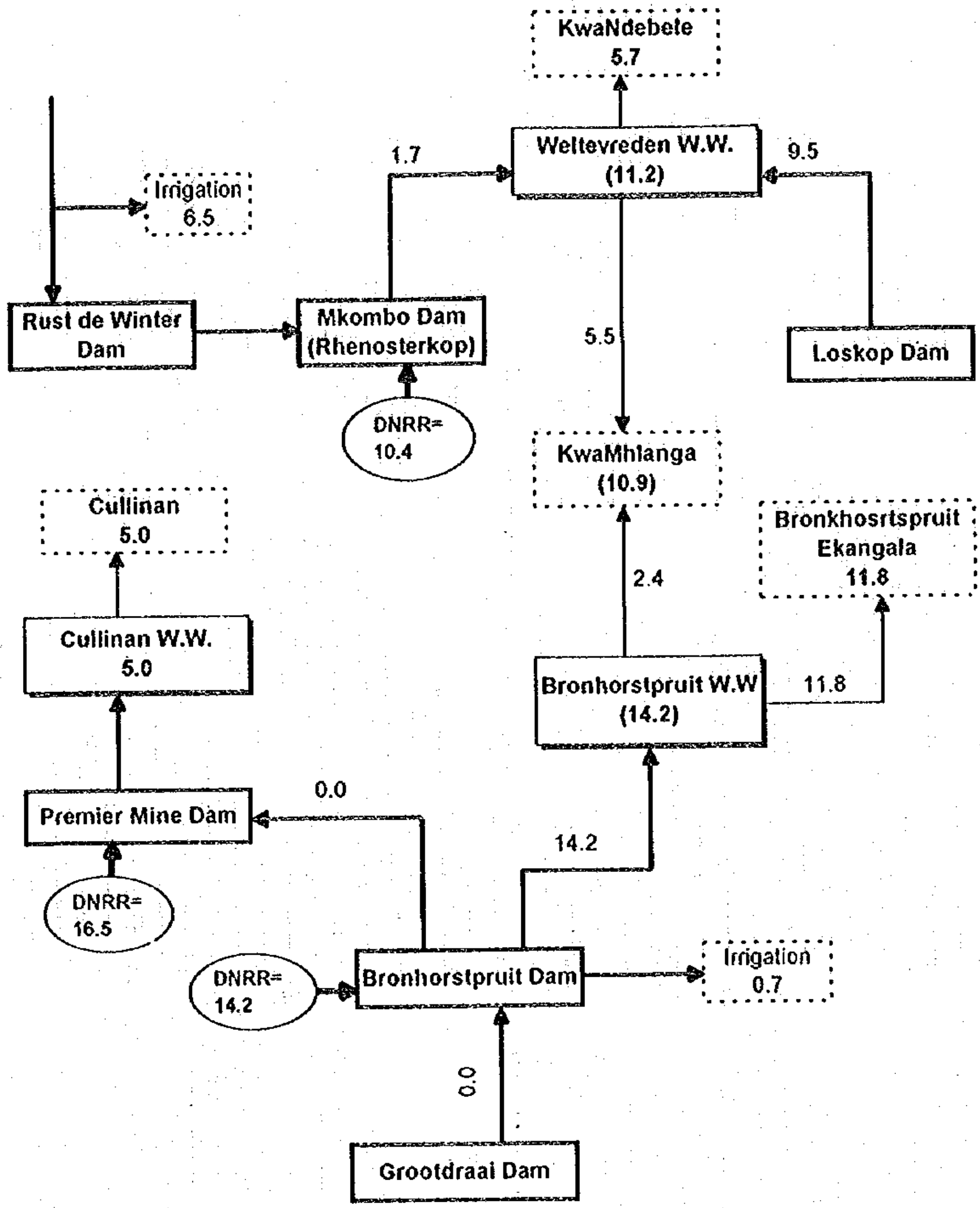


Figure 4-5 : Storage Water Allocation Plan

Eastern Zone (1995 Base)

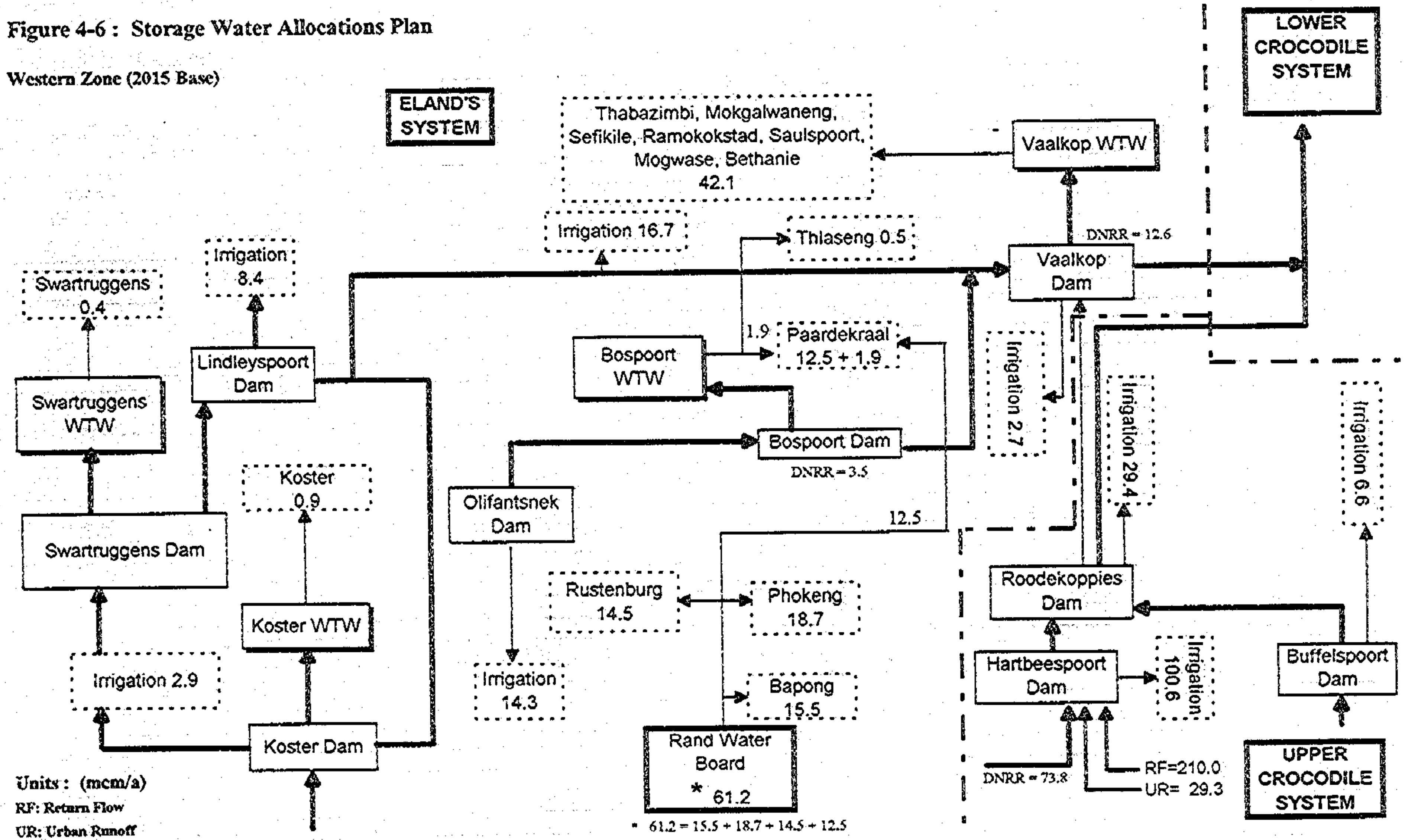


Unit :(mcm/a)

Note : DNRR indicates Drought Naturalised River Runoff at once a ten years return period.

