REPORT NUMBER: P RSA A000/00/8909

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

Project No. WP9528

Report 2

WATER RESOURCES REPORT PRE-FEASIBILITY STAGE

March 2010

Lead Consultant: Africon

In association with: KV3, VelaVKE, WRP (A Miya Group Company)

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REFERENCE

This report is to be referred to in bibliographies as:

Department: Water Affairs, South Africa, 2008. MOKOLO AND CROCODILE (WEST) WATER AUGMENTATION PROJECT (MCWAP) Feasibility Study. Pre-Feasibility Study Report 2 Water Resources.. Prepared by Aurecon in association with Kwezi V3 Engineers, Vela VKE, WRP Consulting Engineers and specialists.

DWA Report No. **P RSA A000/00/8909**

REPORT DETAILS PAGE

Project name:	***Mokolo and Crocodile (West) Water Augmentation Project (MCWAP)***
Report Title:	**Pre-Feasibility Study Report 2 Water Resources**
Author:	***J Pienaar***
DWA report reference no.:	***P RSA A000/00/8909***
PSP project reference no.:	***WP 9528***
Status of report:	***Final***
First issue:	***November 2008***
Final issue:	***March 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:

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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) / 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 and Forestry 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. The solution must over the long term, optimally utilise the full yield from Mokolo Dam.
- **Phase 2:** Transfer water from the Crocodile River (West) to the Lephalale area. Options to phase the capacity of the transfer pipeline (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. 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 draft Feasibility report during October 2009 to the MCWAP Main Report in November 2009.

This report (Report 2 – Pre-Feasibility Stage Report: Water Resources, P RSA A000/00/8909) cover the available surface water resources for the Mokolo and Crocodile River (West) catchment water areas, as well as ground water resources in the Lephalale area.

Executive Summary

Background

The Mokolo River is a major tributary of the Limpopo River and has a total catchment area of over 8 000 km^2 with a total natural mean annual runoff (MAR) of almost 300 Million m^3/a. 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 m^3 (68% of its natural MAR) was commissioned in 1980 for the purpose of supplying water to the nearby Grootegeluk coal mine, Matimba dry-cooled power station, the towns of Lephalale Onverwacht and Marapong and an irrigation scheme located downstream of the dam. The combined current water allocation from the dam is 27.6 Million m^3/a.

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.

In order to obtain estimates of the current and future water resources capability of the Mokolo River system, Department of Water Affairs (DWA) - Directorate: National Water Resource Planning, commissioned the study, Updating the Hydrology and Yield Analysis in the Mokolo River Catchment (DWA 2008a).

DWA has investigated a number of possible measures to ensure long-term availability of sufficient water resources in the Mokolo River system, which included most importantly, the implementation of a transfer scheme to transfer surplus water from the Crocodile River (West) catchment. This study, i.e. Mokolo and Crocodile (West) Water Augmentation Project (MCWAP) Feasibility Study, is a continuation of the process aimed at identifying the most economical option for the transfer of water from the Crocodile West / Marico Water Management Area to the Mokolo Limpopo Water Management Area.

*It is anticipated that the proposed inter-basin transfer from the Crocodile River (West) Catchment, and elsewhere, (as in ToR) will be commissioned in 2014 whilst initial estimates indicates that augmentation would be required by 2011. It was thus envisaged that a number of short-term planning options would need to be investigated in order to bridge shortfalls in water supply to strategic users that may occur in the interim period. The Water Resources Planning Model (WRPM) configuration developed as part of the planning analysis (**DWA, 2008b**) was used for the purposes of this report.*

This report investigates the management options available and determines the period of recovery needed for the Mokolo Dam. The investigation secondly aims to determine whether the implementation of curtailments is required in order for the Mokolo Dam to recover in a suitable period after the implementation of the Crocodile River (West) Transfer Scheme (Phase 2). The investigation included to determine a failure date of the Mokolo Dam for a possible second period of drawdown from the dam in the case where the transfer scheme is implemented in two phases. This will assist DWA in determining the completion date of the second phase (Phase 2B).

Water Resources Availability

The surface water resource availability status quo for the Mokolo and Crocodile River (West), were summarised. It is based on the results of previous studies.

*The Yield Analysis study (**DWA, 2008a**) determined that the historic firm yield (HFY) of the Mokolo Dam is 38.7 Million m^3/a, which occurs at a high recurrence interval of 1:224 years. The 1:200 yield available from the Mokolo Dam under current day conditions is 39.1 Million m^3/a and was used for further planning purposes. This is considerably higher than the total allocation from Mokolo Dam of 27,6 Million m^3/a.*

*The water balances for the Crocodile River (West) System was calculated in the Crocodile River (West) Reconciliation Strategy (**DWA, 2008c**) for four water requirement scenarios:*

1. *High population growth, medium efficiency water conservation and demand management (WC/WDM).*
2. *Base population growth, medium efficiency WC/WDM.*
3. *Low population growth, medium efficiency WC/WDM.*
4. *High population growth, high efficiency WC/WDM.*

The results indicated that sufficient water is available to meet the water requirements within the Crocodile River basin under all of the abovementioned scenarios. Increased surpluses can be expected to occur for the higher water use scenarios, where larger quantities of water will need to be transferred to the urban and industrial centres in the upper parts of the basin from the Vaal River System, with resultant larger volumes of return flow downstream. The scenario of low population growth with medium efficiency water demand management, the lowest water use scenario, shows a close balance between water requirements and availability.

The above-mentioned report also assessed the need for water transfers from the Crocodile River to the Lephalale area for eight development scenarios (Lephalale) by calculating the water balances for the Crocodile/Lephalale System. A projection of the time when the water requirement demands for the Lephalale area exceed the combined available water from the Mokolo catchment and the Crocodile River catchment is provided. This will require additional augmentation from the Vaal River system, either directly or through transfers from the Vaal River system via the Crocodile River catchment.

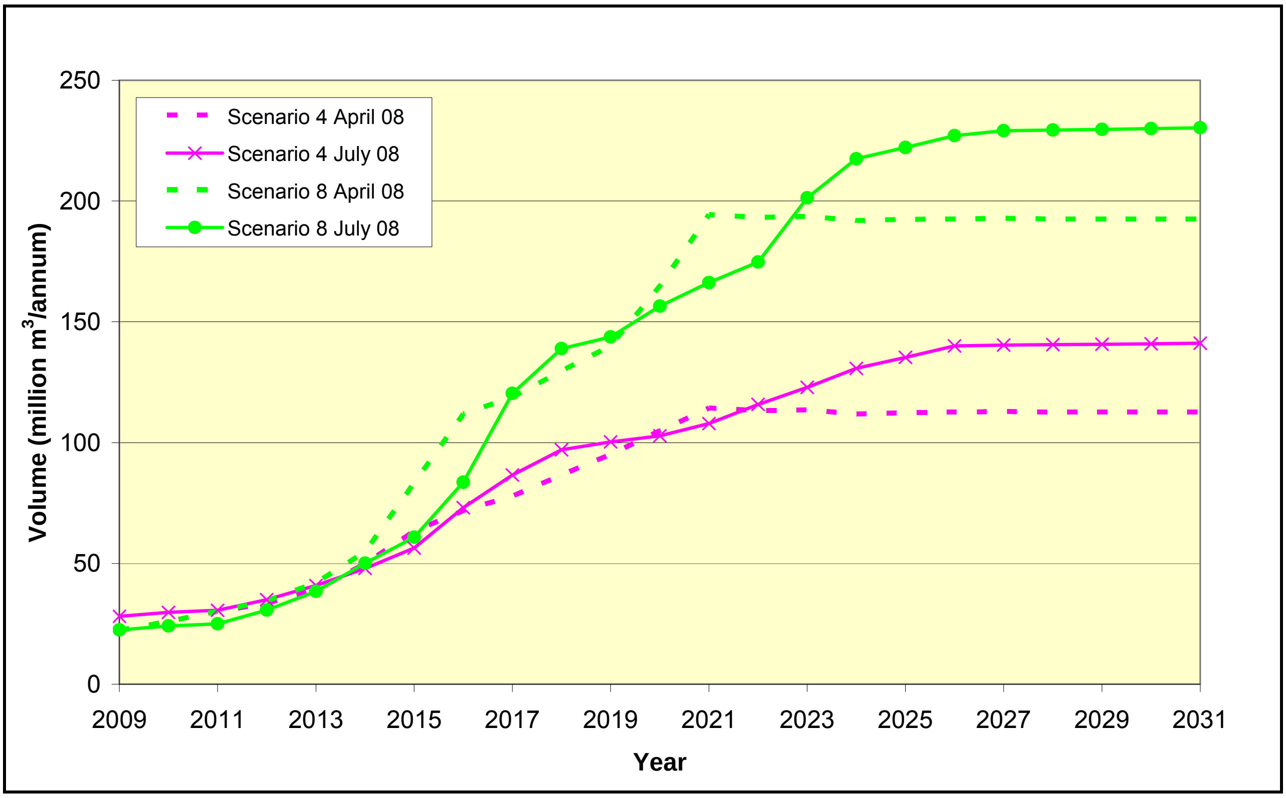

Figure 0-1 Comparison of Water Requirements Scenarios

Planning Analysis

*Planning analyses of the Mokolo River System were conducted using the Water Resources Planning Model (WRPM) that was developed for the entire Mokolo River System in a previous study (**DWA, 2008b**).*

Based on the above information, the following scenarios were analysed:

- ***Mokolo Dam Modelling Scenario I:*** *Determine the point of failure of Mokolo Dam during the interim delivery period based on the revised monthly water requirement projections for* ***Scenario 8*** *(including 2% losses added to the user requirements).*
- ***Mokolo Dam Modelling Scenario II:*** *Determine the period of recovery needed and whether the implementation of curtailments is necessary for the Mokolo Dam to recover in a suitable period after the implementation of the Crocodile River (West) Transfer Scheme. The point of failure of Mokolo Dam during the second period of drawdown was also determined. The revised monthly water requirement projections for* ***Scenario 8*** *(including 2% losses as above) were used.*
- ***Mokolo Dam Modelling Scenario III:*** *Determine the point of failure of Mokolo Dam during the interim delivery period based on the revised monthly water requirement projections for* ***Scenario 4****, i.e. excluding conversion of coal to liquid fuel (CTL) and associated developments (including 2% losses).*

*The Crocodile River (West) Transfer Scheme will transfer treated effluent to the Lephalale supply area. Due to the low quality of the water transferred to Lephalale, the existing water users will still need to obtain a portion of good quality water from the Mokolo Dam. As a result, a minimum supply of water will be supplied from the Mokolo Dam to the existing users during the recovery period, after the transfer scheme has been implemented (****Scenario II****).*

Scenario Results

The planning analysis results for the three scenarios are summarised in ***Table 0-1****. The Mokolo dam's monthly storage projections and the annual irrigation supply projections are presented in the form of projected probability distribution graphs for the three scenarios in* ***Appendix B****. In order to assess whether the irrigating farmers are being supplied at the same assurance that they have been supplied in the past, a scenario was developed (****Base Scenario****) and analysed where constant water requirements were iteratively imposed on the Mokolo Dam (water requirements increased with each iteration) to a maximum, where the system on average does not fail over the projection period. The maximum constant water requirement worked out to 44.18 Million m^3/a, which is similar to the 1:100 year long-term stochastic yield (Irrigation = 16 Million m^3/a with 50% rule). The supply to the irrigation scheme was assessed by calculating the average supply to the irrigating farmers at 2% (98%), 5% (95%) and 10% (90%) risk (assurance) levels for the period 2017-2030.*

Table 0-1 Mokolo Dam Modelling Scenario Results

Scenario	***Mokolo Dam Failure Date (99.5%)***	***Years where Irrigation Supply is Lower than Required Criteria***
Mokolo Dam Modelling Scenario I	*August 2014*	*2013, 2014*
Mokolo Dam Modelling Scenario II	*July 2020* *(Irrigation Scheme curtailed in 2011)*	*2013, 2014, 2015, 2019*
Mokolo Dam Modelling Scenario III	*December 2014*	*2014*

Based on the results of the planning analysis undertaken it can be concluded that if the water requirement projection ***Scenario 8*** *were to realise, a form of intervention would be required before August 2014 (****Scenario I****). The current implementation programme for the inter-basin transfer from the Crocodile River (West) Catchment is expected to be commissioned by July 2014, being just in time without any room for delay in the implementation programme thereof. If the development of the CTL plant and associated commercial and residential developments either do not realise in the Lephalale area or are postponed to a later date the first failure of the Mokolo Dam will only be postponed to December 2014 (****Scenario III****).*

*With a transfer scheme capacity of only 110 Million m^3/a (Phase 2A), active from July 2014, and with the minimum supply of water being provided from the Mokolo Dam to existing users after the implementation of the transfer, the Mokolo Dam date of failure is postponed to July 2020 (****Scenario II****), provided that the Irrigation Scheme is curtailed completely for the year 2011, i.e. required for DWA to acquire the irrigation allocation in 2011. With the Irrigation Scheme not curtailed, the Mokolo Dam does not recover after the implementation of Phase 2A of the transfer scheme and fails in September 2014.* ***A Phase 2B of the transfer scheme would thus need to be commissioned before July 2020****, to ensure sufficient water supply to the water users up to 2030. It must be noted that the planning analysis results indicate that the Mokolo Dam may be drawn down very low with potential failure in the 2014/2015 period. A possibility thus exists that some additional curtailment will be required in the period prior to 2014/2015 in order to prevent the dam from failing, depending on the previous year's rainfall figures.*

The irrigation scheme supply results furthermore indicate that the probability exists that irrigating farmers will be supplied at assurance levels lower than the irrigation supply ***Base Scenario*** *during a number of years. This must be regarded as a potential risk to the DWA and will have to be investigated in more detail.*

It is proposed that a WRPM should be configured to conduct planning analyses on an annual basis to determine whether it will be necessary to curtail certain users i.e. irrigation scheme, to ensure sufficient water supply to the strategic users, based on the current year's water resources situation.

