

Department of Water Affairs

Chief Directorate: Integrated Water Resource Planning

Directorate: Options Analysis



**MOKOLO AND CROCODILE (WEST)
WATER AUGMENTATION PROJECT
(MCWAP) FEASIBILITY STUDY:
TECHNICAL MODULE**



FEASIBILITY STUDY TECHNICAL MODULE SUMMARY REPORT

MAIN REPORT

Lead Consultant:



In association with:



LIST OF REPORTS

REPORT NO	DESCRIPTION	REPORT NAME
FEASIBILITY STAGE		
P RSA A000/00/8109	Main Report	MCWAP FEASIBILITY STUDY TECHNICAL MODULE SUMMARY REPORT
P RSA A000/00/8409	Supporting Report 8A	GEOTECHNICAL INVESTIGATIONS PHASE 1
P RSA A000/00/8709	Supporting Report 8B	GEOTECHNICAL INVESTIGATIONS PHASE 2
P RSA A000/00/8509	Supporting Report 9	TOPOGRAPHICAL SURVEYS
P RSA A000/00/8609	Supporting Report 10	REQUIREMENTS FOR THE SUSTAINABLE DELIVERY OF WATER
P RSA A000/00/8209	Supporting Report 11	PHASE 1 FEASIBILITY STAGE
P RSA A000/00/8309	Supporting Report 12	PHASE 2 FEASIBILITY STAGE
PRE-FEASIBILITY STAGE		
P RSA A000/00/8809	Supporting Report 1	WATER REQUIREMENTS
P RSA A000/00/8909	Supporting Report 2	WATER RESOURCES
P RSA A000/00/9009	Supporting Report 3	GUIDELINES FOR PRELIMINARY SIZING, COSTING AND ECONOMIC EVALUATION OF DEVELOPMENT OPTIONS
P RSA A000/00/9109	Supporting Report 4	DAMS, ABSTRACTION WEIRS AND RIVER WORKS
P RSA A000/00/9209	Supporting Report 5	MOKOLO RIVER DEVELOPMENT OPTIONS
P RSA A000/00/9309	Supporting Report 6	WATER TRANSFER SCHEME OPTIONS
P RSA A000/00/9409	Supporting Report 7	SOCIAL AND ENVIRONMENTAL SCREENING
INCEPTION STAGE		
P RSA A000/00/9609	Inception	INCEPTION REPORT

REFERENCE

This report is to be referred to in bibliographies as:

Department: Water Affairs, South Africa, 2008. Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) Feasibility Study, Main Report Feasibility Stage (Summary Report). Prepared by Africon in association with Kwezi V3 Engineers, Vela VKE, WRP Consulting Engineers and specialists.

DWA Report No. P RSA A000/00/8109

REPORT DETAILS PAGE

Project name: **Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP)**

Report Title: **Main Report**

Author: **C Klopper (Africon)**

DWA report reference no.: **P RSA A000/00/8109**

PSP project reference no.: **WP 9528**

Status of report: **Final**

First issue: **December 2009**

Final issue: **September 2010**

PSP

Approved for PSP by:

J Pienaar
Study Leader

PROJECT CO-ORDINATION AND MANAGEMENT TEAM

Approved for Project Coordinator by:

SC Vogel
Project Coordinator & Manager

DEPARTMENT OF WATER AFFAIRS (DWA)

Approved for Chief Directorate: Integrated Water Resources Planning by:

OJS van den Berg
Chief Engineer: Options Analysis North

LS Mabuda
Chief Director: Integrated Water Resources Planning

Preface

The Mokolo (Mogol) River catchment is part of the Limpopo Water Management Area (WMA). The Mokolo River originates close to Modimolle (Nylstroom) and then drains to the north into the Limpopo River. The Mokolo Dam (formerly known as the Hans Strijdom Dam) is the largest dam in the catchment. The dam was constructed in the late 1970s and completed in July 1980, to supply water to Matimba Power Station, Grootegeluk Mine, Lephalale (Ellisras) Municipality and for irrigation downstream of the dam. Based on the water infrastructure, the current water availability and water use allows only limited spare yield existing for future allocations for the anticipated surge in economic development in the area.

There are a number of planned and anticipated consequential developments in the Lephalale area associated with the rich coal reserves in the Waterberg coal field for which additional water will be required. These developments include inter alia the development of further power stations by Eskom, the potential development of coal to liquid fuel facilities by Sasol and the associated growth in mining activities and residential development.

The development of new power stations is of high strategic importance with tight timeframes. Commissioning of the first generation unit will start in September 2010 and additional water needs to be available by mid-2011 according to the expected water requirements. A solution addressing the water needs of the Lephalale area must be pursued. The options to augment existing water supplies include transferring surplus effluent return flows from the Crocodile River (West) (CRW) / Marico WMA to Lephalale and the area around Steenbokpan shown on the map indicating the study area on the following page.

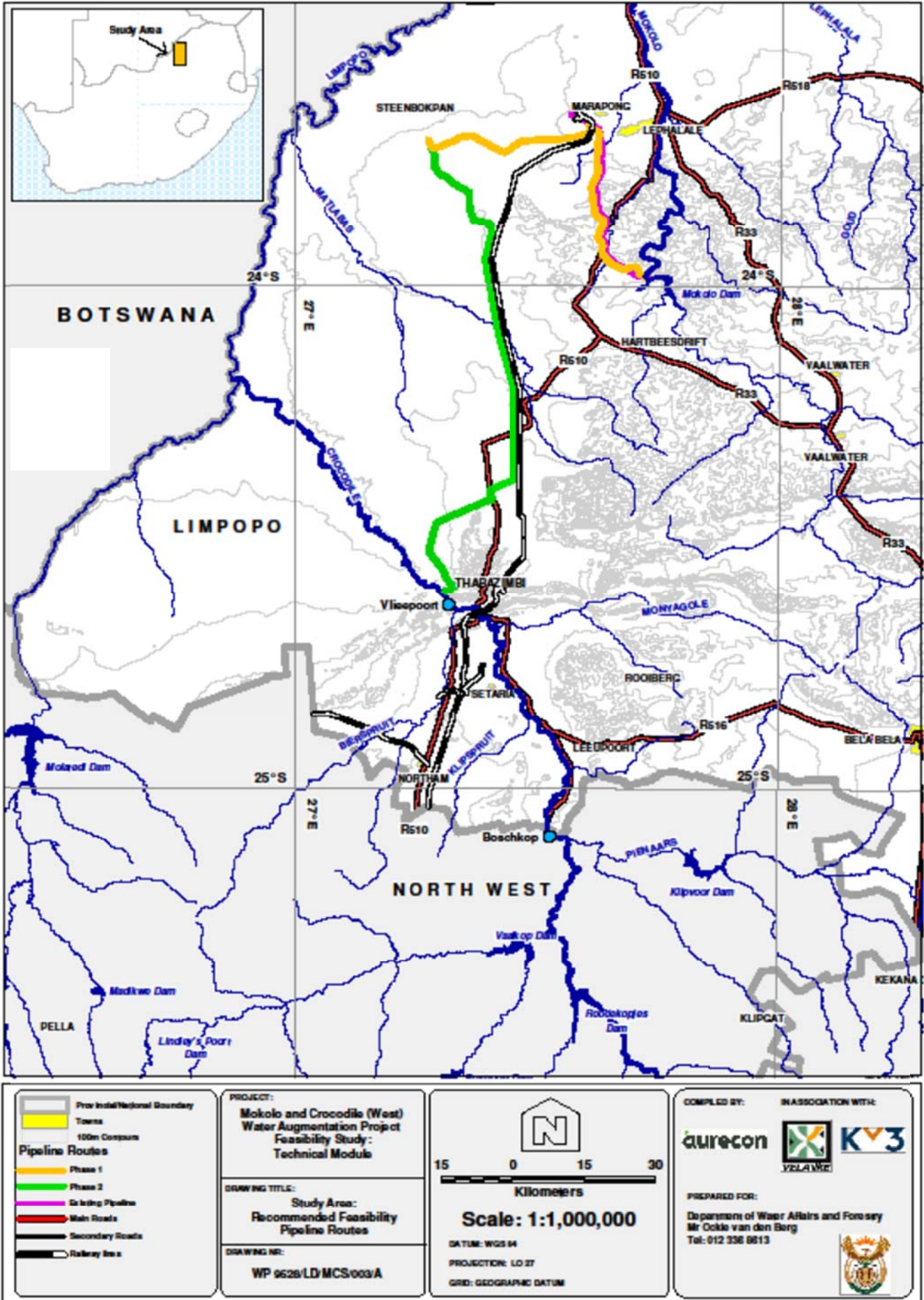
The Department of Water Affairs (DWA) commissioned the Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) to analyse the options for transferring water from the Crocodile River (West). In April 2008, the Technical Module of this study was awarded to Africon in association with Kwezi V3, Vela VKE and specialists. The focus of the Technical Module is to investigate the feasibility of options to:

- Phase 1: Augment the supply from Mokolo Dam to supply in the growing water requirement for the interim period until a transfer pipeline from the Crocodile River (West) can be implemented. Phase 1 must, over the long term, continue to optimally utilise the full yield from Mokolo Dam.
- Phase 2: Transfer water from the Crocodile River (West) to the Steenbokpan and Lephalale area. Options to phase the capacity of the transfer pipeline (Sub-phases 2A and 2B) must be investigated.

The Technical Module has been programmed to be executed at a Pre-feasibility level of investigation to identify different options and recommend the preferred schemes, which was followed by a Feasibility level investigation of the preferred water schemes. Recommendation on the preferred options for Phase 1 and Phase 2 Schemes were presented to DWA during October

2008 and draft reports were submitted during December 2008. The Feasibility stage of the project commenced in January 2009 and considered numerous water requirement scenarios, project phasing and optimisation of pipeline routes. The study team submitted a draft Feasibility report in November 2009.

This report (Main Report Technical Module: MCWAP Feasibility Study, Summary Report P RSA A000/00/8109) provides a summary of the outcomes of all the planning activities performed during both the Pre-feasibility and Feasibility stages and the outcomes of the decisions made in the process that lead to the layout and definition of the components of the proposed Mokolo Crocodile River (West) Water Augmentation Project.



MOKOLO AND CROCODILE RIVER (WEST) WATER AUGMENTATION PROJECT FEASIBILITY STUDY: FEASIBILITY STAGE: MAIN REPORT

EXECUTIVE SUMMARY

BACKGROUND

Lephalale is a relatively small Local Municipality in terms of population and is situated in the south-western part of the Waterberg District Municipality in Limpopo Province.

A very important and relevant feature of Lephalale is the huge coal reserves found in the municipal area, estimated by some sources at 53% of the total reserves of the country. The Grootegeluk Coal Mine is the largest open cast coal mine in the country with the largest coal beneficiation activities in the world, and serves the Matimba Power Station, as well as other domestic and export coal needs. The new Medupi Power Station with a total capacity of approximately 4 800 MW has been approved and construction started in late 2007. At the same time, the Grootegeluk Mine is continuously expanding, while Anglo Coal is implementing a pilot project to establish the feasibility of exploiting Coal Bed Methane extraction. Sasol is presently investigating development of a Coal-to-Liquid fuel plant, and Lephalale is one of the two areas where the development may be located. This, and other potential developments, requires the provision of additional bulk water services for the industrial, mining, domestic and social needs arising directly and indirectly in the area as a result of the industrial development.

WATER RESOURCES

Groundwater - *Three groundwater orientated studies have been initiated in the Lephalale area. The results indicated that the sustainable yield from the boreholes drilled is estimated at 1.7 Million m³/annum.*

It is further estimated that for a short-term two-year use 7.19 Million m³/annum can be abstracted, but will need to be followed by a period of recovery.

Mokolo Dam - *Mokolo Dam is located on the Mokolo River approximately 45 km south-east of Lephalale (formerly Ellisras) in the Limpopo Province. The Mokolo River is a major tributary of the Limpopo River and has a total catchment area of over 8 380 km² with a total natural mean annual runoff (MAR) of almost 300 Million m³. The catchment stretches from the Waterberg Mountains through the upper reaches of the Sand River.*

The Mokolo Dam has a long-term (1:200 year recurrence interval (RI)) yield of 39.1 Million m³/annum of which 10.4 million m³/annum is allocated for irrigation. The remaining 28.7 Million m³/annum is available to supply water to other water users. The

results of a yield analysis conducted for Mokolo dam, which is based on the scenario with the most reliable representation of the current-day situation, are summarised below.

Mokolo Dam Yield Analysis Results

Historic Firm Yield		Yield (Million m³/a), at indicated Recurrence Interval			
(Million m³/a)	Recurrence Interval (years)	1:200	1:100	1:50	1:20
38.7	1:224	39.1	44.6	50.7	66.8

The 1:200 year firm yield available from the Mokolo Dam under current day conditions of land and water use is 39.1 Million m³/annum, and was accepted for further planning purposes.

Crocodile River (West) - The Crocodile River (West) catchment extends northwards from the continental divide in central Johannesburg (where the Crocodile River (West) originates), to the confluence of the Crocodile (West) and Marico Rivers. The catchment area includes part of the Gauteng, North West and Limpopo Provinces. From the confluence of the Crocodile River (West) and Marico River, the river is known as the Limpopo River, which forms the northern border of South Africa with Botswana and then with Zimbabwe, before flowing into Mozambique where it discharges into the Indian Ocean. The total gross catchment area of the Crocodile River (West) is approximately 29 000 km².

PROJECT SCOPE

The intention of the project is to supply water in sufficient quantities and most economically for the anticipated development in the Lephalale/Steenbokpan area. The main components of the MCWAP are:

- Mokolo Dam, located approximately 45 km south-east of Lephalale on the Mokolo River.
- The existing water conveyance system from the Mokolo Dam, consisting of a pump station located at the dam, a rising main, balancing reservoir and gravity main up to the terminal point close the Matimba Power Station; collectively referred to as the Exxaro pipeline.
- The envisaged new water conveyance scheme from Mokolo Dam that will increase the capacity of the existing system.
- A new water transfer scheme from the Crocodile River (West) to the demand area at Steenbokpan, consisting of an abstraction weir at Vlieëpoort, High-lift pump station and balancing dams, rising main, gravity main and terminating in reservoirs at each of the water users.
- The two systems will be interconnected by a reversible west-to-east delivery system with tee-off points onto which the users will connect.

- *The system will be operated as an integrated whole with pressure and flow control at the user terminal reservoirs to ensure operational efficiency and adequate reliability of supply.*
- *Possible future augmentation from the Klip River in the Vaal River Catchment into the Crocodile River (West) catchment, depending on the future (currently unknown) water requirements.*

The objective of this Feasibility Study is to determine the optimum solution for the timely supply of the required quantities of water to the various proposed developments in the Lephale area.

Projected Water Requirements

The current major water users in the study area can be grouped as follows:

- *Urban domestic users: Lephale/Onverwacht/Marapong/Thabo Mbeki;*
- *Scattered domestic users: 38 Villages north of the Lephale River;*
- *Industrial users: Grootegeluk Mine (Exxaro) and Matimba Power Station (Eskom);*
- *Irrigation users: Mainly along the Mokolo-, Lephale- and Limpopo Rivers; and*
- *Rural areas: Farm dwellers.*

The possible additional future water users can be grouped as follows:

- *Urban domestic users: Increase in population in existing towns;*
- *Scattered domestic users: Increase in population in existing villages; and*
- *Industrial users: Eskom's Medupi and additional coal fired power stations, Independent Power Producers (IPPs), Exxaro and other new coal mines, Sasol's Mafutha Plant.*

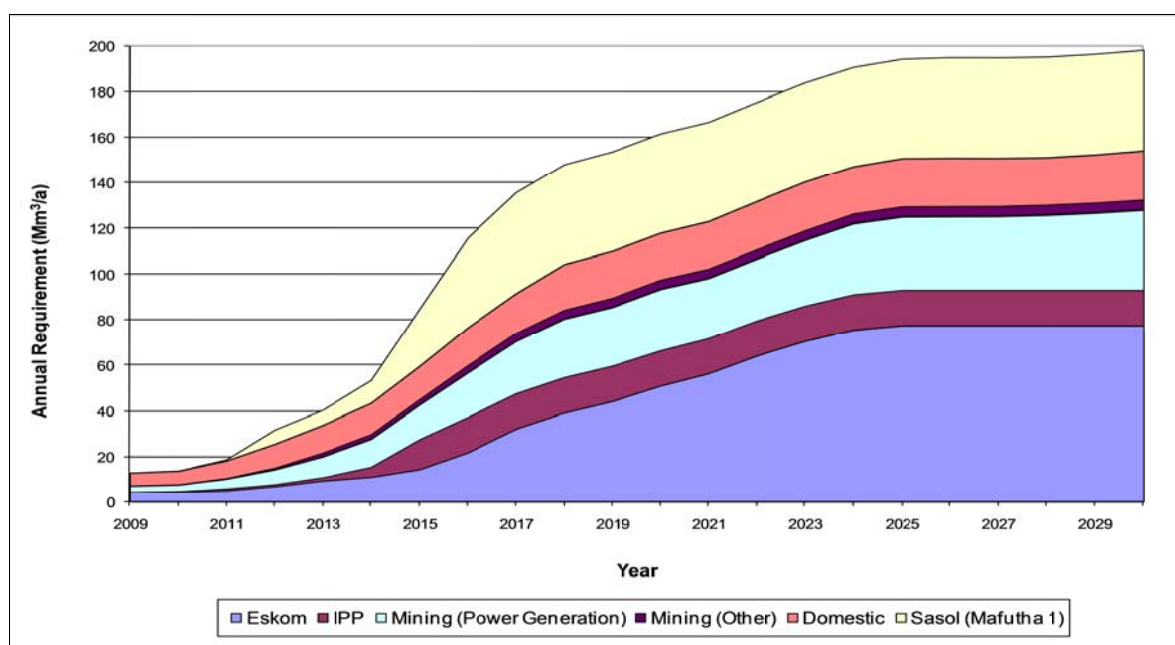
In February 2009, updated water requirements were released and a water requirements scenario (Scenario 9) was used for the Feasibility stage investigation. Scenario 9 incorporates the following water requirements:

- **Eskom:** *Matimba, Medupi plus four additional coal fired power stations (with flue gas desulphurisation (FGD) retrofit for Medupi scheduled for implementation with the first major maintenance shutdown).*
- **Independent Power Producers (IPPs):** *Equivalent of one (1) Eskom power station (starting in July 2010).*
- **Exxaro:** *Matimba coal supply, as well as implementation of projects A to K (expansion of existing and development of a new coal mine).*
- **Additional coal mining:** *Allowance for four (4) additional coal mines each supplying a power station.*
- **Sasol:** *Mafutha 1 Coal-to-Liquid fuel (CTL) plant and associated coal mine (starting in July 2011).*

- **Lephalale and Steenbokpan:** Estimate based on projected growth in households for construction and permanent workforce.

Scenario 9: Water Requirement Projection per Major User Group

Year	Annual Water Requirement (Million m ³ /a)									
	2009	2010	2011	2012	2013	2014	2015	2020	2025	2030
Eskom	4.3	4.3	4.9	6.8	9.3	10.9	14.3	50.9	77.6	77.6
IPP's	0.0	0.4	0.9	0.9	1.5	4.4	13.2	15.6	15.6	15.6
Coal Mining	0.0	0.0	1.1	2.7	4.4	5.3	6.8	14.1	20.0	20.0
Exxaro Projects	3.0	3.2	3.7	4.7	6.6	9.2	10.8	16.9	16.2	19.2
Sasol (Mafutha 1)	0.0	0.0	0.4	6.1	6.6	9.9	25.2	43.5	43.5	44.0
Municipality	5.6	5.9	7.7	10.4	12.0	13.6	14.5	20.4	21.2	21.6
Total	12.9	13.8	18.7	31.7	40.4	53.4	84.8	161.4	194.1	198.0
Irrigation	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4
Total + Irrigation	23.3	24.2	29.1	42.1	50.8	63.8	95.2	171.8	204.5	208.4



Scenario 9: Water Requirement Projection per Major User Group (excluding Irrigation)

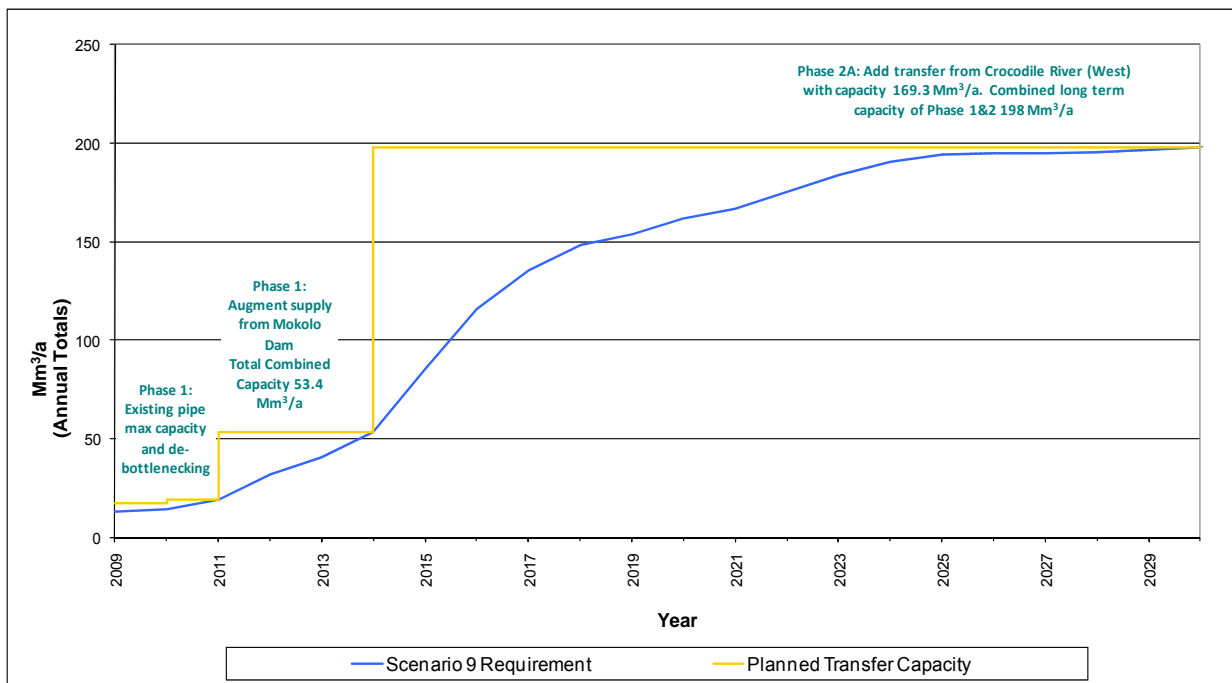
The water requirement scenarios were substantially updated (Scenarios 10a to 10d and 11) to accommodate changes in the implementation planning of the large users. The Feasibility Study was, however, concluded based on Scenario 9 to be in line with the original requirement of DWA. The impact of the changed scenarios were assessed and discussed jointly between the large users and the project team and it was agreed that the eventual design will be based on the final requirement.

Phases Identified

During the Pre-Feasibility Planning phase, it became apparent that a phased development approach is preferred due to the high cost of the development and uncertainty with regards to growth in the water requirements. The following development phases were subsequently defined:

- **Phase 1** – Augment the supply of water from Mokolo Dam to meet the growing needs in Lephale area.
- **Phase 2A** – Transfer water from the Crocodile River (West) to the larger Steenbokpan / Lephale area to further augment the water supplies.
- **Phase 2B** – A future phase for increased supply from the Crocodile River (West) to the larger Steenbokpan / Lephale area.
- **Phase 3** – River conveyance and river management.
- **Phase 4** – Transfer water from the Klip River to the Crocodile River (West) depending on the eventual water requirement, effluent flows and size of Phase 2B.

Phases 2B, 3 and 4 are not reported in this study. The options developed, evaluated and reported on in this document only related to Phases 1 and 2A.



Mokolo and Crocodile River (West) Water Augmentation Project Combined Net Water Requirement and Planned Total Project Transfer Capacity and Implementation Phases

Aspects of Reliability and Redundancy

The strategic importance of the users that will account for the bulk of the water consumption requires that the risk of failure in the supply of water be kept to a minimum. Sufficient reliability and redundancy must therefore be provided in the combined Mokolo and Crocodile River (West) Water Augmentation Project.

It is not feasible or possible to provide absolute reliability, i.e. no risk of an interruption in the delivery of water from a scheme.

In this regard, the schemes shall be sized for 95% reliability, implying that water shall continue to be supplied without interruption even if the scheme is inoperative for up to

18 days of any one year, and the scheme capacity adjusted to allow the full annual requirements to be supplied in 347 days. Eighteen days storage capacity will be designed into the system to ensure that strategic customers will not be exposed to an unduly high risk of supply failure. The storage facilities must be provided by the end users and are therefore excluded from the project cost estimate.

Mokolo Dam Scheme

The following aspects were considered in defining the pipeline routes:

- Abstraction and water supply locations;
- Existing roads, as well as boundaries between land owners along the routes;
- Historical and planned future mining activities in the area, both sub-surface and open cast;
- Site constraints, potential river/stream crossings, road and railway crossings;
- Geotechnical overview;
- Environmental impacts; and
- Social impacts.

The water from the Mokolo Dam is of a much better quality than that from the Crocodile River (West). It was therefore necessary to design and operate the MCWAP system in such a way that the water from the two sources does not mix during normal operation.

The following two most viable options of transferring water from the Mokolo Dam to the end users during Phase 1 have been identified and investigated:

- Construct a weir, abstraction works and a High-lift pump station downstream of Mokolo Dam, as well as a pipeline to deliver water to Zeeland, Matimba and Medupi Power Stations, as well as Steenbokpan; and
- Construct a pump station and new pipeline from Mokolo Dam to Zeeland, Matimba and Medupi Power Stations, as well as Steenbokpan.

The Mokolo Dam pipeline option would follow a route parallel to that of the existing pipeline except for the section from Mokolo Dam to the Wolvenfontein Reservoir where the pipeline will follow the existing access road.

Crocodile River (West) Transfer Scheme

The same aspects that were considered for the Mokolo Dam Scheme were evaluated for the Crocodile River (West) Transfer Scheme. This scheme was also sized to allow for a downtime period of up to 18 days continuous per year.

The following infrastructure components were considered during the Pre-Feasibility assessment of the scheme:

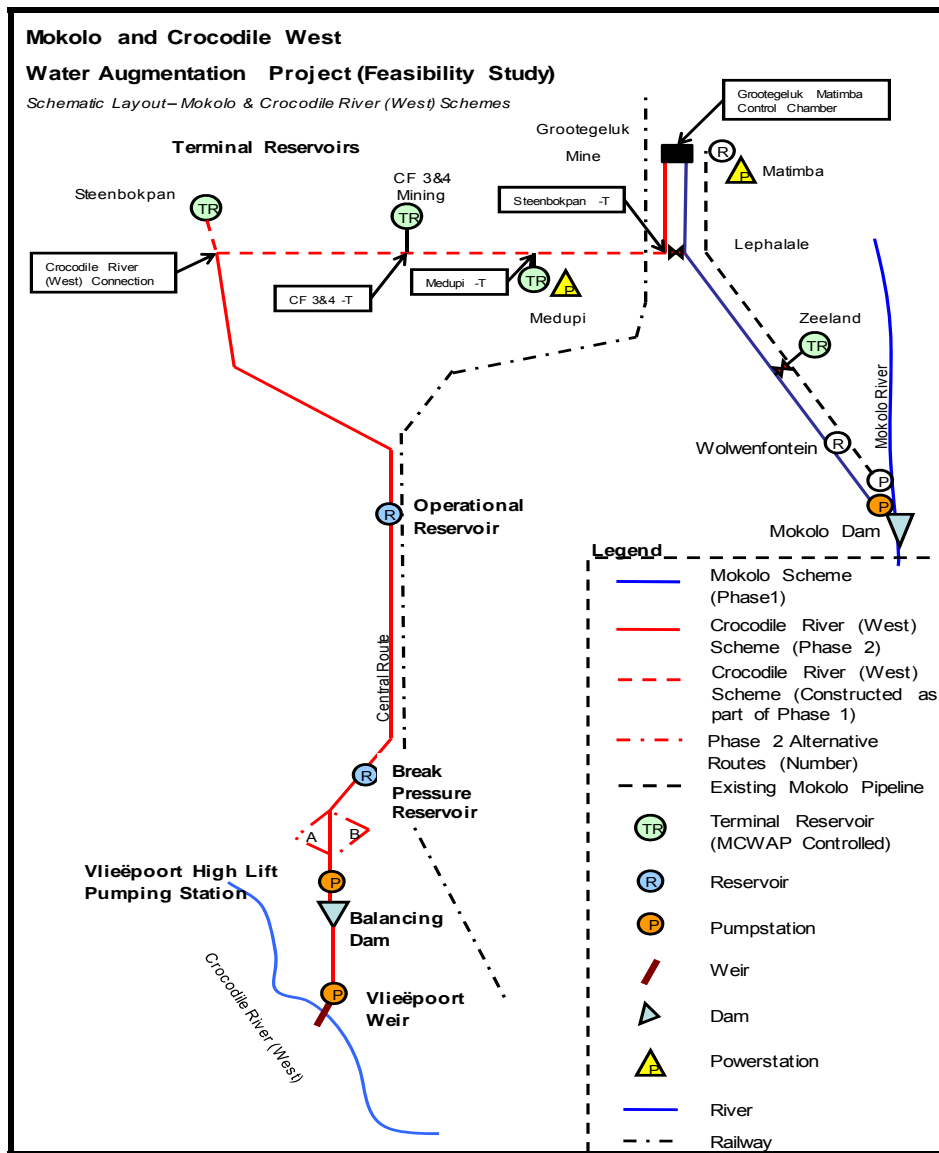
- *Abstraction Weir.* Five sites along the Crocodile River (West) were investigated for appropriateness. Two sites along the Crocodile River (West) (Boschkop and Vlieëpoort) were selected and taken to Pre-Feasibility Study level. Components associated with the abstraction weirs included:
 - Abstraction Pump Stations;
 - Desilting Structures; and
 - Balancing Storage.
- *High-lift pump stations.*
- *Conveyance options.* The following conveyance options and alternatives were considered as part of the pre-feasibility investigation:
 - River conveyance;
 - Canal conveyance; and
 - Pipeline conveyance.
- *A combination of reliability storage and balancing storage options were investigated.*

Options Selected

Based on these findings, the following was recommended for further consideration during the Feasibility stage of the project:

- **Phase 1** – *Mokolo Dam Scheme: Preferred option is a pipeline from Mokolo Dam to Lephale and further to Steenbokpan.*
- **Phase 2** – *Abstraction at Vlieëpoort with a rising main along the Central Route to the position of the Operational Reservoir separating the rising main and gravity main portions of the Crocodile River (West) Transfer Scheme and providing short-term operational balancing storage. From here the water will be gravity fed into on-site Terminal Reservoirs (capacity 18 days + user balancing and emergency storage requirements) at each of the users.*
- **Phase 3** (Not addressed in this report) – *Requirements for the Sustainable Delivery of Water for the stretch of the river impacted by the project. Refer to report P RSA A000/00/8609. Defined as a possible pipeline from Boschkop to Vlieëpoort. This system works was included in the Phase 2 work.*

The preferred options for Phase 1 and Phase 2 are illustrated in the figure below.



Schematic Layout

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

The construction of major civil works and pipelines are listed activities in terms of the National Environmental Management Act 1998 (Act 107 of 1998), which may not commence without environmental authorisation from the competent authority. An environmental screening was conducted under the Feasibility Study to identify the potential environmental impacts of the project. These were reported and subsequently expanded upon in a full Environmental Impact Assessment conducted under a separate assignment of the Department of Water Affairs.

The study further assessed and quantified the most significant socio-economic impacts of the proposed project. The cost of mitigating the environmental and social impacts were determined and considered in the evaluation of alternatives.

OPERATION AND MAINTENANCE

The control and operation of all sites forming part of the MCWAP will be monitored and managed by means of a System Control and Data Acquisition (SCADA) system from a central control room manned on a 24 hour/day basis. The monitoring system must provide adequate planning, operational and costing reports to effectively manage, operate and maintain the system.

The maintenance philosophy must address mechanical, electrical and civil engineering aspects, categorised as follows:

- Routine planned maintenance;
- Major Breakdown repairs; and
- Minor breakdown repairs.