Figure 4-6 : Storage Water Allocations Plan

Western Zone (2015 Base)



Units : (mcm/a)

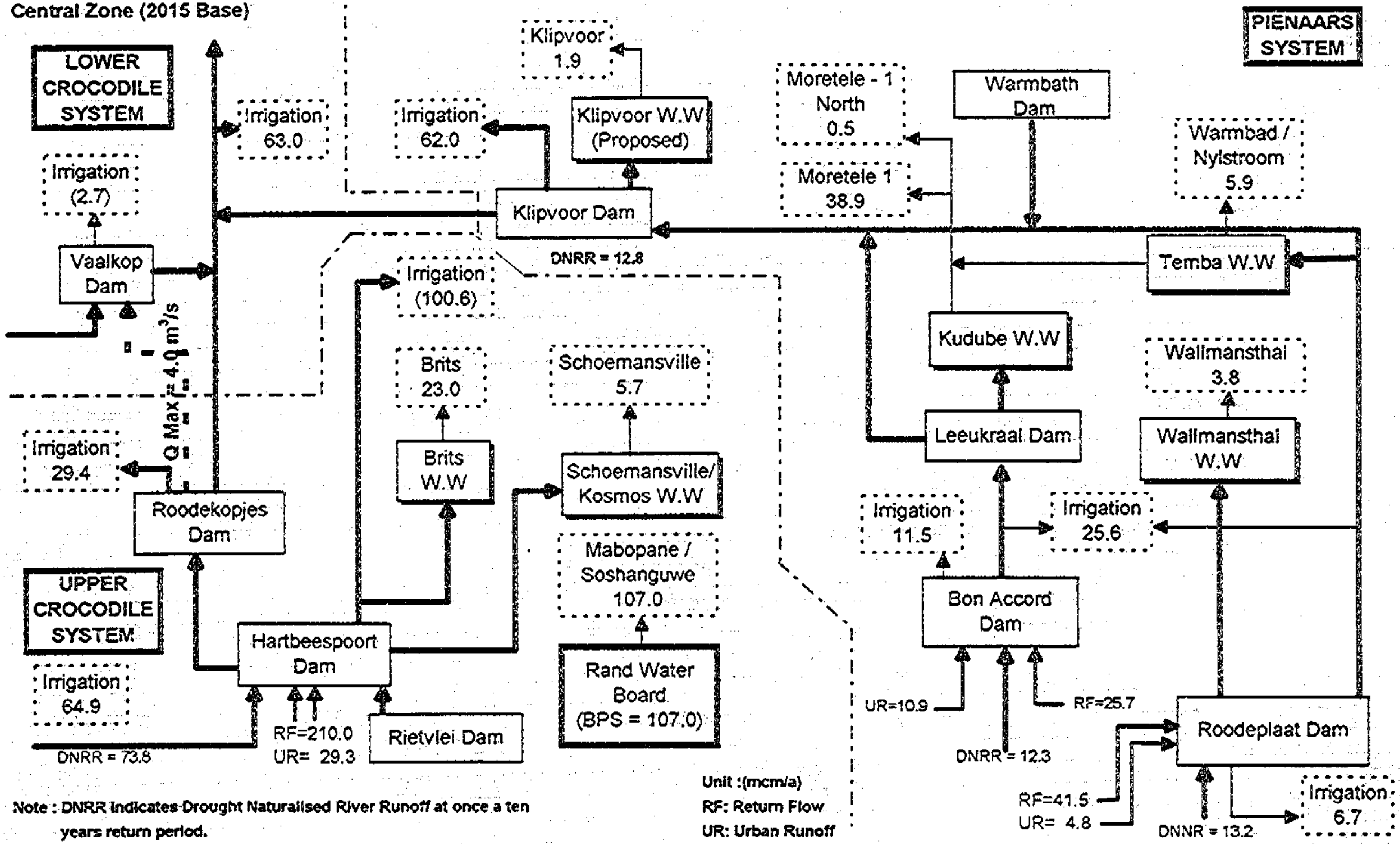
RF: Return Flow

UR: Urban Runoff

Note : DNRR indicates Drought Naturalised River Runoff at one in ten year return period.

Figure 4-7 : Storage Water Allocation Plan

Central Zone (2015 Base)

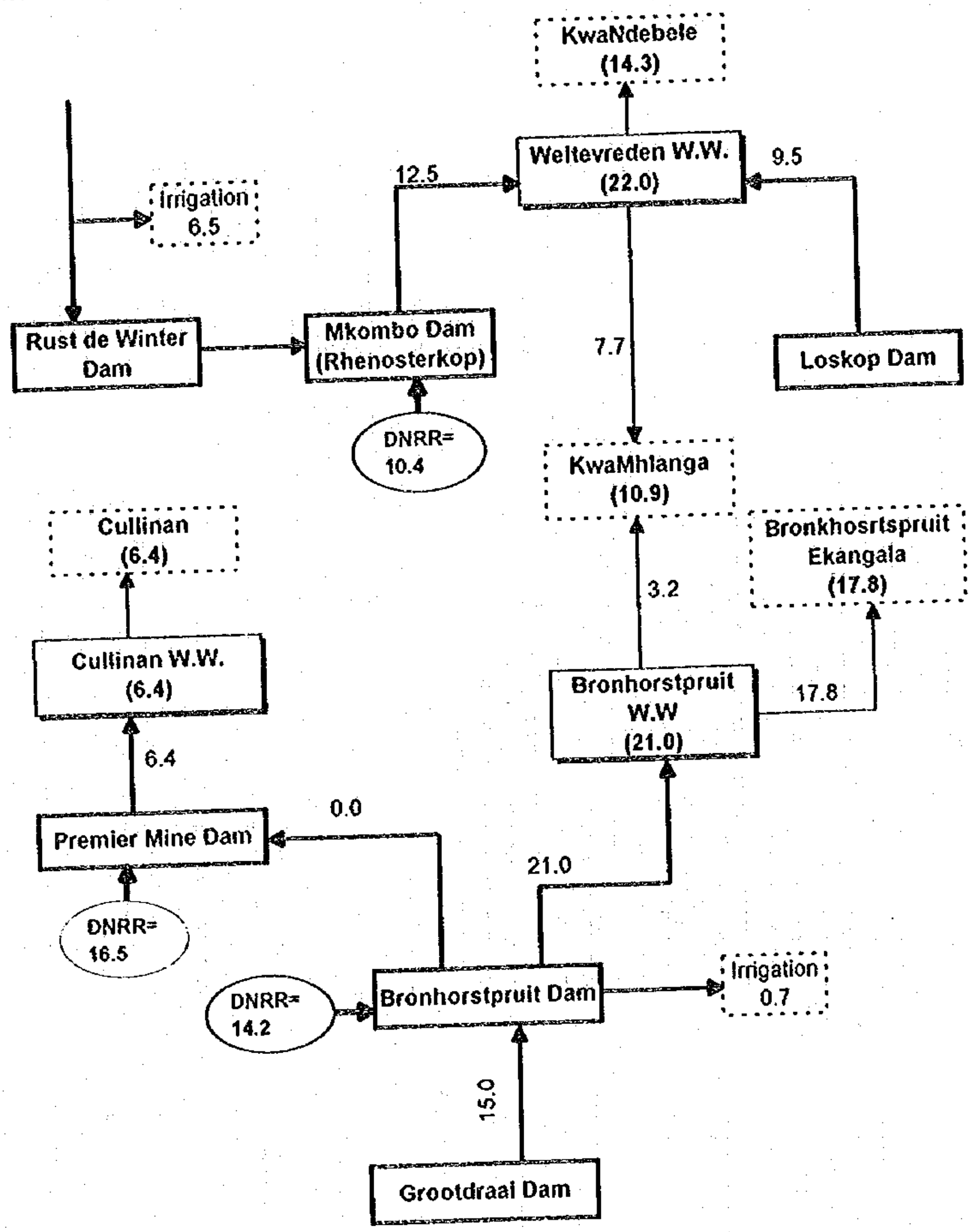


Unit :(mcm/a)
RF: Return Flow
UR: Urban Runoff

Note : DNRR Indicates Drought Naturalised River Runoff at once a ten years return period.

