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Scenarios Evaluation Report

Water Reconciliation Strategy for Richards Bay and Surrounding Towns

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REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AND SANITATION

Directorate: National Water Resources Planning

Water Reconciliation Strategy for Richards Bay and Surrounding Towns

SCENARIOS EVALUATION REPORT

Final: September 2015

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WATER RECONCILIATION STRATEGY FOR RICHARDS BAY AND SURROUNDING TOWNS

APPROVAL

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Study Reports

Report Name	DWS Report Number	Aurecon Report No
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Water Requirements	P WMA 06/W100/00/3114/1	9168
Water Balance	P WMA 06/W100/00/3114/2	9169
Screening of Options	P WMA 06/W100/00/3114/3	9174
Scenarios Evaluation	**P WMA 06/W100/00/3114/4**	**9170**
Reconciliation Strategy	P WMA 06/W100/00/3114/5	9171

Executive summary

Introduction

Scenario planning was done to determine the potential implementation dates of interventions for each scenario within the strategy evaluation period, from now up to 2040. This helped to identify the more favourable interventions or groups of interventions that could potentially be implemented to meet the potential future supply shortfalls for different future water requirement scenarios, and identify when they should be implemented.

Future Water Requirements

Four water requirements scenarios have been evaluated, these being:

- Scenario 1: Low growth
- Scenario 2: Low-Medium growth
- Scenario 3: Medium growth
- Scenario 4: High growth

The future water requirement scenarios are shown in Figure E1.

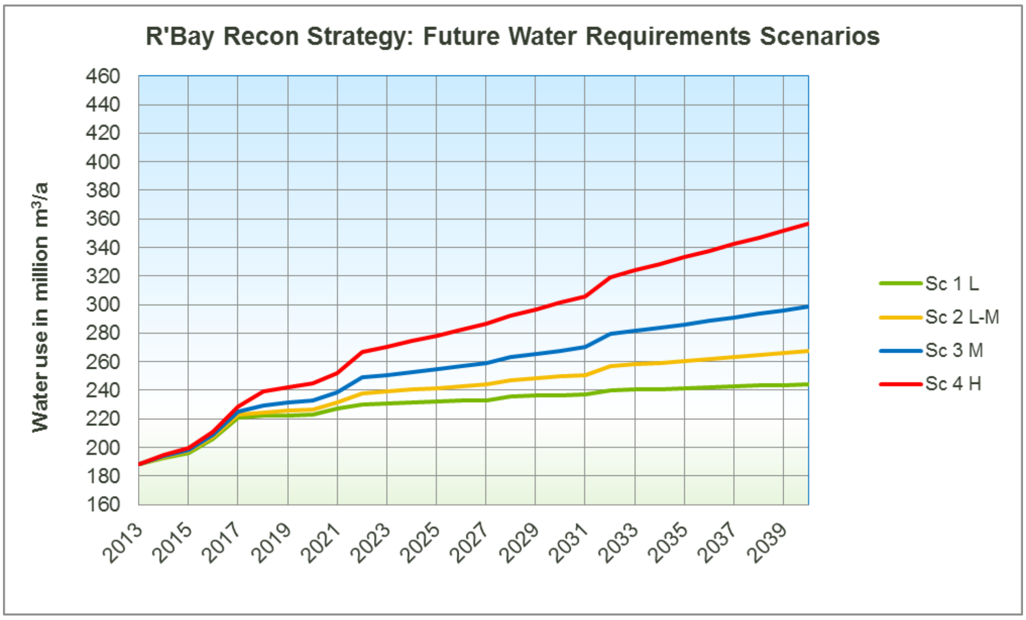


Figure E1: **Best Estimate Future Water Use Scenarios**

What is important is that it is unknown which of these future water requirement scenarios will actually develop? The strategic approach for bulk water development should therefore aim to meet a future shortfall in water requirements, whether growth in requirements is low or high. Monitoring of actual water requirements would be essential to track which water requirements scenario is actually developing.

The scenario planning was done based on the future water requirements (best-estimate) use scenarios, to avoid expensive investment in bulk water infrastructure long before it is actually needed.

Potential shortfall to meet

The detailed WRYM that was previously configured and updated for the strategy area as part of this study was further updated to incorporate and analyse potential interventions. The Water Resources Planning Model (WRPM) was further updated for the strategy area to verify the implementation dates of interventions for the selected water balance scenarios. The WRPM is based on the features of the WRYM, including:

- Inflow hydrology (both historical and with curtailment),
- Dam storage capacities and initial storage conditions,
- Network linkages and conveyance constraints, and
- Operating rules using “penalties” to prioritise sources and water demands.

The WRPM has further been enhanced to simulate system operation, including:

- Growth of water demands over time,
- Addition of new bulk water infrastructure, and
- Curtailment of each demand type during droughts according to different reliability classification tables.

Interventions (either a reduction in water requirements or schemes that add yield to the system) are required when the frequency of curtailment exceeds acceptable limits.

The curtailed (stochastic) system yield was determined as 247.3 million m^3/a. When the water requirements scenarios are compared with the curtailed yield of the water supply system the potential shortages in water supply by 2040 are as indicated in Table E1 (before WC/WDM interventions are implemented).

Table E1: Potential shortfall by 2040 for various water requirements scenarios

Water Requirement Scenario	Water requirement (million m^3/a)	Potential shortfall (million m^3/a)
Scenario 1: Low growth	244.4	2
Scenario 2: Low-Medium growth	267.8	23
Scenario 3: Medium growth	298.4	56
Scenario 4: High growth	356.9	115

Further issues to consider

Important further influences on the future water balance to consider are discussed hereunder.

Climate change: Although there is no consensus in South Africa on how to incorporate climate change into the water resources planning process, an approach has been formulated on how to consider climate change for this strategy area. This was done by integrating the worst estimated case of climate change into the Worst Case Scenario. In all cases a 15% reduction in the available yield for all surface water options have been assumed, as well as a 5% reduction in yield from groundwater options and reuse and a 10% increase in irrigation demands by 2040. For analysis it has been assumed that these impacts are realised linearly. The worst case scenario for the Richards Bay WSS is when high future water requirements are realised, in addition to a worst case climate change situation.

Reducing storage capacity of Goedertrouw Dam: The reducing storage capacity of Goedertrouw Dam is leading to reduced water availability. The dam's storage capacity of 321 million m^3 in 1982 has decreased to an estimated 301 million m^3 by 2000 due to siltation. The capacity of the dam is decreasing further at an estimated 1.1 million m^3/a. It is estimated that the capacity of the dam will have reduced to 257 million m^3 by 2040. The estimated reduction in yield (from the year 2000) by 2040 as a result of siltation is estimated at 4.9 million m^3/a.

National perspective on the future allocation of Thukela River water: The strategic importance of the future allocation of water from the Thukela River must be considered in a broader, national strategic perspective. It is one of the current and potential future sources (phased transfer from the proposed future Mielietuin, Jana or Smithfield dams) of water for the Vaal River system. It is important to consider the most beneficial future allocation of water from the Thukela River, taking other potential future users into account. The strategic national importance of increased future transfer of water to the Mhlatuze catchment in the future must therefore be compared to the importance of providing future transfers to other potential water users.

Future availability and cost of Thukela River water: The maximum volume of Thukela River water available for transfer to the Mhlatuze catchment at an affordable cost may be a limiting factor. It is not exactly clear how much more water is available from the Thukela River, and this will need to be clarified. It is likely that further phases of a Thukela transfer scheme would only be possible should new dams be developed in the Thukela River, and such water would then come at a high cost.

Fast tracking of intervention implementation programmes: The fast tracking of the implementation programme of the first significant scheme to be implemented is important to avoid a situation of shortfall in supply in the medium term. The ability of implementing organisations to successfully undertake such fast tracking would thus need to be considered.

Baseline interventions

The four recommended baseline interventions, which will be included in (almost) all the scenarios postulated, are shown in Table E2 and in Figure E2.

Table E2: Baseline interventions

Intervention	Yield (million m^3/a)	URV (R/m^3)	Impl. Program (years)
Bulk industrial WC/WDM	2.8	varies	5
Urban WC/WDM	4.0	varies	10
Raising Goedertrouw Dam	3.9	1.61	4.5
Dam on the Nseleni River	7.0	1.96	8.5

1) *Note: The implementation programme is the expected time to first delivery of water, and may include a period for dams to fill*

The motivation for this is the following:

- Both Water Conservation and Water Demand Management (WC/WDM) interventions have comparatively low costs and are the most acceptable in terms of environmental sustainability.
- The raising of Goedertrouw Dam is very cost-effective, will have low impacts and is quick to implement.
- A dam on the Nseleni River is very cost-effective and its impacts can, to a reasonable extent be mitigated. In addition it provides some operational advantages, as water can be released downstream to Lake Nsezi / Nsezi WTW. The RBM abstraction point for water pumped to the smelter plant is also located just downstream of the potential dam site. It is understood that irrigators may also be interested in the development of the dam. It was assessed whether a larger Nseleni Dam (~1.5MAR) could provide storage of 'surplus' additional water transferred from the Mfolozi River, but this was found to be too costly to be considered further.

The baseline interventions (Figure E2), shown in comparison to the low, medium and high-growth water requirements, can provide a combined yield of 17.7 million m³/a, depending on the success of the implementation of the WC/WDM measures.

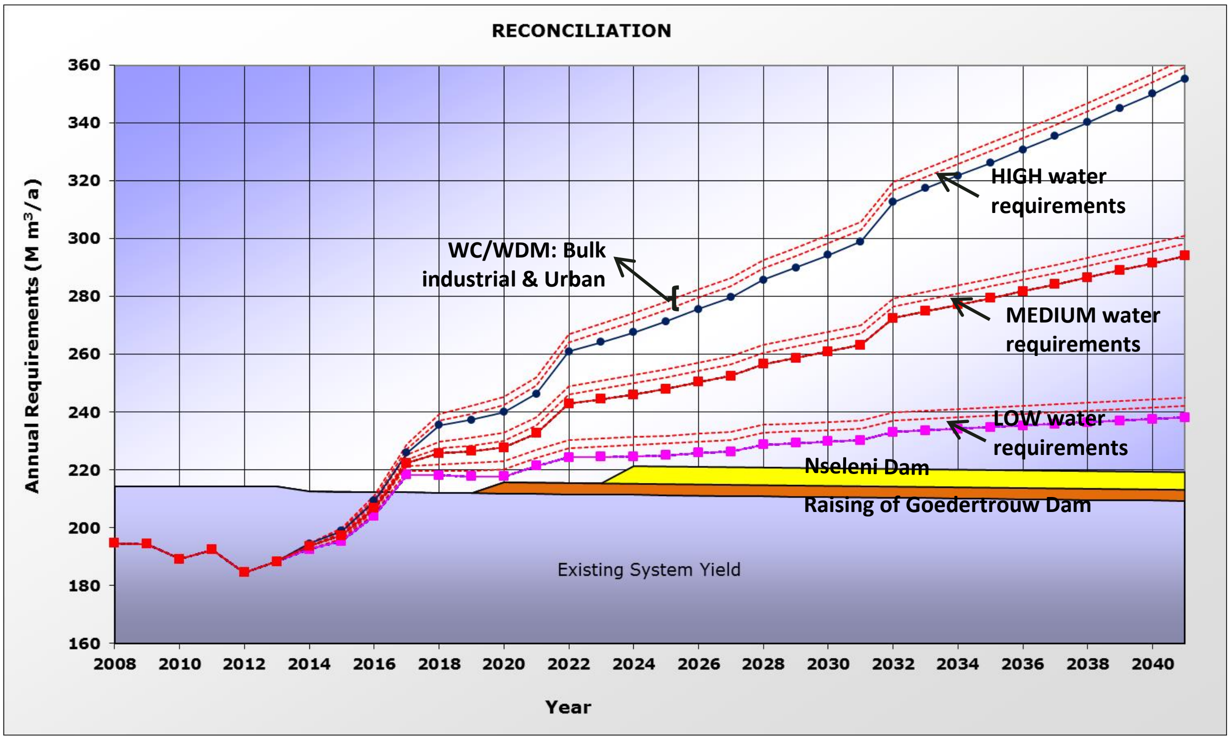


Figure E2: Baseline interventions showing Water Use Scenarios

Identification and Selection of Scenarios

A series of scenario themes were postulated to test specific future situations or different approaches to meet the potential shortfall. These included:

- Testing of supply from only the Thukela River, or without it,
- Emphasis on increased system storage,
- Emphasis on increased assurance of supply,

- Implementing only non-conventional sources,
- A situation where WC/WDM interventions is not effective,
- Worst-case,
- Maximum variation of sources,
- Implementing all potential sources,
- Fast tracking of implementation, and
- Early desalination.

A significant range of scenarios was postulated to address these various themes. Following initial assessment of these scenarios, a range of scenarios was recommended for more detailed evaluation. These are shown in Table E3.

Table E3: Scenarios identified for further evaluation

No	Water Requirement Scenario	Theme	Notes
1	Sc 1: Low growth	Mfolozi	Demonstrates that the shortfall can be met by increased water efficiency
2	Sc 3: Medium growth	Mfolozi FT	Demonstrates that the shortfall can easily be met by one significant scheme. The medium-term benefit of fast-tracking the first significant scheme is further demonstrated
3	Sc 4: High growth	No Thukela	Demonstrates how the shortfall can be met without using water from the Thukela River
4	Sc 4: High growth	Non-conventional	Demonstrates how the shortfall can be met by only non-conventional sources (no surface water)
5	Sc 4: High growth	Worst case	Demonstrates how the shortfall can be met in the worst-case scenario, i.e. taking worst-case climate change into account in addition to high growth in requirements
6	Sc 4: High growth	Fast track Mfolozi	Demonstrates how fast tracking of the Mfolozi scheme improves the water balance in the medium term
7	Sc 4: High growth	Fast track Desal	Demonstrates how the fast tracking desalination improves the water balance in the medium term
8	Sc 4: High growth	Fast track Thukela Middledrift	Demonstrates how the fast tracking of the Thukela Middledrift Phase 1 scheme improves the water balance in the medium term
9	Sc 4: High growth	Fast track Thukela Coastal	Demonstrates how the fast tracking of the Thukela 55 Mℓ/d Coastal scheme improves the water balance in the medium term
10	Sc 4: High growth	Early large desalination	Demonstrates a revised Baseline with early introduction of a larger seawater desalination scheme
11	Sc 4: High growth	Early larger desal plus surplus storage	Demonstrates a revised Baseline with early introduction of seawater desalination, and in addition with storage of 'surplus' Mfolozi River water in a larger Nseleni Dam
12	Sc 4: High growth	Thukela Middledrift only	Demonstrates how the shortfall can be met from phased Thukela Middledrift transfer schemes

Because there is little point in evaluating scenarios where no specific lessons can be learnt from such evaluation or where the solution is so evident, some identified scenarios were not evaluated further.

Preliminary Implementation Programmes

The planning and implementation of interventions takes time, often as long as 10 or more years for a large scheme. It is therefore imperative to clearly identify the steps to be taken in the process and to timeously plan for new longer term interventions. Preliminary implementation programmes were developed for each intervention, to be used in the scenario evaluation. The preliminary implementation programmes are notably dependent on the implementing organisation.

It is possible to fast-track the implementation of projects, should circumstances require it. This usually comes with an associated higher cost and risks, but fixed institutional processes in some organisations may make this challenging to achieve.

Evaluation of selected scenarios

The Reconciliation Planning Support Tool (RPST) was customised for the Richards Bay WSS, to enable planning in support of and to guide the stochastic system modelling undertaken. Information is imbedded in the Tool, including various future water demand scenarios, the current system yield, scheme implementation programmes, scheme yields and financial parameters. Output from the Tool graphically shows when decisions to study selected projects need to be taken to achieve a water balance, in order to implement demand management measures, or to make the yield from a new source available, by a certain date (year).

It is quite difficult to identify a scenario that represents the most likely scenario at this point in time, given the uncertainty regarding what future demands will actually be. The closest is likely either Scenario 2 (see Figure E3) that represents a medium-growth water requirement scenario or Scenario 6 that represents a high-growth water requirement scenario, with implementation of the baseline interventions, with a fast-tracked Mfolozi River off-channel transfer scheme that would also provide water to the Mtubatuba WSS and surrounds, and thereafter the implementation of further schemes of which the order of implementation could be refined following further investigations.

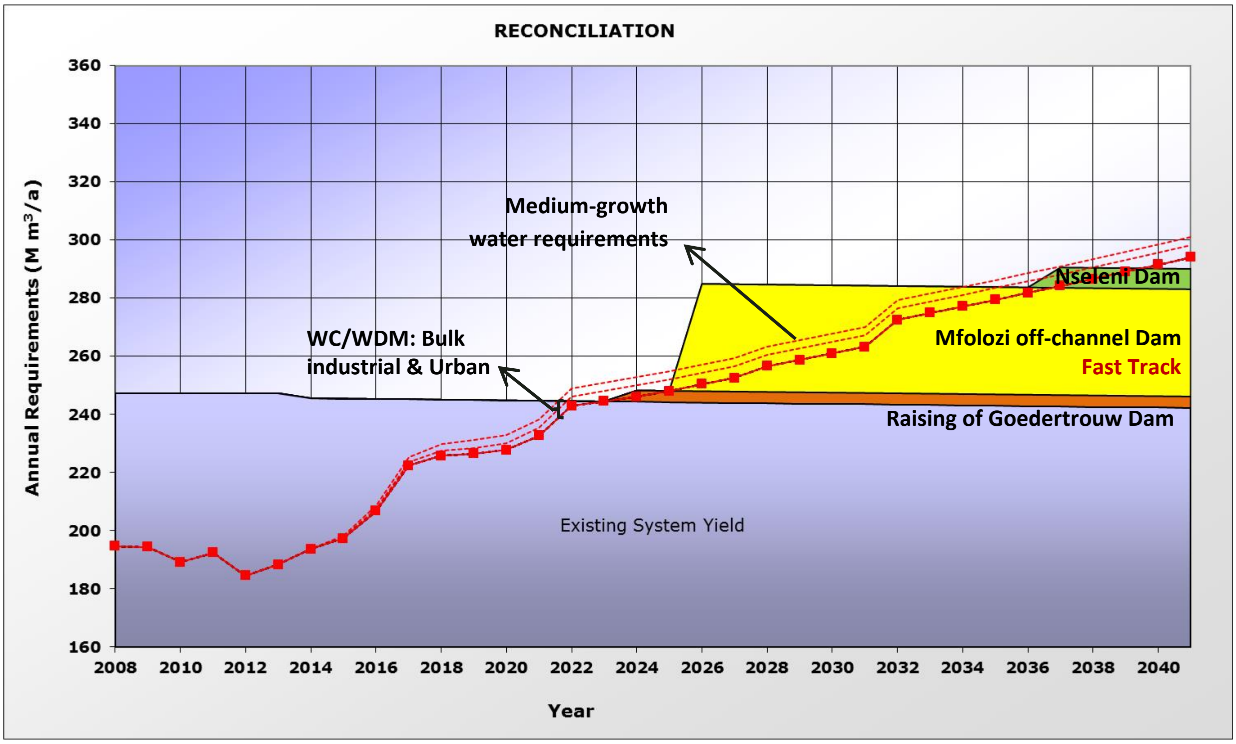


Figure E3: Scenario 2 - medium growth

Conclusions

The most important observations and lessons learnt from the scenario assessment are:

a. Scenario planning was done to determine the potential implementation dates of interventions for selected water balance scenarios within the strategy evaluation period, from now up to 2040, to avoid a shortfall in water supply within the Richards Bay WSS.

b. The WRYM and WRPM were updated for the strategy area to incorporate the potential interventions, and were used to confirm water balance shortfall dates. Interventions are required when the frequency of curtailment in accordance with the assurances of supply for the various user groups exceed acceptable limits.

c. The WRPM indicated that the next intervention is required by 2020 (should WC/WDM interventions not yet be implemented) for high growth in future water requirements, by 2022 for medium growth in future water requirements and by 2033 for low growth in water requirements. Concern was expressed about the practical implementability of urban water use curtailment for the 1:20 years and 1:4 years risk of failure and it is recommended that urban use assurance of supply should be revisited.

d. A reconciliation (water balance) planning tool was set up for the Richards Bay WSS and was populated to assist with reconciliation evaluations and graphic presentation of water balance situations.

e. The more favourable interventions or groups of interventions that could potentially be implemented to meet the potential future supply shortfalls for the various future water requirement scenarios was identified, as well as when such interventions should be implemented.

f. Planning for the implementation of bulk water supply infrastructure within the strategy evaluation period (up to 2040) was done to meet future water use estimations / scenarios, and not to future water allocation scenarios.

g. Four small attractive options have been identified that can provide smaller yields to increase the water availability of the region. These so-called *baseline* interventions, which are recommended for all water balance scenarios are:

   - *Bulk industrial WC/WDM* initiatives should continue and water efficiency should be improved.
   - *Urban WC/WDM* initiatives should continue and water efficiency should be improved.
   - The *raising of Goedertrouw Dam* seems very promising as it can be implemented fairly quickly, apart from being very cost effective. It appears beneficial to a get a feasibility study underway as soon as possible.
   - A *new dam on the lower Nseleni River* would be beneficial from a cost perspective. It could further offer operational benefits, but could likely not be implemented quickly. It appears beneficial to a get a feasibility study underway as soon as possible.

h. Should low growth in future water requirements realise in the long-term, scenario evaluation demonstrates that the shortfall can be met by improved water efficiency.

i. Should medium growth in future water requirements realise in the long-term, scenario evaluation demonstrates that the shortfall can be met by the implementation of one significant bulk water supply scheme, in addition to the baseline interventions, and that there would be medium-term benefit to fast-track the first significant scheme to be implemented.

j. Should high growth in future water requirements realise in the long-term, scenario evaluation demonstrates that several bulk water supply schemes would need to be implemented over the strategy evaluation period, of which the first significant scheme to be implemented would need to be fast-tracked.

k. Three significant available schemes (that would make large quantities of water available) have been identified to meet the future water requirements of the Richards Bay WSS. These are:

- A transfer scheme from an off-channel dam situated close to the Mfolozi River.
- A transfer scheme/s from the Thukela River, either the Thukela Middledrift Phase 1 Scheme or the Lower Thukela 55Mℓ/d Coastal Pipeline, or
- Seawater desalination, which can be appropriately sized and located as well as phased.

All of these significant schemes will have long implementation times, even if it is possible to fast-track their implementation. Although each of these schemes have their respective strong and weak points, it is not yet clear which of these three schemes are preferable. The choice of project needs to be confirmed with higher resolution analysis, such as a pre-feasibility study.

l. The Arboretum Effluent Reuse Scheme is a medium-sized scheme that seems promising and should be compared with the three promising significant schemes. This scheme has already been evaluated at 'feasibility' level, although all the aspects of the full scheme were not addressed. The full scheme should be evaluated and compared with the three significant schemes at pre-feasibility level.

m. There is still significant uncertainty regarding the potential influence of climate change on the WSS. Only the worst possible situation of climate change has been assessed, although climate change may even have a positive influence on the water balance. An adaptation approach to climate change is recommended until there is more clarity.

n. The reducing capacity of Goedertrouw Dam as a result of siltation has a negative influence on the yield of the WSS.

o. A national perspective on the likely future allocation of water from the Thukela River needs clarification, including the future availability and cost of Thukela River water for transfer to the Mhlatuze River.

Contents

Tables

Figures

Acronyms

DEA	Department of Environment Affairs
DWS	Department of Water and Sanitation
EFR	Estuarine flow requirement
ESIA	Environmental and social impact assessment
EWR	Ecological water requirement
FT	Fast track
GCMs	Global general circulation models
IDZ	Industrial development zone
IFR	Instream flow requirements
LTAS	Long Term Adaptation Scenarios
MAP	Mean annual precipitation
MAR	Mean annual runoff
RBM	Richards Bay Minerals
RPST	Reconciliation planning support tool
Sc	Scenario
URV	Unit reference value
WAAS	Water Availability Assessment Study
WC/WDM	Water conservation and water demand management
WRPM	Water Resource Planning Model
WRYM	Water Resource Yield Model
WSS	Water supply system
WTW	Water treatment works
WWTW	Wastewater treatment works

1 Introduction

1.1 Introduction

1.1.1 Background

Richards Bay is the economic centre of the uMhlathuze Local Municipality which further comprises Empangeni, Ngwelezane, Nseleni, eSikhaleni and a number of rural villages. Richards Bay is one of the strategic economic hubs of the country. Though the water resources available to the uMhlathuze Municipality are currently sufficient to cater for the existing requirements, should anticipated growth and industrial development materialise the current water sources are likely to come under stress.

1.1.2 Objective of the Reconciliation Strategy

The objective of the study is to develop a strategy and implementation plan to ensure adequate and sustainable reconciliation of the future water requirements within especially the uMhlathuze Local Municipality with potential supply within the strategy evaluation period (up to 2040). The focus is on Richards Bay / Empangeni, their significant industries, as well as the smaller towns and potential external users that may be supplied with water from the system in future.

1.1.3 Objective of the Scenario Evaluation Task

Water balance scenarios are potential groups of interventions, to be implemented within the defined strategy evaluation period, from now up to 2040. The scenario planning evaluation was done for an identified range of the more feasible interventions and selected water balance scenarios, following screening of the range of possible water balance scenarios. This was done to determine the potential implementation dates of interventions (within each scenario) to avoid potential future supply shortfalls for the selected future water requirements scenarios.

1.1.4 Purpose and Scope of this Report

It is necessary to identify the water balance scenarios, i.e. the appropriate group or groups of interventions that could be implemented to meet the potential future supply shortfalls of the Richards Bay Water Supply System (WSS) up to 2040, and in which order.