IMPLEMENTATION PROGRAMMES

The key project dates at the time of preparing the report (November 2009) are summarised below.

Project Key Dates

Item No.	DESCRIPTION	Anticipated Programme
1.	Topographical Survey	28 Sep 2009
2.	Detail Geotechnical Investigations P1	14 Aug 2009
3.	Detail Geotechnical Investigations P2A	7 Jun 2010
4.	Environmental Module	13 Sep 2010
5.	User Water Supply Agreements P1	09 Dec 2009
6.	User Supply Agreements P2A	12 June 2011
7.	Procure Engineering Services	31 July 2009
7.	Land Acquisition Phase 1	6 Dec 2010
8.	Land Acquisition Phase 2A	28 Jun 2011
9.	Award Contracts Phase 1	6 Dec 2010
10.	Award Contracts Phase 2A	9 Aug 2011
11.	Water Delivery Phase 1	3 Dec 2012
12.	Water Delivery Phase 2A	12 Aug 2015

MCWAP COST ESTIMATES

The cost estimates included the following:

- Capital costs;

- Energy costs;
- Operation and maintenance costs;
- Raw water costs; and
- Other costs; including environmental, social, land acquisition, engineering design and implementation, etc.

The costs listed above are summarised in the two tables below. The first table includes all the capital costs, and the second table includes all the operation and maintenance costs.

Mokolo and Crocodile River (West) Water Augmentation Project Capital Cost Estimate

Component		Total (R)
Mokolo Dam Scheme – Phase 1		
1.1	Pump Station (Civil, Mechanical and Electrical Work)	135 575 000
1.2	Rising Main	86 540 000
1.3	Gravity Mains	1 232 642 000
1.4	Eskom Electricity to Site	76 430 000
1.5	Compensation	2 170 000
1.6	Environmental and Socio-economic	1 000 000
	Sub Total	1 534 357 000
Crocodile River (West) Transfer Scheme - Phase 2		
2.1	Abstraction Weir, Low-Lift Pump Station, De-silting Works and Balancing Dam	898 687 000
2.2	High-lift pump station	350 544 000
2.3	Rising Main	1 263 545 000
2.4	Gravity Mains	4 932 732 000
2.5	Operational and Break Pressure Reservoir	118 964 000
2.6	Eskom electricity to Vlieëpoort site	156 564 000
	Sub Total	7 721 036 000
	TOTAL COMBINED CAPITAL COST – MOKOLO AND CROCODILE RIVER (WEST) WATER AUGMENTATION PROJECT (Phases 1 and 2A)	9 255 393 000

Mokolo and Crocodile River (West) Water Augmentation Project Annual Operation and Maintenance Costs

Component		Total (R)/a
Mokolo Dam Scheme – Phase 1		
<i>New Phase 1 Works</i>		
1.1	<i>Pump Station (Civil, Mechanical and Electrical)</i>	16 734 000
1.2	<i>Rising Main</i>	376 000
1.3	<i>Gravity Mains</i>	5 359 000
	<i>Existing Exxaro Works</i>	394 000
3.1	<i>Raw Water Costs</i>	58 571 000
	Sub Total	81 434 000
Crocodile River (West) Scheme - Phase 2		
4.1	<i>Abstraction Weir, Low-Lift Pump Station, De-silting Works and Balancing Dam</i>	20 366 000
4.2	<i>High-lift pump station</i>	81 750 000
4.3	<i>Rising Main</i>	3 018 000
4.4	<i>Gravity Mains</i>	11 848 000
4.5	<i>Operational and Break pressure Reservoirs</i>	308 000
4.6	<i>Raw water costs</i>	1 142 408 000
	Sub Total	1 239 332 000
5	Annual River Management Cost	4 500 000
	TOTAL COMBINED ANNUAL O&M COST (2030) – MOKOLO AND CROCODILE RIVER (WEST) WATER AUGMENTATION PROJECT	1 345 632 000

Unit Reference Values

The Unit Reference Value (URV) of water has been determined for a discount rate of 6%, 8% and 10% and is based on the net water transferred to the demand centres for a 45-year period. The Unit Reference Values for the Mokolo and Crocodile River (West) Water Augmentation Project are summarised below. These figures exclude VAT, and are based on April 2008 prices. All discounting was done to 2008 and over a period of 45 years after completion of construction of Phase 2A. Residual values at the end of the period were excluded from the analyses.

Unit Reference Values

Discount Rate	Discounted Present Value of Net Water @ R1/m³ (R)	Discounted Present Value (R)	Unit Reference Value (R/m³)
6%	2 020 000 000	20 462 103 000	10.14
8%	1 410 000 000	15 950 388 000	11.35
10%	1 020 000 000	13 029 165 000	12.72

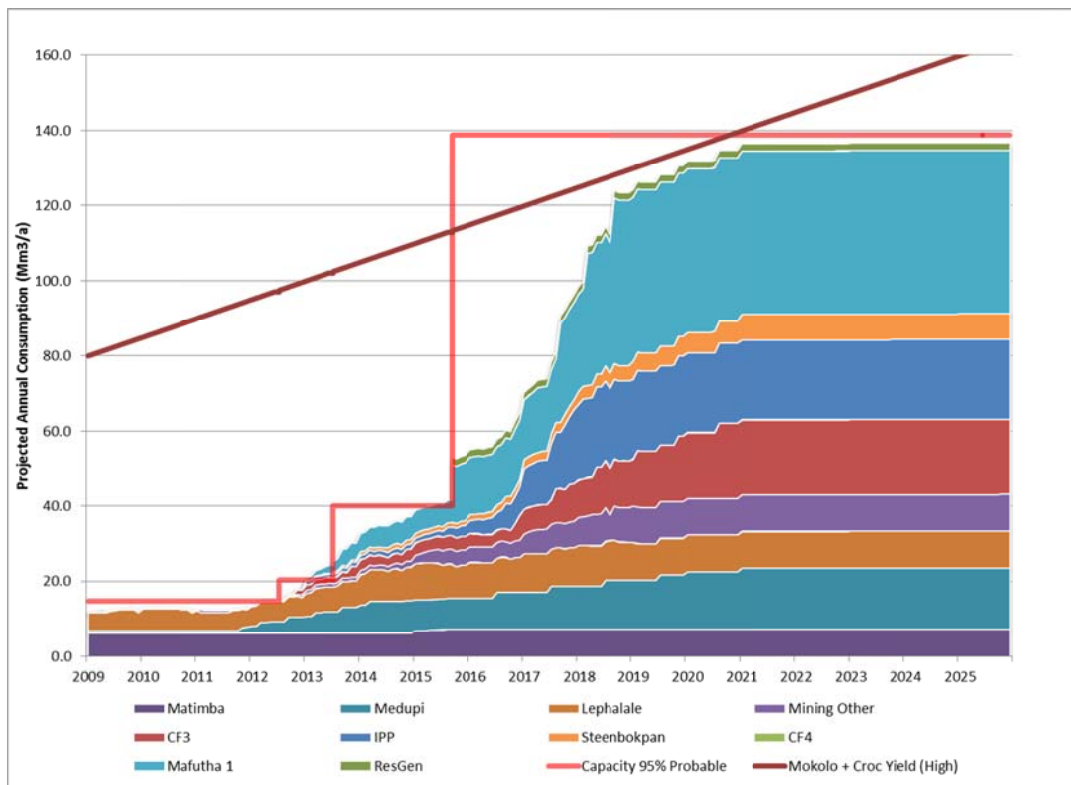
Summary of Discounted Present Values

Discount Rate	Capital (R)	O&M (R)	Total (R/m³)
6%	7 726 136 000	12 733 903 000	20 460 039 000
8%	7 265 744 000	8 682 042 000	15 947 786 000
10%	6 844 128 000	6 181 959 000	13 026 087 000

Changes under Development

Water Requirements for the projects were continually updated during the Feasibility Investigation period to accommodate changes in the planning of the large users. The Project Team decided late in 2009 to correct the requirements to Scenario 9 for the purpose of finalising the feasibility sizing, costing and reporting.

The Project Team, however, continued to assist in the preparation and evaluation of revised water requirement projects, as well as the interpretation of implementation constraints and costing. As such, Scenario 10 was developed and analysed to support the large users at the time in selecting the appropriate scheme capacity and with preparation of their board submissions. Scenario 11 was a further development that considered even further changes. The principles of sizing and costing the infrastructure options for the different scenarios were, however, kept constant throughout. The figure below illustrates the effect of the changed water requirements, i.e. combined scheme capacity reduced to 140 Mm³/a and Phase 2 implementation deferred to 2015.



Scenario 11 Water Requirement – Revised Estimate November 2009

**MOKOLO AND CROCODILE RIVER (WEST) WATER AUGMENTATION
PROJECT FEASIBILITY STUDY:
FEASIBILITY STAGE
MAIN REPORT**

TABLE OF CONTENTS

	PAGE
1 INTRODUCTION AND BACKGROUND	1-1
1.1 Mokolo (Mogol) River Catchment	1-1
1.2 Crocodile River (West) Catchment	1-1
1.3 Lephalale Local Municipality	1-2
1.4 Growth and Rationale for Project	1-2
1.5 Project Scope	1-3
2 STATUS QUO	2-1
2.1 Mokolo River Catchment	2-1
2.2 Crocodile River (West) Catchment	2-2
2.3 Groundwater Resources	2-3
2.4 Mokolo Dam	2-4
2.5 Existing Pump Station and Pipeline	2-5
2.6 Water Quality	2-5
3 PROJECTED WATER REQUIREMENTS	3-1
3.1 Water Users	3-1
3.1.1 Current Users	3-1
3.1.2 Future Additional Users	3-1
3.2 Updated Water User Requirements	3-1
4 RESOURCE AUGMENTATION OPTIONS	4-1
4.1 Groundwater	4-1
4.2 Re-Allocation of Irrigation Water	4-1
4.3 Raising Mokolo Dam	4-1
4.4 Inter-Basin Transfer from Crocodile River (West) Basin	4-2
4.5 Inter-Basin Transfer from Vaal River System	4-3

5	PHASED DEVELOPMENT	5-1
5.1	Phases Identified	5-1
5.2	Aspects of Reliability and Redundancy	5-3
5.2.1	General Criteria	5-4
5.2.2	Reliability Criteria	5-4
5.2.3	Redundancy Criteria	5-6
6	MOKOLO DAM SCHEME	6-1
6.1	Development Options	6-1
6.1.1	Selection and Design Considerations	6-1
6.2	Mokolo Dam Scheme Description	6-6
6.2.1	Pump Station	6-6
6.2.2	Power Supply	6-7
6.2.3	Rising Main	6-7
6.2.4	Gravity Main	6-7
6.2.5	Coating and Lining	6-8
6.2.6	Cathodic Protection (CP) and AC Mitigation	6-8
6.2.7	Existing Infrastructure	6-8
6.3	Geotechnical Aspects	6-8
6.4	Operations and Maintenance	6-9
6.4.1	Optimisation	6-9
6.4.2	Scheduled Maintenance	6-9
6.4.3	Critical Spares	6-10
6.4.4	Operation and Maintenance Philosophy	6-10
7	CROCODILE RIVER (WEST) TRANSFER SCHEME	7-1
7.1	Development Options	7-1
7.1.1	Infrastructure Components	7-1
7.1.2	Route Options	7-1
7.1.3	Options Evaluation	7-4
7.1.4	Conclusions from Options Evaluation	7-8
7.1.5	Sensitivity Analysis	7-10
7.1.6	Options Selected	7-11
7.2	Capacities of Crocodile River (West) Transfer Scheme Components	7-11
7.2.1	River Losses	7-11
7.2.2	River Abstraction Works	7-13
7.2.3	High-Lift Pump Station, Pipelines and Reservoirs	7-16
7.3	River Abstraction Works	7-17
7.3.1	Description of Components	7-17
7.4	High-Lift Pump Station	7-18
7.4.1	Bulk Electricity Connection	7-19
7.5	Pipelines	7-19
7.5.1	Design Considerations	7-19
7.5.2	Cathodic Protection and AC Mitigation	7-22
7.6	Reservoirs	7-23

7.7	Geotechnical Aspects	7-23
7.7.1	Abstraction Works	7-23
7.7.2	Balancing Dam, Silt Trap and High-Lift Pump Station	7-24
7.7.3	Pipeline	7-25
8	ENVIRONMENTAL IMPACT ASSESSMENT INTERFACE	8-1
8.1	Listed Activities	8-1
8.2	Potential Environmental Impacts	8-2
8.3	Environmental Aspects Considered	8-2
8.3.1	General Considerations	8-2
8.3.2	Phase 1 Considerations	8-2
8.3.3	Phase 2A Considerations	8-3
9	SOCIAL IMPACT	9-1
9.1	Loss of Agricultural Land	9-1
9.2	Foreign Work Force and Influx and Efflux of Workers	9-2
9.3	Workers' Camps and Effect on Communities in Vicinity	9-2
9.4	Disruption of Daily Living	9-3
9.5	Safety and Security	9-4
9.6	Impact on Property Values	9-4
9.7	Aesthetic Impacts	9-4
9.8	Employment and Decrease in Local Unemployment Levels	9-4
9.9	Increase in New Business Sales	9-5
9.10	Increased Government Income and Stimulation of Local Economy	9-5
9.11	Increased Standards of Living	9-5
9.12	Transfer of Skills	9-5
9.13	Compensation Costs	9-5
10	INFRASTRUCTURE SUMMARY	10-1
11	IMPLEMENTATION PROGRAMMES	11-1
12	MCWAP COST ESTIMATES	12-1
12.1	Capital Cost Estimates	12-1
12.2	Operation and Maintenance Cost Estimates	12-2
12.3	Unit Reference Values	12-4
13	KEY ISSUES FOR DETAIL DESIGN STAGE	13-1
13.1	Water Requirements	13-1
13.2	Geotechnical Investigations	13-3
13.3	Mokolo and Crocodile River (West) Project infrastructure	13-4

13.4 Phase 2 Alternative Route Alignments	13-9
14 CONCLUSIONS AND RECOMMENDATIONS	14-1
14.1 Introduction	14-1
14.2 Water Requirements and Design Flow	14-1
14.2.1 Water Requirements	14-1
14.2.2 Operation	14-3
14.3 Phase 1	14-3
14.4 Phase 2	14-4
14.4.1 Infrastructure Requirements	14-4
14.5 Operation, Maintenance and Control Philosophies	14-5
14.6 Environmental and Social Aspects	14-6
14.7 Implementation Programme and Cost	14-7
14.7.1 Implementation Programme	14-7
14.7.2 Cost Estimate	14-7
14.8 Further Work	14-7

LIST OF TABLES

	PAGE
Table 2-1: Mokolo Dam Yield Analysis Results.....	2-2
Table 3-1: Scenario 9: Water Requirement Projection per Major User Group.....	3-3
Table 6-1: Mokolo Dam Scheme - Parameters Utilised in the Engineering Economic Analysis.....	6-1
Table 6-2: Interim Scheme Water Balance.....	6-4
Table 6-3: River Bend Weir and Pipeline	6-5
Table 6-4: Pipeline from Mokolo Dam	6-5
Table 6-5: Mokolo Dam Options Comparison	6-6
Table 7-1: Crocodile River (West) Transfer System Route Options	7-3
Table 7-2: Crocodile River (West) Delivery System Route Options	7-3
Table 7-3: Crocodile River (West) Transfer Scheme Options Considered	7-4
Table 7-4: Calculated URVs for Crocodile River (West) Transfer Scheme Options	7-8
Table 7-5: River Losses between Dams and Vlieëpoort	7-12
Table 7-6: Abstraction Works Design Flow and Capacity Parameters	7-14
Table 7-7: Crocodile River (West) Transfer Scheme Design Capacity	7-16
Table 7-8: Vlieëpoort Abstraction Weir Design and Sizing Data	7-17
Table 7-9: Crocodile River (West) High-Lift Pump Station Power Requirements	7-19
Table 7-10: Coating Options.....	7-20
Table 7-11: Long-Term Roughness.....	7-20
Table 7-12: System Hydraulic Assessment.....	7-22
Table 7-13: Geology Summary for Phase 2A Route	7-25
Table 10-1: MCWAP – Summary of Infrastructure Components	10-2
Table 11-1: Project Key Dates.....	11-1
Table 12-1: MCWAP Capital Cost Estimate.....	12-1
Table 12-2: MCWAP Annual Operation and Maintenance Costs	12-3
Table 12-3: Unit Reference Values	12-4
Table 12-4: Summary of Discounted Present Values	12-4
Table 13-1: Scenario 11 - Projected Water Requirements per User (Million m ³ per year)	13-1
Table 14-1: Recommended Coating and Lining Systems	14-2
Table 14-2: Recommended Long-Term Roughness Parameter	14-3

LIST OF FIGURES

	PAGE
Figure 2-1: Crocodile/Mokolo System Balance	2-3
Figure 3-1: Comparison between Scenario 8 and Scenario 9 Water Requirements (excluding Irrigation) ...	3-2
Figure 3-2: Scenario 9: Water Requirement Projection per Major User Group (excluding Irrigation).....	3-3
Figure 3-3: Annual Peak Water Requirements.....	3-4
Figure 3-4: Scenario 11 Water Requirements Projection (November 2009).....	3-5
Figure 5-1: Schematic Layout.....	5-1
Figure 5-2: MCWAP Combined Net Water Requirement and Planned Project Transfer Capacity.....	5-3
Figure 5-3: Scenario 9 Ultimate Projected Water Requirement (40 Years)	5-3
Figure 7-1: Crocodile River (West) Transfer Scheme Options.....	7-2
Figure 7-2: Vlieëpoort Pump Station System Curve.....	7-21
Figure 10-1: Schematic Layout of MCWAP	10-1
Figure 13-1: Cumulative Growth in Water Use and Planned Scheme Capacity (excluding irrigation)	13-2
Figure 13-2: Critical Dates for Commissioning of Phases 1 and 2A	13-3

APPENDICES

Appendix A: Map 1: Mokolo River and Crocodile River (West) Catchments

Map 2: Lephhalale Local Municipality

Appendix B: Long sections Phase 1 and Phase 2A pipelines

Appendix C: Combined URV calculation tables

Appendix D: Memorandum Scenario 10 Water Requirements

Appendix E: Scenario 11 Water Requirements

LIST OF ABBREVIATIONS

AAD	Average Annual Demand
AC	Alternating Electrical Current
BPR	Break Pressure Reservoir
CFD	Computational Fluid Dynamics
CP	Cathodic Protection
CRW	Crocodile River (West)
CTL	Coal to Liquid Fuel
CWRS	Crocodile (West) Reconciliation Strategy
DWA	Department of Water Affairs
EIA	Environmental Impact Assessment
FBC	Fluidised Bed Combustion
FGD	Flue Gas Desulphurisation
FSL	Full Supply Level
HFY	Historic Firm Yield
HV	High Voltage
IGS	Institute for Groundwater Studies
IPP	Independent Power Producer
LDL	Lowest Drawdown Level
MAR	Mean Annual Runoff
MCWAP	Mokolo and Crocodile River (West) Water Augmentation Project
M&E	Mechanical and Engineering
MV	Medium Voltage
MVA	Mega Volt Amperes
MW	Mega Watt
NOC	Non-overspill Crest
NPSH	Net Positive Suction Head
O&M	Operation and Maintenance
OC	Overspill Crest
P&G	Preliminary and General
PMF	Probable Maximum Flood
PSP	Professional Service Provider
RDM	Resource Determined Measures
RI	Recurrence Interval
SANRAL	South African National Roads Agency Limited
SCADA	System Control and Data Acquisition
SEF	Safety Evaluation Flood
SRB	Sulphate Reducing Bacteria

STD	Sexually Transmitted Disease
TLB	Tractor Loader Backhoe
URV	Unit Reference Value
VAPS	Vaal Augmentation Planning Study
VAT	Value Added Tax
VRESAP	Vaal River Eastern Sub-system Augmentation Project
VSD	Variable Speed Drive
WRC	Water Research Commission
WRPM	Water Resources Planning Model
WRYM	Water Resources Yield Model
WSA	Water Services Authority
WTW	Water Treatment Works

1 INTRODUCTION AND BACKGROUND

1.1 Mokolo (Mogol) River Catchment

The Mokolo River is a major tributary of the Limpopo River and has a total catchment area of over 8 380 km² with a total natural mean annual runoff (MAR) of almost 300 Million m³. The catchment stretches from the Waterberg Mountains through the upper reaches of the Sand River, and includes the Mokolo Dam and a number of small tributaries that join the main Mokolo River up to its confluence with the Limpopo River. The only major impoundment in the Mokolo River System is the Mokolo Dam, which is situated near the town of Lephalale (formerly Ellisras), approximately 200 km north-west of Pretoria. The dam, with a total gross storage capacity of 145 Million m³ (68% of its natural MAR) was commissioned in 1980 for the purpose of supplying water to the nearby large industrial users, urban areas and an irrigation scheme located downstream of the dam.

The Mokolo Dam has a long-term (1:200 year recurrence interval (RI)) yield of 39.1 Million m³/a of which 10.4 Million m³/a is allocated for irrigation. The remaining 28.7 Million m³/a is available to supply water to the other water users.

Refer to **Appendix A: Mokolo River and Crocodile River (West) Catchments (No. WP 9528/LD/CS/003)**.

1.2 Crocodile River (West) Catchment

It extends northwards from the continental divide in central Johannesburg (where the Crocodile River (West) originates), to the confluence of the Crocodile River (West) (CRW) and Marico Rivers. The catchment area includes part of the Gauteng, North West and Limpopo Provinces. From the confluence of the Crocodile River (West) and Marico River, the river is known as the Limpopo River, which forms the northern border of South Africa with Botswana and then with Zimbabwe, before flowing into Mozambique where it discharges into the Indian Ocean. The Limpopo River Basin thus is an international basin, shared by South Africa, Botswana, Zimbabwe and Mozambique. The total gross catchment area of the CRW is approximately 29 000 km².

The natural occurrence of both surface and groundwater in the catchment is limited, and those resources are already highly developed and utilised, with little further potential remaining. The water available from resources, naturally occurring in the catchment, is only about 240 Million m³/a, compared to the current total water requirements for water of well in excess of 1 000 Million m³/a. Most of the water used in the catchment is for urban and industrial purposes (representing 50% of the total), followed by irrigation (33%) and mining (8%). The strongest growth in requirements is experienced in the urban/industrial and mining sectors.

The catchment area of the CRW is one of the most developed in the country. It is characterized by the sprawling urban and industrial areas of northern Johannesburg and Pretoria, extensive irrigation downstream of Hartbeespoort Dam and large mining developments north of the Magaliesberg. Approximately 5,5 million people reside in the catchment. Attracted mainly by economic opportunities, strong migration is experienced into the catchment, resulting in a population growth rate of about 1½ times the national average. A strong trend towards further urbanisation is therefore experienced, mainly in the Johannesburg-Pretoria area.

1.3 Lephale Local Municipality

Lephale is a relatively small Local Municipality in terms of population and is situated in the south-western part of the Waterberg District Municipality in the Limpopo Province.

The municipality has been awarded Water Services Authority (WSA) status effective from July 2003, and has one medium sized town, 38 rural villages and a number of very small settlements within its boundaries. It comprise an area of 19 605 km² with a total population of approximately 107 000 people. The largest open cast coal mine and one of the largest coal fired power stations in South Africa can be found in Lephale. Construction of a new coal fired power station has already started and in addition, there are very strong indications that Lephale will experience substantial and rapid growth in industrial activity and population in the immediate future.

The topography can best be described as mostly flat sandy bushveld, with mountains in the south-east. The Municipality is situated between Thabazimbi, Modimolle and Mogalakwena with Blouberg and Musina to the north. It also borders on Botswana along the north-western boundary. Being part of the bushveld, the temperatures are typically hot in summer and mild in winter, and the mean annual rainfall is 410 mm, which falls mainly in the latter part of the summer rainy season.

The Municipality is well known for its tranquil surroundings and rich fauna and flora. Game, cattle and vegetable farming, as well as tourism are the major sources of income and employment.

Refer to **Appendix A**: Waterberg District and Lephale Local Municipality (No. WP9528/LD/CS/002).

1.4 Growth and Rationale for Project

A very important and relevant feature of Lephale is the huge coal reserves found in the municipal area, estimated by some sources at 53% of the total reserves of the country. The Grootegeluk Coal Mine is the largest open cast coal mine in the country with the largest coal beneficiation activities in the world, and serves the Matimba Power Station, as well as other domestic and export coal needs. The new Medupi Power Station, comprising six (6) units with a total capacity of approximately 4 800 MW that has been approved and construction

started in late 2007. At the same time, the Grootegeluk Mine is continuously expanding, while Anglo Coal is implementing a pilot project to establish the feasibility of exploiting Coal Bed Methane extraction. Sasol is presently investigating development options, and Lephalale is one of the two areas where the development may be located. This, and other potential developments, requires the provision of additional bulk water services for the industrial, mining, domestic and social needs arising directly and indirectly in the area as a result of the industrial development.

1.5 Project Scope

The intention of the project is to supply water in sufficient quantities and most economically for the anticipated development in the Lephalale/Steenbokpan area. The main components of the MCWAP are:

- Mokolo Dam, located approximately 45 km south-east of Lephalale on the Mokolo River.
- The existing water conveyance system from the Mokolo Dam, consisting of a pump station located at the dam, a rising main, balancing reservoir at Wolvenfontein and gravity main up to the terminal point close the Matimba Power Station.
- The envisaged new water conveyance scheme from Mokolo Dam that will increase the capacity of the existing system. It will consist of a new pump station, rising main and gravity section that will terminate at the existing Matimba tee-off, with interconnections to the existing infrastructure.
- A new water transfer scheme from the CRW (south of Thabazimbi) to the demand area at Steenbokpan. It will be a pump/gravity system with a weir type abstraction works in the river.
- The two systems will be interconnected by a reversible west-to-east delivery system with tee-off points onto which the users will connect.
- The system will be operated as an integrated whole with pressure and flow control at the user terminal reservoirs to ensure operational efficiency and adequate reliability of supply.
- Management of the CRW System to ensure availability of water in the quantities and levels of assurance congruent with all legal users on the river.
- Possible future augmentation from the Klip River in the Vaal River Catchment into the CRW catchment, depending on the eventual water requirement. It will be a pump/gravity system taking water from a water collection and purification works situated south of Johannesburg on the Klip River.

The objective of this Feasibility Study is to determine the optimum solution for the timely supply of the required quantities of water to the various proposed developments in the Lephalale area.

The objective of this Technical Module was to perform the technical analysis associated with this project and formulate clear recommendations on how to achieve the above. This was

done in close collaboration with the Client and the other study modules (Environmental and Socio-Economic) which form part of the Feasibility Study.

2 STATUS QUO

This section of the report reflects on the current water resource (surface and groundwater) and bulk supply infrastructure. We will focus on the Mokolo and Crocodile River (West) Catchment areas, Mokolo Dam and the existing pump station and pipeline from Mokolo Dam to Lephalale, Matimba Power Station and Grootegeluk Mine.

2.1 Mokolo River Catchment

In order to obtain estimates of the current and future water resources capability of the Mokolo River system, the Department of Water Affairs (DWA) commissioned the Updating of the Hydrology and Yield Analysis Study in the Mokolo River Catchment. The study included the following two components:

- Updating the Hydrology and Yield Analysis in the Mokolo River Catchment: Yield Analysis (WRYM) Study (DWA, 2008a); and
- Updating the Hydrology and Yield Analysis in the Mokolo River Catchment: Planning Analysis (WRPM) Study (DWA, 2008b). This component included a planning analysis with the main objective of developing a detailed Water Resources Planning Model (WRPM) configuration of the entire Mokolo River system.

The main objective of the Yield Analysis- Water Resources Yield Model (WRYM) Study (DWA 2008a) was to approximate the current water resources capability of the Mokolo River System. This process included a detailed system analysis for estimating the long-term yield of the Mokolo Dam for a variety of situations, based on the updated and extended hydrology. The yield analyses results were used in this study.

The WRPM configuration developed as part of the planning analysis (DWA, 2008b) was used in the Pre-Feasibility Study to investigate the management options available and to determine the risks associated with abstracting more water than the long-term yield for short periods and the period of recovery needed for the Mokolo Dam. It is anticipated that the Mokolo Dam will be over abstracted during the initial implementation of Phase 2A. The study also investigated if the implementation of curtailments will be required for the Mokolo Dam to recover in a suitable period after the implementation of the CRW Transfer Scheme (Phase 2A). A second possible failure date of the Mokolo Dam was also investigated for the case where the demand increases beyond the combined supply capacity of the Mokolo and Crocodile River (West) Schemes. This will indicate the latest date by when the second phase of the CRW Transfer Scheme (Phase 2B) would be required.

The Mokolo Dam yield analysis results for the scenario with the most reliable representation of the current-day situation are summarised in **Table 2-1** below. The Historic Firm Yield (HFY) and the long-term stochastic yields at the various RIs are illustrated. The scenario included the catchment developments upstream of Mokolo Dam (at the 2004 development

level), which most importantly included the surface water and groundwater irrigation, small storage dams, weirs and the excavated pits associated with mining activities.

Table 2-1: Mokolo Dam Yield Analysis Results

Historic Firm Yield		Yield (Million m ³ /a), at indicated Recurrence Interval			
(Million m ³ /a)	Recurrence Interval (years)	1:200	1:100	1:50	1:20
38.7	1:224	39.1	44.6	50.7	66.8

From the results it can be seen that the HFY of the Mokolo Dam is 38.7 Million m³/a, which occurs at a high RI of 1:224 years. The 1:200 year firm yield available from the Mokolo Dam under current day conditions of land and water use is 39.1 Million m³/a, and was accepted for further planning purposes. (Note: A 1:200 RI is equivalent to a 99.5% annual reliability of supply).

2.2 Crocodile River (West) Catchment

The DWA initiated a study to develop a reconciliation strategy for the CRW System. This is referred to as the Crocodile (West) Reconciliation Strategy (CWRS) - Report No. P WMA 03/000/00/3608. The CWRS focused on strategies for resolving imbalances between water requirements and water availability in the CRW catchment area. The outcome of the CWRS informed the Project Team regarding the quantity of water that could be transferred to the Lephalale area.

Eight different scenarios of water requirements for the Lephalale area were prepared for this study. The scenarios are the result of several discussions between representatives of DWA, Lephalale Local Municipality, Eskom, Sasol and Exxaro to ascertain the projected water uses for different possible development scenarios.

The eight scenarios are differentiated on the basis of the expected number of power stations, technology used for power stations, the presence of Sasol in the area, the scale of coal mining activities associated with the different levels of industrial development, associated construction activities, and the associated growth in potable and light industrial water requirements. The growth in water requirements were estimated for the period 2007 to 2030, for each of the eight scenarios.

The study commented on the water balance for the Crocodile/Mokolo System by comparing the water requirements scenarios with the modelled yield of water resources (Mokolo Dam + Crocodile River (West) surpluses) in the area. The result for the high growth scenario of effluent return flow into the CRW catchment is depicted in **Figure 2-1** below.