Figure 4-8 : Storage Water Allocation Plan

Eastern Zone (2015 Base)



Unit :(mcm/a)

Note : DNRR indicates Drought Naturalised River Runoff at once a ten years return period.

CHAPTER 5 : INFRASTRUCTURE DEVELOPMENT PLANNING

CHAPTER 5 INFRASTRUCTURE DEVELOPMENT PLANNING

5.1 Assumed Design Standards and Cost Curves

Infrastructure development planning can be viewed as the core of the technical component of Phase 1 of the Study. All other technical tasks were either required in preparation for the infrastructure development planning, or resulted from it.

In order to ensure a consistent approach, it was necessary as an initial step to determine design and cost parameters to form the basis for the technical planning and costing that was undertaken under this portion of the Study. Criteria for process selection, sizing of pipelines and structures, information on materials and cost criteria typical of work undertaken in the past within the Study Area were identified and recorded. The criteria and parameters selected for this purpose are presented in the Data Book.

It is important to note that the design and costing criteria included in the Data Book were prepared to record and to inform interested parties of the standards applied during the preliminary technical planning. The criteria presented are only representative of generally accepted design and costing parameters, and are in no way intended to be interpreted as representing the official technical standards applied by Magalies Water or supported by Magalies Water for application within the Study Area. The assumed design standards do however include many standards that have in the past been applied by Magalies Water, and can possibly therefore serve as a future basis upon which Magalies Water can develop formal design and costing standards and/or guidelines for its extended supply area. During Phase 2 of the Study, applicable design assumptions will be discussed and agreed with MW and other relevant parties for the purpose of the Feasibility Study.

Design standards and cost curves were developed specifically for the following components of the water supply infrastructure.

- storage dams and diversion weirs;
- conveyance canals;
- water treatment works;
- delivery and distribution pipelines;
- pumping stations;
- service reservoirs;
- reticulation; and
- boreholes.

5.1.1 Storage Dams and Diversion Weirs

Planning assumptions and design criteria are presented in the Data Book for three main types of dam, viz concrete gravity dams, embankment dams (earthfill and rockfill) and composite dams having a gravity central section with spillway and embankment flanks. Criteria are included for the determination of spillway design floods, total and effective storage, topographical and geological evaluation of potential dam sites as well as indicative foundation works (including grouting), freeboard allowances, the sizing and location of spillways stilling basins and outlet works, estimated sedimentation yields for specific sites and typical dam dimensions including typical embankment, protection and core dimensions and slopes. As dam design is strictly influenced by site specific condition it was not considered meaningful to prepare a typical design using parametric dimensions. Rather, dam designs typical of those found in the Study Area were presented, using the guidelines and criteria identified above. Cost models for dams are also site specific, and it was not possible to present a typical model that can be extrapolated between different sites. An example was prepared for a specific site, indicating the main measurement items for this kind of project. The relationship between FSL, capacity, yield and the cost for the specific example are indicated in the Data Book.

5.1.2 Conveyance Canals

Planning assumptions and design criteria for conveyance canals were developed based on the RSA publication entitled "Guidelines for the design of canals and related structures". The Data Book contains guidelines for the determination of Q_{yield}, Q_{design}, $Q_{delivered}$ and Q_{losses}. Standard cross-slope categories are presented as the basis for the standard design and cost models. Canal cross-section, form and dimensions are identified, as are design details for canal linings. The cost model consists of a series of cost versus capacity curves, for varying natural cross slopes of the ground traversed by the canal.

5.1.3 Water Treatment Works

Design criteria for water treatment works should take account of the quality of the water resource being treated. Raw waters within the Study Area often exhibit high turbidity (Elands River at Vaalkop), and/or eutrophic characteristics. Treatment processes therefore, have to provide for either sedimentation or for dissolved air flotation (or for both), prior to filtration. Generally, the more eutrophic waters require DAF units in lieu of sedimentation. Sources receiving large return flows from areas to the south of the Study Area, such as Hartbeespoort, Roodekoppies, Roodeplaat, Leeukraal and Klipvoor are eutrophic and require dissolved air flotation to be included in the treatment process. Algae rich waters usually also require special treatment (powdered activated carbon) in order to remove odour and taste.

Four possible process designs for raw waters typical of the Study Area are included in the Data Book. The first of these is a conventional treatment process, the second a standard DAF process, the third a process including both sedimentation and DAF, and the fourth a design proving for either sedimentation or DAF, depending on the water quality at the specific time of the year. The various water treatment unit processes are described in the Data Book, and loading and sizing criteria as well as typical designs are presented. The merits and application of the various optional unit processes are also presented in the Data Book. Losses within the treatment process are also discussed in the Data Book, and a design norm of 5 per cent is recommended for this purpose. Cost curves were prepared for both the capital cost (for each process chain) as well as the operating and maintenance costs associated with treatment works within the Study Area.

5.1.4 Delivery and Distribution Pipelines

Design standards and cost curves were also developed for delivery and distribution pipelines; these standards and curves can also be found in the Data Book. Comprehensive data is included in the Data Book relating to all aspects of the design of bulk delivery and distribution pipelines. Data and standards are presented for pipelines, all valve types, flow meters and associated structures. Fittings, couplings, and associated matters are also described. The most economical pipe type in the RSA for different pressure and flow ranges are included, and these norms formed the basis for the preliminary planning and costing subsequently undertaken. Generally uPVC was adopted for all pipelines up to 400 mm ND and 1600 kPa, and steel pipelines for the balance. Criteria are also included for the hydraulic design of pipelines (friction, peak factors and losses), for anti-corrosion investigations and designs, for the structural (internal pressure, external loads and installation conditions) design of pipelines, for pipeline testing conditions and procedures and for the positioning and sizing of air valve and surge protection devices. Finally, cost curves and tables are included for the costing of planned facilities (capital as well as operation and maintenance), in order to ensure a common basis upon which all alternatives for the Study Area have been costed.

Typical design drawings are included in the Data Book for pipeline installation conditions, and for valves, flow meters and fittings (isolating valve assemblies, scour valve assemblies and air valve assemblies) that are associated with delivery and distribution pipelines.

5.1.5 Pumping stations

New Pumping stations are included in the preliminary planning of technical solutions. These serve to convey raw water from dams and canals to new or extended treatment plants, to boost the pressure of treated water in bulk delivery pipelines, and to raise water from ground level service reservoirs into pressure towers servings towns and villages.

Design criteria and data is included in the Data Book in resect of all aspects of pumping station design. Specifically, data is included concerning wet wells, forebay design, suction and delivery pipework, pump types and selection, NPSH norms, pump speed, motor and motor control sizing and design, pump tolerances and testing, surge control, pumping station layout, safety requirements, hoisting equipment, preferred materials, as well as requirements for operation and maintenance manuals. Finally a cost curve was developed for the estimation of the capital costs of new pumping stations, as well as the operation and maintenance costs associated with pumping stations.

A typical design of a clear water pumping station has also been included in the Data Book, in order to indicate the various design principles described.

5.1.6 Reservoirs

Many new reservoirs will be required within the Study Area within the planning period of the Study (to the year 2015). These reservoirs will either be regional storage reservoirs (to be planned and installed by the water board), or service reservoirs (to be planned and installed by the local authority). The size and function of a prospective reservoir will determine its form and the construction materials to be adopted.

Included in the Data Book is a comparison of the sizing norms applied by Magalies and Rand water respectively. The specific volume of storage required will depend on the method of supply to the reservoir (ie pumped or gravity supply, fed from a regional reservoir or directly from the purification works), and the level of fire protection afforded. For service reservoirs sizing norms are proposed for adoption by the local authority. In the final analysis however, each local authority makes its own choice based on the level of risk of supply interruption that the local authority (or other bulk consumer) is willing to accept. A schematic layout is also included showing pipeline and reservoir design standards, as well as losses, for the full delivery process, from abstraction to the individual consumers.