Ground Water Resources

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

The Institute for Groundwater Studies at the Free State University (IGS) is conducting a Water Research Commission project entitled: An assessment of how water quality and quantity will be affected by mining method and mining of the Waterberg coal reserves. This study addresses the potential impact of mining on the occurrence of available groundwater resources.

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 RDM assessment yielding recharge results at an intermediate level of confidence for the Mokolo sub-catchment. Results were not available on completion of this report.

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 finalized.

The results indicated that the sustainable yield from the boreholes drilled is estimated at 1.7 Million m^3/a. It is further estimated that for a short term two years use 7.19 Million m^3/a can be abstracted but will need a few years to recover. These yields are deemed insufficient to make a significant contribution to the long term water supply requirement of the area.

LIST OF ABBREVIATION & ACRONYMS

a	Annum
CMA	Catchment Management Area
CTL	Coal-to-Liquid Fuel
DWA	Department of Water Affairs
FSL	Full Supply Level
ha	Hectare
HFY	Historic Firm Yield
IGS	Institute for Groundwater Studies
IPPs	Independent Power Producers
MAR	Mean Annual Runoff
MCWAP	Mokolo and Crocodile River (West) Water Augmentation Project
MOL	Minimum Operating Level
RDM	Resource Determined Measures
MSL	Mean Sea Level
RI	Recurrence Intervals
TOR	Terms of Reference
WC/WDM	Water Conservation and Demand Management
WMA	Water Management Area
WRC	Water Research Commission
WRPM	Water Resources Planning Model
WRYM	Water Resources Yield Model

MOKOLO AND CROCODILE (WEST) WATER AUGMENTATION PROJECT FEASIBILITY STUDY

TECHNICAL MODULE

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1. INTRODUCTION AND BACKGROUND

The Lephalale municipal area falls within the Limpopo catchment area. The major part of the municipality is located in the Limpopo flood plain at an elevation of approximately 800 – 860 m, rising to 1 800 m in the south. The annual rainfall is on average between 380 and 420 mm in the north-west, but in the higher areas to the south rainfall increases to 750 mm.

The Mokolo (previously known as the Mogol) and the Lephalala (also referred to as the Phalala) Rivers flow through the municipal area to the north, with the Matlabas River flowing along the south eastern boundary and the Mogalakwena River along the eastern boundary. All four rivers feed into the Limpopo River which forms the north western border of South Africa with Botswana.

Large parts of the Mokolo River catchment area are located on the Waterberg coalfields where, according to preliminary estimates, almost half of South Africa's in-situ coal reserves are situated. As such, the Waterberg has long been considered the country's major coal resource for the future, especially once the current mining areas in the Witbank-Highveld coalfields of the Mpumalanga Province have been depleted.

The Mokolo Dam with a gross capacity of 146 Million m^3 was built in the Mokolo River (completed in 1980), and provides water to the Lephalale town, Matimba and Exxaro coal mines, as well as to the irrigation farmers between the dam and the Limpopo River. The present water allocations, totalling 27,6 Million m^3/a, are as follows:

- Mining - Exxaro (and related municipal requirements) : 10.1 Million m^3/a
- Power station (and Marapong Township requirements) : 7.1 Million m^3/a
- Irrigation : 10.4 Million m^3/a

The population of Lephalale can be grouped according to the geographic area, with the majority residing in villages within the Lephalala River catchment, the urban population found in the Lephalale/Onverwacht/Marapong towns between the Mokolo River and the coal mine, and the farming community living dispersed over the municipal 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:

- Construction of Eskom's Medupi Power Station presently underway;
- Development of further Eskom Power Station;
- Possible development of power stations by Independent Power Producers (IPPs);
- Extension of the Grootegeluk mining operations and further mines;
- Possible petrochemical industries to be developed around the coal field further west of Lephalale;
- Possible exploitation of gas resources; and
- Accelerated growth in the population in the area.

The Mokolo River catchment yield is sufficient for current water use requirements, although no specific allowance exists for the Ecological Reserve. The abovementioned future developments will require additional water which cannot be supplied from the surface resources within the Mokolo River catchment of the Limpopo Water Management Area (WMA). This report therefore addresses the potential water resources that can be utilised to augment the existing water resources. These resources are the following:

- The transfer of surplus treated return flows from the Crocodile River (West) / Marico WMA; and
- Groundwater resources in the Limpopo WMA.

In view of the above situation, the Department of Water Affairs (DWA) has investigated a number of possible intervention measures to ensure long-term availability of sufficient water resources in the Mokolo River system, which included most importantly, the implementation of a transfer scheme to import surplus water from the Crocodile River (West) catchment. This study, i.e. *Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) Pre-Feasibility Study* is a continuation of the process aimed at identifying the most economic option for the transfer of water from the Crocodile River West / Marico WMA to the Limpopo WMA.

In order to obtain estimates of the current and future water resources capability of the Mokolo River system, the DWA, Directorate: National Water Resource Planning commissioned the *Updating the Hydrology and Yield Analysis 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.

Initial results from the planning analysis (**DWA, 2008b**) indicated that augmentation would be required by 2011. As it is anticipated that the proposed inter-basin transfer from the Crocodile River (West) Catchment will be commissioned in 2014 and it was thus envisaged that a number of short-term planning options would need to be investigated for bridging shortfalls to strategic users that may occur in the interim period. The WRPM configuration developed as part of the planning analysis (**DWA, 2008b**) was used for the purposes of this report to investigate the management options required, and also to determine the period of recovery needed for the Mokolo Dam and whether the implementation of curtailments is necessary for the Mokolo Dam to recover in a suitable period after the implementation of the Crocodile River (West) Transfer Scheme (Phase 2). The failure date of the Mokolo Dam was also investigated for a possible second period of drawdown for the option where the transfer scheme is implemented in two phases i.e. date when the second phase of the scheme would be required (Phase 2B).

2. SURFACE WATER RESOURCES

The purpose of this section is to describe the status quo regarding surface water resources. The objective is to provide a summary of previous studies. Refer to Section 5 hereinafter.

2.1. Mokolo River System

The Mokolo River is a major tributary of the Limpopo River and has a total catchment area of 8 380 km^2 with a total natural mean annual runoff (MAR) of almost 300 Million m^3/a. 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 m^3 (68% of its natural MAR) was commissioned in 1980 for the purpose of supplying water to the nearby Grootegeluk coal mine, Matimba dry-cooled power station, the towns of Lephalale Onverwacht and Marapong and an irrigation scheme located downstream of the dam.

The combined current water allocation from the dam is 27.6 Million m^3/a, which includes the Gootegeluk coal mine (3.4 Million m^3/a), Matimba (3.6 Million m^3/a), Medupi Power Station (3.4 Million m^3/a) Lephalale/Onverwacht towns (3.3 Million m^3/a), Marapong township (0.5 Million m^3/a) and the Irrigation Scheme (10,4 Million m^3/a).

The main objective of the Yield Analysis study (**DWA, 2008a**) was to determine the current water resources capability of the Mokolo River system. This process included a detailed system analysis with the main objective of assessing the long-term yield of the Mokolo Dam for a variety of situations, based on the updated and extended hydrology covering the selected study period of 1920 to 2003 hydrological years (i.e. October 1920 to September 2004), which was developed as part of the study. The yield analyses results were used in this study, and the reader is referred to the Yield Analysis (WRYM) report (**DWA, 2008a**), for further details on the updating of the hydrology, physical system components and the details of the yield analyses conducted.

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 recurrence intervals (RI) 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 gravel pits associated with mining activities.

Table 2-1: Mokolo Dam Yield Analysis Results

HFY		Yield (Million m^3/a), at indicated RI			
(Million m^3/a)	RI (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 m^3/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 m^3/a and was used for further planning purposes. This is considerably higher than the total allocation from Mokolo Dam of 27,6 Million m^3/a. A total of 38.7 Million m^3/a, including losses, is therefore available to supply the Lephalale area on a long-term basis.

Refer to Pre-Feasibility Study: Report 1 Water Requirements (*P RSA A000/00/8809*) for detail on future water requirements.

2.2. Crocodile (West) River System

The water balances for the Crocodile (West) River System was calculated in the *Crocodile River (West) Reconciliation Strategy* (**DWA, 2008c**) for four water requirement scenarios:

1. High population growth, medium efficiency water conservation and demand management (WC/WDM).
2. Base population growth, medium efficiency WC/WDM.
3. Low population growth, medium efficiency WC/WDM.
4. High population growth, high efficiency WC/WDM.

The results indicated that sufficient water is available to meet the water requirements within the Crocodile River basin under all of the abovementioned scenarios. Increased surpluses can be expected to occur for the higher water use scenarios, where larger quantities of water will need to be transferred to the urban and industrial centres in the upper parts of the basin from the Vaal River System, with resultant larger volumes of return flow downstream. The scenario of low population growth with medium efficiency water demand management, the lowest water use scenario, shows a close balance between water requirements and availability.

The need for water transfers from the Crocodile River to the Lephalale area was assessed in the *Crocodile River (West) Reconciliation Strategy, Version 1,* (**DWA, 2008c**) for the eight development scenarios (Lephalale) described in **Table 2.2**. Future developments at Lephalale include expansions in the mining sector, as well as possible new developments by Eskom and Sasol (Coal to Liquid Fuel (CTL) Plant) in the area. The first four scenarios in **Table 2.2** exclude the CTL plants and its associated developments. **Scenario 1 - Scenario 4** are duplicated for the case where the CTL plants and associated developments take place in Lephalale (**Scenario 5 - Scenario 8**).

Table 2.2: Lephalale Water Requirement Scenarios

Scenario	Description
Scenario 1	Matimba Power Station (existing technology), Medupi Power Station (existing technology), Exxaro supply coal for two power stations, Lephalale town for two power stations.
Scenario 2	Matimba Power Station (existing technology), Medupi Power Station with flue gas desulphurisation (FGD), 1 additional new power station with FGD technology, coal supply to 3 power stations, Lephalale town for 3 power stations.
Scenario 3	Matimba Power Station (existing technology), Medupi Power Station with FGD technology, 1 additional new power station with FGD technology, 2 additional new power stations with fluidised bed combustion (FBC), coal supply to 5 power stations, Lephalale town for 5 power stations.
Scenario 4	Matimba Power Station (existing technology), Medupi Power Station with FGD technology, 3 additional new power stations with FGD, coal supply to 5 power stations, Lephalale town for 5 power stations.
Scenario 5	Scenario 1 + Coal to Liquid Plants + mine + township.
Scenario 6	Scenario 2 + Sasol (Coal to Liquid Plant) + mine + township.
Scenario 7	Scenario 3 + Sasol (Coal to Liquid Plant) + mine + township.
Scenario 8	Scenario 4 + Sasol (Coal to Liquid Plant) + mine + township.

Water balances were also calculated for the Crocodile River/Mokolo Dam System where the need for water transfers from the Crocodile River to the Lephalale area was assessed for each of the Lephalale water requirement scenarios described above. The water balance diagrams for the Crocodile River/Mokolo Dam system are illustrated in **Figures A-1 to A-4** in **Appendix A** (sourced from the *Crocodile River (West) Reconciliation Strategy, Version 1,* (**DWA, 2008c**)) for the described scenarios. The yield of the Mokolo Dam is shown in the figures to indicate when the requirements in the Lephalale area exceed the available yield and thus indicate when additional augmentation is required i.e. transfer of surplus treated effluent from the Crocodile.

The projection including both the Mokolo Dam yield and the surplus effluent from the Crocodile is also illustrated and where the water requirement projection scenarios of Lephalale cross this line gives an indication when requirements in the Lephalale area exceed the water availability in the Mokolo catchment together with the surplus available from the Crocodile River catchment. This will require additional augmentation from the Vaal River system, either directly or through transfers from the Vaal River system via the Crocodile River catchment.

A decision was made by the study team that water requirement **Scenario 4** and **Scenario 8** (worst case scenario) will be used for planning purposes. It should be noted that both the water requirements scenarios illustrated in **Figures A-1** to **A-4** were revised as part of this study as updated information became available from the users. The reader is referred to the Water Requirements Report 1 (*P RSA A000/00/8909*) of this study for further details.

A comparison of the original and revised **Scenario 4** and **Scenario 8** water requirements (including irrigation) are illustrated in Figure 2.1.

