water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

REPORT NO: P WMA 11/U10/00/3312/2/4

# The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water

## WATER RESOURCES PLANNING MODEL REPORT

FINAL

NOVEMBER 2015

W129_2014/J01763

*Project name:* ***The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study Raw Water***

*Report Title:* ***Water Resources Planning Model Report***

*Author:* ***J Schroder and G de Jager***

*PSP project reference no.:* ***J01763***

*DWA report no.:* ***P WMA 11/U10/00/3312/2/4***

*Status of report:* ***Final***

*First issue:* ***September 2015***

*Final issue:* ***November 2015***

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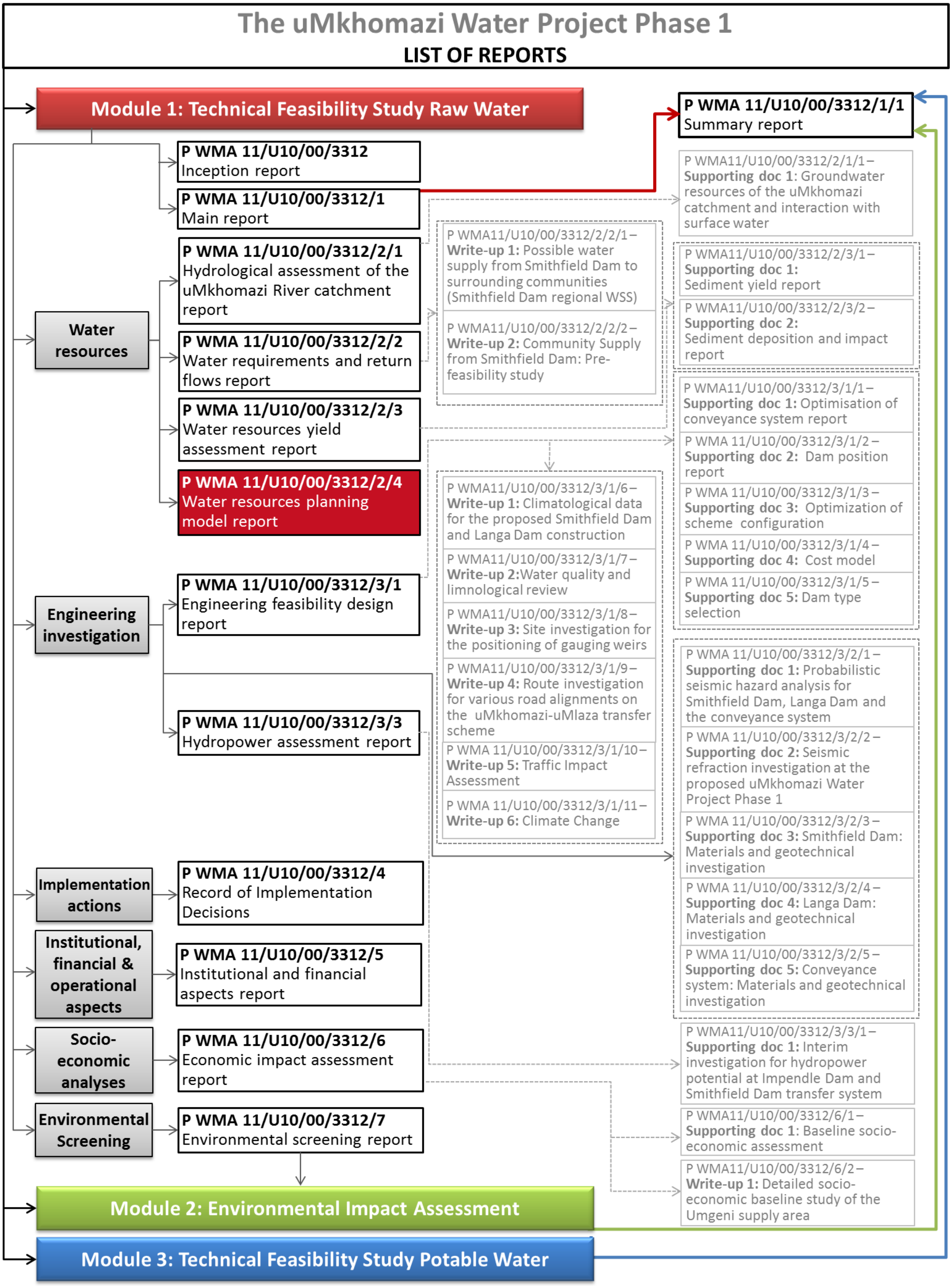
# PREAMBLE

In June 2014, two years after the commencement of the uMkhomazi Water Project Phase 1 Feasibility Study, a new Department of Water and Sanitation was formed by Cabinet, including the formerly known Department of Water Affairs.

In order to maintain consistent reporting, all reports emanating from Module 1 of the study will be published under the Department of Water Affairs name.



# The uMkhomazi Water Project Phase 1

## LIST OF REPORTS

**Module 1: Technical Feasibility Study Raw Water**

**Water resources**

- **P WMA 11/U10/00/3312** Inception report
- **P WMA 11/U10/00/3312/1** Main report
- **P WMA 11/U10/00/3312/2/1** Hydrological assessment of the uMkhomazi River catchment report
- **P WMA 11/U10/00/3312/2/2** Water requirements and return flows report
- **P WMA 11/U10/00/3312/2/3** Water resources yield assessment report
- **P WMA 11/U10/00/3312/2/4** Water resources planning model report

**Engineering investigation**

- **P WMA 11/U10/00/3312/3/1** Engineering feasibility design report
- **P WMA 11/U10/00/3312/3/3** Hydropower assessment report

**Implementation actions**

- **P WMA 11/U10/00/3312/4** Record of Implementation Decisions

**Institutional, financial & operational aspects**

- **P WMA 11/U10/00/3312/5** Institutional and financial aspects report

**Socio-economic analyses**

- **P WMA 11/U10/00/3312/6** Economic impact assessment report

**Environmental Screening**

- **P WMA 11/U10/00/3312/7** Environmental screening report

P WMA11/U10/00/3312/2/2/1 – **Write-up 1:** Possible water supply from Smithfield Dam to surrounding communities (Smithfield Dam regional WSS)

P WMA11/U10/00/3312/2/2/2 – **Write-up 2:** Community Supply from Smithfield Dam: Pre-feasibility study

P WMA11/U10/00/3312/3/1/6 – **Write-up 1:** Climatological data for the proposed Smithfield Dam and Langa Dam construction

P WMA11/U10/00/3312/3/1/7 – **Write-up 2:**Water quality and limnological review

P WMA11/U10/00/3312/3/1/8 – **Write-up 3:** Site investigation for the positioning of gauging weirs

P WMA11/U10/00/3312/3/1/9 – **Write-up 4:** Route investigation for various road alignments on the uMkhomazi-uMlaza transfer scheme

P WMA 11/U10/00/3312/3/1/10 – **Write-up 5:** Traffic Impact Assessment

P WMA 11/U10/00/3312/3/1/11 – **Write-up 6:** Climate Change

**P WMA 11/U10/00/3312/1/1** Summary report

P WMA11/U10/00/3312/2/1/1 – **Supporting doc 1:** Groundwater resources of the uMkhomazi catchment and interaction with surface water

P WMA11/U10/00/3312/2/3/1 – **Supporting doc 1:** Sediment yield report

P WMA11/U10/00/3312/2/3/2 – **Supporting doc 2:** Sediment deposition and impact report

P WMA11/U10/00/3312/3/1/1 – **Supporting doc 1:** Optimisation of conveyance system report

P WMA 11/U10/00/3312/3/1/2 – **Supporting doc 2:** Dam position report

P WMA 11/U10/00/3312/3/1/3 – **Supporting doc 3:** Optimization of scheme configuration

P WMA 11/U10/00/3312/3/1/4 – **Supporting doc 4:** Cost model

P WMA 11/U10/00/3312/3/1/5 – **Supporting doc 5:** Dam type selection

P WMA 11/U10/00/3312/3/2/1 – **Supporting doc 1:** Probabilistic seismic hazard analysis for Smithfield Dam, Langa Dam and the conveyance system

P WMA 11/U10/00/3312/3/2/2 – **Supporting doc 2:** Seismic refraction investigation at the proposed uMkhomazi Water Project Phase 1

P WMA 11/U10/00/3312/3/2/3 – **Supporting doc 3:** Smithfield Dam: Materials and geotechnical investigation

P WMA 11/U10/00/3312/3/2/4 – **Supporting doc 4:** Langa Dam: Materials and geotechnical investigation

P WMA 11/U10/00/3312/3/2/5 – **Supporting doc 5:** Conveyance system: Materials and geotechnical investigation

P WMA11/U10/00/3312/3/3/1 – **Supporting doc 1:** Interim investigation for hydropower potential at Impendle Dam and Smithfield Dam transfer system

P WMA11/U10/00/3312/6/1 – **Supporting doc 1:** Baseline socio-economic assessment

P WMA11/U10/00/3312/6/2 – **Write-up 1:** Detailed socio-economic baseline study of the Umgeni supply area

**Module 2: Environmental Impact Assessment**

**Module 3: Technical Feasibility Study Potable Water**

# Executive Summary

*This report described the development of an integrated* Water Resources Planning Model *(WRPM) configuration for the uMkhomazi, uMngeni and upper Mooi river catchments and its use in undertaking detailed planning analyses to:*

- *Confirm the phasing of the proposed uMWP infrastructure, including uMWP-1 (Smithfield Dam) and uMWP-2 (Impendle Dam), to augment water supply to the Mgeni Water Supply System (WSS).*
- *Assess the need for and capacity of balancing storage required to provide water to the Mgeni WSS during periods of scheduled maintenance or emergency downtime of the uMWP-1 transfer tunnel.*

*The development and refinement of the integrated WRPM system model was undertaken in three distinct steps, namely (i) developing a new model configuration for the uMkhomazi system; (ii) refining the existing model configuration for the Mooi-Mgeni system; and (iii) combining the uMkhomazi and Mooi-Mgeni systems into a single model configuration, referred to as the* ***Integrated Mgeni WSS****.*

*The WRPM model configuration for the uMkhomazi system was based on the* Water Resources Yield Model *(WRYM) configuration developed as part of the earlier* Water Resources Yield Assessment *task of this study. As such the model incorporates updated information on the characteristics of the uMkhomazi and upper uMlaza river catchments, including hydro-meteorological data sets, projected in-catchment water use, the projected extent, distribution and characteristics of small dams and wetlands, proposed major dams in the uMkhomazi River catchment (Impendle Dam, Smithfield Dam, the off-channel Ngwadini Dam and Bulwer Dam), as well as the proposed uMWP balancing dam in the upper uMlaza River catchment (Langa Dam).*

*Furthermore, combining the uMkhomazi and Mooi-Mgeni systems required some modifications to the existing Mooi-Mgeni system model configuration to better capture the spatial division of water users within the proposed uMWP supply area, as well as to incorporate the water supply capacity constraints of significant infrastructure in the Mgeni WSS. Furthermore, a revised water requirement projection was developed for the uMWP supply area based on information from the* Technical Feasibility Study: Potable Water *(Module 3 of this study).*

*Conclusions and recommendations emanating from detailed planning analyses undertaken using the new WRPM model for the Integrated Mgeni WSS are summarised below:*

- *Despite the commissioning of MMTS-2 (Spring Grove Dam and transfer infrastructure) planned for December 2015, the Mgeni WSS will be subjected to continued risk of supply violations from 2016. The system has been in a negative balance situation for almost a decade and MMTS-2 will only provide relief for the existing shortfall.*
- *As a result of the above situation,* ***augmentation of the Mgeni WSS is required almost immediately****, much earlier than the practical implementation date of the uMWP-1 (Smithfield Dam) in 2023.*
- *Shorter-term intervention options have been identified to alleviate the shortfall situation in the Mgeni WSS prior to 2023. These options include the desalination of seawater and the direct re-use of effluent. However, it is recommended that this issue is investigated further as part of other studies, in particular the ongoing* KwaZulu-Natal Reconciliation Strategy *study.*
- *Subsequent to the commissioning of uMWP-1, it is estimated that the system would require further augmentation through the* ***implementation of uMWP-2 (Impendle Dam) by 2046****. This is assuming that, in the interim period, Smithfield Dam is effectively utilised with growing transfer volumes implemented in phases according to the relevant water requirements, infrastructure capacity and water resource constraints in the Mgeni WSS.*
- *Both of the above results are in line with preliminary findings obtained in the earlier* Water Resources Yield Assessment *of this study, which were based on a simple water balance of the Mgeni WSS developed using the available water resources and updated water requirement projections for the system.*
- *Analysis results confirm the need for balancing storage to provide water to the Mgeni WSS over periods of scheduled maintenance or emergency downtime of the uMWP-1 transfer tunnel.*
- *The timing of the balancing dam is affected by the extent to which risk of non-supply in the Mgeni WSS can be tolerated, the utilisation of excess water supply infrastructure capacity in the Mgeni WSS and the timing of tunnel downtime. Specifically, if downtime occurs during a peak month (such as in an emergency situation) and excess infrastructure capacity in the Mgeni WSS can be fully utilised,* ***balancing storage will be required by approximately 2025*** *(i.e. shortly after uMWP-1).*

- *The storage capacity required for the balancing dam increases over time as growing water requirements result in a reduction in the excess infrastructure capacity in the Mgeni WSS. If tunnel downtime occurs during a peak month a capacity of approximately 6 million m³ is required in 2050 (i.e. close to the projected implementation date of uMWP-2). However, if a significant tunnel problem occurs maintenance will probably be required over a period of closer to two months and the* ***balancing storage capacity required is therefore 12 million m³****.*
- *It is recommended that the planning, sizing and design of the balancing dam are further refined in the* Feasibility Design *task of this study. As part of that task, due consideration should be given to the findings summarised above, together with aspects such as the implementation programme of the uMWP scheme as a whole. In particular, the possible alignment of the construction of uMWP-1 and the balancing dam should be considered as this would provide an opportunity for using excavation material from the tunnel in the construction of the balancing dam.*
- *Finally, it is recommended that the new WRPM model configuration for the Integrated Mgeni WSS is used for updating the* Reconciliation Strategy *in the* KwaZulu-Natal Reconciliation Strategy *study. However, once results from the parallel* Classification of Water Resources and Determination of the Comprehensive Reserve and Resources Quality Objectives in the Mvoti to Umzimkulu Water Management Area *study become available, the WRPM must be updated accordingly and the results presented in this report confirmed and/or reviewed as required.*

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| AADD | Average Annual Daily Demand |
| AMSL | Above Mean Sea Level |
| CV | Coefficient of Variation |
| DM | District Municipality |
| DSL | Dead Storage Level |
| DWA | Department of Water Affairs |
| DWS | Department of Water and Sanitation |
| FSL | Full Supply Level |
| GG | Government Gazette |
| KZN | KwaZulu-Natal |
| LM | Local Municipality |
| MAE | Mean Annual Evaporation |
| MAP | Mean Annual Precipitation |
| MAR | Mean Annual Runoff |
| MMTS | Mooi-Mgeni Transfer Scheme |
| MMTS-1 | Mooi-Mgeni Transfer Scheme Phase 1 |
| MMTS-2 | Mooi-Mgeni Transfer Scheme Phase 2 |
| PMC | Project Management Committee |
| PSP | Professional Services Provider |
| RI | Recurrence Interval |
| RSA | Republic of South Africa |
| SCA | South Coast Augmentation |
| SD | Standard Deviation |

| | |
|---|---|
| uMWP | uMkhomazi Water Project |
| uMWP-1 | uMkhomazi Water Project Phase 1 (Smithfield Dam) |
| uMWP-2 | uMkhomazi Water Project Phase 2 (Impendle Dam) |
| WMA | Water Management Area |
| WRPM | Water Resources Planning Model |
| WRYM | Water Resources Yield Model |
| WSS | Water Supply System |
| WTW | Water Treatment Works |
| WwTW | Wastewater Treatment Works |
| YRC | Yield-Reliability Characteristics |

# LIST OF UNITS

| | |
|---|---|
| $km^2$ | square kilometre |
| m | metre |
| $m^3$ | cubic metre |
| million $m^3/a$ | million cubic metre per annum |
| Mℓ | mega litre |

# 1 INTRODUCTION

The Department of Water Affairs (DWA) appointed **BKS (Pty) Ltd** in association with three sub-consultants **Africa Geo-Environmental Services, MM&A and Urban-Econ** with effect from 1 December 2011 to undertake the **uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study Raw Water** study.

On 1 November 2012, BKS (Pty) Ltd was acquired by **AECOM Technology Corporation**. The new entity is a fully-fledged going concern with the same company registration number as that for BKS. As a result of the change in name and ownership of the company during the study period, all the final study reports will be published under the AECOM name.

*In 2010, the Department of Arts and Culture published a list of name changes in the Government Gazette (GG No 33584, 1 October 2010). In this list, the Mkomazi River's name was changed to the* **uMkhomazi River**. *The published spelling will thus be used throughout this technical feasibility study.*

## 1.1 BACKGROUND TO THE PROJECT

The current water resources of the integrated Mgeni Water Supply System (WSS) are insufficient to meet the long-term water requirements of the system. The Mgeni WSS is the main water source that supplies about five million people and industries in the eThekwini Municipality, uMgungundlovu District Municipality (DM) and Msunduzi Local Municipality (LM), all of which comprise the economic powerhouse of the KwaZulu-Natal Province.

The Mgeni WSS comprises the Midmar, Albert Falls, Nagle and Inanda dams in KwaZulu-Natal, a water transfer scheme from the Mooi River and the newly constructed Spring Grove Dam. The current system (Midmar, Albert Falls, Nagle and Inanda dams and the MMTS-1) has a yield of 334 million $m^3/a$ (measured at Inanda Dam) at a recurrence interval (RI) of failure of 1:100 years (or an annual assurance of supply of 99%). The short-term augmentation measure, Phase 2 of the Mooi-Mgeni Transfer Scheme (MMTS-2), currently being implemented with the construction of Spring Grove Dam, will increase water supply from the Mgeni WSS by 60 million $m^3/a$. However, this will not be sufficient to meet the long-term requirements of the system.