The Data Book also includes norms for the selection of reservoir type. Smaller service reservoirs and towers will probably be of sectional steel design, while concrete reservoirs are expected to be adopted for all larger and regional storage reservoirs. Small concrete reservoirs will be conventional circular RC, while larger reservoirs will be either rectangular RC, or post-tensioned concrete with a domed shape roof. Typical shapes and dimensions with capacity ranges within which the reservoir type is economical are presented in schematic form in the Data Book. Finally, costs curves are included for the most common reservoir types required in the preliminary planning.

5.1.7 Reticulations

The reticulation of unserved towns and villages will form a substantial portion of the future financial commitment required in the water supply sector. This commitment is however generally the responsibility of the Third Tier, and not directly of water boards such as Magalies Water, except in an agency or supportive role.

Reticulation development is closely associated with the level of service assumed for each of the communities within the Study Area. Level of service, in turn, is dependent on disposable income within the individual communities, and affects primary water demand. It was necessary for planning purposes both to identify the water demand associated with each level of service within the Study Area, as well as the cost of the reticulation associated with each level of service. The Data Book contains planning assumptions associated with reticulations, such as pipe type and class, street pipe spacing for RDP level of service, fire protection options, peak factors for design, minimum residual pressures required, and physical design standards such as valve spacing and pipeline cover.

Reticulation cost curves are also included, showing all inclusive reticulation costs for the different levels of service, based on development or settlement density. These curves were used extensively in identifying the expected cost of reticulating unserved or partially served towns and villages within the Study Area.

5.1.8 Boreholes

Groundwater development was only assumed in cases where Class 0 and 1 water quality is present, and where the extension of a surface water supply system would be prohibitively expensive. This approach was adopted in the light of the far greater security of surface water resources, and the high potential for chemical and bacteriological contamination associated with subterranean supplies.

The standard design for borehole development included in the Data Book assumes that all boreholes under 0.5 l/s will be equipped with a hand pump only. For motorised pumps, electrical drivers have been assumed where a power supply is available close at hand; elsewhere diesel driven boreholes are assumed. Costing has assumed boreholes at 1 km from the village boundary and 500 m apart. Steel clad pump houses with concrete floors and plinths are assumed. Details regarding cost assumptions in respect of draw-down level, strike rate, installation depth, static rise, drilling depth and test pumping requirements are also included in the Data Book. Full details of the cost build-up for typical boreholes, for each of the various driver types possible, are also included as well as operation and maintenance cost graphs for motorised boreholes.

Typical details of an electrically driven borehole with a steel clad pumphouse are given in the Data Book, as are casing and borehole finishing details for a typical borehole.

5.2 General Planning Approach

The planning approach for the Study Area was developed before commencing with preliminary infrastructure planning in order to achieve the following goals and objectives :

(1) To identify possible technical options and solutions for the supply of potable water that meets generally accepted quality and health standards to the unserved and underserved communities within the Study Area.

(2) To group the various demand units within Supply Blocks, Areas and Zones, thereby informing management decisions regarding the Study Area, and regarding the expansion of the capacity of Magalies Water.

(3) To balance water demand to supply, thereby informing water resources planners of further water resources development that may be required.

(4) To advise DWAF as well as the water boards operating within the Study Area of the effect that future water supply development and increasing return flows will have on raw water quality within the Study Area.

(5) To Advise DWAF and the water boards as to the most favourable long term supply boundaries for each of the water boards operating within the Study Area.

(6) To serve as the basis for capital investment programmes for the short, medium and long term development of water supply infrastructure within the Study Area.

(7) To serve as a basis for the development of local government water supply planning, operation and maintenance within the Study Area.

The approach adopted in undertaking the preliminary water supply infrastructure planning was as follows :

(1) The Study Area was grouped into Supply Blocks, Areas and Zones. These units were then assigned to the various existing or potential water sources, in accordance with the results

of the water balance study. Where the water balance study indicated more than one possible source, technical options were investigated.

(2) Each Supply Block was represented schematically on supply diagrams that were generated using a spreadsheet. The primary demand that is estimated for each community was transferred to the schematic. Two spreadsheets were generated for each Supply Block, the first representing the status quo situation, and the second the upgrading that will be required in order to meet primary water demands in the year 2015. For Supply Blocks where there is no existing infrastructure, the first spreadsheet was not produced.

(3) For each Supply Block, the capacity of the existing infrastructure was tested against the estimated 2015 primary water demands. Capacity shortfalls were indicated on the first spreadsheet.

(4) Where existing infrastructure does not have sufficient capacity to meet the projected 2015 demands, a possible technical option was formulated and costed (second spread sheet) using the cost curves described in Section 5.1 above. In a number of cases more than one viable technical option was identified. In such cases each of the alternative technical options was planned and costed and then evaluated to determine the most favourable option.

(5) The schematic layouts indicate the flow sequence, size, capacity and cost of proposed new infrastructural components within each Supply Block. Such characteristics are also shown on the first sheet, (but without the associated costs), for existing infrastructural components. Schematics for each Supply Blockand Cost Summary Sheets indicating total demand, capacities, pipework lengths and costs for each Supply Area are provided in Appendix 1. Schematics are also available in electronic format in the Data Book.

(6) Technical planning has been undertaken on the assumption that all areas will be supplied from a surface water source by the year 2015, with the exception of isolated farming communities, isolated rural villages and a portion of the demand of Thabazimbi, where a strong groundwater aquifer exists, and Koster where the 2015 demand cannot be met from the local surface water resources. It was further assumed in the planning that all areas that are currently supplied with groundwater of Class 3 or 4 quality will be replaced with a surface water supply by the year 2002, whilst areas with a Class 2 groundwater supply will be replaced with a surface water source by the year 2015.

(7) Although areas that are currently supplied with Class 0 and 1 groundwater could remain on groundwater indefinitely from a quality point of view, it has been considered prudent, for the purposes of the preliminary technical planning, to assume that groundwater supplies of any magnitude offer low security in the long term, and to plan for these villages to be served from surface water sources by the year 2015. This approach is perhaps somewhat conservative, but is considered realistic as the quality of groundwater supplies generally deteriorate with increasing development in a town or village.

(8) In the preliminary planning, little attempt has been made to optimise individual components of bulk supply systems, but rather to identify feasible and realistic options

for the provision of new infrastructure, or for the upgrading of existing infrastructure to meet the required demands. The general approach has been to assume that each village or group of adjacent communities will have its own service reservoir, and if reqiured by the topography, its own pumping station and elevated tank. Service reservoirs are costed separately in the schematic layouts. Village water towers and pumping stations have been included in the cost of the reticulations.

The proposed development of the water supply system is shown on the drawing attached to the Main Report entitled "Proposed Primary Water Supply Infrastructure Development Plan for JICA Study Area".

5.3 Development Planning for the Western Zone

The Western Supply Zone consists of four separate Supply Areas, ie Vaalkop North Supply Area, Vaalkop South Supply Area, Barnardsvlei Supply Area and Koster Supply Area. The Western Supply Zone is supplied with water from four sources, ie the Elands and Crocodile rivers via Vaalkop Dam, the Hex River from Bospoort Dam, and the Vaal River via Barnardsvlei (supplied by Rand Water). In the near future, primary water from all four of these sources will be consumed within the Greater Rustenburg region, and for this reason these sources have been grouped into a single Supply Zone. The Koster Supply Area has also been included in this Zone, in view of the small, locally-sourced demands that are encountered within this Supply Area.

5.3.1 Vaalkop North Supply Area

Vaalkop Water Treatment Works is located at Vaalkop Dam, which forms part of the Crocodile River System and is operated as a unit together with Hartbeespoort Dam and Roodekoppies Dam. The water stored in Vaalkop Dam is supplemented from the Crocodile River using water transferred from Roodekoppies Dam during times of shortfall. Increasing demand will require increasing transfers between these two dams.