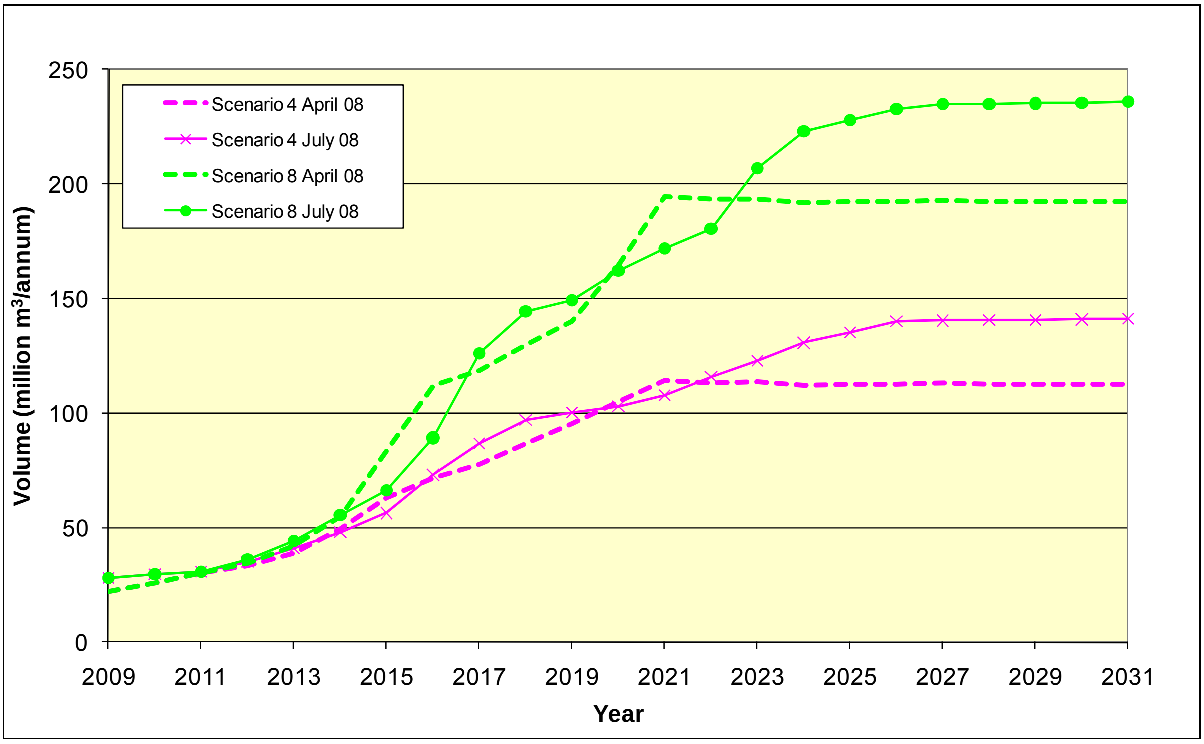

Figure 2-1: Comparison of Water Requirement Scenarios (including irrigation)

The projections are very similar in the initial period and larger differences occur toward the end of the projection period with the revised **Scenario 4** and **Scenario 8** ending at 29 Million m^3/a and 43 Million m^3/a higher than the original projections. The implementation of the CTL projects has also been delayed slightly as illustrated by the revised **Scenario 8** water requirement projection.

3. PLANNING ANALYSIS

Planning analyses of the Mokolo River System were conducted using the Water Resources Planning Model (WRPM) that had been configured for the entire Mokolo River System in a previous study (**DWA, 2008b**). The reader is referred to the *Updating the Hydrology and Yield Analysis in the Mokolo River Catchment Study: Planning Analysis (WRPM)* Report (**DWA, 2008b**) for background on the WRPM and details of the WRPM configuration of the Mokolo River System and the functioning thereof.

It was assumed that the Crocodile River (West) Transfer Scheme will be implemented in two phases. The capacity of the first phase of the scheme (Phase 2A) is 110 Million m^3/a and the commissioning date of the scheme is July 2014, as indicated by the study team. Based on the above information, the following scenarios were analysed:

- **Mokolo Dam Modelling Scenario I:** Determine the point of failure of Mokolo Dam during the interim delivery period based on the revised monthly water requirement projections for **Scenario 8** (including 2% losses added to the user requirements).
- **Mokolo Dam Modelling Scenario II:** Determine the period of recovery needed and whether the implementation of curtailments is necessary for the Mokolo Dam to recover in a suitable period after the implementation of the Crocodile River (West) Transfer Scheme. The point of failure of Mokolo Dam during the second period of drawdown was also determined. The revised monthly water requirement projections for **Scenario 8** (including 2% losses added to the user requirements) were used.
- **Mokolo Dam Modelling Scenario III:** Determine the point of failure of Mokolo Dam during the interim delivery period based on the revised monthly water requirement projections for **Scenario 4**, i.e. excluding CTL and associated developments (including 2% losses added to the user requirements).

Several planning analyses were conducted where various management options were investigated using the original annual water requirement projections. The results were however superseded with the results of the above scenarios that were conducted with the revised monthly water requirement projections and an increased minimum operating level (MOL) of the dam (increased from 871.82 to 881.5 m above see level). The MOL was increased based on the investigations carried out for the design of the new pump station, conducted as part of the study.

It must be noted that the planning analyses undertaken in the WRPM were based on the following:

- An analysis period of 23 years, from 1 May 2008 to 30 April 2030.
- May was implemented as the decision month for the Mokolo River System as it signals the start of the dry season.
- Using the PARAM.DAT-file developed as part of the stochastic stream flow analysis and based on 1 000 stochastically generated sequences for the above 23-year period.
- The current storage characteristics of Mokolo Dam were applied (i.e. un-raised), with a full supply level (FSL) of 911.98 m above mean sea level (MSL) , a full supply capacity of 145.92 Mm^3 and a minimum operating level of 881.50 m above MSL.
- The storage level of Mokolo Dam on 1 May 2008, which was at the start of the WRPM analyses period, was at the FSL of 911.98 m above sea level. Since no dependable information was available for the small storage dams, weirs and gravel pits it was assumed that these were also at FSL at the start of the analysis. The assumption was considered reasonable in view of the storage condition of Mokolo Dam at the same time, as well as the fact that May is at the end of the wet season in the Mokolo River System.

3.1. Scenario Assumptions

The components included in each of the scenarios are illustrated in **Table 3.1** below. The irrigation scheme located downstream of the Mokolo Dam is supplied through releases that are made from the dam with a current allocation of 10.4 Million m^3/a. The current agreement between the irrigating farmers and the operators of the dam is that 16 Million m^3/a is released provided that the Mokolo Dam is at a level above 50% of its live full supply capacity. If the dam is below 50% of its live full supply level no releases are made. The WRPM was configured to simulate the current agreement of 16 Million m^3/a (50% rule) releases to the irrigating farmers in the two scenarios. The effect of the latter rule on the remaining yield of the Dam was found to be about the same, although the effects on the down stream river flow are quite different.

The Crocodile River (West) Transfer Scheme will transfer treated effluent to the Lephalale supply area. Due to the low quality of the water transferred to Lephalale, the existing water users will still need to obtain a portion of good quality water from the Mokolo Dam. As a result, a minimum supply of water will be supplied from the Mokolo Dam to the specific users during the recovery period after the transfer scheme has been implemented. The users and their respective minimum supply volumes from Mokolo Dam during the recovery period as specified by the users are illustrated in **Table 3.1** (**Scenario II** Description). The irrigation scheme is supplied through releases from the Mokolo Dam and is thus also supplied from the Mokolo Dam during the recovery period.

Table 3.1: Mokolo Dam Modelling Scenario Description

Scenario	Description
Mokolo Dam Modelling Scenario I	- Updated **Scenario 8** monthly water requirement projection (including 2% losses) - Updated Mokolo Dam MOL of 881.5 m above sea level - Irrigation scheme requirement = 16 Million m^3/a (50% storage rule)
Mokolo Dam Modelling Scenario II	- Updated **Scenario 8** monthly water requirement projection (including 2% losses) - Updated Mokolo Dam MOL of 881.5 m above sea level - Crocodile River (West) Transfer active from July 2014 with a capacity of 110 Million m^3/a - Minimum supply from the Mokolo Dam during recovery period: Irrigation = 16 Million m^3/a (50% storage rule), Eskom = 3.6 Million m^3/a, Exxaro = 2.5 Million m^3/a, Lephalale = 11.9 Million m^3/a
Mokolo Dam Modelling Scenario III	- Updated **Scenario 4** monthly water requirement projection (including 2% losses) - Updated Mokolo Dam MOL of 881.5 m above sea level - Irrigation scheme requirement = 16 Million m^3/a (50% storage rule)

3.2. Scenario Results

The planning analysis results are presented in the form of projected probability distribution graphs, which are expressed using a “box-and-whisker”-plot, the definition of which is shown in Error! Reference source not found..

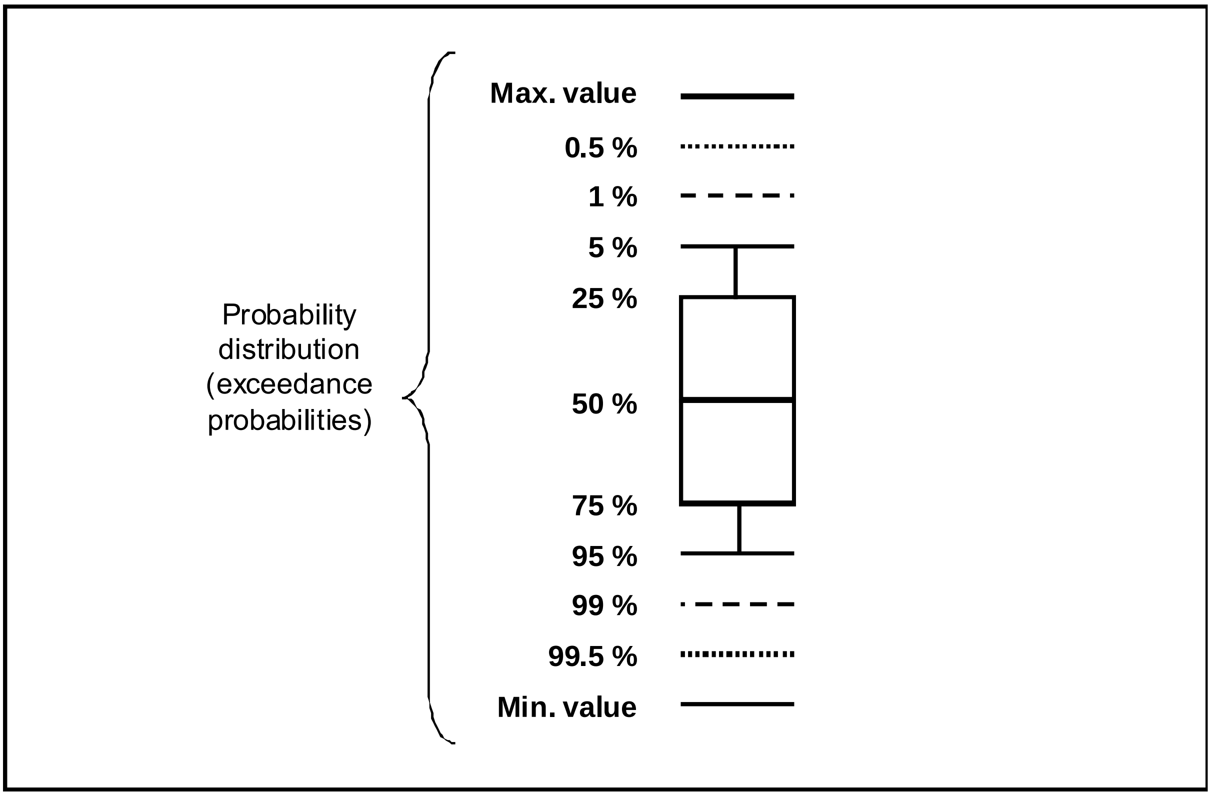

Figure 3-1: Definition of the "Box-and-Whisker"-Plot used in the Projected Annual Probability Distribution Graphs

3.2.1. Mokolo Dam Modelling Scenario I

The planning analysis results of **Scenario I** are presented in **Figures B-1** and **B-2** of **Appendix B** in the form of projected probability distribution graphs of the following, for the analysis period of 23 years from 1 May 2008 to 30 April 2030:

- Monthly storage volumes in Mokolo Dam, shown in units of million m^3
- Annual volumes supplied to the irrigation scheme in units of million m^3

The Mokolo Dam monthly storage volume projection presented in **Figure B-1**, illustrates that according to the assurance of supply criteria of 99.5% (i.e. risk of non supply of 1 in 200 years) the dam fails in August 2014. Since the Crocodile River (West) Transfer Scheme is scheduled to be commissioned by July 2014, no additional short term management options needed to be investigated for implementation, although very little time is available as buffer to accommodate any delays in the implementation of Phase 2A of the transfer scheme.

The simulated failure date is later than the date indicted in the *Updating the Hydrology and Yield Analysis in the Mokolo River Catchment Study: Planning Analysis (WRPM)* Report (**DWA, 2008b**), i.e. 2011. The reason for this is that the **Mokolo Dam Modelling Scenario I** included the revised **Scenario 8** water requirement projection, where the growth in water requirements is slightly delayed due the delay in the implementation of the CTL plants. The monthly values of the revised water requirement projection were also used in **Mokolo Dam Modelling Scenario I** whereas an annual water requirement projection was used in the previous analysis. The irrigation scheme demand of 16 Million m^3/a with the 50% live full supply capacity rule (current agreement) was used in the **Mokolo Dam Modelling Scenario I** simulation, whereas the irrigation scheme demand of 10.4 Million m^3/a, which is supplied irrespective for the Mokolo Dam storage capacity, was used in the previous planning analysis. The differences described above all contributed to the postponed Mokolo Dam failure date of August 2014.