Pre-feasibility investigations indicated that Phase 1 of the uMkhomazi Water Project (uMWP-1), which entails the transfer of water from the undeveloped uMkhomazi River to the existing Mgeni WSS, is the scheme most likely to fulfil this requirement. The uMkhomazi River is the third-largest river in KwaZulu-Natal in terms of mean annual runoff (MAR).

Eight alternative schemes were initially identified as possible alternatives, and the Impendle and Smithfield scheme configurations have emerged as suitable for further investigation. The pre-feasibility investigation, concluded in 1998, recommended that the Smithfield Scheme be taken to a detailed feasibility-level investigation as its transfer conveyances would be independent of the existing Mgeni WSS, thus reducing the risk of limited or non-supply to eThekwini and some areas of Pietermaritzburg, and providing a back-up to the Mgeni WSS.

The ***Mkomazi-Mgeni Transfer Pre-feasibility Study*** concluded that the first phase of the uMWP would comprise a new dam at Smithfield on the uMkhomazi River near Richmond, a multi-level intake tower and pump station, a water transfer pipeline/tunnel to a balancing dam at Baynesfield Dam or a similar in-stream dam, a water treatment works at Baynesfield in the uMlaza River valley and a gravity pipeline to Umgeni Water's bulk distribution reservoir system, below the reservoir at Umlaas Road. From here, water will be distributed under gravity to eThekwini and possibly low-lying areas of Pietermaritzburg. Phase two of the uMWP may be implemented when needed, and could comprise the construction of a large dam at Impendle further upstream on the uMkhomazi River to release water to the downstream Smithfield Dam. Together, these developments have been identified as having a 99% assured stochastic yield of about 388 million $m^3/a$.

The DWA aims to have this scheme implemented by 2023.

## 1.2 OBJECTIVE OF THE STUDY

According to the Terms of Reference (November 2010), the objective of the study project is to undertake a feasibility study to finalise the planning of the proposed uMkhomazi Water Project (uMWP) at a very detailed level for the scheme to be accurately compared with other possible alternatives and be ready for implementation (detailed design and construction) on completion of the study.

The feasibility study has been divided into the following modules, which will run concurrently:

- Module 1: Technical Feasibility Raw Water (DWA) (*defined below*).
- Module 2: Environmental Impact Assessment (DWA).
- Module 3: Technical Feasibility Potable Water (Umgeni Water) (*ranging from the Water Treatment Plant to the tie-in point with the eThekwini distribution system*).

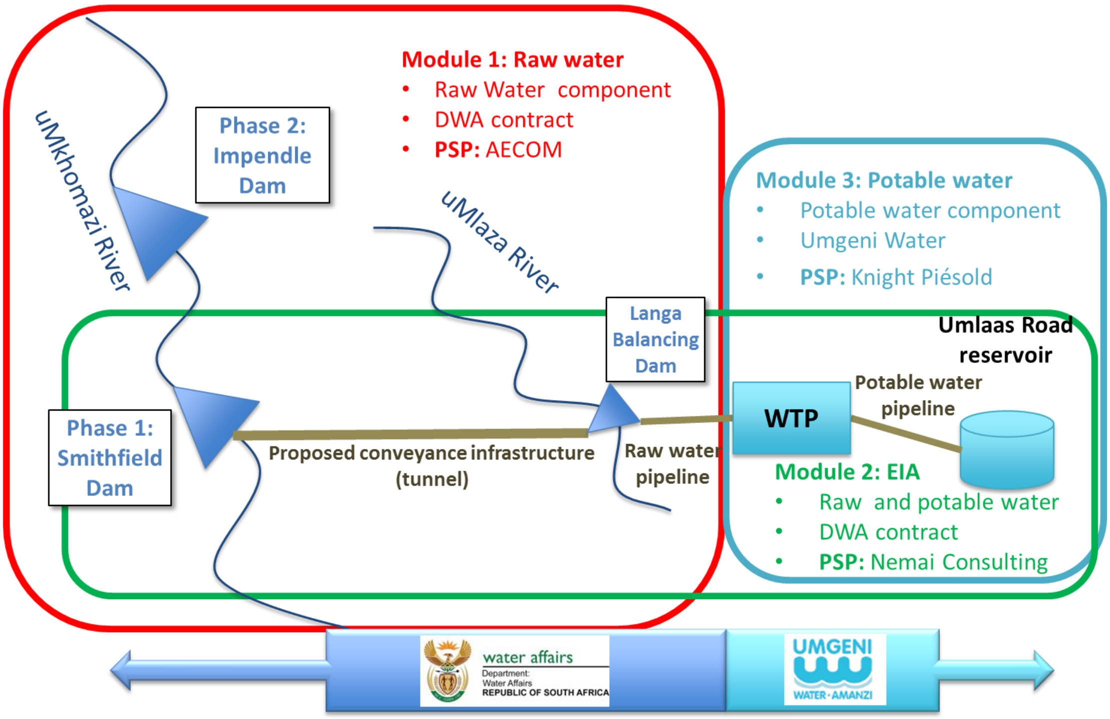


**Figure 1.1: uMWP-1 feasibility study modules**

This module, the raw water technical feasibility study, considers water resources aspects, engineering investigations and project planning and scheduling and implementation tasks, as well as an environmental screening and assessment of socio-economic impacts of the proposed project.

Some specific objectives for this study, recommended in the *Mkomazi-Mgeni Transfer Scheme Pre-feasibility* study are listed below:

- Smithfield Dam (Phase 1) to be investigated to a detailed feasibility level.
- Investigate the availability of water from Impendle Dam (Phase 2) as a future resource to release to Smithfield Dam, and refine the phasing of the selected schemes.
- Optimise the conveyance system between Smithfield Dam and the proposed Baynesfield Water Treatment Plant.
- Undertake a water resources assessment of the uMkhomazi River Catchment, including water availability to the lower uMkhomazi.
- Evaluate the use of Baynesfield dam as a balancing dam.

- Investigate the social and economic impact of the uMWP.

This one of three studies was undertaken in close collaboration with the DWA, Umgeni Water and the Professional Services Providers (PSPs) of the other modules.

## 1.3 STUDY AREA

The study focus and key objective is related to the feasibility investigation of the Smithfield Dam and related raw water conveyance infrastructure. However, this is a multi-disciplinary project with the study area defined as the uMkhomazi River catchment, stretching to the north to include the uMngeni River catchment, refer to **Figure 1.2**.

The various tasks have specific focus area, defined as:

- Water Resources: uMkhomazi and uMngeni river catchments.
- Water requirements: water users in the existing Mgeni WSS and the uMkhomazi River catchment.
- Engineering Investigations: proposed dams at Impendle (only for costing purposes) and Smithfield, and the raw water conveyance infrastructure corridor between Smithfield Dam and the Water Treatment Plant of Umgeni Water.
- Environmental screening as input for the Environmental Impact Assessment.
- Socio-economic impact assessment: regional, provincial (KwaZulu-Natal (KZN)) and national.

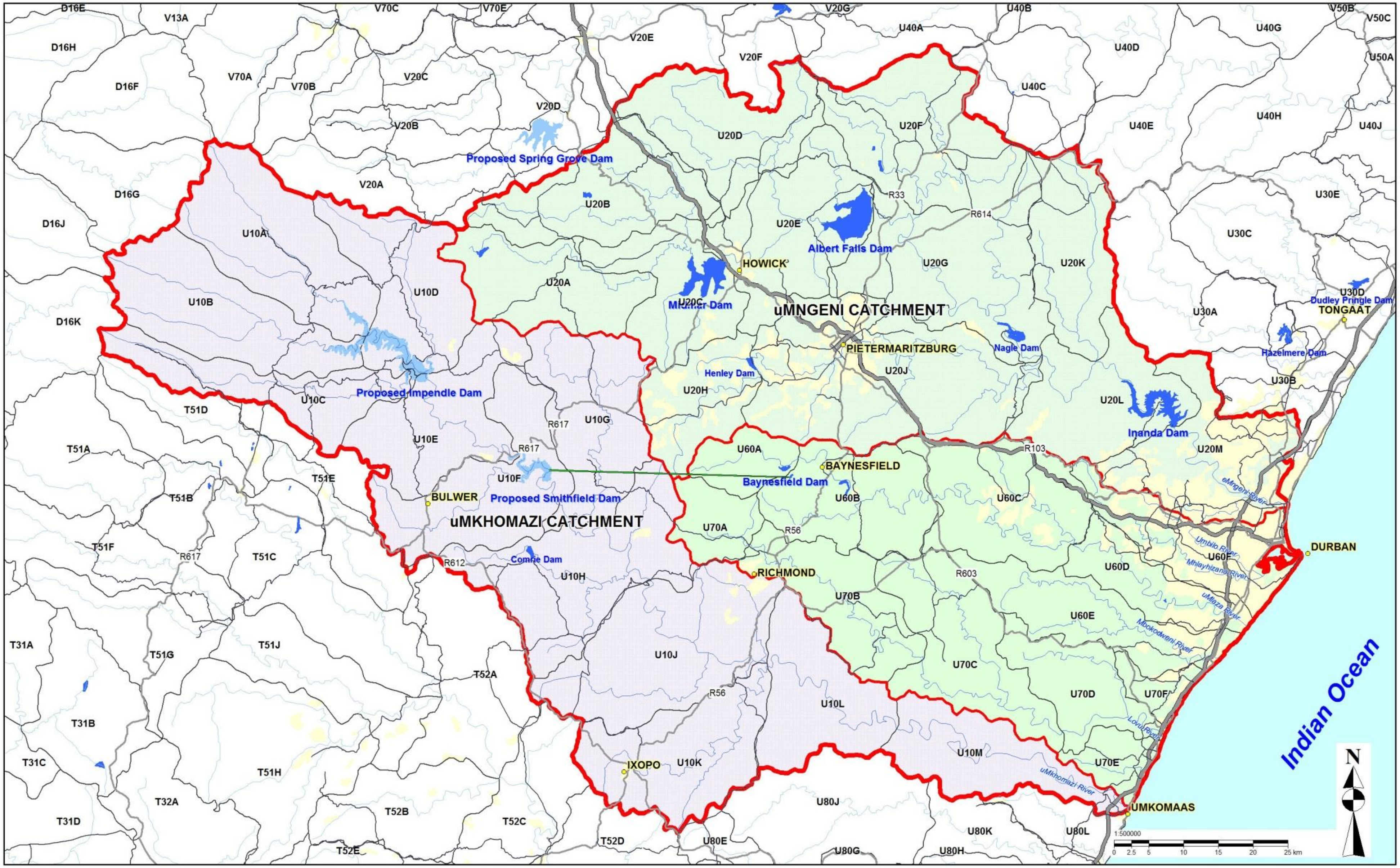


Figure 1.2: Study area of the uMWP

## 1.4 SCOPE OF THIS REPORT

This report described the development of an integrated *Water Resources Planning Model* (WRPM) configuration for the uMkhomazi, uMngeni and upper Mooi river catchments and its use in undertaking detailed planning analyses to:

- Confirm the phasing of the proposed uMWP infrastructure, including uMWP 1 (Smithfield Dam) and uMWP-2 (Impendle Dam), to augment water supply to the Mgeni WSS.
- Assess the need for and capacity of balancing storage required to provide water to the Mgeni WSS over periods of scheduled maintenance or emergency downtime of the uMWP-1 transfer tunnel.

# 2 MODEL CONFIGURATION

## 2.1 MODEL DESCRIPTION

The water resources systems analysis of the uMkhomazi and Mgeni WSS was undertaken using both the *Water Resources Yield Model* (WRYM) and the *Water Resources Planning Model* (WRPM). The WRYM was configured for the uMkhomazi River catchment as part of this study, and was used to determine the yield potential of the uMWP and other proposed developments in the uMkhomazi River catchment. This is described in greater detail in the *Water Resources Yield Assessment Report* of this study (AECOM, et al., 2014).

The WRPM is an extension of the WRYM but with extensive additional functionalities as outlined below:

- Where the WRYM allows only for analyses to be undertaken at a constant development level the WRPM has the ability to simulate a dynamic changes within the system, such as changing water requirements and the implementation or decommissioning of water resources infrastructure.
- An allocation procedure which allows water users to be curtailed based on short-term water availability linked to water storage volumes in the system.

## 2.2 HYDRO-METEOROLOGICAL DATA

The WRPM model configuration for the uMkhomazi River catchment was based on the hydro-meteorological data sets developed as part of this study and reported on in the *Hydrological Assessment of the uMkhomazi River Catchment Report* of this study (AECOM, et al., 2014). These include:

- Representative monthly catchment rainfall time-series data.
- Monthly point rainfall time-series data sets for proposed major dams, namely Impendle, Smithfield and Langa dams.
- Monthly average lake evaporation.
- Monthly incremental natural runoff time-series data.

The data sets were developed at a quaternary catchment scale and include the uMkhomazi River catchment (quaternary catchments U10A to U10M) and upper uMlaza River catchment (U60A and U60B). The latter was included since the proposed Langa Dam will be located in U60B on a tributary of the uMlaza River near Baynesfield. Summaries are provided in **Table 2.1** to **Table 2.4**.

### Table 2.1: Summary of rainfall characteristics

| Quaternary catchment | Area (km$^2$) | MAP$^{(1); (2)}$ (mm) |
|---|---|---|
| **uMkhomazi River catchment** | | |
| U10A | 418 | 1 287 |
| U10B | 392 | 1 176 |
| U10C | 267 | 1 091 |
| U10D | 337 | 999 |
| U10E | 327 | 1 034 |
| U10F | 379 | 963 |
| U10G | 353 | 981 |
| U10H | 458 | 924 |
| U10J | 505 | 878 |
| U10K | 364 | 793 |
| U10L | 307 | 758 |
| U10M | 280 | 858 |
| **Total/average$^{(3)}$:** | **4 387** | **981** |
| **Upper uMlaza River catchment** | | |
| U60A | 105 | 981 |
| U60B | 316 | 822 |
| **Total/average$^{(3)}$:** | **421** | **862** |

*Notes: (1) Mean annual precipitation (WRC, 1994).*
*(2) Over the period 1925 to 2008, hydrological years.*
*(3) Weighted average based on catchment area.*

### Table 2.2: Point rainfall for proposed major dams

| Dam site | Location (quaternary catchment) | MAP$^{(1); (2)}$ (mm) |
|---|---|---|
| Impendle Dam | U10E | 920 |
| Smithfield Dam | U10F | 905 |
| Langa balancing dam | U60B | 810 |

*Notes: (1) Mean annual precipitation (WRC, 1994).*
*(2) Over the period 1925 to 2008, hydrological years.*

## Table 2.3: Summary of lake evaporation characteristics

| Quaternary catchment | Average lake evaporation, for indicated month (mm) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total (MAE[1]) |
| **uMkhomazi River catchment** | | | | | | | | | | | | | |
| U10A | 100 | 102 | 122 | 117 | 108 | 110 | 83 | 68 | 57 | 62 | 78 | 88 | 1 095 |
| U10B | 100 | 102 | 122 | 117 | 108 | 110 | 83 | 68 | 57 | 62 | 78 | 88 | 1 095 |
| U10C | 100 | 102 | 122 | 117 | 108 | 110 | 83 | 68 | 57 | 62 | 78 | 88 | 1 095 |
| U10D | 100 | 102 | 122 | 117 | 108 | 110 | 83 | 68 | 57 | 62 | 78 | 88 | 1 095 |
| U10E | 100 | 102 | 122 | 117 | 108 | 110 | 83 | 68 | 57 | 62 | 78 | 88 | 1 095 |
| U10F | 100 | 102 | 122 | 117 | 108 | 110 | 83 | 68 | 57 | 62 | 78 | 88 | 1 095 |
| U10G | 96 | 98 | 117 | 112 | 104 | 106 | 80 | 66 | 55 | 60 | 75 | 85 | 1 054 |
| U10H | 91 | 95 | 105 | 106 | 99 | 98 | 80 | 67 | 57 | 60 | 70 | 82 | 1 010 |
| U10J | 91 | 95 | 105 | 106 | 99 | 98 | 80 | 67 | 57 | 60 | 70 | 82 | 1 010 |
| U10K | 91 | 95 | 105 | 106 | 99 | 98 | 80 | 67 | 57 | 60 | 70 | 82 | 1 010 |
| U10L | 91 | 95 | 105 | 106 | 99 | 98 | 80 | 67 | 57 | 60 | 70 | 82 | 1 010 |
| U10M | 91 | 95 | 105 | 106 | 99 | 98 | 80 | 67 | 57 | 60 | 70 | 82 | 1 010 |
| **Average[2]:** | **96** | **99** | **114** | **112** | **104** | **104** | **81** | **67** | **57** | **61** | **74** | **85** | **1 054** |
| **Upper uMlaza River catchment** | | | | | | | | | | | | | |
| U60A | 91 | 95 | 105 | 106 | 99 | 98 | 80 | 67 | 57 | 60 | 70 | 82 | 1 010 |
| U60B | 91 | 95 | 105 | 106 | 99 | 98 | 80 | 67 | 57 | 60 | 70 | 82 | 1 010 |
| **Average[2]:** | **91** | **95** | **105** | **106** | **99** | **98** | **80** | **67** | **57** | **60** | **70** | **82** | **1 010** |

*Notes: (1) Mean annual lake evaporation (WRC, 1994).*

*(2) Weighted average based on catchment area.*

## Table 2.4: Summary of natural runoff characteristics

| Quaternary catchment | Area (km$^2$) | MAR[1] | | | SD[2] (million m³/a) | CV[3] |
|---|---|---|---|---|---|---|
| | | million m³/a | mm | % MAP | | |
| **uMkhomazi River catchment** | | | | | | |
| U10A | 418 | 209.52 | 501 | 39% | 84.20 | 0.40 |
| U10B | 392 | 164.49 | 420 | 36% | 66.10 | 0.40 |
| U10C | 267 | 96.70 | 362 | 33% | 38.86 | 0.40 |
| U10D | 337 | 98.22 | 291 | 29% | 39.47 | 0.40 |
| U10E | 327 | 100.92 | 309 | 30% | 40.56 | 0.40 |
| U10F | 379 | 67.08 | 177 | 18% | 35.78 | 0.53 |
| U10G | 353 | 70.12 | 199 | 20% | 37.40 | 0.53 |
| U10H | 458 | 82.66 | 180 | 20% | 44.09 | 0.53 |
| U10J | 505 | 77.99 | 154 | 18% | 41.60 | 0.53 |
| U10K | 364 | 40.42 | 111 | 14% | 21.56 | 0.53 |
| U10L | 307 | 29.56 | 96 | 13% | 15.77 | 0.53 |
| U10M | 280 | 40.06 | 143 | 17% | 21.37 | 0.53 |
| **Totals:** | **4 387** | **1 077.74** | **246** | **25%** | **464.18** | **0.43** |

| Quaternary catchment | Area (km$^2$) | MAR(1) | | | SD(2) (million $m^3$/a) | CV(3) |
|---|---|---|---|---|---|---|
| | | million $m^3$/a | mm | % MAP | | |
| **Upper uMlaza River catchment(4)** | | | | | | |
| U60A | 105 | 22.65 | 216 | 22% | 10.19 | 0.45 |

*Notes: (1) Natural mean annual runoff, over the period 1925 to 2008, hydrological years, derived by scaling time-series data sets of gauged catchments.*

*(2) Standard deviation.*

*(3) Coefficient of variation, calculated as MAR/SD.*

*(4) Quaternary catchment U60B is not shown as it was not included in the hydrological investigation undertaken as part of this study.*

## 2.3 PHYSICAL SYSTEM COMPONENTS

### *a) Small dams and wetlands*

The extent, distribution and characteristics of small dams and wetlands in the uMkhomazi and upper uMlaza River were estimated based on assumptions and information from various sources as detailed in the report *Hydrological Assessment of the uMkhomazi River Catchment* (AECOM, et al., 2014).