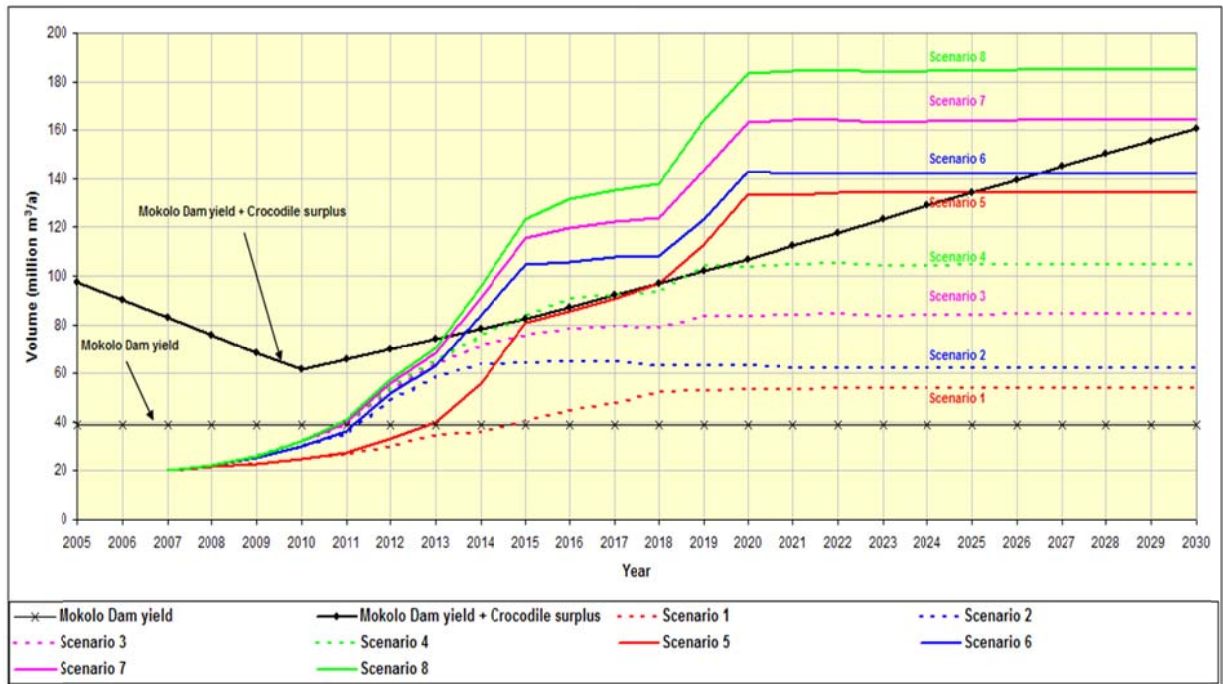


Figure 2-1: Crocodile/Mokolo System Balance¹

The water requirement scenarios were investigated and updated as part of the feasibility Study and the updated scenarios presented in more detail in the Water Requirements report, supporting report No. P RSA A000/00/8809.

The water balances were calculated by subtracting the water requirements from the water availability. Water balances were calculated for the four scenarios (High/Low Population Growth/Demand combinations) for the CRW catchment on its own. It was established that sufficient water will be available for transfer to Lephalale under specific combinations of the growth/demand scenarios, whilst additional transfers from the Klip River will be needed for the balance of scenarios. These combinations are further explored in Section 4.4 of this report.

The conclusion that sufficient water may be available in the CRW to augment the shortfall in the Mokolo River catchment, at least for the initial years of the project, formed the primary motivator for the study.

2.3 Groundwater Resources

Three groundwater orientated studies have been initiated in the Lephalale area and are presently being completed and final results should be available early in 2010.

- i. The Institute for Groundwater Studies at the Free State University (IGS) is conducting a Water Research Commission (WRC) project entitled: An Assessment of how Water Quality and Quantity will be affected by Mining Method and Mining of the Waterberg

¹ Source P WMA 03/000/00/3608

Coal Reserves. This study addresses the potential impact of mining on the occurrence of available groundwater resources.

- ii. An Intermediate Reserve Determination Study for the Mokolo River Catchment (WMA1) is presently being completed by Water for Africa in association with Clean Stream. The primary objective of the study is to implement a Resource Determination Measures (RDM) assessment yielding recharge results at an intermediate level of confidence for the Mokolo sub-catchment.
- iii. The first phase of the hydrogeological assessment by DWA of the secondary fractured aquifer by deep drilling on the fault zones and especially focusing on the Waterberg – Karoo contact fault is being finalised. The results indicated that the sustainable yield from the boreholes drilled is estimated at 1.7 Million m³/a. It is further estimated that for a short-term two-year use, 7.19 Million m³/a can be abstracted, but will need a few years to recover.

2.4 Mokolo Dam

Mokolo Dam is located at latitude 23°58'30" and longitude 27°43'30" on the Mokolo River, approximately 45 km south-east of Lephalale in the Limpopo Province. It is classified as a Category III dam.

The dam consists of a composite rock-fill embankment with a zoned clay core between sand, gravel and Bidim filters. The spillway is located in a cutting into the mountain on the right bank and consists of a fixed crump concrete spillway with three different sill levels.

An inlet tower located upstream to the left of the earth embankment allows for water to be abstracted via two vertical stacks that allow for compensation releases, as well as for irrigation and domestic use. A series of outlet pipes are connected to the stacks and bifurcate at the downstream section to the river and to a pump station 100 m downstream of the dam on the left river bank. A de-silting (scour) outlet has been provided.

The main features of the dam when constructed were:

- | | |
|---|----------------------------|
| • Non-overspill crest (NOC) level: | RL 922 m |
| • Full supply level (FSL) at lowest spillway crest: | RL 912 m |
| • Effective spillway crest length: | 200.00 m |
| • Riverbed level: | RL 867.00 m |
| • Lowest foundation level: | RL 865.00 m |
| • Lowest drawdown level: | RL 879.00 m |
| • Height of dam above lowest foundation: | 57.00 m |
| • Length of embankment crest: | 525 m |
| • Water surface area at FSL: | 838.73 ha |
| • Storage capacity between lowest drawdown level (LDL) and FSL: | 146 Million m ³ |

Provision was made in the original design to raise the embankment crest and FSL by 12.0 m. Raising the spillway by up to 7.0 m by means of spillway crest gates was also considered to be possible.

2.5 Existing Pump Station and Pipeline

The existing water supply scheme from the Mokolo Dam to Lephalale, Matimba Power Station and the Grootegeluk Mine consists of a pump station at the Mokolo Dam pumping water to Wolvenfontein Reservoir from where it gravitates to a T-off point at Zeeland Water Treatment Works (WTW) and further to Matimba.

The infrastructure of the existing Mokolo Dam Water Supply Scheme is generally in a good condition for its age with some repair works proposed on sections of the pipeline. The scheme comprises the following infrastructure:

- Pump station at Mokolo Dam - 3 duty pumps with total capacity of 820 l/s;
- Rising main to Wolvenfontein Reservoir - 700 mm diameter steel pipeline;
- Gravity main from Wolvenfontein Reservoir to Zeeland WTW - 700 mm diameter steel pipeline; and
- Gravity main from Zeeland WTW to Matimba - 600 mm diameter steel pipeline.

The free flow capacity of the gravity main between Wolvenfontein and Zeeland WTW – 570 l/s converting to a capacity of 14.7 Million m³/a. The friction coefficient of the gravity pipeline was calculated as $k = 0.5\text{mm}$.

It is envisaged that the entire existing pipeline will be refurbished in 2015 after commissioning of the CRW Transfer Scheme. The extent and feasibility of the works required was however not assessed.

2.6 Water Quality

The quality of water from these sources varies greatly. The water being abstracted from Mokolo Dam is considered to be of good quality and require only basic treatment to render it suitable for domestic use. The water to be abstracted from the CRW, however, is known to be of poor quality. This water, being return flows from WTWs has a high organic content and will require treatment to render it suitable for industrial and domestic purposes. The Feasibility Study has considered these factors and planned the infrastructure such that the water will not be mixed. This implies that supply to Zeeland WTWs will only be from Mokolo Dam as these works are not equipped to treat water with a high organic content. The WTWs to be constructed at Steenbokpan must be designed according to the quality parameters of the CRW water. The quality of deep aquifer ground water was found adequate for blending with domestic water.

3 PROJECTED WATER REQUIREMENTS

3.1 Water Users

3.1.1 Current Users

The present major water users in the study area can be grouped as follows:

- Urban domestic users: Lephalale/Onverwacht/Marapong/Thabo Mbeki;
- Scattered domestic users: 38 villages north of the Lephalale River;
- Industrial users: Grootegeluk Mine (Exxaro) and Matimba Power Station (Eskom);
- Irrigation users: Mainly along the Mokolo-, Lephalale- and Limpopo Rivers; and
- Rural areas: Farm dwellers.

3.1.2 Future Additional Users

The possible additional water users can be grouped as follows:

- Urban domestic users: Increase in population in existing towns;
- Scattered domestic users: Increase in population in existing villages; and
- Industrial users: Eskom's Medupi and additional coal fired power stations, Independent Power Producers (IPPs), Exxaro and other new coal mines, Sasol's Mafutha Plant.

3.2 Updated Water User Requirements

Two water requirement scenarios were analysed at Pre-Feasibility stage for the period up to 2030:

Scenario 4 – Matimba Power Station, Medupi Power Station equipped with flue gas desulphurisation (FGD) technology, three (3) additional new power stations (FGD), coal supply to five (5) power stations, Exxaro projects, the associated construction activities and the associated growth in Lephalale and Steenbokpan.

Scenario 8 – Scenario 4 + Sasol development of two coal to liquid fuel (CTL) plants and the associated mine construction activities and the associated population growth in Steenbokpan.

In February 2009, updated water requirements were released and Scenario 8 was superseded by Scenario 9, which was subsequently used for the Feasibility stage investigation. The detailed water requirement calculation sheets are included in Supporting Report 12 – Technical Module: Phase 2 Feasibility Stage (No. P RSA A000/00/8309).

Scenario 9 incorporates the following water requirements:

- **Eskom:** Matimba (Fluidised Bed Combustion (FBC)), Medupi plus four (4) additional coal fired power stations (the FGD retrofit for Medupi was scheduled for the first major shutdown).
- **Independent Power Producers (IPPs):** Equivalent of one (1) Eskom power station (starting in July 2010).
- **Exxaro:** Matimba coal supply, as well as implementation of projects A to K (new coal mines).
- **Coal mining:** Allowance for 4 additional coal mines, each supplying a power station.
- **Sasol:** Mafutha 1 CTL plant and associated coal mine (starting in July 2011).
- **Lephalale and Steenbokpan:** Estimate based on projected growth in households for construction and permanent workforce.

Return flows (estimated to be approximately 10.8 Million m³/a in 2030) were recognised but not included as a potential source in the estimated transfer capacities given above.

A comparison between the Scenario 8 and 9 water requirements is illustrated by **Figure 3-1** and the relative contributions by the respective users for Scenario 9 are summarised in **Table 3-1** and illustrated by **Figure 3-2**.

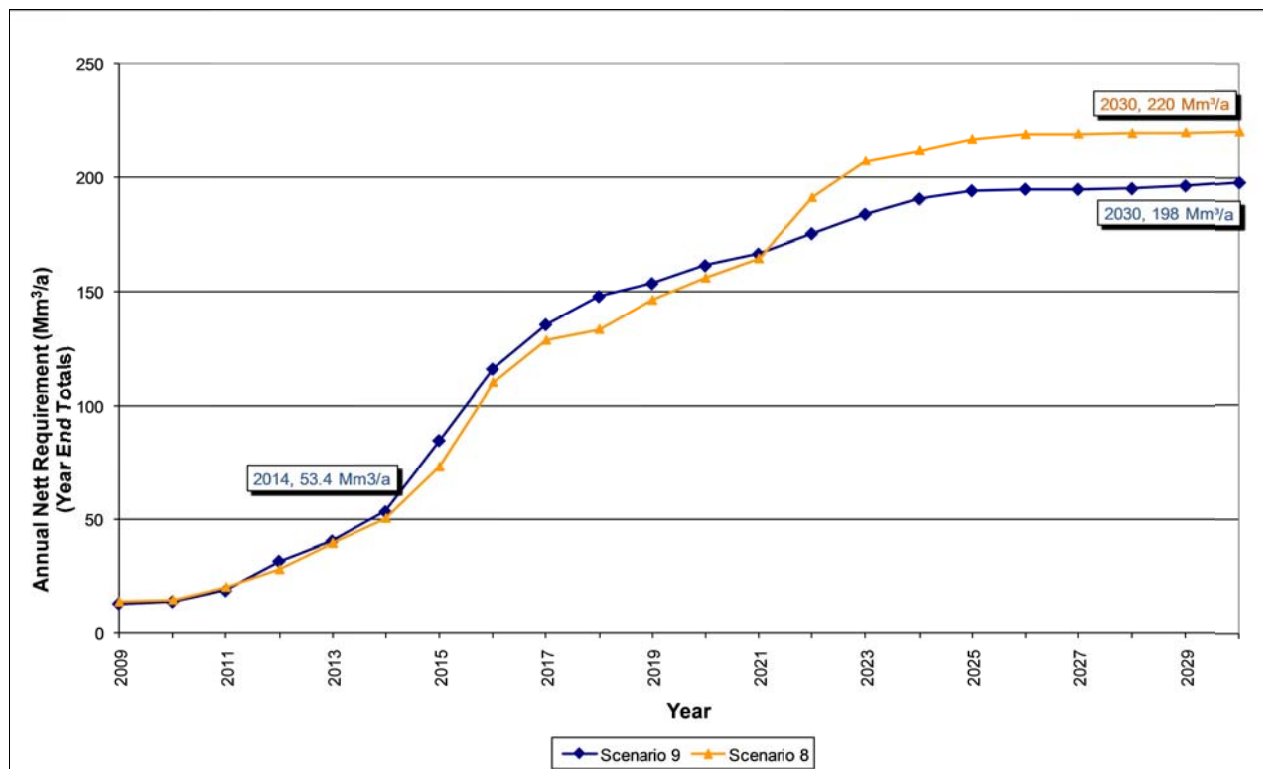


Figure 3-1: Comparison between Scenario 8 and Scenario 9 Water Requirements (excluding Irrigation)

Table 3-1: Scenario 9: Water Requirement Projection per Major User Group

Year	Annual Water Requirement (Million m ³ /a)									
	2009	2010	2011	2012	2013	2014	2015	2020	2025	2030
Eskom	4.3	4.3	4.9	6.8	9.3	10.9	14.3	50.9	77.6	77.6
IPPs	0.0	0.4	0.9	0.9	1.5	4.4	13.2	15.6	15.6	15.6
Coal Mining	0.0	0.0	1.1	2.7	4.4	5.3	6.8	14.1	20.0	20.0
Exxaro Projects	3.0	3.2	3.7	4.7	6.6	9.2	10.8	16.9	16.2	19.2
Sasol (Mafutha 1)	0.0	0.0	0.4	6.1	6.6	9.9	25.2	43.5	43.5	44.0
Municipality	5.6	5.9	7.7	10.4	12.0	13.6	14.5	20.4	21.2	21.6
Total	12.9	13.8	18.7	31.7	40.4	53.4	84.8	161.4	194.1	198.0
Irrigation	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4
Total + Irrigation	23.3	24.2	29.1	42.1	50.8	63.8	95.2	171.8	204.5	208.4

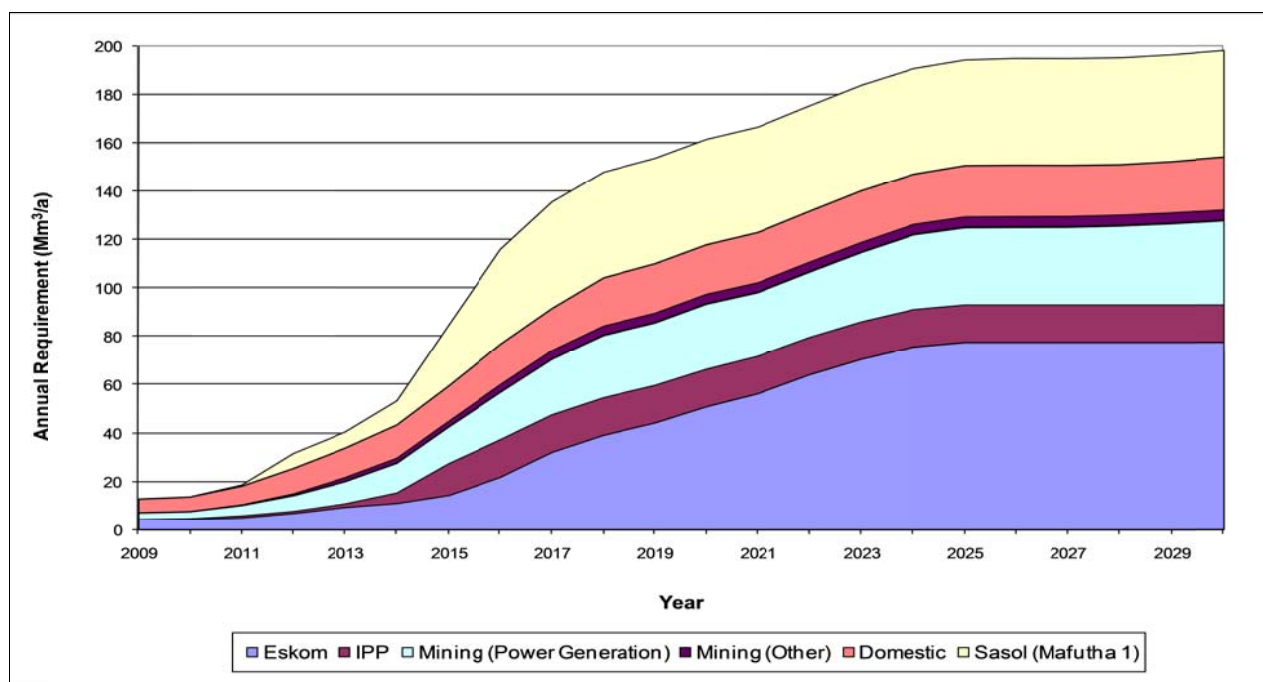


Figure 3-2: Scenario 9: Water Requirement Projection per Major User Group (excluding Irrigation)

The expected annual peak requirements on the system were analysed as part of the Pre-Feasibility investigation (refer to **Figure 3-3**). Peak flow requirements have been applied to the monthly water requirement for Eskom and Lephalale Municipality. The peak factor included for Eskom is based on historic measurements supplied by Eskom for Matimba Power Station, which indicates that a 25% consumption peak is experienced annually from August to October. Monthly peaks included for Lephalale Municipality are based on historic flow measurements taken at Zeeland WTW. The resultant monthly peak flow requirement, based on the annual average daily demand for the total scheme, is 9%.

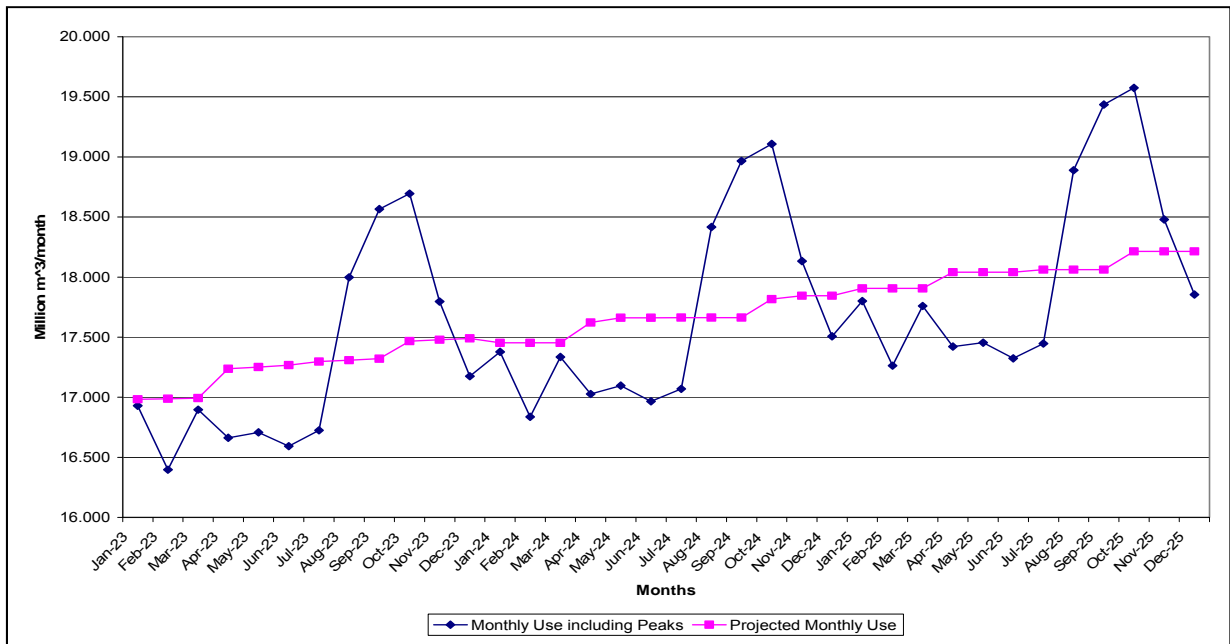


Figure 3-3: Annual Peak Water Requirements

The design capacity of the Phases 1 and 2A infrastructure components must allow for this peak factor. It was determined that the redundancy peak requirement set for the scheme (20% on total water annual water transferred) is sufficient to accommodate these individual peaks.

At the time of compiling this report, the water requirements were being reviewed by the large users and two further scenarios were developed (Scenarios 10 and 11) to support the large users with selecting the appropriate scheme capacity and with preparation of their board submissions. The Feasibility reports were, however, finalised based on Scenario 9 and it is therefore recommended that the Professional Service Provider (PSP) be tasked with detailed design of the infrastructure review on the above water requirements. The principles of sizing and costing the infrastructure options for the different scenarios were, however, kept constant throughout. **Figure 3-4** below illustrates the effect of the changed water requirements, i.e. combined scheme capacity reduced to 140 Mm³/a and Phase 2 implementation deferred to 2015. The reader is referred to **Annexures D** and **E** for the detail of the revised water requirement scenarios.

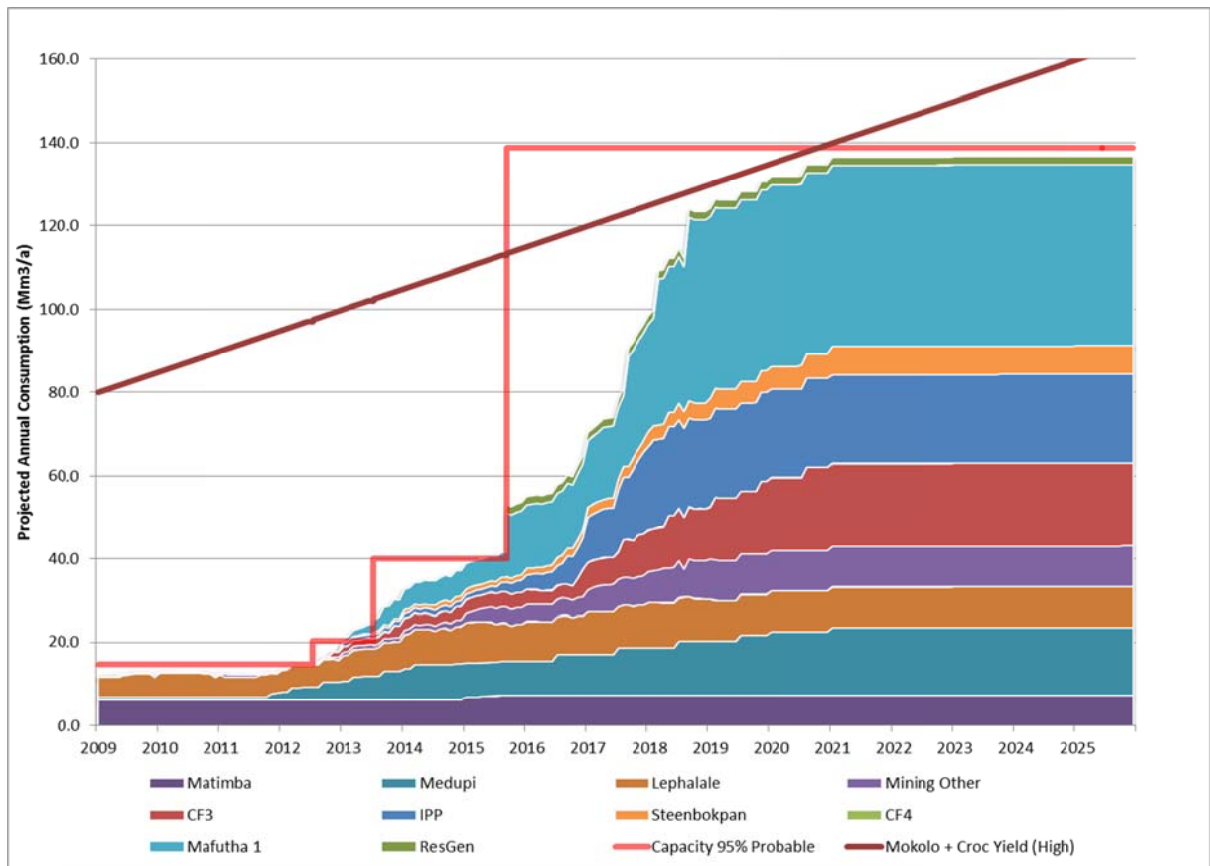


Figure 3-4: Scenario 11 Water Requirements Projection (November 2009)

4 RESOURCE AUGMENTATION OPTIONS

Based on the results of the planning analyses undertaken, it can be concluded that if the water requirement projection **Scenario 9** were to realise a form of water supply augmentation would be required before the end of 2014.

The 1:200 year firm yield available from the Mokolo Dam under current land- and water use conditions is 39.1 Million m³/a, but the estimated demand (including irrigation) is 63.8 Million m³/a (by 2014) and 208,4 Million m³/a (by 2030). Thus, an initial shortfall of 24,7 Million m³/a plus losses and an ultimate shortfall of 169,3 Million m³/a plus losses is anticipated.

A number of resource augmentation options were considered and these are highlighted below.

4.1 Groundwater

The first phase of the groundwater assessment focused on the fault zones and especially on the Waterberg – Karoo contact fault zone. There are other fault structures more distant from Lephalale that can be investigated. However, the cost of Feasibility Studies and implementation need to be assessed. The second phase of the hydrogeological assessment by DWA of the secondary fractured aquifer in the fault zone is artificial recharge of treated waste water. Recharge of the aquifer with treated storm water or sewage effluent will provide a good source of water in this aquifer. This study will only be completed in the 2010. The other potential groundwater resources in the area are the alluvial aquifers along the Mokolo and Crocodile (West) Rivers. The flow of groundwater, mostly irrigation return flows, from the shallow, underlying fractured aquifer systems to the alluvial aquifer systems seems to be insignificant. The alluvial aquifers are recharged by river flow and therefore do not constitute significant additional resources and are already exploited by the irrigators. Any other use will be in competition with irrigation and will need considerable debate.

4.2 Re-Allocation of Irrigation Water

Irrigation water could be re-allocated (through purchase or temporary lease) to the developments in Lephalale. Such irrigation areas could be located either upstream or downstream of the Mokolo Dam. The current allocation of irrigation water downstream of the Mokolo Dam is 10,4 Million m³/a. This option will not provide sufficient water to supply the water requirements in 2030. Any water acquired upstream of Mokolo Dam will be difficult to manage to ensure that it is available in the dam.

4.3 Raising Mokolo Dam

Preliminary investigations done under this study concluded that the yield of the dam, if raised by 12 m, could increase by about 17 Million m³/a at a 1:200 year assurance of supply. This is not sufficient to meet the projected water requirements in 2030. The estimated cost

exceeds R 1 billion and is not considered a cost effective measure compared to the alternatives. The time required for international agreements to be reached on the impacted water resources were considered too long to implement the raising of the dam wall within the time limits for Phase 1.

4.4 Inter-Basin Transfer from Crocodile River (West) Basin

Given that the growth in water requirements for the main urban centres (Johannesburg, Midrand, Pretoria, Rustenburg) will continue to be supplied from the Vaal River System via the Rand Water network, and the commensurate growth in urban return flows towards the CRW and its tributaries, sufficient water is expected to be available to meet all the requirements for water in the CRW catchment until 2030 for most of the scenarios analysed. Refer to DWA Report No. P WMA 03/000/00/3608 – Crocodile (West) River Reconciliation Strategy: Version 1.

Return flows to the CRW are discharged into various tributaries. These all converge upstream and at the confluence of the Pienaars River with the Crocodile River, which offers the opportunity for large scale abstraction (such as for the Lephalale area) and possible regulation downstream of that point.

For the high population growth, medium efficiency scenario; there could be enough surpluses in the CRW catchment to supply the projected water requirements for Lephalale Scenarios 1 to 4 (refer to **Figure 2-1**). For Scenarios 5 and 6, an interim deficit is projected, whilst Scenarios 7 to 9 need to be supplemented with water from elsewhere. Although some other interim measures may be taken, the long-term solution would probably be that water be transferred from the Vaal River System.

For the base population growth, medium efficiency scenario; there could be enough surpluses in the CRW catchment to supply the projected water requirements for Lephalale Scenarios 1 and 2. Scenario 3 would experience a small interim deficit, whilst Scenarios 4 to 9 need to be supplemented with water from the Vaal River System.

For the low population growth, medium efficiency scenario; there would only be enough surpluses in the CRW catchment for Lephalale Scenario 1. The remainder needs to be supplemented with water from the Vaal River System.

For the high population growth, high efficiency scenario; there should be enough surpluses in the CRW catchment for Lephalale Scenario 1. Scenarios 2 to 9 will need to be supplemented with water from the Vaal River System.

The water requirement forecast in Scenario 11 (**Figure 3-4**) is lower, thus augmentation may not be required. This will be confirmed by the resources determination study and the actual requirements at the time of finalising the design of Phase 2a.

4.5 Inter-Basin Transfer from Vaal River System

The transfer of water from the Vaal River System for use in the CRW catchment (potable water via Rand Water network) continues to grow for all the scenarios.

Should the need for water transfer from the CRW catchment to the Lephalale area be taken into account, together with the effluent flows from the Rand Water transfers to the CRW catchment, the low water use scenarios in the CRW catchment also result in the lowest total transfers from the Vaal River System, despite the need for additional augmentation (raw water) in the Lephalale area to meet the growing needs.

5 PHASED DEVELOPMENT

5.1 Phases Identified

The primary purpose of the MCWAP was to investigate the options to transfer water from the Mokolo and Crocodile River (West) to the Lephalale and Steenbokpan areas to supply the primary and industrial users in this fast developing area.

Various options were identified to convey water to the end users. These included the CRW Transfer Scheme, as well as the Mokolo Dam Conveyance Scheme. The latter is intended to supply the interim water requirements for a period until the CRW Transfer Scheme has been constructed and to continue supplying a reduced quantity of water thereafter and to support the reliability and redundancy requirements once the CRW Transfer Scheme is operational. The MCWAP is illustrated below in **Figure 5-1**, showing the different components forming part of the project.

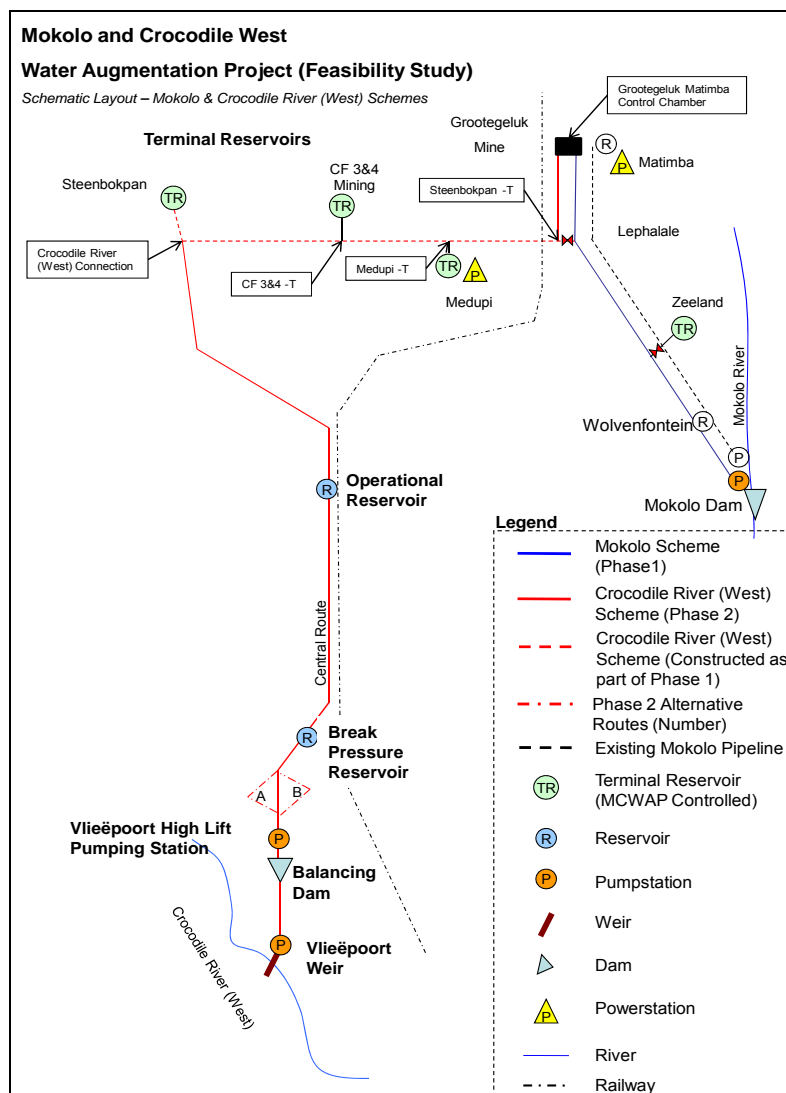


Figure 5-1: Schematic Layout

During the Pre-Feasibility Planning phase, it became apparent that a phased development approach is preferred due to the high cost of the development and uncertainty with regards to growth in the water requirements. The following four development phases were subsequently defined:

- **Phase 1** – Augment the supply of water from Mokolo Dam to meet the growing needs in Lephalale area.
- **Phase 2A** – Transfer water from the CRW to the larger Steenbokpan / Lephalale area to further augment the water supplies.
- **Phase 2B** – A future phase for increased supply from the CRW to the larger Steenbokpan / Lephalale area.
- **Phase 3** – River conveyance and river management.
- **Phase 4** – Transfer water from the Klip River to the CRW, depending on the eventual water requirement, effluent flows and size of Phase 2B.