In order to assess whether the irrigating farmers are being supplied at the same assurance that they have been supplied in the past, a scenario was developed (Base Scenario) and analysed where constant water requirements were iteratively imposed on the Mokolo Dam (water requirements increased with each iteration) to a maximum, where the system on average does not fail over the projection period. The maximum constant water requirement worked out to 44.18 Million m^3/a, which is similar to the 1:100 year long-term stochastic yield (Irrigation = 16 Million m^3/a with 50% rule). The supply to the irrigation scheme was assessed by calculating the average supply to the irrigating farmers at 2% (98%), 5% (95%) and 10% (90%) risk (assurance) levels for the period 2017-2030. This was regarded as the criteria against which the supply to the irrigators should be supplied and could be compared to the scenario results.

The average 2%, 5% and 10% irrigation supply volumes from the base scenario were plotted on the irrigation supply projection of **Mokolo Dam Modelling Scenario I** (**Figure B- 5**. It can be seen that the 5% (95%) assurance value in the year 2013 is below the average 5% line indicating that the irrigators are supplied at a lower assurance than usual in that year.

3.2.2. Mokolo Dam Modelling Scenario II

The planning analysis results of **Mokolo Dam Modelling Scenario II** are presented in **Figures B-3** to **B-5** of **Appendix B** in the form of projected probability distribution graphs of the following, for the analysis period of 23 years from 1 May 2008 to 30 April 2030:

- Monthly storage volumes in Mokolo Dam, shown in units of million m^3
- Annual volumes supplied to the irrigation scheme in units of million m^3

The Mokolo Dam monthly storage volume projection presented in **Figure B-3**, illustrates that, according to the assurance of supply criteria of 99.5 % (i.e. risk of non supply of 1 in 200 years), the dam fails in September 2014 and then recovers again in January 2015 due to the implementation of the Crocodile River (West) Transfer Scheme with a capacity of 110 Mm^3/a, which is active from July 2014. As a result, it was necessary to curtail the Irrigation Scheme completely for a year in 2011, in order for the dam to recover after the implementation of the transfer scheme without failing. Curtailing the irrigation at a later stage i.e. 2012 or 2013 was not effective in preventing the system from failing, as the irrigation was already curtailed in some instances due to a combination of the lower Mokolo Dam storage levels and the irrigation operating rule (16 Million m^3/a is released provided that the Mokolo Dam is at a level above 50% of its live full supply capacity). The Mokolo Dam monthly storage volume projection, with the irrigating farmers curtailed completely in 2011, is illustrated in **Figure B-4**. It can be seen that the 99.5% failure date has been postponed to July 2020, which implies that the second phase of the Crocodile (West) Transfer Scheme (Phase 2B) needs to be planned to be commissioned before July 2020. The results also illustrate that the dam may be drawn very low in the 2014/2015 period and the possibility thus exists that additional curtailments might need to be imposed prior to this period, depending on the previous year's rainfall figures.

The average 2%, 5% and 10% risk irrigation supply volumes from the base scenario were plotted on the irrigation supply projection of **Mokolo Dam Modelling Scenario II** (**Figure B-5**). It can be seen that the 5% (95%) assurance is below the average 5% line in the years 2013, 2014, 2015 and 2019 indicating that the irrigators are supplied at a lower assurance than usual in those years. The curtailments imposed on the Irrigation Scheme in 2011 is also illustrated, i.e. no supply to the irrigating farmers.

3.2.3. Mokolo Dam Modelling Scenario III

Scenario III was simulated in order to assess the impact on the Mokolo Dam failure date if the development of the CTL plants and associated developments do not realise in the Lephalale area, i.e. water requirement **Scenario 4** (including 2% losses). The Mokolo Dam monthly storage volume projection presented in **Figure B-6**, illustrates that according to the assurance of supply criteria of 99.5% the dam fails in December 2014, i.e. postponed by 4 months. The impact on the date of failure is not that severe as the first CTL plant is scheduled to be commissioned only in approximately 2015 with substantial volumes of water only required from 2016 onwards.

The average 2%, 5% and 10% risk irrigation supply volumes from the base scenario were plotted on the irrigation supply projection of **Mokolo Dam Modelling Scenario III** (**Figure B-7**). It can be seen that the 5% (95%) assurance is below the average 5% line from 2014 onwards, when the dam fails, indicating that the irrigating farmers are supplied according to this criteria before 2014.

3.3. Conclusions and Recommendations

Based on the results of the planning analysis undertaken it can be concluded that if the water requirement projection **Scenario 8** were to realise, a form of intervention would be required before August 2014. The current implementation programme for the first phase inter-basin transfer from the Crocodile River (West) Catchment is expected to be commissioned by July 2014, being just in time without any room for delay in the implementation programme thereof. If the development of the CTL plant and associated commercial and residential developments either do not realise in the Lephalale area or are postponed to a later date the first failure of the Mokolo Dam will only be postponed to December 2014

With a transfer scheme capacity of 110 Million m^3/a for Phase 2A, active from July 2014 and with the minimum supply of water being provided from the Mokolo Dam to existing users after the implementation of the transfer, the Mokolo Dam date of failure is postponed to July 2020, provided that the Irrigation Scheme is curtailed completely during the year 2011, i.e. required DWA to acquire the irrigation allocation in 2011. With the Irrigation Scheme not curtailed, the Mokolo Dam does not recover after the implementation of a Phase 2A of the transfer scheme and fails in September 2014. A Phase 2B of the transfer scheme would thus need to be commissioned before July 2020, to ensure sufficient water supply to the water users up to 2030. It must be noted that the planning analysis results indicate that the Mokolo Dam may be drawn down very low with potential failure in the 2014/2015 period. A possibility thus exists that some additional curtailment will be required in the period prior to 2014/205 in order to prevent the dam from failing, depending on the previous year's rainfall season.

The irrigation scheme supply results furthermore indicate that the probability exists for irrigators to be supplied at assurance levels lower than the Base Scenario during a number of years. This must be regarded as a potential risk to the DWA and will have to be investigated in more detail.

It is proposed that a WRPM should be configured to conduct planning analyses on an annual basis to determine whether it will be necessary to curtail certain users, i.e. irrigation scheme, to ensure sufficient water supply to the strategic users, based on the current year's water resources situation. This should be available when the new Phase 1A (or parts of it) supply from Mokolo Dam is put to use.

4. GROUNDWATER RESOURCES

4.1. Introduction

The objective of this study is to assess at desktop level the available groundwater resources in the Lephalale area to augment the water supplies in the interim period when construction of the transfer pipeline from Crocodile River (West) is taking place. The options being considered to augment the current water supplies in the Lephalale area will take a number of years to be completed and fully operational. Groundwater resources are therefore considered as a further supply option to augment current supplies.

A previous desktop study on the groundwater potential for the Mokolo River catchment was done for the Department of Water Affairs and Forestry (**DWA 2000**). The description below is a summary of the groundwater potential in the area taken from this study and those referenced at the end of this report

4.2. Primary Aquifer

A primary aquifer occurs in the Mokolo River alluvium. The basin of the Mokolo River consists of coarse-grained alluvial sand with inter-bedded lenses of finer clay/shale material. Previous limited investigations done by DWA indicated this primary aquifer in the riverbed has a thickness varying between 5 m to greater than 25 m. (Fanie Botha pers. com.) This aquifer is primarily used for irrigation and is recharged by the river during the rainy season. The quality of the water in this aquifer is regarded as good with TDS < 500 mg/ℓ which makes it attractive as a source.

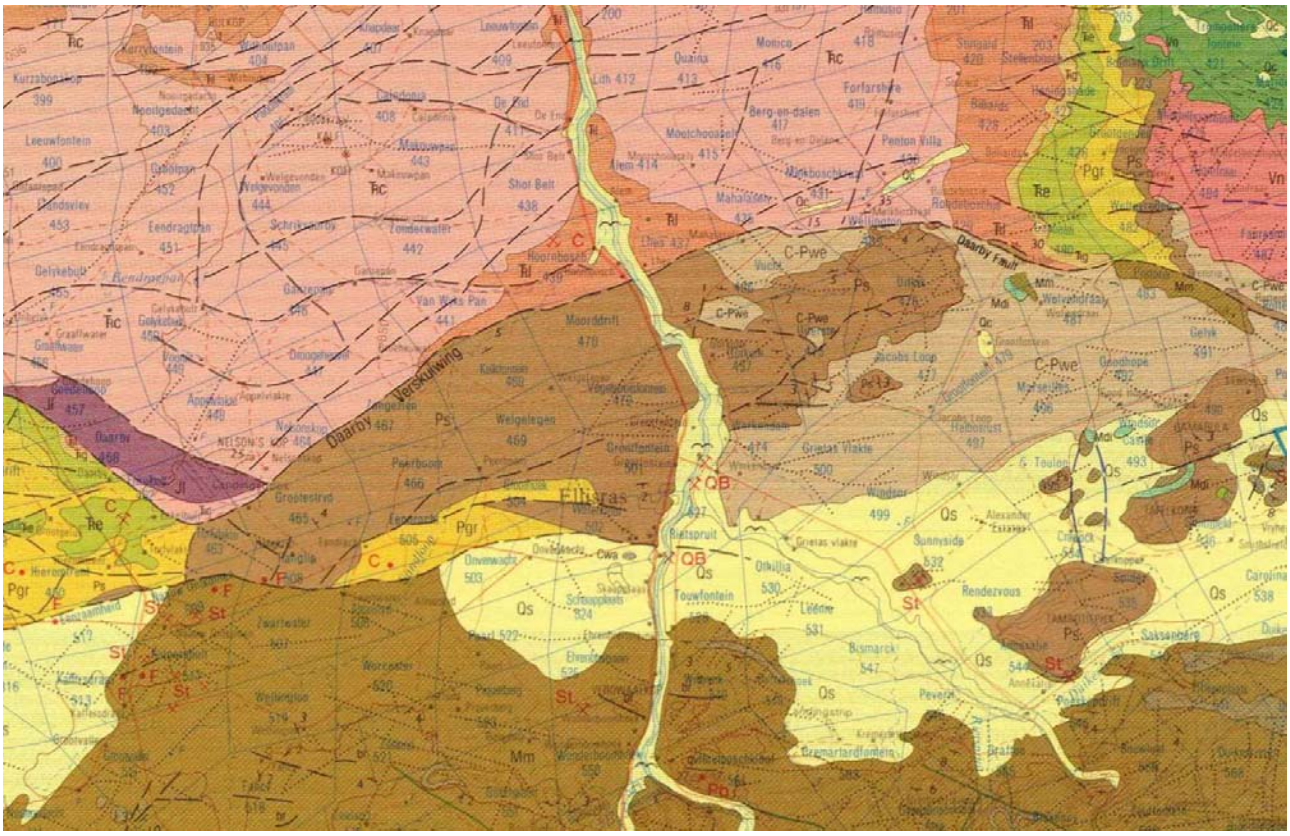

Figure 4-1: Geological Map Surrounding the Primary Aquifer (Mokolo River)

4.3. Secondary Aquifer

Groundwater in the study area, away from the Mokolo River, occurs mainly in the fractured secondary aquifers located in the rocks of the Waterberg Group and the Karoo Supergroup. The geology of the area is shown on the geological map in Figure 4.1. Both quantity and quality need to be evaluated for the potential establishment of one or more well fields.

A hydrogeological assessment is presently being carried out on the secondary fractured aquifers by deep drilling on the fault zones and especially focusing on the Waterberg – Karoo contact fault zone (**DWA, 2008d**). During this investigation the potential for artificial aquifer recharge will also be investigated. The following results produced to date were obtained from the drilling project team:

- Twelve (12) boreholes were drilled and their positions are shown in Figure 4.2;
- Water was intersected at levels of between 120 m – 160 m;
- Blow yields of 1 x 0.1 ℓ/s; 6 x 2-4 ℓ/s; 3 x 8-10 ℓ/s; 2 x 15-25 ℓ/s were recorded;
- Some boreholes are artesian;
- To date the sustainable yield of four (4) boreholes were tested;
- The transmisivity (T) values are high (Observation boreholes 750 m apart react within 2 min); and
- The potential of the boreholes are estimated at approximately15 ℓ/s on a continuous basis (0.47 Million m^3/a) from drilled boreholes.