The purpose of this Report is to describe the identification and evaluation of future water balance scenarios, and the resultant findings and recommendations.

1.2 Approach and methodology

The following process has been followed:

a) Identification of the potential shortfalls in water supply by 2040, for selected future water requirements scenarios,
b) Identification of the variables that influence the future water balance,
c) Identification of the small attractive ‘baseline’ interventions, that should form part of virtually all scenarios to be evaluated,

d) Identification of a range of potential future water balance scenarios and screening them to select scenarios to evaluate further,
e) Setting up the Reconciliation Planning Support Tool (RPST) for the WSS and initial evaluation of the selected scenarios with the RPST to determine preliminary implementation dates of interventions,
f) Updating of the Water Resources Yield Model (WRYM) and the Water Resources Planning Model (WRPM) for the WSS with water requirements and potential interventions,
g) Evaluation of the WSS with the WRYM / WRPM to determine the required implementation dates of initial interventions,
h) Refinement of water availability information in the RPST so that the RPST is in line with the WRPM findings, and updating of the RPST scenarios,
i) Drawing of conclusions from the scenario evaluation undertaken,
j) Holding a scenarios workshop with key stakeholders,
k) Refining scenarios following the workshop,
l) Preparation of the Scenarios Evaluation Report, for comment and finalisation.

1.3 Structure of this Report

This report is presented in five chapters. The contents of these chapters are as follows:

Chapter 1: Introduction (this Chapter) which introduces the reader to the background to and purpose of the Reconciliation Strategy, and the approach to the Scenarios Evaluation Task.

Chapter 2: Identification of Scenarios describes the identification of baseline interventions, and further interventions and issues to consider.

Chapter 3: Selection of Scenarios describes the process followed to identify the scenarios to evaluate further, and provides preliminary implementation programmes of interventions.

Chapter 4: Evaluation of Selected Scenarios describes the tool and models used for the scenario evaluation, and present the findings of the modelled scenarios.

Chapter 5: Conclusions describes the conclusions drawn.

2 Identification of Scenarios

2.1 Driving factors

The driving factors for the identification of future water balance scenarios are:

a. Which future water requirements should be considered?

b. What will the potential future shortfall in water supply be by 2040?

c. Are there potential interventions that are so attractive (so-called ‘baseline’ interventions) that they should form part of all future scenarios?

d. Which interventions should be considered in addition to the Baseline interventions, notably the first significant scheme?

e. What other issues would influence the future water balance and would need to be considered further?

These driving factors are described in the following sections.

2.2 Future Water Requirements Scenarios

A number of potential future water requirement scenarios were determined for the WSS, up to 2040, these being dependent on the population and socio-economic growth of the strategy area. Four water requirements scenarios have been evaluated (as described in the *Water Requirements Report* of this study), these being:

- Scenario 1: Low growth
- Scenario 2: Low-Medium growth
- Scenario 3: Medium growth
- Scenario 4: High growth

The evaluation was done for both water allocation and for best-estimate water use scenarios. These potential future water requirement scenarios are shown in Figure 2.1 and Figure 2.2.

What is important is that it is unknown which of these future water requirement scenarios will actually develop? The strategic approach for bulk water development should therefore aim to be prepared to meet a future shortfall in water requirements, whether growth in requirements is low or high. Monitoring of actual water requirements would be essential to track which water requirements scenario is actually developing.

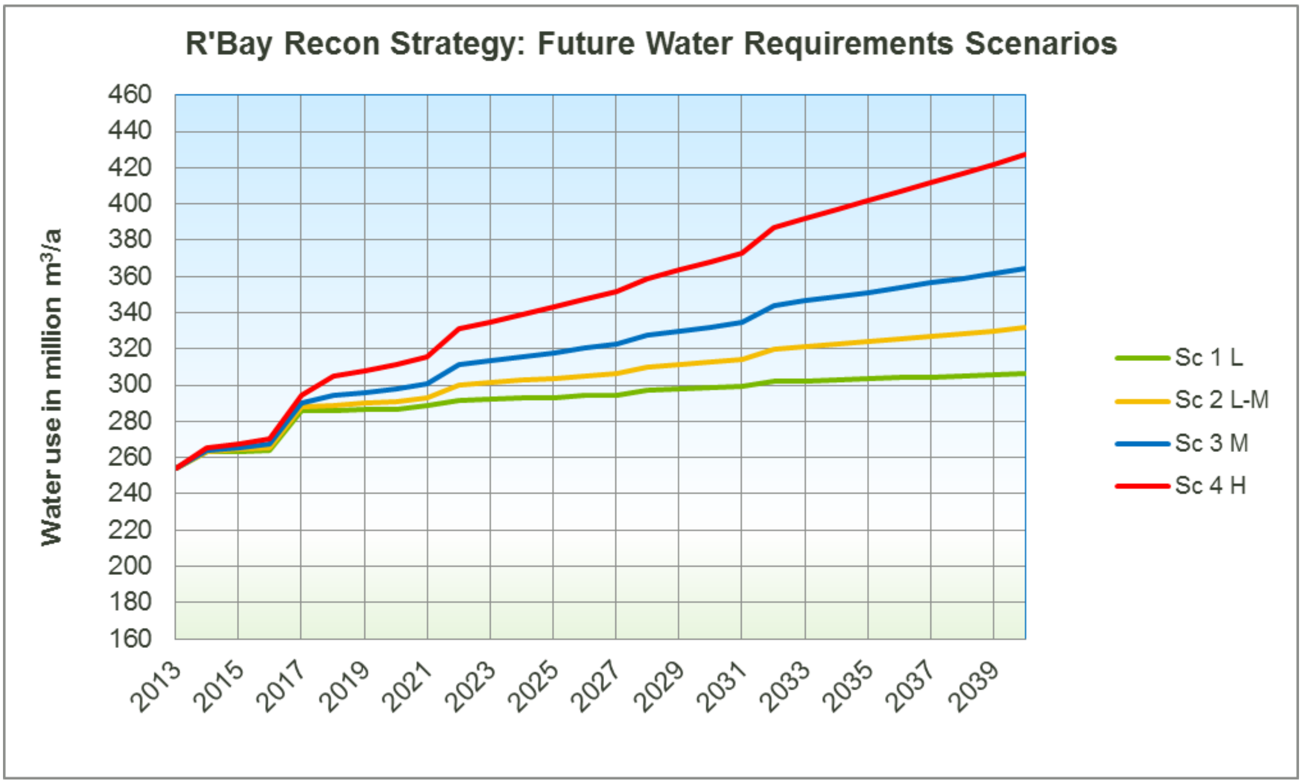


Figure 2.1: **Water Requirements Scenarios - Allocations**

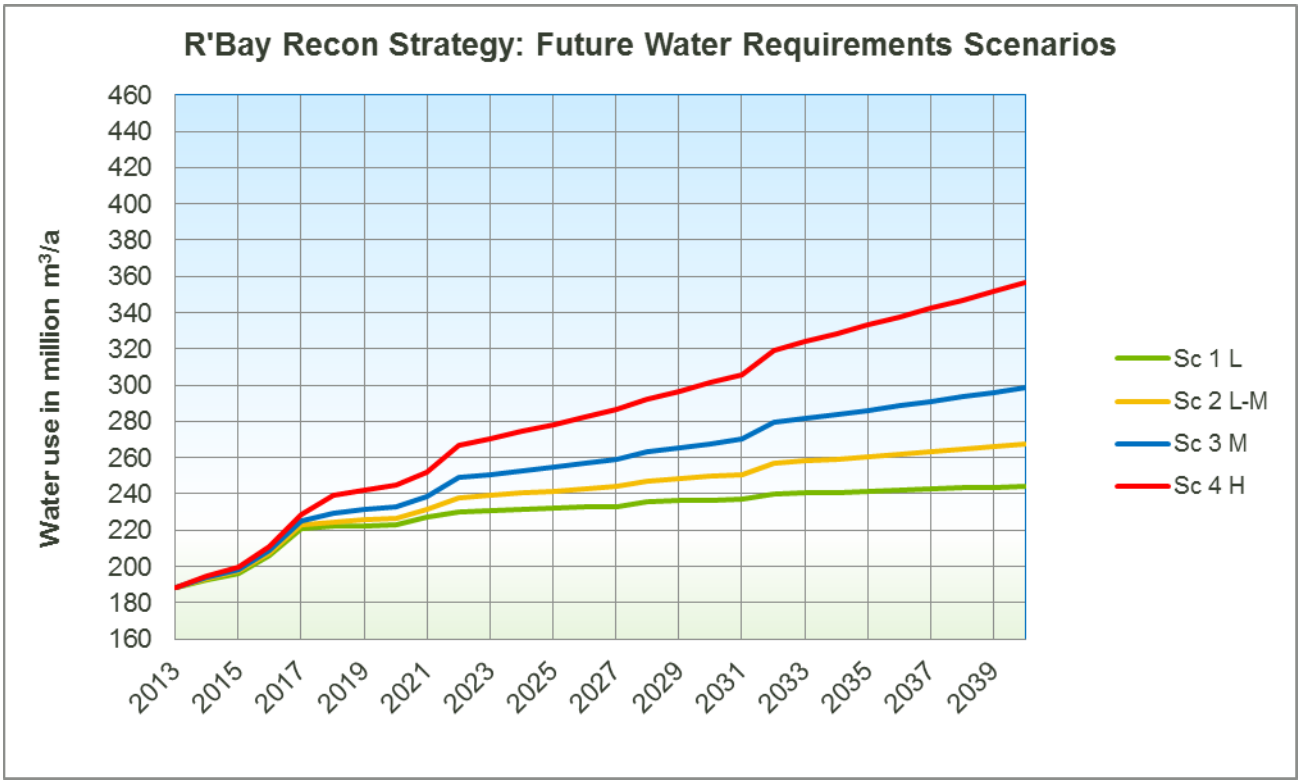


Figure 2.2: **Water Requirements Scenarios - Best Estimate Water Use**

A comparison of water requirements scenarios for expected future allocations versus water requirements for best-estimate future water use are shown in Figure 2.3, for medium-growth and high-growth in future water requirements respectively.

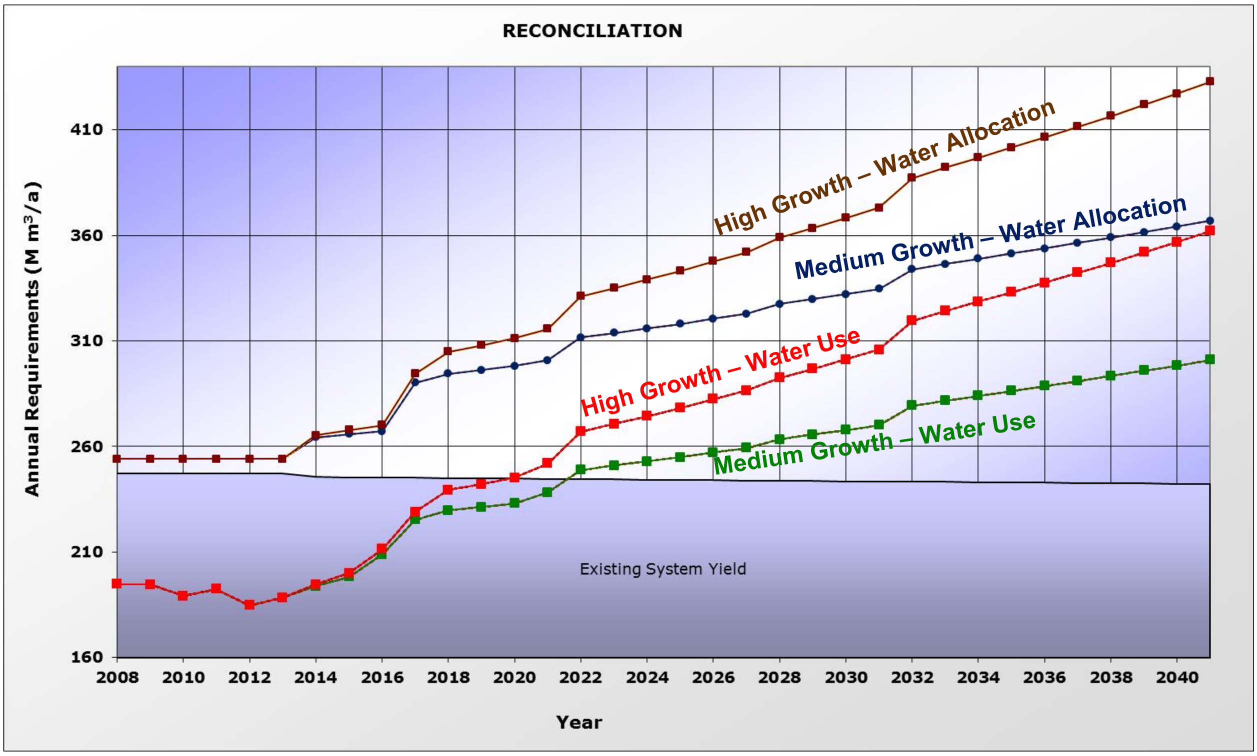


Figure 2.3: Comparison of Allocations and Use water requirements scenarios

The scenario planning was done based on the *best-estimate future water use* scenarios, to avoid expensive investment in bulk water infrastructure long before it is actually needed, in line with acceptable practice. From Figure 2.3 it is evident that the Medium Growth water requirement allocation scenario has a very similar water requirement to the High Growth best-estimate water use scenario by the end of the evaluation period.

2.3 Preliminary future shortfall in water supply

The WRYM that was configured in the Mhlathuze Water Availability Assessment Study and the subsequent Licensing Support Study was used in the current study as the most representative model configuration of the Mhlathuze catchment to date. The model was refined where appropriate and was updated with current water requirements and allocations. An updated current water balance for the Mhlathuze WSS was determined for the *firm* yield (i.e. when urban/industrial users can just be supplied fully) situation, which is considered to be a *conservative* indication of water availability from the system.

A system firm yield of 214.3 million m^3/a was initially used to form an idea of the potential shortfall in supply which the water supply system could face in 2040 for the various future water requirements scenarios. When the firm yield of the water supply system is compared to the future water requirements as a result of high growth in water demands, the water balance indicated that, in 2013, there was a small surplus of 12.7 million m^3/a in the water supply system. These shortfalls were updated following stochastic system modelling, as described in Section 4.3.

2.4 Further issues to consider

Important further influences on the future water balance to consider are described hereunder.

2.4.1 Climate change

Introduction to climate change

There is currently no consensus in South Africa on how to incorporate climate change into the water resources planning process. This is partly due to the high level of uncertainty still inherent in the global and even regional downscaled climate models. Many of these models actually show potential increased precipitation in the critical water supply areas of South Africa. There is further the feeling that the current approach to water resources planning is sufficient to address any long term climate change risks through a process of adaptive management and continuous updating of hydrological records used in the model simulation.

There are many aspects by which climate change could impact on the water sector. These include changes in precipitation and streamflow, increased intensity of runoff and elevated flooding risks, changes in water temperature and water quality, as well as increasing water demands, particularly for irrigation. In terms of assessing the specific potential impacts, the two primary impacts are on water supply and on water demand.

There is strong scientific consensus that global temperatures are rising. Local downscaled climate projections from the CSIR and CSAG for various emissions scenarios indicate that there will be an increase in both mean minimum and mean maximum temperatures. The data suggests this will range between 1.3 – 2.8 °C for maximum temperatures and 1.3 – 2.3°C for minimum temperatures (from Lumsden, 2013) for the period of 2046 to 2065 as reported by Mhlatuze Water (2013).

There is still much uncertainty relating to the potential impacts of climate change. Global circulation models tend to show potential for increased wetting over the eastern part of the country including KZN, while regional downscaled models tend to show possibilities of both wetting and drying conditions (LTAS).

Climate change and the Richards Bay WSS

A review of the available data for the Mhlatuze catchment showed a range of projected precipitation futures from a 15% decrease to a 16% increase in mean annual precipitation (Mhlatuze Water, 2013). The LTAS study confirmed a similar wide range of potential impacts on MAR from -20% to +80%, but with a median impact of around +6% on MAR for the Mhlatuze Catchment.

The LTAS study showed a median impact of +7% (range - 12% to + 19%) for irrigation demands by 2050.

The LTAS study also looked at the potential impacts in terms of the average annual water supply using a national configuration of the WRYM to assess the potential impacts on future water supply for irrigation, bulk industry and domestic supply at the level of individual water management areas. The results show a much narrower range of potential impacts on the percentage of average annual water demand that can be supplied, ranging from around a 5% reduction to a 20% increase with a median impact of around +2% with very little difference between the UCE and L1S mitigation scenarios. These results show the importance of considering water supply as different from changes in precipitation or runoff, as well as the potential for the existing bulk WSS to provide some resilience to future climate change impacts.

A closer analysis of the ability to supply future water demands in the Mhlatuze catchment shows that the greatest risk of a reduced water supply under drier climate scenarios is for urban and industrial water supply. This is because these users are located at the downstream end of the catchment and receive water only after it has been accessed for irrigation.

Part of the reason why a change in streamflow does not directly translate into an equivalent change in water availability under future climate scenarios is the ability of the Mhlatuze system to respond and to transfer water between catchments.

Incorporating climate change in planning

For initial planning purposes it is sufficient to consider the range of potential impacts and to determine how consideration of the potential extreme scenario may impact on decision-making, particularly around the timing of potential interventions and the priority of options for further investigation. This analysis is based on a vulnerability assessment of both current and future water supply options and an analysis, using the Richards Bay RPST to consider how a worst case scenario of potential climate change impacts, based on existing information, might affect the timing for future interventions and planning requirements.

Increasing the surface water storage and increased transfers from the Thukela and Mfolozi River are likely to experience similar climate change risks as the existing supply from the Mhlatuze Catchment. In particular the LTAS study, using the HFD approach (Cullis et al, 2014), concluded that the median impact on the MAR of the Thukela and Mfolozi Rivers by 2050 was +9% and +6% respectively, with the worst case scenario being a reduction of around 16% for both. For the worst case scenario we have assumed a 15% reduction in the yield of these options.

Surface water interventions will be impacted by changing precipitation and possibly also in terms of increased variability at the daily level depending on storage capacity. This would require additional modelling at the daily level to assess the potential impacts, but under the worst case scenario it could be assumed to be similar to the worst expected change in MAP. According to the Mhlatuze Climate Change study this would be around 15% reduction in the worst case scenario.

Increasing reuse of treated effluent and desalination are much less impacted by climate change. Reuse could potentially be impacted if demand drops in response to reduced availability from the existing and alternative surface and groundwater options and in a worst case scenario could be considered to have a similar risk under future climate change scenarios. Desalination however is completely independent of future climate change scenarios and therefore provides a highly robust solution to future water supply options under increasing future uncertainty. The true value of this added security of supply has not yet been assessed in South Africa and requires further research.

Worst Case Scenario

Based on the above high level assessment of the relative climate change risks for both current and future water supply options a Worst Case Scenario has been developed. For analysis it has been assumed that these impacts are realised linearly. In all cases we have assumed a 15% reduction in the available yield for all surface water options, a 5% reduction in yield from groundwater options and reuse and a 10% increase in irrigation demands by 2040.

The worst case scenario for the Richards Bay WSS is when high future water requirements are realised, in addition to worst case climate change.

Refer to **Appendix A** that contains an evaluation of climate change in the Richards Bay area and recommendations on how to include climate change in the Worst Case climate change scenario.

2.4.2 Reducing storage capacity of Goedertrouw Dam

The reducing storage capacity of Goedertrouw Dam is leading to reduced water availability. The dam had a storage capacity of 321 million m^3 when it was constructed in 1982. The storage capacity of the dam has decreased to an estimated 301 million m^3 (year 2000) due to siltation. The capacity of the dam is decreasing further at an estimated 1.1 million m^3/a. It is estimated that the capacity of the dam will have reduced to 257 million m^3 by 2040.

The estimated reduction in yield (from the year 2000) by 2040 as a result of siltation is estimated at 4.9 million m^3/a.

2.4.3 National perspective on the future allocation of Thukela River water

The strategic importance of the future allocation of water from the Thukela River must be considered in a broader, national strategic perspective. It is one of the current and potential future sources (phased transfer from the proposed future Mielietuin, Jana or Smithfield dams) of water for the Vaal River system. An issue to consider is the most beneficial future allocation of water from the Thukela River, taking other potential future users into account, i.e. the strategic national importance of providing further water to the Mhlatuze River vs. the importance of providing further water to other potential water users.

2.4.4 Future availability of Thukela River water

The maximum volume of Thukela water available for transfer to the Mhlatuze catchment at a feasible **cost** may be a limiting factor. It is not exactly clear how much more water is available from the Thukela River, and this will need to be clarified if the scheme is investigated further. While it currently seems certain that further water can be diverted to the Mhlatuze catchment (via the Middledrift Phase 1 Scheme or the Lower Thukela coastal pipeline), there is much less certainty regarding availability of water for Phases 2 or 3 of the Middledrift Scheme. It is likely that phases 2 or 3 transfers would only be possible should further dams be developed in the Thukela River. The associated cost of such dams would however significantly increase the unit cost of further Thukela transfer phases, potentially to a point where further transfers will not be feasible from a cost-perspective. This limitation may imply that either the Thukela Middledrift Phase 1 Scheme should be considered or the Thukela 55 Mℓ/d Coastal Scheme, but possibly not both, and not further phases, until this issue can be clarified.

2.4.5 Fast tracking of intervention implementation programmes

The importance of fast tracking of the implementation programme of the first significant scheme to be implemented after the baseline interventions (and possibly also further schemes) is potentially important to avoid a situation of shortfall in supply in the medium term. The ability of implementing organisations to successfully undertake such fast tracking would need to be considered, specifically related to the fast-tracking of budgetary and procurement processes, as well as technical studies and construction. The ability to fast-track the necessary approvals to proceed would be crucial.

2.5 Baseline Interventions

The four recommended baseline interventions, which will be included in all the scenarios postulated, are shown in Table 2.1.

Table 2.1: Baseline interventions

Intervention	Prelim. Yield (million m^3/a)	URV (R/m^3)	Impl. Program (years)
Bulk industrial WC/WDM	2.8	varies	5
Urban WC/WDM	4.0	varies	10
Raising Goedertrouw Dam	3.9	1.61	4.5
(1 MAR, 22.5m high) Dam on the Nseleni River	7.0	1.96	8.5

1) *Note: The implementation programme is the expected time to first delivery of water, and may include a period for dams to fill*

The baseline interventions can provide a combined yield of 17.7 million m^3/a, depending on the success of the implementation of WC/WDM measures.

The motivation for this is the following:

- Both WC/WDM interventions likely have the lowest costs and are the most acceptable in terms of environmental sustainability.
- The raising of Goedertrouw Dam is very cost-effective, will have low impacts and is quick to implement.
- A dam on the Nseleni River is very cost-effective and its impacts can, to a reasonable extent be mitigated, although it will have a longer implementation period. In addition it may provide some operational advantages, as water can be released downstream to Lake Nsezi / Nsezi WTW when needed. The RBM abstraction point for water pumped to the smelter plant is also located just downstream of the potential dam site. It is understood that irrigators may also be interested in the development of the dam. A potential variation to consider is the possibility that a larger Nseleni River Dam (~1.5MAR) could provide storage of surplus flows from the Mhlatuze Weir.

2.6 Interventions to consider following the Baseline

From the remainder of the possible interventions that can be included in the scenario evaluation, any of the interventions shown in Table 2.2 can be considered for implementation, following the baseline interventions.

Table 2.2: Further interventions to consider following the baseline interventions

Intervention	Prelim. Yield (million m^3/a)	URV (R/m^3)	Impl. Program[1] (years)
Groundwater schemes	1.6	4.93 to 10.69	8.5
Arboretum Effluent Reuse Scheme	11.0	6.97	6.5
Thukela-Mhlathuze Transfer Scheme Phase 1, incremental 1.5 m^3/s	47.3	6.43	8.75
Lower Thukela coastal pipeline (clear) (55Mℓ/d)	15.1	4.96	8.5
26m high Kwesibomvu Dam on the Mfolozi River (mutually exclusive)	66.6-20=46.6[2]	4.21	10.25
42m high Mfolozi off-channel dam (mutually exclusive)	56.9-20=36.9[2]	6.22	9.5
Desalination of seawater Phase 1 (harbour intake)	21.9	7.82	7.75
Desalination of seawater Larger Scheme Phase 1 (harbour intake)	43.8	7.82	8.5

1) *Note: The implementation programme is the expected time to first delivery of water, and may include a period for dams to fill to an acceptable volume to be able to abstract*
2) *It has been estimated that a Mfolozi River dam scheme could supply 20 million m^3/a to the Mtubatuba WSS and surrounding areas by 2040*

Interventions that are not selected for implementation following the Goedertrouw Dam raising could be considered for later implementation.

The yield of the groundwater schemes are so limited, that they cannot practically be considered for bulk water supply. Local use should rather be encouraged.

The **Kwesibomvu Dam** and **Mfolozi off-channel dam** are regarded as mutually exclusive schemes for this exercise, and only one Mfolozi Scheme will be considered per water balance scenario. It is however not inconceivable that in the very long term more than one lower Mfolozi River scheme might be considered; possibly entailing a further off-channel dam/s.

Similarly, for the **Lower Thukela coastal pipeline**, likely only one of the 55Ml/d or 110Mℓ/d schemes can be implemented, keeping in mind that the 110Mℓ/d scheme could not seriously be considered before 2027, at the projected closure date of the Fairbreeze mine, and only if the Mvoti Dam is developed by Umgeni Water to replace the urban water supply from the Lower Thukela Bulk Water Supply Scheme to the south of the Thukela River. Given the significant uncertainty regarding the likelihood of a potential 110Mℓ/d Lower Thukela coastal pipeline intervention, it is proposed that this intervention not be considered further at this point, but it could potentially be considered again in the future, should improved information become available.