Small dams were modelled in the WRPM by combining all individual dams located within each quaternary catchment into a single representative modelling unit referred to as a “dummy dam”. Wetlands were modelled in a similar way by defining “dummy wetlands”. A summary of modelled dummy dam and dummy wetland characteristics is shown in **Table 2.5**, representative of 2008-development levels.

**Table 2.5: Modelled characteristics of small dams and wetlands**

| Quaternary catchment | Small dams | | Wetlands | |
|---|---|---|---|---|
| | Total storage capacity(1) (million $m^3$) | Total surface area(3) (km$^2$) | Total nominal water storage capacity (million $m^3$) | Total nominal surface area(2); (3) (km$^2$) |
| **uMkhomazi River catchment** | | | | |
| U10A(2) | 0.25 | 0.12 | 1.40 | 1.40 |
| U10B(2) | 0.30 | 0.14 | 1.30 | 1.30 |
| U10C | 0.70 | 0.32 | 2.48 | 2.48 |
| U10D | 1.91 | 0.85 | 4.30 | 4.30 |
| U10E(2) | 0.29 | 0.13 | 0.82 | 0.82 |
| U10F | 1.20 | 0.55 | 1.43 | 1.43 |
| U10G | 3.29 | 1.51 | 1.36 | 1.36 |
| U10H | 6.82 | 2.95 | 0.98 | 0.98 |
| U10J | 0.83 | 0.38 | 1.89 | 1.89 |

| Quaternary catchment | Small dams | | Wetlands | |
|---|---|---|---|---|
| | Total storage capacity(1) (million $m^3$) | Total surface area(3) ($km^2$) | Total nominal water storage capacity (million $m^3$) | Total nominal surface area(2); (3) ($km^2$) |
| U10K | 4.17 | 1.91 | 2.89 | 2.89 |
| U10L(2);(5) | 0.40 | 0.19 | 0.12 | 0.12 |
| U10M(5) | - | - | 0.18 | 0.18 |
| **Totals:** | **20.16** | **9.05** | **19.15** | **19.15** |
| **Upper uMlaza River catchment** | | | | |
| U60A(5) | 2.42(4) | 0.64 | 0.37 | 0.37 |
| U60B | 12.05(5) | 3.70 | 1.91 | 1.91 |
| **Totals:** | **14.47** | **4.34** | **2.28** | **2.28** |

*Notes:* *(1) Dams not modelled in catchments where total capacity is smaller than 0.5 million $m^3$ (shown in grey font).*

*(2) Wetlands not modelled in catchments where the total wetland area is smaller than 0.5 $km^2$ (shown in grey font).*

*(3) Derived from for the surface area of individual dams/wetlands.*

*(4) Includes Baynesfield Dam.*

*(5) Includes Thornlea and Mapstone dams.*

As a large proportion of small dams in the uMkhomazi River catchment are used for irrigation purposes it was assumed that the future growth in small dam storage volume would follow that of irrigated areas supplied from small dams. Details on the latter are provided in the *Water Requirements and Return Flows Report* (AECOM, et al., 2014). A summary of the resulting projected total storage volume of small dam, over a selected planning period of approximately 40 years up to 2050, is shown in **Table 2.6**.

### Table 2.6: Projected growth in small dams

| Quaternary catchment | Total storage volume (million $m^3$), at indicated development level | | | | |
|---|---|---|---|---|---|
| | 2008 | 2020 | 2030 | 2040 | 2050 |
| U10A(1) | 0.25 | 0.27 | 0.29 | 0.30 | 0.32 |
| U10B(1) | 0.30 | 0.32 | 0.35 | 0.37 | 0.39 |
| U10C | 0.70 | 0.74 | 0.80 | 0.85 | 0.90 |
| U10D | 1.91 | 2.03 | 2.17 | 2.32 | 2.46 |
| U10E(1) | 0.29 | 0.31 | 0.33 | 0.35 | 0.37 |
| U10F | 1.20 | 1.28 | 1.37 | 1.46 | 1.55 |
| U10G | 3.29 | 3.48 | 3.73 | 3.98 | 4.23 |
| U10H | 6.82 | 7.23 | 7.75 | 8.27 | 8.78 |
| U10J | 0.83 | 0.88 | 0.94 | 1.01 | 1.07 |
| U10K | 4.17 | 4.42 | 4.74 | 5.05 | 5.37 |
| U10L(1) | 0.40 | 0.42 | 0.45 | 0.48 | 0.51 |

| Quaternary catchment | Total storage volume (million $m^3$), at indicated development level | | | | |
|---|---|---|---|---|---|
| | 2008 | 2020 | 2030 | 2040 | 2050 |
| U10M(1) | - | - | - | 0.01 | 0.01 |
| **Totals:** | **20.16** | **21.38** | **22.92** | **24.45** | **25.96** |

Finally, historical data suggest that the number of functional wetlands in the study area declined significantly prior to 2012, largely as a result of draining or inundation for agricultural purposes. However, for planning purposes it was assumed that there would be no further deterioration of wetland areas. This assumption is based on increasing public awareness of the importance of wetlands. Organs of State need to enforce strict catchment management practices in future to ensure the protection and sustainability of wetlands, especially subsequent to the commissioning of the uMWP.

### *b) Major dams*

A summary of the modelled physical characteristics of proposed major dams in the uMkhomazi and upper uMlaza river catchments is provided in **Table 2.7**. More information in this regard is provided in the study report *Supporting Document 5: Dam Type Selection Report* (AECOM, et al., 2014) and the *Water Resources Yield Assessment Report* (AECOM, et al., 2014).

**Table 2.7: Physical characteristics of proposed major dams**

| Dam name | FSL(1) (m AMSL(2)) | Stage (m) | Storage capacity | | | Surface area ($km^2$) |
|---|---|---|---|---|---|---|
| | | | Gross (million $m^3$) | Live | | |
| | | | | (million $m^3$) | (% MAR(3)) | |
| Impendle Dam(4) | 1 199.5 | 107.5 | 914.24 | 857.10 | 150% | 27.81 |
| | 1 187.9 | 95.9 | 628.54 | 571.40 | 100% | 21.70 |
| | 1 172.1 | 80.1 | 342.84 | 285.70 | 50% | 14.63 |
| Smithfield Dam | 930.0 | 74.0 | 251.43 | 226.20 | 31% | 9.53 |
| Ngwadini Dam | 118.0 | 43.0 | 10.66 | 10.06 | -(5) | 0.74 |
| Bulwer Dam | 1 500.5 | 24.0 | 9.92 | 9.02 | 110% | 1.08 |
| Langa Dam | 923.0 | 43.0 | 15.67 | 14.24 | 1 236% | 0.95 |

*Notes: (1) Full supply level.*
*(2) Above mean sea level.*
*(3) Mean annual runoff.*
*(4) Characteristics shown for various possible dam sizes.*
*(5) Not shown as the proposed Ngwadini Dam is an off-channel storage dam.*

A sediment yield assessment was also undertaken as part of this study and documented in the *Supporting Document 1: Sediment Yield Report* (AECOM, et al., 2014). Based on these results as well as a number of assumptions discussed in the *Water Resources Yield Assessment Report* (AECOM, et al., 2014) the impact was assessed of sediment deposition on the physical characteristics for Smithfield Dam at the 2050-development level. The results are summarised in **Table 2.8**.

**Table 2.8: Adopted physical characteristics for Smithfield Dam (2050)**

| Elevation (masl) | Gross storage capacity (million m³) | | | Remaining live storage capacity above the minimum outlet level | | Surface area (km²) | Notes |
|---|---|---|---|---|---|---|---|
| | Original(1) | Impact of sediment deposition (2) | At 2050 | (million m³) | (% MAR) | | |
| 930.0 | 251.43 | 17.87 | 233.56 | 211.74 | 29% | 9.53 | FSL(3) |
| 887.2 | 25.23 | 3.41 | 21.82 | 0.00 | 0% | 2.17 | DSL(4) |
| 856.0 | 0.00 | 0.00 | 0.00 | - | - | 0.00 | Bottom |

*Notes: (1) At date of commissioning.*
*(2) Over 30-year sedimentation period.*
*(3) Full supply level.*
*(4) Dead storage level.*

## 2.4 WATER REQUIREMENTS AND RETURN FLOWS

Current and future projected water requirements and return flows have been covered in detail as part of this study and are described in the *Water Requirements and Return Flows Report* of this study (AECOM, et al., 2014). **Table 2.9** provides a summary of the projected in-catchment water use in the uMkhomazi River catchment over a selected planning period of approximately 40 years up to 2050.

**Table 2.9: Projected water use and return flows in the uMkhomazi River catchment**

| Water user category | Water use(1) (million m³/a), at indicated development level | | | | |
|---|---|---|---|---|---|
| | 2008 | 2020 | 2030 | 2040 | 2050 |
| Irrigation, supplied from all sources(2) | 37.90 | 41.90 | 46.85 | 51.69 | 56.54 |
| Commercial forestry | 59.71 | 62.96 | 67.03 | 71.10 | 75.17 |
| Dry-land sugarcane | 1.64 | 1.64 | 1.64 | 1.64 | 1.64 |
| Invasive alien plants | 6.37 | 6.37 | 6.37 | 6.37 | 6.37 |
| Stock watering(3) | 2.66 | 2.77 | 2.90 | 3.04 | 3.17 |
| Domestic water use, supplied from all sources(4) | 3.89 | 4.09 | 4.27 | 4.44 | 4.61 |

| Water user category | Water use[1] (million m³/a), at indicated development level | | | | |
|---|---|---|---|---|---|
| | 2008 | 2020 | 2030 | 2040 | 2050 |
| Industrial water use[5] | 53.00 | 53.00 | 53.00 | 53.00 | 53.00 |
| **Total water use:** | **165.17** | **172.73** | **182.06** | **191.28** | **200.50** |
| Return flows | 6.66 | 7.06 | 7.55 | 8.03 | 8.51 |
| **Total net water use:** | **158.51** | **165.67** | **174.51** | **183.25** | **191.99** |

Furthermore, a water requirement projection for the Mgeni WSS was developed based on the individual projections for a number of defined sub-areas of the system. Detailed information in this regard is provided in the *Water Requirements and Return Flows* report of this study (AECOM, et al., 2014). A graphical representation of the sub-areas in question is provided in **Figure 2-1** and the associated water projections are summarised in **Table 2.10**.

Note that the “Shed Zones” in the Lower Mgeni shown in **Figure 2-1** represent those areas that will be supplied from the uMWP, once implemented, and no longer from Durban Heights.

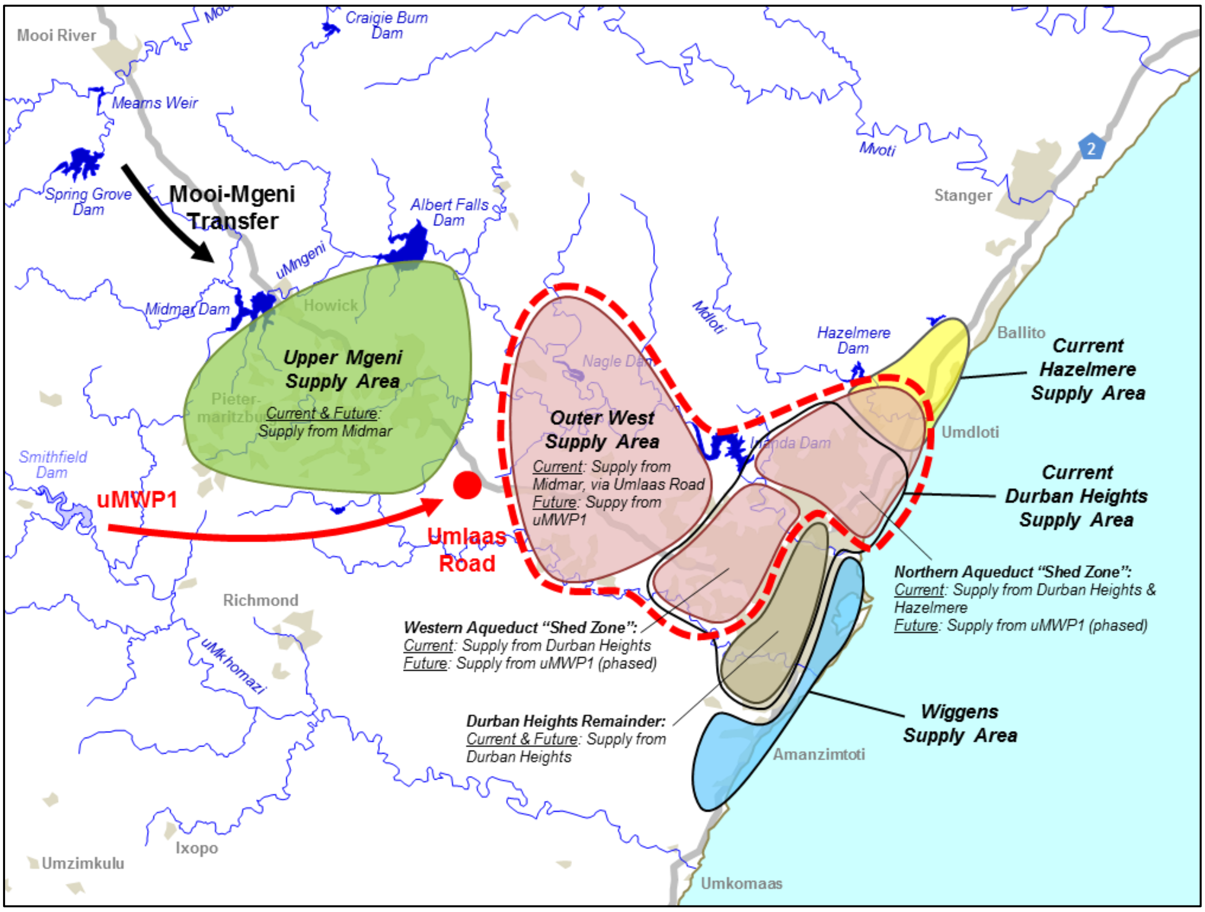


**Figure 2-1: Schematic representation of the water supply areas in the Mgeni WSS**

**Table 2.10: Long-term water requirement projection for the Mgeni WSS**

| Supply area | Water requirement (million m³/a), at indicated level of development | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
| Outer West | 29.0 | 31.0 | 36.1 | 41.2 | 46.3 | 51.4 | 56.5 | 61.6 | 66.7 |
| Western Aqueduct | 57.8 | 58.4 | 67.2 | 68.7 | 70.2 | 71.7 | 73.2 | 74.7 | 76.1 |
| Northern Aqueduct | 24.1 | 26.5 | 34.1 | 43.7 | 53.9 | 64.1 | 74.4 | 84.5 | 94.5 |
| South Coast | 12.2 | 13.7 | 23.6 | 23.8 | 23.8 | 23.8 | 23.8 | 23.8 | 23.8 |
| Upper Mgeni | 80.6 | 83.0 | 89.4 | 96.2 | 103.0 | 109.8 | 116.7 | 123.7 | 130.7 |
| Wiggens | 81.4 | 83.1 | 89.5 | 96.5 | 103.9 | 111.9 | 120.6 | 129.6 | 138.5 |
| Durban Heights Rem. | 104.0 | 106.0 | 118.3 | 123.2 | 128.1 | 133.0 | 137.9 | 142.9 | 148.1 |
| Industrial re-use | 8.8 | 8.8 | 8.8 | 8.8 | 8.8 | 8.8 | 8.8 | 8.8 | 8.8 |
| **Totals:** | **397.9** | **410.6** | **467.2** | **502.0** | **537.9** | **574.5** | **611.8** | **649.5** | **687.1** |

## 2.5 USER CLASSIFICATION AND ASSURANCE OF SUPPLY CRITERIA

The water user priority classification and assurance of supply criteria adopted for planning purposes were based on those currently adopted for the Mooi-Mgeni WSS. These are also incorporated into the existing WRPM model configuration of that system (as discussed later in **Section 2.6 (b)**). These were obtained from the earlier *Water Reconciliation Strategy Study for the KwaZulu-Natal Coastal Metropolitan Areas* study (WRP, et al., 2009) and are summarised in **Table 2.11**.