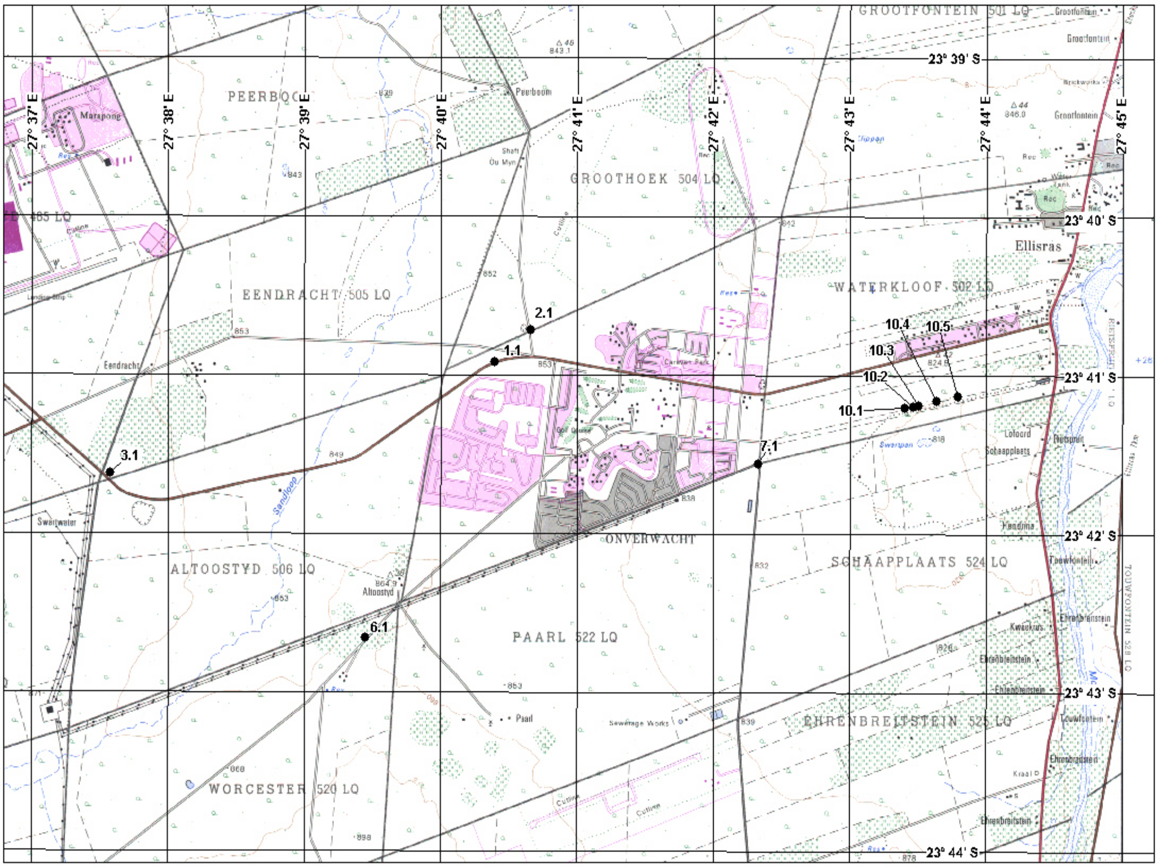

Figure 4-2: Drilling Targets for the DWA Programme

The study (**DWA, 2008d**) also intends to carry out the following activities:

- Drilling of six (6) boreholes around Lephalale in the period October to December 2008;
- Drilling of four (4) to five (5) boreholes between Lephalale and Steenbokpan for the Institute for Groundwater Studies (IGS) study to fill data gaps;

- Drilling of one (1) geotechnical diamond core borehole 700 m deep; and
- Approximately eight (8) pump tests.

The project team also provided the following preliminary conclusions regarding the study:

- The possibility of artificial recharge looks promising based on the physical properties of the aquifer;
- The isotope data indicate only two (2) boreholes very close to the drainage record some surface water recharge, but further isotope studies are recommended. The stable isotope data indicates rainwater recharge to the aquifer at Lephalale and excluding the Mokolo River alluvial aquifer, it can potentially yield 1.7 Million m^3/a. This value is derived from all the boreholes drilled to date;
- Based on the results achieved to date, the aquifer may potentially yield up to 7.19 Million m^3/a but will not be sustainable over the long term;
- The alluvial aquifer recharged by overflow of the Mokolo Dam only is not yet studied but could potentially yield a further 3.8 Million m^3/a. If this is added to the potential 1.7 Million m^3/a yield from boreholes, it increases the total sustainable yield to 5.5 Million m^3/a; and
- The alluvial aquifer needs to be investigated further in order to establish its potential contribution.

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 coal reserves* **(WRC, 2008)**. At a WRC workshop held, the IGS reported that the data collection stage is still in progress. The potential obtained by the DWA project was discussed with Prof Danie Vermeulen of the IGS. The IGS supported the opinion that it is unlikely that the secondary fractured aquifer will be able to yield the estimated 10 Million m^3/a required based on date collected to date. There are no geohydrological map covering the Mokolo River catchment area and IGS is presently working on the data for such a map. The only map available was prepared in 1992 (**DWA Report P A500/00/0291**), covering the Lephalala River Catchment.

In addition to the above, the Intermediate Reserve Determination study for the Mokolo River Catchment (**DWA, 2007**) is currently being executed by Water for Africa in association with Clean Stream. According to the Inception Report of this study (**DWA, 2007**), the primary objective of the study is to implement a RDM assessment yielding results at an intermediate level of confidence for the Mokolo River sub-catchment, taking into account water resource management aspects raised in relevant sources. Both quantity and quality will be addressed and the groundwater reserve study will essentially support the more detailed surface water reserve studies. The results of this study will be necessary to evaluate the impact of groundwater resource development on the available groundwater resource in the catchment and will as far as available be included in potential further groundwater investigations. Results were however not available at the time of compiling this report.

Further potential work towards establishing the groundwater potential in the area is the following:

- The recharge and dynamics of the aquifer system will not be addressed by the current studies. Groundwater flow and the inherent hydrochemical processes belong to the hydrological cycle which is aquifer dependent. It is important to understand transit and residence times of groundwater recharge in an aquifer especially secondary, confined and deep aquifer systems. Because of the available sampling points and data, such a study should not take more than 3 to 6 months. Isotope hydrology has in numerous instances assisted in understanding and managing aquifer systems. This aspect is important for establishing the sustainability of the resources and must be addressed should the resource be utilised to augment the water supply to Lephalale during the interim.

- A comprehensive report commenting on the potential to utilise groundwater resources in the secondary fractured aquifer can only be compiled once the current studies and suggested further isotope hydrology studies have been completed. The isotope study will establish to a large degree the sustainability of the resources.
- The preparation and completion of a geohydrological map for the area is being undertaken prepared by the IGS and will be vital in establishing the potential of groundwater in the area.
- The impact on the Limpopo River flow needs to be considered as it is an internationally shared watercourse.

Groundwater quality data around the Lephalale at this stage seems to be limited. Groundwater quality data from the DWA project (**DWA, 2008d**) indicates unacceptable Fluoride levels as the main quality concern. Present data shows groundwater with localised EC levels as high as 100mS/m and marginal elevated nitrate, possibly a result of poor sanitation and farming practices (**DWA 2008d**). The Water for Africa project (**DWA 2007**) argues that the groundwater quality is poor due to the presence of coal and gas in the area and is potentially impacting on the surface water quality of the Mokolo River catchment.

4.4. Conclusions and Recommendations

It is doubted that groundwater resources in the Limpopo River Catchment Management area (CMA) will yield water on an economically viable level to augment the existing surface water resources in the future, even on an interim basis. The following recommendations have therefore been made:

- The present results from the DWA drilling project indicate 1.7 Million m^3/a from boreholes drilled to date, based on these results the aquifer may potentially yield up to 2.2 Million m^3/a if fully developed.
- The groundwater quality results from the DWA drilling project indicate unacceptable Fluoride levels which will have to be addressed, possibly by treatment or reducing with surface water mixing.
- No further hydrogeological work should be executed prior to the completion of the current studies being carried out on behalf of the WRC and the DWA drilling project.
- Critical scrutiny of the final results from abovementioned studies needs to be carried out prior to the consideration of further hydrogeological work.
- Only if the results from the abovementioned studies clearly indicate towards the potential for the development of an economically viable well field(s) should further hydrogeological and geophysical work be considered

5. REFERENCES

DWA, 2008a Department of Water Affairs, South Africa. **Updating the Hydrology and Yield Analysis in the Mokolo River Catchment: Yield Analysis (WRYM).** Study executed by WRP Consulting Engineers (Pty) Ltd, in association with DMM Development Consultants CC and Golder Associates Africa (Pty) Ltd on behalf of the Directorate: National Water Resource Planning, 2008

DWA, 2008b Department of Water Affairs, South Africa. **Updating the Hydrology and Yield Analysis in the Mokolo River Catchment: Planning Analysis (WRPM).** Study executed by WRP Consulting Engineers (Pty) Ltd in association with DMM Development Consultants CC and Golder Associates Africa (Pty) Ltd on behalf of the Directorate: National Water Resource Planning, 2008

DWA, 2008c Department of Water Affairs, South Africa. **Crocodile River (West) Reconciliation Strategy Version 1.** Study executed by BKS (Pty) Ltd. on behalf of the Directorate: National Water Resource Planning, 2008

DWA, 2008d Department of Water Affairs, South Africa. **Hydrogeological Assessment and Aquifer Recharge Potential at Lephalale Local Municipality.** Study being executed by VSA Leboa Consulting on behalf of the Directorate: Water Resource Planning Systems, January 2008 to date.

DWA, 2007 Department of Water Affairs, South Africa. **Intermediate Reserve Determination Study for the Surface and Groundwater Resources in the Mokolo Catchment, Limpopo Province.** Study being executed by Water for Africa, Inception Report Project No WP 9132, August 2007.

WRC, 2008 Water Research Commission. **An assessment of how water quality will be affected by mining method and mining of the Waterberg coal reserves and how this would be affected by different mining methods.** Study being executed by the University of the Freestate (IGS) on behalf of the Water Research Commission. 2008 to date.

DWA, 2000 Ground Water Resource Study Lephalale River Catchment. DWA report PA500/00/0291

APPENDIX A

Water Balances for the Crocodile/Mokolo Dam System

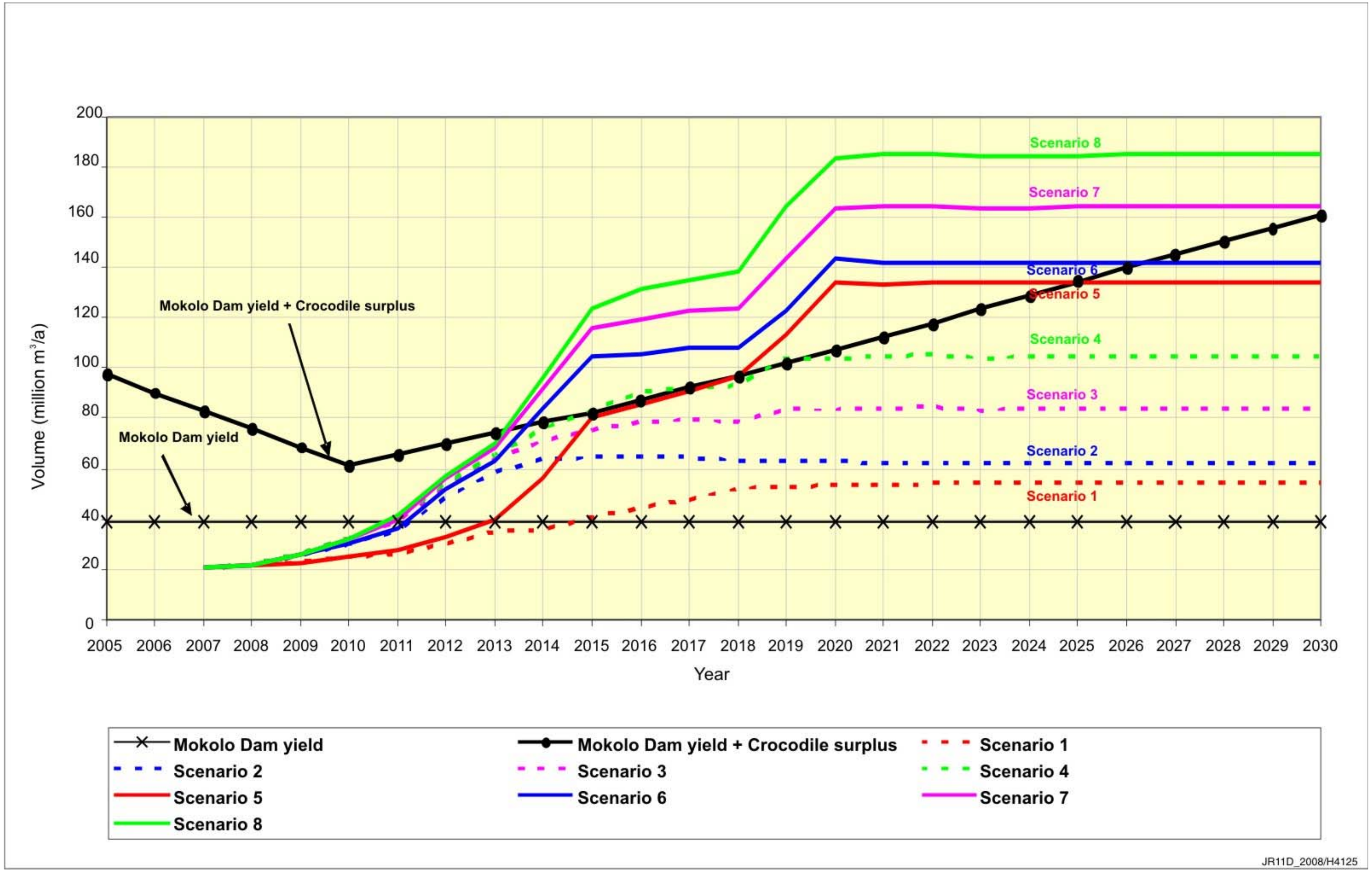

Figure A-1: Water Balance at Lephalale: High population, Medium Efficiency (DWA, 2008c)