Two of these interventions would add **further benefit**, apart from the additional yield to the Richards Bay water supply system (WSS). These are:

- An **Mfolozi River scheme** would not only supply the Richards Bay WSS, but could also provide an assured water supply to the Mtubatuba WSS and potentially surrounding areas for a significant period. The off-channel dam will be evaluated further in the scenario analysis, having a slightly lower yield and much lesser impacts.
- **Seawater desalination** could provide water at almost 100% assurance of supply and is well-suited to incremental development. This resource would not be affected by droughts and climate change. It could potentially also add further incremental yield to the WSS, in addition to the direct supply of the scheme. A drawback is the high operational energy requirement of the scheme.

For further Thukela River transfers, the most important issue is the availability of water from the Thukela River for transfer, at an acceptable cost. Besides the current allocation that have been made for a Thukela River transfer scheme (which could be transferred to the Middledrift site) only small further volumes is likely available to allocate for transfer to the Mhlatuze catchment. Essentially, the volume required for the Thukela Middledrift Phase 1 transfer scheme (47.3 million m^3/a) is likely about the limit of what could be transferred, without the development of a further dam/s in the Thukela catchment to make more water available. Such further transfers would likely also have higher associated costs, as they would include the currently-unknown costs of dam development in the Thukela River, possibly rendering further phases unfeasible.

The development of **groundwater** and **effluent reuse** would diversify the water sources of the WSS, but these are not drought-proof sources, and their yields are limited, especially that of groundwater. Seawater desalination provides a drought-proof supply.

The first significant (large) intervention to be implemented following the (small) baseline interventions is an important decision to be made. At this stage several schemes look feasible and the range of URVs and potential impacts are not that dissimilar. A pre-feasibility study or first phase of a feasibility study would probably be needed to first clarify which is the better large scheme to implement in addition to the baseline interventions.

2.7 Further interventions to consider

Following the initial intervention (apart from the baseline interventions) selected for evaluation, further interventions could be considered. The next interventions to be considered for implementation, could be either one of the other interventions included in Table 2.2, or an intervention from Table 2.3, these mainly being further phases of schemes e.g. for the Thukela (Middledrift) Transfer Scheme or seawater desalination.

The 110Mℓ/d Lower Thukela coastal pipeline would only become a possibility, should Umgeni Water develop an Umvoti River scheme to replace the supply to the southern supply area of the Lower Thukela Water Supply Scheme and will not be considered further at this stage.

Table 2.3: Further interventions to consider

Intervention	Prelim. Yield (million m^3/a)	URV (R/m^3)	Impl. Program[1] (years)
Thukela-Mhlathuze Transfer Scheme Phase 2, incremental $2.7 m^3/s$	94.6	4.74	8.75
Thukela-Mhlathuze Transfer Scheme Phase 3, incremental $2.7 m^3/s$	94.6	3.92	7.75
Lower Thukela coastal pipeline (110Mℓ/d)	35.2	5.23	9
Desalination of seawater Phase 2 and further phases	21.9	7.82	5.75
Desalination of seawater Larger Scheme Phase 2 and further phases	43.8	7.82	7

1) *Note: The implementation programme is the expected time to first delivery of water, and may include a period for dams to fill*

3 Selection of Scenarios

3.1 Scenario Themes

It is recommended that the following scenarios be evaluated for the high-growth scenario, but that at least one scenario is evaluated for the low-growth and medium growth scenarios respectively in addition:

- Testing of supply from only the Thukela River, or without it,
- Emphasis on increased system storage,
- Emphasis on increased assurance of supply,
- Only non-conventional sources,
- WC/WDM interventions not being effective,
- Worst-case,
- Maximum variation of sources,
- All potential sources,
- Fast tracking of implementation, and
- Early desalination.

Several potential scenarios that would meet (or almost meet) the potential shortfall in supply by 2040 were postulated.

3.2 Water Balance Scenarios Selected for Evaluation

Following initial assessment and screening of postulated scenarios, it was recommended that the scenarios as shown in Table 3.1 be evaluated further. These scenarios are useful to illustrate potential strategies to meet the potential future shortfall in water supply. Apart from the baseline interventions, the remainder of the potential interventions being considered in the scenario evaluation are all potential candidates for development. It is further evident that the interventions in some of these scenarios could be considered in different orders, taking their preliminary implementation programmes into account.

Because it is quite easy to meet the 2040 shortfall for the Low Growth, Low-Medium Growth and Medium Growth scenarios, it is recommended that the High-Growth scenarios be evaluated more closely to learn lessons about which interventions to evaluate further when, so as to be prepared for different future eventualities.

The term FT refers to fast-tracked implementation.

Table 3.1: Scenarios to evaluate further

No	Water Requirement Scenario	Theme	Notes
1	Sc 1: Low growth	Mfolozi	Demonstrates that the shortfall can be met by increased water efficiency
2	Sc 3: Medium growth	Mfolozi FT	Demonstrates that the shortfall can easily be met by one significant scheme. The medium-term benefit of fast-tracking the first significant scheme is further demonstrated
3	Sc 4: High growth	No Thukela	Demonstrates how the shortfall can be met without using water from the Thukela River
4	Sc 4: High growth	Non-conventional	Demonstrates how the shortfall can be met by only non-conventional sources (no surface water)
5	Sc 4: High growth	Worst case	Demonstrates how the shortfall can be met in the worst-case scenario, i.e. taking worst-case climate change into account in addition to high growth in requirements
6	Sc 4: High growth	Fast track Mfolozi	Demonstrates how fast tracking of the Mfolozi scheme improves the water balance in the medium term
7	Sc 4: High growth	Fast track Desal	Demonstrates how the fast tracking desalination improves the water balance in the medium term
8	Sc 4: High growth	Fast track Thukela Middledrift	Demonstrates how the fast tracking of the Thukela Middledrift Phase 1 scheme improves the water balance in the medium term
9	Sc 4: High growth	Fast track Thukela Coastal	Demonstrates how the fast tracking of the Thukela 55 Mℓ/d Coastal scheme improves the water balance in the medium term
10	Sc 4: High growth	Early large desalination	Demonstrates a revised Baseline with early introduction of a larger seawater desalination scheme
11	Sc 4: High growth	Early larger desal plus surplus storage	Demonstrates a revised Baseline with early introduction of seawater desalination, and in addition with storage of 'surplus' Mfolozi River water in a larger Nseleni Dam
12	Sc 4: High growth	Thukela Middledrift only	Demonstrates how the shortfall can be met from phased Thukela Middledrift transfer schemes

3.3 Water Balance Scenarios not considered further

There is little point in undertaking further assessment of intervention scenarios, when no specific lessons can be learnt from such evaluation. Keeping that in mind, scenarios that were not considered further, as well as the reasons for doing so has been included in Table 3.2.

Table 3.2: Scenarios that will not be considered further

No	Water Requirement Scenario	Theme	Reason for not evaluating further
1	Sc 2: Low-Medium growth	Mfolozi	The medium-growth scenario is quite similar so this scenario would not add value
2	Sc 3: Medium growth	Desal FT	The Mfolozi FT theme illustrates that one significant scheme is needed, and no further lesson will be learnt
3	Sc 3: Medium growth	Thukela Middledrift FT	The Mfolozi FT theme illustrates that one significant scheme is needed, and no further lesson will be learnt
4	Sc 4: High growth	Mfolozi + Thukela	Demonstrates that the shortfall cannot be met by only the Mfolozi and Thukela Middledrift Ph 1 schemes

No	Water Requirement Scenario	Theme	Reason for not evaluating further
5	Sc 4: High growth	Thukela Middledrift only: one combined scheme	Not evaluated as the implementation of one combined scheme is unlikely
6	Sc 4: High growth	Maximise storage	Only a dam in the Mfolozi can be added, following the baseline, which does not meet the shortfall by far
7	Sc 4: High growth	Drought-proofing	Desalination is the only drought-proofing intervention that can be considered after the baseline. As its yield is regarded as almost infinite, by adding phases, the outcome is evident
8	Sc 4: High growth	WC/WDM not effective	As the WC/WDM interventions can only lead to a small reduction in demand, this is not a particularly useful scenario
9	Sc 4: High growth	Varied sources	This demonstrates that the shortfall can potentially be met by a wide variety of sources if necessary
10	Sc 4: High growth	All schemes - max yield	Not useful for the modelling, but does illustrate that, if all these sources could be developed, the potential future bulk water sources of the strategy area could likely meet shortfall for some decades, following this strategy evaluation period
11	Sc 4: High growth	Early desalination	Demonstrates a revised Baseline with early introduction of seawater desalination. This is similar to the scenario that includes the early introduction of a larger desalination plant

3.4 Preliminary Implementation Programmes

The preliminary implementation programmes of the evaluated interventions to be considered further in the scenario evaluation are shown in Table 3.3.

The planning and implementation of interventions takes time, often as long as 10 or more years for a large scheme. It is therefore imperative to clearly identify the steps to be taken in the process and to timeously plan for new longer term interventions. The preliminary implementation programmes are notably dependent on the implementing organisation.

Projects could further be fast-tracked, if circumstances require it. Fast tracked intervention implementation programmes have been indicated in red text.

Table 3.3: Interim Implementation Programmes (years)

INTERVENTION	Pre-Feasibility	Feasibility			Implementation / Construction							TOTAL Time to develop yield	
		Budget/ TOR / Appoint Consultant	Feasibility Study/ EIA/ Monitoring	DWS Reserve determination	Budget/ TOR / Appoint Consultant	DWS licensing process (incl Reserve)	DEA&DP approval process	Design / tender preparation & award	Construct /Implement/Council Bylaw	Warm up / first filling			
			Simultaneous	Simultaneous		Simultaneous	Simultaneous			Start	End	Start	End
Bulk industrial WC/WDM								1	4	0	5	0	5
Urban WC/WDM								1	9	0	10	0	10
Rainwater harvesting									1				1
Sustainable supply from coastal lakes		1	3	2					0.5				4.5
Increased capacity of the Thukela-Mhlathuze Transfer Scheme Ph 1		1	2	1	0.75	0.5	1.5	1.5	2				8.75
Increased capacity of the Thukela-Mhlathuze Transfer Scheme Ph 2		1	1.5	1	0.75	1	1.5	1.5	2.5				8.75
Thukela-Mhlathuze Transfer Scheme Ph 1 + Ph 2		1	2.5	1	0.75	1	1.5	2	3				10.75
Increased capacity of the Thukela-Mhlathuze Transfer Scheme Ph 3		1	1	1	0.75	1.5	1.5	1	2.5				7.75
Coastal pipeline from the lower Thukela River (20Mm^3/a))		1	1.75	1	0.75	0.5	1.5	1.5	2				8.5
Coastal pipeline from the lower Thukela River (40Mm^3/a)		1	1.75	1	0.75	1.5	1.5	2	2				9
Mfolozi River on-channel transfer scheme: Kwesibomvu Dam		1	2	2	0.75	1.5	1.5	2	3	0	1	9.25	10.25
Mfolozi River off-channel transfer scheme		1	1.75	1.75	0.75	1.5	1.5	2	2.5	0	1	8.5	9.5
Raising Goedertrouw Dam		1	0.5	0	0.75	0.5	0.5	0.5	1.25				4.5
Dam on the Nseleni River		1	1.5	1.5	0.75	1.5	1.5	1.5	2.25	0	1	7.5	8.5
Groundwater scheme	0.75	0.75	1.5	1	0.75	1.5	1.5	2	1.25				8.5
Arboretum Effluent Reuse Scheme		0.75	0.75	0	0.75	1	1.5	1	1.75				6.5
Desalination of seawater Ph 1		0.75	2	0	0.75	1	1.5	1	1.75				7.75
Desalination of seawater, Ph 2 & further phases		0.75	1	0	0.75	1	1	0.75	1.5				5.75
Desalination of seawater double size Ph 1		0.75	2	0	0.75	1	1.5	1.25	2.25				8.5
Desalination of seawater, double size, Ph 2 & further phases		0.75	1	0	0.75	1	1	1	2.5				7
Thukela-Mhlathuze Transfer Scheme Ph 1 Fast Track		0.25	1.25	1	0.25	1	1	1.25	2				6
Coastal pipeline from the lower Thukela River (20Mm^3/a) Fast Track		0.25	1	1	0.25	0.5	0.75	1	1.75				5
Mfolozi River off-channel transfer scheme Fast Track		0.75	1.25	1.25	0.5	1	1	1.5	2	0	1	6	7
Desalination of seawater Ph 1 Fast Track		0.5	1.5	0	0.25	1	1	0.75	1.5				5.5
Desalination of seawater Ph 1 + Ph 2 Fast Track		0.5	1.5	0	0.25	1	1	1	1.75				6

3.5 Potential Medium Term Shortfall in Supply

Figure 3.1 illustrates a hypothetical water balance scenario over the strategy period (up to 2040) for the High Growth water requirements scenario. In this scenario all the potential more significant interventions (i.e. Thukela Middledrift transfer scheme, Lower Thukela Coastal 55Ml/d pipeline, Desalination and Mfolozi Off-Channel Dam transfer scheme) are shown should they all be *implemented as soon as possible*, ***but not fast-tracked***, in addition to the baseline interventions (also shown implemented as soon as possible).

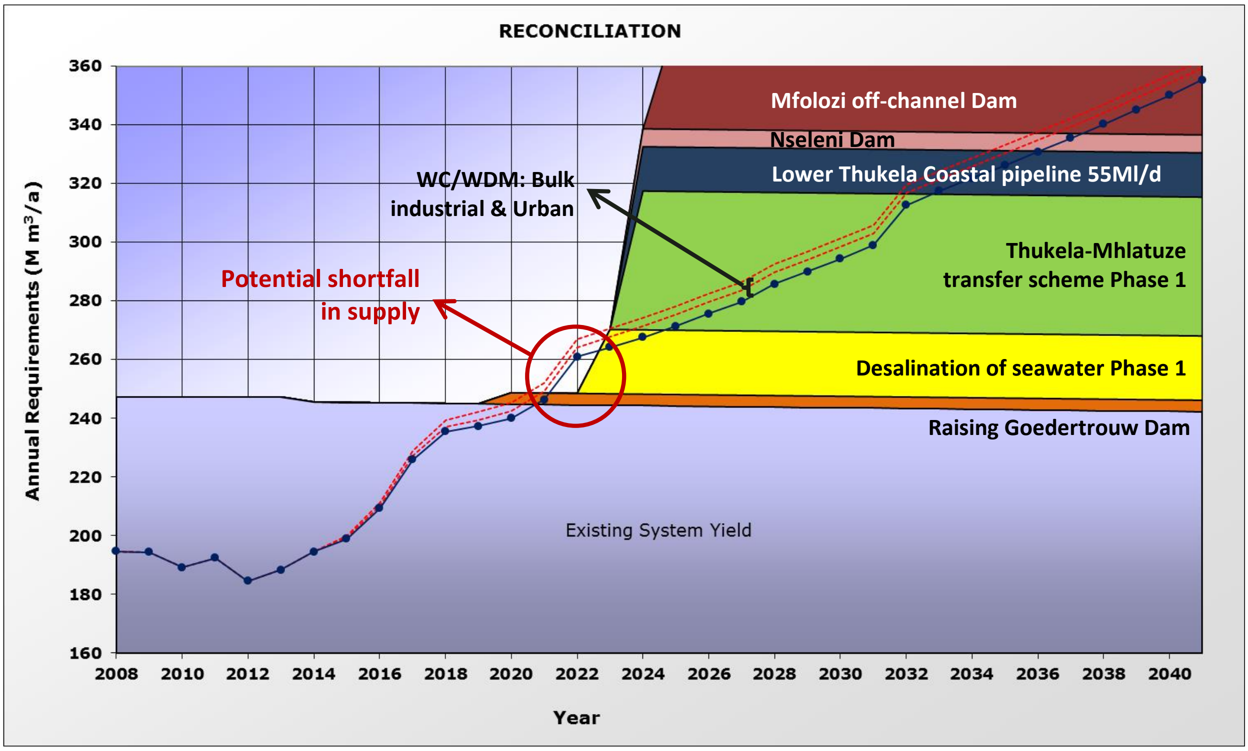


Figure 3.1: Graphic illustration of Early Implementation of Significant Schemes Scenario

It is evident that, due to the implementation programmes of the interventions, it is not possible to implement schemes in time to avert a shortfall occurring, should such high growth in water requirements be experienced. It follows that it would be advisable to consider the **fast-tracking** of one or more significant schemes in the short term to medium term, to avert or at least reduce a shortfall in supply and placing the users of the Richards Bay WSS at risk.

4 Evaluation of selected scenarios

4.1 Reconciliation Planning Support Tool

4.1.1 The need for a reconciliation planning support tool

The selection of projects, either to be studied further or to be implemented, to reconcile water availability with growing water demands, is a complex task, with many diverse issues and criteria to consider. The need for a customised planning tool, to provide support to water managers for this task, was identified during the Western Cape Reconciliation Strategy Study. To meet this need, a Reconciliation Planning Support Tool (RPST) was developed by Aurecon to assist the reconciliation planning process.

The RPST allows the user to compare potential projects, or groups of projects, with one another, and with one or more selected future water demand scenarios. The purpose of this Tool is to provide graphical interactive support, to assist managers in planning how best to meet future water demands from small or large systems. It facilitates the selection of a suite of potential interventions, for a particular water requirement curve and/or for a particular scenario, which is being evaluated, to ensure a future system water balance.

The RPST was customised for the Richards Bay WSS, to undertake scenario planning and to determine the implementation dates of interventions for the selected scenarios. The output from the RPST was used to guide the system modelling with the WRPM that followed.

4.1.2 Overview of the Tool

Information is imbedded in the Tool, including various future water demand scenarios, the current system yield, scheme implementation programmes and scheme yields. The Tool is run in Excel, with Visual Basic macro-programmes. It is interactive, and the user can adjust all input data. The Tool graphically shows when decisions regarding investigations for selected interventions need to be taken to achieve a water balance. It also shows the time-related implementation programmes, the effects of e.g. WC/WDM projects in reducing future water demands and the increases in system yield provided by selected interventions. Output from the Tool graphically shows when decisions to study selected projects need to be taken to achieve a water balance, in order to implement demand management measures, or to make the yield from a new source available, by a certain date (year).

4.2 WRYM / WRPM Evaluation of scenarios

4.2.1 WRYM and WRPM

The *Water Balance Report* of this study describes the updating of the detailed WRYM of the Richards Bay WSS. The model was updated with the latest estimates for industrial and urban water use for the Richards Bay WSS as reported in the *Water Requirements Report* of this study. In addition the estimated irrigation use was amended according to the latest estimates. The WRYM was further updated to incorporate the final configurations of potential interventions.

The Water Resources Planning Model (WRPM) obtained from the study "*Mhlathuze Catchment - Modelling Support for Licensing Scenarios"* was also updated with the latest estimates for irrigation, industrial and urban water use for the strategy area.

These models were then used to verify initial intervention implementation dates for water balance scenarios. The WRYM and WRPM are both network models that model the following features of the water resources of a given system:

- Inflow hydrology (both historical and stochastic),
- Dam storage capacities and initial storage conditions,
- Network linkages and conveyance constraints,
- Operating rules using "penalties" to prioritise sources and demands.

In addition, the WRPM has been enhanced to simulate system operation, including:

- The growth of water requirements over time,
- The addition of new bulk water infrastructure,
- The inclusion of an annual allocation routine which allows the curtailment of each demand type during droughts according to different reliability classification tables.

The WRPM enables planners to model the impact of interventions (reduction of demand or additional schemes) when the frequency of curtailment exceeds acceptable limits.

4.2.2 Annual allocation in the WRPM

At least once a year, the annual allocation model is run and uses the current storage of the system to assess whether the current demands on the system can be met or whether the less essential demands need to be curtailed to meet the demand. For the Mhlathuze catchment this allocation decision is made around the 1st of May, after the rainy season and prior to the dry winter period. The available supply from the system is assessed prior to the decision date by simulating the behaviour of the system under different initial storage conditions, under say 1000 alternative stochastic inflow sequences. On the decision date, the results from the closest set of initial storage conditions are used to estimate the behaviour for the initial conditions on the decision date.

The demands on the system are categorised into different reliability classes, as can be seen in
Table 4.1 which was used in the *Mhlathuze Catchment: Modelling Support for Licensing Scenarios* Study. According to the table 50% of the irrigation can be curtailed once every four years and all irrigation can be curtailed completely once every 50 years. Also, 40% of the urban demand can be curtailed every twenty years. These criteria may be difficult to achieve in practice.

Table 4.1: Assurance of supply criteria from the Licensing Scenario Study

Water use sector	% demand at indicated risk of failure				
	1 in 200 years	1 in 100 years	1 in 50 years	1 in 20 years	1 in 4 years
	0.5%	1%	2%	5%	25%
Irrigation			50%		50%
Urban	30%	30%		30%	10%
Industrial 1 (1)	70%	20%		10%	
Industrial 2	90%	10%			

From the "Mhlathuze Catchment - Modelling Support for Licensing Scenarios" study
(1) Tongaat Hulett irrigators

It is useful to illustrate the effect of curtailment on the irrigation water requirements in the Mhlatuze catchment. The analyses are based on a monthly simulation of 1000 sequences over the simulation period from 2015 to 2040.

In the Mhlathuze catchment releases are made from the Goedertrouw Dam for users downstream. It is intended that the irrigators receive their water at a lower reliability than the industrial users. In practice many of the irrigation pumps are located upstream of the industrial consumers. Unless management measures to curtail the abstraction by irrigators during a drought are effective there is a risk that some water released for industrial and urban use will be intercepted. The augmentation dates from the WRPM assume effective curtailment management measures of all consumer demands and should this not be achieved the augmentation dates will be considerably earlier. Indications are however that the Mhlatuze catchment irrigators are very effectively curtailing their water demand during the current drought.

According to the WRYM analysis, the system can supply 106.6 million m^3/a to urban/industrial consumers and an *average* of 88.5 million m^3/a to irrigation giving a total supply of 195.1 million m^3/a.

Allowance has been made for a continuous reduction in yield as a result of the decreasing storage in Goedertrouw Dam due to sedimentation.

4.2.3 WRPM Scenarios and Results

A number of WRPM scenarios were analysed to determine the implementation date for the next augmentation scheme for the Mhlatuze WSS:

- The “medium” and “high” demand” water use projections,
- Implementing baseline interventions (urban and industrial WC/WDM and the raising of Goedertrouw Dam by 2.8m to counteract the effect of ongoing siltation of the storage),
- Implementing a transfer of 1.5m^3/s from the Thukela River (Phase 1),
- Starting with current (2015) storage conditions equating to 45% storage in Goedertrouw Dam as opposed to starting full.

The detailed curtailment plots results are presented in Annexure A. According to these results, the medium growth scenarios require augmentation by 2022. The high growth scenarios require augmentation by 2020.

4.3 Updated potential future shortfall in water supply

For a *curtailed* system yield of 247.3 million m^3/a, the potential shortages in water supply by 2040 are as indicated in Table 4.2.

Table 4.2: Potential shortfall by 2040 for various water requirements scenarios

Water Requirement Scenario	Water requirement (million m^3/a)	Potential shortfall (million m^3/a)
Scenario 1: Low growth	244.4	2
Scenario 2: Low-Medium growth	267.8	23
Scenario 3: Medium growth	298.4	56
Scenario 4: High growth	356.9	115

The 12 scenarios selected for further assessment are discussed in the following sections.

4.4 Scenario 0: Baseline

This scenario demonstrates that the baseline scenario that forms the basis for most of the remainder of the scenarios comprises of four attractive small interventions with limited yields, as shown relative to future water requirement curves in Figure 4.1. The Nseleni Dam could be implemented later than shown in this scenario, should a large scheme be implemented in the medium term.

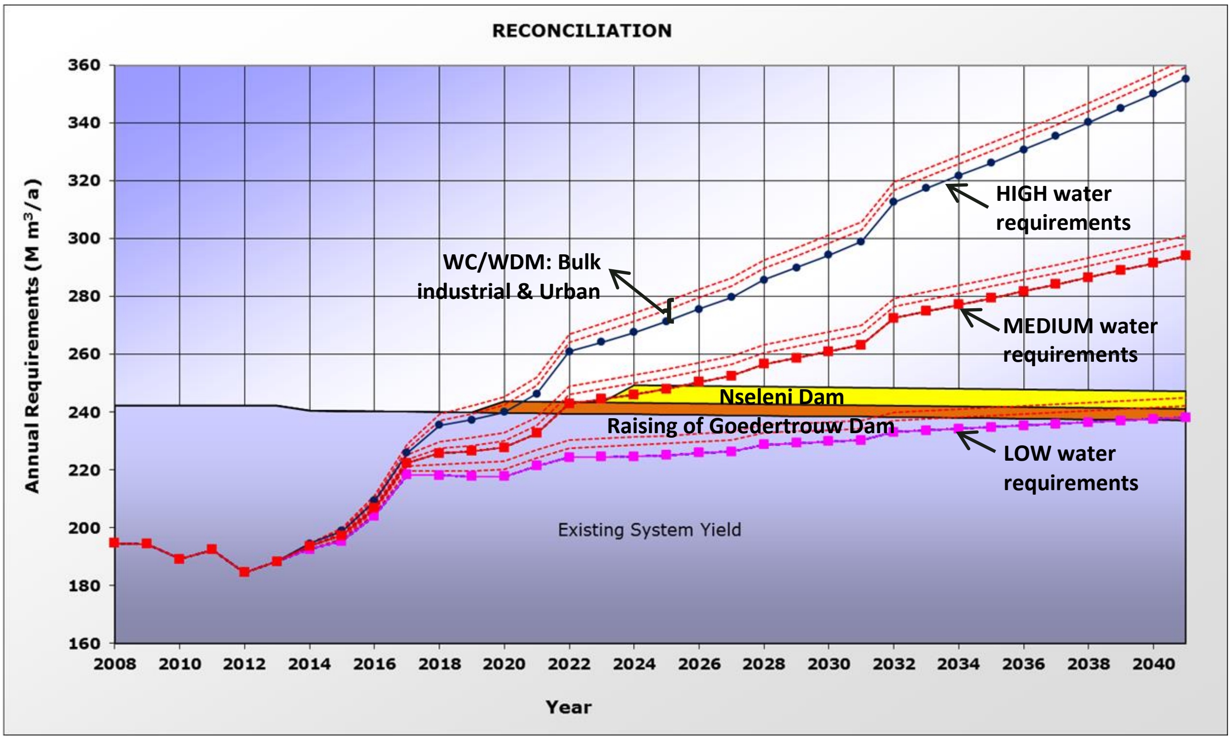


Figure 4.1: **Baseline Scenario**

The interventions of this scenario are shown in Table 4.3.