**Table 2.11: Priority classification and assurance of supply criteria for the Mgeni WSS**

| User group | % of requirement in indicated priority class and associated RI[(1)] of failure (annual assurance of supply) | | | |
|---|---|---|---|---|
| | High | Medium-high | Medium-low | Low |
| | 1:200 years (99.5%) | 1:100 years (99.0%) | 1:50 years (98.0%) | 1:20 years (95.0%) |
| Urban and industrial[(2)] | 63% | 13% | 12% | 12% |
| uMngeni River compensation | 50% | 25% | - | 25% |
| Durban effluent reuse | 70% | 20% | - | 10% |
| uMngeni River irrigation | 5% | 25% | - | 70% |
| **Associated curtailment level** | **4** | **3** | **2** | **1** |

*Notes: (1) Recurrence interval.*

*(2) Includes water supply and losses associated with users currently supplied from the Midmar, DV Harris, Durban Heights and Wiggins water treatment works (WTW), as well as the Outer West, Western and Northern Aqueduct "Shed Zones" areas that will be supplied from the proposed uMWP.*

## 2.6 MODEL DEVELOPMENT AND REFINEMENTS

The development and refinement of the WRPM system model for the Integrated Mgeni WSS was undertaken in three distinct steps, namely:

- The development of a new model configuration for the uMkhomazi WSS.
- Refining the existing model configuration for the Mooi-Mgeni WSS.
- Combining the uMkhomazi and Mooi-Mgeni systems into a single model configuration including the uMkhomazi, uMngeni, upper Mooi River and the recently completed Mooi-Mgeni transfer scheme from Spring Grove Dam.

Details in this regard are provided in the following subsections.

### a) uMkhomazi WSS

The WRPM model configuration for the uMkhomazi River system was developed based on the WRYM configuration developed earlier as part of this study (as discussed in **Section 2.1**). For this purpose the WRYM data input files were updated and edited to include the necessary changes for running the WRPM. This includes the incorporation of:

- The short-term yield-reliability characteristics (YRC) curve sets developed for Smithfield Dam in the earlier *Water Resources Yield Assessment* task of this study (AECOM, et al., 2014). The curve sets were based on the adopted FSL for Smithfield Dam of 930 masl and the 2050-development level (which roughly coincides with the anticipated implementation date of uMWP-2). Furthermore, the curves were developed for a range of starting storage levels in Smithfield Dam, namely 100%, 80%, 60%, 40%, 20% and 10% of the live storage capacity.
- The adopted future characteristics of small dams and wetlands in the uMkhomazi River catchment (as discussed in **Section 2.3 (a)**).
- Projected in-catchment water use for the uMkhomazi River catchment (as discussed in **Section 2.4**).
- Projected transfers from the uMkhomazi to the uMngeni catchment.
- Projected water requirements for industrial user SAPPI-SAICCOR.

During the process of converting WRYM to WRPM data input files, all node and channel numbers were revised by adding a value of 1 000 (e.g. channel number 34 was changed to 1034). The purpose of this was to avoid conflicting node and channel numbers once the uMkhomazi WRPM configuration was integrated with the Mooi-Mgeni WSS. Further to this, all the relevant model channel and reservoir penalty definitions were defined to be identical to those applied in the Mooi-Mgeni configuration. Some additional changes were also necessitated by the fact that the Mooi-Mgeni was configured based on an earlier model version of the WRPM and these changes were attended to during the integration process.

The final WRPM system schematic diagram for the uMkhomazi WSS configuration is provided in **Appendix B** of this report.

### *b) Mooi-Mgeni WSS*

The existing WRPM model configuration for the Mooi-Mgeni WSS was obtained from DWA and is identical to the latest version used in the *KwaZulu-Natal Reconciliation Strategy Study* (DWA, 2013). Before integration with the uMkhomazi WSS a number of changes to the existing configuration were required and these are discussed below. It should be noted that, although necessary, the changes were limited wherever possible to minimise any deviation from an already accepted system configuration and the associated modelled results.

- Significant water supply infrastructure capacity constraints in the upper Mgeni WSS were included in the model configuration. The aim was to ensure that the model was more representative of the actual water supply system, as well as to allow for analyses to test the ability of the system to operate without a balancing dam at the outlet of the uMWP-1 transfer tunnel.
- Controlled water requirements (i.e. modelled using the “master control channel”-feature) were updated in the Mooi-Mgeni WSS to align with the definition of water requirements in the uMWP supply area. The Mooi-Mgeni water requirements were not spatially defined but rather linked to the supply areas of Water Treatment Works (WTW). These requirements were therefore subdivided in such a way that the transfer and supply of water from the uMWP to specific sub-areas could be accommodated.
- Modelled return flows were redefined to align with the new water requirement definitions. A small return flow was also added to account for the small volumes of effluent from the Howick Wastewater Treatment Works (WwTW).

Specific information on the changes in water requirement definitions and modelled infrastructure capacity constraints in the Mooi-Mgeni WSS is provided below.

*Water requirement definitions*

Upper Mgeni sub-system:

- Howick and Howick West.
- Pietermaritzburg and Edendale.
- Clarendon.
- Pietermaritzburg North (supplied from the Claridge Reservoir).
- Albert Falls, Wartburg and other towns on the Msunduzi Pipeline.

Lower Mgeni sub-system:

- The Outer West area (supplied through the '57 Pipeline).
- The "Shed Zones" linked to the Western Aqueduct.
- The "Shed Zones" linked to the Northern Aqueduct (which includes some areas currently supplied from Hazelmere Dam).
- The remainder of the Durban Heights supply area.
- The Wiggins supply area, excluding supply to the South Coast via the South Coast Augmentation (SCA) scheme.
- The South Coast supply area.

*Infrastructure capacity constraints*

A summary of the modelled infrastructure capacity constraints in the Mgeni WSS is provided in **Table 2.12** and further information in this regard thereafter.

**Table 2.12: Model infrastructure capacity constraints in the Mgeni WSS**

| Description | Current capacity (Mℓ/d) | Current utilisation (Mℓ/d) | Future capacity (Mℓ/d) | Modelled capacity (Mℓ/d) | Comment |
|---|---|---|---|---|---|
| **Water Treatment Works** | | | | | |
| Midmar | 250 | 175 | 375 | 375 | - |
| DV Harris | 110 | 98 | 110 | 110 | - |
| Durban Heights | 615 | 525 | 615 | 615 | Reduce capacity to 80% after uMWP |
| Wiggins | 350 | 260 | 350 | 350 | Reduce capacity to 80% after uMWP |
| **Pipelines** | | | | | |
| '251 bulk | 347 | 138 | - | 347 | - |
| Midmar Tunnel | 330 | 138 | - | 330 | Upgrade not feasible |
| '61 to Umlaas Road | 40 | 41 | 200 | 200 | Currently being upgraded |
| '53 | 45 | 45 | 0 | - | Decommission after uMWP |

| Description | Current capacity (Mℓ/d) | Current utilisation (Mℓ/d) | Future capacity (Mℓ/d) | Modelled capacity (Mℓ/d) | Comment |
|---|---|---|---|---|---|
| Nagle Aqueduct | 660 | - | - | 660 | Already in previous WRPM configuration |
| Inanda Aqueduct | 670 | - | - | 670 | Capacity set as sum of Wiggins WTW, Shaft Pumps and Inanda Pumps |
| Shaft Pumps | 150 | - | - | 150 | Already in previous WRPM configuration |
| Inanda Pumps | 170 | - | - | 170 | Already in previous WRPM configuration |
| SCA to Amanzimtoti | 23 | - | 65 | 65 | New booster pump station to increase capacity |
| Load shift Durban Heights to Wiggins | 85 | 85 | | 85 | Maximum load shift in previous WRPM configuration |
| uMWP tunnel | | | 750 | 750 | Maximum planned tunnel capacity |

The Western Aqueduct is currently being constructed for the dual purpose of (i) increasing supply from Midmar Dam to the Lower Mgeni sub-system in the short-term (referred to in the Reconciliation Strategy as a “load shift”); and (ii) supplying water to the Mgeni WSS from the uMWP once it is implemented. It should be noted that, depending on the levels in Midmar Dam, the Reconciliation Strategy identified a possible load shift of 22 million m³/a that could be supplied reliably and up to a maximum of 45 million m³. This load shift was retained in the WRPM configuration but included in such a way as to be linked to the infrastructure constraints between Midmar Dam and Umlaas Road.

### *c) Integrated Mooi-Mgeni-uMkhomazi WSS*

Following the configuration, revision and testing of both the uMkhomazi and Mgeni models the two sets of WRPM data files were integrated into a single system. To aid in version control and avoid confusion, the integrated system was given a new system prefix, namely “MMM” (for Mooi, Mgeni and uMkhomazi).

In linking the uMkhomazi to the Integrated Mgeni WSS, it was important to accurately capture and simulate the operation and supply priorities in the system. A specific “system logic” was therefore adopted as outlined below:

- The short-term “load shift” for increasing supply from Midmar Dam to the Lower Mgeni sub-system was defined based on the supply limitations discussed at the end of the previous subsection (i.e. from a reliable 22 million m³/a to a maximum of 45 million m³/a), as well as the assumption that the “load shift” would be discontinued in 2023 with the implementation of the uMWP.

- Supply to the Outer West area will be moved from Midmar Dam to the uMWP in 2023.
- Supply to both the Western and Northern Aqueduct “Shed Zones” will be moved from Durban Heights WTW to the uMWP, but using a phased approach as the requirement in the Durban Heights supply area increases above its optimal operating capacity of about 500 Mℓ/d (80% of its design capacity). Furthermore, since Durban Heights is already operating slightly above the optimal capacity, some of the “Shed Zone” requirement will be moved onto the uMWP immediately after its implementation in 2023.
- In order to optimally use the resource and minimise spills from the system, water from Inanda Dam will be used first. This means that the Shaft and Inanda Pumps, used for supplying water from Inanda to Durban Heights WTW will be prioritised while water from Nagle Dam supplied through the Nagle Aqueduct will only be used to supplement shortages. This corresponds to the operating and supply priority applied in the existing version of the Mooi-Mgeni WRPM configuration.
- The effective volume of return flows from eThekwini that enter the uMngeni River below Inanda Dam is limited to the sum of the estuarine water requirement and the possible re-use of effluent by industries. Any return flows greater than this volume are therefore assumed not to contribute to the water supply potential of the system.
- The preliminary estuarine water requirement of 47 million $m^3/a$ (1.5 $m^3/s$) is supplied from Inanda Dam with 45 million $m^3/a$ assumed to reach the estuary. It should be noted that once the results from the Reserve Classification study currently being undertaken by DWA for the Water Management Area (WMA) become available, the WRPM configuration should be updated accordingly.

The target “shedding” of supply onto the uMWP discussed above was achieved with two different modelling approaches, as described below:

- WRPM allocation procedure: The “Shed Zone” requirements were imposed on the relevant subsystem within the Mooi-Mgeni WSS for the period prior to 2023 and thereafter supported by the Smithfield Dam.
- Normal flow routing: The “shedding” of requirements was achieved at model run-time using penalties and defined maximum channel flow constraints. The “Shed Zone” water users are supplied first by Durban Heights based on

a lower routing penalty and up to the desired operation capacity of the WTW (using the WRPM "multi-purpose min-max" channel-type). When the water requirement exceeds this capacity it is supplied from Smithfield Dam via the transfer infrastructure, but at a higher routing penalty. The tunnel capacity can also be limited, if needed, to the growing transfer requirement or even a stepped infrastructure expansion program for the proposed Baynesfield WTW.

The final WRPM system schematic diagram for the Integrated Mooi-Mgeni-uMkhomazi WSS configuration is provided in **Appendix B** of this report.

## 2.7 SYSTEM OPERATING RULES

The currently adopted operating rules of the Mgeni WSS are aimed at maximising the yield of the system as a whole. This is achieved, primarily, by utilising stored water in a way that spillages from the system are minimised. As such, water stored in Inanda and Spring Grove dams, the most downstream major dams on the uMngeni and Mooi rivers respectively, is used first.

Once uMWP-1 is commissioned, however, excess yield will initially be available in the system, which means that the possibility may exist to change the current operating rules to reduce operating costs. This would be achieved by operating Inanda Dam at higher water levels to reduce the cost of pumping water to the Durban Heights WTW. It is important to note that such a change to the current operating rule would be dependent on the excess yield available in the system and would therefore only be possible over a limited period (up to, say, 2035).

For the purposes of the WRPM analyses discussed in this report, the system operating rule applied with the implementation of uMWP-1 was based on a combination of the principles discussed above. As such, water is utilised from major dams in the system according to the following sequence:

- First: **Smithfield Dam** and **Spring Grove Dam** – as the most downstream major dams on the uMkhomazi and Mooi rivers, respectively (used up to appropriate infrastructure capacity constraints).
- Second: **Nagle Dam** (and **Albert Falls Dam**) – used before Inanda to reduce operating costs while excess yield is available in the system.
- Third: **Inanda Dam**.
- Fourth: **Midmar Dam** – as the most upstream dam on the uMngeni River.

With regard to the above, it is important to note that further analyses are required to optimise the operating rules of the Mgeni WSS for the implementation of uMWP-1. Such an optimisation should consider aspects like the phased capacity increase of the Baynesfield WTW and the possible impacts on the potential of the scheme to generate hydropower (as described in the *Hydropower Assessment Report* of this study (AECOM, et al., 2014)). Also, the actual impact of all changes should be continually monitored to ensure that the desired outcomes are achieved.

# 3 DESCRIPTION OF SCENARIOS

The new WRPM configuration of the integrated Mooi-Mgeni-uMkhomazi WSS (as discussed earlier in **Section 2.6 (c)**) was used to undertake planning analysis scenarios. These scenarios were aimed primarily at investigating the need for and timing of proposed uMWP infrastructure to augment water supply to the Mgeni WSS.

Based on the principles of risk-based planning the need for augmentation was assessed by comparing the acceptable risk of non-supply for water users in a system (as defined in the priority classification criteria discussed earlier in **Section 2.5**) with modelled curtailment projections. In the event that the likelihood of curtailment exceeds the acceptable risk of non-supply, this is deemed to be a violation of the user criteria and signifies the need for intervention.

Details in this regard are provided in the following subsections and results of the analyses are discussed in **Section 4**.

## 3.1 TIMING OF UMWP-1 (SMITHFIELD DAM)

The timing of uMWP-1 (Smithfield Dam) was determined by identifying the date when an intervention would be required after the commissioning of MMTS-2 (Spring Grove Dam and transfer infrastructure). For this purpose two WRPM scenarios were analysed, namely:

- **Scenario 1A: Timing of uMWP-1**, using the **existing** WRPM model configuration for the Mooi-Mgeni WSS obtained from the *KwaZulu-Natal Reconciliation Strategy Study* (DWA, 2011) (as discussed earlier in **Section 2.6 (b)**).
- **Scenario 1B: Timing of uMWP-1**, using the **new** WRPM model configuration developed as part of this study for the integrated Mooi-Mgeni-uMkhomazi WSS (as discussed in **Section 2.6 (c)**).

In both cases the system was analysed without uMWP-1 and the results assessed to identify the first violation date after MMTS-2.

## 3.2 TIMING OF UMWP-2 (IMPENDLE DAM)

The new WRPM model configuration for the integrated Mooi-Mgeni-uMkhomazi WSS was used to refine the estimated implementation date for uMWP-2 (Impendle Dam). This was achieved by identifying the date at which an additional intervention would be required subsequent to the commissioning of Smithfield Dam (discussed in the previous subsection). It should be noted that results obtained from this analysis were dependent on a number of assumptions, in particular the following:

- The selected system water requirement projection and the inherent associated uncertainties toward the end of the planning horizon.
- The system operating rules applied and, in particular, the timing and magnitude of uMWP water transfers into the Mgeni system.

Within this context three separate scenarios were analysed to assess the timing of uMWP-2, as outlined below:

- **Scenario 2: Timing of uMWP-2 (Module 3 Projected Transfers)**: This scenario was based on the projected water transfers and phasing of associated infrastructure as developed in the parallel study *uMWP-1: Module 3: Technical Feasibility Study: Potable Water* (Knight Piésold, 2014).
- **Scenario 3A: Timing of uMWP-2 (Increased Utilisation of uMWP-1)**: This scenario was analysed to test the option of increasing the utilisation of uMWP-1 by supplying from Smithfield Dam once both the Durban Heights and Wiggins WTW reach their ideal level of operation at 80% of their respective design capacities. The need for investigating this option was identified based on the results of **Scenario 2**, as discussed later in **Section 4.2 (a)**.
- **Scenario 3B: Timing of uMWP-2 (Increased Utilisation of uMWP-1, Phased)**: This is similar to the previous scenario, but with the growing transfer volumes implemented in phases. This accounts for both infrastructure capacity constraints and water resource constraints in the Mgeni WSS. **Scenario 3B** was derived for consideration by Umgeni Water and builds on the work undertaken in the *Module 3* study.

A comparison of the modelled transfer volumes associated with the above scenarios is shown in **Figure 3.1**. In the case of **Scenario 3B** (shown in green) the projection includes an initial capacity of 375 Mℓ/d (135 million m³/a) in 2023 and capacity upgrades of 125 Mℓ/d (45 million m³/a) in 2030 and 250 Mℓ/d

(90 million m³/a) in 2039, totalling 750 Mℓ/d (275 million m³/a). Note that capacity upgrades before 2040 are required essentially to augment the Durban Heights and Wiggins WTW capacities, while the final increase by approximately 2040 is needed from a water resources perspective to allow for full transfer support by the uMWP-1 to the Mgeni WSS.