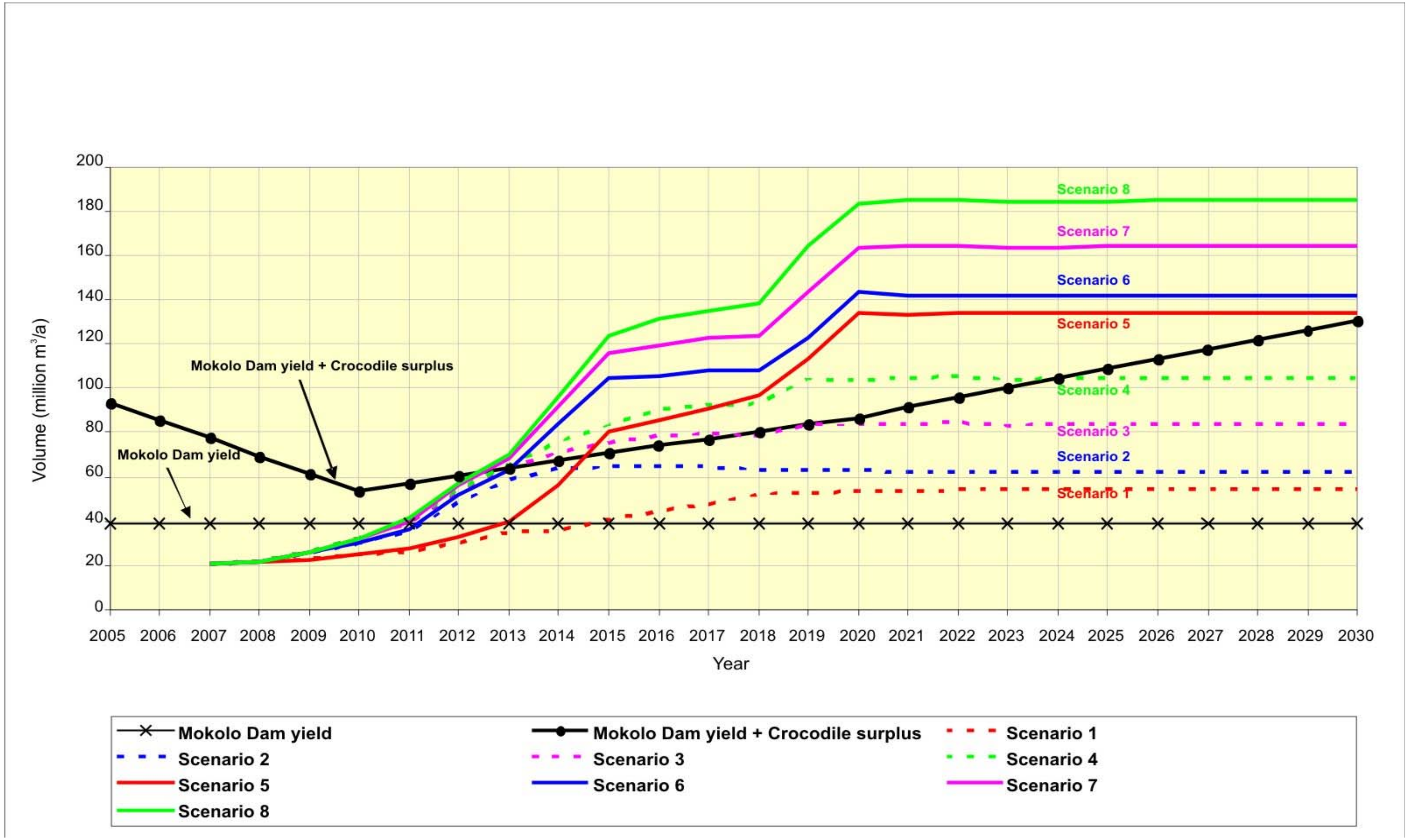

Figure A-2: Water Balance at Lephalale: Base Population, Medium Efficiency (DWA, 2008c)

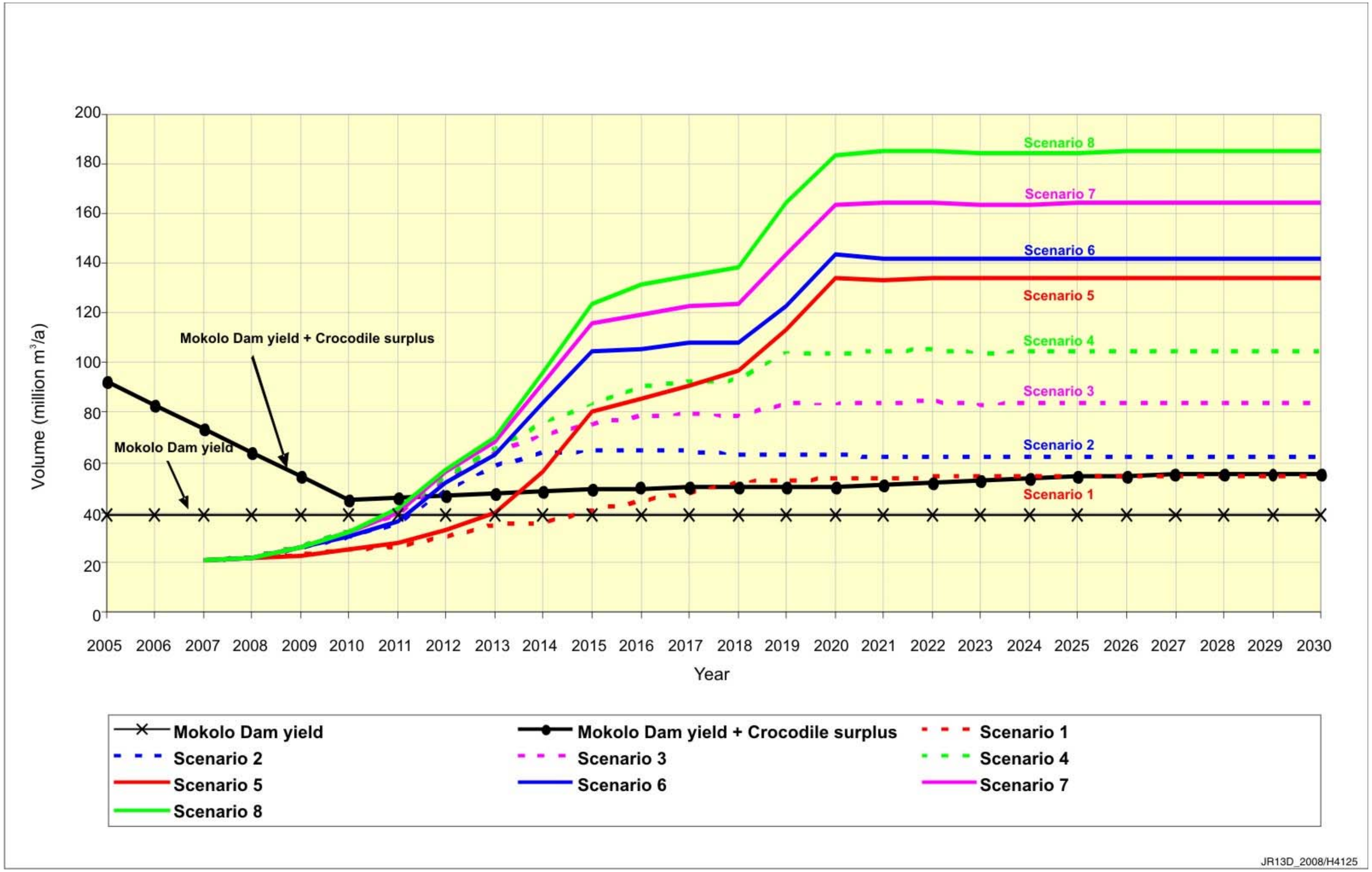

Figure A-3: Water Balance at Lephalale: Low Population, Medium Efficiency (DWA, 2008c)

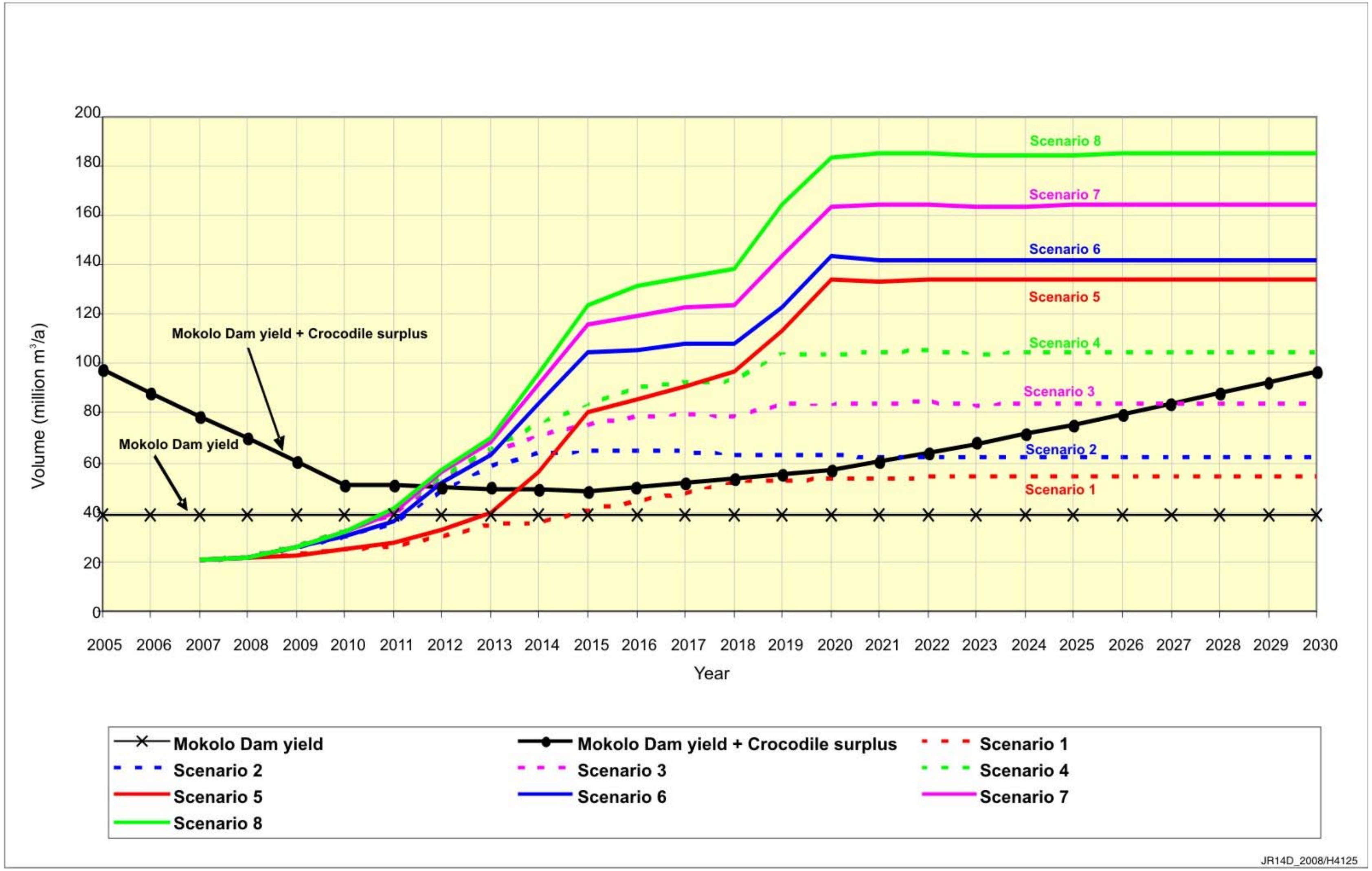

Figure A-4: Water Balance at Lephalale: High Population, High Efficiency (DWA, 2008c)

APPENDIX B

WRPM Analyses Results
(Scenario I & Scenario II)

