The Orange-Senqu River Commission (ORASECOM)
Sharing the Water Resources of the Orange-Senqu River Basin
Botswana | Lesotho | Namibia | South Africa

Contract No.: P-Z1-EAZ-048/CS/01

# Preparation of Climate Resilient Water Resources Investment Strategy & Plan and Lesotho-Botswana Water Transfer Multipurpose Transboundary Project

## OPTIMIZED IWRMP CORE SCENARIO ECONOMIC APPROACH

### Component I and II

May 2023
FINAL REPORT

Report number: ORASECOM 010/2019

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# PREPARATION OF CLIMATE RESILIENT WATER RESOURCES INVESTMENT STRATEGY & PLAN AND LESOTHO-BOTSWANA WATER TRANSFER MULTIPURPOSE TRANSBOUNDARY PROJECT

## COMPONENT I AND II

# OPTIMIZED IWRMP CORE SCENARIO ECONOMIC APPROACH

**Prepared for**

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# PREPARATION OF CLIMATE RESILIENT WATER RESOURCES INVESTMENT STRATEGY & PLAN AND LESOTHO-BOTSWANA WATER TRANSFER MULTIPURPOSE TRANSBOUNDARY PROJECT

## COMPONENT I AND II

# OPTIMIZED IWRMP CORE SCENARIO ECONOMIC APPROACH

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# EXECUTIVE SUMMARY

The Orange-Senqu River Basin is one of the largest river basins south of the Zambezi with a catchment area of approximately 1 million km$^2$. It encompasses all of Lesotho, as well as a significant portion of South Africa, Botswana and Namibia. In terms of spatial coverage, about 64.2% of the basin lies in South Africa, 24.5% in Namibia, 7.9% in Botswana and 3.4% in Lesotho. The Orange-Senqu River originates in the Lesotho Highlands and flows in a westerly direction approximately 2 300 km to the west coast of South Africa and Namibia where the river discharges into the Atlantic Ocean.

The Orange-Senqu River Basin is a highly complex and integrated water resource system. It is characterized by a high degree of regulation and several major inter-basin transfer schemes to manage the resource availability between areas of relatively abundant precipitation and the areas of greatest water requirements. The existing infrastructure involves most of the largest water storage reservoirs in Southern Africa, as well as the associated water conveyance infrastructure, transmitting water to more than 250 major demand centres that are in some cases located outside of the Orange-Senqu River Basin, through Intra and inter-basin transfers. There are also several inter-basin transfer schemes, which augment the water resource in the Basin from other neighboring river catchments.

Water scarcity is an important challenge in the Orange-Senqu River Basin and requires coordinated efforts for the development, management and conservation of the water resources in the Basin. Much of the Basin is semi-arid to hyper-arid. A decrease in precipitation due to climate variability and change will have a huge impact on various sectors of the economy that are dependent on the resource. There is a high level of inter and intra-annual variability in precipitation.

The Basin is of major economic importance to South Africa and the entire SADC region, contributing to South Africa's Gross Domestic Product (GDP) from the Vaal and the Orange Rivers' water resource developments for agriculture, mining, energy production and manufacturing. In Lesotho, all the economic activities (agriculture, livestock and manufacturing) lie within the Orange-Senqu River Basin, as the country is located entirely within the Basin. The Basin also contributes to the GDP of Botswana and Namibia, where mining and agriculture are the main water users.

To co-ordinate and facilitate the water resources development and management in the Basin, the Orange–Senqu River Commission (ORASECOM) was established in November 2000. This led to the development of a basin level Integrated Water Resources Management (IWRM) Plan, adopted in February 2015, by the ORASECOM State Parties. The IWRM Plan provides a strategic transboundary water resources management framework and action targets and serves as a guiding and planning tool for achieving the long-term development goals in the Basin.

The IWRM Plan identified the absence of an integrated transboundary water resources investment strategy and plan, as one of the key challenges for achieving the sustainable development of the Basin's water resources. The need for joint projects and their implementation was identified as a requirement for providing mutually inclusive transboundary benefits.

**The objective of the current study** is to assist the Orange Sengu River Commission (ORASECOM) and its member States in operationalizing the IWRM plan developed in 2015.

The study is divided into two main modules:

- A climate resilient investment plan, based on the updated Water Resources Yield and Planning Model and the updated Core Scenario (Components I & II of the study); and
- The Lesotho-Botswana Water Transfer Project Pre-feasibility and Feasibility Study (Components III & IV of the study)

**This report falls under Component I: Climate Resilient Water Resources Investment Plan.** This report presents the findings of the economic optimisation conducted through an assessment of the economic effectiveness and efficiency of the various project interventions that constitute the updated IWRMP Core Scenario. Optimizing the Core Scenario enables an optimal allocation of water resources across the different categories of water use.

The objective is to inform the process of prioritising potential investments by assessing their economic effectiveness through the use of Unit Reference Value (URV). Further each project intervention's economic efficiency to unlocking the socio-economic impact relative to the cost of the investment, was determined through the use of a Cost-Benefit Analysis (CBA) model. Both approaches inform the economic optimisation of IWRMP Core Scenario.