Table 4.3: **Baseline interventions**

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4.0	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2021	3.9	4.5
1 MAR dam on the Nseleni River	2024	7.0	8.5

It is evident that these interventions do not go a very long way towards meeting the potential shortfall in water supply should high growth in water requirements materialise, although they will help to reduce the shortfall.

4.5 Scenario 1: Low Growth future water requirements

This scenario demonstrates that the shortfall can easily be met by effective industrial and urban WC/WDM as shown in Figure 4.2.

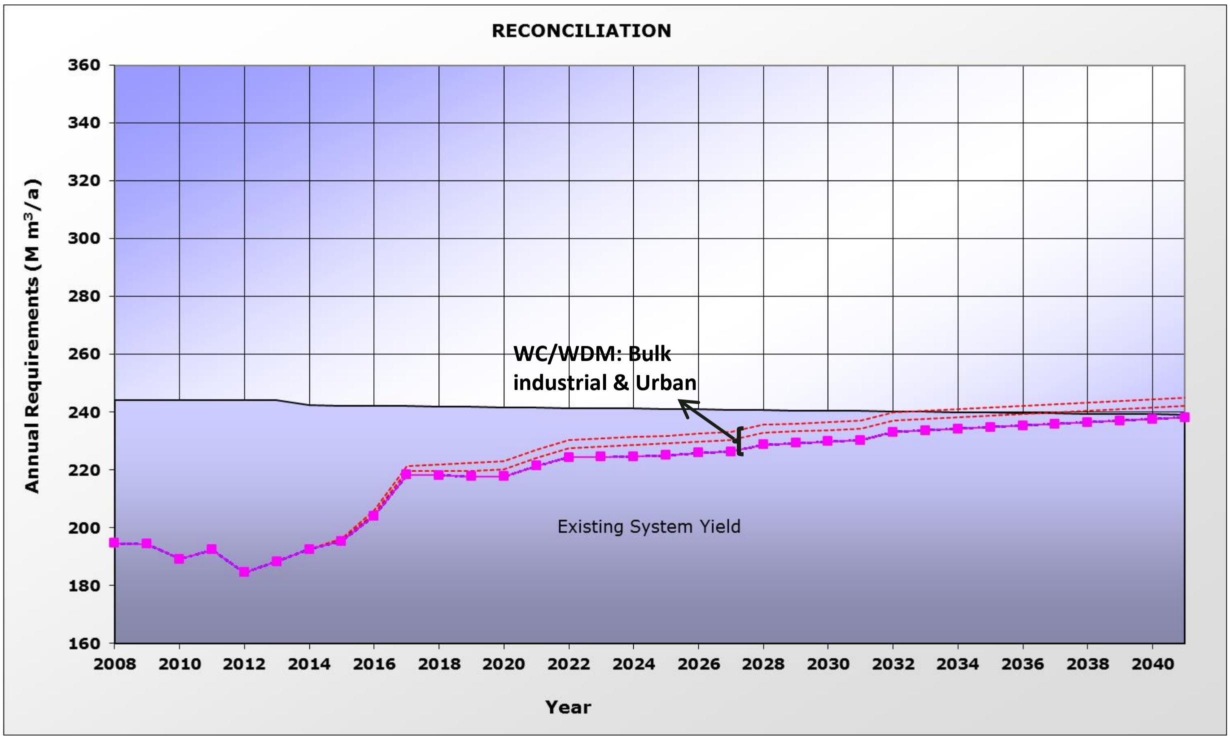


Figure 4.2: **Scenario 1 water balance**

The interventions of this scenario are shown in Table 4.4.

Table 4.4: **Scenario 1 interventions**

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4	0
Bulk industrial WC/WDM	2015	2.8	0

4.6 Scenario 2: Medium Growth future requirements, theme Mfolozi Fast Track

This scenario demonstrates that the shortfall can easily be met by the implementation of one significant scheme – it could be alternate schemes as well, and the medium-term benefit of fast-tracking the first significant scheme is further demonstrated, as shown in Figure 4.3.

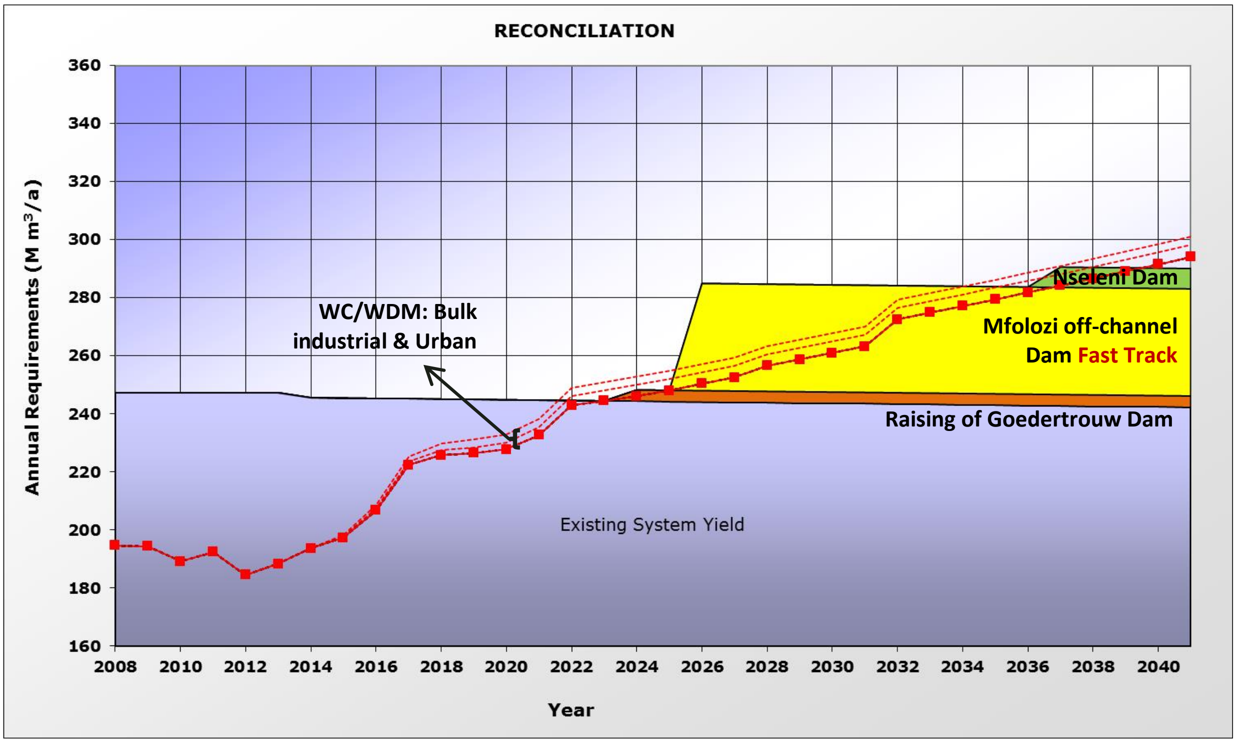


Figure 4.3: Scenario 2 water balance

The interventions of this scenario are shown in Table 4.5.

Table 4.5: Scenario 2 interventions

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4.0	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2024	3.9	4.5
Mfolozi River off-channel transfer scheme Fast Track	2026	36.9	7
1 MAR dam on the Nseleni River	2037	7.0	8.5

4.7 Scenario 3: High Growth future requirements, theme No Thukela

This scenario demonstrates how the shortfall can be met without using water from the Thukela River, as shown in Figure 4.4.

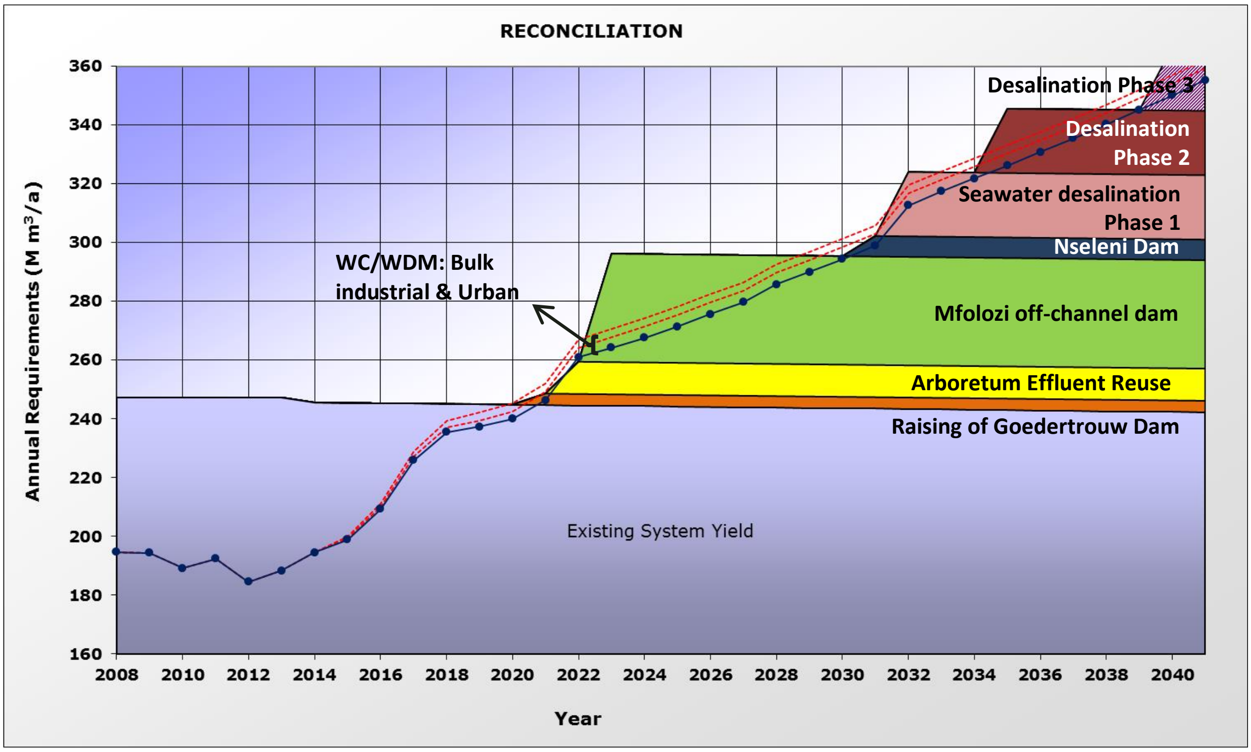


Figure 4.4: **Scenario 3 water balance**

The interventions of this scenario are shown in Table 4.6. The importance of seawater desalination interventions in this scenario is evident. The order in which the implementation of schemes are shown are less important than the principle being illustrated; i.e. that it is possible to ensure a future water balance without using further water from the Thukela River.

Table 4.6: **Scenario 3 interventions**

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4.0	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2021	3.9	4.5
Arboretum Effluent Reuse Scheme	2022	10.95	6.5
Mfolozi 78Mm^3 capacity off-channel Dam with 2.5m^3/s transfer rate to Nsezi WTW	2023	36.9	9.5
1 MAR dam on Nseleni River	2031	7.0	8.5
Desalination of seawater Phase 1	2032	21.9	7.75
Desalination of seawater Phases 2 and 3	2035	21.9 per phase	5.75 per phase

4.8 Scenario 4: High Growth future requirements, theme Non-Conventional sources only

This scenario demonstrates how, apart from the small baseline interventions, the shortfall can be met by only non-conventional sources (no implementation of surface water interventions) as shown in Figure 4.5. The importance of seawater desalination interventions in this scenario is evident, as other non-conventional sources are limited.

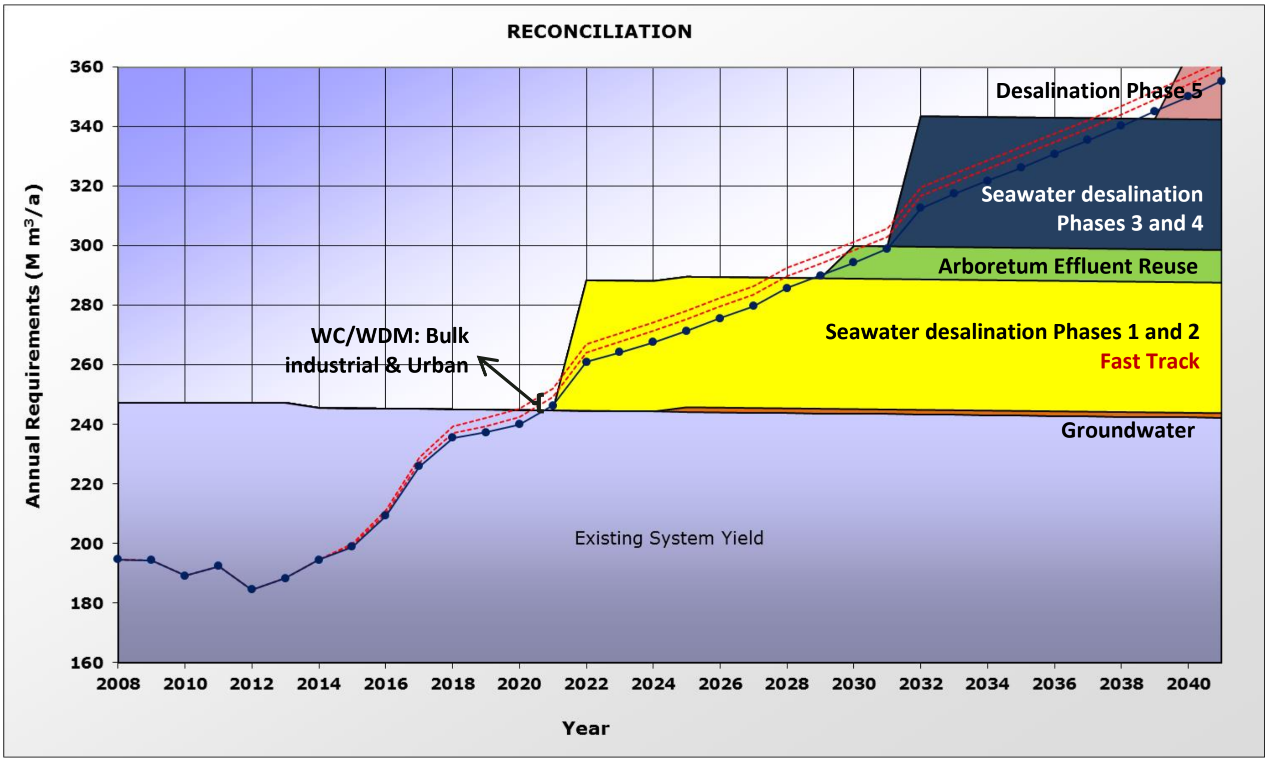


Figure 4.5: Scenario 4 water balance

The interventions of this scenario are shown in Table 4.7.

Table 4.7: Scenario 4 interventions

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4	0
Bulk industrial WC/WDM	2015	2.8	0
Desalination of seawater Ph 1 + Ph 2 Fast Track	2022	43.8	6
Groundwater scheme, combined 3 schemes	2025	1.55	8.5
Arboretum Effluent Reuse Scheme	2030	10.95	6.5
Desalination of seawater further phases	From 2032	21.9 per phase	5.75 per phase

4.9 Scenario 5: High Growth future requirements, theme Worst Case

This scenario demonstrates how the shortfall can be met in the worst-case scenario, i.e. high-growth water requirements, whilst in addition taking the worst possible influence of climate change into account. The reconciliation of future water supply options for Richards Bay for the Worst Case Scenario is given in Figure 4.6.

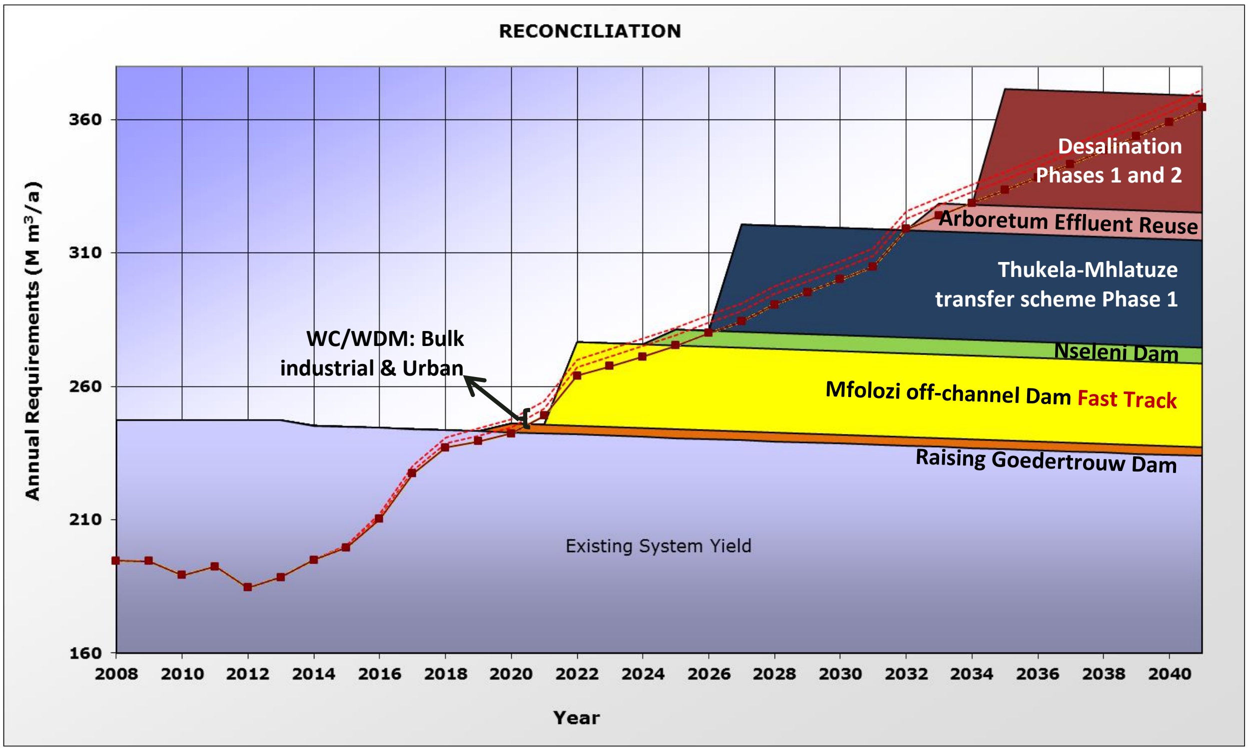


Figure 4.6: Scenario 5 (Worst Case) water balance

The interventions of this scenario are shown in Table 4.8.

Table 4.8: Scenario 5 (Worst Case) Interventions

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4.0	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2020	3.3	4.5
Mfolozi River off-channel transfer scheme Fast Track	2022	31.4	7
1 MAR dam on Nseleni River	2025	5.95	8.5
Thukela-Mhlathuze Transfer Scheme Phase 1	2027	40.2	8.75
Arboretum Effluent Reuse Scheme	2033	10.4	6.5
Desalination of seawater Ph 1 + Ph 2	2035	43.8	8.5

The results of this scenario suggest that at least one significant intervention is needed as soon as it can be implemented – the fast-tracked Mfolozi River Off-channel Transfer Scheme has been used as example. An additional intervention will be required compared to when climate change is not taken into account. This is needed as a result of the assumed decline in the yield of the existing water supply system, increased irrigation demand as well as the potential reduction in yield of the potential surface water interventions.

4.10 Scenario 6: High Growth future requirements, theme Fast Tracking of the Mfolozi transfer scheme

This scenario demonstrates how fast tracking of the implementation of the Mfolozi off-channel scheme improves the water balance in the medium term, as shown in Figure 4.7, by implementing the scheme earlier.

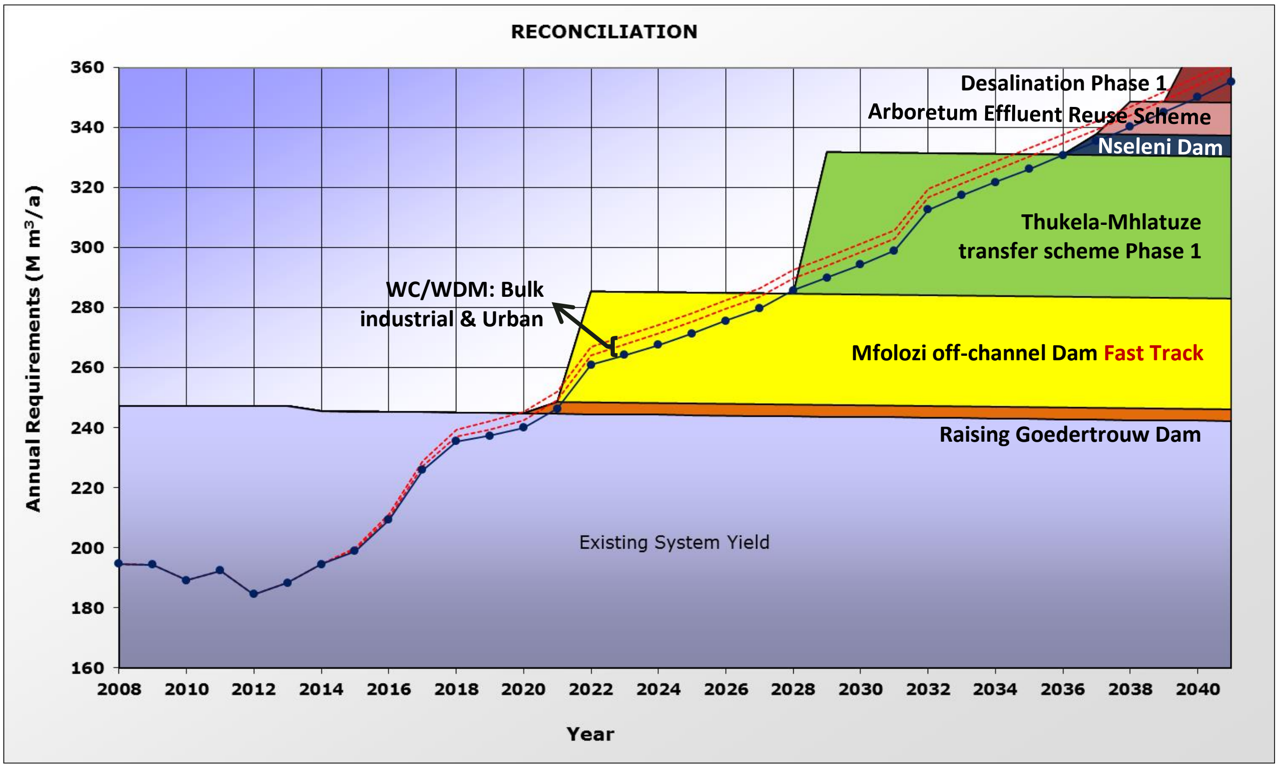


Figure 4.7: Scenario 6 water balance

The interventions of this scenario are shown in Table 4.9.

Table 4.9: Scenario 6 interventions

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2021	3.9	4.5
Mfolozi River off-channel transfer scheme Fast Track	2022	36.9	7
Thukela-Mhlathuze Transfer Scheme Phase 1	2029	47.3	8.75
1 MAR dam on Nseleni River	2037	7.0	8.5
Arboretum Effluent Reuse Scheme	2038	10.95	6.5
Desalination of seawater Phase 1	2040	21.9	7.75

4.11 Scenario 7: High Growth future requirements, theme Fast Tracking of Desalination

This scenario demonstrates how fast tracking of a (larger) desalination scheme improves the water balance in the medium term in Figure 4.8.