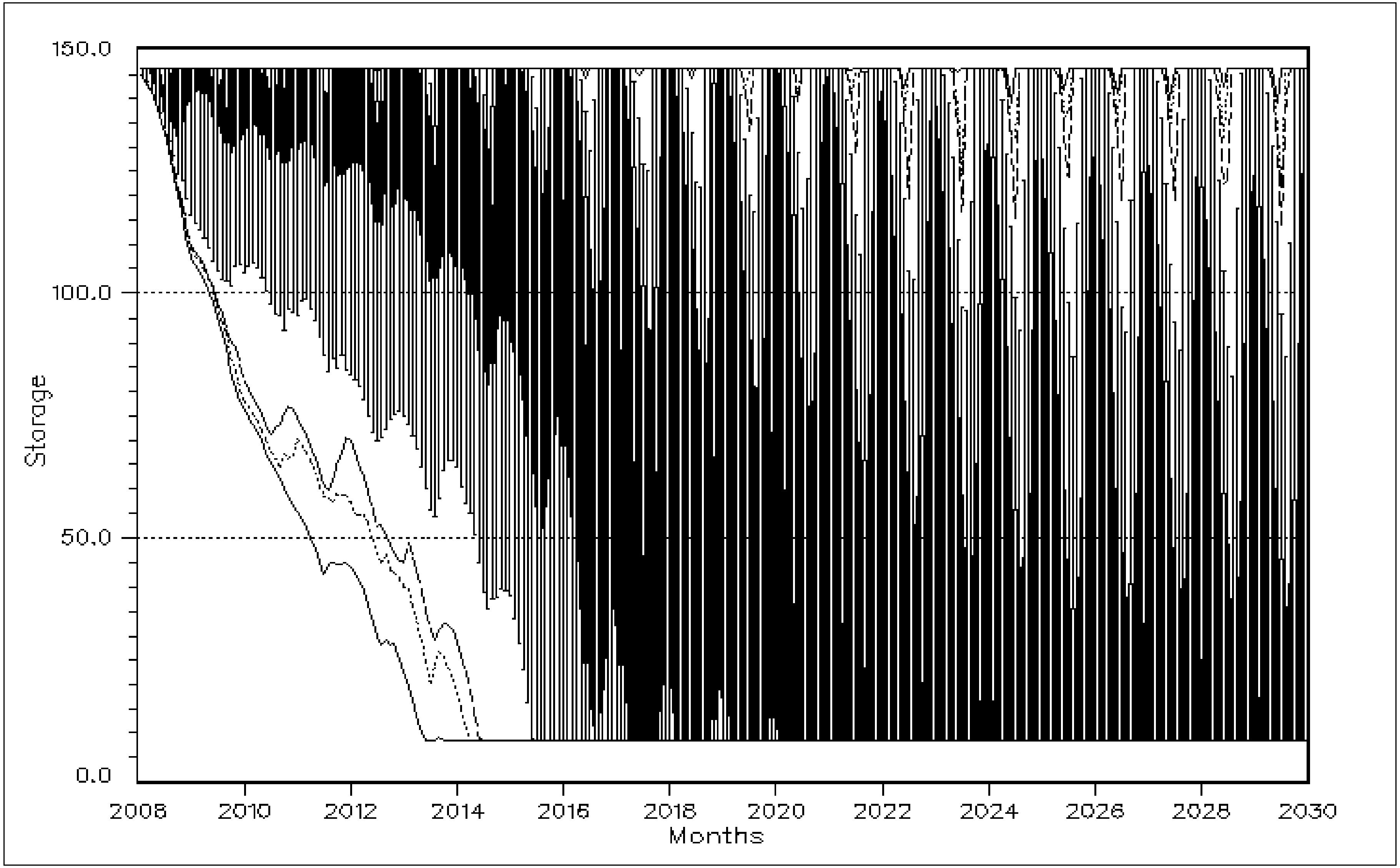

Figure B-1: Monthly Storage Volumes of Mokolo Dam: Scenario I

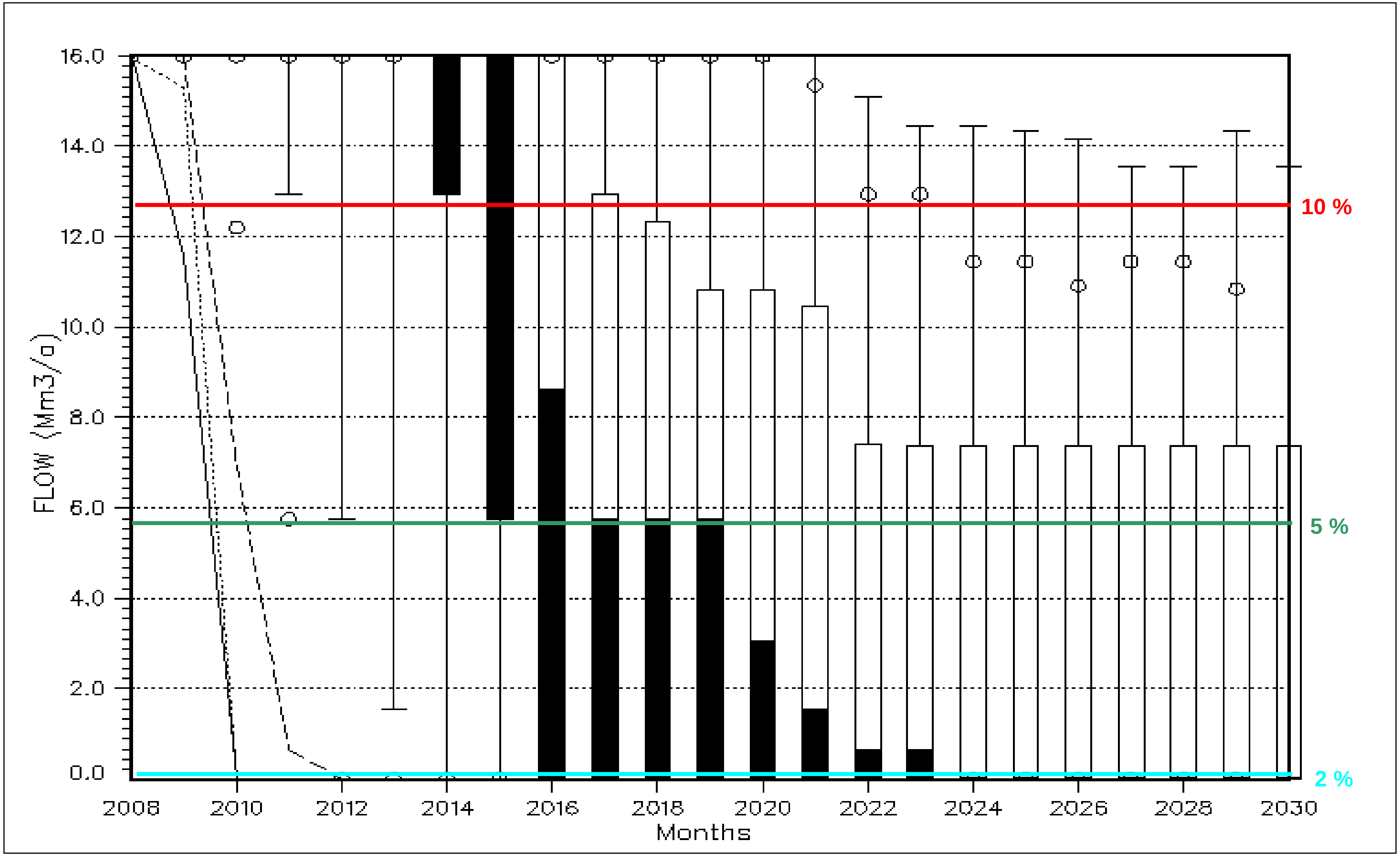

Figure B-2: Annual Irrigation Scheme Supply: Scenario I

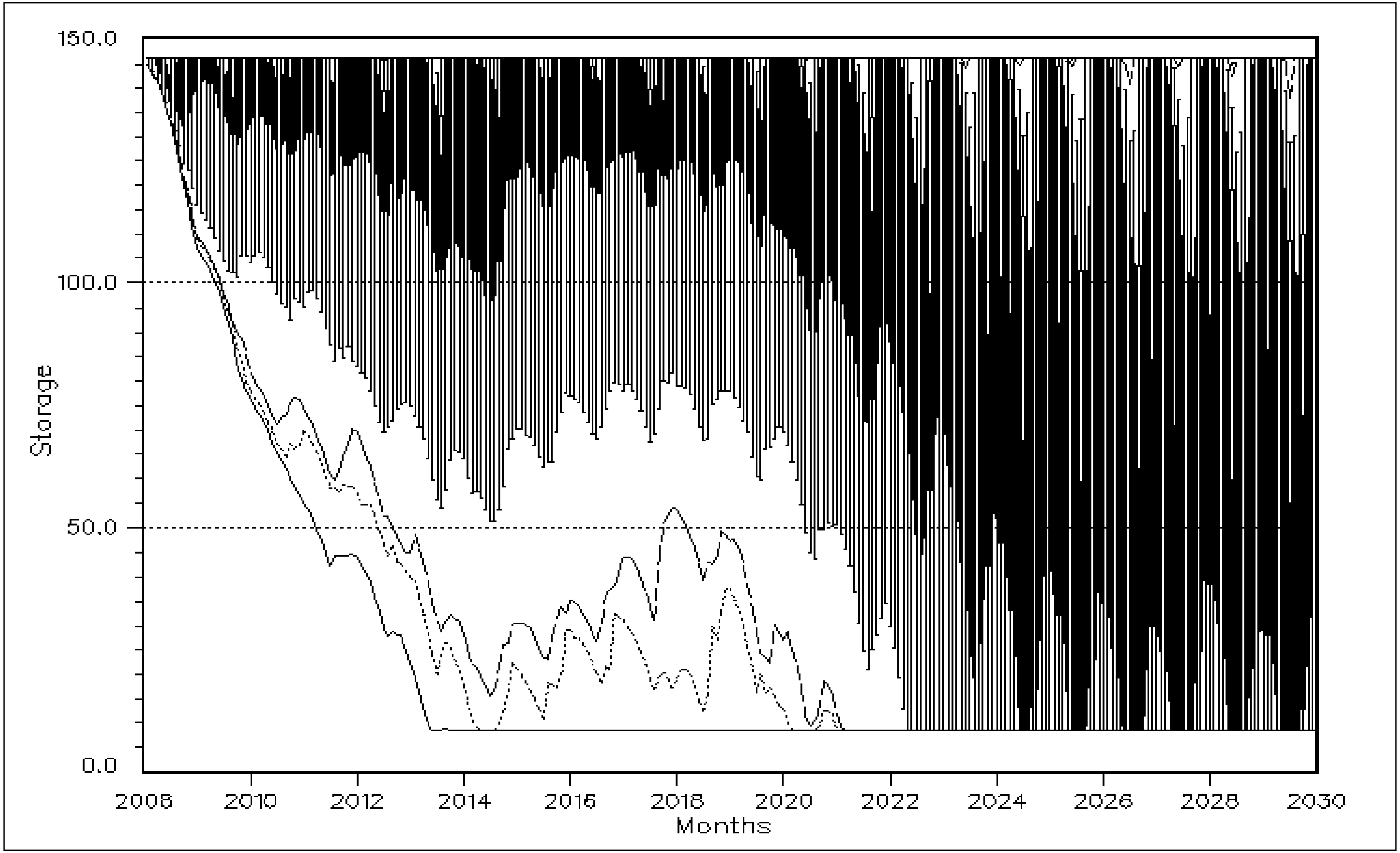

Figure B-3: Monthly Storage Volumes of Mokolo Dam: Scenario II

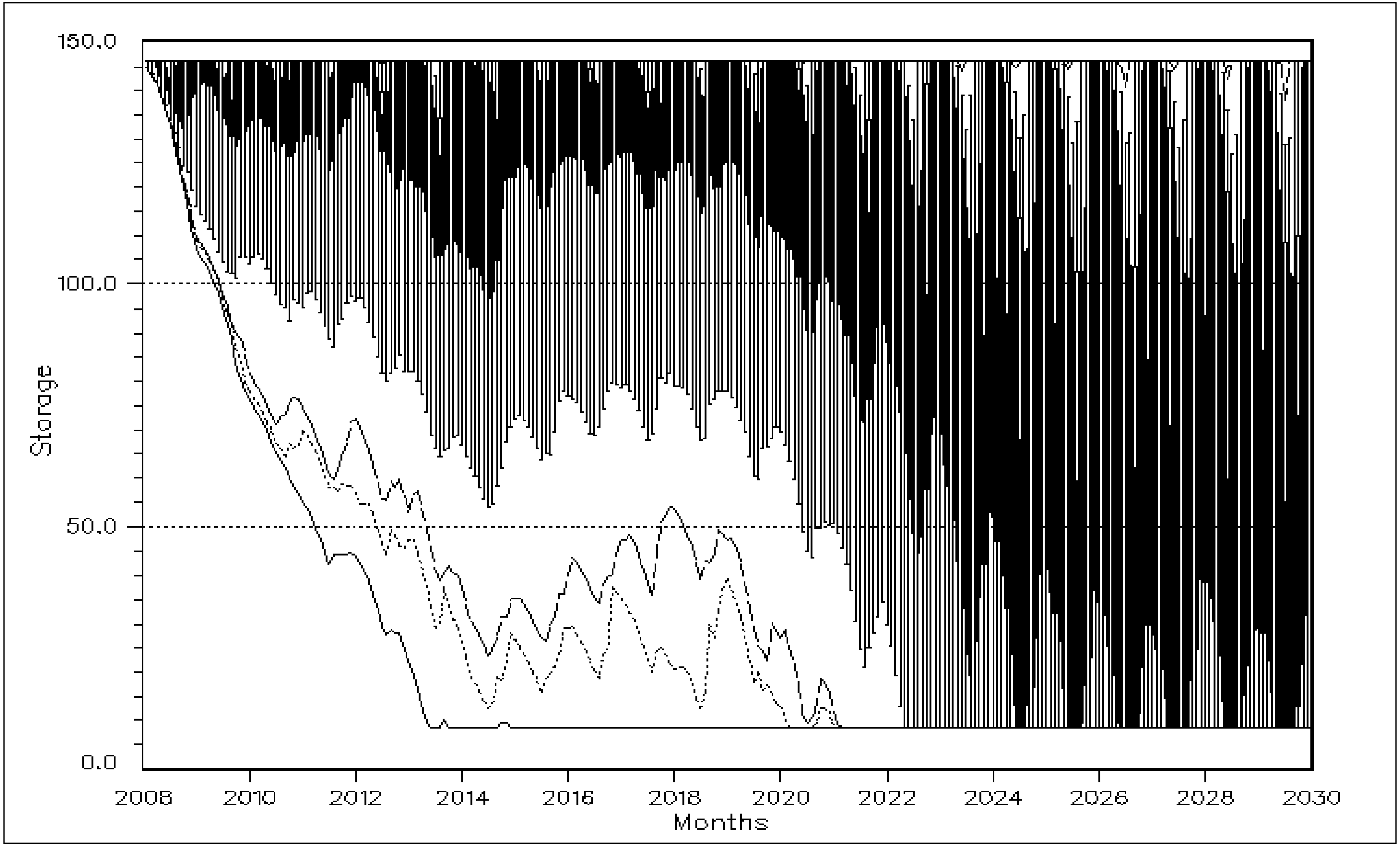

Figure B-4: Monthly Storage Volumes of Mokolo Dam: Scenario II (Irrigation totally curtailed in 2011)