The Vaalkop North Supply Area is developed around a main north-south axis with several branches to the west. Historically, supplies by MW from this system were to bulk mining and industrial consumers. Domestic water was sold to Thabazimbi, to Northam and to NWWA in bulk for distribution to villages within the Mankwe District, and to commercial developments along the southern fringe of the Pilanesberg. The responsibilities of NWWA in Mankwe District have recently been taken over by Magalies Water.

The Vaalkop North Supply Area has been subdivided into the following six Supply Blocks, each of which was analysed separately :

(1) Thabazimbi Supply Block is currently supplied from Magalies Water's La Patrie Reservoirs via the Boards main south-north pipelines. Water is supplied from La Patrie to the Sefikile Supply Block draw off, south of Northam. At Northam the Mokgalwaneng Block branches off the main supply to Thabazimbi. The existing pipelines to the north of Northam discharge into the Elandsfontein and Goewermentsplaas Reservoirs. RPM Amandelbult and Northam Platinum are supplied from these reservoirs. In addition existing pipelines from these reservoirs supply the Zwartkop Chrome Mine, Rhino

Andulasite, and Thabazimbi. The iron ore mine at Thabazimbi is completely served from groundwater sources and the town is also partly served from groundwater, this being the only significant groundwater supply within the Study Area. It is assumed that this situation will continue. It is proposed to strengthen the main north-south pipeline and to provide additional storage at Elandsfontein SR (15 Ml).

(2) Mokgalwaneng Supply Block is located in the far north of Mankwe District. At Northam a secondary rising main branches off to the PPC Cement factory at Dwaalboom. This pipeline is owned by PPC and passes close to villages around Mokgalwaneng. These villages can be supplied from the existing pipeline, although reinforcement will be required up to Modimong. Negotiation with PPC will be required in order to address the matter of supply from a privately owned pipeline.

(3) Sefikile Supply Block is located in the north of Mankwe District. A few kilometres south of Northam, two pipelines branch off the main La Patrie to Thabazimbi pipelines and feed Spitskop Reservoir, on the hill above Sefikile. This reservoir supplies water to RPM's Swartklip Mine and Union Section, as well as to the mines' residential areas. Extensions of this system are proposed in order to accommodate mining growth, and to serve the nearby towns and villages within this Supply Block.

(4) Ramokokstad Supply Block will be supplied from a branch off the main Vaalkop - La Patrie pipelines. This Block is currently supplied by groundwater at a very low level of service. The total demand of this Supply Block is small.

(5) Saulspoort Supply Block is supplied from the La Patrie Reservoirs, where water was previously sold in bulk to NWWA. Existing infrastructure within this Block already stretches as far west as Mabeskraal, and is fairly well developed. New extensions to the north and south of this branch pipeline are proposed.

(6) Mogwase Supply Block is currently fed from a branch pipeline off the Vaalkop - La Patrie main, but is also linked to the La Patrie reservoirs from which water gravitates to the communities within the Block, terminating at Doornhoek Reservoir near Sun City. The Mogwase/Bodirello industrial area and the Sun City Holiday Resort falls into this Supply Block. The existing supply via Mogwase is already at the limit of its capacity, and a future upgrade will be unavoidable. It is proposed to extend the existing system to serve Phatsima, Ledig and the neighbouring communities.

Table 5-1 below presents a summary of additional bulk infrastructure which will be required for the Vaalkop North Supply Area to meet the projected 2015 primary water demand.

Table 5-1 Summary of Additional Bulk Infrastructure Required for Vaalkop North S/A

Bulk Infrastructure	Location	Diameter (mm)	Unit	Quantity
Water Treatment Works	Vaalkop		Mld	115
Clear Water P.Station	Vaalkop		kld	150,375
Reservoirs	La Patrie		Ml	40
	Elandsfontein		Ml	22
	Spitskop		Ml	1.5
Pipelines		110 to 200	km	112.13
		250 to 400	km	140.35
		450 to 600	km	62.60
		650 to 800	km	22.50

5.3.2 Vaalkop South Supply Area

An extension, in the form of a large diameter north to south-west pipeline to regional reservoirs at Bospoort (the Vaalkop Southern Supply Block) is about to be implemented to extend the MW supply from Vaalkop WTW. Supply to the Greater Rustenburg region will be made from these reservoirs. Historically, Magalies Water's only supply in the Vaalkop South Supply Area was to the former SADT settlement of Hartbeesfontein, via its Kortbegrip Reservoir (portion of the Bethanie Supply Block). Supplies are also made at present from Bospoort WTW at Bospoort Dam to Rustenburg and to RPM.

The Vaalkop South Supply Area has been subdivided into the following two Supply Blocks, each of which was analysed separately.

(1) Bethanie Supply Block is based on an existing scheme that was constructed by Magalies Water in order to supply water to the settlement of Hartbeesfontein. Under the scheme water is pumped from Vaalkop WTW to a reservoir constructed at Kortbegrip and on to the settlement of Hartbeesfontein. Substantial spare capacity exists, due to slow growth in Hartbeesfontein. Current planning proposes that a portion of this be used to implement a new gravity fed regional supply scheme to serve the rural settlements of Modikwe, Berseba and Bethanie.

(2) Vaalkop Southern / Bospoort Supply Block is partly supplied from Bospoort Water Treatment Works which is located at the outlet from Bospoort Dam. The yield of the dam is limited, so supplementary supplies to Rustenburg from Barnardsvlei and Vaalkop are necessary. Bospoort WTW is fairly old and is jointly owned by Rustenburg TLC and RPM. It supplies water to these two parties (30% and 40% respectively), and to DWAF (30%). During negotiations relating to the Vaalkop Southern Supply Block, DWAF agreed to donate their water supply rights from Bospoort WTW to Magalies Water, for distribution as part of that supply scheme.

Rapid urban growth within the Greater Rustenburg region, and growth in the mining demand in the Barnardsvlei Supply Area has resulted in the urgent need for an augmentation scheme to supply the growth points between Bospoort and Barnardsvlei. Water resources investigation and water supply planning identified that this region should be reinforced from Vaalkop WTW, using Crocodile River water. This finding was confirmed by the Study. The proposed scheme comprises a substantial extension of Vaalkop WTW, a rising main to a regional storage reservoirs at Bospoort, and a network of major distribution mains supplying the service reservoirs of bulk consumers within the region. Major consumers to be supplied from the proposed scheme are Rustenburg TLC, the Bafokeng Tribe and Impala Platinum. Potable water will be sold by Magalies Water to Rand Water, probably at the outlet from the Bospoort Reservoirs; Rand Water will in turn sell the water to consumers within its area of supply. The proposed supply from Vaalkop to Rustenburg North, Phokeng and Thlabane will replace the existing supply that is currently imported into this portion of the Supply Block from the Barnardsvlei Supply Area. This solution will reduce the existing primary demand within the Barnardsvlei Supply Area, thereby enabling the existing Rand Water supply from Randfontein to Barnardsvlei to meet demand growth along the Rustenburg to Bapong axis to the year 2015.

Table 5-2 below provides a summary of additional bulk infrastructure which will be required for the Vaalkop South Supply Area to meet the projected 2015 primary water demand.

Table 5-2 Summary of Additional Bulk Infrastructure Required for Vaalkop South S/A

Bulk Infrastructure	Location	Diameter (mm)	Unit	Quantity
Water Treatment Works	Vaalkop		Mld	60
Clear Water P.Station	Vaalkop		kld	100,000
Booster P. Station	Townsland		kld	45,000
Reservoirs	Bospoort		Ml	70 (2x35)
Pipelines		110 to 200	km	5.50
		250 to 400	km	23.0
		450 to 600	km	10.0
		650 to 800	km	9.50
		950 to 1,100	km	49.95

5.3.3 Barnardsvlei Supply Area

The Barnardsvlei Supply Area is supplied with water from Rand Water's Zuikerbosch Water Treatment Works on the Vaal Dam through an extensive distribution system, via Witpoortjie and Barnardsvlei reservoirs. No extensions are proposed within the Barnardsvlei Supply Area during the planning horison of the Study. Demand growth will be accommodated by discontinuing the existing supply to Rustenburg North, Phokeng and Thlabane, which will be supplied in future from Vaalkop. Rustenburg North, Phokeng and Thlabane have accordingly been included into the Vaalkop South Supply Area.