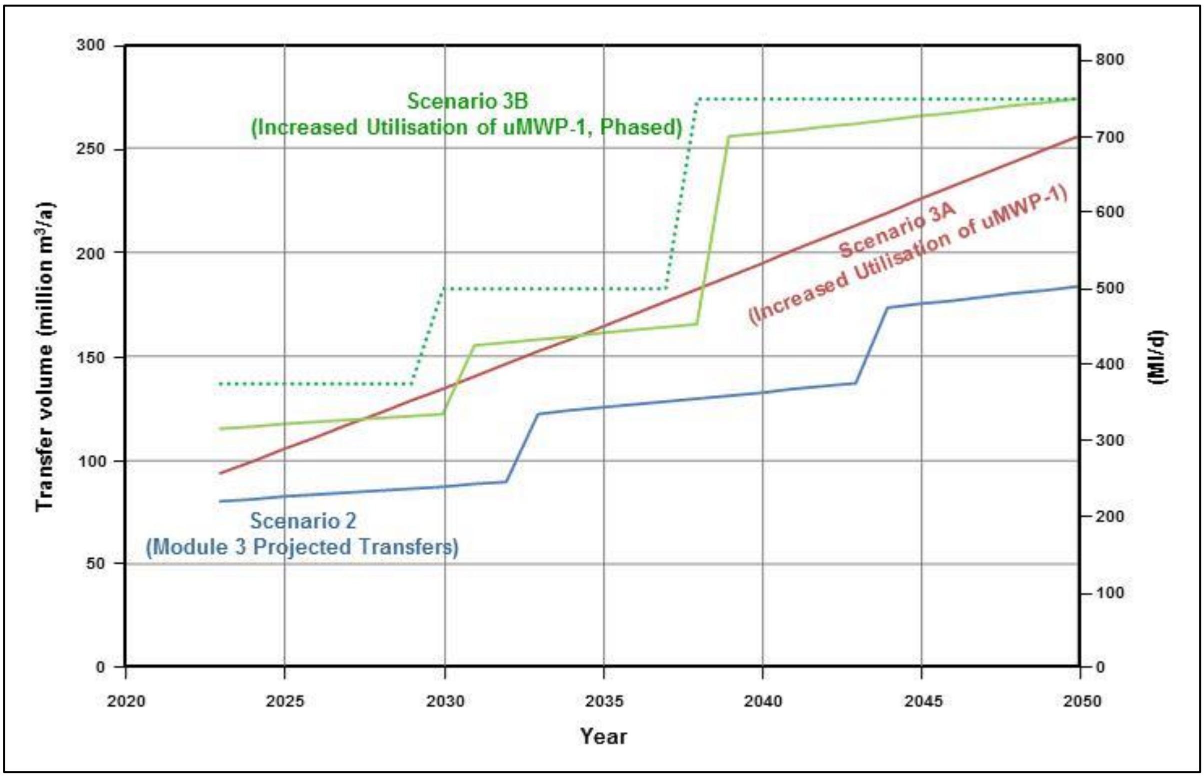


**Figure 3.1: Comparison of uMWP-1 water transfer volume scenarios**

## 3.3 BALANCING DAM

### a) Background

As outlined in the *Supporting Document 3: Optimization of Scheme Configuration* (AECOM, et al., 2014) the proposed uMWP scheme will require balancing storage in the proximity of the water treatment plant at Baynesfield to provide water during periods of scheduled maintenance or emergency downtime of the uMWP-1 transfer tunnel. The sizing of the proposed balancing dam, provisionally called “Langa” balancing dam, was undertaken as part of the engineering investigation of this study and more information in this regard is provided in the above document.

As part of the *Module 3* study an investigation was undertaken on the operation of the Mgeni WSS and associated water supply infrastructure capacities. This involved undertaking nodal mass balances at key dates in the future when scheduled maintenance of the tunnel could be expected. The investigation concluded that, if the tunnel were not in use for three weeks, sufficient excess infrastructure capacity is available within the Mgeni WSS to supply water users – but only up to 2024, which is one year after its date of commissioning. Furthermore, in 2034, which corresponds to the second scheduled maintenance period, the shortfall is approximately 54 Mℓ/d. The *Module 3* study also investigated other scenarios, namely (i) with the ’53 Pipeline (from the DV Harris WTW to the Umlaas Road Reservoir) assumed to be decommissioned; and (ii) with a 10% increase in water requirements.

### b) Purpose of analyses

In this study, however, it was found that the *Module 3* analyses (referred to above) were undertaken using projected average annual daily demands (AADD). It was therefore considered possible that, if maintenance could be scheduled for off-peak periods, the Mgeni WSS would provide sufficient excess supply infrastructure capacity to meet water requirements up to a date later than 2024. For example, in the month of October water requirements could be as much as 6% lower than the annual average, which, on a total system requirement of approximately 1 370 Mℓ/d (500 million $m^3/a$), represents a reduction of approximately 60 Mℓ/d.

On this basis additional analyses were undertaken in this study using the new WRPM model configuration for the integrated Mooi-Mgeni-uMkhomazi WSS (as described earlier in **Section 2.6 (c)**) to confirm both the need for and capacity of balancing storage. The analyses were undertaken based on the following basic assumptions:

- Maintenance and inspection of the tunnel results in downtime of three weeks and is required every 10 years.
- Growth in the water requirements of the Mgeni WSS will result in the excess supply infrastructure capacity in the system to reduce over time.
- At some point this excess capacity will be less than the required transfer from the uMWP and an additional source of water would therefore be required to supply users when the tunnel is not in use.
- When this point is reached, balancing storage will be required.

It should be noted that although balancing storage is not a water resource issue, but an infrastructure issue, the WRPM provided the ideal modelling environment for investigating the issue since it had been configured to model the impacts of key bulk water infrastructure constraints of the Mgeni WSS. The WRPM also simulates water requirements on a monthly basis with associated variations over the year (e.g. due to holiday and off-peak seasons), as well as the impacts of varying rainfall and evaporation on the magnitude of water requirements.

### *c) Description of scenarios*

Within the context of the discussion in the previous subsection, WRPM scenarios were analysed to confirm both the need for and capacity of balancing storage for various possible situations. These are described below.

- **Scenario 4A: Balancing Storage (Off-peak)**: For this scenario it is assumed that maintenance and inspection of the tunnel will be scheduled for the off-peak month of October.
- **Scenario 4B: Balancing Storage (Average)**: In this case, it is assumed that maintenance and inspection of the tunnel will be required during December, when water requirements equal the annual average.
- **Scenario 4C: Balancing Storage (Peak)**: In this case, it is assumed that maintenance and inspection of the tunnel will be required during the peak-month of February.

Furthermore, each of the above scenarios was also analysed with the following two options relating to the ’53 Pipeline (from the DV Harris WTW to the Umlaas Road Reservoir):

- **Option 1: ’53 Pipeline Refurbished:** For this option the possibility was considered of refurbishing the ’53 Pipeline. This means that the pipeline would be active prior to and during periods of tunnel maintenance and could also be pressurised to provide more water to Umlaas Road.
- **Option 2: ’53 Pipeline Decommissioned:** For this option it is assumed that the pipeline is decommissioned and therefore inactive over the entire analysis period.

Finally, the storage capacity required to ensure that water users in the Mgeni WSS are fully supply during tunnel maintenance periods was assessed. For this purpose it was assumed that the tunnel would be out of service for a period of one month and the analysis was based on the following scenario combinations:

- **Best case scenario**: Maintenance of the tunnel in the off-peak month of October and the ’53 Pipeline is refurbished (i.e. a combination of **Scenario 4A** and **Option 1**).
- **Average scenario**: Maintenance of the tunnel in December, when water requirements equal the annual average, and the ’53 Pipeline is refurbished (i.e. a combination of **Scenario 4B** and **Option 1**).
- **Worst case scenario**: Maintenance of the tunnel in the peak month of February and the ’53 Pipeline is decommissioned (i.e. a combination of **Scenario 4C** and **Option 2**).

# 4 ANALYSIS RESULTS

Results from the planning analysis scenarios described in **Section 3** are discussed in the following subsections.

## 4.1 TIMING OF UMWP-1 (SMITHFIELD DAM)

Modelled curtailment projection plots for **Scenario 1A** (existing Mooi-Mgeni WSS model) and **Scenario 1B** (new Mooi-Mgeni-uMkhomazi WSS model) are presented in **Figure 4-1** and **Figure 4-2**, respectively. In both cases the plots show continued supply violations (highlighted in orange) from the start of the analysis, despite the recent commissioning of Spring Grove Dam. Further augmentation of the Mgeni WSS is therefore required almost immediately, much earlier than the practical implementation date of Smithfield Dam in 2023. This is as a result of the fact that the Mgeni WSS has been in a negative balance situation for almost a decade (i.e. water requirements exceed the available resources) and Spring Grove Dam will only provide relief for the existing situation.

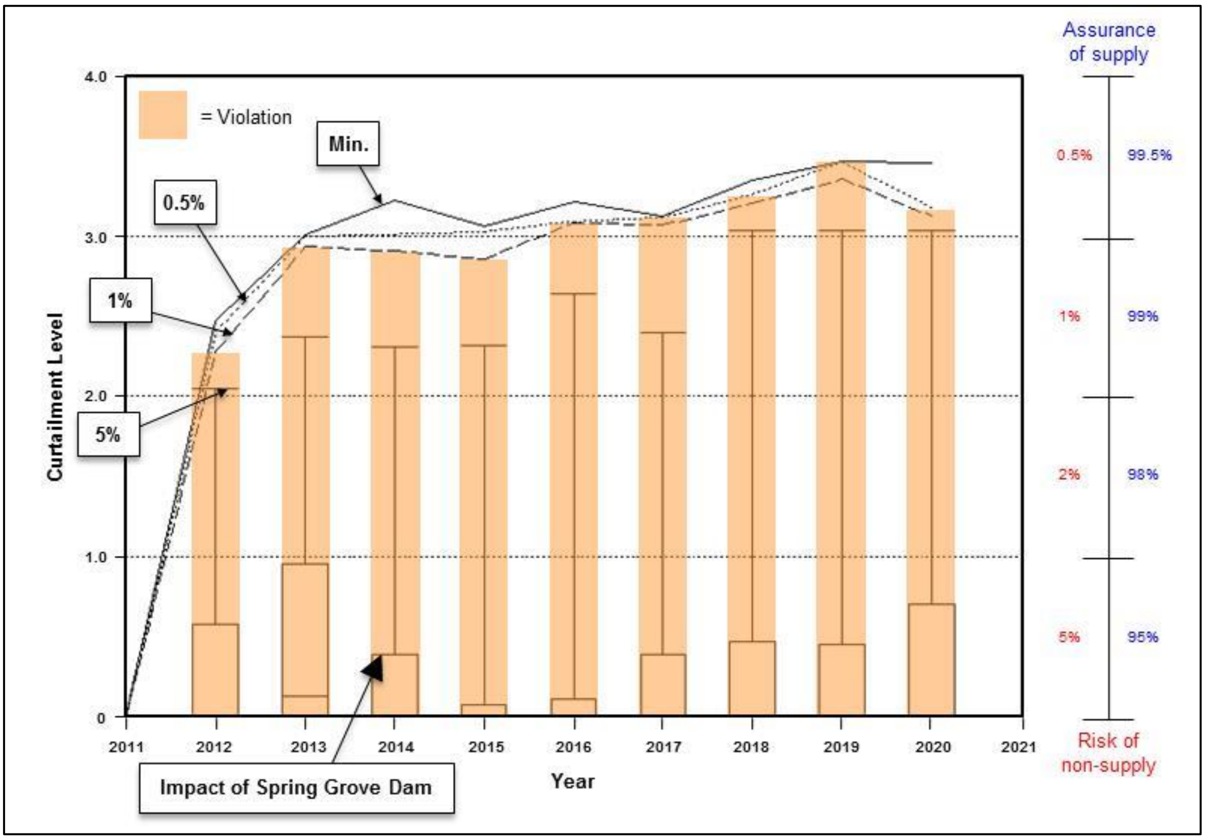


Figure 4-1: Curtailment projection for the Mgeni WSS without uMWP (existing Mooi-Mgeni WSS model)

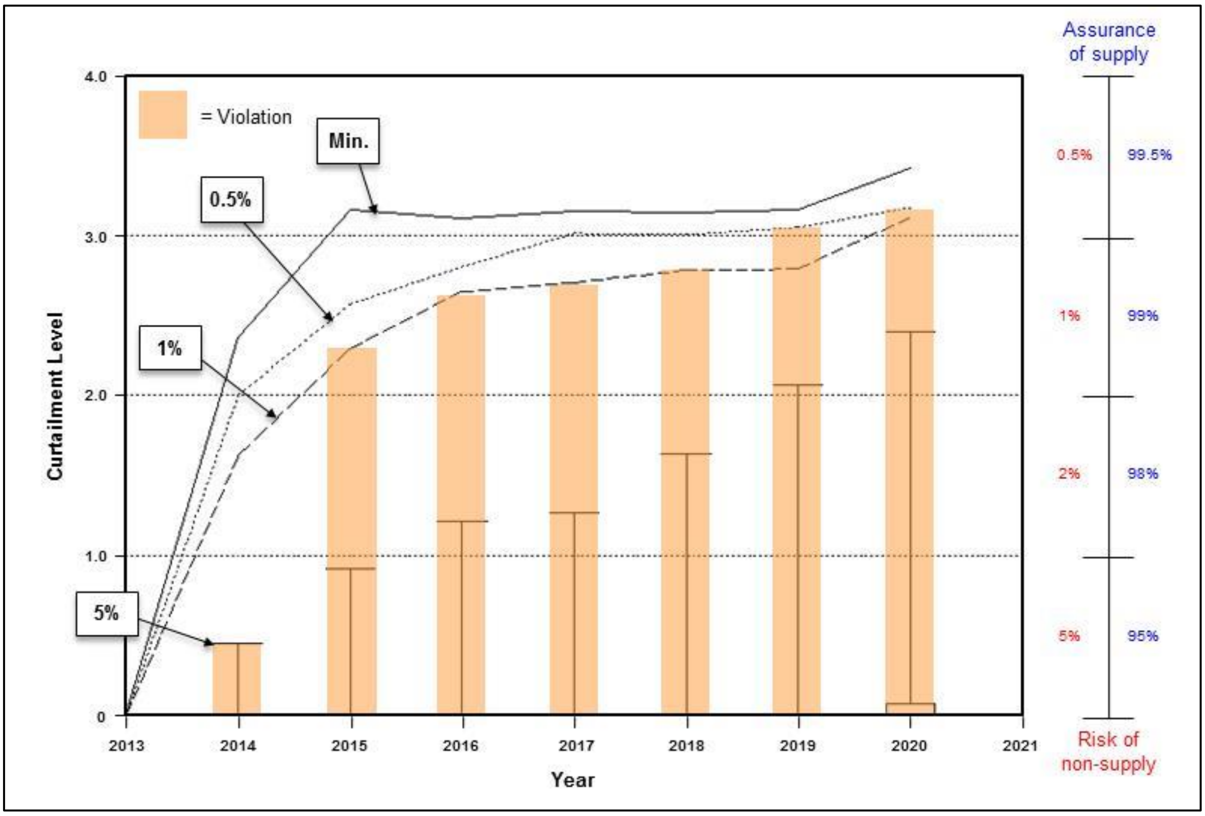


Figure 4-2: Curtailment projection for the Mgeni WSS without uMWP (new Mooi-Mgeni-uMkhomazi WSS model)

It should be noted that in the earlier *Water Resources Yield Assessment* of this study (AECOM, et al., 2014) a simple water balance was developed for the Mgeni WSS based on (i) the available resources in the Mgeni WSS; and (ii) updated water requirement projections for the supply area. The water balance showed that, subsequent to the commissioning of Spring Grove Dam, the system would again require augmentation by 2017 – which is in line with the WRPM results shown above.

## 4.2 TIMING OF UMWP-2 (IMPENDLE DAM)

### *a) Based on "Module 3" projected transfers*

Results for **Scenario 2**, based on projected water transfers and phasing of associated infrastructure as developed in the *Module 3* study (as discussed earlier in **Section 3.2**), are presented in **Figure 4-3** and **Figure 4-4**. These results show that, subsequent to the commissioning of uMWP-1 the Mgeni WSS will again be exposed to supply violations from 2028 (highlighted in orange). However, it should also be noted that the projected storage volumes suggest that, for this scenario, the available storage in Smithfield Dam is not fully utilised

– an observation that prompted the analysis of **Scenarios 3A** and **3B**, as discussed in the next subsection.