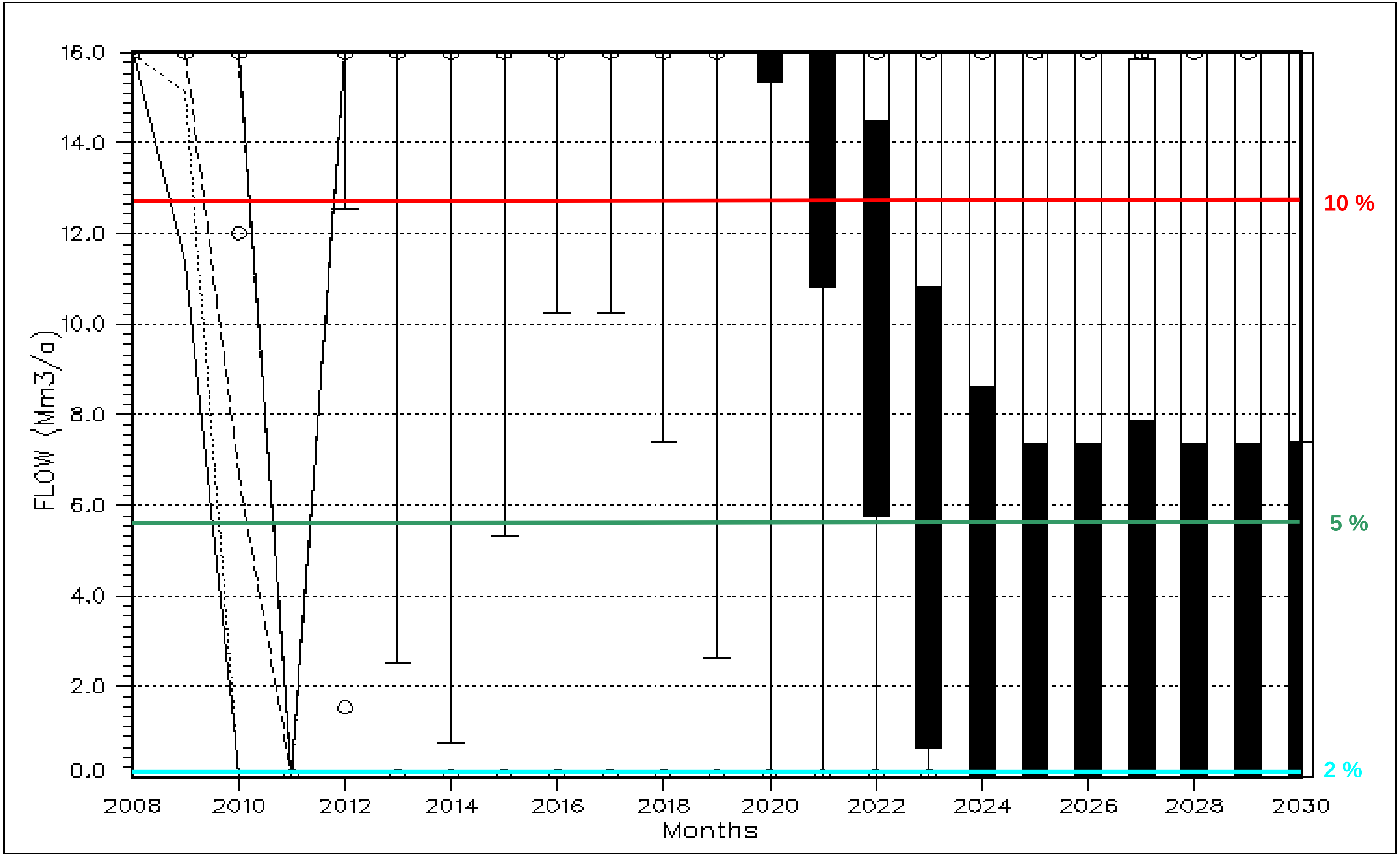

Figure B-5: Annual Irrigation Scheme Supply: Scenario II (Irrigation totally curtailed in 2011)

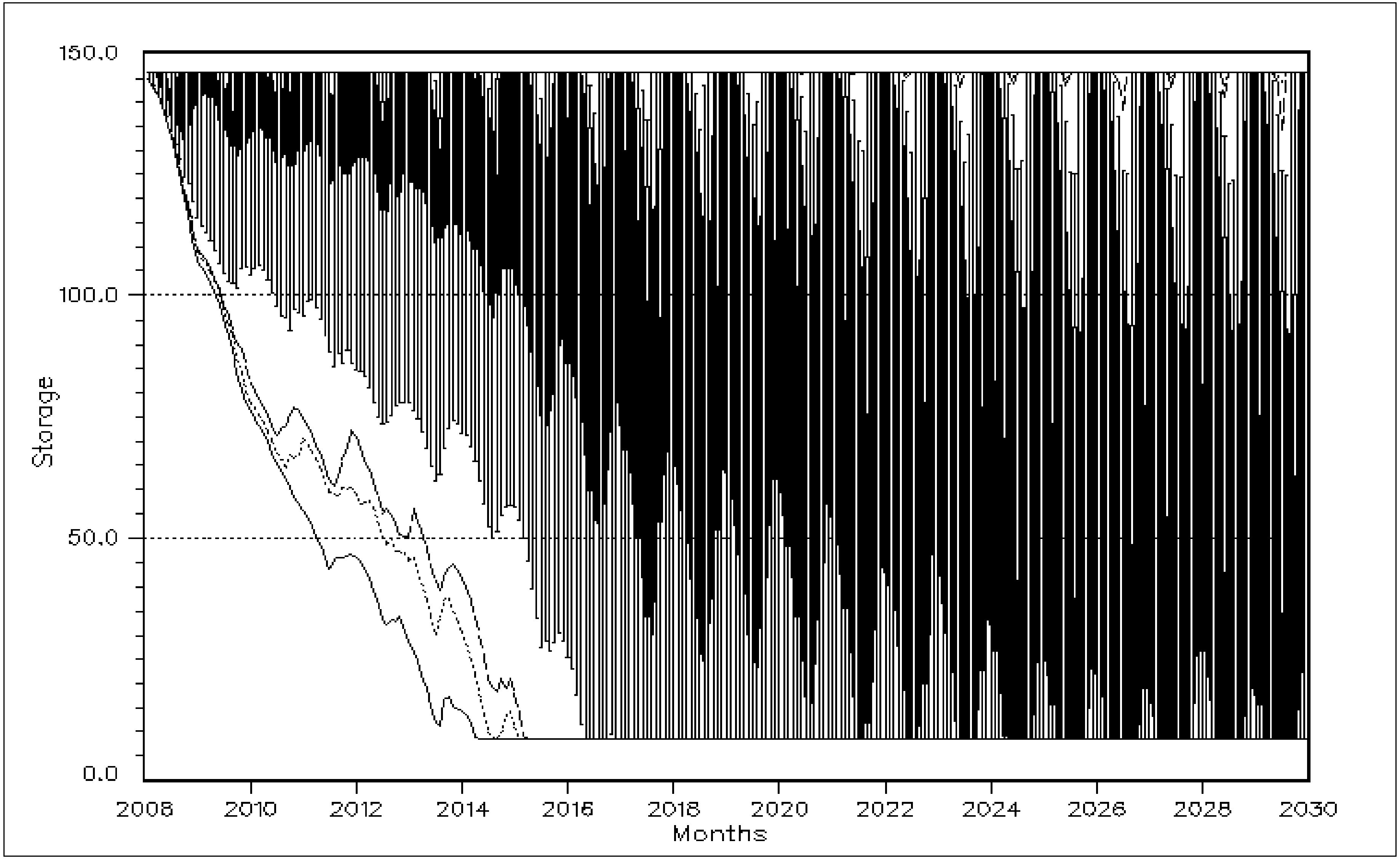

Figure B-6: Monthly Storage Volumes of Mokolo Dam: Scenario III

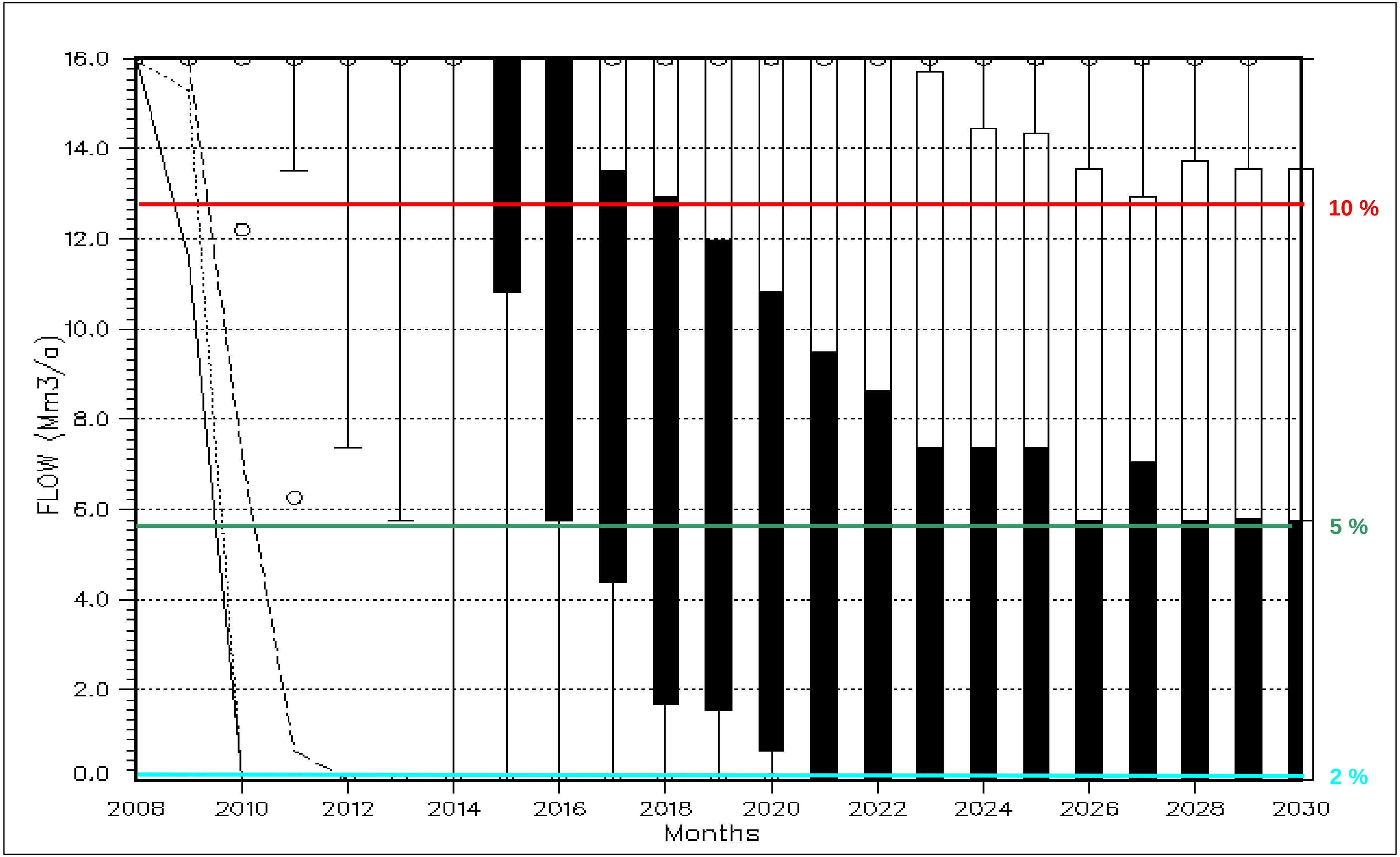

Figure B-7: Annual Irrigation Scheme Supply: Scenario III

REPORT DETAILS PAGE

Project name:	***Mokolo and Crocodile (West) Water Augmentation Project (MCWAP)***
Report Title:	**Pre-Feasibility Study Report 2 Water Resources**
Author:	***J Pienaar***
DWA report reference no.:	***P RSA A000/00/8909***
PSP project reference no.:	***WP 9528***
Status of report:	***Final***
First issue:	***November 2008***
Final issue:	***March 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