Phases 2B, 3 and 4 were not included in this study. Options developed, evaluated and reported on in this document only related to Phases 1 and 2A.

It should further be noted that return flows from the water users being supplied by the MCWAP (estimated to be approximately 10.8 Million m³/a in 2030, depending on the actual water requirements) were not included as a potential local source of water in the estimated transfer capacities.

For additional support information, refer to Supporting Report 1 – Technical Module: Water Requirements (No. P RSA A000/00/8809) and Supporting Report 12 – Technical Module: Phase 2 Feasibility Stage (No P RSA A000/00/8309). The combined net water requirement and planned transfer capacity of the project is illustrated in **Figure 5-2**. (Based on Scenario 9 – detailed design will be based on Scenario 11 or any later scenario that may be agreed).

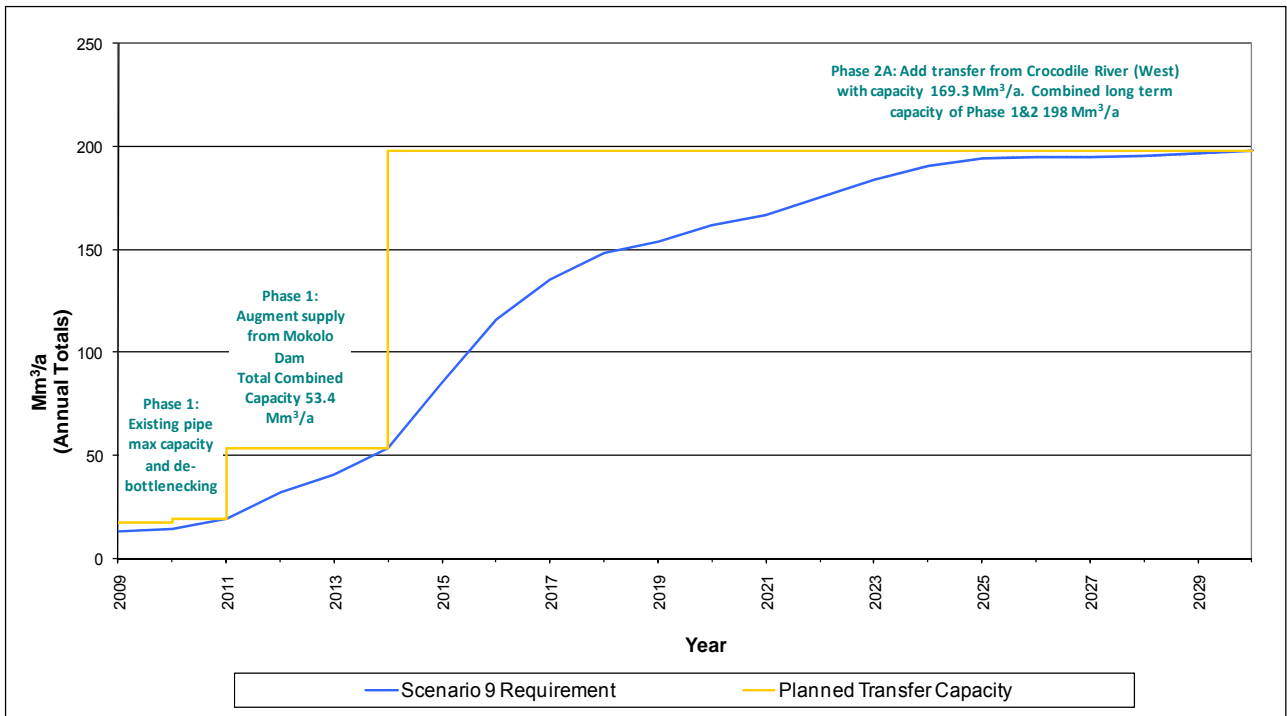


Figure 5-2: MCWAP Combined Net Water Requirement and Planned Project Transfer Capacity

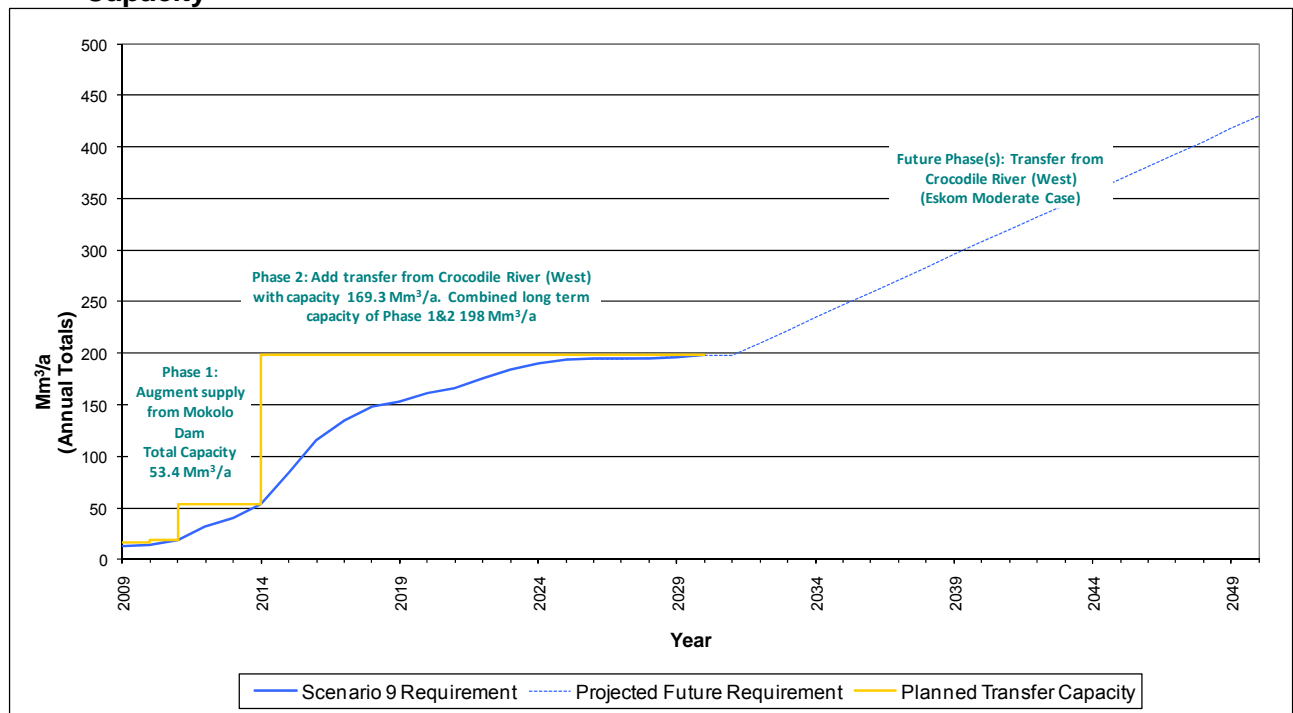


Figure 5-3: Scenario 9 Ultimate Projected Water Requirement (40 Years)

5.2 Aspects of Reliability and Redundancy

The strategic importance of the users that will account for the bulk of the water consumption requires that the risk of failure in the supply of water be kept to a minimum. Sufficient reliability and redundancy must therefore be provided in the combined MCWAP.

5.2.1 General Criteria

It is not feasible or possible to provide absolute reliability (or 100% system availability), i.e. no risk of an interruption in the delivery of water from a scheme. It is, however, possible to reduce the risks of the project to acceptably low levels, to cater for the strategic importance of most of the water that will be supplied by the project. The risk can further be reduced by providing redundancy between schemes.

In this regard, the schemes shall be sized for 95% reliability, implying that water shall continue to be supplied without interruption even if the scheme is inoperative for up to 18 days of any one year, and the scheme capacity adjusted to allow the full annual requirements to be supplied in 347 days. Eighteen days storage capacity will be designed into the system to ensure that strategic customers will not be exposed to an unduly high risk of supply failure. The storage facilities must be provided by the end users and are therefore excluded from the project cost estimate. The operation of the facilities will, however, be under the control of the MCWAP selected operator.

Allowing for a scheme to be inoperative continuously for 5% of the time during any one year (18 days) will be sufficient to cater for the following situations:

- Pump station failures if there had been severe damage such as flooding of the electrical equipment, etc.;
- Constructing temporary by-passes to repair pipeline linings and joints; and
- The time required to restore power supplies after major interruptions such as bushfires, flooding, lightning, etc.

Limited redundancy will be provided by interconnecting the Mokolo and Crocodile River (West) Schemes. No redundancy will, however, be available during the interim period (Phase 1) before the CRW Transfer Scheme is operational.

5.2.2 Reliability Criteria

The following sizing criteria were incorporated into the planning and costing of components to ensure reliability of supply:

- Terminal reservoirs must be provided at all end user delivery points to provide on-site storage with a minimum storage capacity of 18 days.
- System losses were assumed to be 2% of the average annual water requirement.
- The diameter optimisation and economic evaluation was based on 105% of the gross annual average water requirement (including system losses) to account for the annual 18 days downtime of the scheme (Design Flow Rate).
- Pumping stations were sized and pipe pressure rating (wall thickness) determined to enable a transfer rate of 120% (Recovery Peak Flow Rate) of the gross annual water requirement (at uneconomical pumping rates) in order to refill the Terminal Reservoirs over a 90-day period, following 18 days of continuous downtime.

- The worst case emergency scenario for the CRW Transfer Scheme occurs when the Phase 1 Scheme (Mokolo Delivery) makes no contribution to the project. The CRW Transfer Scheme (Phase 2) must therefore be able to transfer the full water requirement in the short-term to those water users that can accept the lower quality CRW water. The flow under these circumstances was found to be less than the 120% recovery peak flow and no additional allowance was made for this scenario in the sizing of the scheme components.
- The annual peak of 9% (Peak Flow Rate) was not applied simultaneously with the design or recovery peak factors in sizing the components. In the interim period (lower demand), the system will have sufficient capacity under normal operating conditions to accommodate the expected annual peak requirements. The normal reliability capacity (Design Flow Rate) will be able to supply the monthly peak until approximately the end of 2024. Should an 18-day continuous system failure occur on the CRW Transfer Scheme during a period of seasonal peak flow in 2030, the maximum recovery period could be as much as 164 days. This risk can be mitigated by:
 - i. Providing additional storage at the terminal reservoir sites (approximately 8 days additional storage would be required at each site).
 - ii. Increasing the capacity of the CRW Transfer Scheme to cater for the anticipated peak of 9%.
 - iii. Temporary utilisation of the full transfer capacity from the Mokolo Scheme installed as part of Phase 1 ($28.7 \times 1.02 \times 1.2 = 47.4 - 28.7 = 18.7$ Million m^3/a surplus supply). This will result in a reduction in the recovery period on the CRW Transfer Scheme to 83 days.

Option (iii) is recommended as it would not involve further capital expenditure to increase the size of infrastructure components and it is in line with the redundancy approach adopted for the project (see below).

- Switchgear and instrumentation at abstraction sites will be located in the superstructure of the abstraction weir, or on the river bank next to the weir, but in both cases, the equipment will be located above the Probable Maximum Flood (PMF) level. Other components forming part of the abstraction and desilting process (i.e. secondary desilting bays, balancing dam, etc.) will also be located above the PMF level.
- High-lift and booster pump stations will be positioned above the PMF and designed such that they will always be free-draining in the event of flooding due to failure of internal pipework.
- High-lift and booster pump stations will be designed with a minimum of one standby pump unit per station ensuring a minimum standby capacity of 25%. The maximum motor size will be limited to 10 MW per unit. A 4 duty-1 standby configuration is preferred.
- Abstraction pump stations will consist of multiple abstraction bays housing submersible pumps capable of pumping a maximum of 1 m^3/s per unit. In the case of Vlieëpoort, one

additional fully equipped standby bay plus one full spare pump including Mechanical and Engineering (M&E), valves and screens will be provided.

- All electrical equipment will be located above the PMF level.
- Strategic spares and equipment will be kept for medium voltage (MV) and low voltage (LV) electrical equipment and other critical components.
- 100% Duplication of the power supply from the switch yards to the pump stations will be provided and a duplicate power supply (firm) will be provided by Eskom.
- Gravity pipelines downstream of the Break Pressure Reservoir (BPR) will also have a capacity of 120% of the gross average annual demand, as determined by the rising main capacity.

5.2.3 Redundancy Criteria

The following criteria were incorporated into the planning, sizing and costing of components to ensure redundancy of supply:

- The existing pipeline from the Mokolo Dam should be refurbished and operated in parallel with the new pipeline to eventually provide redundancy for this scheme. The location of inter connections between the pipelines must be optimised as part of the detail design. The ultimate combined peak transfer capacity of the Mokolo Scheme after decommissioning of the existing pump station is 47.4 Million m³/a [(QAADD (53.4 – 14.7 = 38.7 Million m³/a) + losses (2%)) x 1.20]. The long-term available yield from the dam is 28.7 Million m³/a resulting in a 18.7 Million m³/a surplus supply capacity being available to provide redundancy backup in case of an emergency on the CRW Transfer Scheme.
- Redundancy will further be provided by an interconnection between the CRW and the Mokolo Schemes for those users that can accept the lower quality CRW water, so that either system can be augmented from the other.
- It should be noted that the CRW Scheme will not provide redundancy to Zeeland WTW due to the difference in water quality that cannot be accommodated by the treatment plant. Due care must therefore be taken with regards to the difference in water quality supplied by the Mokolo and CRW Schemes when designing for the redundancy connections between the two schemes.
- It can be considered to amend the water license to allow the transfer of additional Mokolo Dam water (better quality and less expensive) to more of the end users during times of excess water availability (i.e. when the dam is spilling and there is surplus water flowing into the Limpopo River from the Mokolo River), by utilising the surplus transfer capacity on the Mokolo Scheme.

6 MOKOLO DAM SCHEME

6.1 Development Options

6.1.1 Selection and Design Considerations

The following aspects were considered in defining the pipeline routes:

- Abstraction and water supply locations;
- Existing roads, as well as boundaries between land owners along the routes;
- Historical and planned future mining activities in the area, both sub-surface and open cast;
- Site constraints, potential river/stream crossings, road and railway crossings;
- Geotechnical overview;
- Environmental impacts; and
- Social impacts.

During the execution of the Vaal Augmentation Planning Study (VAPS) (mid 1990s), the Project Planning Division of the DWA recognised that the standard methodology developed during that study for the sizing and costing of water resource project components and for the economic evaluation of water resource development options would be a valuable tool for subsequent planning studies.

Costing and sizing guidelines were compiled during the VAPS. The purpose of the guidelines was to provide a standard framework for initial comparative costing and project engineering economic evaluation of water resources development options. The guidelines stipulated in this document are based on the VAPS Guidelines (January 1996). The necessary amendments to cater only for items required in this study were made. Refer to Supporting Report 3 – Technical Module: Guidelines for Preliminary Sizing, Costing and Economic Evaluation of Development Options (No. P RSA A000/00/9009) for more detail.

The following parameters in **Table 6-1** were utilised in the engineering economic analysis during this investigation:

Table 6-1: Mokolo Dam Scheme - Parameters Utilised in the Engineering Economic Analysis

Description	Note/Assumption
Energy Tariff	Megaflex
Discount rate (real prices)	6, 8 and 10%
Annual increase in energy tariffs	20% compounded for initial 5 years, inflation rate thereafter
Analysis period	45 years
Pipe roughness	0.1 mm (and tested for long term roughness of 0,5 mm)

The optimal pipe size was based on 120% of the required average annual transfer capacity of the scheme plus 2% losses at a maximum flow velocity of approximately 1.8 m/s for the rising mains. For the gravity mains the pipe size was determined by the available head.

The steady state energy grade line was calculated with minimum 15 m at the end consumers. The wall thickness was calculated based on 50% of the material yield strength for the particular grade of steel adopted.

Considering the Reliability and Redundancy requirements, the design flow was calculated with due allowance for a downtime period of up to 18 days continuous per year for planned and unplanned closures, consumer peaks, as well as a storage dam re-fill peak of 120%. This will enable the storage dams to be re-filled in 90 days following an 18 continuous supply interruption. Losses were assumed to be 2% of the Average Annual Demand (AAD).

6.1.1.1 Delivery Points

Water will be supplied to the delivery points at Matimba, Medupi, CF3&4 mining and Zeeland WTW. Due to the uncertainty regarding the exact location of the Exxaro, Eskom and possibly Sasol users in the Steenbokpan area, only one other delivery point has been allowed for at planning stage, namely Steenbokpan.

An 18-day storage capacity Terminal Reservoir will have to be provided by the users at each delivery point of Exxaro, Eskom and Sasol to ensure the prescribed reliability for those users.

6.1.1.2 System Operation

The water from the Mokolo Dam is of a much better quality than that from the CRW. It is therefore necessary to design and operate the MCWAP system in such a way that the water from the two sources does not mix during normal operation.

The quantity of water that can be taken from the dam in the event of failure of the CRW Transfer Scheme will have to be determined on a case-by-case basis. A planning model and operating rules to Mokolo Dam must be established for this purpose.

6.1.1.3 Options Considered

The following two most viable options of transferring water from the Mokolo Dam to the end users during Phase 1 have been identified and investigated:

- Construct a weir, abstraction works and a High-lift pump station downstream of Mokolo Dam, as well as a pipeline to deliver water to Zeeland, Matimba and Medupi Power Stations, as well as Steenbokpan (to supply the development of further Eskom power stations, Sasol, and coal mining activities).
- Construct a pump station and new pipeline from Mokolo Dam to Zeeland, Matimba and Medupi Power Stations, as well as Steenbokpan (to supply the development of further

Eskom power stations, Sasol, and coal mining activities). This pipeline will be constructed parallel (or close) to the existing pipeline for most of the route.

For more detail regarding the Mokolo River development options, refer to the following project reports:

- Supporting Report No. 4 – Technical Module: Dams, Abstraction Weirs and River Works
- Supporting Report No. 5 – Technical Module: Mokolo River Development Options
- Supporting Report No. 8A – Technical Module: Geotechnical Investigations Phase 1

Five alternative weir sites along the Mokolo River were investigated for appropriateness. The most suitable option was identified approximately 41 km downstream of Mokolo Dam on the boundary between the farms Sandier 559L0 and Rivers Bend 591L0 and immediately downstream of the confluence of the Rietspruit. This site was selected on the basis that it is located at the end of the deep and narrow valley section with only a small amount of developed irrigation along the river, and has a short rising main to Zeeland. The objective was to minimize river losses and to limit the degree of water resource management that would be required. The Low-lift pump station to abstract the sediment laden water from the river, located on the left flank of the weir, was conceptually configured and sized with two pumping bays to each accommodate a 750 l/s submersible pump. Degritting and desilting facilities to remove coarse sediment and a balancing dam with 4 hours storage capacity was provided between the Low- and High-lift pump stations. It was planned that water will be pumped from the High-lift pump station to the Zeeland WTW, Matimba raw water dam and Steenbokpan area. The total length of pipeline would have been approximately 63.23 km.

Simulated losses along the stretch of river from the dam to the abstraction site amounted to 17.2% of the total release down the river of 61.9 Million m³/a from Mokolo Dam.

The Project Team investigated the scenario where it would be required to over-utilise Mokolo Dam for a short period to make up for the shortfalls in water delivery anticipated until the CRW Transfer Scheme (Phase 2a) is implemented. This was referred to as the Interim Scheme. The short-term maximum target delivery is 53.4 Million m³/a. Of this, 14.7 Million m³/a will be transferred by the existing Exxaro Pipeline, leaving a maximum of 36.9 Million m³/a to be transferred in the interim by the Phase 1 Scheme.

For the Interim Scheme (Phase 1), the water balance from commissioning to July 2014 is summarised in **Table 6-2**.

Table 6-2: Interim Scheme Water Balance

Item Description	Over Utilisation of Mokolo Dam (million m ³ /annum)
Net Balance Required at Weir	36.9
Associated River Losses (at 17.2%)	7.6
Releases required from Mokolo Dam for Phase 1	44.5
Transfer via Existing Exxaro Pipeline	14.7
Irrigation Requirement (including losses).	17.4*
Total Required Releases from Mokolo Dam	76.6

* The reported irrigation requirement is 10.4 Million m³/a, but the registered total is 1 800 ha x 8 000 m³/ha/a which equals 14.4 m³/a net and 14.4 x 1.207 = 17.4 m³/a gross.

With the long-term yield of the Mokolo Dam being 39.1 Million m³/a, it can be seen from **Table 6-2** that the Abstraction Weir Option can only supply the required water requirement if Mokolo Dam is over utilised by up to 93%. Under these conditions, the risk is very high that the dam will be emptied before completion of the CRW Transfer Scheme. Yield analysis on the dam indicated that the dam will run empty in 2014 under normal water requirements from 2010 onwards. The additional losses resulting from the weir option will result in a very high risk of the dam emptying earlier.

The Mokolo Dam pipeline option would follow a route parallel to that of the existing pipeline except for the section from Mokolo Dam to the Wolvenfontein Reservoir where the pipeline will follow the existing access road. A total pipeline length of 79.78 km (including the rising main from the Mokolo Dam and the gravity main to the end consumers) will be required, including the extension to Steenbokpan. Blasting in close proximity to the existing pipeline may be problematic and needs to be mitigated, especially in the steep and rocky sections at Rietspruitnek and where the pipeline exits the Mokolo River valley. The existing servitude of 15 m wide will have to be widened to a temporary construction width of 30 m and a permanent width of at least 20 m.

6.1.1.4 Options Evaluation

The following tables summarise the scheme components and information for both alternatives:

Table 6-3: River Bend Weir and Pipeline

Component	Description
Concrete Weir	1.5 m above riverbed level
Low-lift pump station, incl. desilting facility and balancing dam	2 x 750 l/s submersible duty pumps
High-lift pump station:	Static head = 118 m Total head pumped (peak) = 230 m Design Flow = 1 423 l/s
1 000 mm of rising main	25 400 m (Design Flow = 1 423 l/s, V = 1.81 m/s)
800 m of rising main (Steenbokpan)	36 000 m (Design Flow = 715 l/s, V = 1.41 m/s)
800 m of rising main (Matimba)	1 900 m (Design Flow = 708 l/s, V = 1.40 m/s)

Table 6-4: Pipeline from Mokolo Dam

Component	Description
High-lift pump station:	Static head 228 m Total head pumped (peak) = 262 m Design Flow = 1 423 l/s
1 000 mm of rising main	5 600 m (Design Flow = 1 423 l/s, V = 1.84 m/s)
1 000 mm of gravity main	36 400 m (Design Flow = 1 423 l/s, V = 1.81 m/s)
800 mm of gravity main (Steenbokpan)	36 000 m (Design Flow = 715 l/s, V = 1.41 m/s)
800 mm of gravity main (Matimba)	1 900 m (Design Flow = 708 l/s, V = 1.40 m/s)

The construction of a weir, as well as the construction of a pipeline is both listed activities in terms of the National Environmental Management Act, 1998 (Act no. 107 of 1998) (the Act).

Neither of the proposed options have an environmental fatal flaw should the correct mitigation measures be put in place, although the pipeline routes do traverse some sensitive areas where particular care should be taken. These need to be pinpointed during a detailed investigation. Rocky areas are most sensitive due to the presence of aloe species, as well as the distinct habitat they provide for animal species.

For the weir option, the weir will impact on the flow of the river and therefore the movement of fish species. The decrease in the flow speed will also lead to siltation upstream of the weir, as well as the alteration of the riverine habitat. The possibility also exists that some terrestrial ecosystems next to the river may be inundated.

Due to the fact that the pipeline alignment for the Mokolo Dam pipeline option is adjacent to the existing pipeline and the vegetation has recovered along the existing pipeline, it is a clear indication that the disturbance of the vegetation is of a temporary nature compared to the permanent impact of the weir on the river. With mitigation measures the construction of the pipeline will have a minimal lasting effect on the surrounding area. The pipeline option is therefore considered the most unobtrusive option.

Table 6-5 is a comparison between the two options investigated.

Table 6-5: Mokolo Dam Options Comparison

Description	Pipeline from Mokolo Dam	Pipeline from Rivers Bend Weir
Total Pipeline Length (km)	79	63
Total Peak Pumping Head (m)	* 262	** 230
Project Capital Cost excl VAT (April 2008 Values) (R)	1 340 120 000	1 327 115 000
Discounted Present Value (8%) to 2008 (R)	1 179 872 000	1 173 028 000
URV (8%) (R/m ³)	6.73	8.18

Note: * Static height difference plus friction losses between pump station (874 m) and Wolvenfontein (FSL=1 102 m) balancing dams.

** This scheme pumps water from the weir (level = 820 m) over a high point (level = 929 m) all the way to the users.

From **Table 6-5**, it can be seen that the capital cost of the River Bend Weir option is approximately R13 million less than that of the Mokolo Dam pipeline option, but there is more risk attached to the cost and construction of the weir in the river due to the very limited geotechnical information available and uncertainties concerning river losses. Due to the river losses, this option will also require a larger CRW Transfer Scheme with the associated operational and maintenance costs. The Mokolo River Weir option has a higher unit reference value (URV) due the replacement cost of the water due to river losses.

It was agreed that from an engineering economic point of view, the Mokolo Dam pipeline option is the preferred option to be implemented. Refer to schematic options illustrated in **Figure 5-1** above.

6.2 Mokolo Dam Scheme Description

The philosophy employed in aligning the new pipelines of the proposed Mokolo Dam Conveyance Scheme was to stay as far as possible parallel to existing infrastructure such as roads, power lines and the existing pipeline belonging to Exxaro in order to minimise negative social and environmental impacts.

6.2.1 Pump Station

The new pump station at Mokolo Dam will be required to transfer the following quantities of water from the dam to the balancing reservoir at Wolvenfontein from where it will gravitate to the consumers:

- *The existing pump station:* The three duty pumps have a total capacity of 820 l/s.

- *The maximum interim requirement from Mokolo Dam for the new Phase 1:* 53.4 (Total volume of water transferred during 2014) – 14.7 (normal operating capacity of the existing rising main) = 38.7 Million m³/a (2014) + 2% losses + 20% refill peak = 47,4 Million m³/a = 1 502,1 l/s.
- *The long-term requirement from Mokolo Dam:* 28,7 Million m³/a + 20% refill peak = 34.4 Million m³/a = 1 092 l/s.

Due to the highly strategic importance of this project the top of the pump well, as well as all electrical infrastructure (switchgear, gantry crane, access road, etc.) of the pump station, will be sited above the maximum tailwater level directly downstream of the dam, so as to have a low probable risk of natural flooding.

6.2.2 Power Supply

The existing 33 kV line feeding from Waterberg sub-station will be upgraded to a 132 kV, while a new 132 kV line will be constructed from Bulge River sub-station to Mokolo Dam to ensure a reliable redundant supply to Mokolo Dam with adequate capacity. It is also proposed that a new switch yard be constructed at the Mokolo Dam.

6.2.3 Rising Main

A new 900 mm diameter steel rising main with 8,0 mm standard wall thickness (Grade X42) will be constructed from the new Mokolo Dam Pump Station to Wolvenfontein Reservoirs, following the route of the existing access road. The combined capacity of the existing and proposed rising mains should be 53,4 Million m³/a (maximum interim water requirement, 2014) + 2% losses + 20% refill peak = 2 072 l/s. The new Phase 1 rising main will deliver 1502 l/s. The existing and new rising mains will be interconnected near the pump station to allow for the option to operate the two pipelines separately or as a system.

6.2.4 Gravity Main

A new 1 100 mm diameter steel pipeline with 7,0 mm standard wall thickness (Grade X42) will be constructed from Wolvenfontein Reservoirs to Rietspruitnek and a 1 000 mm diameter steel pipeline with 7,8 mm standard wall thickness (Grade X42) from Rietspruitnek to the Steenbokpan T-off. This new gravity main will follow the alignment of the existing Exxaro pipeline. The capacity of the proposed new gravity main will be 53,4 (maximum interim water requirement, 2014) – 14.7 (capacity of existing gravity main) = 38,7 Million m³/a + 2% losses + 20% refill peak = 1 502 l/s.

A new gravity main will also be constructed from the Steenbokpan T-off point to Steenbokpan. This section of pipeline was sized to supply the Phase 1 water requirements of the Steenbokpan area users, but was optimised to form part of the delivery line of the CRW Transfer Scheme.

The components of the gravity main are as follows:

- Steenbokpan T-off to Medupi off take - 900 mm diameter steel pipeline with 6.3 mm standard wall thickness (Grade X42).
- Medupi T-off to CF3&4 mining T-off - 900 mm diameter steel pipeline with 6.3 mm standard wall thickness (Grade X42).
- CF3&4 mining T-off to CRW Transfer Scheme connection – 1 100 mm diameter steel pipeline with 6.1 mm standard wall thickness (Grade X42).
- CRW Transfer Scheme connection to Steenbokpan – 1 900 mm diameter steel pipeline with 12.1 mm standard wall thickness (Grade X42).

6.2.5 Coating and Lining

The pipe material proposed for installation for both the rising and gravity mains are steel pipes with Sintakote external coating and epoxy internal lining. Joints will be welded and repaired.

6.2.6 Cathodic Protection (CP) and AC Mitigation

The proposed pipeline routes run parallel to and cross a number of existing and proposed future HV power line routes. The pipeline also crosses a railway siding which is currently not electrified, but if electrified in future, it is expected to be with AC power.

Stray current interference is expected on the pipeline and CP and AC mitigation measures will be required to protect the proposed pipeline.

6.2.7 Existing Infrastructure

The capacity of the existing Exxaro infrastructure (pump station and rising-gravity main) was considered to be available for further supply in combination with the new Mokolo Dam Scheme. The condition of the existing pipeline is however reported to be questionable and therefore need to be assessed to determine its further useful life in combination with the new infrastructure. The new Mokolo Dam Scheme was sized considering the reliable supply capacity of the existing infrastructure, taking into consideration that the pipeline can probably be refurbished over a two year period immediately following commissioning of the new pipeline.

It is further planned that the existing pump station should be decommissioned. This is necessary due to the current location of the pump station being below the PMF and due to aging electrical infrastructure. The capacity of this pump station can be economically incorporated in the new pump station.

6.3 Geotechnical Aspects

For detail of the geotechnical conditions refer to Supporting Report No 8A – Technical Module: Geotechnical Investigations Phase 1(No. P RSA A000/00/8409).

Rock occurs at shallow depths (generally less than 1 m) at the position where the construction of the new Mokolo Dam pump station is proposed and the structure will be founded entirely on rock.

The geotechnical condition along the pipeline route was assessed and found to be hard along the majority of the route. It will, however, be possible to excavate to trench bottom in certain areas. The scarcity of soft material in the mountainous sections south of Zeeland and haul distances may be significant (particularly in the vicinity of Rietspruitnek). It is also expected that excavation rates will be low (particularly in the mountainous part) due to the large amount of rock present.

No significant constraints are anticipated on the pipeline route extending westwards from the Matimba towards Steenbokpan. Soft material should be readily available and haul distances should be reasonable. Excavation rates should be significantly higher than on the Mokolo Dam - Matimba route.

6.4 Operations and Maintenance

The control and operation of all sites forming part of the MCWAP will be monitored and managed by means of a System Control and Data Acquisition (SCADA) system from a central control room manned on a 24 hour/day basis. The monitoring system must provide adequate planning, operational and costing reports to effectively manage, operate and maintain the system.