An additional sub-task was also included as part of this report, to evaluate the assurance of supply to users on an economic basis. For the purpose of this task four scenarios were considered for the assurance of water supply sensitivity analysis, by considering the ORP (Orange River Project) water supply system, being the largest water supply system in the Orange -Senqu River Basin.

The Core Scenario has been updated to reflect all existing and future water requirements from the basin. There are 37 project interventions in the updated Core Scenario that were grouped into nine clustered schemes (See **Table 2 1** in the text for detail).

The output from this report forms the key input to the Basin Wide investment Plan (ORASECOM 010/2019). These two reports are closely interlinked and should preferable be considered together.

<u>**The economic effectiveness for the project**</u> intervention options and clusters were determined through the use of Unit Reference Value (URV). To ensure consistency in the analysis, costs were escalated to a base year of 2018 at constant prices based on the average inflation rate in South Africa for 2018 of 4.7%.

URV calculations are generally used to rank water resource development options that are comparable in that the options serve the same purpose or supply the same area. It is acknowledged that the different clusters are not comparable and serve different water demand areas, although the projects within a cluster are generally comparable. However, the URV as a single indicator does give the relative cost of each cluster in that it shows that the cluster might be extraordinarily expensive or cheap.

The table below presents a summary of the URV analysis for the various clusters.

**Table 1: Summary of Clustered Scheme URVs**

| | **Discount Rates** | | | **Investment Cost** | **Yield** |
|---|---|---|---|---|---|
| | **8%** | | | | |
| | **URV** | **PV Costs** | **PV Water** | | |
| **Cluster Name** | **R/m³** | **R millions** | **Million m³** | **R millions** | **Million m³/a** |
| Cluster 1 ORP intervention options* | **6.52** | 35,869 | 5,501 | 39,808 | 724 |
| Cluster 2 L-BWT Scheme | **53.17** | 54,775 | 1,030 | 54,257 | 162/334 |
| Cluster 3 Lesotho Lowlands | **1.60** | 1,290 | 806 | 1,381 | 65 |
| Cluster 4 IVRS intervention options (includes the Thukela transfer option) | **6.55** | 44,476 | 6,792 | 32,739 | 578 |
| Cluster 5 Caledon to Greater Bloemfontein transfer | **4.08** | 253 | 62 | 180 | 6 |
| Cluster 6 Greater Bloemfontein internal resource improvements | **10.79** | 3,592 | 333 | 1,638 | 30 |
| Cluster 7 Gariep to Greater Bloemfontein Transfer | **14.71** | 6,582 | 448 | 4,300 | 43 |
| Cluster 9 Integrated Water management options ** | **9.74** | 22,422 | 2,302 | 6,314 | 228 |

Notes: * - Includes Polihali and associated net yield.

** - Only includes the WC/WDM intervention options

The URV results provide a broad range of outputs, driven by a number of project specific design features, which impact on an intervention's cost profile and water balance impact – the two key variables in the URV analysis. The implication of this is that a linear comparison of the URVs across the clusters is quite difficult to establish.

Although the URV figures vary significantly, it is observed that the interventions which involve large transfer schemes and pipelines – clusters 2 and 7 have the highest URV figures. This aligns with the higher upfront costs associated with such large schemes, compared with the other clusters. The intervention with the lowest URV (implying extreme effectiveness) – cluster 1, involves the construction of only a pump station at an existing storage facility (Vanderkloof Dam) indicating a high output (yield impact) for a low input (investment cost).

**The Cost-Benefit Analysis (CBA) model** was used to unlock the socio-economic impact relative to the cost of the investments. The Economic Benefit is based on the potential increase in GDP that could result from the water yield or water saving of the investment. The Results of the Cost Benefit Analysis are provided in **Table 2**.

A CBA was conducted for each intervention under each scheme in order to determine the resulting net benefit or loss. The NPV of each intervention's economic costs and benefits were then aggregated to the scheme level. It is assumed that the quantitative benefits identified (impact on economic activity and the health benefit) are applicable to all the interventions in the schemes. The benefits are discounted, at a rate of 8%, over the operational period of the intervention to arrive at a net benefit.

The CBA produces 3 important outcomes, the Economic Net Present Value (ENPV), Benefit/Cost Ratio (BCR) and Economic Internal Rate of Return (EIRR). The ENPV describes the net present value of the economic costs and benefits for the Core Scenario, where a positive ENPV indicates a net benefit associated with the project intervention and therefore economic viability and rationale for implementing the intervention. The EIRR is an indication of a project intervention's rate of return at which the NPV will be zero.

The economic benefits were a summation of the estimates of the impact on economic activity and health benefit. As seen in the CBA results above most clustered schemes produced positive economic outcomes, which suggests that most are worthwhile to invest in. Only two clustered schemes yielded negative ENPVs and BCR of below 1. The results also indicate that despite the irrigation sector being the largest water user, the urban & industrial sector has the greatest productive use of water. That is, the impact on economic output is greater for every cubic metre of water used by the urban & industrial sector.