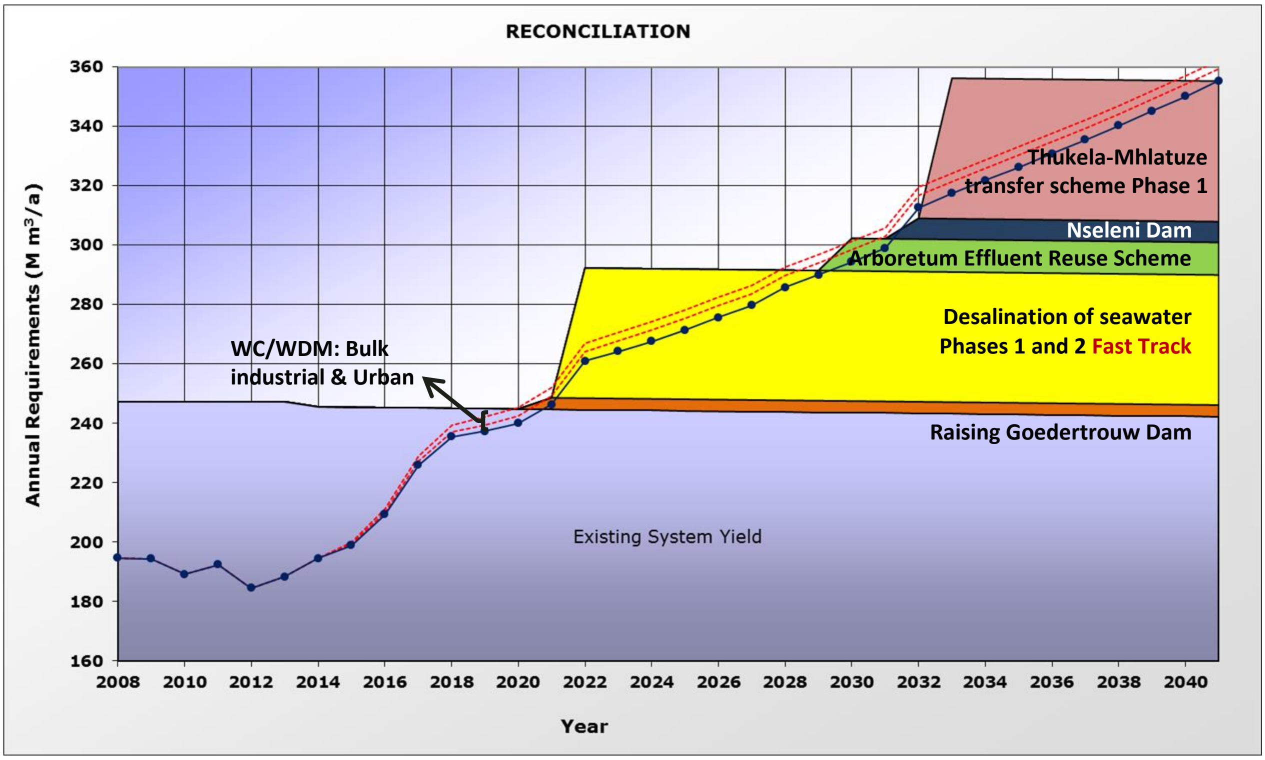


Figure 4.8: Scenario 7 water balance

The interventions of this scenario are shown in Table 4.10.

Table 4.10: Scenario 7 interventions

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2021	3.9	4.5
Desalination of seawater Phases 1 and 2 Fast Track	2022	43.8	6
Arboretum Effluent Reuse Scheme	2030	10.95	6.5
1 MAR dam on Nseleni River	2032	7.0	8.5
Thukela-Mhlathuze Transfer Scheme Phase 1	2033	47.3	8.75

4.12 Scenario 8: High Growth future requirements, theme Fast Tracking of the Thukela Middledrift transfer scheme

This scenario demonstrates how fast tracking of the Thukela Middledrift Phase 1 scheme improves the water balance in the medium term, as shown in Figure 4.9.

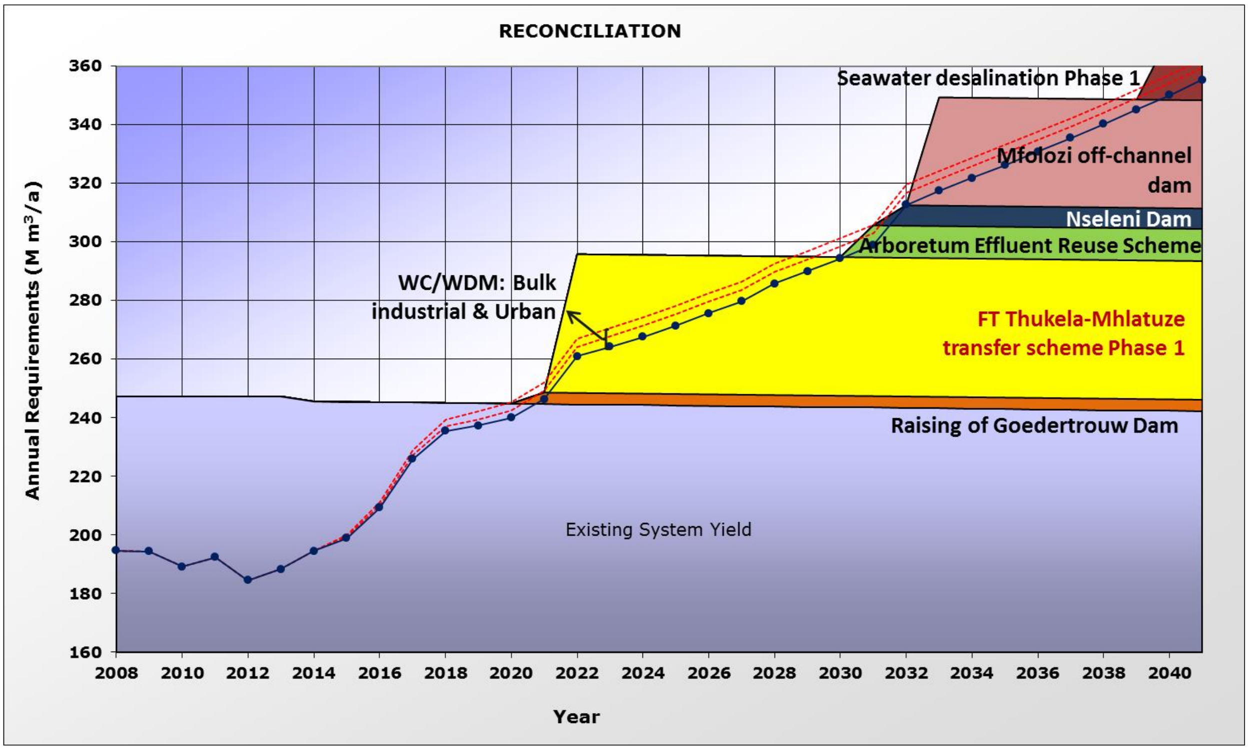


Figure 4.9: Scenario 8 water balance

The interventions of this scenario are shown in Table 4.11.

Table 4.11: Scenario 8 interventions

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2021	3.9	4.5
Thukela-Mhlathuze Transfer Scheme Phase 1 Fast Track	2022	47.3	6
Arboretum Effluent Reuse Scheme	2031	10.95	6.5
1 MAR dam on Nseleni River	2032	7.0	8.5
Mfolozi 78Mm^3 capacity off-channel Dam with 2.5m^3/s transfer rate to Nsezi WTW	2033	36.9	9.5
Desalination of seawater Phase 1	2040	21.9	7.75

4.13 Scenario 9: High Growth future requirements, theme Fast Tracking of the Thukela Coastal transfer scheme

This scenario demonstrates how fast tracking of the Thukela 55 Mℓ/d Coastal scheme improves the water balance in the medium term as shown in Figure 4.10. This assumes that the Thukela Phase 1 scheme may then no longer be an option to consider – this is currently uncertain and needs to be confirmed.

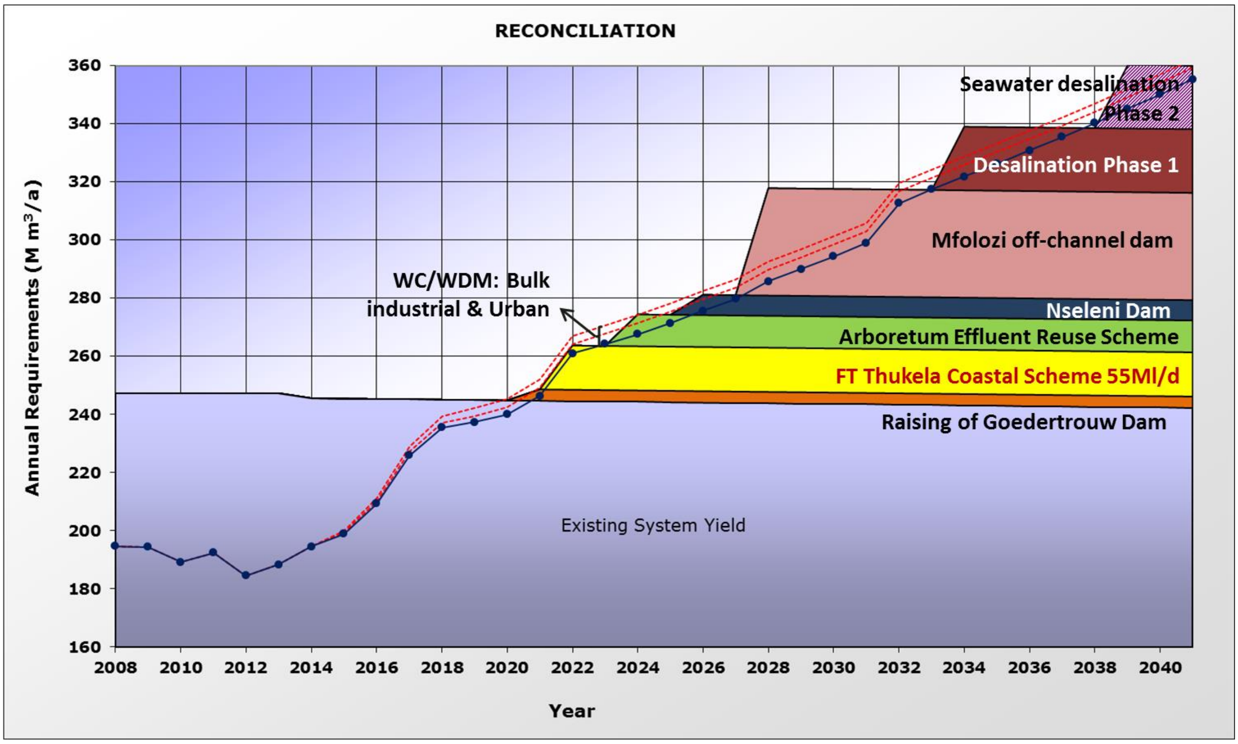


Figure 4.10: Scenario 9 water balance

The interventions of this scenario are shown in Table 4.12.

Table 4.12: Scenario 9 interventions

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2021	3.9	4.5
Thukela River Coastal pipeline (55Ml/d) Fast Track	2022	15.2	5
Arboretum Effluent Reuse Scheme	2024	10.95	6.5
1 MAR dam on Nseleni River	2026	7.0	8.5
Mfolozi 78Mm^3 capacity off-channel Dam with 2.5m^3/s transfer rate to Nsezi WTW	2028	36.9	9.5
Desalination of seawater Phase 1	2034	21.9	7.75
Desalination of seawater Phase 2	2039	21.9	5.75

4.14 Scenario 10: High Growth future requirements, theme Early Large Desalination with revised Baseline

This scenario demonstrates a revised Baseline with early introduction of a large seawater desalination scheme in Figure 4.11. This scenario shows similarities with Scenario 7.

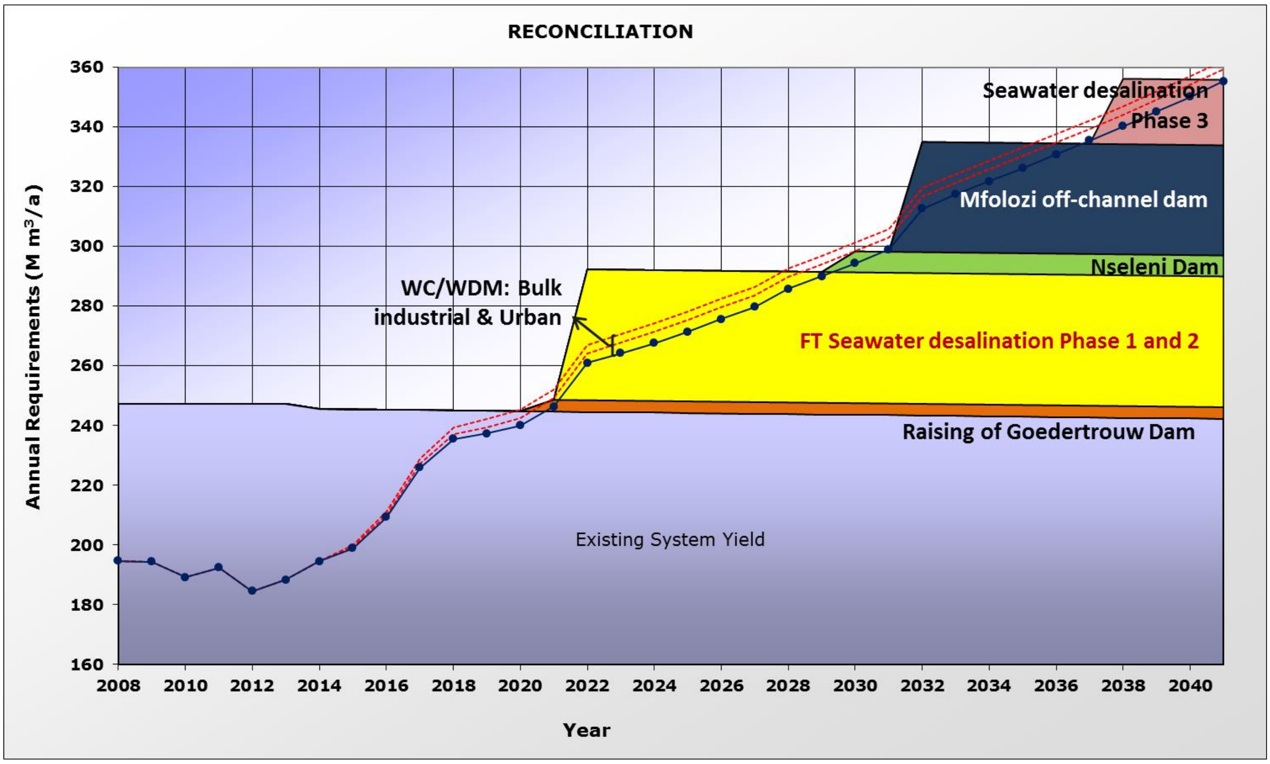


Figure 4.11: Scenario 10 water balance

The interventions of this scenario are shown in Table 4.13.

Table 4.13: Scenario 10 interventions

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2021	3.9	4.5
Desalination of seawater Phases 1 and 2 Fast Track	2022	43.8	6
1 MAR dam on Nseleni River	2030	7.0	8.5
Mfolozi 78Mm^3 capacity off-channel Dam with 2.5m^3/s transfer rate to Nsezi WTW	2032	36.9	9.5
Desalination of seawater Phase 3	2038	21.9	5.75

4.15 Scenario 11: High Growth future requirements, theme Early Large Desalination plus surplus storage in Large Nseleni Dam

This scenario (Figure 4.12) demonstrates the early introduction of a large seawater desalination scheme, with storage of surplus Mfolozi water in a larger (1.5MAR) Nseleni Dam. This scenario only differs from Scenario 10 in terms of the additional yield obtained from the larger Nseleni Dam plus additional yield obtained from storage of transferred additional 'surplus' water from the Mfolozi River to support and potentially store water in the larger Nseleni Dam.

Increasing the abstraction capacity from the Mfolozi River (for the 78 million m^3 off-channel dam) from 2.5 m^3/s to 5 m^3/s could potentially provide an additional 12.7 million m^3/a of water that can either be transferred to a 1.5 MAR Nseleni Dam for storage (or would alternatively be available for direct transfer to the Nsezi WTW). The additional yield is a portion of this, when operating rules are considered. Transfer of 'surplus' Mfolozi water to the Nseleni Dam for storage will however be extremely expensive, and is not considered worthwhile. This does however illustrate that the yield from an off-channel dam could potentially be further increased by increased river abstraction rates.

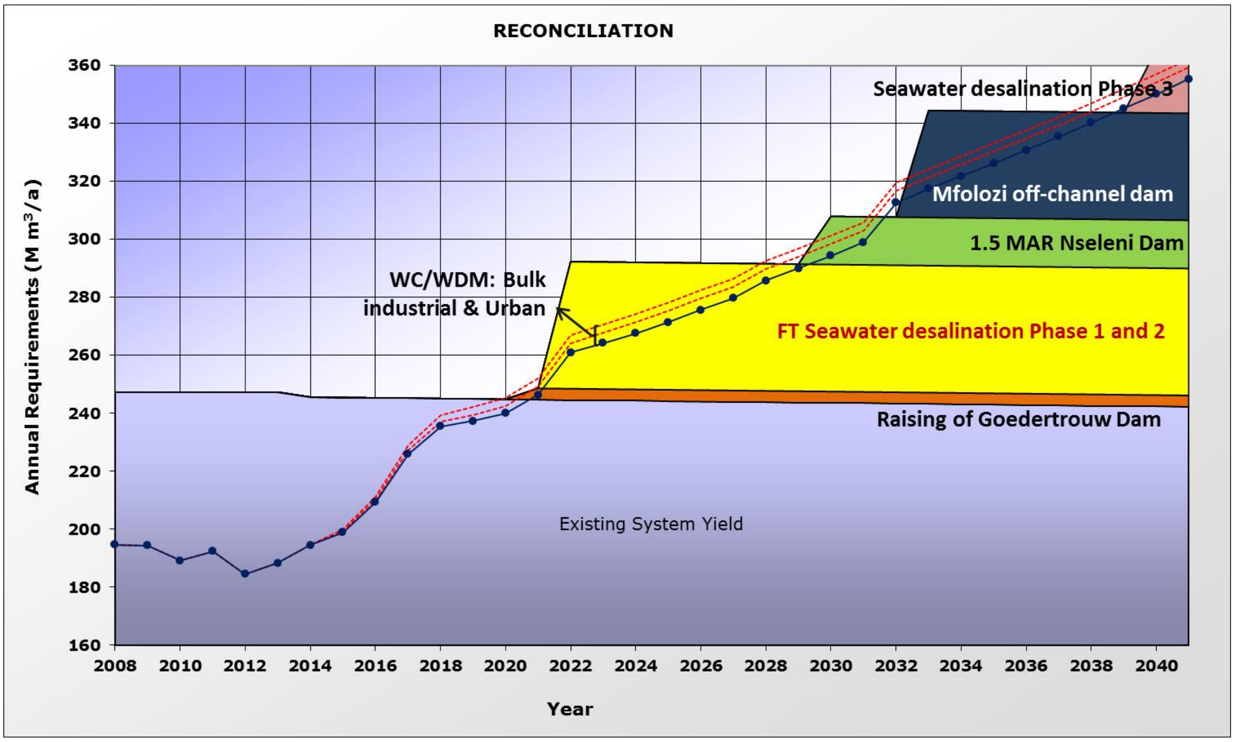


Figure 4.12: Scenario 11 water balance

The interventions of this scenario are shown in Table 4.14.

Table 4.14: Scenario 11 interventions

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2021	3.9	4.5
Desalination of seawater Phases 1 and 2 Fast Track	2022	43.8	6
1.5 MAR dam on the Nseleni River	2030	16.6	9
Mfolozi 78Mm^3 capacity off-channel Dam with additional transfer (>2.5 m^3/s) to Nseleni Dam	2033	36.9	9.5
Desalination of seawater Phase 3	2040	21.9	5.75

4.16 Scenario 12: High Growth future requirements, theme Only Thukela

This demonstrates a scenario where only Thukela Middledrift transfer schemes are considered in addition to the baseline interventions, as shown in Figure 4.13.

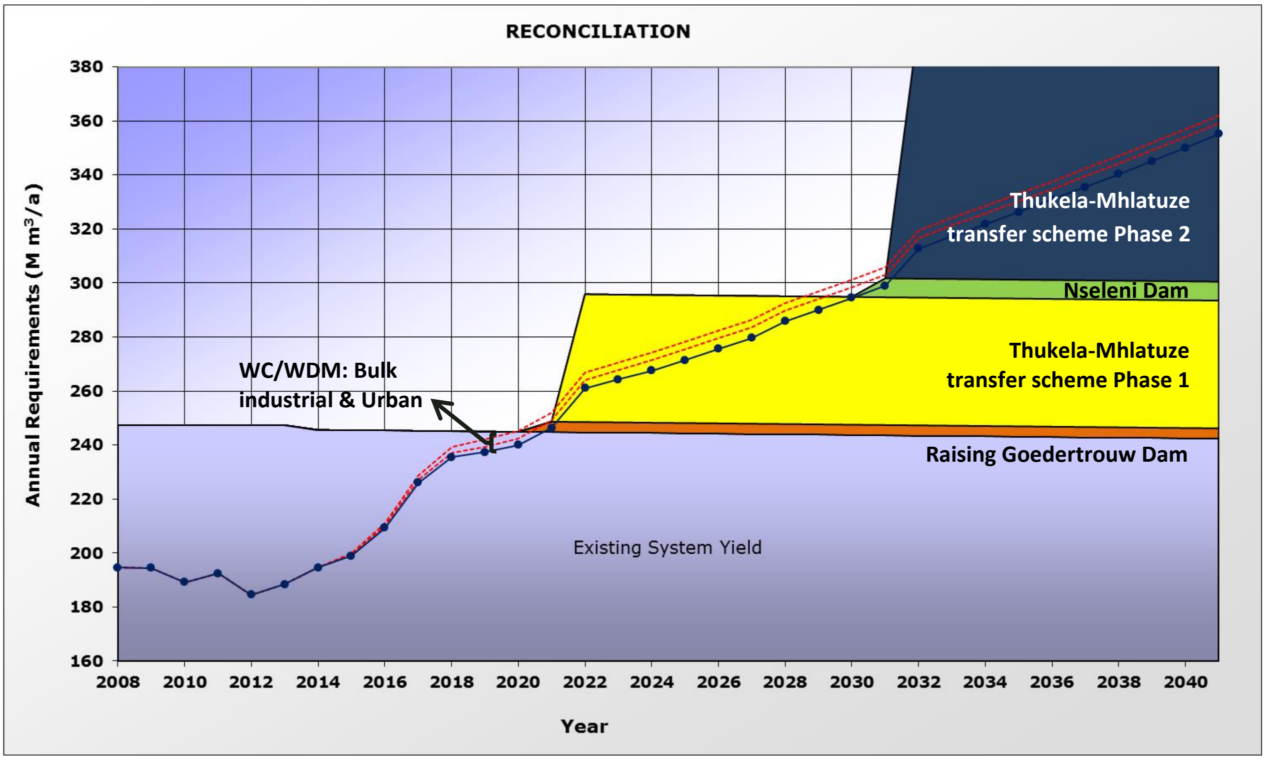


Figure 4.13: Scenario 12 water balance

The interventions of this scenario are shown in Table 4.15.

Table 4.15: Scenario 12 interventions

Intervention	Year of First Water or Saving	Yield	Total Lead Time
Urban WC/WDM	2015	4.0	0
Bulk industrial WC/WDM	2015	2.8	0
Raising Goedertrouw Dam	2021	3.9	4.5
Thukela-Mhlathuze Transfer Scheme Ph 1 Fast Track	2022	47.3	6
1 MAR dam on Nseleni River	2031	7.0	8.5
Thukela-Mhlathuze Transfer Scheme Ph 2	2032	94.6	8.75

5 Conclusions

The most important observations and lessons learnt from the scenario assessment are:

a. Scenario planning was done to determine the potential implementation dates of interventions for selected water balance scenarios within the strategy evaluation period, from now up to 2040, to avoid a shortfall in water supply within the Richards Bay WSS.

b. The WRYM and WRPM were updated for the strategy area to incorporate the potential interventions, and were used to confirm water balance shortfall dates. Interventions are required when the frequency of curtailment in accordance with the assurances of supply for the various user groups exceed acceptable limits.

c. The WRPM indicated that the next intervention is required by 2020 (should WC/WDM interventions not yet be implemented) for high growth in future water requirements and by 2022 for medium growth in future water requirements. Concern was expressed about the practical implementability of urban water use curtailment for the 1:20 years and 1:4 years risk of failure and it is recommended that urban use assurance of supply should be revisited.

d. A reconciliation (water balance) planning tool was set up for the Richards Bay WSS and was populated to assist with reconciliation evaluations and graphic presentation of water balance situations.

e. The more favourable interventions or groups of interventions that could potentially be implemented to meet the potential future supply shortfalls for the various future water requirement scenarios was identified, as well as when such interventions should be implemented.

f. Planning for the implementation of bulk water supply infrastructure within the strategy evaluation period (up to 2040) was done to meet future water use estimations / scenarios, and not to future water allocation scenarios.

g. Four small attractive options have been identified that can provide smaller yields to increase the water availability of the region. These so-called *baseline* interventions, which are recommended for all water balance scenarios are:

   - *Bulk industrial WC/WDM* initiatives should continue and water efficiency should be improved.
   - *Urban WC/WDM* initiatives should continue and water efficiency should be improved.
   - The *raising of Goedertrouw Dam* seems very promising as it can be implemented fairly quickly, apart from being very cost effective. It appears beneficial to a get a feasibility study underway as soon as possible.

- A *new dam on the lower Nseleni River* would be beneficial from a cost perspective. It could further offer operational benefits, but could likely not be implemented quickly. It appears beneficial to a get a feasibility study underway as soon as possible.

h. Should low growth in future water requirements realise in the long-term, scenario evaluation demonstrates that the shortfall can be met by improved water efficiency.

i. Should medium growth in future water requirements realise in the long-term, scenario evaluation demonstrates that the shortfall can be met by the implementation of one significant bulk water supply scheme, in addition to the baseline interventions, and that there would be medium-term benefit to fast-track the first significant scheme to be implemented.

j. Should high growth in future water requirements realise in the long-term, scenario evaluation demonstrates that several bulk water supply schemes would need to be implemented over the strategy evaluation period, of which the first significant scheme to be implemented would need to be fast-tracked.

k. Three significant available schemes (that would make large quantities of water available) have been identified to meet the future water requirements of the Richards Bay WSS. These are:

   - A transfer scheme from an off-channel dam situated close to the Mfolozi River.
   - A transfer scheme/s from the Thukela River, either the Thukela Middledrift Phase 1 Scheme or the Lower Thukela 55Mℓ/d Coastal Pipeline, or
   - Seawater desalination, which can be appropriately sized and located as well as phased.