6.4.1 Optimisation

A detailed hydraulic model needs to be developed for optimisation of the conveyance system. It should simulate the actual flow data collected through the SCADA interface and optimise the operations of the system related to energy use and water stagnation. This should be an on-going process, "remodelling" current data.

6.4.2 Scheduled Maintenance

A scheduled maintenance plan will inform the system operator regarding the operational staff requirements (level of competence and structure). A complete asset register must be developed during the design phase, including the maintenance requirements (what and when) as provided by the component supplier. This must be set out in the operation and maintenance manuals for the pump station and pipelines. The maintenance philosophy must address mechanical, electrical and civil engineering aspects, categorised as follows:

- Routine planned maintenance;
- Major Breakdown repairs; and
- Minor breakdown repairs.

6.4.3 Critical Spares

The system operator must establish a store of critical spares. This will follow after all critical elements of the entire conveyance system have been listed. Attention must be given to the existing Exxaro conveyance system as this will need refurbishment in the near future.

6.4.4 Operation and Maintenance Philosophy

The Project Team have developed an Operation and Maintenance (O&M) philosophy that will inform the detailed design stage. It addresses the basic operation and maintenance requirements, and is set out in Supporting Report 10 – Technical Module: Requirements for the Sustainable Delivery of Water (No. P RSA A000/00/8609).

7 CROCODILE RIVER (WEST) TRANSFER SCHEME

7.1 Development Options

An approach similar to that described above for the Mokolo Dam Scheme was adopted for development and analysis of the CRW Transfer Scheme. The information below is a summary taken from Supporting Report No 6 – Technical Module: Water Transfer Scheme Options (No. P RSA A000/00/9309).

7.1.1 Infrastructure Components

The following infrastructure components were considered during the Pre-Feasibility assessment of the scheme:

- Abstraction Weir. Five sites along the CRW were investigated for appropriateness. Two sites along the CRW (Boschkop and Vlieëpoort) were selected and taken to Pre-Feasibility Study level. Components associated with the abstraction weirs included:
 - Abstraction Pump Stations;
 - Desilting Structures; and
 - Balancing Storage.
- High-lift pump stations.
- Conveyance options. The following conveyance options and alternatives were considered as part of the Pre-feasibility investigation:
 - River conveyance;
 - Canal conveyance; and
 - Pipeline conveyance.
- A combination of reliability storage and balancing storage options were investigated.

An updated and revised version of the Vaal Augmentation Planning Study (VAPS) guideline was adopted for preliminary sizing, costing and engineering economic evaluation of the development options. Refer to Study Supporting Report No 3 – Technical Module: Guidelines for Preliminary Sizing, Costing, and Economic Evaluation of Development Options (No. P RSA A000/00/9009).

7.1.2 Route Options

The following aspects were considered in defining and evaluating the different pipeline routes:

- Possible abstraction and delivery locations.
- Existing roads, as well as boundaries between land owners along the routes.
- Historical and planned future mining activities in the area.

- Existing and planned future services and infrastructure.
- Site constraints, potential river/stream crossings, and road and railway line crossings.
- Geotechnical conditions based on a high level geotechnical screening.
- CP requirements with special consideration of the impact that the potential future 765 kV overhead power line corridors might have on the alternating electrical current (AC) mitigation requirements.
- Environmental overview.
- Social impact overview of the proposed pipeline route.

Based on the two abstraction weir sites (Boschkop and Vlieëpoort), water from the CRW can be delivered along alternative route(s) to either one of the two identified Terminal Dam sites (Sites 1 or 3), or via a break pressure balancing reservoir to Terminal Reservoirs at the major consumer sites. A schematic diagram of the alternative pipeline route options and system nodes is shown below. A layout drawing of the scheme (**Figure 7-1**) is included in **Appendix A** (DWG No WP 9528/LC/CTS/001/A).

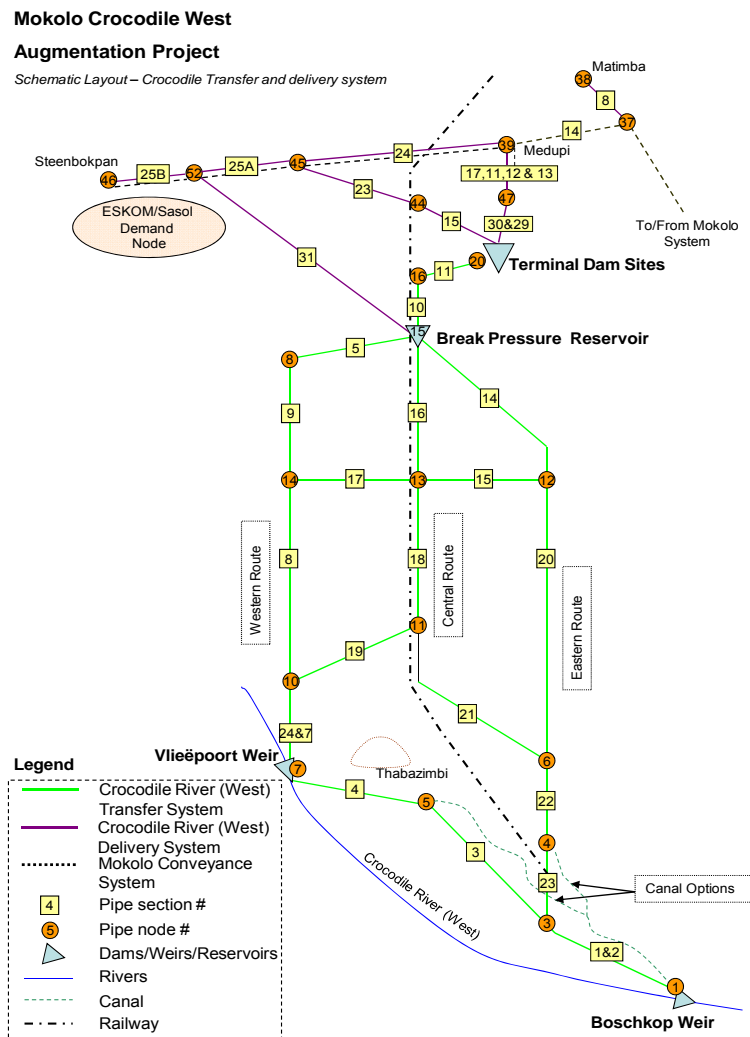


Figure 7-1: Crocodile River (West) Transfer Scheme Options

The alternative pipeline routes that were identified are summarised below for the CRW Transfer and Delivery Systems.

Table 7-1: Crocodile River (West) Transfer System Route Options

Description	Flow Routing – Transfer System (Pipe Section No – Refer to Schematic)	Section Length (km)	Route Option Number
Vlieëpoort Weir Abstraction Options			
Abstraction at Vlieëpoort Weir with conveyance to Terminal Dam/Operational Reservoir (Phased or un-phased)	Western Route to Terminal Dam site entrance: <24-7-8-9-5-10-11>	111.3	T1
	Central Route to Terminal Dam site entrance: <24-7-19-18-16-10-11>	106.1	T2
	Central Route to Operational Reservoir (Node 15): <24-7-19-18-16>	97.9	T3
Boschkop Weir Abstraction Options			
Abstraction at Boschkop Weir with conveyance to Terminal Dam/Operational Reservoir (Phased or un-phased)	Eastern Route to Terminal Dam site entrance: <1-2-23-22-20-14-10-11>	161.8	T4
	Central Route to Terminal Dam site entrance: <1-2-23-22-21-18-16-10-11>	152.8	T5
	Eastern Route to Operational Reservoir (Node 15): <1-2-23-22-20-14>	153.6	T6
	Central Route to Operational Reservoir (Node 15): <1-2-23-22-21-18-16>	144.6	T7
Boschkop/Vlieëpoort Weir Abstraction Options			
Abstraction at Boschkop Weir with conveyance to Vlieëpoort Weir for transfer to Terminal Dam/Operational Reservoir (Associated with Phase 3)	Western-Route to Vlieëpoort Weir: <1-2-3-4>	70.0	T8

Table 7-2: Crocodile River (West) Delivery System Route Options

Description	Flow Routing – Delivery (Pipe Section No – Refer to Schematic)	Section Length (km)	Route Option Number
Delivery from the Terminal Dams			
Conveyance from Terminal Dam No 1 to end users	<15-23> Link to Lephale-Steenbokpan Pipeline (Node 45)	21.8	D2(a)
	<25A-25B> Link to Steenbokpan	13.8	
	<24-14> Link to Lephale (Constructed as part of Phase 1)	22.2	
	<8> Link to Matimba (Constructed as part of Phase 1)	1.9	
	<13> Link to Medupi	1.7	
Conveyance from Terminal Dam No 3 to end users	<30-29-17-11-12-13> Link to Lephale-Steenbokpan Pipeline (Node 39)	19.3	D2(b)
	<24-25A-25B> Link to Steenbokpan	28.4	
	<8> Link to Matimba (Constructed as part of Phase 1)	1.9	
	<14> Link to Lephale (Constructed as part of Phase 1)	7.6	
Delivery from the Operational Reservoir			
Conveyance from Operational Reservoir to end users	<31> Link to Lephale-Steenbokpan Pipeline (Node 52)	24.8	D3
	<25B> Link to Steenbokpan	5.1	
	<25A-24-14> Link to Lephale (Constructed as part of Phase 1)	30.8	
	<8> Link to Matimba (Constructed as part of Phase 1)	1.9	
	<13> Link to Medupi	1.7	

A Feasibility screening of the following aspects was performed on the different route options:

- Geology and geotechnical conditions;
- CP and AC mitigation;
- Bulk electrical supply;
- Environmental and social screening; and
- Technical and practical considerations.

The findings of the Feasibility screening are provided in Supporting Report No 6 – Technical Module: Water Transfer Scheme Options (No. P RSA A000/00/9309).

7.1.3 Options Evaluation

Development of the Phase 2 options included the following:

- Various alternative pipeline routes. Three general routes have been identified – East, Central and West.
- A number of different weir and abstraction works sites.
- Terminal and/or on-site storage
- Two implementation approaches:
 1. Un-phased (full capacity) scheme implemented in a single construction phase with an ultimate net transfer capacity of 198 Million m³/a (excluding system losses).
 2. Phased approach where the capacity is provided through two parallel pipelines constructed during two consecutive construction phases.
 - Phase 2A – First phase pipeline from Vlieëpoort with a net transfer capacity of 110 million m³/a.
 - Phase 2B – Second phase pipeline from Vlieëpoort to achieve ultimate required net transfer capacity of 198 million m³/a.

The following table defines the options that were developed as part of the pre-feasibility investigations and analysis.

Table 7-3: Crocodile River (West) Transfer Scheme Options Considered

Option No.	Option Code	Description	Flow Routing (Refer to schematic diagram)
1	8-P1-MD-ID1	Scenario 8 – Phase 1, transfer from Mokolo Dam via pump/gravity main to the users.	Refer Mokolo River Development Options Report (Supporting Report No 5)
2	8-P1-RBW-IW1	Scenario 8 – Phase 1, transfer from weir in Mokolo River (Rivers Bend) via rising main to users.	Refer Mokolo River Development Options Report (Supporting Report no 5)
3	8-P2-TVCD1-DD1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Terminal Dam 1 and deliver via Delivery Route 2(a)	Transfer Route Option T2: <24-7-19-18-16-10-11> Delivery Route Option D2(a): <15-23> <25A-25B > <24-14-8> <13>

Option No.	Option Code	Description	Flow Routing (Refer to schematic diagram)
4	8-P2-TVCD3-DD3	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Terminal Dam 3 and deliver via Delivery Route 2(b)	Transfer Route Option T2: <24-7-19-18-16-10-11> Delivery Route Option D2(b): <30-29-17-11-12-13> <24-25A-25B > <14-8>
5	8-P2-TVCB1-DB1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Central Route to Operational Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option T3: <24-7-19-18-16> Delivery Route Option D3: <31> <25B> <25A-24-14-8> <13>
6	8-P2-TVWB1-DB1	Scenario 8 - Phase 2, transfer from Vlieëpoort via Western Route to Operational Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option T1(part) <24-7-8-9-5> Delivery Route Option D3: <31> <25B> <25A-24-14-8> <13>
7	8-P2-TBCB1-DB1	Scenario 8 – Phase 2, transfer from Boschkop via Central Route to Operational Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option T7: <1-2-23-22-21-18-16> Delivery Route Option 3: <31> <25B> <25A-24-14-8> <13>
8	8-P2-TBEB1-DB1	Scenario 8 – Phase 2, transfer from Boschkop via Eastern Route to Operational Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option T6: <1-2-23-22-20-14> Delivery Route Option D3: <31> <25B> <25A-24-14-8> <13>
9	8-P2A-TVCB1-DB1	Scenario 8 - Phase 2A (first pipeline), transfer from Vlieëpoort via Central Route to Operational Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option T3: <24-7-19-18-16> Delivery Route Option D3: <31> <25B> <25A-24-14-8> <13>
10	8-P2B-TVCB1-DB1	Scenario 8 - Phase 2B (second pipeline), transfer from Vlieëpoort via Central Route to Operational Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option T3: <24-7-19-18-16> Delivery Route Option D3: <31> <25B> <25A-24-14-8> <13>
11	8-P2A&B-TVCB1-DB1	Scenario 8 - Phase 2A&B, transfer from Vlieëpoort via Central Route to Operational Reservoir and delivery to the Terminal Reservoirs via Delivery	Transfer Route Option T3: <24-7-19-18-16> Delivery Route Option D3:

Option No.	Option Code	Description	Flow Routing (Refer to schematic diagram)
		Route 3.	<31> <25B> <25A-24-14-8> <13>
12	8-P3-TBVCB1-DB1	Scenario 8 - Phase 3, transfer from Boschkop through Vlieëpoort via Central Route to Operational Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3 (Option 5).	Transfer Route Option T8 & T3: <1-2-3-4> <24-7-19-18-16> Delivery Route Option D3: <31> <25B> <25A-24-14-8> <13>
13	4-P2-TBCB1-DB1	Scenario 4 – Phase 2, transfer from Boschkop via Central Route to Operational Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route option T7: <1-2-23-22-21-18-16> Delivery Route Option D3: <31> <25B> <25A-24-14-8> <13>
14	4-P2-TVCB1-DB1	Scenario 4 – Phase 2, transfer from Vlieëpoort via Central Route to Operational Reservoir and delivery to the Terminal Reservoirs via Delivery Route 3.	Transfer Route Option T3: <24-7-19-18-16> Delivery Route Option D3: <31> <25B> <25A-24-14-8> <13>

It should be noted that water requirement Scenarios 8 and 4 were used when evaluating and eliminating development options. Scenario 9 was then developed and feasibility costing and sizing was done on this basis.

The following logical decision-making process was followed to eliminate options based on URVs:

(1) Determine preferred Option for Phase 1 – Mokolo Dam System:

Calculate URVs for Phase 1 (Mokolo Dam System)

Option 1 – Pipeline < 8-P1-MD-ID1>
and Option 2 – Weir < 8-P1-RBW-IW1>

Select preferred option and use further in combination with CRW transfer and delivery options.

(2) Determine the preferred Terminal Dam / Operational Reservoir Option:

Calculate URVs for Scenario 8, Phase 2, Vlieëpoort Abstraction via Central Route

to Terminal Dam 1 < 8-P2-TV CD1-DD1>
or Terminal Dam 3 < 8-P2-TV CD3-DD3>
or Operational Reservoir < 8-P2-TV CB1-DB1>

Select preferred storage option and use further in combination with route options.

(3) Select between the Western and Central Routes:

Calculate URVs for Scenario 8, Phase 2, Vlieëpoort Abstraction via Western Route
to selected Terminal Dam/Operational Reservoir option < 8-P2-TV WB1-DB1>

Compare with (2) and select preferred route option for Vlieëpoort abstraction.

(4) Select between the Eastern and Central Routes and between Abstraction at Vlieëpoort or Boschkop:

Calculate URVs for Scenario 8, Phase 2, Boschkop Abstraction to Operational Reservoir
via Eastern route < 8-P2-TBEB1-DB1>
and via Central Route < 8-P2-TBCB1-DB1>

Select preferred route option for Boschkop abstraction; and
Select between Vlieëpoort and Boschkop as the abstraction site.

(5) Determine whether the Phased Approach is preferred:

Calculate URVs for Scenario 8, Phase 2A, Vlieëpoort Abstraction via Central Route
to Operational Reservoir < 8-P2A-TV CB1-DB1>
and Scenario 8, Phase 2B, Vlieëpoort Abstraction via Central Route
to Operational Reservoir < 8-P2B-TV CB1-DB1>

Compare the un-phased approach and select.

(6) Compare the cost of Phase 3 pipeline with River Management:

Calculate URV for Scenario 8, Phase 2 and 3, Boschkop Abstraction via Vlieëpoort and
Central Route to Break Pressure Reservoir < 8-P3-TBVCB1-DB1>
plus < 8-P2-TVCB1-DB1>

Compare with (4).

(7) Determine URVs for Scenario 4 Demands and compare:

Calculate URV for Scenario 4, Phase 2, Vlieëpoort Abstraction Central Route
to Balancing Reservoir < 4-P2-TV CB1-DB1>
Calculate URV for Scenario 4, Phase 2, Boschkop Abstraction Central Route
to Balancing Reservoir < 4-P2-TB CB1-DB1>

Table 7-4 below summarises the calculated URVs for each of the options evaluated according to the above logic. The option with the lowest URV determined in each group of calculation steps is indicated in bold.

Table 7-4: Calculated URVs for Crocodile River (West) Transfer Scheme Options

Calculation Step	Option		Preferred	URV (excluding VAT)*				
				@6%	@8%	@10%		
1	Determine preferred option for Phase 1A							
1.1	1	<8-P1-MD-ID1>	Option 1 (Pipeline)	5.92	6.73	7.57		
1.2	2	<8-P1-RBW-IW1>		7.38	8.18	9.01		
2	Determine preferred Terminal Dam/Operational Reservoir option							
2.1	3	<8-P2-TVCD1-DD1>		10.10	11.68	13.48		
2.2	4	<8-P2-TVCD3-DD3>		10.32	11.98	13.87		
2.3	5	<8-P2-TVCB1-DB1>	Operational Reservoir + end user storage	9.39	10.74	12.28		
3	Select between western and central routes							
3.1	6	<8-P2-TVWB1-DB1>		9.51	10.90	12.48		
3.2	5	<8-P2-TVCB1-DB1>	Central Route	9.39	10.74	12.28		
4	Select between eastern and central routes and between abstraction at Vlieëpoort or Boschkop							
4.1	8	<8-P2-TBEB1-DB1>		10.26	12.17	14.35		
4.2	7	<8-P2-TBCB1-DB1>	Central Route	10.07	11.91	14.01		
4.3	5	<8-P2-TVCB1-DB1>	Vlieëpoort abstraction	9.39	10.74	12.28		
5	Determine whether a phased approach is preferred							
5.1	9	<8-P2A-TVCB1-DB1>		9.53	10.93	12.46		
5.2	10	<8-P2B-TVCB1-DB1>		5.07	5.28	5.45		
5.3	11	<8-P2A&B-TVCB1-DB1>		9.56	10.83	12.25		
5.4	5	<8-P2-TVCB1-DB1>	Un-phased	9.39	10.74	12.28		
6	Compare the cost of Phase 3 with River Management							
6.1	12	<8-P3-TBVCB1-DB1>		10.18	12.03	14.13		
6.2	5	<8-P2-TVCB1-DB1>	Vlieëpoort abstraction	9.39	10.74	12.28		
7	Determine URV's for Scenario 4 demands							
7.1	13	<4-P2-TBCB1-DB1>		10.25	12.15	14.24		
7.2	14	<4-P2-TVCB1-DB1>	Vlieëpoort abstraction	10.01	11.53	13.21		

*URV at April 2008 prices

7.1.4 Conclusions from Options Evaluation

The URVs of the groups of options were all very close (within 10%). Therefore, other factors also had to be considered to arrive at the recommended option.

The following was concluded from the options evaluation:

1. The pipeline from Mokolo Dam to the users is the preferred option for Phase 1 Mokolo Dam Scheme.
2. The Operational Reservoir plus user terminal reservoirs option is preferred above the terminal dam and user terminal reservoirs option for the following reasons:
 - Lowest URV for the total system.
 - The potential negative environmental impact of some of the proposed terminal dam sites.
 - The CRW water will be prone to the development and growth of algae. It will be more difficult to manage algae growth on the surface of the terminal dams compared to the smaller Operational Reservoir and terminal reservoirs at the user sites.

- Reliability storage capacity can be limited to 18 days in total as the storage is provided on-site (as opposed to 18 days at the end of the rising main and 9 days at the end of the gravity main). The Operational Reservoir will provide sufficient short term balancing storage between the end of the transfer main section and the delivery main section to facilitate pump control. The transfer main and delivery main sections will, however, operate as a combined system.
3. The Central route is the preferred route for the transfer pipeline from Vlieëpoort Weir for the following reasons:
 - It is the shortest route with the lowest total scheme cost (and URV).
 - It is the preferred route from an environmental and social point of view due to it being located along a disturbed corridor.
 - It is the route option where the least hard rock excavation is expected, based on the geotechnical screening.
 - Access to the route along the railway line is generally good.
 - Neither the electrification of the Lephalale railway line nor the positioning of the future Eskom 765 kVA power line corridors would result in unmanageable CP and AC mitigation conditions. Locating the pipeline along an Eskom power line corridor would, however, increase the operational and maintenance burden associated with the pipeline and will also have to be properly considered from a Health and Safety point of view during the operation of the system.
 4. The Central route is the preferred route for the transfer pipeline from Boschkop due to this being the shortest route with the lowest total scheme cost (and URV). The eastern route will be negatively impacted by higher quantities of hard material excavation and the expected higher environmental and social sensitivity.
 5. The pipeline profiles along all three the main CRW Transfer Scheme routes (East, Central and West) are very similar. The final location of the Operational Reservoir and the merits of an increased length of gravity supply to the end users will be investigated in more detail during the Feasibility stage.
 6. Abstraction at Vlieëpoort is preferred based on the lower total scheme URV (river losses and management included) compared to abstraction at Boschkop. The URVs for the different schemes are, however, within 8% and are therefore not the only factors to be considered for eliminating the Boschkop option. An important factor to consider is the additional length of pipeline to be constructed for abstraction at Boschkop (145-98 = 47 km) and the additional time required to construct this pipeline (47 km / 0.2 km/day = 230 workdays or 11 months). Considering the risk of Mokolo Dam being emptied during construction of Phase 2 and the corresponding longer recovery period, the shortest possible construction duration is preferred, i.e. shortest possible pipeline.

7. A phased approach for constructing the Phase 2 Transfer Scheme from Vlieëpoort should be considered due to the benefit it provides in delaying the decision on the final capacity of the pipeline. It also distributes the capital expenditure programme over a longer period. The URV calculations indicate only a small difference between a phased and un-phased implementation, which could easily be outweighed by the benefits of the other considerations or a slight delay in the growth of the water requirements beyond the capacity of Phase 2A. The URV difference can be overcome by encroaching on some of the pipeline reliability capacity of Phase 2A and advancing the construction of the Phase 2B Terminal Reservoir storage.
8. The option to construct a pipeline from Boschkop to Vlieëpoort as Phase 3 of the project will not be cost effective unless the implementation of Phase 3 is postponed until 2026. This is, however, sensitive to the cost of raw water and the extent of river losses and should be reconsidered once the water tariff has been finalised and a more accurate estimate of the river losses has been made, following the management of potential unauthorised irrigation water use.
9. The URVs calculated for the Scenario 4 options indicate that Vlieëpoort will again be the preferred abstraction site based on total life cycle cost.
10. The river losses are being revised with the expectation that the actual river losses between Boschkop and Vlieëpoort will be considerably less than that stated in the report. A reduction in the river losses will further benefit the Vlieëpoort abstraction option over the Boschkop abstraction option.

7.1.5 Sensitivity Analysis

A sensitivity analysis on selected options revealed the following:

- **Pumped vs. Pump-gravity:** The gravity supply option is less favourable from a financial point of view. There are, however, practical and operational benefits that can be derived from having a gravity supply from Node 10. A BPR at this point could also serve as and replace the Operational Reservoir at Node 15. The cost of the pipeline between Nodes 10 and 15 can also be reduced by optimising the wall thickness of the steel pipe as less operational variations that could cause pressure surges are expected in the gravity section. This would make the options with longer gravity mains financially comparable to those with a rising main as far as Node 15. The final decision on the pump-gravity approach should be based on practical considerations rather than price.
- **Raw water cost:** To make the Boschkop abstraction options viable compared to Option 5 will require the cost of raw water to be R2.18/m³ and R1.95/m³ for Options 7 and 12, respectively. This is similar to the raw water price charged for the existing CRW allocation and less than the current Vaal River Eastern Sub-system Augmentation Project (VRESAP) raw water cost of approximately R4.50/m³. It is generally accepted that it would not be possible to supply additional raw water at less than the VRESAP tariff. The river losses between Boschkop and Vlieëpoort used for

the prefeasibility stage are most probably over-stated. A reduction in the river losses will further advantage the Vlieëpoort abstraction options.

- **Project phasing:** Due to the rapid increase in water requirements in the short- to medium-term, it would not be practical to delay the implementation of Phase 2B beyond 2020. The URVs of the phased and un-phased approaches are almost equal (compare Options 5 and 11) and a one or two year delay in the implementation of Phase 2B will favour the phased approach. It should, however, be noted that this will require either increased transfer capacity to be provided as part of Phase 2A or it will again require over-abstraction from the Mokolo Dam until Phase 2B is commissioned. A further possibility would be to temporarily over-utilise Phase 2A by encroaching on the 90-day replenishment requirement for the terminal reservoirs. None of these options was analysed in detail as part of the sensitivity analysis.
- **Phase 3:** This will become viable if the commissioning of the abstraction works, pump station and pipeline from Boschkop to Vlieëpoort is delayed until 2026.
- **Reduction in steel prices:** The ranking of options is not affected by the reduction in steel pipe prices.

7.1.6 Options Selected

Based on these findings, the following was recommended for further consideration during the Feasibility stage of the project:

- **Phase 1 – Mokolo Dam Scheme:** Option 1 which consists of a pipeline from Mokolo Dam to Lephalale and further to Steenbokpan. Option <8-P1-MD-ID1> is the preferred option.
- **Phase 2 – Abstraction at Vlieëpoort** with a rising main along the Central Route to the position of the Operational Reservoir separating the rising main and gravity main portions of the CRW Transfer Scheme and providing short-term operational balancing storage. From here the water will be gravity fed into on-site Terminal Reservoirs (capacity 18 days + user balancing and emergency storage requirements) at each of the users. Option 5 <8-P2-TVCB1-DB1> was selected as the preferred option.
- **Phase 3 – Delayed implementation** of the link from Boschkop to Vlieëpoort to be considered in future in order to limit river losses, if the river losses remain high even with improved river flow and irrigation water use management. Option <8-P3-TBVCB1-DB1> is the preferred option.

7.2 Capacities of Crocodile River (West) Transfer Scheme Components

7.2.1 River Losses

The Pre-feasibility analyses were based on a model where all irrigation water requirements were assumed to be abstracted directly from the river and the assumption that the evapotranspiration losses from the vegetation in the riparian strip and the seepage outflows from the river would not be significantly affected by increased releases from Klipvoor, Roodekopjes and Vaalkop Dams. The additional water losses that could occur were deemed to be due to increased evaporation losses from the river water surface and

increased abstraction by the irrigators. The water abstracted from the boreholes in the alluvial aquifers underlying the floodplains in the river valley for irrigation and the unregulated runoff contributions from the catchments downstream of the Klipvoor, Roodekopjes and Vaalkop Dams were not included in the analyses, but would in fact be available to the system to supply the irrigators during periods with simulated shortfalls.

By considering the mass balance relationship at Vlieëpoort, a re-arrangement of the data presented in Supporting Report 4 was possible. The results are presented in **Table 7-5**.

Table 7-5: River Losses between Dams and Vlieëpoort

Item No.	Description	Scenario 9	Scenario 2050
		million m ³ /a	million m ³ /a
1.	Observed historic dam releases.	101,9	101,9
2.	Observed historic flow past Vlieëpoort site.	28,9	28,9
3.	Total Area under Irrigation between Dams and Vlieëpoort (ha).	15 000	15 000
4.	Unit irrigation allowance (m ³ /ha/a).	8 000	8 000
5.	Net irrigation water requirements from Dams ⁽³⁾ .	120,0	120,0
6.	Evaporation and evapo-transpiration losses (calculated).	24,7	24,7
7.	MAR in sub-catchment (WR90) to Paul Hugo Weir (A2H116).	48,2	48,2
8.	Accruals Balance = Net inflow from runoff downstream of the dams plus other diffuse inflows minus diffuse outflows (Pre-feasibility Report, Tables 8-3 and 8-4).	7,6	7,6
9.	Diffuse Outflows - diffuse inflows other than natural runoff (Items 7 – 8).	40,6	40,6
10.	Dam releases minus net irrigation and evaporation plus accruals balance (Items 1 – (5 + 6 + 8)).	-35,2	-35,2
11.	Irrigation requirements not supplied by dams ⁽⁴⁾ (Items 2 – 10).	64,1	64,1
12.	River Losses other than evapo-transpiration & evaporation losses (mean irrigation shortfall) (Items 11 – 9).	23,5	23,5
13.	Total River Losses (evapo-transpiration & evaporation losses plus shortfall) (Items 6 + 12).	48,2	48,2
14.	MCWAP Phase 2 Water Requirements (maximum average), including system losses	173,3	410,9
15.	Additional evaporation and evapo-transpiration losses (due to additional releases) (calculated)	4,0	5,8
16.	Additional releases to cater for losses resulting from additional releases for MCWAP water requirements (Items 12 + 15).	27,5	29,3
17.	Total dam releases required (Items 2 + 5 + 6 - 7 + 14 + 15)	302,7	562,2

Notes:

1. Average net evaporation = 1 200 mm/a.

2. Total river length U/S of Boschkop = 93 km and total river length U/S of Vlieëpoort = 176 km.
3. Net requirements from the river, i.e. after allowing for distribution losses and irrigation return flows or enhanced runoff.
4. Derived from the mass balance relationship.

Consequently, when additional water is released from the upstream dams for the MCWAP there will be a mean diffuse net seepage water loss of 23,5 Million m³/a (**Table 7-5** Item 12) to the alluvial aquifers connected to the river.

The analyses have been done on the basis of medium-term mean annual flows and the actual average daily river flows can vary significantly from these mean flows. Active management of water releases from the upstream dams will be required to take maximum advantage of downstream inflows. Since the aquifers will be full most of the time when once the water is released from the upstream dams there will be less induced recharge of the aquifer during the high flow months and therefore more water is likely to flow past Vlieëpoort during the high flow season. This would constitute an additional loss from the system that can only be quantified by means of river flow measurements.

7.2.2 River Abstraction Works

Design capacity parameters for the Feasibility stage were generated from data obtained from the Water Resources and Water Requirements reports and are summarised in the following table (**Table 7-6**).