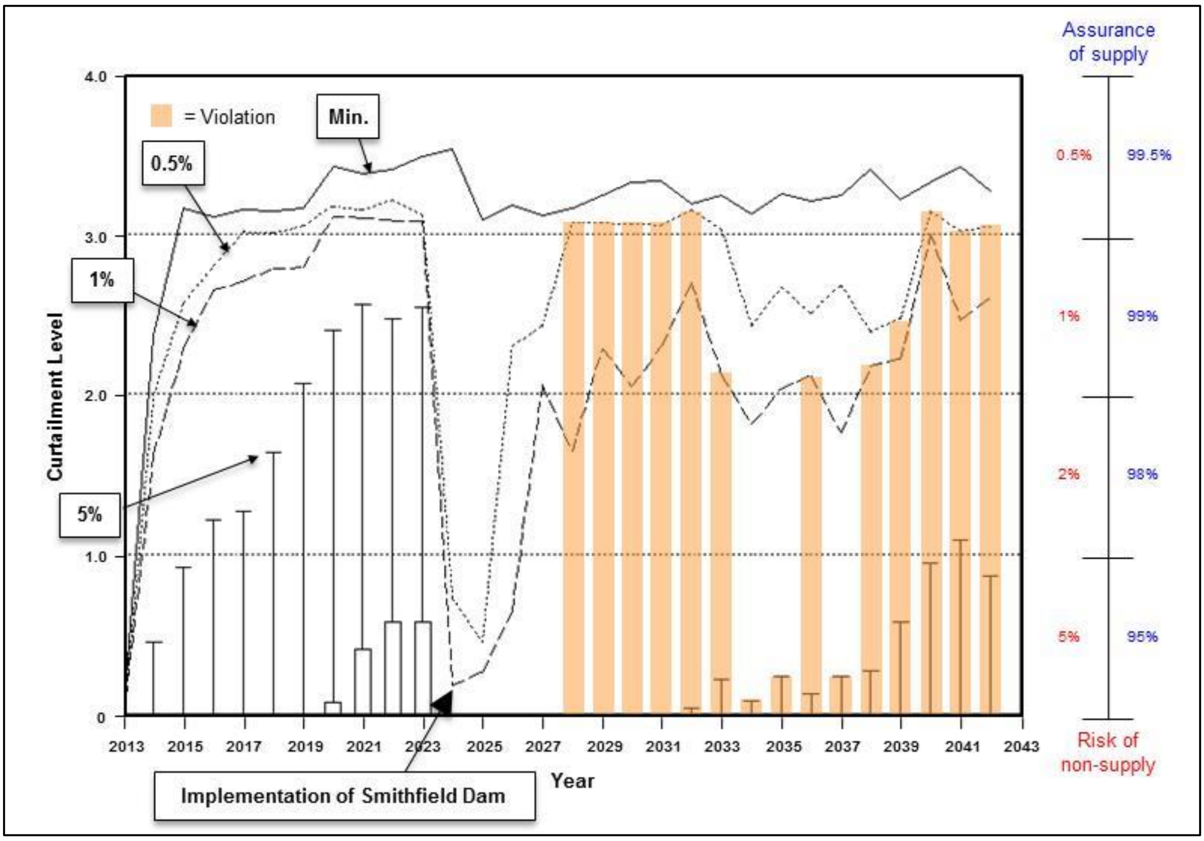


**Figure 4-3: Curtailment projection for the Mgeni WSS after Smithfield Dam (with "Module 3" projected transfers)**

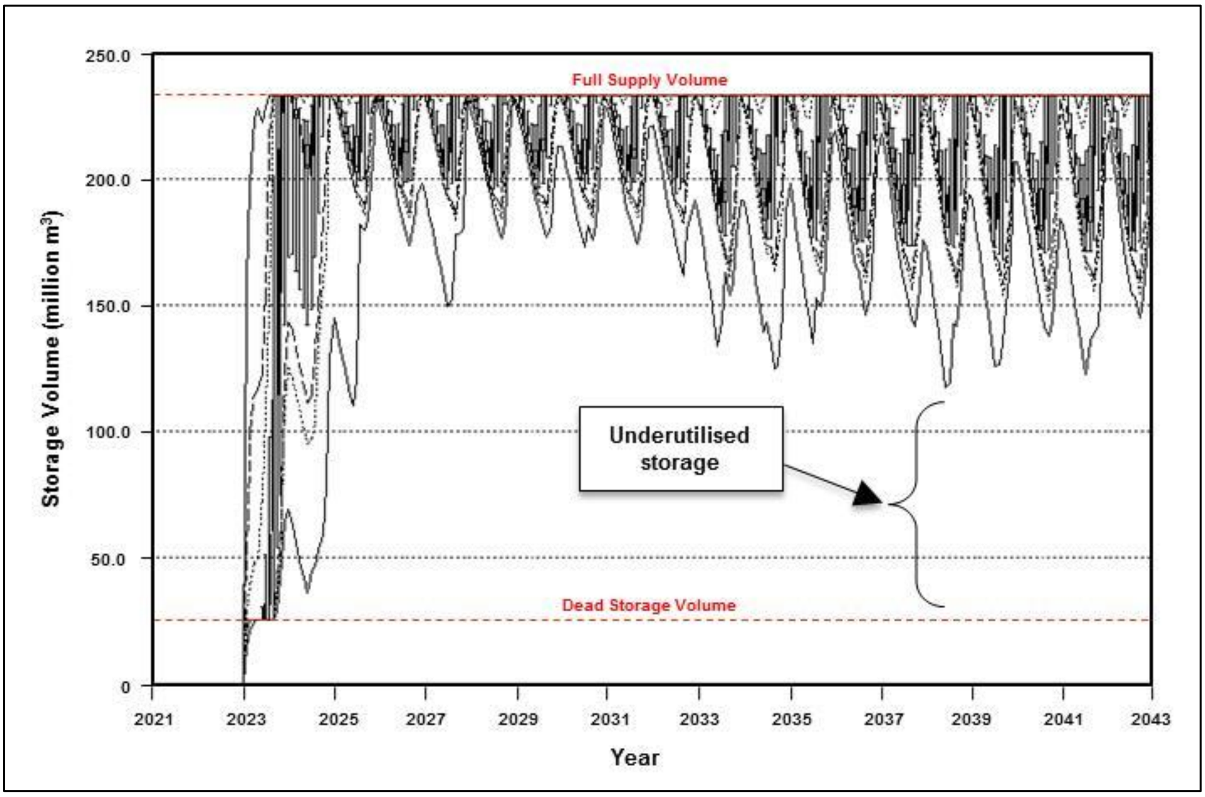


Figure 4-4: Storage volume projection for Smithfield Dam (with "Module 3" projected transfers)

### *b) Based on increased utilisation of uMWP-1*

The impact of increasing the utilisation of uMWP-1 results in improved support to the Mgeni WSS. This is clearly shown in the results for both **Scenario 3A** (with increased utilisation of uMWP-1), presented in **Figure 4-5** and **Figure 4-6** and for **Scenario 3B** (with increased utilisation of uMWP-1, implemented using a phased approach), presented in **Figure 4-7** and **Figure 4-8**. In both scenarios, the occurrence of supply violations are delayed significantly compared to the results obtained for **Scenario 2** (presented in the previous subsection) and suggest an estimated implementation date of **approximately 2045** for uMWP-2 (Impendle Dam).

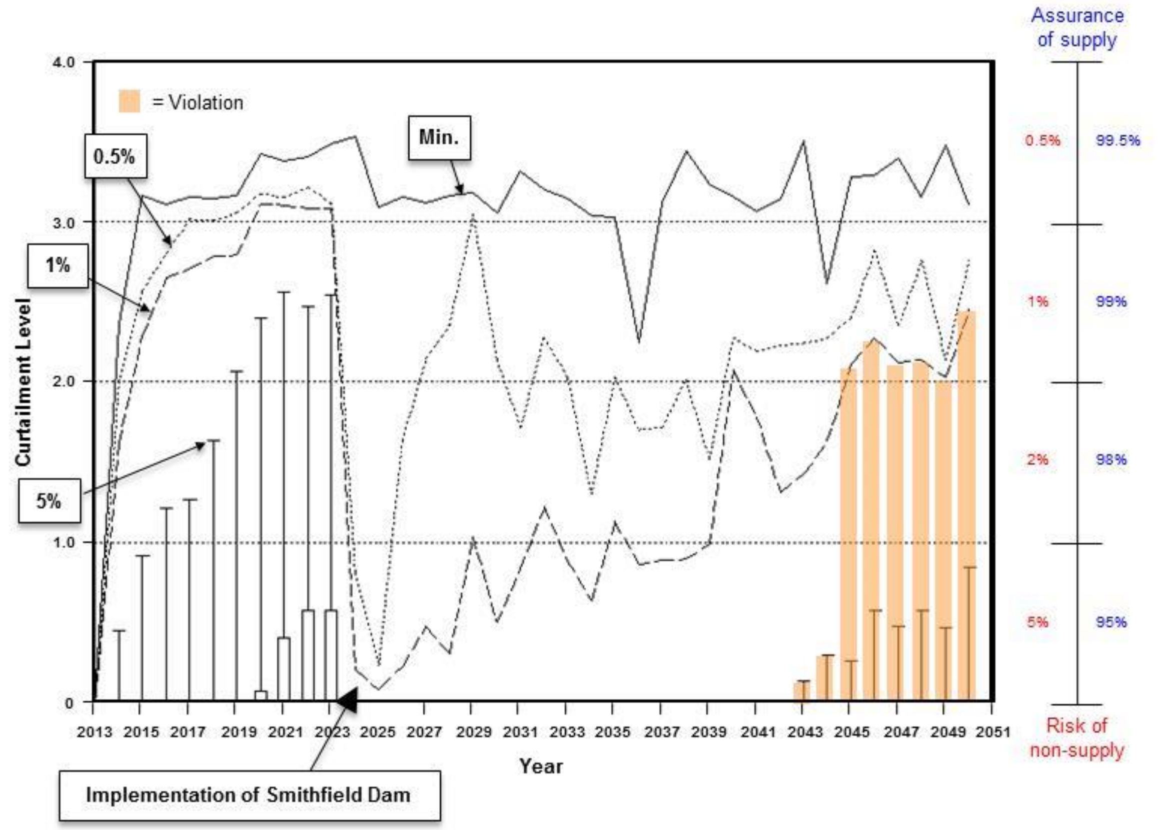


Figure 4-5: Curtailment projection for the Mgeni WSS after Smithfield Dam (with increased utilisation of uMWP-1)

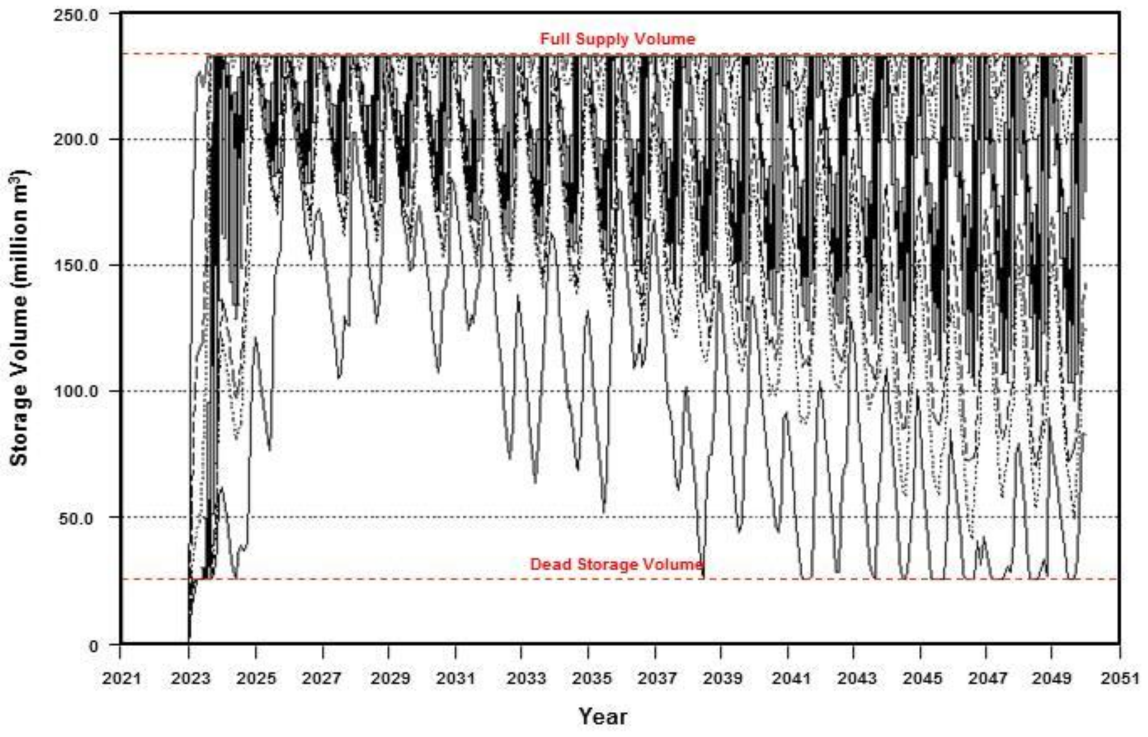


Figure 4-6: Storage volume projection for Smithfield Dam (with increased utilisation of uMWP-1)

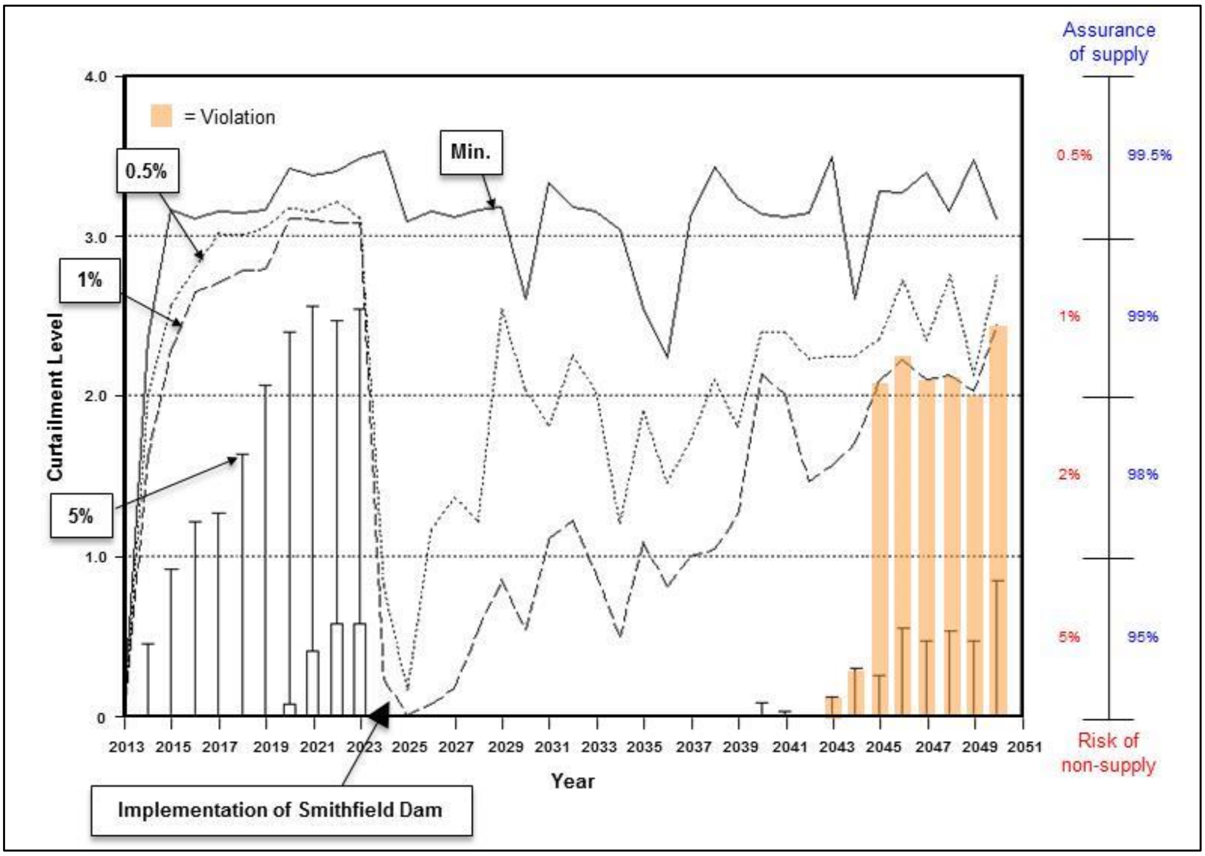


Figure 4-7: Curtailment projection for the Mgeni WSS after Smithfield Dam (with increased utilisation of uMWP-1, phased)

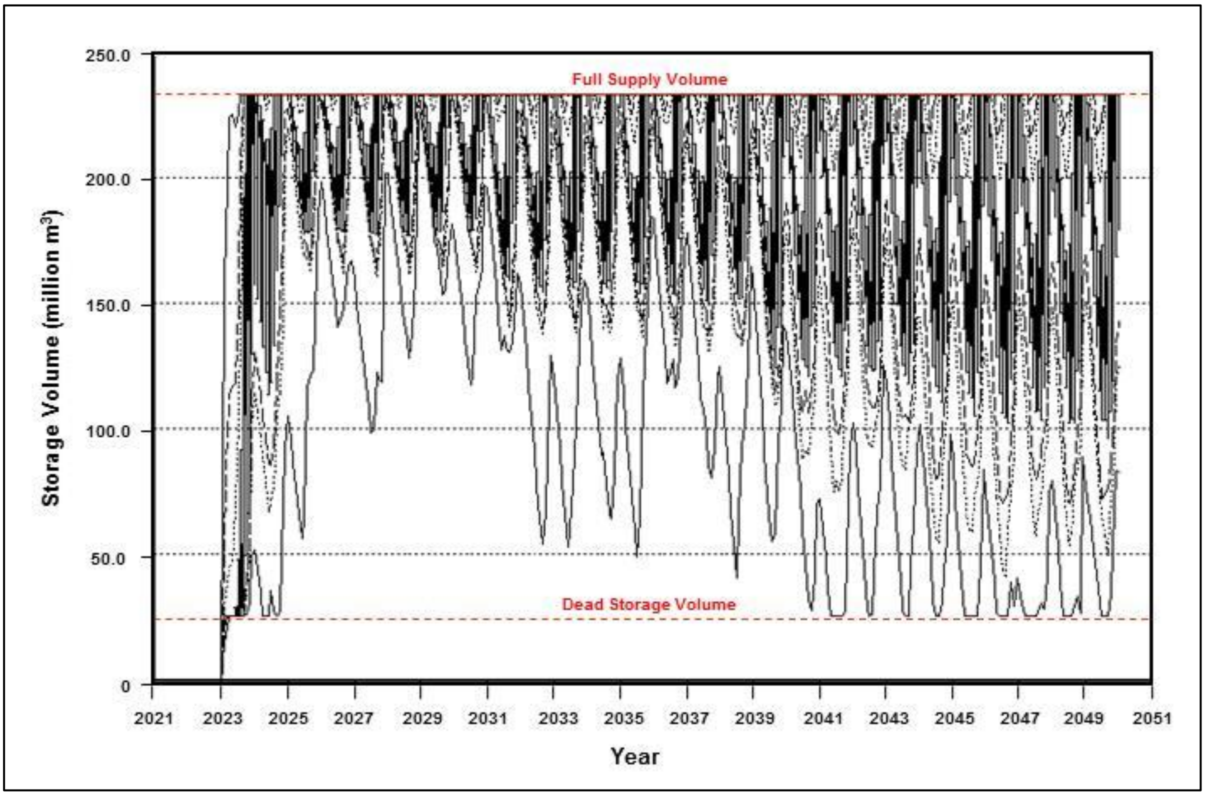


Figure 4-8: Storage volume projection for Smithfield Dam (with increased utilisation of uMWP-1, phased)

As mentioned earlier in **Section 4.1** a simple water balance was developed for the Mgeni WSS as part of the earlier *Water Resources Yield Assessment*. The water balance showed that, subsequent to the commissioning of uMWP-1, the system would again require augmentation by 2046. This preliminary estimate is confirmed by the results from the detailed WRPM analyses presented above.