The Barnardsvlei Supply Area has been subdivided into two Supply Blocks, both supplied from Rand Water's Barnardsvlei Reservoir.

(1) Barnardsvlei Western Supply Block is served by Rand Water's Roodepoort-Barnardsvlei-Rustenburg supply scheme. The scheme was implemented by Rand Water during the 1960's, in order to accommodate the development of Rustenburg as well as mining operations within this portion of the Study Area. Water is supplied by gravity from Witpoortjie Reservoir in Randfontein, via a series of break pressure tanks to a new regional reservoir at Barnardsvlei. From this point water is supplied westwards towards Rustenburg. The Western Supply Block supplies Karee Mine, Marikana, Rustenburg Platinum Mines (including Frank Shaft, Waterval Mine, Paardekraal Mine, Eastern Platinum, and the Bafokeng villages of Kwa-Photsaneng, Mfidikwe and Thekwane), Impala Platinum Mines (including the Bafokeng mines, the Wildebeesfontein mines and Minpro) as well as all of Rustenburg South. As discussed under the Vaalkop Southern/Bospoort Supply Block, no augmentation is planned within the Barnardsvlei Western Supply Block within the time frame of the Study, demand growth being met by the proposed discontinuation of the existing export of primary water to the Vaalkop Southern Supply Block for consumption within the urban and peri-urban areas of Rustenburg North, Phokeng and Thlabane.

(2) Barnardsvlei Eastern Supply Block is also fed from Rand Water's Barnardsvlei Reservoir which supplies two separate supply systems owned by Western Platinum. The first system employs a break pressure reservoir near the Rand Water connection, immediately north of Barnardsvlei while the second system uses the full pressure from Barnardsvlei Reservoir. The first system feeds Mooinooi and a portion of the Western Platinum Mine under gravity through a supply main from the break pressure reservoir. The second (high pressure) system supplies water through a steel pipeline to Jakkelskop Reservoir (Wonderkoppies Supply Unit), to the balance of the Western Platinum Mine and to the Segwaelane Supply Unit (which is fed from the Segwaelane Reservoir). Water is also supplied to the Bapong Supply Unit, but it is proposed that this supply from the north via the mine should be discontinued, and replaced with a direct connection to the proposed new Majakaneng Reservoir in the south. This proposed reservoir against the Magaliesberg, will allow the present pressure tower at Bapong to be taken out of service.

The feasibility of meeting the 2015 demand of the Barnardsvlei Eastern Supply Block from Brits WTW was investigated. The resulting reduction in demand from the Barnardsvlei Reservoir could, under such a scenario, be applied to meet the 2015 demands of Rustenburg North, Phokeng and Thlabane (which are almost equal to the total demand of the Barnardsvlei Eastern Supply Block). The Vaalkop source to the Vaalkop Southern/Bospoort Supply Block would under this alternative be relieved of approximately 42 Mld of summer demand, which will in turn be imported from the Barnardsvlei Supply Area. The alternative supply to the Barnardsvlei Eastern Supply Block would be pumped directly from Brits WTW to Majakaneng Reservoir. As for the base case, the Bapong Supply Unit would be fed directly under gravity from Majakaneng Reservoir. The proposed gravity pipeline between Mooinooi and Majakaneng would however, under this alternative, have to operate in the reverse direction (ie east to west), in order to replace the existing supply that is made from Barnardsvlei to Western Platinum Mine, to the Wonderkoppies Supply Unit and to the Segwaelane Supply Unit. The alternative supply to the Barnardsvlei Eastern Supply Block assumes that existing and future demands within this Supply Block can be met from Brits WTW. Since Brits WTW uses the same water resource (the Crocodile River System), as Vaalkop WTW, the results of the water balance study will not be compromised. In fact, less raw water would be required from the Crocodile River System under this alternative, as conveyance and storage losses will be reduced. This alternative however, does not appear from the preliminary calculations to offer a cheaper solution for supply to Rustenburg North, Phokeng and Thlabane than the supply from Vaalkop WTW. In addition, implementing a supply from Brits WTW will present institutional difficulties in the short term, as Brits TLC owns and manages the Treatment Plant at Brits. Neither Magalies Water nor Rand Water has an existing presence or management structure in Brits.

Table 5-3 below provides a summary of additional bulk infrastructure which will be required for the Barnardsvlei Supply Area to meet the projected 2015 primary water demand.

Table 5-3 Summary of Additional Bulk Infrastructure Required for Barnardsvlei S/A

Bulk Infrastructure	Location	Diameter (mm)	Unit	Quantity
Pipelines		300	km	13

5.3.4 Koster Supply Area

The Koster Supply Area is supplied from the Elands River and its tributaries. This Supply Area is essentially rural in nature, with no large urban communities, mining or industrial developments. Despite only moderate population growth the water balance study identified surface water shortfalls in the target year 2015. Although sufficient surface water is available in the Crocodile River System (at Vaalkop), the distance from this source is considered to be excessive, and cannot be economically justified in view of the small volumes involved. In future the Koster Supply Area is expected to have to resort to groundwater resources, in order to augment supply.

Each of these contains only a local supply scheme, providing purified water to the town that forms the core of the block. The remaining area consists of farming communities, and is thus totally dependant on groundwater sources.

(1) Koster Supply Block is supplied from Koster Dam on the Koster River, a tributary of the Elands River. Raw water is pumped 16 km northwards from this dam to the purification works in the town of Koster. Future upgrading work will entail extension of the treatment works and the development of groundwater supplies in the vicinity of the town.

(2) Swartruggens Supply Block is supplied from Swartruggens Dam on the Elands River south of the town. Future upgrading works will comprise a small extension of the treatment works.

Table 5-4 below provides a summary of additional bulk infrastructure which will be required for the Koster Supply Area to meet the projected 2015 primary water demand.

Table 5-4 Summary of Additional Bulk Infrastructure Required for Koster S/A

Bulk Infrastructure	Location	Diameter (mm)	Unit	Quantity
Water Treatment Works	Koster		Mld	1.27
Clear Water P.Station	Koster		kld	1,933
Pipelines		140	km	5.0

5.4 Development Planning for the Central Zone

The Central Supply Zone also consists of four separate Supply Areas, ie the Brits Supply Area, the Klipvoor Supply Area, the Rand Water Supply Area and the Temba Supply Area. The Zone is supplied with water from four sources, ie the Crocodile River via Hartbeespoort Dam, the Pienaars and Apies Rivers from the Roodeplaat and Leeukraal dams, the Moretele River via Klipvoor Dam, and the Vaal River via Hartbeeshoek Reservoir (supplied by Rand Water). With the exception of the Rand Water supply via Hartbeeshoek, all of the sources form part of the Upper Crocodile River System, and will be heavily dependant on increasing return flows from the Pretoria-Witwatersrand complex to meet demands in this Supply Zone in future. This heavy reliance on return flows will have an increasingly negative effect on water quality, and special co-operation between the water boards and DWAF will be required to properly monitor and manage water resources quality within the Supply Zone. The individual Supply Areas within the Central Supply Zone are discussed below.

5.4.1 Brits Supply Area

The largest volume of water in the Brits Supply Area is supplied from Brits WTW which is owned and operated by Brits TLC. A further two treatment works draw water directly from Hartbeespoort Dam. Hartbeespoort Dam receives extensive return flows from the Pretoria-Witwatersrand complex, mainly via the Hennops River from the Northern Outfall Works. These return flows are generally increasing at a faster rate than the rise in demand within the Brits Supply Area, and an increasing surplus will develop in future in this system, even after allowing for planned increased transfers to Vaalkop Dam during times of shortfall via the Roodekopies transfer channel. Historically, Magalies Water has not supplied within the Brits Supply Area. This situation will have to be reviewed by DWAF, with a view to rationalizing the areas of supply of water boards within the Study Area.