Table 7-6: Abstraction Works Design Flow and Capacity Parameters

Item No.	Design Data	SCENARIO 9			SCENARIO 9 IN 2050		
		Design Flow ⁽¹⁾	Peak Flow ⁽²⁾	Recovery Peak Flow	Design Flow ⁽¹⁾	Peak Flow ⁽²⁾	Recovery Peak Flow
1.	Water Requirements	million m ³ /a	million m ³ /a	million m ³ /a	million m ³ /a	million m ³ /a	million m ³ /a
1.1	Phase 1 Transfer requirements (maximum long-term average) ⁽⁴⁾ .	28.7	28.7	28.7	28.7	28.7	28.7
1.2	Exxaro pipeline contribution.	14.7	14.7	0	14.7	14.7	0
1.3	Phase 1 Transfer requirements (maximum long-term average)	14.0	14.0	43.4	14.0	14.0	43.4
1.4	Phase 2 CRW Transfer requirements (maximum average), including system losses (2%) along Phase 1 and Phase 2 pipelines and reservoirs.	173.3	173.3	173.3	410.9	410.9	410.9
1.5	Additional Losses in CRW (due to additional release) for weir at Vlieëpoort. See section on river losses below.	27.5	27.5	27.5	29.3	29.3	29.3
1.6	Total irrigation water requirements upstream of Vlieëpoort	120.0	120.0	120.0	120.0	120.0	120.0
1.7	Present water requirements downstream of Vlieëpoort	28.9	28.9	28.9	28.9	28.9	28.9
1.8	Total Releases from Dams to provide for Phase 2 – Vlieëpoort Option	302.7	302.7	302.7	562.1	562.1	562.1
1.9	Total Flow Releases from Dams to provide for Phase 2 - Vlieëpoort Option	9.6 m ³ /s	9.6 m ³ /s	9.6 m ³ /s	17.2 m ³ /s	17.2 m ³ /s	17.2 m ³ /s
2.	Vlieëpoort Abstraction Weir						
2.1	Design flow allowance	5%	0%	0%	5%	0%	0%
2.2	Peak flow allowance	0%	9%	0%	0%	9%	0%
2.3	Recovery Period allowance	0%	0%	20%	0%	0%	20%
2.4	Design Flow Vlieëpoort Weir	5.8 m ³ /s	6.0 m ³ /s	6.6 m ³ /s	13.7 m ³ /s	14.2 m ³ /s	15.6 m ³ /s

Item No.	Design Data	SCENARIO 9			SCENARIO 9 IN 2050		
		Design Flow ⁽¹⁾	Peak Flow ⁽²⁾	Recovery Peak Flow	Design Flow ⁽¹⁾	Peak Flow ⁽²⁾	Recovery Peak Flow
2.5	Number of Low-Lift Pump Station bays ⁽³⁾ .	4 No.	4 No.	4 No.	8 No.	8 No.	9 No.
2.6	Number of Low-Lift Pump Station pump sets ⁽³⁾ .	7 No.	7 No.	8 No.	15 No.	16 No.	17 No.
2.7	Number of desilting channels in Desilting Works ⁽³⁾ .	7 No.	7 No.	8 No.	15 No.	16 No.	17 No.
3.	Net Storage Capacity Options of High Lift Pump Station Balancing Dam	m³	m³	m³	m³	m³	m³
3.1	Capacity based on Operational Storage Criterion of 6 hours.	125 300	129600	142 600	296 000	307 000	337 000
3.2	Capacity based on Nominal Storage Criterion of 3 days.	1 503 400	1 555 200	1 710 800	3 551 100	3 680 800	4 043 700
3.3	Capacity based on River Hydrograph Storage Criterion adopted for Feasibility Stage.	1 173 000	1 173 000	1 173 000	1 321 000	1 321 000	1 321 000

Notes:

1. Total Phase 2 water requirements less the Phase 1 contribution plus allowance for seasonal peaks.
2. The worst case peak emergency scenario for Phase 2 Works occurs when the Phase 1 Scheme (Mokolo Delivery) makes no contribution to transfer scheme (the Phase 2 Crocodile Works therefore transfers the full water requirement), OR, 20% allowance for recovery period after downtime, whichever is the largest.
3. One additional fully equipped standby bay plus one full spare pump including M&E, valves, screens for the design case. For the Crocodile weirs this is based on submersible pump with 1 m³/s rated capacity. Data for suitable pumps were obtained from pump suppliers. Nine double pump bays were provided to cater for the projected long-term requirements.
4. Ultimate Mokolo Dam supply after commissioning of Crocodile River (West) Transfer Scheme (28,7 Million m³/a including any losses).

7.2.3 High-Lift Pump Station, Pipelines and Reservoirs

The three design cases were applied as follows to size components of the CRW Transfer Scheme (Vlieëpoort High-lift pump station from the Balancing Dam to the Steenbokpan connection with the Steenbokpan-Lephalale pipeline).

Table 7-7: Crocodile River (West) Transfer Scheme Design Capacity

Item No.	Design Data	SCENARIO 9		
		Design Flow ⁽¹⁾	Peak Flow ⁽²⁾	Recovery Peak Flow ⁽³⁾
1.	Water Requirements	million m³/a	million m³/a	million m³/a
1.1	Phase 1 Transfer requirements (maximum average) ⁽⁵⁾	28.7	28.7	28.7
1.2	Exxaro pipeline contribution.	14.7	14.7	0
1.3	Phase 1 Transfer requirements (maximum average).	14.0	14.0	43.4
1.4	Phase 2 CRW Transfer requirements (maximum average), including system losses (2%) along Phase 1 and Phase 2 pipelines and reservoirs.	173.3	173.3	173.3
2.	Transfer Scheme			
2.1	Design flow allowance.	5%	0%	0%
2.2	Peak flow allowance.	0%	9%	0%
2.3	Recovery Period allowance ⁽³⁾ .	0%	0%	20%
2.4	Design Flow Transfer Scheme .	5.8 m ³ /s	6.0 m ³ /s	6.6 m ³ /s
2.5	Number of High-lift pump sets ⁽⁴⁾ .	5 No.	5 No.	5 No.
3.	Net Storage Capacity of Break Pressure and Operational Reservoirs	m³	m³	m³
3.1	Capacity based on Operational Storage Criterion of 8 hours.	167 000	173 000	190 000

Notes:

- Total Phase 2 water requirements less the Phase 1 contribution plus 5% allowance for reliability peak.
- Total Phase 2 water requirements less the Phase 1 contribution plus 9% allowance for seasonal peaks.
- The worst case peak emergency scenario for the Phase 2 Scheme occurs when the Phase 1 Scheme (Mokolo Delivery) makes no contribution to the water supply (the Phase 2 CRW Transfer Scheme therefore transfers the full water requirement), OR, 20% allowance for recovery period after downtime, whichever is the largest.
- Based on 4 duty, 1 standby pump configuration for the 2030 Scenario 9 requirement. Future upgrading will require additional pumping units.
- Ultimate Mokolo Dam supply after commissioning of CRW Transfer Scheme (28.7 Million m³/a, including any losses).

7.3 River Abstraction Works

The details of the River Abstraction Works are given in Supporting Report 11 – Technical Module: Phase 1 Feasibility Stage and are summarised below.

During the Feasibility stage, the following aspects of the River Abstraction Works component of the MCWAP Study were developed further:

- The Vlieëpoort Abstraction Weir, Gravel Trap, Low-lift Pump Station, Desilting Works and High-lift Pump Station Balancing Dam;
- River Management and in particular issues such as possible functional arrangements, river flow management, gauging weir requirement assessments and operation and maintenance philosophies; and
- Assessment of dam options at Vlieëpoort.

Sizing criteria were prepared during the course of the Pre-feasibility stage and the structures were sized accordingly for costing purposes. Pertinent sizing data for the Vlieëpoort River Abstraction Works are summarised below.

Table 7-8: Vlieëpoort Abstraction Weir Design and Sizing Data

Item No.	DESIGN DATA	VALUE
1.	Design Flood (RDF) (1:200 year Recurrence Interval flood)	5 740 m ³ /s
2.	Safety Evaluation Flood (SEF) (PMF)	11 180 m ³ /s
3.	1:20 year Recurrence Interval Flood	2 870 m ³ /s
4.	1:50 year Recurrence Interval Flood	4 020 m ³ /s
5.	River bed Level	890.0 masl
6.	Lowest Overspill Crest (OC) Level	894.3 masl.
7.	NOC Level (PMF plus 0.5m Freeboard)*	914.43 masl
8.	OC Length	153 m
9.	Total Length of Structure	308 m

* The NOC level refers to the top of river training wall level along the left bank, the control room floor level in the Low-lift Pump Station and the embankment/access bridge level on the right bank.

7.3.1 Description of Components

The Abstraction Works arrangement consists of:

- Mass concrete gravity type Diversion Weir, 4.3 m high with ogee and roller bucket spillway. This will be built to the final requirements for Phase 2.
- Gravel Trap in weir basin with flushing facility and trash rack with concrete channels leading from gravel trap to each pump-well in the Low-lift pump station that is incorporated partly into the NOC flank of the weir and partly into the river bank. Nine pump bays, each capable of accommodating two fully equipped 1.0 m³/s capacity

submersible grit pumps were provided. This will be built to the final requirements for Phase 2, but only be equipped for Phase 2A initially.

- Low pressure rising main to the Desilting Works for Phase 2A, which will be duplicated for Phase 2B.
- The rising main for Phase 2A will consist of a 2 100 mm diameter steel pipeline approximately 5 km long. It will then be split with a manifold into nine 750 mm diameter pipes leading to the Desilting Works inlets. Each pipe will have a gate valve in a valve chamber adjacent to the Desilting Works.
- Desilting Works with flushing facility located near the low-lift pump station, but above the PMF level.
- The Desilting Works for Phase 2A will consist of nine 120 m long channels, 2.5 m wide and depth varying from 4.0 m to 5.5 m.
- Each desilting channel will have a 750 mm diameter steel outlet.
- A gravity pipeline between the Desilting Works and Balancing Dam inlets.
- A multi-compartment Balancing Dam situated above the PMF level sized to provide balancing storage to cater for unplanned changes in river flows and for differences in inflows from the Desilting Works and outflows to the High-lift Pump Station. The Balancing Dam will also be equipped with a drain and silt flushing facility, although only infrequent use, perhaps once every 10 years, is expected.
- The Balancing Dam has top dimensions of 600 m x 370 m, five compartments and a total live storage capacity of 1 300 000 m³. The depth varies from 10.5 m at the inlet side to 13.2 m at the outlet side. A freeboard provision of 0.5 m above the spillway crest, which is 0.5 m above the FSL, was made.

7.4 High-Lift Pump Station

The pump investigations showed that the required delivery capacity can be achieved by using four duty pumps with one standby unit. Each pump set will comprise an in-line booster pump and a main high pressure pump (no valve in-between). The minimum static suction head required for the booster pumps, based on the site conditions and the likely net positive suction head (NPSH) of the booster pumps, was estimated to be 8 m. To reduce excavation depth careful design of the inlet conditions in the Balancing Dam and the suction manifold will be required. It is presently envisaged that Variable Speed Drive (VSD) units be installed to enable continuous, more economical pumping and improve the flexibility of the pumping scheme. In addition, VSD drives would greatly reduce starting currents and reduce pressure surges in the system.

The estimated absorbed power (Mega Volt Amperes (MVA)) at the design flow and recovery peak flow duty ratings are summarised below for the minimum and maximum operating head.

Table 7-9: Crocodile River (West) High-Lift Pump Station Power Requirements

	Design Flow	Recovery Peak Flow
<i>Minimum System Head (Min static head and 0.05 mm absolute roughness)</i>		
Duty	5.8 m ³ /s @ 216 m	6.6 m ³ /s @ 226 m
Absorbed power	14.8 MVA	17.7 MVA
<i>Maximum System Head (Max static head and 0.5 mm absolute roughness)</i>		
Duty	5.8 m ³ /s @ 240 m	6.6 m ³ /s @ 255 m
Absorbed power	16.5 MVA	19.9 MVA

7.4.1 Bulk Electricity Connection

The Vlieëpoort site will be supplied from the Thabazimbi Munic (Thaba Combined) and Thabazimbi Rural (Thabatshipi) 132 kV sub-stations. High Voltage (HV) transmission lines will be built from each sub-station to the Vlieëpoort site, in order to ensure redundancy. (Loop in – Loop out system)

7.5 Pipelines

An option analysis for the Phase 2A pipeline found that a rising main to an Operational (and also Break Pressure) Reservoir at Ch 26700 (node 10) and gravity flow to a possible future Operational Reservoir and further to the connection with the Lephale-Steenbokpan pipeline were the most feasible.

The transfer pipeline starts at the Vlieëpoort High-lift Pump Station and continues north along the Thabazimbi-Dwaalboom Road (D1649). The pipeline crosses the farm Paarl 124 KQ parallel to an existing high voltage power line before turning east towards the R510. The proposed site for the Operational (and also Break Pressure) Reservoir is located on the farm Zondagskuil 130 KQ. From the Operational Reservoir, the route continues north along the R510 for a short distance before turning east on the boundary between Tarantaalpan and Diepkuil. The route then heads north along the western boundary of the railway line servitude to the site of a possible future Operational Reservoir located on the Farm Rooipan 357 LQ, crossing the Matlabas River en route. From the possible future Operational Reservoir, the pipeline continues north-west towards Steenbokpan, where it links up with the pipeline from Lephale constructed as part of Phase 1 of the MCWAP. Refer to Drawings 9528-LD-CTS-001 included in **Appendix A** for the locality and layout of Phase 2A of the project.

7.5.1 Design Considerations

7.5.1.1 Coating and Lining

The following generic coating and lining systems are recommended for the CRW Transfer Scheme Pipelines.

Table 7-10: Coating Options

Product/Method		Field Joint Repair Method
External Coating	Preferred: Trilaminate Polyethylene (3LPE) or Polyurethane	Liquid or powder epoxy plus cold tape wrap Polyurethane
	Alternative: Polymer modified bitumen/Glass Fibre (Bituguard)	Bituguard hot applied tape
Internal Lining	Preferred: Epoxy or Cement Mortar	Epoxy Cement Mortar

7.5.1.2 Long-Term Roughness

The recommended long-term roughness parameters, as well as the influence of biofilm are summarised below in **Table 7-11**.

Table 7-11: Long-Term Roughness

Parameter	Cement Mortar Lining		Epoxy Lining	
	Suggested	Maximum	Suggested	Maximum
Long-term absolute roughness (mm)	1.1	1.5	0.5	0.7
Influence of biofilm	Reduction in diameter of 5-8 mm			

7.5.1.3 Structural Design and Optimisation

The design of flexible buried pipes involves consideration of the interaction between the steel shell and the surrounding backfill, as well as the deflection limits appropriate to the lining and coating system. Flexible pipes obtain a large portion of their load carrying capacity from the surrounding backfill, and therefore, the incorporation of this interaction is important. The design method should take into account the strength of the pipe-soil system as a whole, without relying solely on the strength of the individual components. A detailed structural analysis and optimisation was not performed during the Feasibility stage investigation and must be carried out during the detail design stage.

7.5.1.4 Minimum Pipe Wall Thickness

The wall thickness is a function not only of the internal pressure (i.e. operating pressure and the surge over-pressure), but also of the external pressure exerted on the pipe (i.e. soil overburden, external fluid pressure, vehicular and vacuum loading etc.). On large diameter steel pipelines practical requirements such as pipe handling and installation requirements may in fact control the minimum pipe wall thickness. Therefore, the selection of the minimum pipe wall thickness is a function of:

- Internal Design Pressure (i.e. maximum design pressure and vacuum);
- External Design Pressure (i.e. soil overburden plus vacuum and vehicular loading);

- Pipe Handling Requirements (i.e. pipe manufacture, transportation, laying and backfilling requirements); and
- Pipe Buckling Capacity (Considering good quality soils, poor quality soils, as well as hydrostatic or unsupported soil conditions).

For more detail on the criteria for the selection of the minimum pipe wall thickness, refer to Supporting Report No. 12 – Technical Module: Phase 2 Feasibility Stage.

7.5.1.5 Optimum Diameter Selection

The optimum pipe diameter for the rising main was determined by performing an economic analysis over a 45-year period for a number of different pipe diameters and resultant D/t ratios. The analysis found that a 1 900 mm ND was the optimum pipe diameter. This also corresponds well with the graph below indicating that a pipe of this diameter has the lowest URV value.

The respective system duty points are illustrated in **Figure 7-2** below.

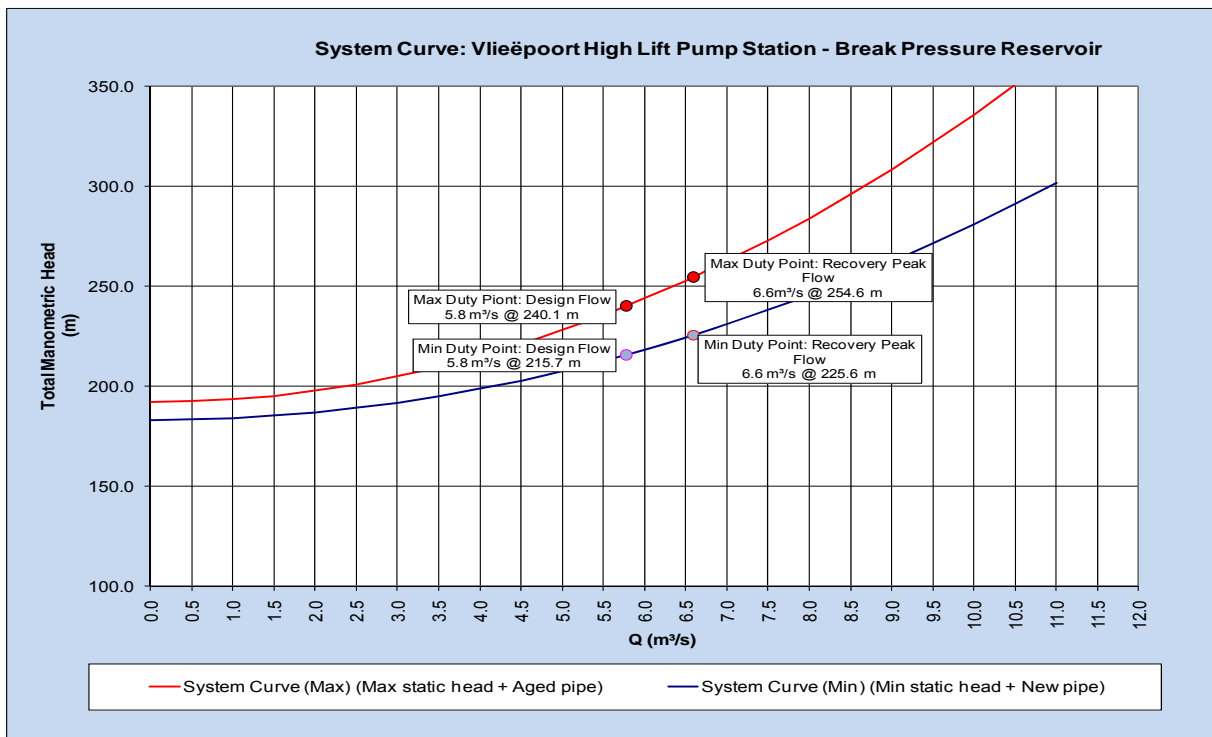


Figure 7-2: Vlieëpoort Pump Station System Curve

7.5.1.6 System Hydraulics

Based on a hydraulic assessment of the scheme, the pipe sections required for the CRW Transfer Scheme are summarised below in **Table 7-12**.

Table 7-12: System Hydraulic Assessment

Pipe Section	Diameter (mm)	Length (km)	D/t & wt	Velocity (m/s)	
				Design Flow	Recovery Peak Flow
Vlieëpoort High-lift Pumpstation to Operational and Break Pressure Reservoir (Rising Main)	1900	26.7	110 17.5 mm	2.05	2.34
BPR to possible future Operational Reservoir (Gravity Main)	2200	62.7	130 17.2 mm	1.52	1.73
Operational Reservoir to CRW Connection (Gravity Main)	2300	28.2	140 16.7 mm	1.39	1.58
CRW Connection to Steenbokpan (Constructed as part of Phase 1) (Gravity Main)	1900	1.4	160 12.1 mm	1.58	1.80
CRW Connection to CF 3&4 Mining T-off (Constructed as part of Phase 1) (Gravity Main)	1100	27.2	160 7.0 mm	1.35	1.54
CF 3&4 Mining to Medupi T-off (Constructed as part of Phase 1) (Gravity Main)	900	3.6	160 5.7 mm	1.48	1.69
Medupi T-off to Steenbokpan T-off (Constructed as part of Phase 1) (Gravity Main)	900	8.2	160 5.7 mm	1.23	1.41
Steenbokpan T-off to Grootegeluk / Matimba Control Chamber (Gravity Main)	800	1.9	160 5.1 mm	1.56	1.78

The final position and number of end user Terminal Reservoirs has not been confirmed as most of the end users are still in various stages of planning. The position of the system off-takes and Terminal Reservoirs and the ultimate water requirements of the end users will have an influence on the pipe sizes and system operation along the Lephalale-Steenbokpan link and must be confirmed as part of the detail design stage. The operation of the Lephalale-Steenbokpan link, built under Phase 1 will be reversed for the ultimate system operation to transfer water from west to east to provide water to users in the Lephalale area. This will require careful consideration of the valve selection and positioning, as well as the accommodation of potential surge pressures. Consideration must also be given to the water quality requirements of the various users and the effects on the valve positions.

A detailed hydraulic analysis for the positioning of the air valves, as well as isolating, reflux and control valves must therefore be performed as part of the detail design for each of the Phase 1 and Phase 2 Schemes.

7.5.2 Cathodic Protection and AC Mitigation

The proposed pipeline routes run parallel to and cross a number of existing and proposed future HV power line routes, most notably, the planned new Eskom corridors that will be constructed as part of the Mmamabula-Medupi Transmission Integration Project. These corridors will contain six 765 kV overhead high voltage AC power lines.

The pipeline also runs parallel to the railway line for a significant distance. The railway line is currently not electrified, but if electrified in future, it is expected to be with AC power.

Stray current interference is expected on the pipeline and CP and AC mitigation measures will be required to protect the proposed pipeline.

7.6 Reservoirs

The CRW Transfer Scheme includes an Operational and Break Pressure Reservoir located on the farm Zondagskuil 130 KQ, as well as a possible future Operational Reservoir located on the farm Zoutpan 367 LQ.

The scheme will supply water into Terminal Reservoirs located on the sites of the end consumers. The Terminal Reservoirs must provide a minimum of 18 days reliability storage and will be built by the respective end users, but will be operated and controlled by the MCWAP.

The Reservoirs will generally be in the form of an artificial dam formed by shallow excavation and surrounding earthfill embankments. The final depth and size of the reservoirs will be determined by the site topography (cut and fill balance) with the aim of minimising surface area to reduce evaporation and maximum flow through to prevent stagnation of the water.

Reservoirs will have to be lined with an appropriate waterproof lining system (HDPE or similar material) and suitable sub-surface drainage must be provided.

As part of Phase 2B it is expected that the Break Pressure Reservoir can be converted to a Surge Reservoir by converting the first portion of the gravity pipeline to a rising main to a new Operational Reservoir (at Node 15) to increase the capacity of the CRW Transfer Scheme.

The Terminal Reservoirs, will typically be compartmentalised and have a minimum storage of 18 days of the consumers' average annual water requirement (reliability requirement), which will be reserved for purposes of the MCWAP operation and maintenance only, plus storage to be determined by consumers for their own internal peak balancing and operational requirements

7.7 Geotechnical Aspects

For more detail on the geotechnical aspects, refer to Supporting Report 8B – Technical Module: Geotechnical Investigations Phase 2.

7.7.1 Abstraction Works

An exploratory geotechnical investigation was undertaken during the course of the Feasibility stage. Pertinent findings of the exploratory work were:

- The Vlieëpoort Abstraction Weir appears to be located upstream of the Dolomite/Ironstone contact known to be present in the poort. This will reduce the complexity of the foundation designs to be undertaken.
- The depth of the alluvium appears to be significantly thicker than originally thought and in the central section of the river bedrock was only found 40 m below surface. The extent of the foundation treatment would therefore effectively be double of what was originally anticipated. This has consequently resulted in a doubling of the estimated cost of the Works.
- The original balancing dam site was to be located on dolomite. An alternative site, located on residual Ventersdorp lava some 5 km downstream of the Abstraction Works, is now favoured.

A full geotechnical investigation during the future design phases will be required to:

- Refine the location of the Weir in order to reduce founding costs and costs of seepage control;
- Confirm the materials properties of the alluvium (grading, permeability, clay content, etc.);
- Investigate foundation improvement alternatives;
- Rising main centreline investigation; and
- Undertake a detailed investigation of the two proposed Balancing Dam and High-lift Pump Station sites.

7.7.2 Balancing Dam, Silt Trap and High-Lift Pump Station

The exploratory geotechnical investigation revealed that the proposed site is underlain by dolomitic rocks, cherts and subordinate shales of the Malmani Subgroup, Chuniespoort Group, Transvaal Supergroup.

The proposed site is located on the gentle topography to the north-west of the Vlieëpoort Mountains, which are aligned with the banded ironstone formations of the Penge Formation. The strata strike roughly in a north-easterly direction, and dip at angles between 20° and 30° in a south-easterly direction.

The proposed site is covered by colluvial materials and no geological structure is indicated on the geological map. It is likely, however, that the dolomitic strata reflect a similar attitude, i.e. dipping at moderate angles in a south-easterly direction.

The geological map indicates a minor fault aligned roughly parallel to the Vlieëpoort Mountains, a short distance downstream of the indicated weir site. The geological map gives no indication of faulting at the proposed site, although this may be masked by the cover of colluvial materials.

The rotary core boreholes revealed the following horizons:

- Colluvium;
- Dolomite residuum; and
- Dolomite bedrock.

No water tables were recorded in any of the four boreholes drilled on the footprint and it may be assumed that the water table occurs at depths greater than 10 m.

7.7.3 Pipeline

The pipeline route commences in the south at Vlieëpoort, where it is underlain by rocks of the Transvaal Supergroup (mostly dolomite, chert, arkoses and andesite), before crossing onto Archaean Granite. After crossing back onto Transvaal Supergroup rocks, it then traverses mainly Waterberg sediments (sandstone and some mudstone), with patches of granite and diabase. In the north (from about 10 km south of the point where the pipeline splits from the Spoonet line), the pipeline is on Quaternary sands (with calcrete and ferricrete), which overlie Waterberg Group sandstone.

The various geological units encountered along the centreline of the pipeline are given sequentially (from south to north on **Table 7-13**) and their extent is shown.

Table 7-13: Geology Summary for Phase 2A Route

Km	Anticipated Geology
0 – 5	Dolomite
5 - 7.7	Pretoria Group and dolomite
7.7 - 15.7	Granite
15.7 - 34.2	Alluvium
34.2 - 37.2	Dolomite
37.2 - 42.6	Waterberg sandstone
42.6 - 57.6	Alluvium
57.6 - 86.6	Waterberg sandstone, diabase
86.6 - 98.8	Alluvium
98.8 – 125	Quaternary sand, diabase

Test pits were excavated at a nominal spacing of 5 km along the route of the pipeline. No seepage was encountered in any of the test pits dug along the route and it appears that this is unlikely, except in the vicinity of streams (and particularly on the south bank of the Matlabas River).

No investigations for bedding and soft backfill were carried out. Notwithstanding this, bedding material and soft backfill should be freely available north of about km 55 and an

average haul distance of 5 km seems to be indicated. In this area, it is probable that much of the soil excavated from the pipe trench will be re-usable for bedding and soft backfill. Between km 0 and 55 borrow sources would seem to be difficult to locate and haul distances of at least 10km are likely.

8 ENVIRONMENTAL IMPACT ASSESSMENT INTERFACE

The development of new power stations is of high strategic importance and the construction of the first new power station, Medupi, is already underway. The first units will be commissioned by the end of 2010. The proposed Mokolo Dam Scheme will be implemented as a first phase because of the availability of water in the Mokolo Dam and the shorter time required to commission it while the CRW Transfer Scheme is under construction.

The required Environmental Impact Assessments (EIAs) and obtaining Environmental Authorisation for both phases are currently underway as part of the Environmental Module of the MCWAP Feasibility Study. The focus of this process is similar to the implementation planning for the two phases of the project with Phase 1 receiving priority attention.

The Environmental feasibility of the Phase 1 and Phase 2 routes was evaluated as part of the Pre-Feasibility investigation as an initial screening (Refer to Supporting Report No 7 – Technical Module: Social and Environmental Screening, No. P RSA A000/00/9409).

A screening process was conducted to evaluate each route option and identify potential fatal flaws that may eliminate a specific route or position of an infrastructure component. Both the biophysical and social environments were assessed and reported on. The above report also comments on the likely costs associated with mitigating the impacts.

8.1 Listed Activities

Activities identified in terms of Section 24(2)(a) and (d) of the National Environmental Management 1998 (Act 107 of 1998) (the Act), which may not commence without Environmental Authorisation from the competent authority and in respect of which the investigation, assessment and communication of potential impact of activities must follow the procedure as described in Regulations 22 to 26 of the Environmental Impact Assessment Regulations, 2006, promulgated in terms of Section 24(5) of the Act, are listed below.

The construction of major civil works and pipelines are listed activities in terms of the Act. The following listed activities are included under Regulation 386 indicating a basic assessment:

- 1(k) The bulk transportation of sewage and water, including storm water, in pipelines with -
 - (i) an internal diameter of 0.36 metres or more; or
 - (ii) a peak throughput of 120 litres per second or more.

4. The dredging, excavation, infilling, removal or moving of soil, sand or rock exceeding 5 cubic metres from a river, tidal lagoon, tidal river, lake, in-stream dam, floodplain or wetland.

Although indicated as a Basic Assessment it is anticipated that several detailed specialist investigations such as fauna, flora and heritage assessments will have to be completed. The timing of the project is therefore significant as some of the studies can only be conducted during certain periods of the year. Due to the extent of the project, a full EIA must also be conducted.

The duration of a full EIA process can be anything from 18 to 24 months.

8.2 Potential Environmental Impacts

The construction of a pipeline could have numerous environmental impacts, including the following:

- Destruction of vegetation;
- Faunal habitat loss;
- Soil erosion;
- Hydrocarbon pollution of soil, ground and surface water;
- Air pollution (dust during blasting and drilling); and
- Noise pollution.

8.3 Environmental Aspects Considered

8.3.1 General Considerations

The detailed investigations envisaged for the design stage will be the responsibility of the consultant responsible for the EIA. The Pre-Feasibility and Feasibility stages only consisted of a desktop investigation and a brief site visit to identify major fatal flaws, if any should exist. During the Design Phase, detailed fauna and flora investigations will have to be conducted to identify specific sensitive plant communities that are sensitive, as well as sensitive habitats that will be affected by the MCWAP. The investigation also needs to indicate how well such communities are represented in the vicinity and elsewhere.

8.3.2 Phase 1 Considerations

The pipeline planned as part of Phase 1 traverses some sensitive areas where particular care should be taken. These will be pinpointed during a detailed investigation. Rocky areas are most sensitive due to the presence of aloe species, as well as the distinct habitat it provides for animal species.

The construction of the new pump station at the Mokolo Dam is not foreseen to have a significant impact due to the fact that it will be located close to the existing facility. Precautionary measures regarding possible erosion will have to be taken due to the fact that it is situated on steep slopes. The area surrounding the dam has very steep slopes, as well as large areas of sensitive rocky outcrops. The construction of the pump station will in all likelihood result in the destruction of some of these areas. To minimise this impact, the site for the pump station must be identified in conjunction with faunal and floral specialists.

Due to the fact that the pipeline alignment is adjacent to the existing pipeline and the vegetation has recovered along the existing pipeline, it is a clear indication that the disturbance of the vegetation is of a temporary nature. With mitigation measures the construction of the pipeline will have a minimal lasting effect on the surrounding area.

8.3.3 Phase 2A Considerations

The pipeline does traverse some sensitive areas where particular care should be taken. These will be pinpointed during a detailed environmental investigation. Rocky areas are most sensitive due to the presence of aloe species as well as the distinct habitat it provides for animal species. The construction of the river Abstraction Works (and Balancing Dam) and High-lift Pump Station at Vlieëpoort will have an impact that must be mitigated. To minimise this impact the sites must be identified in conjunction with faunal and floral specialists where not dictated by physical features.

The location of the pipeline adjacent to the existing linear infrastructure, together with adequate mitigation measures, will ensure that the construction of the pipeline will have a minimal lasting effect on the surrounding area.

In the southern regions, the proposed pipeline is located relatively close to some sensitive rocky outcrops in certain areas and particular care should be taken to minimise the disturbance of these areas. For the most part, the central route runs along the railway line from Thabazimbi to Lephalale and then along an existing gravel road to Steenbokpan. The railway line has a maintenance road adjacent to it.

The railway line and road has resulted in an existing linear impact along most of the proposed pipeline route. The vegetation types along the route consist mainly of Western Sandy Bushveld and Limpopo Sweet Bushveld. Both these vegetation types are listed as Least Threatened. Due to the pipeline alignment being parallel and near the railway line and other existing linear infrastructure, it limits the impact on farm areas and it should not lead to significant further fragmentation.

The central route crosses only one major hydrological feature along its length (Matlabas River). The crossing of the river by the pipeline should preferably coincide with the crossing of the railway line. The area has already been disturbed and the river crossing for the pipeline should therefore not be significant.

The Abstraction Works (and Balancing Dam) and High-lift Pump Station are located on cultivated land in the Mooivallei area. This portion of the works will have a higher and more permanent impact on the area that would have to be mitigated.