   All of these significant schemes will have long implementation times, even if it is possible to fast-track their implementation. Although each of these schemes have their respective strong and weak point, it is not yet clear which of these three schemes are preferable. The choice of project needs to be confirmed with higher resolution analysis, such as a pre-feasibility study.

l. The Arboretum Effluent Reuse Scheme is a medium-sized scheme that seems promising and should be compared with the three promising significant schemes. This scheme has already been evaluated at 'feasibility' level, although all the aspects of the full scheme were not addressed. The full scheme should be evaluated and compared with the three significant schemes at pre-feasibility level.

m. There is still significant uncertainty regarding the potential influence of climate change on the WSS. Only the worst possible situation of climate change has been assessed, although climate change may even have a positive influence on the water balance. An adaptation approach to climate change is recommended until there is more clarity.

n. The reducing capacity of Goedertrouw Dam as a result of siltation has a negative influence on the yield of the WSS.

o. A national perspective on the likely future allocation of water from the Thukela River needs clarification, including the future availability and cost of Thukela River water for transfer to the Mhlatuze River.

6 References

1. Cullis J, Alton T, Arndt C, Cartwright A, Chang A, Gabriel S, Gebretsadik Y, Hartley F, De Jager G, Makrelov K, Robertson G, Schlosser A, Strzepek K, Thurlow J. (2015). *An uncertainty approach to modelling climate change risk in South Africa* United Nations University World Institute for Development Economics Research. WIDER Working Paper 2015/045

2. Cullis JDS, Strzepek K, Tadross M, Sami K, Havenga B, Gildenhuys B and Smith J (2011). "Incorporating climate change into water resources planning for the town of Polokwane, South Africa" *Climate Change* 108:437-456

3. De Jager G and Summerton M (2012). *Assessment of the Potential Impacts of Climate Change on the Long-Term Yield of Major Dams in the Mgeni River System* Report prepared for Umgeni Water. June 2012

4. Department of Environmental Affairs (2013). *Long term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Change Implications for the Water Sector In South Africa.* Pretoria, South Africa.

5. Department of Water Affairs, South Africa. (2012). "Climate Change Pilot Studies" Report prepared by Pegasys, Aurecon and UCT as part of the *Development of a National Climate Change Strategy* (DWA project No. WP10550)

6. Department of Water Affairs, South Africa. 2012. (2012) Mhlathuze Catchment: Modelling Support for Licensing Scenarios Study. Prepared by Seago, CJ of WRP

7. Department of Water Affairs, South Africa. 2009. Mhlathuze Water Availability Assessment Study. Systems Analysis. Prepared by WRP Consulting Engineers (Pty) Ltd in association with DMM Development Consultants CC, WSM Leshika (Pty) Ltd and Laubscher Smith Engineers. DWA Report No. PWMA 06/000/00/1007.

8. Department of Water and Sanitation, South Africa. 2014. Water Reconciliation Strategy for Richards Bay and Surrounding Towns. *Water requirements Report*. Prepared by Aurecon South Africa (Pty) Ltd as part of the Water Reconciliation Strategy for Richards Bay and Surrounding Towns.

9. Department of Water and Sanitation, South Africa. 2015. Water Reconciliation Strategy for Richards Bay and Surrounding Towns. Water Balance Report. Prepared by Aurecon South Africa (Pty) Ltd as part of the Water Reconciliation Strategy for Richards Bay and Surrounding Towns.

10. Department of Water and Sanitation, South Africa. 2015. Water Reconciliation Strategy for Richards Bay and Surrounding Towns. Evaluation of Options Report. Prepared by Aurecon South Africa (Pty) Ltd as part of the Water Reconciliation Strategy for Richards Bay and Surrounding Towns.

11. Gerber A, de Jager G and Strydom C (2011) *Development of a Practical Methodology for Assessing the Potential Impacts of Climate Change on the Yield Characteristics of Reservoirs.* WRC Report No KV 266/10, April 2011.

12. Mantel SK, Slaughter A, Hushes DA (2012) *Developing Climate Change adaptation measures and decision support system for selected South African water boards* WRC Report No.K5/2018/7

13. Mhlathuze Water. 2014. Mhlathuze Water Climate Adaptation Study: Background Technical Information Report, Draft 1. Prepared by WSP Environmental.

14. Mhlathuze Water. 2014. Preparing for the Future: Mhlathuze Water Climate Change Adaptation Strategy 2015 – 2020. Prepared by WSP Environmental and Mhlathuze Water.

Appendices

Appendix A Incorporating climate change

INCORPORATING CLIMATE CHANGE INTO WATER RESOURCES PLANNING IN SOUTH AFRICA: A CASE STUDY OF THE RICHARDS BAY RECONCILIATION STRATEGY STUDY

1. Background

It is now widely accepted that the global climate is changing and that a large part of this can be attributed to human impacts (IPPC 5th) and that water supply is considered to be one of the principal mechanisms for the realisation of climate change impacts on society (UN Water, 2010) due to the fact that water is directly related to changes in precipitation, temperature and evaporation. In addition, water is a fundamental requirement for life and critical to most, if not all, requirements for livelihood support, economic growth and development. Hence it is vital that climate change risks are considered in terms of water resource planning, particularly given the fact that the resulting water supply infrastructure is likely to be in operation for up to fifty years or more - by which stage any potential climate change impacts will have been realised and could impact on the sustainability of the system.

Out of necessity, however, South Africa has developed a high level of skills in water resources planning, where for example the use of stochastic time series simulations are used to design the bulk water supply to a high level of assurance of supply, typically around 98% assurance of supply to urban areas and 99.5% to key industries based on over eighty years of observed and simulated streamflow data (DWAF, 2004). Water supply for irrigation typically receives about 80% assurance of supply. This provides reliability in the system despite highly variable precipitation and streamflow.

In most catchments increasing water demands have already exceeded the availability of supply leading to even more expensive augmentation options (DWA, 2012). Climate change is likely to add additional stress to this system with potentially significant economic implications (DEA, 2011), but South Africa also has an active planning process for securing future supplies through augmentation options. Ensuring that climate change is incorporated into this planning process is critical to ensuring future sustainability of supply and support for economic development in South Africa (DWA, 2012).

A review of the impacts of climate change on the water sector in South Africa concluded that it was not all “doom and gloom” (Schulze, 2011). Due to variability in the impacts of climate change some areas of South Africa would most likely be “winners” while other areas and other sectors would be “losers”. Particular “hotspots” of concern primarily due to decreasing rainfall are the south west of the country, the West Coast and to a lesser extent the extreme north of the country. Even in areas considered to be winners due to increasing precipitation, there are potentially increases in risks due to increased intensity of rainfall events and associated water logging and flooding (Schulze, 2011).

Other studies of the potential impacts of climate change on future water supply have focused on individual systems including the water supply to Polokwane (Cullis et al, 2010), the uMgeni catchment

(De Jager and Summerton, 2012) and the Western Cape water supply system (DWA, 2012). The results from these studies have shown that the provision of additional storage capacity will not necessarily improve resilience to future climate variability, particularly under a drying scenario (Cullis et al, 2011), that the impacts of climate change on the available yield from complex systems is highly non-linear (DWA, 2012), and that the robust decision making is almost impossible given the current range of possible model outputs for future climate scenarios (De Jager and Summerton, 2012).

A recent study based on a probabilistic analysis of potential climate change impacts on the water supply system of South Africa as a whole as part of an assessment of the potential economic impacts of climate change (Cullis et al 2015) showed that a combination of the spatial variability in climate change impacts overlapped with key water supply areas, and the existing highly developed water resources planning process and resulting integrated water supply system that has been developed in South Africa to deal with the high degree of natural spatial and temporal variability in rainfall, provides some resilience to potential climate change risks in terms of water supply at the national level. It is important to note that this study evaluated the potential impacts in terms of the average annual water supply and not on the extreme cases where climate change is considered to have a much greater impact on the reliability of future water supplies. The study also further highlights the observation in the DWS climate change strategy (DWS, 2014) that well developed and highly integrated water supply systems are less vulnerable to potential climate change impacts than single isolated systems dependent on a single source or a single catchment for their water supply.

2. A methodology for incorporating climate change impacts into water resources planning

Currently there is no consensus in South Africa on how to incorporate climate change into the water resources planning process. This is partly due to the high level of uncertainty still inherent in the global and even regional downscaled climate models. Many of these models actually show potential increased precipitation in the critical water supply areas of South Africa. There is further the feeling that the current system of water resources planning is sufficient to address any long term climate change risk through a process of adaptive management and continuous updating of hydrological records used in the model simulation. Recent developments in terms of incorporating broader uncertainties into water resources planning in South Africa (Hughes et al, 2013) and direct use of stochastic generated precipitation time series data (Geoff Pegram) however have opened up the possibility for more detailed analysis of potential climate change impacts on water resources planning in South Africa. Such an uncertainty-based approach was used to evaluate the potential impacts of climate change on future water supply across the country in support of the economic evaluation of potential climate change impacts (Cullis et al, 2015).

It remains the case, however that this level of “top down” modelling is time consuming and expensive and even then not likely to significantly alter decision making for future water resources planning. This has led to the recommended “bottom up” approach to assessing potential climate change risk both by the Alliance for Global Water Adaptation[1] (AGWA) as well as the South African Long Term Adaptation Scenarios (LTAS) program (DEA, 2013)).

The “bottom up” approach essentially starts with an assessment of the vulnerability and potential climate change risks associated with both current and future water supply options. This is then mapped onto a probability distribution of potential climate impacts to determine the range of possible impacts in order to inform the consideration of specific adaptation options or alternative development scenarios. Depending on the magnitude of the potential climate change risks and the available resources, this analysis could be done either on a qualitative basis or a quantitative basis involving complex hydrological and water resources modelling.

[1] http://alliance4water.org/Beyond/beyond.html

Here we propose a mixed approach that utilises the existing water resources planning system in South Africa and determines the potential climate change risks on a semi-quantitative basis first before deciding on the need for additional more qualitative analysis. The recommended approach is then used to evaluate the potential climate change risk in a specific case study and informing the Reconciliations Strategy study for the water supply to the Richards Bay area in northern KwaZulu-Natal.

The recommended approach consists of the following basic steps:

- Initial risk and vulnerability assessment of current and future water supply options including a review of latest climate change scenarios for the relevant areas.
- Assessment of potential impacts for water resources planning decision-making by considering a worst-case and best-case climate change scenario of possible impacts.
- Consideration for potential adaptation options and recommendations
- Additional "top down" or "bottom up" assessments (modelling) of potential climate change impacts or the benefits of alternative adaptation scenarios if considered significant.

The recommended process acknowledges the fact that **the primary objective for incorporating potential climate change impacts into water resources planning is not so much to determine the probability and potential impact of future climate, but rather to determine how these potential futures might impact on the current decision-making with regards to water resource planning**. For example would the possibility of a particularly dryer scenario change the prioritisation of future augmentation options that may be needed earlier than would be anticipated under the current climate scenario?

3. Background to the Case Study Area

The primary existing water source for the Richards Bay water supply system is from the Mhlatuze River consisting of the Goedertrouw Dam and the Mhlatuze diversion weir. The Goedertrouw Dam can also be augmented with the water transferred from the Thukela catchment into the Mhlatuze catchment.

Additional water sources include a number of coastal lakes that are also within the Mhlatuze catchment including Lake Nsezi, Lake Mzingazi, Lake Cubhu and Lake Nhlabane. Lake Nsezi can also be augmented with water transferred from the Mfolozi catchment.

Significant future augmentation options include increased transfers from the Thukela and Mfolozi catchments as well as the desalination of sea water and re-use of treated effluent. There are also a number of smaller interventions intended to either reduce demand or to increase supply, including improved water conservation and demand management (WDCM), a new small dam on a tributary river, raising of Goedertrouw Dam, increased rainwater harvesting and small ground water supply options. Each of these potential future supply options has different climate change risks and opportunities for increased adaption to future climate change uncertainty.

4. Risk and Vulnerability Assessment of Current and Future Water Supply Options

There have been a number of studies considering the potential impact of climate change on the water resources of South Africa (Schulze, 2012, DEA, 2014), including specific studies on the potential impacts on the Mhlatuze catchment, which is the main water supply area for the town of Richards Bay (Lumsden, 2013, Mhlathuze Water, 2014). These studies consider model results from both global general circulation models (GCMs) and regional downscaled models for South Africa and present results in terms of potential future changes in temperature and precipitation as discussed below.

There are many aspects by which climate change could impact on the water sector. These include changes in precipitation and streamflow, increased intensity of runoff and elevated flooding risks, changes in water temperature and water quality, as well as increasing demands particularly for irrigation. In terms of assessing the specific potential impacts, the two primary impacts are on water supply and on water demand.

There is strong scientific consensus that global temperatures are rising. The 2013 South African LTAS (DEA, 2013) and the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5) (2014) suggest warming relative to 1986–2005 of 3–6°C by 2081–2100 in the interior of the country, and 2–3°C at the coast. Near surface mean temperature is indicated at 1–1.5°C on the coast and around 3°C inland for South Africa (reference period 1986–2005 and future period 2081–2100). Local downscaled climate projections from the CSIR and CSAG for various emissions scenarios show similar outputs and indicate that there will be an increase in both mean minimum and mean maximum temperatures. The data suggests this will range between 1.3 – 2.8 °C for maximum temperatures and 1.3 – 2.3°C for minimum temperatures (from Lumsden, 2013) for the period of 2046 to 2065 across the A2 and B1 as reported by Mhlatuze Water (2013).

There is still much uncertainty relating to the potential impacts of climate change. Global circulation models tend to show potential for increased drying over the western part of South Africa but potential for increased wetting over the eastern part of the country including KZN, while regional downscaled models tend to show possibilities of both wetting and drying conditions (LTAS). A review of the available data for the Mhlatuze catchment showed a range of projected precipitation futures from a 15% decrease to a 16% increase in mean annual precipitation (Mhlatuze Water, 2013).

In terms of the potential impact on streamflow, the above mentioned study assumed that under a worst case scenario there would be a 15% reduction in mean annual runoff (MAR) and an 8% increase in peak runoff in the Mhlatuze catchment (Mhlatuze Water, 2014). This study then assumed that this would result in a similar risk in terms of the reduced future water supply and concluded that even under the worst case scenario, additional water supply options would be required in 2040 based on a high demand growth scenario, while under the best case scenario of increasing water availability, additional supply would only be required in 2085, also for the high growth demand scenario.

A separate study undertaken for National Treasury and the Long Term Adaptation Scenario (LTAS) program, however considered the probabilities of potential water supply impacts by using a hybrid frequency distribution (HFD) approach to investigate the potential impacts of all available global climate models on future precipitation, streamflow, irrigation demand and water supply (Cullis et al, 2014). This study confirmed a similar wide range of potential impacts on MAR from -20% to +80%, but with a median impact of around +6% on MAR for the Mhlatuze Catchment (Figure 1).

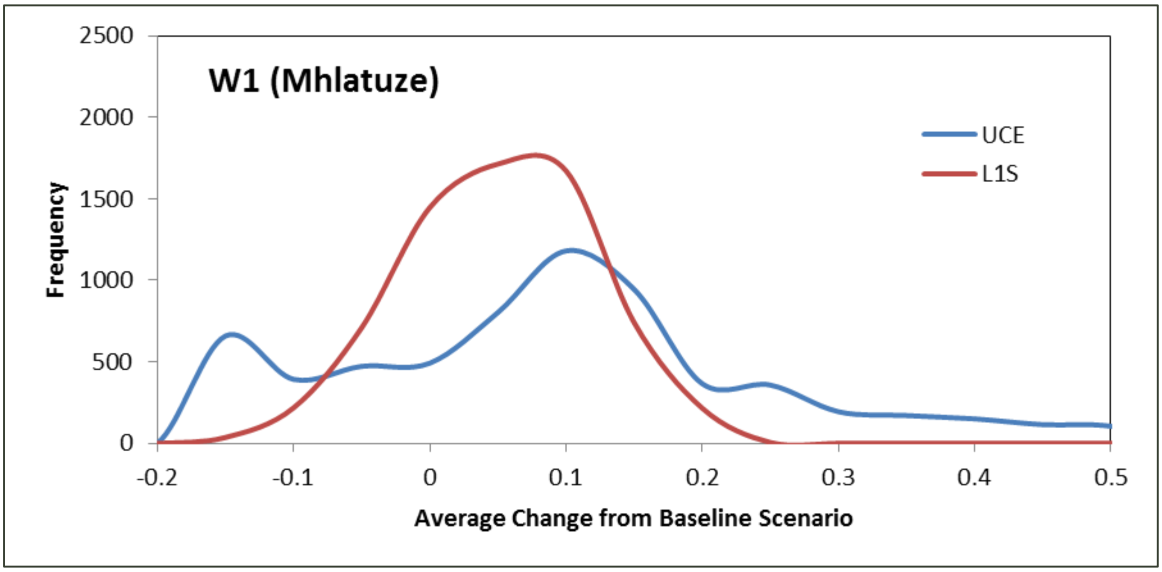


Figure 1: Hybrid Frequency Distribution (HFD) of potential change in mean annual runoff for the Mhlatuze Catchment by 2050 under two future global mitigation scenarios (Source: Cullis et al, 2015)

The same study, however also showed a median impact of +7% (range - 12% to + 19%) for irrigation demands by 2050 (Figure 2). Both figures show a significant reduction in the associated risk (i.e. the spread of potential impacts) under a scenario resulting from significant global mitigation efforts (Level 1 Stabilisation (L1S) scenario) as compared to an Unconstrained Emissions (UCE) Scenario.

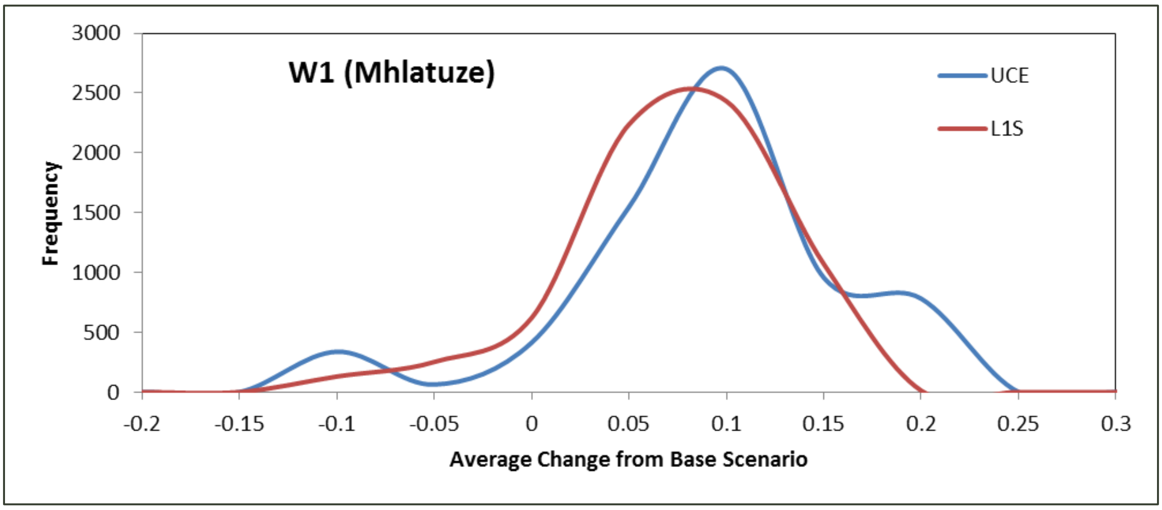


Figure 2: Hybrid Frequency Distribution (HFD) of potential change in mean annual irrigation demand for the Mhlatuze Catchment by 2050 under two future global mitigation scenarios (Source: Cullis et al, 2015)

The same study also looked at the potential impacts in terms of the average annual water supply using a national configuration of the water resources yield model (WRYM) to assess the potential impacts on future water supply for irrigation, bulk industry and domestic supply at the level of individual water management areas (WMA). The results show a much narrower range of potential impacts on the percentage of average annual water demand that can be supplied ranging from around a 5% reduction to a 20% increase with a median impact of around +2% with very little difference between the UCE and L1S mitigation scenarios. These results show the importance of considering water supply as different from changes in precipitation or runoff as well as the potential for the existing bulk water supply system to provide some resilience to future climate change impacts.

A closer analysis of the ability to supply future water demands in the Usutu to Mhlatuze WMA shows that the greatest risk of a reduced water supply under drier climate scenarios is for urban and industrial water supply. This is because these users are located at the downstream end of the catchment and receive water only after it has been accessed for irrigation. Hence without significant management of increasing upstream irrigation demands it is likely that increasing water demands from irrigation are likely to also contribute to reduced water availability for Richards Bay even in cases where there is no associated reduction in streamflow. The importance of accounting for the nature of the upstream irrigation demands was also highlighted when determining the current water availability as it had a significant impact on the available yield as described in the Water Balance Report.

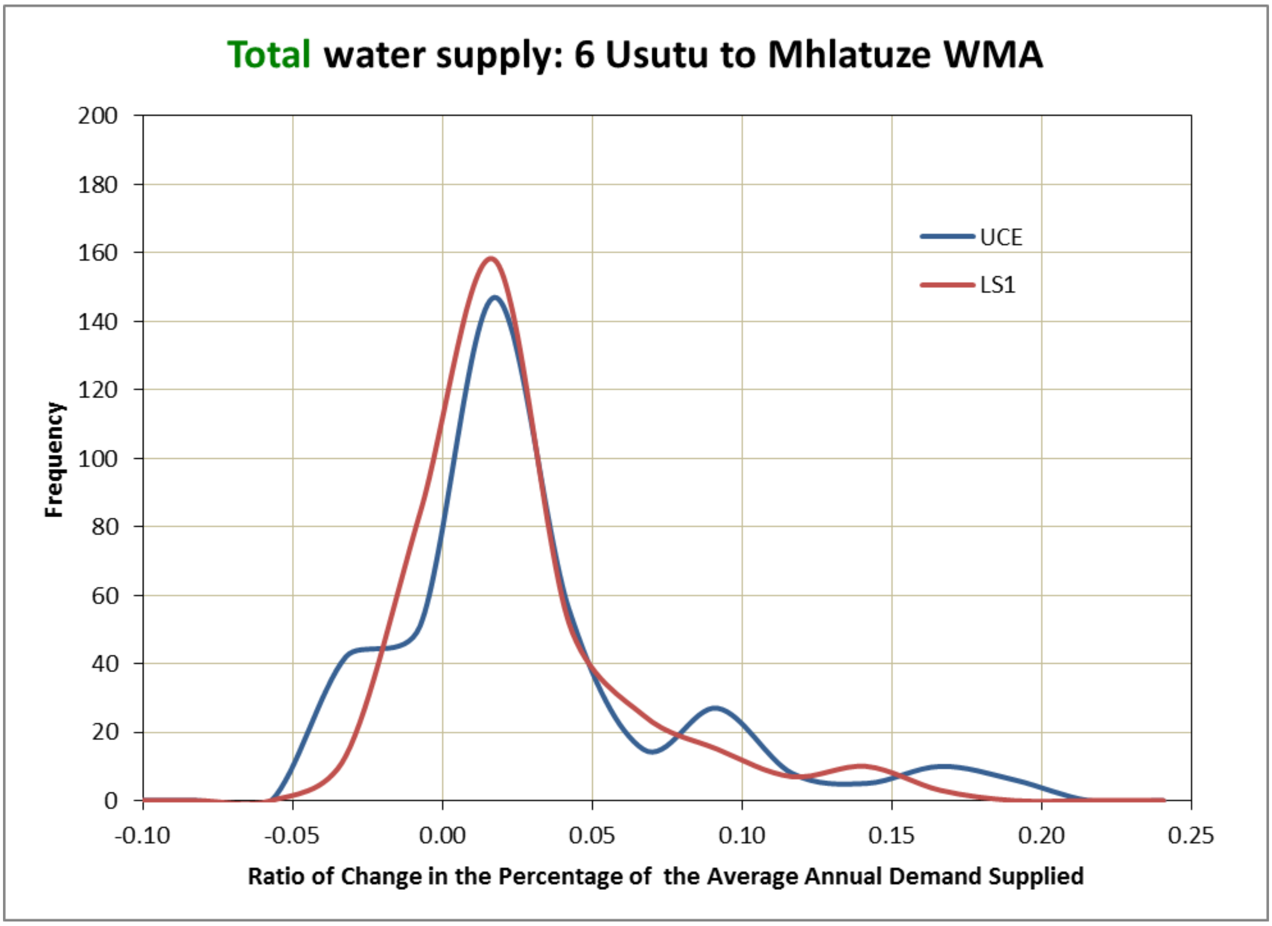


Figure 3: Hybrid frequency distribution (HFD) of the relative change in the percentage of future total water demands that can be met under the UCE and L1S mitigation scenario compared to the base scenario for the Usutu to Mhlatuze WMA by 2050. (Source: Cullis et al, 2015).

Part of the reason why a change in streamflow does not directly translate into an equivalent change in water availability under future climate scenarios is due to the ability for the system to respond and to transfer water between catchments. For example in the case of the Usutu to Mhlatuze WMA, some of the changes in the water balance of the Mhlatuze catchment due to increasing demands or reducing streamflow are compensated for by increased transfers from the Thukela River as shown in Figure 4.