Projected dam storage and transfer volumes for the major dams and inter-basin transfers in the system as modelled for **Scenario 3B** (i.e. with increased utilisation of uMWP-1, implemented using a phased approach) are provided in **Appendix A**.

## 4.3 BALANCING DAM

Results of the WRPM analysed to determine the year in which balancing storage will be required are presented in **Table 4.1**. This includes scenarios where maintenance of the transfer tunnel occurs during either off-peak, average or peak months, in combination with options where the '53 Pipeline is assumed to have been either refurbished or decommissioned (as discussed earlier in **Section 3.3 (c)**). Note that the year shown in the table signifies the date at which the excess water supply infrastructure capacity in the Mgeni WSS will no longer be sufficient to fully supply water users when the tunnel is being maintained.

Table 4.1: Projected balancing storage capacity requirements

| Scenario | Month for tunnel maintenance | Analysis option | '53 Pipeline status | Date at which balancing dam is first required |
|---|---|---|---|---|
| **4A** | October (Off-peak) | **1** | Refurbished | 2036 |
| | | **2** | Decommissioned | 2033 |
| **4B** | December (Average) | **1** | Refurbished | 2033 |
| | | **2** | Decommissioned | 2031 |
| **4C** | February (Peak) | **1** | Refurbished | 2026 |
| | | **2** | Decommissioned | 2025 |

Finally, results of the analysis to assess the balancing storage capacity required to ensure that water users in the Mgeni WSS are fully supplied when the tunnel is being maintained are presented in **Figure 4-9**.

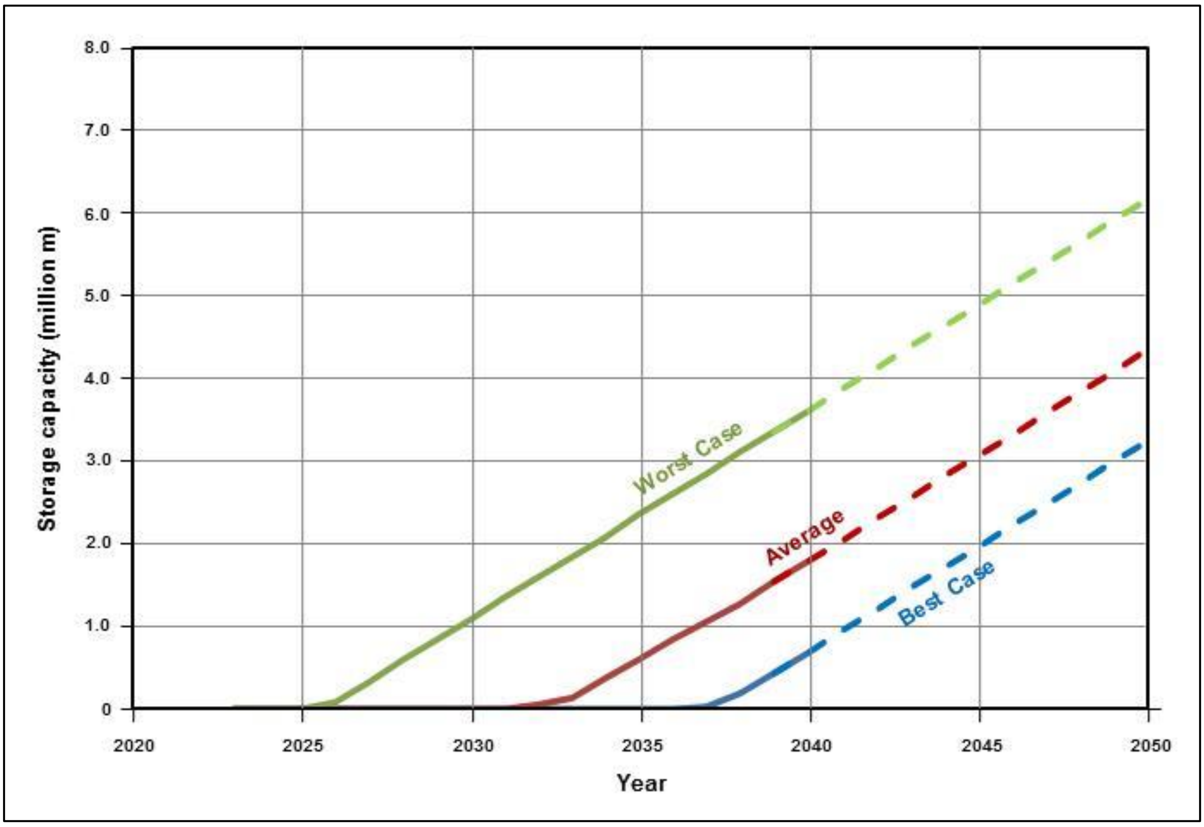


Figure 4-9: Projected balancing storage capacity requirements

For each of the scenarios shown, the required balancing storage capacity increases over time as growing water requirements result in a reduction in the excess water supply infrastructure capacity in the Mgeni WSS. For the worst-case scenario, where tunnel maintenance occurs during a peak month (as shown in green in **Figure 4-9**), the storage capacity required is approximately 6 million m³ in 2050. The ultimate storage capacity for this scenario is 12 million m³, which equals the full potential transfer volume of the tunnel over the maintenance period. However, this capacity will only be required well after 2050.

The above results were presented at the Project Management Committee (PMC) Meeting No. 8 of this study, where the results were noted with the following comments and conclusions:

- Planning and sizing for routine tunnel maintenance in the off-peak part of the year is possible, but then reduces the ability of handling un-planned tunnel problems. As such, the Peak analysis (i.e. **Scenario 4C**) is the preferred scenario from a risk perspective.

- Although unlikely, the possibility exists of an operation or maintenance problem on other infrastructure in the Mgeni WSS occurring during a tunnel maintenance period.
- Umgeni Water indicated that if the ’53 Pipeline were to be refurbished and pressurised, this would result in a very small increase in the volume of water supplied to Umlaas Road – from the current 45 Mℓ/d to 48 Mℓ/d.
- Longer term planning may result in some water from Spring Grove Dam being allocated to the Lower Tugela which could reduce the excess water available for supporting the Mgeni WSS. However, considering that tunnel maintenance is only for a period of one month, this situation could be managed over the short-term and is highly unlikely to cause water resource problems in the system.
- If a significant tunnel maintenance problem occurs, a period of closer to two months may be required, rather than one month as used for the analyses – assuming that the cost is not prohibitive.
- Tunnel and tunnel portal excavation material could be used for the construction of the balancing dam.

Based on the analysis results and conclusions summarised above the need for balancing storage was confirmed. Furthermore, although it may be possible to delay the commissioning of the dam to 2035, this introduces significant water supply risks due to uncertainties around the utilisation of water supply infrastructure in the Mgeni WSS and the timing of tunnel maintenance – suggesting that it may be advantageous to commission the balancing dam earlier than 2035. This is supported by the fact that excavation material from the uMWP-1 tunnel and tunnel portal may be used for the construction of the balancing dam.

# 5 CONCLUSIONS AND RECOMMENDATIONS

Conclusions and recommendations emanating from detailed planning analyses undertaken using the new WRPM model for the integrated Mooi-Mgeni-uMkhomazi WSS are summarised below:

- Despite the commissioning of MMTS-2 (Spring Grove Dam and transfer infrastructure) planned for December 2015, the Mgeni WSS will be subjected to continued risk of supply violations from 2016. The system has been in a negative balance situation for almost a decade and MMTS-2 will only provide relief for the existing shortfall.
- As a result of the above situation, augmentation of the Mgeni WSS is required almost immediately, much earlier than the practical implementation date of the uMWP-1 (Smithfield Dam) in 2023.
- Shorter-term intervention options have been identified to alleviate the shortfall situation in the Mgeni WSS prior to 2023. These options include the desalination of seawater and the direct re-use of effluent. However, it is recommended that this issue is investigated further as part of other studies, in particular the ongoing *KwaZulu-Natal Reconciliation Strategy* study.
- Subsequent to the commissioning of uMWP-1, it is estimated that the system would require further augmentation through the implementation of uMWP-2 (Impendle Dam) by 2046. This is assuming that, in the interim period, Smithfield Dam is effectively utilised with growing transfer volumes implemented in phases according to the relevant water requirements, infrastructure capacity and water resource constraints in the Mgeni WSS.
- Both of the above results are in line with preliminary findings obtained in the earlier *Water Resources Yield Assessment* of this study, which were based on a simple water balance of the Mgeni WSS developed using the available water resources and updated water requirement projections for the system.
- Analysis results confirm the need for balancing storage to provide water to the Mgeni WSS over periods of scheduled maintenance or emergency downtime of the uMWP-1 transfer tunnel.
- The timing of the balancing dam is affected by the extent to which risk of non-supply in the Mgeni WSS can be tolerated, the utilisation of excess water supply infrastructure capacity in the Mgeni WSS and the timing of tunnel downtime. Specifically, if downtime occurs during a peak month (such as in an emergency situation) and excess infrastructure capacity in the

Mgeni WSS can be fully utilised, balancing storage will be required by approximately 2025 (i.e. shortly after uMWP-1).

- The storage capacity required for the balancing dam increases over time as growing water requirements result in a reduction in the excess infrastructure capacity in the Mgeni WSS. If tunnel downtime occurs during a peak month a capacity of approximately 6 million $m^3$ is required in 2050 (i.e. close to the projected implementation date of uMWP-2). However, if a significant tunnel problem occurs maintenance will probably be required over a period of closer to two months and the balancing storage capacity required is therefore 12 million $m^3$.
- It is recommended that the planning, sizing and design of the balancing dam are further refined in the *Feasibility Design* task of this study. As part of that task, due consideration should be given to the findings summarised above, together with aspects such as the implementation programme of the uMWP scheme as a whole. In particular, the possible alignment of the construction of uMWP-1 and the balancing dam should be considered as this would provide an opportunity for using excavation material from the tunnel in the construction of the balancing dam.
- Finally, it is recommended that the new WRPM model configuration for the integrated Mooi-Mgeni-uMkhomazi WSS is used for updating the Reconciliation Strategy in the *KwaZulu-Natal Reconciliation Strategy Study*. However, once results from the parallel *Classification of Water Resources and Determination of the Comprehensive Reserve and Resources Quality Objectives in the Mvoti to Umzimkulu Water Management Area* study (DWA, 2013) become available, the WRPM must be updated accordingly and the results presented in this report confirmed and/or reviewed as required.

# 6 REFERENCES

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# Appendix A

# Boxplots of projected dam storage and transfer volumes

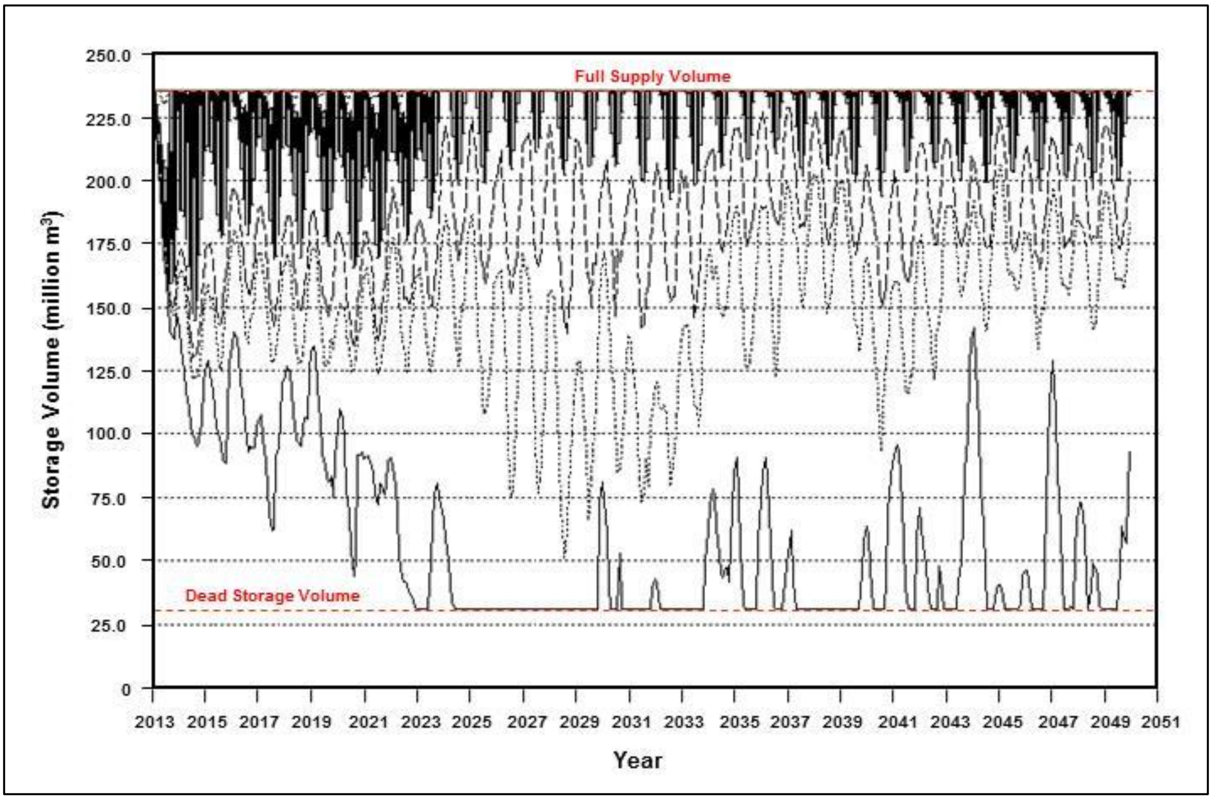

Figure A.1: Storage volume projection for Midmar Dam (Scenario 3B)

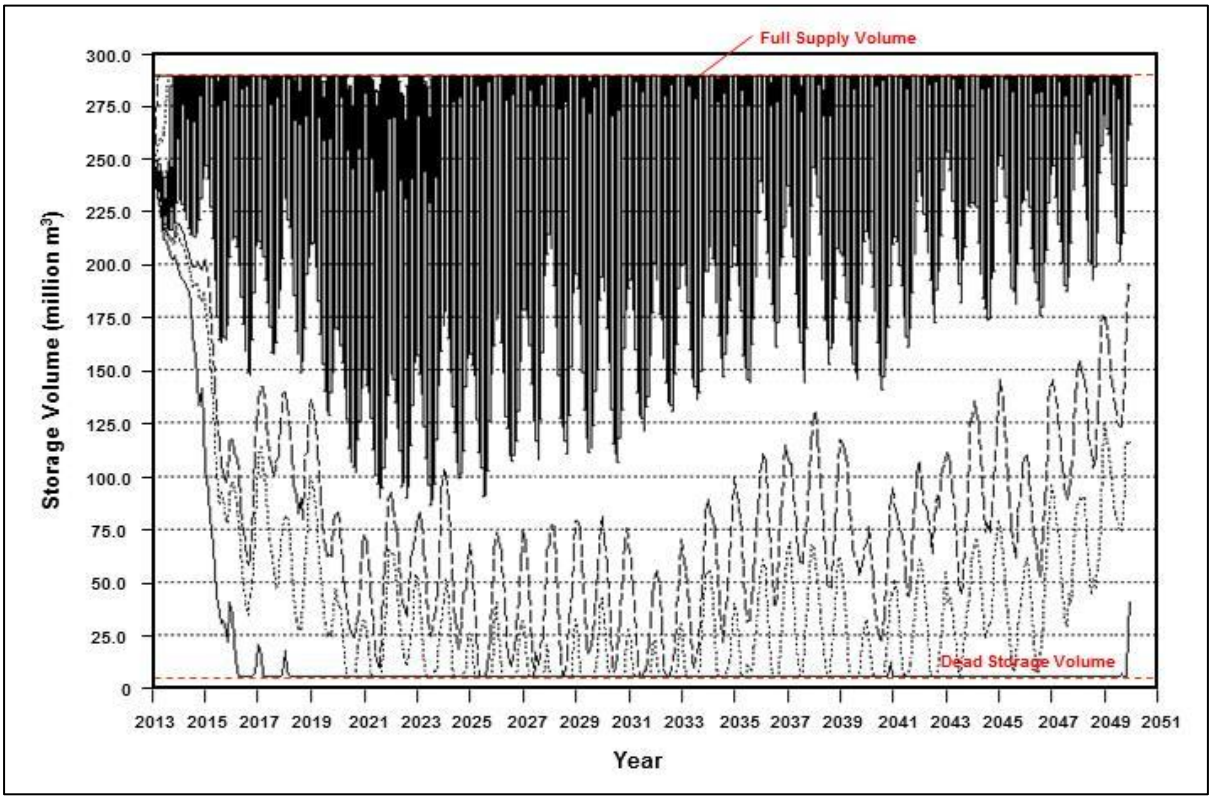

Figure A.2: Storage volume projection for Albert Falls Dam (Scenario 3B)