The Brits Supply Area has been subdivided into two Supply Blocks, each of which was analysed separately.

(1) Brits Supply Block obtains purified water from Brits WTW which is fed from a raw water pumping station on the banks of the Crocodile River, west of Brits. Purified water is pumped from this treatment works into four separate sub-schemes, viz Sonop-

Losperfontein, Brits Town, Lethlabile-Jericho and Mothutlung-Madidi. The first of these sub-schemes serves Sonop and Losperfontein, which are Government correctional and rehabilitational institutions, and is supplied with water under gravity from Brits WTW. Infrastructure serving this sub-scheme has sufficient capacity to meet demands in the year 2015, and no upgrading is envisaged within this time frame.

The second sub-scheme meets all demands within the formally developed town of Brits, including domestic, commercial, institutional and industrial demands. All upgrading of this sub-scheme will be the responsibility of Brits TLC, and will be in response to specific development initiatives within the town, eg the extensions to the industrial areas that are now under way. Upgrading of certain municipal trunk mains will be required for this purpose.

The supply to Lethlabile-Jericho is the sub-scheme within the Brits Supply Area that will require the most upgrading works within the planning horizon of the Study. Although the existing infrastructure is adequate to meet the 1995 demands, additional pumping plant will be required at Brits WTW in order to meet the envisaged demands to the north of Lethlabile. In addition, the rising main between Brits and Lethlabile will have to be reinforced, while new gravity lines are required between the Lethlabile and Jericho Reservoirs. The villages of Lethlabile, Mboloka, Letlhakaneng, Madinyane and Jericho will be served from the new regional scheme.

The final sub-scheme from Brits WTW serves Mothutlung and Madidi. This will provide purified water from Brits all the way to Madidi in the Odi 1 District. The villages of Damonsville, Mothutlung, Oskraal, Ramogoadi (2) and Lerulaneng are all served along the way. Under this sub-scheme, water will be pumped from the treatment plant all the way to the Oskraal Reservoir, on the western boundary of the Rand Water Supply Area. Draw-offs are made along this line towards the town of Damonsville and Mothutlung to the existing reservoirs serving these towns. From Oskraal Reservoir, water gravitates to Madidi Reservoir. The Oskraal Reservoir is at present still connected to the Ga-Rankuwa Industrial Reservoir in the Rand Water Supply Area. This supply will however be terminated, and all future supplies made from Brits. In order to meet the 2015 demands the rising main between Damonsville and Mothutlung will have to be reinforced. A new pipeline is currently being implemented between Mothutlung and the Oskraal Reservoirs. Additional storage is required at Mothutlung, Oskraal and Madidi.

(2) Hartbeespoort Supply Block (Schoemansville and Cosmos) obtains water directly from Hartbeespoort Dam. Two treatment works purify water drawn directly from Hartbeespoort Dam, for distribution within the villages of Schoemansville and Kosmos. These villages operate and maintain the plants as solely local supplies. The only current involvement of Magalies Water in these schemes is to provide advise and co-ordination regarding future planning. The possibility of Magalies Water taking over of these plants in the future, could be considered provided such a take over is in the interests of consumers within the Supply Block. Rand Water supply is made to the southern and eastern fringes of the Hartbeespoort Dam from the Valindaba supply line. The division of supply responsibilities and areas between the two water boards within this Supply Block must still be finalised.

Table 5-5 below presents a summary of additional bulk infrastructure which will be required for the Brits Supply Area to meet the projected 2015 primary water demand.

Table 5-5 Summary of Additional Bulk Infrastructure Required for Brits S/A

Bulk Infrastructure	Location	Diameter (mm)	Unit	Quantity
Water Treatment Works	Brits		Mld	25
	Hartbeespoort		Mld	11.6
Reservoirs	Lethlabile		Ml	10
Pipelines		200	km	23.40
		300 to 400	km	27.30

5.4.2 Klipvoor Supply Area

The Klipvoor Supply Area has no surface water supply scheme at present. This area is essentially rural, and is expected to exhibit slow growth within the planning horison of the Study. In addition, low settlement densities, low income levels and low affordability have, in the past, resulted in little water supply development within this Supply Area. The area falls entirely within the jurisdiction of Eastern District Council, and includes no formal towns. The regional water supply scheme proposed for the Supply Area will necessitate the construction of a new water treatment plant downstream of Klipvoor Dam, which in view of its limited size, will require special consideration during the planning stage. The technical proposals have been prepared on the basis of continuous operation however it may be cost effective to design the treatment plant to only operate during normal working hours, and to staff and support it from an existing Magalies Water management centre (Vaalkop or Temba/Kudube). Water resources planning shows that the fairly minor 2015 primary demands can be met from Klipvoor Dam, without significant negative effects on supplies elsewhere. As described in Sections 4.4 and 4.5, Klipvoor Dam receives extensive return flows, mainly via the Apies River from Rooiwal STW, and via the Pienaars River from Baviaanspoort and Zeekoeigat STW. These return flows are generally increasing at a faster rate than the rise in demand and an increasing surplus will develop in future. Historically, Magalies Water has not operated within the Klipvoor Supply Area, however it has recently taken over management of the rural water supply programme in Odi 1 and Moretele 1 districts from NWWA.

The Klipvoor Supply Area has been subdivided into three Supply Blocks. Under the recommended alternative, all three Supply Blocks will be supplied with purified water from the proposed Klipvoor WTW.

(1) The Klipvoor West Supply Block lies to the south and west of the Klipvoor Dam within Odi 1 District. The division between the supply from Brits and the supply from Klipvoor was taken to be the division previously adopted in the fixed planning of the Lethlabile-Jericho sub-scheme. Water from the treatment plant will be pumped to the Klipvoor West Regional Reservoir. From which it will gravitate to a regional/service reservoir serving the village of Legonyane, filling reservoirs supplying the settlements of Fafung and

Sephai en-route. Ga Rasai will be served by gravity from the Klipvoor West Reservoir to Fafung pipeline, while supplies to Ga Tsogwe, Ga Tsefoge and Kgomo-Kgomo will be pumped from Legonyane Reservoir. All supply infrastructure will be new.

(2) The Klipvoor East Supply Block lies to the east, north-east and south-east of Klipvoor Dam within the Odi 1 and Moretele 1 districts and the Moretele North Supply Block lies in the north-east corner of Moretele 1 District. Under the preferred option, water to the Klipvoor West Supply Block, is pumped in an easterly direction to a regional reservoir at Bollantlokwe. At the Bollantlokwe the pipeline splits with water being pumped through one branch to Slagboom, and eventually Makekeng on the eastern periphery of Moretele North Supply Block, and gravitating southwards along the other branch to Sutelong, from where it is pumped southwards to Rantebeng and Makgabetlwane. At Makgabetlwane the pipeline again splits, with the pumping main continuing in a south westerly direction to Shakung, Buffelsdoorn and Moiletswane; a gravity line feeds from Makgabetlwane in a south-easterly direction to Botshabelo.

As an alternative, the viability of supplying both Klipvoor East and Moretele North Supply Blocks fromTemba WTW was considered. Under this alternative a new pumping station at Temba and a new rising main to Makakeng would be necessary. Although the villages in the two Supply Blocks are linked in the same manner as for the preferred option, the altered source would require that the Slagboom to Makakeng branch be supplied from the opposite direction, with the water being eventually discharged into Bollantlokwe Regional Reservoir. The balance of the supply scheme remains unaltered. The second alternative provided for the Klipvoor East Supply Block to be supplied from the proposed new Klipvoor WTW, and the Moretele North Supply Block to be supplied from Temba WTW. The division between the supply from Kudube and the supply from Klipvoor was taken to be the division previously adopted in the fixed planning of the Moretele 1 Regional Water Supply Scheme. All supply infrastructure would be new. The preliminary costing showed that the proposed option is likely to represent the most economical solution.

Table 5-6 below presents a summary of additional bulk infrastructure which will be required for the Klipvoor Supply Area to meet the projected 2015 primary water demand.