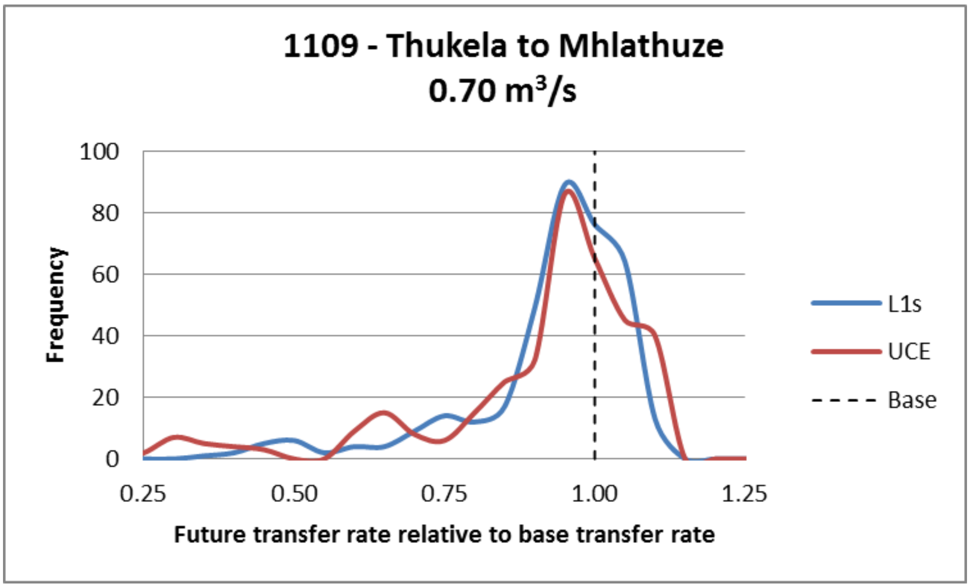


Figure 4: Hybrid frequency distribution (HFD) of the change in the average annual volume of water transferred from the Thukela to the Mhlatuze by 2050 under the L1S and UCE mitigation scenarios. (Source: Cullis et al 2015)

The results of these studies highlight the importance of considering the impacts of the water supply system when assessing the potential impacts of climate change on future water supply. This requires significant additional modelling and consideration for a wide range of possible climate scenarios.

While these additional studies are necessary to better understand the potential impacts of climate change and for consideration of suitable adaptation options, for initial planning purposes it is sufficient to consider the range of potential impacts and to determine how consideration of the potential extreme scenarios may impact on decision making, particularly around the timing of potential interventions and the priority of options for further investigation. This analysis is based on a vulnerability assessment of both current and future water supply options and an analysis using the available Reconciliation Planning Support Tool (RPST) to consider how a worst case scenario of potential climate change impacts, based on existing information, might affect the timing for future interventions and planning requirements. This process is described in the following sections of the report.

5. Future Water Supply Options

The future water supply options for Richards Bay include increased transfers from the Thukela and Mfolozi catchments with the option of additional storage capacity on the Mfolozi, raising of Goedertrouw Dam, a dam on the Nseleni River, increased use of rain water harvesting, a number of small groundwater schemes, seawater desalination and reuse of treated effluent.

Increasing the storage capacity from existing surface water options and including increased transfers from the Thukela and Mfolozi River are likely to have similar climate change risks as the existing supply from the Mhlatuze Catchment. In particular the LTAS study using the HFD approach (Cullis *et al*, 2014) concluded that the median impact on the MAR of the Thukela and Mfolozi Rivers by 2050 was +9% and +6% respectively with the worst case scenario being a reduction of around 16% for both. For the worst case scenario we have assumed a 15% reduction in the yield of these options.

The potential for rainwater harvesting will also be impacted by changing precipitation and possibly also in terms of increased variability at the daily level due to much lower storage capacity. This would require additional modelling at the daily level to assess the potential impacts, but under the worst case scenario could be assumed to be similar to the expected change in MAP. According to the Mhlatuze Climate Change study this would be around 15% reduction in the worst case scenario.

Increasing reuse of treated effluent and desalination are much less impacted by climate change. Reuse could potentially be impacted if demand drops in response to reduced availability from the existing and alternative surface and groundwater options and in a worst case scenario could be considered to have a similar risk under future climate change scenarios. Desalination however is completely independent of future climate change scenarios and therefore provides a highly robust solution to future water supply options under increasing future uncertainty. The true value of this added security of supply has not yet been assessed in South Africa and requires further research.

Based on the above high level assessment of the relative climate change risks for both current and future water supply options a worst case scenario has been developed for comparison of water supply options and reconciliation of future water supply and demand options. The details of the worst case scenario for potential future interventions are given in Table 1, irrespective of when they are implemented within the strategy evaluation period (up to 2040). For analysis it has been assumed that these impacts are realised linearly to 2040. In all cases we have assumed a 15% reduction in the available yield for all surface water options, a 5% reduction in yield from groundwater options and reuse and a 10% increase in irrigation demands by 2040.

Table 1: Adjusted yields for water supply inteventions due to worst-case climate change impacts

Scheme	Yield/Saving (million m^3/a)	Adjustment for Potential Climate Change Impacts (%)	Adjusted Yield (million m^3/a)/Saving
Bulk industrial WC/WDM	2.8	0%	2.8
Urban WC/WDM	4.0	0%	4.0
Rainwater harvesting	Up to 200kl/a per household	-15%	0
Limiting supply from over-abstracted coastal lakes	-9.9	15%	-11.4
Thukela-Mhlathuze Transfer Scheme Phase 1	47.3	-15%	40.2
Thukela-Mhlathuze Transfer Scheme Phase 2	94.6	-15%	80.4
Thukela-Mhlathuze Transfer Scheme Phase 1 + Phase 2	141.9	-15%	120.6
Thukela-Mhlathuze Transfer Scheme Phase 3	94.6	-15%	80.4
Coastal pipeline from the lower Thukela River (55Ml/d)	15.1	-15%	12.8
Coastal pipeline from the lower Thukela River (110Ml/d)	35.2	-15%	29.9
Mfolozi River: Kwesibomvu Dam 26m high to Nsezi WTW	46.6	-15%	39.6
Kwesibomvu Dam 26m high to Mposa crossing	46.6	-15%	39.6
Mfolozi 63Mm^3 off-Channel Dam 2m^3/s to Nsezi WTW	27.1	-15%	23.0
Mfolozi 63 Mm^3 off-Channel Dam 2m^3/s to Mposa crossing	27.1	-15%	23.0
Mfolozi 78Mm^3 off-Channel Dam 2.5m^3/s to Nsezi WTW	36.9	-15%	31.4
Mfolozi 78 Mm^3 off-Channel Dam 2.5m^3/s to Mposa crossing	36.9	-15%	31.4
Raising Goedertrouw Dam	3.9	-15%	3.4
1 MAR dam on Nseleni River	6.1	-15%	5.2
1.5 MAR dam on the Nseleni River	8.5	-15%	7.2
Groundwater scheme, combined 3 schemes	1.6	-5%	1.5
Groundwater scheme 1	0.7	-5%	0.7
Groundwater scheme 2	0.5	-5%	0.5

Scheme	Yield/Saving (million m^3/a)	Adjustment for Potential Climate Change Impacts (%)	Adjusted Yield (million m^3/a)/Saving
Groundwater scheme 3	0.3	-5%	0.3
Arboretum Effluent Reuse Scheme	11.0	-5%	10.4
Desalination of seawater Phase 1	21.9	0%	21.9
Desalination of seawater Phase 2	21.9	0%	21.9
Desalination of seawater Phase 3	21.9	0%	21.9
Desalination of seawater Phase 4	21.9	0%	21.9
Desalination of seawater Phase 1 + Phase 2	43.8	0%	43.8
Desalination of seawater Phase 3 + Phase 4	43.8	0%	43.8

The resulting reconciliation of future water supply options for Richards Bay for the Worst Case Scenario is given in Figure 5.

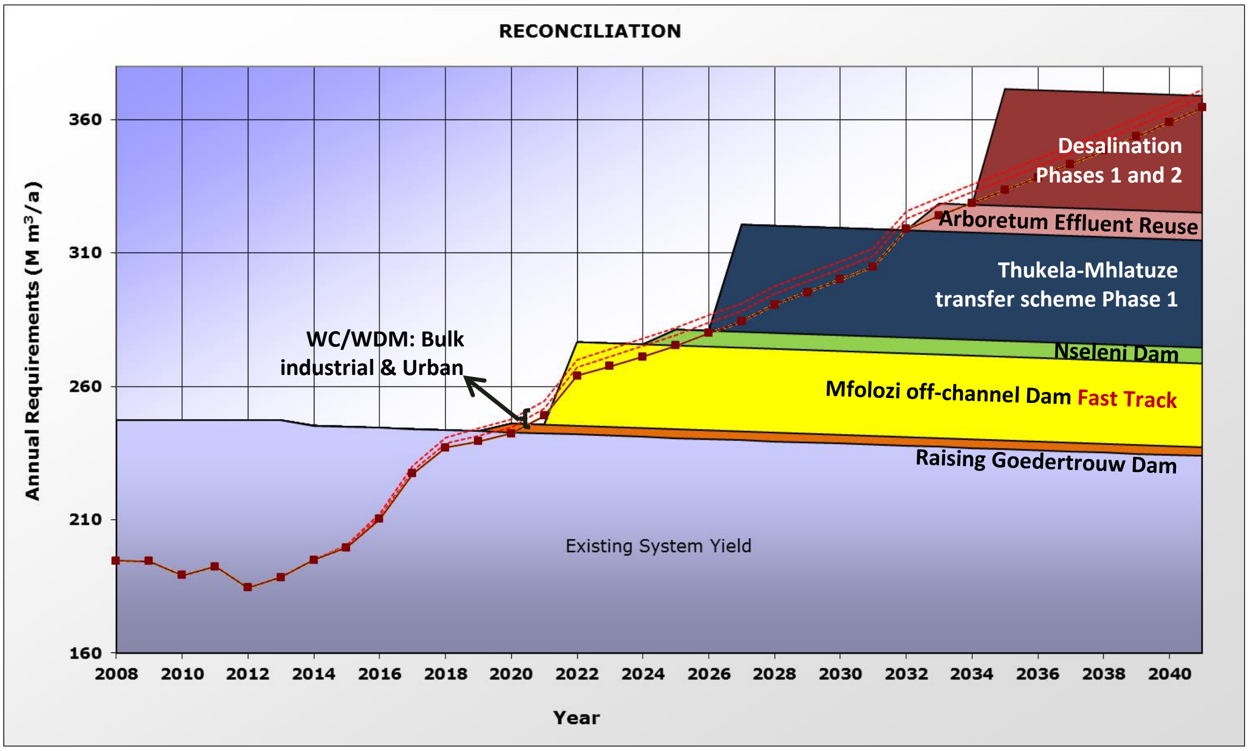


Figure 5: Reconciliation of future water supply options for the worst case climate change scenario

The interventions of this scenario are shown in Table 2.

Table 2: Worst Case Interventions

Intervention	Year of First Water or Saving	Yield(1)	Total Lead Time
Urban WC/WDM	2015	4.0	10
Bulk industrial WC/WDM	2015	2.8	5
Raising Goedertrouw Dam	2020	3.3	4.5
Mfolozi River off-channel transfer scheme Fast Track	2022	31.4	7
1 MAR dam on Nseleni River	2025	5.95	8.5
Thukela-Mhlathuze Transfer Scheme Phase 1	2027	40.2	8.75
Arboretum Effluent Reuse Scheme	2033	10.4	6.5
Desalination of seawater Ph 1 + Ph 2	2035	43.8	8.5

(2) Reduced intervention yields

The results of this scenario suggest that a significant intervention is needed as soon as it can be implemented – the fast-tracked Mfolozi River Off-channel Transfer Scheme has been used as example. For the Worst Case Scenario, even one significant intervention may not be enough and, as illustrated, this is augmented with another fast-tracked intervention, in this case desalination. This is due to the anticipated decline in the yield of the existing water supply system, increased irrigation demands as well as the potential reduction in yield for the various surface water options.

6. Recommendations

It is clear that there is still much uncertainty about the potential impacts of future climate change on the water supply options for Richards Bay, but it is still important that these risks are considered with regards to the future planning for water supply infrastructure. In particular the potential impacts of increasing temperature and demands need to be considered and consideration given to how these could be met particularly with regards to the future demands from agriculture.

Given that a number of industries in the region are dependent on a reliable water supply it is also important to identify the thresholds of change that would require a different response or consideration for specific adaptation options, i.e. a “bottom up” approach to assessing the climate change risk should be undertaken for the region. In particular this study should consider the potential benefits of alternative supply options such as desalination which have a guaranteed assurance of supply independent on potential climate in terms of reducing the overall economic risks in the region.

Finally it is important to consider the latest climate change scenario being developed though the CORDEX system as well as a probabilistic analysis of future impacts such as those produced by the MIT IGSM model (See Cullis *et al*, 2015). Careful consideration needs to be given to the overlap of the latest future climate change impacts and the individual water supply options, but it is also critical to evaluate these in terms of the overall combined risks resulting from the integrated nature of the water supply system to Richards Bay. It may be the case that spreading the risk between different water supply options may be a more sustainable solution than opting for the most cost effective individual option based on current and historical hydrological information, given the uncertainty of future impacts.

7. References

Cullis J, Alton T, Arndt C, Cartwright A, Chang A, Gabriel S, Gebretsadik Y, Hartley F, De Jager G, Makrelov K, Robertson G, Schlosser A, Strzepek K, Thurlow J. (2015) *An uncertainty approach to modelling climate change risk in South Africa* United Nations University World Institute for Development Economics Research. WIDER Working Paper 2015/045

Cullis JDS, Strzepek K, Tadross M, Sami K, Havenga B, Gildenhuys B and Smith J (2011) "Incorporating climate change into water resources planning for the town of Polokwane, South Africa" *Climate Change* 108:437-456

De Jager G and Summerton M (2012) *Assessment of the Potential Impacts of Climate Change on the Long-Term Yield of Major Dams in the Mgeni River System* Report prepared for Umgeni Water. June 2012

Department of Environmental Affairs (2013) *Long term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Change Implications for the Water Sector In South Africa.* Pretoria, South Africa.

Department of Water Affairs (2012) "Climate Change Pilot Studies" Report prepared by Pegasys, Aurecon and UCT as part of the *Development of a National Climate Change Strategy* (DWA project No. WP10550)

Gerber A, de Jager G and Strydom C (2011) *Development of a Practical Methodology for Assessing the Potential Impacts of Climate Change on the Yield Characteristics of Reservoirs.* WRC Report No KV 266/10, April 2011.

Mantel SK, Slaughter A, Hushes DA (2012) *Developing Climate Change adaptation measures and decision support system for selected South African water boards* WRC Report No.K5/2018/7

Appendix B
WRYM / WRPM Evaluation of scenarios

1. WRYM and WRPM

The *Water Balance Report* of this study describes the updating of the detailed WRYM of the Richards Bay WSS. The model was updated with the latest estimates for industrial and urban use for the Richards Bay WSS as reported in the *Water Requirements Report* of this study. In addition the irrigation allocations were amended according to the latest available information. The WRYM was further updated to incorporate the final configurations of potential interventions.

The Water Resources Planning Model (WRPM) obtained from the study "*Mhlathuze Catchment - Modelling Support for Licensing Scenarios"* was also updated with the latest estimates for irrigation, industrial and urban water use for the strategy area.

These models were then used to verify the implementation dates of interventions for the selected water balance scenarios, as described in Section 3.2.

The WRYM and WRPM are both network models that model the following features of the water resources of a given system:

- Inflow Hydrology (both historical and stochastic),
- Dam storage capacities and initial storage conditions,
- Network linkages and conveyance constraints,
- Operating rules using "Penalties" to prioritising sources and demands.

In addition, the WRPM has been enhanced to simulate system operation, including:

- The growth of demands over time,
- The addition of new infrastructure,
- The inclusion of an annual allocation routine which allows the curtailment of each demand type during droughts according to different reliability classification tables.

The WRPM enables planners to model the impact of interventions (demand reduction or additional schemes) when the frequency of curtailment exceeds acceptable limits.

2. Annual allocation in the WRPM

At least once a year, the annual allocation model uses the current storage of the system to assess whether the current demands on the system can be met or whether the less essential demands need to be curtailed to meet the demand. For the Mhlathuze catchment this allocation decision is made around the 1st of May, after the rainy season and prior to the dry winter period.

The available supply from the system is assessed prior to the decision date by simulating the behaviour of the system under different initial storage conditions under say 1000 alternative stochastic inflow sequences. On the decision date, the results from the closest set of initial storage conditions are used to estimate the behaviour for the initial conditions on the decision date.

The demands on the system are categorised into different reliability classes, as can be seen in the following Table 1 which was used in the *Mhlathuze Catchment: Modelling Support for Licensing Scenarios* Study. According to the table 50% of the irrigation can be curtailed once every four years and all irrigation can be curtailed completely once every 50 years. Also, 40% of the urban demand can be curtailed every twenty years. These criteria may be difficult to achieve in practice.

Table 1: Assurance of supply criteria from the Licensing Scenario Study

Water use sector	% demand at indicated risk of failure				
	1 in 200 years	1 in 100 years	1 in 50 years	1 in 20 years	1 in 4 years
	0.5%	1%	2%	5%	25%
Irrigation			50%		50%
Urban	30%	30%		30%	10%
Industrial 1 (1)	70%	20%		10%	
Industrial 2	90%	10%			

From the "Mhlathuze Catchment - Modelling Support for Licensing Scenarios" study

(1) Tongaat Hulett irrigators

It will be useful to illustrate the effect of curtailment on the irrigation water requirements in the Mhlatuze catchment. The analyses are based on a monthly simulation of 1000 sequences over the simulation period from 2015 to 2040, which means that for each month there is a cloud of 1000 possible storages or streamflows. This interpretation of this cloud of solutions is simplified using a “box-and-whisker” symbol to represent the percent-exceedance of different values (see Figure 1).

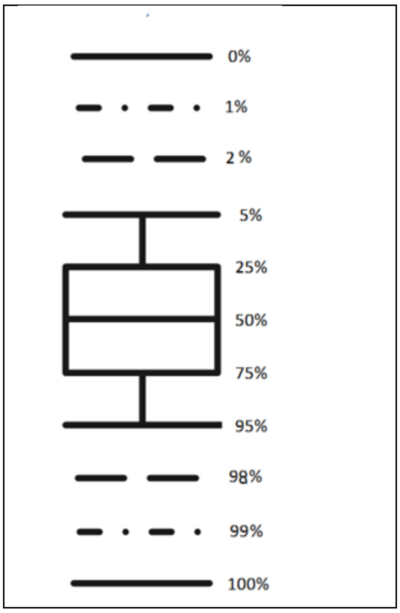


Figure 1: Exceedance Reliability Key

For instance, 50% of the values simulated would lie above the 50% exceedance line through the box. The box-and-whisker symbol has been used to plot the irrigation water demand and supply in Figures 2 and 3 for a scenario where the system demands are supplied at their agreed reliability from Table 1. The variation in demand shown in Figure 2 is caused by the variations in the rainfall from year to year. The wider fluctuation in supply shown in Figure 3 is caused by the imposition of additional curtailments in supply when the system was drawn down. Note that there is about a 1 in 20 probability of the supply to irrigation being halved due to drought conditions.

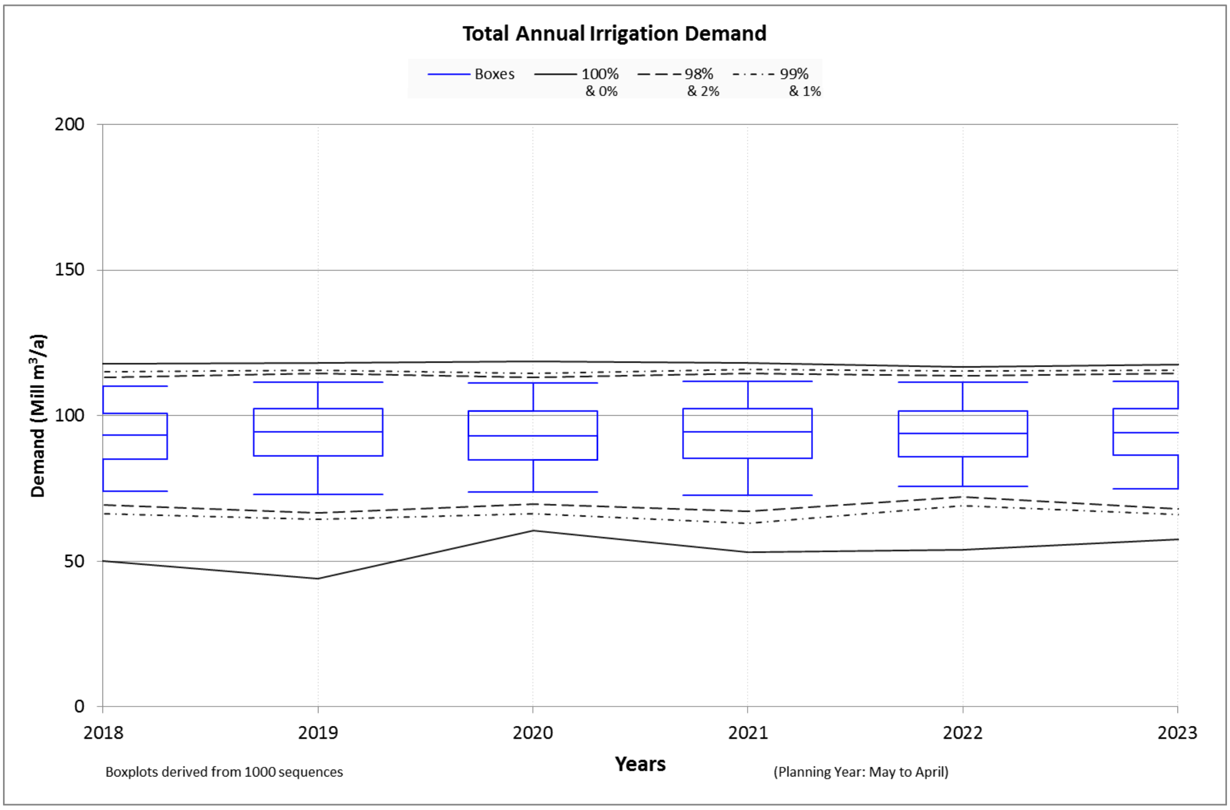


Figure 2: Irrigation Water requirements in the Mhlathuze

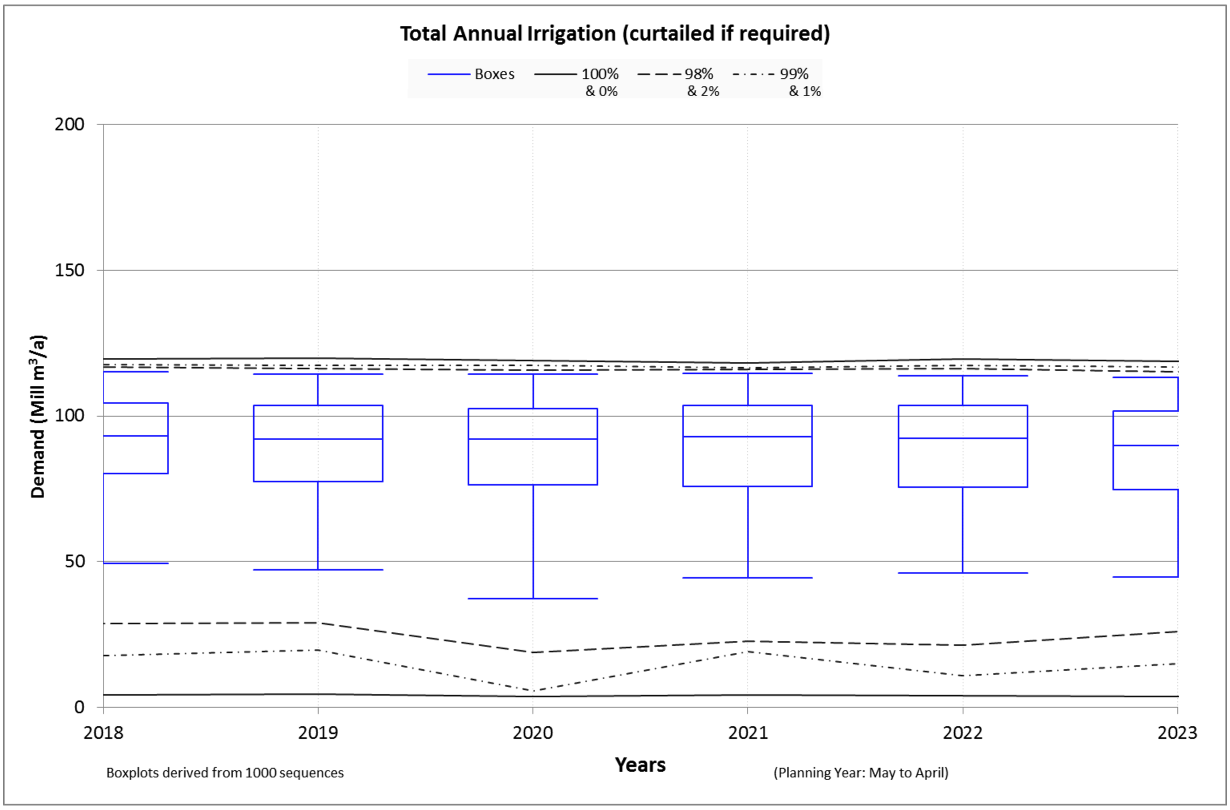


Figure 3: Irrigation Water supply in the Mhlathuze

In the Mhlathuze catchment releases are made from the Goedertrouw Dam for users downstream. While it is intended that the irrigators receive their water at a lower reliability than the industrial users, in practice many of the irrigation pumps are located upstream of the industrial consumers. Unless comprehensive plans are made to curtail the abstraction by irrigators during a drought there is a risk that water released for industrial consumers will be intercepted. The augmentation dates from the WRPM assume effective monitoring / policing of all consumer demands and should this not be achieved the augmentation dates will be considerably earlier. Indications are that the irrigators are very effectively curtailing their water demand during the current drought.