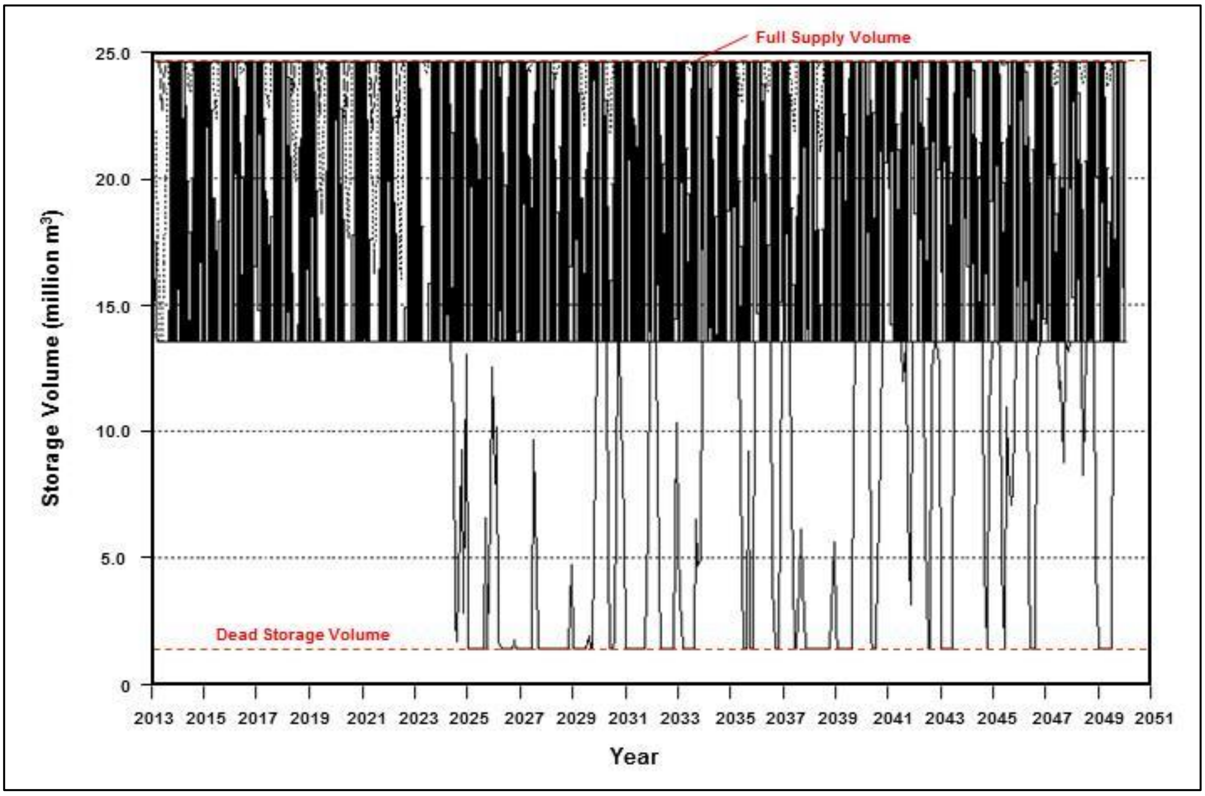

Figure A.3: Storage volume projection for Nagle Dam (Scenario 3B)

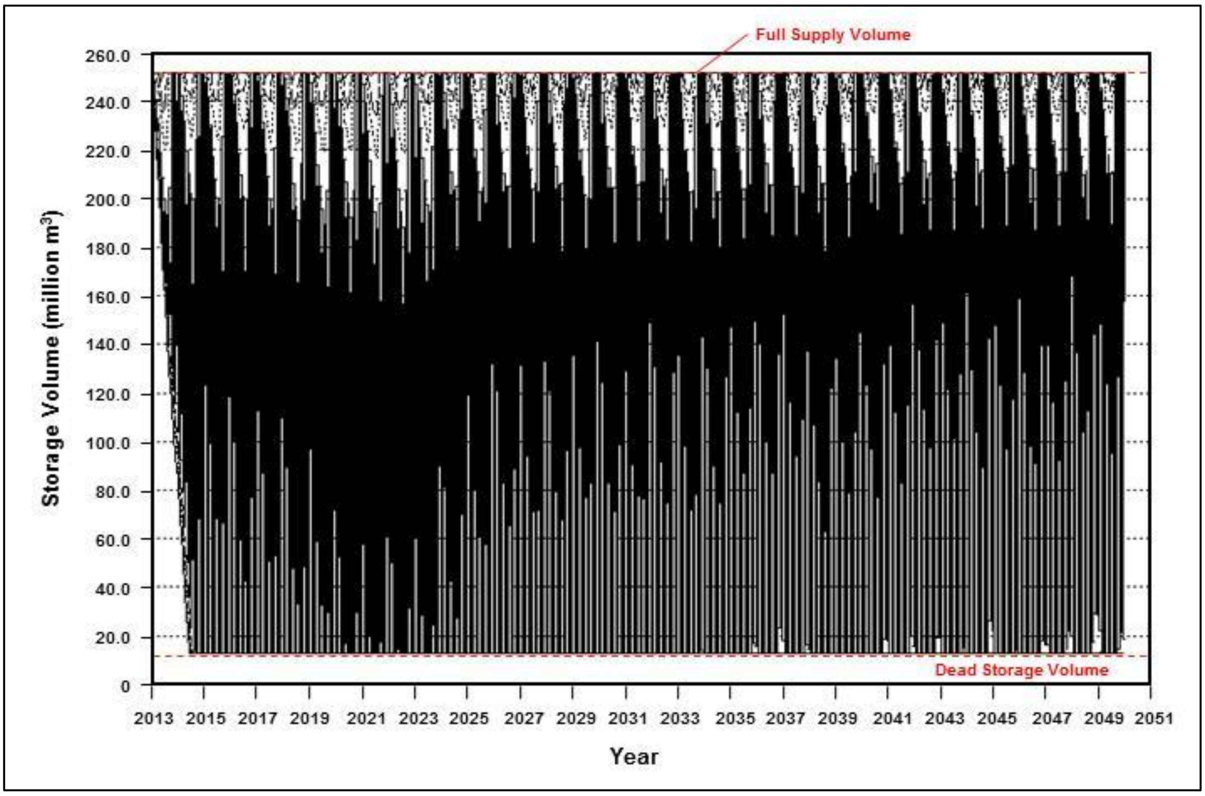

Figure A.4: Storage volume projection for Inanda Dam (Scenario 3B)

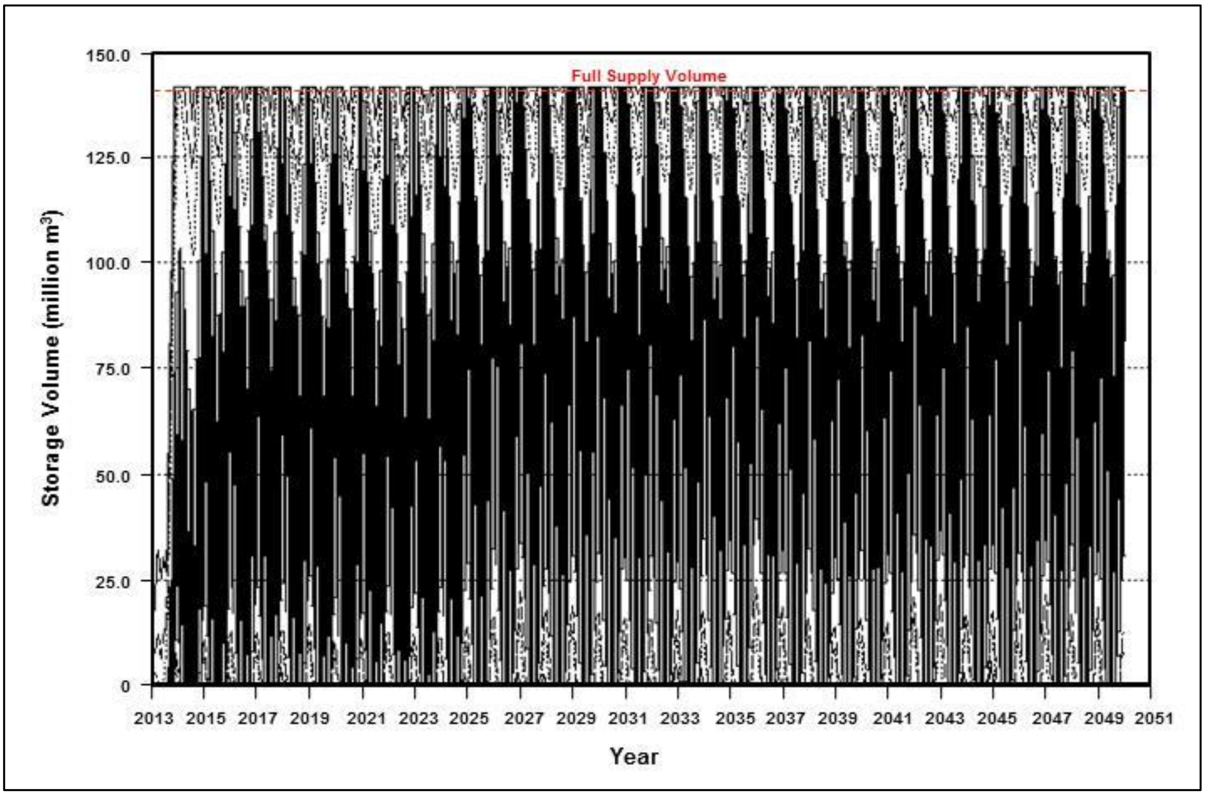

Figure A.5: Storage volume projection for Spring Grove Dam (Scenario 3B)

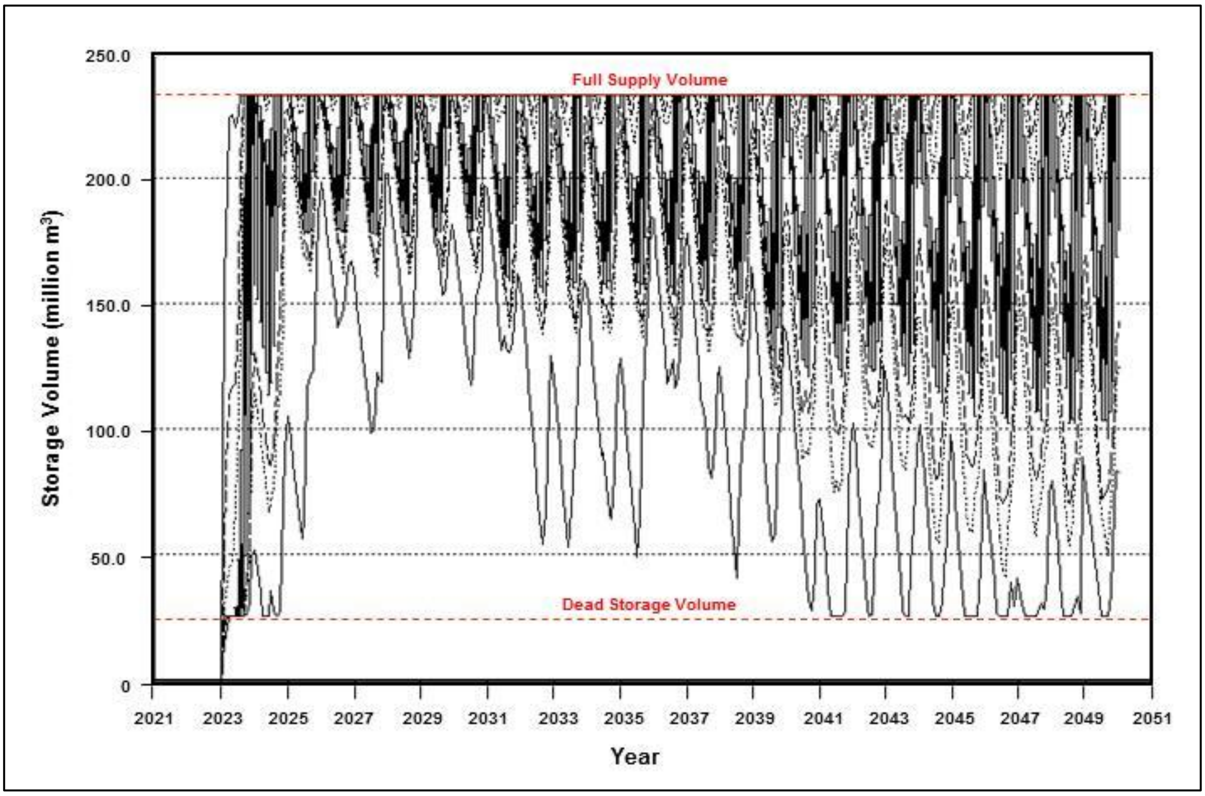

Figure A.6: Storage volume projection for Smithfield Dam (Scenario 3B)

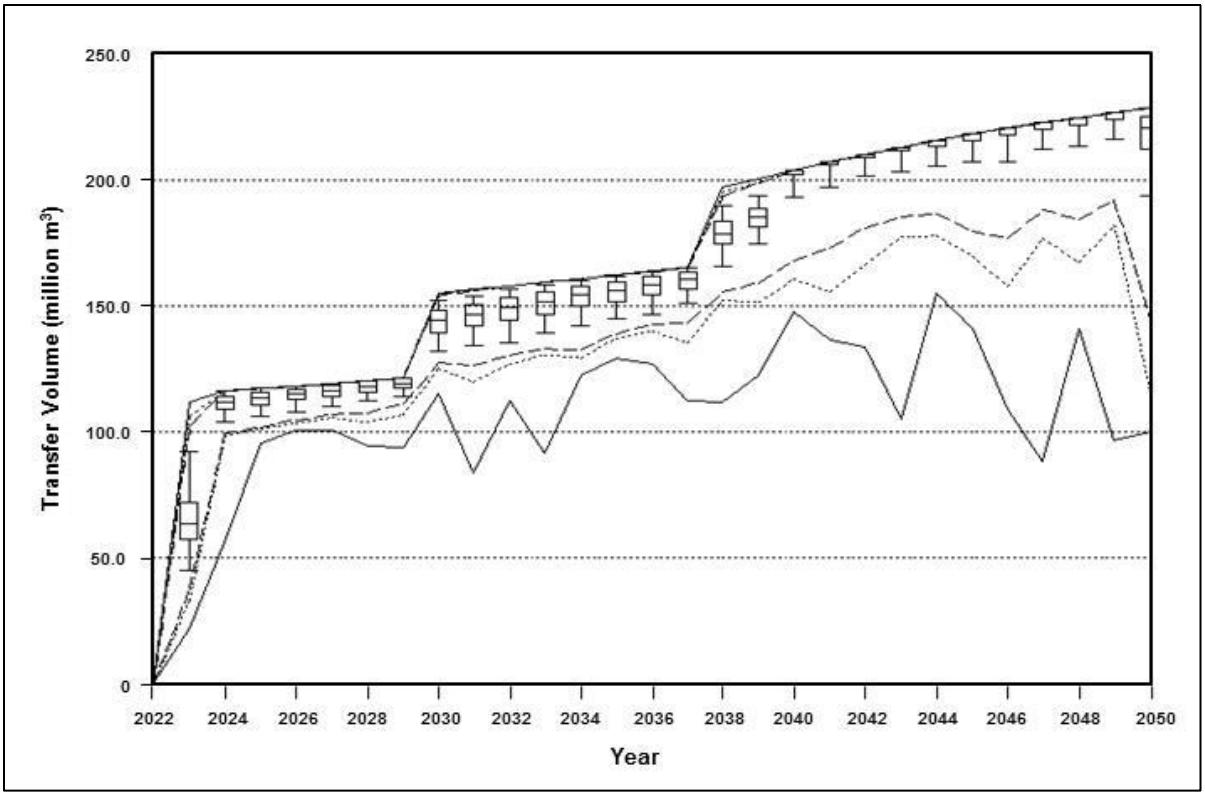

Figure A.7: uMWP transfer volume projection (Scenario 3B)

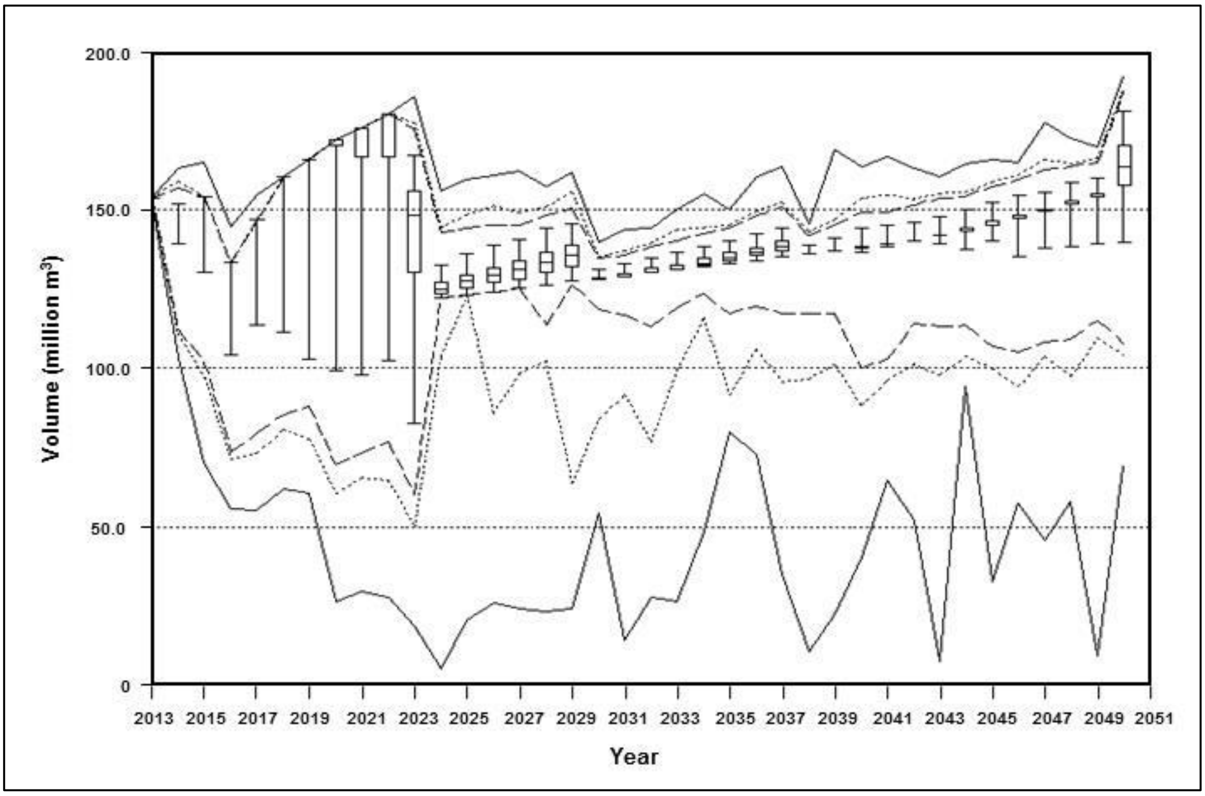

Figure A.8: Durban Heights supply volume projection (Scenario 3B)

# Appendix B

# WRPM system schematic diagrams

Note: numbering for uMkhomazi has had 1000 added to each channel and node number
E.g. node number 21 became node 1021

UMGENI WATER-AMANZI

# WRPM System Schematic Diagram for the Mooi-Mgeni River System (Scenario A)

Last updated on 23/02/2009