Many of the potential impacts associated with the pipeline can be negated or minimised through proper construction management and diligent communication and consultation with affected land owners.

9 SOCIAL IMPACT

A high level social impact assessment was done in order to identify the perceived impact of the MCWAP and to quantify to potential cost to be included in the analysis of the options. The most significant socio-economic impacts of the proposed pipelines are:

- Negative impacts:
 - Loss of agricultural Land;
 - Foreign work force and inflow and outflow of workers;
 - Workers' camps and effect on communities in the vicinity;
 - Possible disruption of daily living;
 - Safety and security;
 - Impact on property values; and
 - Aesthetic impacts.

- Positive impacts:
 - Increased government income and stimulation of local economy;
 - Employment and decrease in local unemployment levels;
 - An increase in new businesses and in sales;
 - Increased standards of living; and
 - Transfers of skills.

9.1 Loss of Agricultural Land

The pipeline servitude will mainly run alongside various existing roads, power lines and the railway line. Along such sections of the route, the socio-economic impacts of the pipeline are expected to be minimal.

Most of the land that will be affected by the pipeline servitude is currently natural pasture (agricultural land with bushes and shrubs).

During construction, the owners of the affected farms will experience a loss of either cultivated or pastoral land. The permanent servitude will, however, not be fenced and the owners will be able to regain use of the land after construction. The inconvenience to the farmer will therefore mostly only be during the construction phase.

Farming activities and arable land might be negatively affected for an area larger than the servitude width especially during construction, due to vehicle movements, dust, etc. Provision must be made for fencing to be put up during the construction of the pipeline, with provision for agricultural vehicles to gain access to all areas of the farms.

During the operation phase, the land preparation and construction of the pipeline would have removed vegetation, causing increased surface run-off, erosion, etc. The necessary

management procedures need to be put in place and implemented so that the negative impacts can be reduced.

9.2 Foreign Work Force and Influx and Efflux of Workers

Local socio-economic impacts of large-scale development projects tend to be closely associated with the location (migration) of project workers and families to communities near the project site.

The influx of people could be brought about by a number of factors. Through its positive economic impacts, the construction phase can attract unemployed persons in search of work (both directly and indirectly related to the construction). Squatter camps can develop and will have a number of environmental impacts, which include adverse health effects resulting from lack of sanitation facilities, waste disposal facilities, poor ventilation and an increase in crime.

The presence of a workforce from outside the project area could lead to conflict between them and local residents due to differences in culture and values, competition for employment opportunities, a perception among local residents that services are being provided for outsiders while their own needs are not addressed, etc.

During the construction period, the inflow of temporary workers will also result in demographic changes, disruption of existing social networks and an increase in Sexually Transmitted Diseases (STDs) and related illnesses. An increase in the population could indirectly also trigger other impacts such as increased crime.

9.3 Workers' Camps and Effect on Communities in Vicinity

It is proposed that workers' camps be provided for the construction of the scheme, since not all the workers will be able to be locally recruited. Failure to provide for workers' camps will cause a large influx of persons and squatters in search of work. These could result in the contractors not being able to adequately manage the workers and lead to negative impacts.

While relatively close proximity to the construction sites is attractive when determining suitable sites for the workers' camps, factors such as the availability of space for temporary housing, camps and adequate public and private sector services must also be considered.

The workers' camps should preferably be within close proximity to existing towns/settlements (in this case Steenbokpan/Thabazimbi) within the vicinity of the pipeline.

The exact locations for the workers' camps need to be determined beforehand in consultation with Lephalale and Thabazimbi Municipalities. The positive impacts of availing land for workers' camps outweighs the negative factors as highlighted previously. This should be clearly indicated to the applicable Municipality.

The decision to allow employees to live in accommodation separate from the workers' camp will contribute towards curtailing an increase in the incidence in STDs and AIDS. Furthermore, the accommodation of staff within a single-sex workers' camp or as residents within neighbouring villages – in the absence of the family members – has the potential to result in an increased incidence of STDs.

Early efforts to provide workers' camps and support services in the Pre-Construction stage should be initiated and the workers' camps need to conform to public health and safety regulations.

Other less tangible impacts that may occur in the areas as a result of the workers' camps include a reduction in social stability, loss of social support structure, decrease in safety and security, community conflicts and loss of sense of community.

9.4 Disruption of Daily Living

Changes in the routine living, activities, movement patterns and infrastructure (to a lesser degree) of residents in the affected areas will be brought about by the alteration to the visual environment, noise, transportation route changes, etc. These impacts will be most significant during the Construction phase only.

Numerous gravel roads in the area will also affect the flow of pedestrians and vehicular traffic along routes in the area and cause more dust. Furthermore, construction vehicles on these roads will increase the air pollution.

Some structures may be affected by the infrastructure to be provided as part of the scheme and some farmers may lose major portions of their farms in the Mooivallei area. Apart from the impact associated with the Abstraction Works and the High-lift Pump Station, the overall social impact of the pipeline route is considered to be very modest.

Although temporary, the construction stage will be responsible for the greatest amount of disruption caused during the entire Implementation, Operation and Maintenance stages.

During operation, regular inspections will be undertaken and a certain amount of maintenance will need to be carried out periodically. This will include repair to the pipeline. Access will need to be granted to operating, inspection and maintenance teams to all components of the scheme where the servitude is not located close to the road, railway line or power line servitude, which may inconvenience farmers. Where pipeline problems occur below ground, excavation may need to be done in order to assess the problem. This will lead to further temporary disruption to address the problem. It is expected that pipeline sections alongside existing servitudes (roads, railway and power lines) will be relatively easy to access and therefore to inspect and maintain.

9.5 Safety and Security

Mainly during the Construction phase and to a lesser degree during the Operation phase, safety and security problems are foreseen due to people having to gain access to private land. Individuals could sustain permanent physical harm during the construction period from injury, noise, dust and stress, sometimes causing long-term psychological problems. Since few dwellings are located near the pipeline route, safety and security impacts for the construction workers could be more significant.

9.6 Impact on Property Values

The prices of farms in the impacted areas may be affected. The uncertainty of property owners and potential new property owners could have negative impacts on the value of land and surrounding farms affected by the pipeline.

The farmers need to get compensated for any loss of value of land in the vicinity of the area on which a servitude is to be registered.

9.7 Aesthetic Impacts

Aesthetic impacts on the surrounding landscape will most notably occur during the Construction phase, which is temporary. Factors such as the width of servitude and size of the buried pipeline have a temporary influence on the visual quality of the landscape during the Construction phase.

Other visual intrusions during the construction phase include:

- Fencing erected in the construction servitude area;
- Workers' camps at the proposed locations;
- Prefabricated offices and vehicle storage places along the route; and
- The 50-metre wide servitude along the length of the pipeline.

Since the pipeline is below ground, except for the valve and access chambers, the visual impact is far less marked, than had it been situated above ground. During operation, the only visual impact will be gravel access roads and valve chambers along the pipeline. The visual impact during operation is thus relatively small.

The permanent infrastructure at the Abstraction Works, Break Pressure and Operational Reservoir sites is located above ground and covers vast areas. These facilities will result in a permanent aesthetic impact that will be difficult to mitigate.

9.8 Employment and Decrease in Local Unemployment Levels

The scheme will provide sufficient water which will allow the mines and industries to grow at the pace desired, thus bringing an increase in employment and mining activity, as well as decreasing the local unemployment level.

9.9 Increase in New Business Sales

The increased employment expected, will impact positively upon the regional and local economy. Increased employment is associated with increased income and consequently with increased buying power in the area, thus leading to new business sales to accommodate the new demand for services and goods. The employees will spend more, and more money will be injected into the economy.

9.10 Increased Government Income and Stimulation of Local Economy

The potential positive economic benefits such as increased financial spending, increased infrastructure investment, increased expenditure by employees, etc. are likely to result in increased markets for the sale of local goods for the new employment (permanent and temporary) that will be created and the direct future employment by the mines and industries such as Eskom and Sasol.

The supply of water can thus be seen as an economic injection to the area that would also lead to increased government income, through an increased tax base, and increase the capacity of the local municipality to increase and/or improve social and service support actions and local spending.

9.11 Increased Standards of Living

The multiplier or spin-off effects from this economic activity will improve standards of living, decrease dependence on pensions, increase disposable income and ability to purchase additional goods and/or establish other business enterprises. Apart from having the potential to create occupational opportunities, the proposed development could also stimulate economic growth in the region by attracting other commercial activities. If this is the case, indirect local benefits may accrue in the form of job opportunities in other sectors and industries. The proposed development may also serve as a catalyst for the improvement of services and infrastructure in the longer term. A stimulation of the economy is also expected in the transport sector, as more public transport will have to be made available for workers and their families. An increase in trade, which includes retailers, wholesalers, restaurants and accommodation establishments, is also expected when large numbers of people enter an area.

9.12 Transfer of Skills

With an increase in employment, a definite transfer of skills will result. Skills development is a prerequisite for human resource development, and will have a lasting impact on the economy.

9.13 Compensation Costs

The compensation cost for the land to be acquired is based on a 50 m wide permanent servitude. Apart from the physical land value, the additional cost associated with implied losses as result of the impact of construction on game farming and hunting, accommodation

and eco-tourism will have to be considered. To account for this, a value for purposes of estimating the scheme cost was based on a conservative estimate of R24 000/ha.

10 INFRASTRUCTURE SUMMARY

A schematic layout of the proposed MCWAP is given in **Figure 10-1**. Details of the main project components are given in **Table 10-1**.

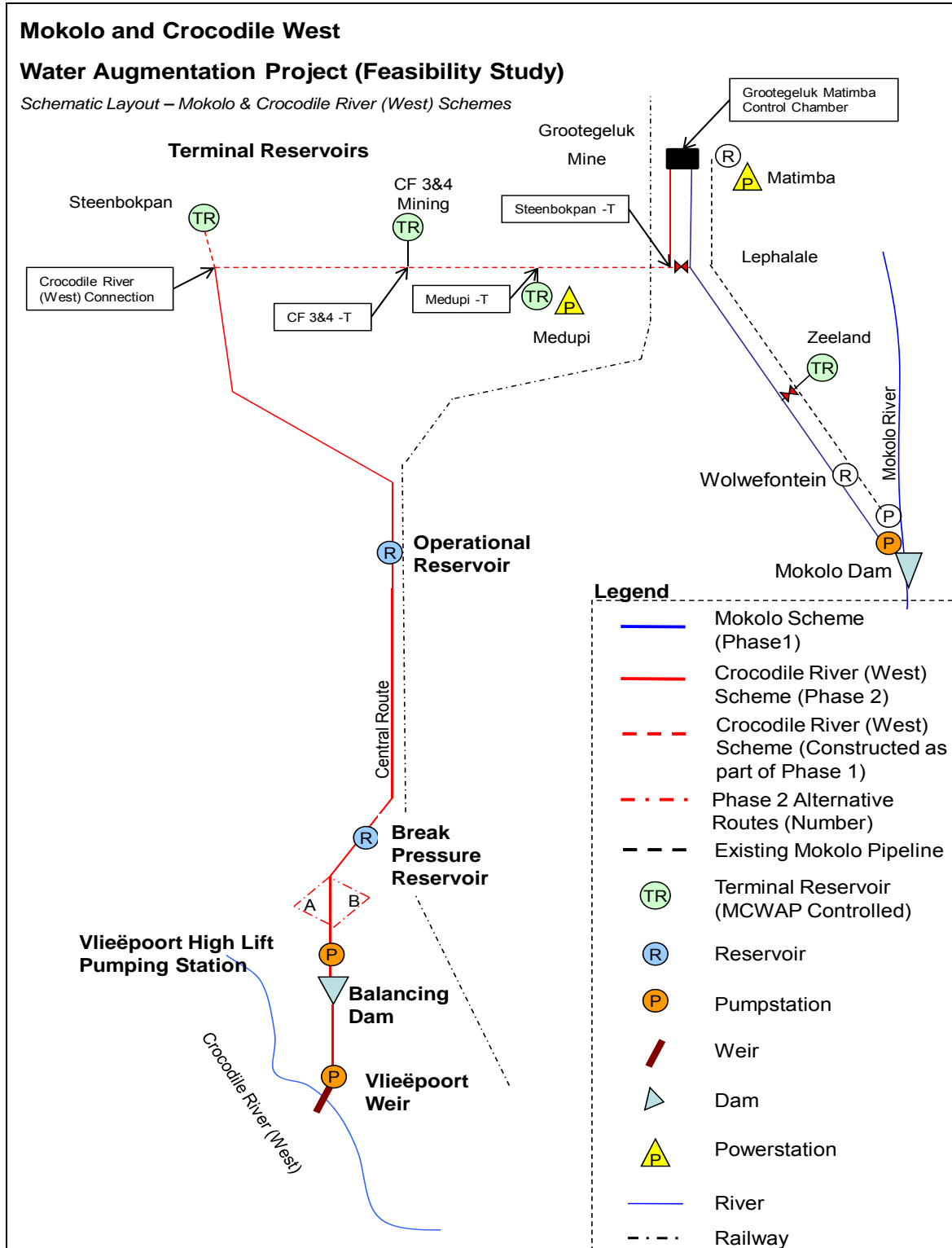


Figure 10-1: Schematic Layout of MCWAP

Table 10-1: MCWAP – Summary of Infrastructure Components

Component	Description
<i>Mokolo Dam Scheme (Phase 1)</i>	
<i>Phase 1</i>	New pumping station and additional pipeline from Mokolo Dam to end-users located from Lephalale in the east to Steenbokpan in the west. The Lephalale-Steenbokpan link will be built as part of Phase 1 but will ultimately form part of the Crocodile River (West) Transfer Scheme to transport Crocodile River (West) water to Medupi and the Grootegeluk/Matimba control chamber.
<i>Lephalale-Steenbokpan Link</i>	
Crocodile River (West) Connection to Steenbokpan	Diameter : 1900 mm ND Length : 1.4 km
Crocodile River (West) Connection to CF 3&4 Mining T-off	Diameter : 1100 mm ND Length : 27.1 km
CF 3&4 Mining to Medupi T-off	Diameter : 900 mm ND Length : 3.6 km
Medupi T-off to Steenbokpan T-off	Diameter : 900 mm ND Length : 8.2 km
<i>Crocodile River (West) Transfer Scheme (Phase 2A)</i>	
<i>Vlieëpoort Abstraction Works</i>	Concrete weir, gravel trap and pump intake structure–civil structures sized for ultimate project water requirements (431 million m ³ /a) 1 x fully equipped standby bay plus 1 standby pump unit (stored on site) 8 x 1.0 m ³ /s submersible pumps Maximum duty point: 6.6 m ³ /s @ 49.5 m Absorbed Power: 4.7 MVA 1 300 000 m ³ active balancing storage
<i>High-lift pump station</i>	Static head : 183-192 m Design peak flow (DPF) : 5.8 m ³ /s Min manometric head at DPF : 216 m Recovery peak flow (RPF) : 6.6 m ³ /s Max manometric head at RPF : 255 m Power consumption DPF/RPF : 16/19 MW
<i>Pipelines</i>	
Rising main – High-lift pump station to Operational and Break Pressure Reservoir (Node 10)	Diameter : 1900 mm ND Length : 26.7 km
<i>Break Pressure and Operational Reservoir</i>	8 hrs storage of recovery peak flow rate : 190 000 m ³
Operational and Break Pressure Reservoir to Node 15	Diameter : 2200 mm ND Length : 62.7 km
to Crocodile River (West) Transfer Scheme Connection (Phase 2A)	Diameter : 2300 mm ND Length : 28.2 km
Steenbokpan T-off to Grootegeluk/Matimba Control Chamber	Diameter : 800 mm ND Length : 1.9 km

11 IMPLEMENTATION PROGRAMMES

The prospective beneficiaries of the MCWAP were requested to provide key dates of their water requirement timeframes. A detailed project programme for the project was compiled taking into account these key dates. The project implementation is, however, taking place within a very dynamic planning environment and the project programme had to be revised on numerous occasions. Revisions to the key project dates up to 30 June 2009 are summarised below.

Table 11-1: Project Key Dates

Item No.	DESCRIPTION	Original Programme dated April 2008	Revised Programme dated June 2009
1.	Topographical Survey		28 Sep 2009
2.	Detail Geotechnical Investigations P1		14 Aug 2009
3.	Detail Geotechnical Investigations P2A		7 Jun 2010
4.	Environmental Module		13 Sep 2010
5.	User Water Supply Agreements P1		09 Dec 2009
6.	User Supply Agreements P2A		12 June 2011
7.	Procure Engineering Services		31 July 2009
7.	Land Acquisition Phase 1		6 Dec 2010
8.	Land Acquisition Phase 2A		28 Jun 2011
9.	Award Contracts Phase 1		6 Dec 2010
10.	Award Contracts Phase 2A		9 Aug 2011
11.	Water Delivery Phase 1	Nov 2011	3 Dec 2012
12.	Water Delivery Phase 2A	Jun 2014	12 Aug 2015

The original target date for delivery of water to Medupi was September 2010 and for delivery to Steenbokpan, November 2011. The target date for commissioning of the Phase 2A infrastructure was originally June 2014.

As shown above, the key dates derived from the revised program dated 30 June 2009 indicate that the delivery date for water from Phase 1 has shifted to December 2012 and for Phase 2A to August 2015.

The engineering economic analysis was based on the earlier implementation planning for the project of December 2011 for Phase 1 and December 2014 for Phase 2A.

The actual project implementation will be dictated by the finalisation of the User Supply Agreements which are expected to remain dynamic well into the detail design phase.

12 MCWAP COST ESTIMATES

The cost estimates included the following:

- Capital cost;
- Energy costs;
- Operation and maintenance costs; and
- Raw water costs.

12.1 Capital Cost Estimates

The total capital cost for the MCWAP is summarised below. The capital cost estimates include the costs of Phases 1 and 2A. The costs include infrastructure, preliminary and general (P&Gs), contingencies and design fees and excludes VAT. The base date for the cost estimate is April 2008.

Table 12-1: MCWAP Capital Cost Estimate

Component		Total (R)
Mokolo Dam Scheme – Phase 1 ⁽¹⁾		
1.1	Pump Station (Maximum duty 1.5 m ³ /s @ 263 m)	
	- Civil Works	64 805 000
	- Mechanical & Electrical Work	70 770 000
1.2	Rising Main	
	- 900 mm diameter (5 700 m)	86 540 000
1.3	Gravity Mains ⁽³⁾	
	- 1 900 mm diameter (1 400 m)	51 243 000
	- 1 100 mm diameter (42 950 m)	692 875 000
	- 1 000 mm diameter (19 970 m)	308 070 000
	- 900 mm diameter (11 770 m)	152 910 000
	- 800 mm diameter (1 940 m)	27 544 000
1.4	Eskom Electricity to Site	76 430 000
1.5	Compensation	2 170 000
1.6	Environmental and Socio-economic	1 000 000
	Sub Total	1 534 357 000
Crocodile River (West) Transfer Scheme - Phase 2		
2.1	Abstraction Weir and Low Lift Pump Station Civil Works ⁽³⁾	247,983,890
2.2	Low Lift Pump Station M&E Works ⁽⁴⁾	74,073,110

Component		Total (R)
2.3	Rising Main to De-silting Works	171,573,000
2.4	Desilting Works	86,148,000
2.5	High-Lift Pump Station Balancing Dam	318,909,000
2.6	High lift pump station (Maximum duty 6.6 m ³ /s @ 255 m)	350 544 000
2.7	Rising Main ⁽⁵⁾ - 1 900 mm diameter (26 700 m)	1 263 545 000
2.8	Gravity Mains (not constructed under Phase 1) ⁽⁶⁾ - 2 200 mm diameter (62 700 m) - 2 300 mm diameter (28 200 m) - 800 mm diameter (1940 m)	3 464 072 000 1 440 550 000 28 110 000
2.9	Operational and Break Pressure Reservoir	118 964 000
2.10	Eskom electricity to Vlieëpoort site ⁽⁷⁾	156 564 000
	Sub Total	7 721 036 000
	TOTAL COMBINED CAPITAL COST – MOKOLO AND CROCODILE RIVER (WEST) WATER AUGMENTATION PROJECT (Phases 1 and 2A)	9 255 393 000

Notes:

1. The residual value of the existing pump station at Mokolo Dam, as well as the existing pipeline between Mokolo Dam and Matimba was calculated as R8 million and R33 million, respectively. These costs were added to the project capital cost in the engineering economic analysis.
2. Includes the Lephalale-Steenbokpan link sized for the ultimate scheme requirements.
3. The costs of pipework, valves, screens and craneage have been included in the civil works portions of the cost estimate.
4. Only includes for the costs of the pumps and any M&E control equipment required, as well as any pipework and valve items directly associated with the pump installations.
5. Rising main from the High-Lift Pump Station to the Operational and Break Pressure Reservoir.
6. Includes the gravity pipeline sections from the Operational and Break Pressure Reservoir to the CRW Connection near Steenbokpan, as well as the connection from the Steenbokpan tee-off to the Matimba control chamber required to prevent mixing Crocodile River (West) and Mokolo Dam water. The remainder of the Lephalale-Steenbokpan link will be built under Phase 1.
7. Includes for the bulk electrical supply to the High-Lift Pump Station and the Low-Lift Pump Station.

12.2 Operation and Maintenance Cost Estimates

Table 12-2 summarises the annual operation and maintenance costs, when the scheme is operating at maximum capacity (2030), excluding overhaul costs of pump stations and excludes VAT.

Table 12-2: MCWAP Annual Operation and Maintenance Costs

Component		Total (R)/a
Mokolo Dam Scheme – Phase 1		
New Phase 1 Works		
1.1	Pump Station	
	- Civil Works	141 000
	- Mechanical & Electrical	2 462 000
	- Electricity	14 131 000
1.2	Rising Main	376 000
1.3	Gravity Mains	5 359 000
	Existing Exxaro Works	
2.1	- Civil	6 000
	- Mechanical & Electrical	223 000
2.2	Pipeline	165 000
3.1	Raw Water Costs ⁽¹⁾	58 571 000
	Sub Total	81 434 000
Crocodile River (West) Scheme - Phase 2		
4.1	Abstraction Weir, Low-Lift Pump Station, De-silting Works and Balancing Dam	
	- Civil	995 000
	- Mechanical & Electrical	2 035 000
	- Electricity	17 336 000
4.2	High-Lift Pump Station (Maximum duty 6.6 m ³ /s @ 255 m)	
	- Civil	87 000
	- Mechanical & Electrical	4 797 000
	- Electricity	76 866 000
4.3	Rising Main	3 018 000
4.4	Gravity Mains (not constructed under Phase 1)	11 848 000
4.5	Operational and Break pressure Reservoirs	308 000
4.6	Raw water costs	1 142 408 000
	Sub Total	1 317 098 000
5	Annual River Management Cost	4 500 000
	TOTAL COMBINED ANNUAL O&M COST (2030) – MCWAP	1 345 632 000

⁽¹⁾ Raw water priced at R4,50/m³

12.3 Unit Reference Values

The URV of water is not the tariff for the water, but the value attached to the net water requirement supplied to the consumers so that the discounted present value of the water is equal to the discounted present value of the cost.

The URV of water has been determined for a discount rate of 6%, 8% and 10% and is based on the net water transferred to the demand centres for a 45-year period. The URVs for the MCWAP are summarised in **Table 12-3**. These figures exclude VAT, are based on April 2008 prices. All discounting was done to 2008 and over a period of 45 years after completion of construction of Phase 2A. Residual values at the end of the period were excluded from the analyses.

Table 12-3: Unit Reference Values

Discount Rate	Discounted Present Value of Net Water @ R1/m ³ (R)	Discounted Present Value (R)	Unit Reference Value (R/m ³)
6%	2 020 000 000	20 462 103 000	10.14
8%	1 410 000 000	15 950 388 000	11.35
10%	1 020 000 000	13 029 165 000	12.72

Table 12-4: Summary of Discounted Present Values

Discount Rate	Capital (R)	O&M (R)	Total (R/m ³)
6%	7 726 136 000	12 733 903 000	20 460 039 000
8%	7 265 744 000	8 682 042 000	15 947 786 000
10%	6 844 128 000	6 181 959 000	13 026 087 000

13 KEY ISSUES FOR DETAIL DESIGN STAGE

13.1 Water Requirements

The Pre-Feasibility and Feasibility Stages of the MCWAP took place within a highly variable planning environment. As a result, further variations to the water requirements and design capacities are to be expected and must be incorporated into the detail design process. In this regard the following needs to be performed:

1. Confirm and implement the latest, approved water requirement scenario for the MCWAP. In the CRW Reconciliation Strategy, DWA developed possible future water requirements scenarios, considering different project mixes, as well as projected quantities for return flows into the CRW System. Scenario 8, which includes five Eskom power stations, Sasol's Mafutha 1 and the associated mining, industrial and residential development, was adopted for the project and then further refined to account for the most recent projections of water requirements at the time. The resultant water requirements table was designated Scenario 9 and used to determine the size and timing of Phases 1 and 2A of the MCWAP. More recent changes (after completion of the feasibility analysis and designs) however necessitated the development of further water requirement scenarios, the latest being Scenario 11 (refer to **Annexure E**), which includes the following:
 - Matimba Power Station and associated mining activity;
 - Medupi Power Station and associated mining activity;
 - One further Eskom power station and associated mining;
 - A power station to be constructed by IPPs and associated mining;
 - Other coal mining activities by Exxaro, Sekoko and Resource Generation;
 - Mafutha1 CTL facility and associated mining; and
 - Resultant urban growth from industrial activities.

Based on Scenario 11, the quantities to be taken by each of the users are listed in **Table 13-1** below.

Table 13-1: Scenario 11 - Projected Water Requirements per User (Million m³ per year)

	2009	2010	2011	2012	2013	2014	2015	2020	2025
Eskom	4.3	4.2	4.3	6.0	9.5	12.2	13.0	35.3	37.6
Exxaro	2.9	3.1	3.1	4.1	5.4	6.6	9.2	19.4	19.4
Sekoko	0.0	0.0	0.0	0.0	0.4	0.6	1.3	9.7	9.7
IPP	0.0	0.0	0.0	0.0	0.4	0.5	0.6	7.8	7.8

Sasol	0.0	0.0	0.0	0.0	2.7	5.7	9.1	43.5	43.5
ResGen	0.0	0.0	0.0	0.0	0.0	0.0	0.7	2.0	2.0
Municipal	5.5	5.7	5.2	5.6	8.1	10.7	11.1	15.6	16.7
Total	12.7	13.0	12.6	15.7	26.4	36.3	45.0	133.2	136.7

Figure 13-1 below indicates the growth in the water requirements for Scenario 11 over the time and the planned implementation dates for Phase 1 and Phase 2A infrastructure. The assumed combined yield of Mokolo Dam and surplus flows in the CRW is also shown in **Figure 13-1**. The implementation date for Phase 1 infrastructure is indicated at December 2012 with a capacity increase from 14,7 Million m³/a to 40,0 Million m³/a. Phase 2A is expected to be commissioned only in August 2015 and will increase the conveyance capacity by 110 Million m³/a to a total of 138,7 Million m³/a. Depending on the actual volume of surplus flow available in the CRW, further augmentation from the Klip River (Phase 4) may be required by 2018.

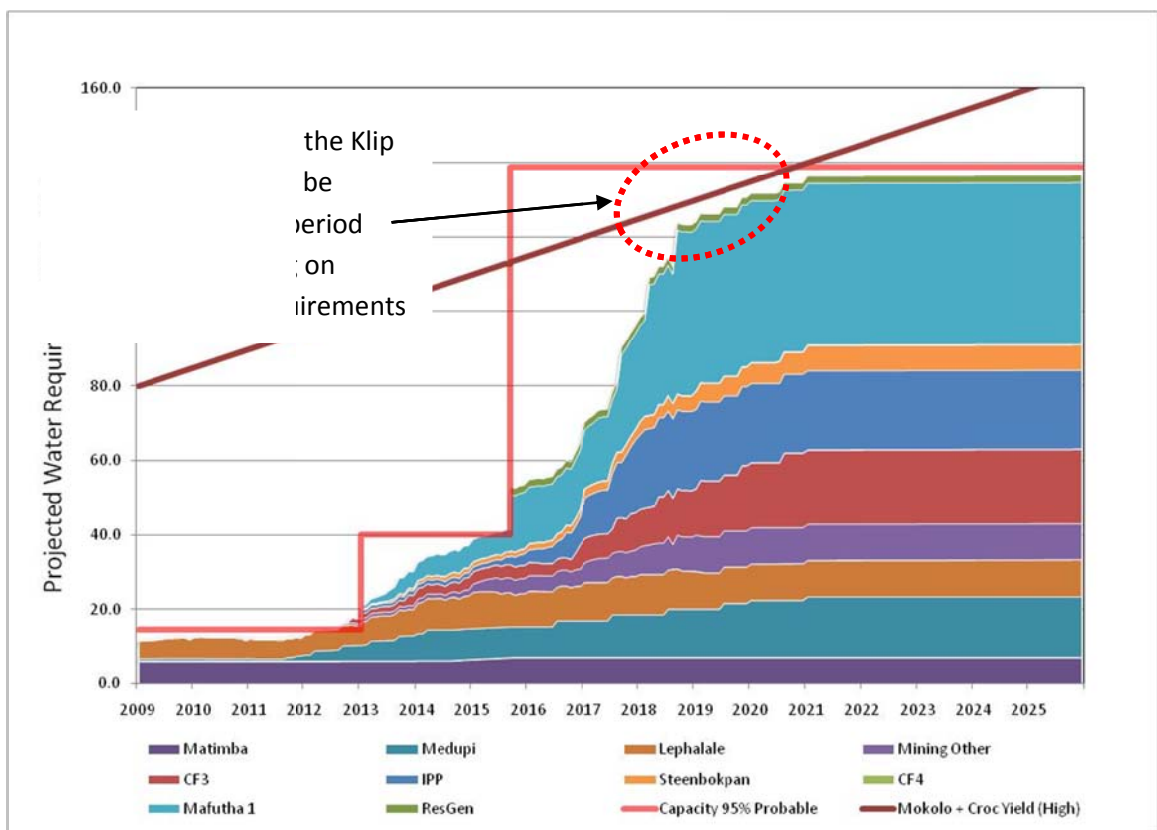


Figure 13-1: Cumulative Growth in Water Use and Planned Scheme Capacity (excluding irrigation)

Figure 13-2 illustrates that the eventual commissioning dates of both Phases 1 and 2A are critical in relation to the planned start of construction and commissioning dates for the user projects. It will therefore be required to update the Scenario 11 water

requirements tables at key decision points to verify that the commissioning dates for the project phases still satisfy the combined water requirement. The so-called de-bottlenecking of the existing Exxaro infrastructure (expedited implementation of the first 9 km stretch of Phase 1 gravity main) will be a critical contingency measure should delays be experienced with the implementation of Phase 1. Other possible mitigating measures are to utilise groundwater resources and controlled over-abstraction of Mokolo Dam.