The WRYM does not model the curtailment of irrigation. While there is still sufficient water in the Goedertrouw Dam both the irrigation and urban demands will abstract according to their full requirements. When Goedertrouw Dam is empty and there is limited supply from the dam then the urban demands will receive priority. However, no curtailment measures are introduced in advance to conserve water for the high priority consumers which reduce the reliability of their supply. Hence, if curtailment of irrigation can be enforced then the WRPM is the preferred tool to determine the curtailment of the system. Should this curtailment not occur then the WRYM provides an indication of when augmentation will be required. According to the WRYM analysis, the system can supply 106.6 million m^3/a to urban/industrial consumers and an *average* of 88.5 million m^3/a to irrigation giving a total supply of 195.1 million m^3/a.

3. WRPM Scenarios and Results

The number of WRPM scenarios were analysed to determine the sensitivity of the date for the next augmentation date of the system to the following:

- The "medium" and the "high" demand projection''
- Implementing 3 baseline interventions (namely urban and industrial WC/WDM and the raising of Goedertrouw Dam by 2.8m to counteract the effect of ongoing siltation of the storage
- Implementing a transfer of 1.5m^3/s from the Thukela River (Phase 1),
- Starting with current (2015) storage conditions equating to 45% storage in Goedertrouw Dam as opposed to starting full.

The detailed curtailment plots results are presented in Annexure A and the results are summarized in Table 3. According to these results, the medium growth scenarios require augmentation between 2022 and 2024. The high growth scenarios require augmentation by 2020. Note that because of the precautionary curtailment of irrigation in the WRPM the system demands when augmentation is required vary between 245 and 253 million m^3/a if the same reliability table as the Licensing Scenario Study was adopted.

More detailed plots for scenario H have been produced below, comprising an annotated curtailment plot (Figure 4), and supplies to irrigation (Figure 5) and to the non-irrigation sectors (Figure 6).

Figure 4 indicates that in 2017 the frequency of curtailment of irrigation exceeds 1 in 4 years and this has been flagged as a violation of the "0" curtailment level. If one examines this in more detail, the extent of the curtailment is actually negligible (possibly .02 of the irrigation demand that can be curtailed during a level 1 restriction, which is 50% of the total irrigation demand). A curtailment of say 0.02*50% or1% that occurs just over once every 4 years is actually negligible. For this reason, the augmentation dates triggered by the level 0 curtailment level was generally ignored in Table 3, and the selected augmentation date was usually based on the earliest date from the level 1 to level 3 curtailment levels. The one exception is the HBT1 scenario where the level 0 curtailments were not negligible in 2030 and this date was used to time the augmentation.

The 2015 demands in Figures 5 and 6 match the demand growth scenario. However, as the system comes under increasing stress the water supplied falls short of the projected demand.

Table 2: WRPM Results

Scenario	Growth[3]	Baseline schemes [1]	Additional schemes	Starting conditions for GT	Augmentation dates for different Curtailment levels				Selected Augm. Date	Approx. system demand
					0	1	2	3		
HF	**H**igh	N		**F**ull 2013	'19	'20	'22	'32	2020	245
H	**H**igh	N		45% 1 May 2015	'17	'20	'22	'31	2020	245
HB	**H**igh	**B**		45% 1 May 2015	'20	'20	'25	'32	2020	245
MF	**M**edium	N		**F**ull 2013	'22	'22	'28		2022	249
M	**M**edium	N		45% 1 May 2015	'21	'22	'30		2022	249
MB	**M**edium	**B**		45% 1 May 2015	'22	'24	'32		2024	253
HBT1	**H**igh	**B**	**T**hukela Phase **1**	45% 1 May 2015	'26	'32			2030	301

[1] Baseline initiatives comprise WC/WDM and raising Goedertrouw Dam by 2.8m
[2] Sedimentation of Goedertrouw Dam was modelled for all scenarios
[3] Growth Projections are based on the "Water Requirements Report" (DWS Report No P WMA06/W100/00/3114/1) compiled as part of this study

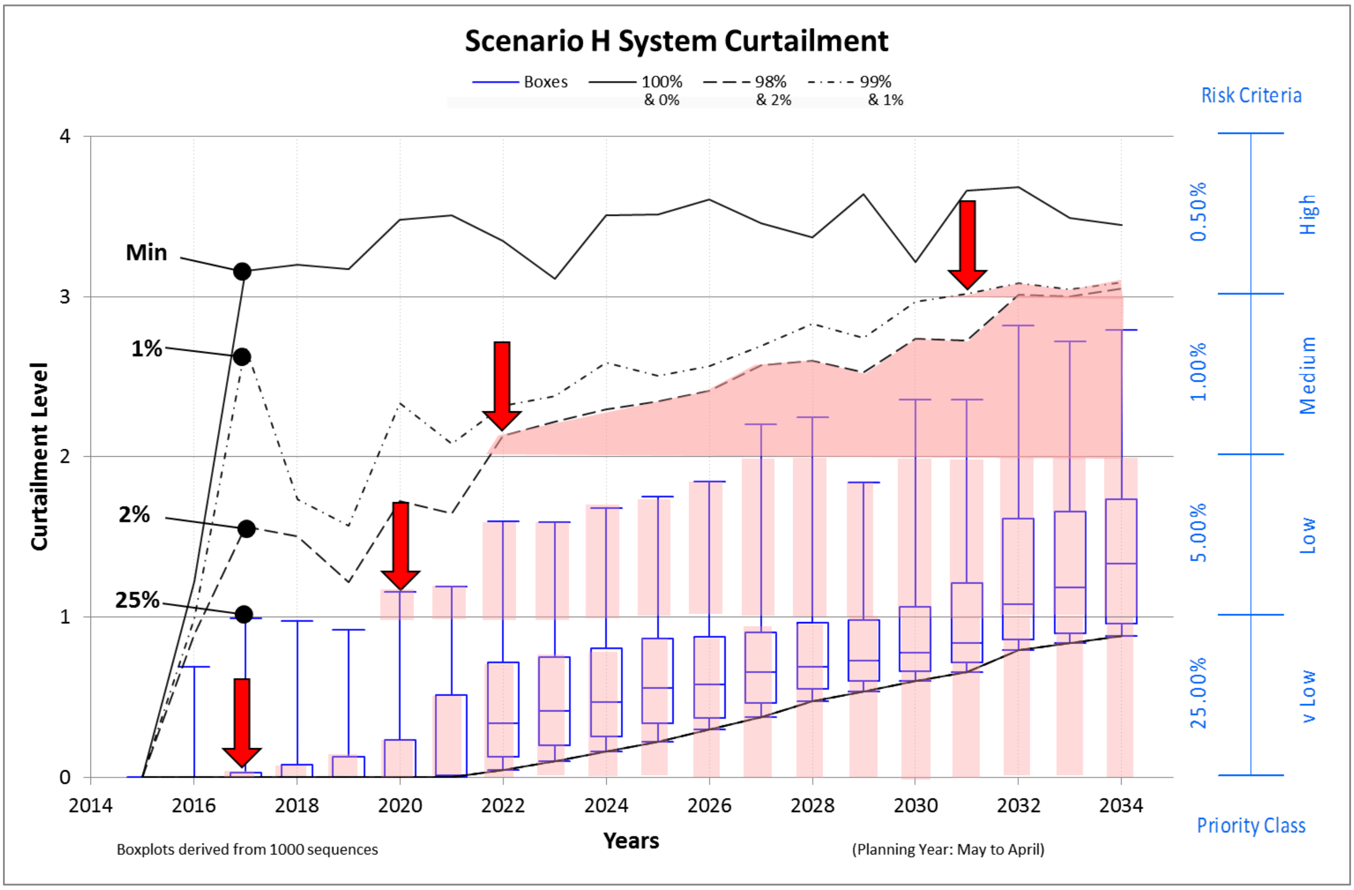


Figure 4: Annotated curtailment plot for scenario H

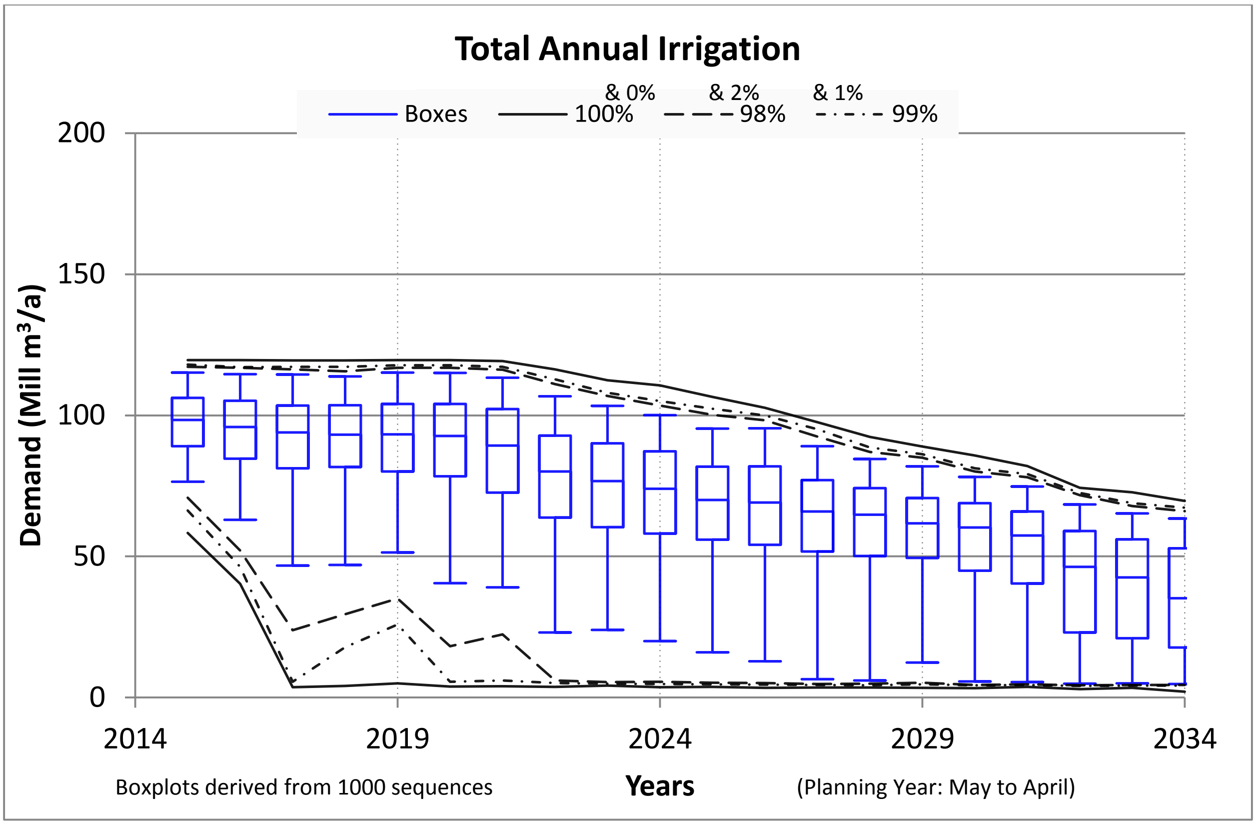


Figure 5: Irrigation supply for Scenario H

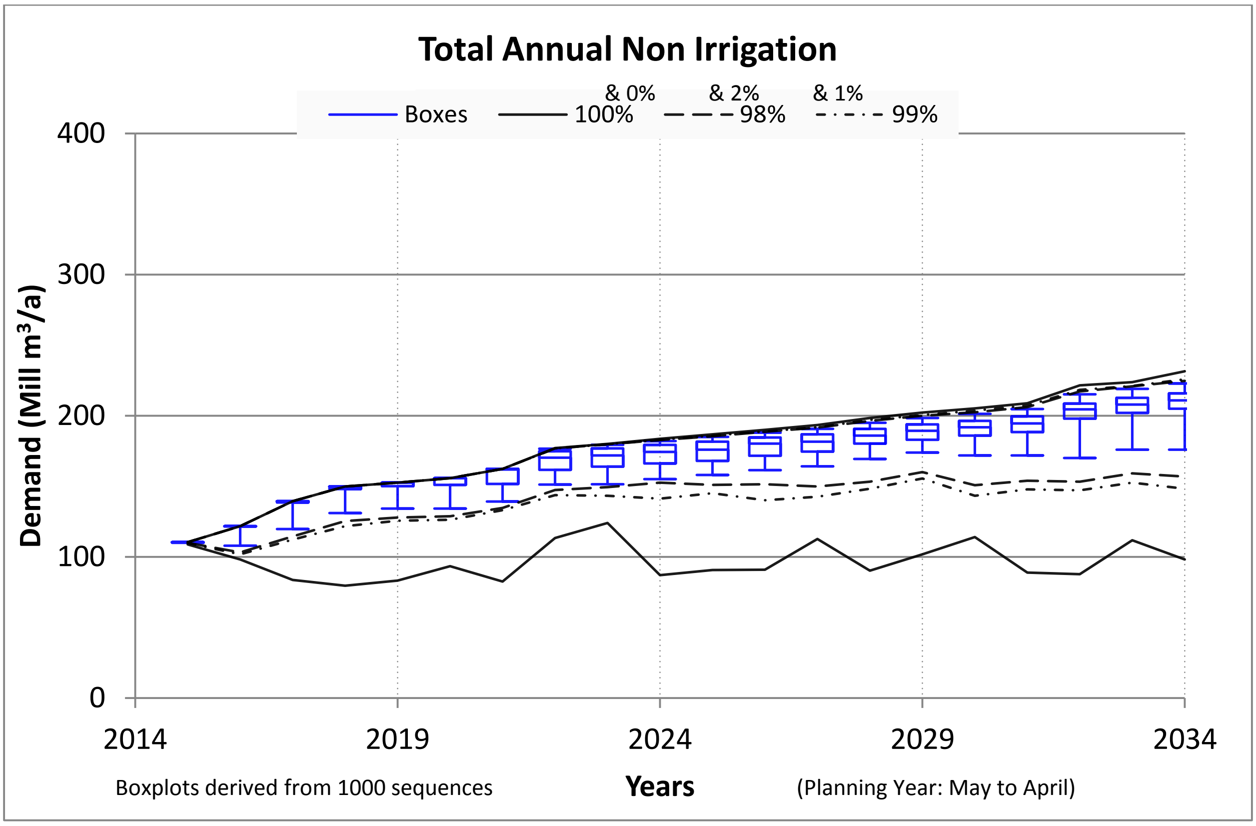
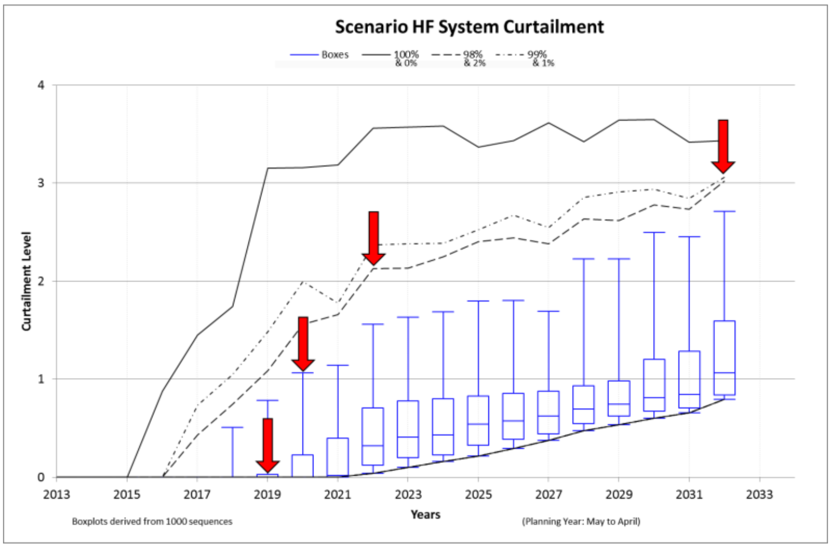
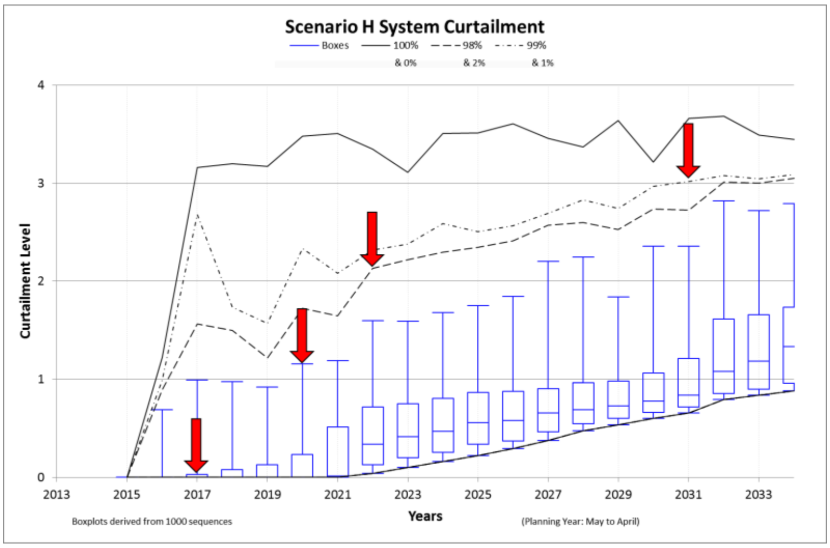
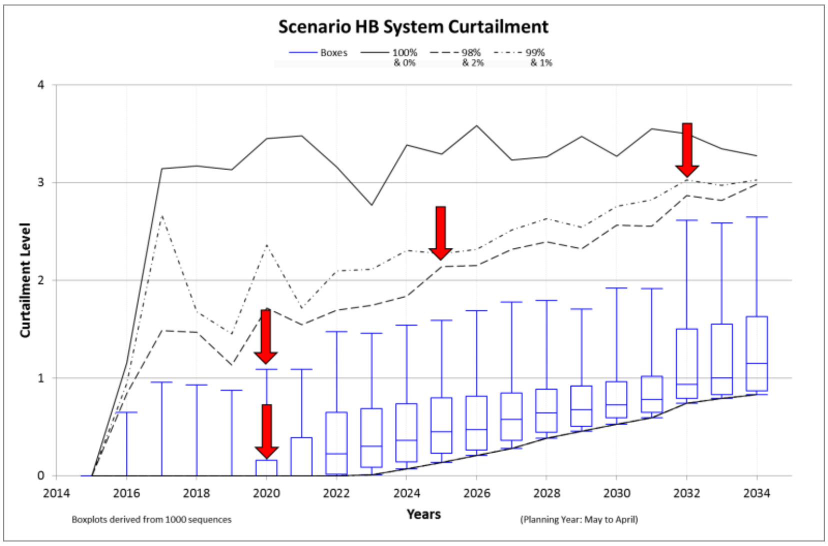


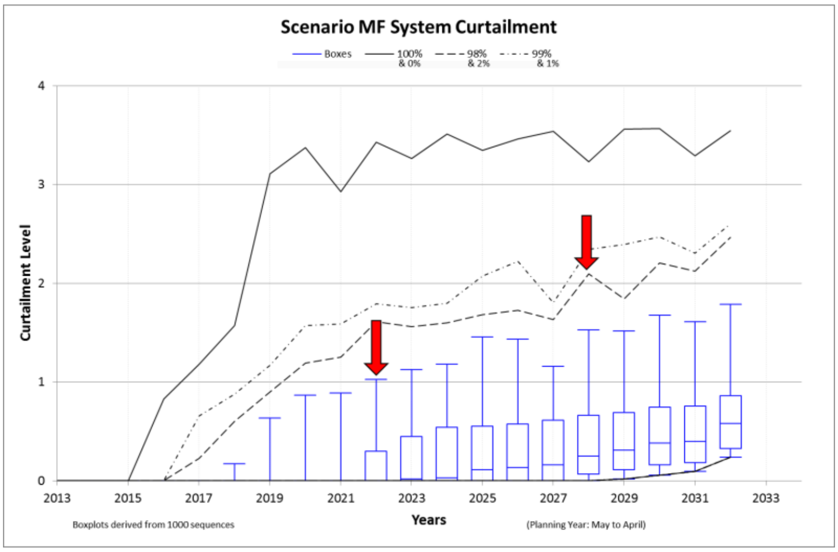
Figure 6: Urban and Industrial (non-irrigation) supply for Scenario H

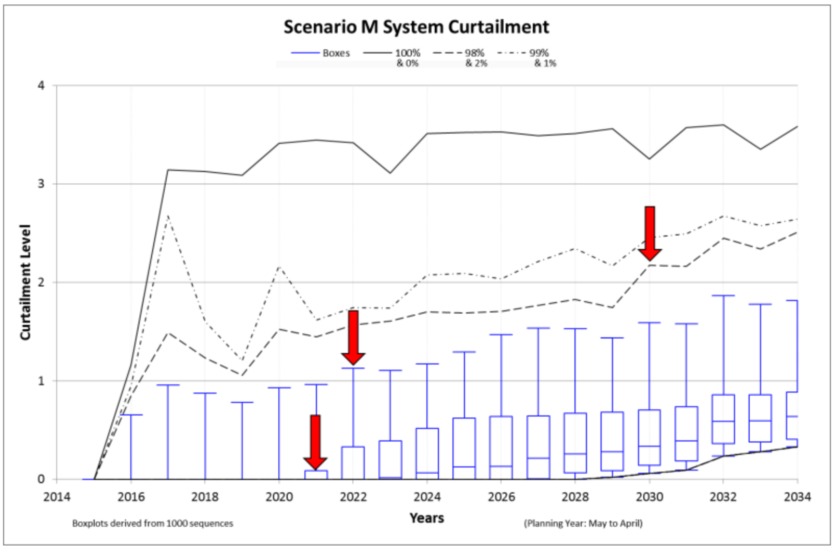
Annexure A: WRPM Curtailment Analysis Results

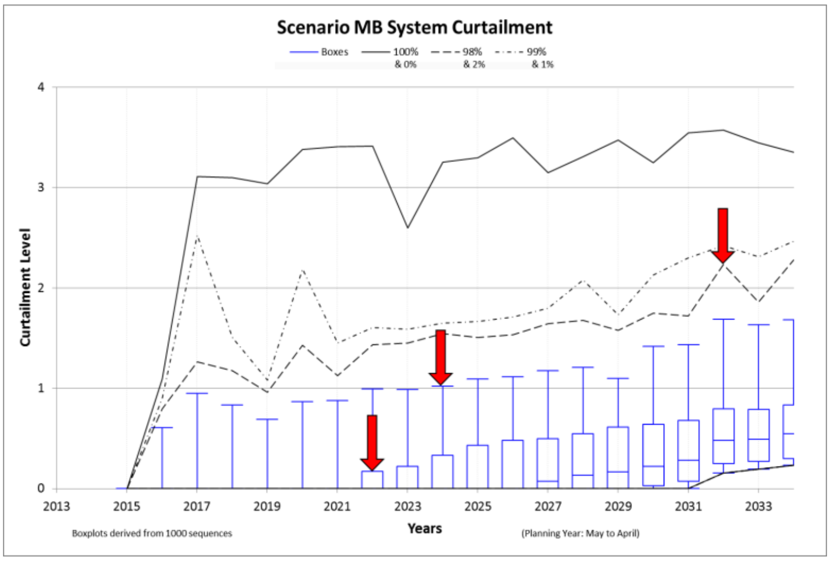


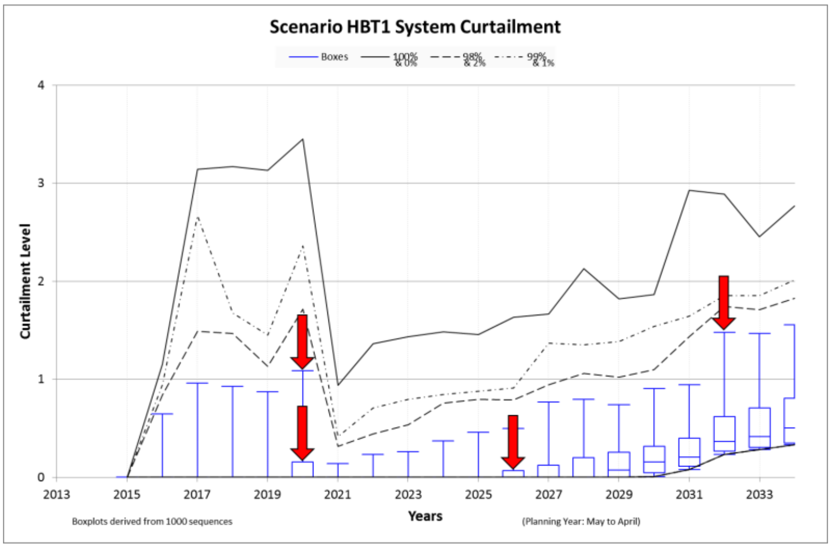





Scenario MF System Curtailment
Boxes
100% & 0%
98% & 2%
99% & 1%
Curtailment Level
Years
Boxplots derived from 1000 sequences
(Planning Year: May to April)


Scenario M System Curtailment
Boxes
100% & 0%
98% & 2%
99% & 1%
Curtailment Level
Years
Boxplots derived from 1000 sequences
(Planning Year: May to April)


Scenario MB System Curtailment
Boxes
100% & 0%
98% & 2%
99% & 1%
Curtailment Level
Years
Boxplots derived from 1000 sequences
(Planning Year: May to April)



Scenario HBT1 System Curtailment
Boxes
100% & 0%
98% & 2%
99% & 1%
Curtailment Level
4
3
2
1
0
2013
2015
2017
2019
2021
2023
2025
2027
2029
2031
2033
Years
Boxplots derived from 1000 sequences
(Planning Year: May to April)

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