Table 5-6 Summary of Additional Bulk Infrastructure Required for Klipvoor S/A

Bulk Infrastructure	Location	Diameter (mm)	Unit	Quantity
Water Treatment Works	Klipvoor		Mld	3.878
Pumping station	Klipvoor West		kld	731
	Klipvoor East		kld	3,127
	Slagboom		kld	1,171
	Sutelong		kld	889
Reservoirs	Klipvoor West		Ml	1.3
	Sutelong		Ml	1.0
	Bollantlokwe		Ml	0.841
Pipelines		110 to 200	km	183.0

5.4.3 Rand Water Supply Area

The Rand Water Supply Area (consisting of only one Supply Block) is served almost entirely with water imported by Rand Water from its Zuikerbosch WTW below the Vaal Dam. This area is urban and peri-urban in nature, and is expected to exhibit rapid growth characteristics within the planning horizon of the Study. It has had a higher than average level of water supply development in the past. The Rand Water Supply Area covers the entire Soshanguve 1 and 2 Districts, the south-western portion of Wonderboom District and the south-eastern portion of Odi 1 District. Areas of jurisdiction of the Eastern (Brits) DC, the Eastern Services Council (Gauteng) and the Western Services Council (Gauteng) are included in this Supply Area. The major portion of the primary demand however comes from formal urban and peri-urban towns and villages, under the control of TLC's. The supply made by Rand Water is pumped from Zuikerbosch Treatment Works through an extensive distribution system to Klipfontein and Hartbeeshoek Reservoirs. From Hartbeeshoek Reservoir supply is made northwards to the urban and peri-urban areas of Klip-Kruisfontein, Akasia, Rosslyn, Ga-Rankuwa and Ga-Rankuwa Industrial, Mabopane, Soshanguve, Klipan, Rietgat and Winterveld. The supply is at present being upgraded by Rand Water from a capacity of 140Mld (peak day) to 300 Mld (peak day). For purposes of the preliminary planning, it has been assumed that Rand Water will continue its involvement in this Supply Area, but that the supply will be augmented towards the end of the planning horizon from Kudube WTW, to meet the 2015 projected summer day demand of approximately 341 Mld. The water resources availability is such that excess capacity becomes available from the Crocodile River System around 2005. As the augmentation will only be required in the medium to long term, adequate time is available for the various stakeholders to resolve any issues relating to adjusted limits of supply in order to accommodate the proposed supply from Kudube WTW. An option was also investigated under which the entire existing supply by Rand Water would be replaced with an alternative supply from Brits WTW. It is unlikely to be preferable tospend capital to implement a scheme to replace existing infrastructure when other areas remain unserved.

Table 5-7 below presents a summary of additional bulk infrastructure which will be required for the Rand Water Supply Area to meet the projected 2015 primary water demand.

Table 5-7 Summary of Additional Bulk Infrastructure Required for Rand Water S/A

Bulk Infrastructure	Location	Diameter (mm)	Unit	Quantity
Water Treatment Works	Kudube		Mld	41
Pumping Station	Kudube		kld	41,218
Reservoirs	Hartbeeshoek		Ml	138
	Kudube / Temba		Ml	45
Pipelines		110 to 200	km	13.0
		300	km	6.5
		600	km	27.0

5.4.4 Temba Supply Area

The Temba Supply Area is served from the Pienaars and Apies rivers (Roodeplaat and Leeukraal Dams respectively), which are tributaries of the Moretele River and eventually the Lower Crocodile River. This Supply Area is partly urban, partly peri-urban and partly rural, and is expected to exhibit varying growth characteristics within the planning horizon of the Study, depending on the Block under consideration. Portions of the Temba Supply Area fall into the areas of jurisdiction of the Eastern DC (North West Province), Bosveld DC (Northern Province), the Western Regional Services Council (Gauteng Province) and the Eastern Regional Services Council (Gauteng Province). There are existing water treatment works operated by Magalies Water at Wallmannsthal, Temba and Kudube. The Wallmannsthal Treatment Works serves the Wallmannsthal Supply Block. Temba serves the Warmbaths/Nylstroom Supply Block while Temba and Kudube can be viewed as a unit, supplying the two other Supply Blocks in Kudube North and Kudube South. Water resources planning shows that the substantial 2015 primary demands in the Temba Supply Area can be met from the Roodeplaat/Leeukraal Dam system, without significant negative effect on primary or non-primary supplies elsewhere. Both Roodeplaat and Leeukraal Dams receive extensive return flows, mainly via the Apies River from Rooiwal STW, and via the Pienaars River from Baviaanspoort and Zeekoeigat wastewater treatment works. These return flows are generally increasing at a faster rate than the demand. Historically, Magalies Water has not operated within the Kudube North and Kudube South Supply Blocks, but has recently taken over the management of these areas from NWWA. The Temba to Nylstroom supply is also a new scheme, which was recently completed.

The Temba Supply Area has been subdivided into four Supply Blocks . No alternatives exist for supply in this area.

(1) The Kudube North Supply Block follows the east and west banks of the Apies River, between Kudube and Babelegi and the confluence of the Apies and Pienaars rivers. The Block is fed from both Temba WTW (primarily the East Bank supply) and Kudube WTW (West Bank supply). In the medium to long term these two sources may be used in combination, and water can be transferred to either side of the Apies River as required.

At present there is already an inter-connection between the two treatment works. Existing infrastructure supplying the West Bank from Kudube WTW and the regional storage reservoir comprises a pipeline which conveys water northwards to Majaneng, Bosplaas, Dertig, Maticbiestad (with a branch to Thulwe, Witgatboom and Goedgewaagd), Swartbooistad, and Makapanstad. At Makapanstad the pipeline branches to Tladistad and Kwanmatlhwaele in the south and to Moratele, Kontante, Kgomo-Kgomo and Leeukraal in the north. The East Bank supply is made from Temba WTW, via Babelegi Regional Reservoir, northwards to the settlements of Ramotse, Ramokolong, Bosplaas East and Maubane (Wynandskraal). The Babelegi industrial complex and the Carousel casino complex are supplied en-route. Supply is also made southwards from Babelegi Reservoir to Mandela Village and Hammanskraal. A presidential lead project is still on-going within this Supply Block, for the supply of water to the RDP level of service. Initiatives are also under way in places to investigate upgrading from the RDP level of service.

(2) The Kudube South Supply Block lies in the south-western corner of Moretele 1 District, west of Kudube and north of Soshanguve and Winterveld. The Block is fed from Kudube WTW, which can be augmented from Temba WTW as required. Infrastructure supplying the Kudube South Supply Block comprises a bulk pipeline which conveys water westwards to the Regional Reservoir, and on to Matatenteng, Stinkwater, Mogogelo and Nuwe Eesterus. From Nuwe Eesterus Reservoir the pipeline continues under gravity to Ga-Motle, Kwa-Ratsiepane, and Gamoeka. The pipeline then branches with one arm continuing westwards to Mmakaunyane and the other going northwards to Swartdamstad North and Legkraal. As for Kudube North, an RDP level presidential lead project and initiatives to investigate the upgrading from the RDP level of service are underway.

(3) The Wallmannsthal Supply Block mainly supplies small holdings and State institutions such as Baviaanspoort Prison, Roodeplaat Agricultural Research Station, Wallmannsthal Defence Base. Projected demand growth will require a minor expansion of the Wallmannsthal WTW, but no new pipelines or reservoirs are expected to be required. Supply is made to the east and south-eastwards from the treatment works to the various consumers within the Block.

(4) The Warmbaths/Nylstroom Supply Block is supplied from Temba WTW. Water is pumped northwards to supply the formal towns of Warmbaths/Belabela and Nylstroom/Phagameng. This system has only recently been commissioned. The cost of supply to Nylstroom is fairly high and was implemented as a result of the dearth of local resources within the upper Nyl catchment.

Table 5-8 below presents a summary of additional bulk infrastructure which will be required for the Temba Supply Area to meet the projected 2015 primary water demand.