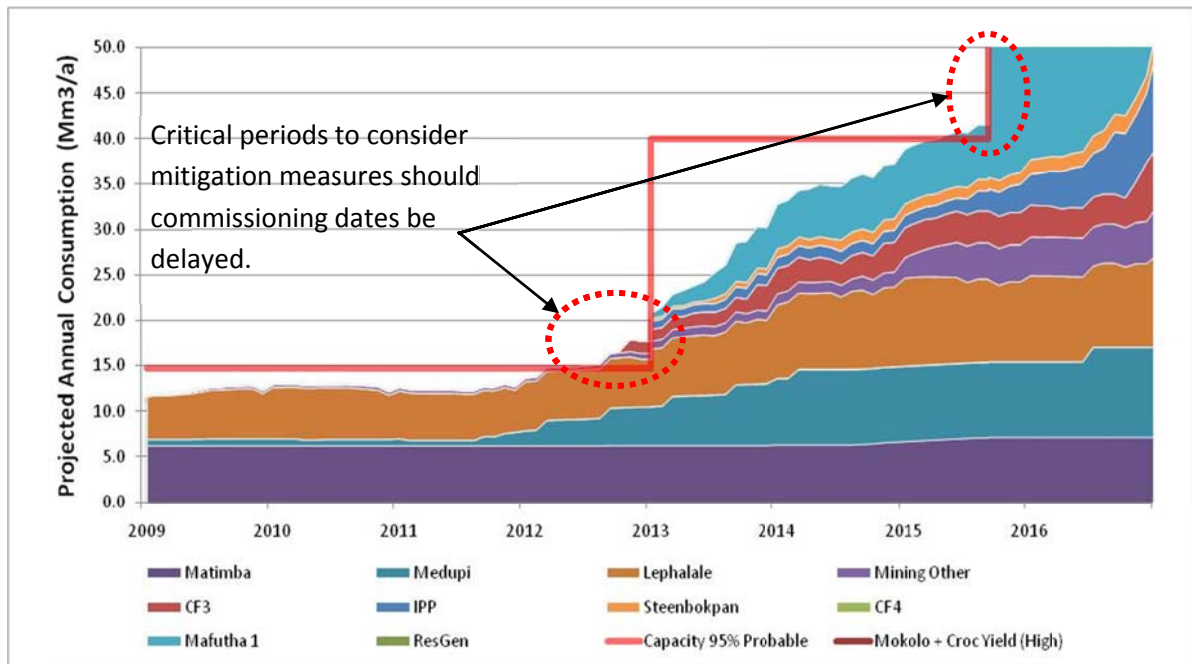


Figure 13-2: Critical Dates for Commissioning of Phases 1 and 2A

2. Re-confirm the reliability and redundancy criteria that must be applied to size the Phase 1 and Phase 2 infrastructure components. Aspects that might impact on these criteria include the following:
 - The conditions of the final end user agreements;
 - The final system operating philosophy; and
 - Risk assessment.
3. Quantify evaporation and system transmission losses more accurately (a value of 2% was assumed for the Feasibility stage).
4. Perform a water balance incorporating latest requirements, system losses, peak and recovery factors and a statistical assessment of storage requirements and system reliability.

13.2 Geotechnical Investigations

Detailed investigations will need to be carried out along the pipeline routes as follows:

- Centreline soil survey. This will entail pitting at a nominal 5 test pits per km to refusal or a maximum depth of 4 m along the centrelines of the routes. An excavator of known capability and correlation to material “excavatability” must be used to dig the test pits in order to describe the hardness (and particularly the depth to refusal) of the materials encountered. This would provide information to classify the material so as to determine its suitability for re-use, the rates of construction and the costs. The position, nature and extent of rock outcrops along the route must be mapped. Representative samples of material that could be used as bedding and selected backfill material must be recovered and laboratory tested to characterise the materials encountered. The tests must include indicator tests (grading and Atterberg Limits), compactability tests and chemical tests for deleterious materials such as nitrates and chlorides.
- Borrow pit investigations. Borrow pits should be located at a nominal 5 km spacing and aimed at proving sufficient material for use as bedding, and selected fill. The quantities that are proven must take account of trial pit spacing and material variability to ensure ample proven reserves. These borrow pits will, of necessity, have to be located on private property and it is important that landowners along the route are notified timeously of this investigation. The teams carrying out the investigation must not negotiate with the landowners concerning extraction of the material.
- During the borrow pit investigation, data must also be collected regarding the commercial availability and quality of sources of materials, particularly concrete aggregate .
- Foundation Investigations. Core drilling must be carried out at the Mokolo Dam pump station to define the foundation conditions at this site. Drilling must extend to the founding level of the pump station or only moderately weathered rock, whichever is the deeper in order to investigate the quality of the in-situ materials so that it can be classified and an assessment can be made of the excavatability and suitability for founding and erodibility with high floods.

Tenders must be sought from drilling and geotechnical contractors and soils testing laboratories to carry out the investigations. The work must be carried out under the direction of a geotechnical team.

13.3 Mokolo and Crocodile River (West) Project infrastructure

The following issues were identified during the course of the Feasibility stage and would require further investigation to ensure fit for purpose designs:

1. It should be noted that since April 2008 there have been a number a changes to the parameters that could influence the capacity, location and design of the MCWAP and the CRW Transfer Scheme in particular. The pipe systems can also be optimised further when final design capacities, and more detailed survey and geotechnical information becomes available. It is therefore recommended that a more comprehensive evaluation

and optimisation be performed during the detail design stage to verify the Feasibility findings.

2. River Management System (Phase 3) – It is recommended that planning and implementation of a river management system be incorporated in Phase 2A of the MCWAP and not as a separate phase as it is currently defined. The importance of the river management system to the success of the project and for promoting cooperative management of the Crocodile River (West) river conveyance section of Phase 2 should not be underestimated.
3. Route planning and coordination. The following is required:
 - Detailed coordination and a commitment to the MCWAP by the bulk consumers along the Lephalale-Steenbokpan corridor in order to ensure integrated planning of infrastructure and water requirements. Eskom is planning to construct a number of HV power lines through the region. A number of these will be located in a corridor routed from north to south that could affect the routing and design of the CRW Transfer Scheme pipelines.
 - Agree on the permanent servitude requirements to allow for future expansion.
 - Source detailed cadastral and existing services information along the final pipeline route alignments.
 - Facilitate and support the land acquisition and servitude registration process taking cognisance of issues raised by interested and affected parties during the Public Participation process.
 - Confirm the location of farmer off-takes and requirements.
 - Services coordination/way-leave approvals to be performed with:
 - Eskom: Capital projects planning, Transmission and Distribution.
 - Spoornet: Apply for permission to use railway line access road during construction and for future maintenance access to the pipeline and confirm future upgrade/electrification planning for the railway line.
 - South African National Roads Agency Limited (SANRAL): Apply for a concession to use the road reserves as temporary construction servitudes where pipelines are located nearby. Also apply for access point to pipeline servitude from road reserve.
 - Limpopo Provincial Roads Department: Apply for a concession to use the road reserves as temporary construction servitudes where pipelines are located nearby. Also apply for access point to pipeline servitude from road reserve.
 - Thabazimbi Local Municipality: Future township establishment that might affect pipeline routes.
 - Lephalale Local Municipality: Future township establishment that might affect pipeline routes.
 - Telkom: Confirm the location of services and apply for way-leaves to cross the services

- Neotel: Confirm the location of services and apply for way-leaves to cross the services.
 - Department of Minerals and Energy: Inform them of the planned pipeline route in order to update their database.
 - Coordination with DWA: Confirm the need to apply for water use licenses for river and stream crossings and obtain the necessary permission if required.
 - Local farmers: Take forward the land acquisition and servitude registration process to ensure that servitudes for the pipeline and borrow areas are agreed timeously to prevent delays during construction.
4. Phase 1 infrastructure:
- Optimisation of pump station and pipeline based on the final agreed capacity (currently 40 Mm³/a); and
 - Valuation and possible incorporation of the existing Exxaro infrastructure.
5. Phase 2 pipeline routes
- Finalisation of route alternatives, considering significant opposition from water user groups.
 - Specifically, a further investigation into the feasibility of a route that runs through Thabazimbi.
 - A detailed hydraulic analysis to determine the optimum positioning of the air (type and size), isolating, reflux, drainage and control valves. Pipeline dewatering will require careful consideration due to:
 - Potential poor water quality and fears of contamination; and
 - Very flat topography – management of scour water will be problematic. Scour time of the pipeline must be considered.
 - Optimum sizing of the Operational and Break Pressure Reservoirs to take cognizance of final operating philosophy and risk assessment. The detailed design of Operational and Break Pressure Reservoirs must consider operational storage requirements, storage time, and water quality management to prevent ‘dead zones’ in the reservoirs. The initial Operational and Break Pressure Reservoir must be configured to allow conversion to a surge tank during later phases of the development.
 - River and stream crossings – Matlabas River crossing will require careful consideration of geotechnical conditions at the site, environmental considerations and rehabilitation. The stream and river crossings of the pipelines should preferably coincide with the crossing of the railway line.
 - Further investigation into the feasibility of using the so called “Faure” weir situated 30 km downstream of Vlieëpoort as an abstraction point.

6. Vlieëpoort Abstraction Works: The following issues were identified during the course of the Feasibility stage and would require further investigation to ensure fit for purpose designs:

- Depth of scour at Vlieëpoort during high floods. Scour potential at the weir must be modelled to confirm the depth of founding of the weir structure. The present Feasibility stage layout assumes that the proposed jet grouting foundation treatment will provide adequate founding conditions and that together with the roller bucket spillway design and extensive downstream heavy riprap protection will protect the structure against scour.
- Foundation Design. Deep jet grouted foundations have been successfully used in the past to improve hydraulic structure founding conditions. Once the results of a detailed materials investigation are available, the layouts need to be reviewed and refined.
- Alluvial aquifer flows at Vlieëpoort. The Feasibility stage layouts show that the entire river bed section below the weir will be jet grouted, thereby effectively blocking the flow in the aquifer. Whilst this arrangement is intended to prevent piping foundation failure, greater loads could be imposed on the weir foundations if the water table downstream of the weir is lowered. This can be counteracted if the flow past Vlieëpoort is regulated sufficiently to maintain a continuous flow over the weir. The water table level downstream of the weir should nevertheless be monitored continuously to alert the operators of any potentially dangerous situation.
- Liquefaction potential. The nature of the underlying alluvial sands and silts at Vlieëpoort must be investigated to determine the potential for liquefaction during a natural or induced seismic event.
- Sizing and configuration of Desilting Channels. Feedback received on the operation of the Lebalelo Abstraction Works in the Olifants River in Limpopo Province indicated that the very fine fraction of the suspended silt in the Olifants River, when in flood, failed to completely settle out in the de-silting channels. This fraction requires longer retention times to settle out and therefore only settled in the balancing dams where it affected the operational availability of the system and was also difficult and time-consuming to remove, primarily because the balancing dams were not designed to be maintained at frequent intervals. In the case of the CRW Transfer Scheme the problem is accentuated by the relatively large storage capacity and retention times of the Balancing Dam.
- Location of High-lift Pump Station Balancing Dam. The Feasibility layouts identified two potential sites for the dam. The site closest to the Abstraction Weir has since been confirmed to be located on dolomite and should therefore be avoided if possible. The preferred site is some 5 km downstream of the Abstraction Weir and on much more favourable founding conditions (residual Ventersdorp lava), but further planning is required to refine the layout and assess the socio-economic impacts.
- Sizing of the High-lift Pump Station Balancing Dam. The present approach is based on river flow management with a 3 to 4-day river flow response time from the

upstream dams to Vlieëpoort. With improved control over flows in the river and shorter actual response times it is anticipated that the required capacity of the Balancing Dam should reduce accordingly. A storage capacity in the order of 200 000 m³ less may be possible.

- Hydraulic computer modelling of the river is recommended once the detail survey becomes available. This model will allow for better computation of flood levels applicable to the base conditions and post-construction conditions and allow better assessments of the impact of the Abstraction Works on affected landowners and existing infrastructure.
 - The hydraulic model will also provide flood levels downstream of the weir that are required for the placement of the Desilting Works, Balancing Dam, High-lift Pump Station and switchyards and might also influence the choice of the site for these components.
 - A prototype or computational fluid dynamics (CFD) model of the Abstraction Weir, Gravel Trap and Low-lift Pump Station is recommended in order to optimise the placement, layout and size of these structures.
 - During flushing of the Desilting Works and desilting of the Balancing Dam, high amounts of silt need to be handled which cannot be discharged into the river. Further investigation is required to confirm environmental requirements and to identify appropriate silt separation facilities and storage and/or disposal thereof.
 - Flows passing the Abstraction Weir must be measured. A downstream flow gauging structure will be required to measure surface flows since flows over the weir may not be uniform enough.
7. The following detail design and optimisation actions must also be performed:
- Confirmation of the systems operating and control philosophy.
 - Review of the pump selection philosophy with specific reference to the option of implementing VSDs and the associated implications it has on the operational control, power supply, etc.
 - A detailed pipeline design (optimum diameters and wall thickness). Consider both the interim (rising main/Operational and Break Pressure Reservoir/gravity mains) and ultimate (rising main directly to a new operational reservoir with the initial Operational and Break Pressure Reservoir converted to a surge reservoir) scenarios and perform the detailed surge analyses.
8. Pipeline coatings and linings: New pipeline coating and lining processes are becoming available on the market and must be considered. A detailed corrosion protection design will be required.
9. Detailed AC mitigation design:
- Cognisance of possible future infrastructure that might affect the design;

- A detailed soil resistivity survey at 100 to 500 m centres, depending on soil conditions;
- Soil sampling and analysis to confirm the aggressiveness of the soil and the possible presence of Sulphate Reducing Bacteria (SRB) that could affect the coating selection; and
- Detailed AC modelling to confirm the extent of AC mitigation required.

10. Detailed Geotechnical Investigation:

- Geological mapping - Delineation and description of outcrop areas, including discontinuity survey, geological structures, etc.
- Test pitting with an excavator at selected spots at an average of about 200 m centres – The maximum depth of the proposed pipeline is generally more than 4 m, deeper than the reach of a tractor loader backhoe (TLB). The soil profile must be described according to the standard method of Jennings *et al* with reference to shallow water table conditions, excavability, etc.
- Core drilling – to investigate pipe jacking and reservoir sites.
- In situ testing - For the determination of soil parameters for pipeline design (the empirical E' value (bulk modulus of horizontal soil reaction), limited plate load tests must be conducted at selected representative positions.
- Sampling and Laboratory testing – Disturbed and undisturbed samples of selected representative soil horizons must be collected and tested at an SABS approved laboratory to determine the soil characteristics such as grading, expansiveness, collapse, potential use for backfill, indicators, etc.
- The corrosiveness of the material must be determined by analysing the pH and electrical conductivity of selected samples.
- Identification and proving of potential borrow sites – Borrow sites to be identified to ensure that haul distances are kept to a minimum. The volume of borrow material to be proven by a dense grid survey and adequate laboratory testing, providing at least twice the volume required at each site.
- Field electric resistivity survey - A field survey must be conducted to determine the in situ electrical resistivity along the entire route in collaboration with the CP analysis and design.

13.4 Phase 2 Alternative Route Alignments

After completion of the Pre-Feasibility stage, the MCWAP Technical Module PSP was invited to participate in the public participation process with the affected land owners that were arranged by the MCWAP Environmental Module PSP. Consultation also took place with bulk water consumers like Sasol, Eskom and Exxaro. The purpose of the discussions was to assimilate more information about the planned future developments that could affect the positioning of the pipelines to be built during Phases 1 and 2A. Due to the dynamic nature of the planning currently taking place, the positioning of infrastructure components will also be a dynamic process that will require close coordination during the Detail Design phase to

ensure that other planning processes are considered in the final positioning of the pipelines and structures.

During the part of the consultation process that involved the land owners, further information came to hand that could affect the routing of the pipeline between Vlieëpoort and Steenbokpan. There is strong public opposition towards the CRW Transfer Scheme in the areas north-west of Vlieëpoort. Eskom also provided revised details of planned future power station development around Steenbokpan, which would affect the routes of the pipelines.

A number of alternative routes were therefore identified during this process that could potentially limit the impacts associated with the CRW Transfer Scheme in the south and avoid planned future infrastructure in the north. Due to their late addition, these routes were, however, not investigated in sufficient detail during the Feasibility stage to confirm their viability. It is therefore recommended that the process be taken forward as part of the detailed design when more detailed information will also be available on the planned developments in the north. It must be noted that changes to the preferred route should be coordinated with the Environmental Consultant as a matter of urgency to ensure that any changes can be incorporated into the EIA.

14 CONCLUSIONS AND RECOMMENDATIONS

14.1 Introduction

As the project was fast tracked, some aspects of the design and drafting of the Water User agreements ran concurrently with this study. As such, certain of the conclusions and recommendations were already operationalised in the other parallel actions.

The primary purpose of the Feasibility Study for the MCWAP is to develop the options to transfer water from the Mokolo Dam and Crocodile River (West) to the Lephalale area to supply the primary and industrial users in this fast developing area.

Development from Lephalale westwards towards Steenbokpan and the Botswana border is driven by large coal deposits. Potential large users (Eskom, Exxaro, Sasol, etc.) provided estimates of their expected water consumption for the medium- to long-term industrial, commercial and domestic use. The water requirements for the feasibility investigation were originally based on the Scenario 9 projections of strategic, mining, industrial and associated domestic water requirements up to 2030. That was used for the determination of the water resources and the routing options and then later the infrastructure sizing was adjusted in accordance to the Scenario 11 projections. This resulted in downsized infrastructure for Phase 2 called Phase 2A.

Various options have been identified to convey water to the end users. The recommended works include the Mokolo Dam Scheme (Phase 1), as well as the Crocodile River (West) Transfer Scheme (Phase 2) to be operated in combination as the MCWAP. Phase 1 is intended to supply the interim water requirements for a period until the Crocodile River (West) Transfer Scheme – Phase 2 has been constructed and then continue to supply the quantity of water that will optimally utilise the full yield of the Mokolo System.

It is recommended that the project be implemented in phases as follows:

- Phase 1 - Mokolo Dam Scheme: Augmentation from the Mokolo Dam.
- Phase 2A - Crocodile River (West) Transfer Scheme: Transfer system from the Crocodile River (West) to the Lephalale and Steenbokpan area where the pipeline will link to the infrastructure constructed as part of Phase 1. This will provide most and be the major water source for the MCWAP.

14.2 Water Requirements and Design Flow

14.2.1 Water Requirements

The Pre-Feasibility and Feasibility studies of the MCWAP took place within an uncertain and variable planning environment. As a result, further variations to the water requirements

and design capacities are to be expected and must be incorporated into the detail design process. In this regard, it is recommended that the following actions need to be performed and maintained on a continuous basis until all agreements are finalised:

- Confirm projections of known prospective users.
- Include water requirements of new prospective users or make provision for such.
- Finalise and seek commitment on the updated water requirement scenario for the MCWAP.
- Re-confirm the size of the Phase 2A infrastructure components in terms of the conditions in the final end user agreements; the final system operating philosophy; etc.

The water requirements for the Feasibility Investigation were finally based on the Scenario 11 projections up to 2030. Generally, accepted and agreed reliability and redundancy criteria were applied to arrive at the recommended design capacity of the respective scheme components. In this regard a 95% reliability factor (system availability) was utilised and a recovery peak due to failure or interruption of service of 20% Gross Average Annual (Water) Requirement (GAAR) was applied.

Coating and lining systems were investigated and the following recommendations for the MCWAP Pipelines are made in **Table 14-1**.

Table 14-1: Recommended Coating and Lining Systems

Product/Method		Field Joint Repair Method
External Coating	<p><u>Preferred:</u> Trilaminate Polyethylene (3LPE) or Polyurethane</p> <p><u>Alternative:</u> Polymer modified bitumen/Glass Fibre (Bituguard)</p>	<p>Liquid or powder epoxy plus cold tape wrap Polyurethane</p> <p>Bituguard hot applied tape</p>
Internal Lining	<p><u>Preferred:</u> Epoxy</p> <p><u>Alternative:</u> Cement Mortar</p>	<p>Epoxy</p> <p>Cement Mortar</p>

The recommended pipe roughness parameters to be used during the detailed hydraulic design are summarised in **Table 14-2**.

Table 14-2: Recommended Long-Term Roughness Parameter

Parameter	Cement Mortar Lining		Epoxy Lining	
	Suggested	Maximum	Suggested	Maximum
Long-term absolute roughness (mm)	1.1	1.5	0.5	0.7
Influence of biofilm	Reduction in diameter of 5-8 mm			

14.2.2 Operation

In order to meet the water requirements of the prospective users, the following should be implemented:

- The water from the Mokolo Dam is of a much better quality than that from the Crocodile River (West). It is therefore necessary to design and operate the MCWAP system in such a way that the water from the two sources does not mix during normal operation.
- Operating rules for the MCWAP should be developed during the detail design stage of the project.
- As agreed by the stakeholders, the design philosophy of the scheme at this stage is that the Crocodile River (West) will not provide water directly to Zeeland WTW and Matimba Power Station, and that the Mokolo Dam will not provide water to users at Steenbokpan on a continuous basis.

Water should be supplied to the termination points at Matimba, Medupi, Zeeland WTW and others. Due to the uncertainty regarding the exact location of the Sasol and other users in the Steenbokpan area, only one other termination point has been allowed for at this stage, namely at Steenbokpan.

An 18-day storage capacity Terminal Reservoir will have to be provided by the users at each termination point of Exxaro, Eskom, Sasol and others to ensure the prescribed reliability for the MCWAP infrastructure. These will be built by the respective end users, but need to be operated and controlled by the MCWAP.

14.3 Phase 1

The Mokolo Dam is considered to be the only viable source of water that can supply in the water requirements until the Crocodile River (West) Transfer Scheme has been constructed. The Mokolo Dam has a yield of 39,1 Million m³/a at a recurrence interval of 1:200 years of which 10,4 Million m³/a at 70% assurance is allocated for irrigation. The remaining yield is available to supply and augment the water requirements of users in the Lephalale areas.

The date that water is required at the new Medupi Power Station determines the Phase 1 programme, while the Steenbokpan requirement will be finalised when the Phase 2 users commit to the user agreements. It is recommended that the Phase 1 works be implemented as a matter of urgency.

The details of the proposed MCWAP Phase 1 Feasibility works is described in the Supporting Report No. 11, while the design details of the works are described in the water users agreements that are being developed in parallel with the Feasibility Investigation.

Briefly, it comprise the constructing a new pump station at the Mokolo Dam above the 1:200 year floodline to replace the existing pumping station. It needs to transfer water from the dam through a steel rising main to the existing balancing reservoir at Wolvenfontein from where it will gravitate via a new steel pipeline to the consumers. It also include the upgrade of the existing 33 kV Eskom power line feeding from the Waterberg sub-station to a 132 kV line and construct a new 132 kV line from Bulge River sub-station to Mokolo Dam.

The capacity of the existing gravity pipeline from Wolvenfontein Reservoirs to Matimba will not be sufficient to supply in the water requirement until the Phase 1 Mokolo Dam Transfer Scheme is completed, with the constraining section being between Wolvenfontein Reservoirs and Rietspruitnek. It is recommended that the construction sequence of the new pipeline should therefore be programmed to first increase the capacity of the existing gravity section from Wolvenfontein Reservoir to Rietspruitnek by means of interconnections to the new pipeline (debottlenecking). It is recommended that the entire existing pipeline is considered for refurbishment after commissioning of Phase 1. There will then be sufficient capacity in the new Phase 1 pipeline to completely decommission the existing pipeline for evaluation and refurbishment.

14.4 Phase 2

14.4.1 Infrastructure Requirements

The infrastructure components that are recommended for implementation are described in Supporting Report 12: Phase 2 Feasibility Stage, consisting of the following main components as part of Phase 2A:

The abstraction weir and de-silting works consist of the following main components:

- Mass concrete gravity type Diversion Weir, 4.3 m high with ogee and roller bucket spillway;
- Gravel Trap in weir basin with flushing facility, nine (9) pump bays, each capable of accommodating two (2) fully equipped 1 m³/s capacity submersible pumps;

- Low pressure steel pipeline rising main of approximately 5 km long to the Desilting Works;
- Desilting Works with flushing facility located near the Balancing Dam above the PMF level; and
- A multi-compartment Balancing Dam sized to cater for unplanned changes in river flows with a total live storage capacity of 1 300 000 m³.

The Transfer Scheme consists of the following main components:

- A free draining High-lift pump station with no risk of flooding;
- Pumps comprising four identical duty sets plus one standby Variable Speed Drive (VSD) pump sets;
- A firm electricity supply to the Vlieëpoort site for both the Low-lift and High-lift pumping stations;
- A steel rising main of 1 900 mm diameter (ND) to the BPR;
- Steel gravity pipeline of 2 200 mm (ND) from the BPR to the Operational Reservoir;
- A 2 300 mm ND steel gravity pipeline downstream of the Operational Reservoir to the connection with the Lephale-Steenbokpan pipeline; and
- A new pipeline from the Steenbokpan T-off point close to Medupi Power Station to Steenbokpan with diameters ranging from 800 mm to 1 900 mm ND connecting to Phase 1.

A permanent servitude width of 50 m was used for costing purposes. It is recommended that it be reviewed during the detailed design. No adverse geotechnical and CP conditions, that would totally prohibit the construction of the pipeline, were found to exist along the proposed routes. Further detailed coordination with services authorities and affected parties will be required to obtain the necessary way-leaves and approvals prior to construction.

The recommended Phase 2 works includes a BPR located on the farm Zondagskuil 130 KQ, as well as an Operational Reservoir located on the farm Zoutpan 367 LQ. These reservoirs will have a minimum total combined storage capacity of 8 hours of the recovery peak flow to provide effective balancing capacity for differences in outflow and inflow. A minimum of two compartments is to be provided for normal operational and maintenance purposes.

14.5 Operation, Maintenance and Control Philosophies

It is recommended that the control and operation of all sites forming part of the MCWAP infrastructure be monitored and managed by means of a SCADA system from a central control room manned on a 24 hours/day basis. The monitoring system must provide adequate planning, operational and costing reports to effectively manage, operate and maintain the system. Repairs on pipe and check valves will have to take place during planned system maintenance. The maintenance philosophy must address mechanical,

electrical and civil fields in all of the routine planned maintenance, major breakdown repair and minor breakdown repair categories.

The MCWAP Phase 1 and Phase 2 infrastructure need to be operated as an integrated scheme, with consolidated tariffs, allocations, etc. Such a MCWAP Scheme also needs to be managed in an Integrated Water Resource Management approach with the existing users on the river systems. In this regard, it is of crucial importance that the management of river flows and abstractions along the Crocodile River (West) be incorporated in the management of MCWAP infrastructure.

Water resources management will be a critical success factor for MCWAP. The catchment of Mokolo Dam needs to be properly controlled to prevent any further development that can impact negatively on the runoff to Mokolo Dam. Likewise, the monitoring and control of abstraction from the Crocodile River (West) will need to be managed intensively.

As the water, utilised from the Crocodile River (West), is made available in the river as return flows, effective and efficient measures need to be in place to control the water quality, i.e. pollution control measures and actions need to be managed well. It is of crucial importance that adequate resources be made available to perform this function. Technical and legal expertise will be required. It is recommended that DWA and TCTA attend to this aspect in detail.

14.6 Environmental and Social Aspects

The pipeline and the Break Pressure and Operational Reservoir(s) traverse some sensitive areas where particular care should be taken. These will be pinpointed during a detailed environmental investigation before implementation. Rocky areas are most sensitive due to the presence of aloe species, as well as the distinct habitat they provide for animal species. The potentially largest impact will be the River Abstraction Works, Balancing Dam and High-lift Pump Station at Vlieëpoort. The positioning of components of this site will need to be optimised in conjunction with all EIA specialists, including faunal and floral specialists, geotechnical experts, etc.

The philosophy employed in determination of the new pipeline routes was to stay as far as possible parallel to existing infrastructure such as roads, railway lines, power lines and the existing pipeline belonging to Exxaro (for Phase 1) in order to minimise negative social and environmental impacts. It will be a requirement that best practice be followed in terms of the EIA processes to minimise the ecological impacts of the construction work. All remedial actions contained in the EMP and EIA authorisation conditions are to be implemented.

The EIA processes for Phase 1 and De-bottlenecking is in an advanced stage and the process for Phase 2 will consider all alternate routes, etc.

14.7 Implementation Programme and Cost

14.7.1 Implementation Programme

The original target date for delivery of water to Medupi was September 2010 and for delivery to Steenbokpan, November 2011. The target date for commissioning of the Phase 2 infrastructure was originally June 2014. The actual project implementation was delayed and will be dictated by the finalisation of the User Supply Agreements which is expected to remain dynamic well into the Detail Design and Construction phase.

14.7.2 Cost Estimate

The cost estimates considered: Capital, Energy, Operations and Maintenance and Raw Water costs, and is discussed in Chapter 12. The cost of the project is R1 534 million for Phase 1 and R 7 721 million for Phase 2A in April 2008 prices.

The relevance of considering a raw water cost for the Crocodile River (West) needs to be considered in terms of the DWA pricing strategy and opportunity cost. This is a policy matter and outside the scope of the study. However, it has a significant impact on the unit cost and future operational cost of Phase 2.

14.8 Further Work

The details of the further work that are to be performed are described in the relevant reports, but the salient points are mentioned below.

The recommendation to maintain and continually update the projected water requirements was already discussed. It is seen as a key activity for the future implementation and decision-making.

The details of further considerations for the design are described in Chapter 13 of the report. Most importantly a number of issues regarding the Vlieëpoort Weir that need further technical investigations are highlighted and it is recommended that those are proceeded with.

Another matter that needs attention in the technical and environmental field is the appropriate method of dealing with the silt of the desilting works at Vlieëpoort. The possible presence of heavy metals in the silt need to be investigated to determine if special measures will be required. Similarly, the Matlabas River crossing will require careful consideration of engineering, environmental and geotechnical conditions at the site.

The upgrading of existing water resource infrastructure for Phase 2 will most probably be required. The outlet capacities of at least the Hartebeespoort, Roodekopjes, Roodeplaat and Klipvoor Dams will need to be investigated further. Betterments to the outlet structures may be required, also considering Reserve requirements.

The accurate measurement and control of abstractions from the river will be a crucial factor. All irrigation abstraction needs to be fitted with meters and control mechanisms as it is the case with the MCWAP users. It is recommended that the above capital requirements be incorporated in the capital costs of MCWAP Phase 2.

Additional flow gauging will be required on the Mokolo and Crocodile (West) Rivers and also on the Bierspruit and Sandrivier close to the confluence with the Crocodile River (West). In the case of the Mokolo River, none of the gauging weirs downstream of Mokolo Dam are functional and would make water flow measurement control and management more complex. Station A4H013 would be very useful in this regard and it should be investigated if it can be re-instated or an alternative site developed.

Flow measurement at the end of the Crocodile River (West) Irrigation Board's area would be very valuable. The existing structure at "Hugo's" Weir (A2H116) which is located some 20 km upstream of Vlieëpoort is ideal, but considerable betterments should be undertaken to improve the weir structure to DWA standards and to install the latest flow gauging instrumentation. The present installation appears to have stopped functioning in 1995 and was only capable of measuring flows up to 7 m³/s.

The alluvial aquifer in the Crocodile River (West) and Mokolo River sustain the current irrigation use, and is an important source. The monitoring of the groundwater in the alluvium will be very important, specifically in the proximity of the Vlieëpoort Weir. It is recommended that a proper groundwater monitoring system be developed for the river and implemented as a matter of priority.

Regarding the future institutional management of MCWAP and the water resources serving this area, it will require new challenges to institutions. The water resources management of DWA in these catchments will require more resources in skilled and dedicated staff. The management of MCWAP and the management of the abstraction from the rivers will also require an order of magnitude increase in intensity of the management function and cost in relation to what is currently operational in the area. Focused and dedicated staffing will be required.

The challenge for the institutional arrangement will be to resource the institution properly in terms of budgeting, equipment, human resources, etc. In this regard, it is important that a partnership is sought between DWA and the large users for the management of MCWAP. There are a number of institutional options available, including Water Boards, concessionaires, dedicated authorities such as Basin Water Authority, etc. It is recommended that the institutional arrangements be investigated in consultation and close cooperation with the users and the Irrigation Boards (WUAs).

APPENDIX A

MAPS

APPENDIX B

Long Sections

APPENDIX C

Combined Scheme URV calculations

APPENDIX D

Water Requirements Scenario 10

APPENDIX E

Water Requirements Scenario 11

REPORT DETAILS PAGE

Project name: **Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP)**

Report Title: **Main Report**

Author: **C Klopper (Africon)**

DWA report reference no.: **P RSA A000/00/8109**

PSP project reference no.: **WP 9528**

Status of report: **Final**

First issue: **December 2009**

Final issue: **September 2010**

PSP

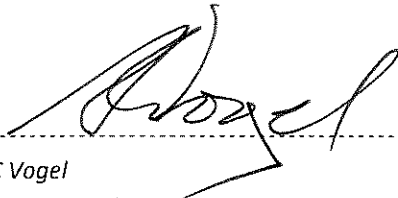
Approved for PSP by:



J Pienaar
Study Leader

PROJECT CO-ORDINATION AND MANAGEMENT TEAM


Approved for Project Coordinator by:



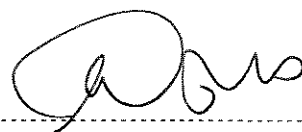
SC Vogel
Project Coordinator & Manager

DEPARTMENT OF WATER AFFAIRS (DWA)

Approved for Chief Directorate: Integrated Water Resources Planning by:



OJS van den Berg
Chief Engineer: Options Analysis North



LS Mabuda
Chief Director: Integrated Water Resources Planning