### Table 2 : Cost Benefit Analysis Results

Discount rate 8%

| | Cluster 1: Orange River Project Scheme future improvements | Cluster 2: L-BWT Scheme | Cluster 3: Lesotho Lowlands | Cluster 4: IVRS intervention options | Cluster 5: Caledon to Greater Bloemfonte in transfer | Cluster 6: Greater Bloemfontein internal resource improvements | Cluster 7: Gariep to Greater Bloemfonte in Transfer |
|---|---|---|---|---|---|---|---|
| E-NPV | 6,469 | -22,994 | 200 | 119,783 | 2,093 | 6,723 | -1,006 |
| E-IRR | 10.7% | 0.8% | 5.0% | 13.6% | 38.7% | 22.6% | 1.9% |
| BCR | 2.63 | 0.46 | 1.20 | 3.43 | 10.92 | 3.72 | 0.80 |
| **NPV (R millions)** | | | | | | | |
| **Total Economic Costs** | 3,969 | 42,248 | 1,008 | 49,342 | 211 | 2,468 | 5,001 |
| Capital Cost | 3,743 | 37,840 | 966 | 37,606 | 149 | 1,105 | 3,312 |
| Operational Cost | 227 | 4,408 | 42 | 11,736 | 62 | 1,363 | 1,689 |
| **Total Economic Benefits** | 10,439 | 19,254 | 1,208 | 169,125 | 2,304 | 9,191 | 3,995 |
| Increase in economic activity | 5,000 | 18,483 | 660 | 161,889 | 25 | 725 | 747 |
| Urban & Industrial | 3,290 | 5,992 | 89 | 161,889 | 25 | 725 | 747 |
| Irrigation | 1,089 | 226 | 571 | - | - | - | - |
| Mining | 620 | 12,264 | - | - | - | - | - |
| Health benefit | 5,439 | 771 | 548 | 7,236 | 2,279 | 8,466 | 3,247 |

Note: - Polihali Dam (Lesotho Highland Water project (LHWP) Phase II and connecting tunnel to Katse Dam intervention is clustered under the ORP scheme, however, its economic impact is realizable under the IVRS scheme. Therefore, the economic costs and benefits are accounted for under the IVRS scheme.

The CBA model indicators were tested for sensitivity using a 6% and 10% discount rate against the 8% used for the model. Different institutions usually use a base rate across different projects. The World Bank and European Bank for Research and Development use 10% as a standard conventional cut-off rate for water and power projects in Southern Africa.

The Water Research Commission (WRC) of South Africa recommends for South African water projects to be assessed with an 8% discount rate with possible variation between 6% and 10%. This rate conforms to the discount rate recommended by major international development institutions whilst taking into account the macro-economic context of the country.

The results indicate that the CBA model is sensitive to variability in the discount rate particularly for the clustered schemes with a larger NPV (i.e. where benefits outweigh costs more significantly). Whereas the variability in the model is limited in the quantitative benefits inputs. Overall, the output indicates a robust model.

It is important to note that further work will be carried out to determine in more detail the costs and benefits of the L-BWT Scheme. For that purposes a financial assessment was contracted separately from this study. This assessment and analysis will look at the cost and benefit for the “with and without” project situations for the L-BWT Scheme. This is required to establish the incremental net benefit arising from this transfer project over a long-term time horizon. The estimates of the project benefits include direct and indirect benefits, tangible and intangible benefits and secondary benefits related to the project as well as externalities. Benefits associated with hydropower production will also be considered. Indirect costs and externalities, such as the impact of possible reduction of the water allocation to the Orange systems, will also be quantified. A key consideration of the assessment is the climate resilience benefits that the scheme provides to Botswana which cannot be properly quantified in monetary terms.

**<u>The assurance of water supply</u>** is a very important component of water supply to users that are taken into account in water resource modeling, planning and management of the water resources. Although the assurance of water supply can be modelled in detail by both the WRYM and the WRPM, these results are seldom taken forward into economic assessments.

Work was in this regard for the first time carried out in 2017 for the Water Research Commission of RSA. The Water Research Commission study was specifically focused on the assurance of irrigation supply versus the related economic impacts. The goal of this assessment as part of the ORASECOM study is to carry out a sensitivity analysis with the focus to determine whether irrigation in some areas could not be optimized by supplying water at lower assurances than the existing norm currently applicable to the system. (In general for most systems irrigation is supplied at 95% assurance urban/industrial use at 98% assurance and strategic industries such as Eskom at 99.5% assurance)

The following scenarios analysed by using the WRPM were considered for the assurance of water supply sensitivity analysis, considering the Orange River Project (Gariep and Vanderkloof dams and related supply area). The assurance of supply for the different users in the ORP as currently used, is defined by the Priority Classification Table as given in **Table 3**.

- Scenario 1: Consider the current system with the priority classification as shown in **Table 3** (existing priority classification as currently used for the ORP) The expected growth in water requirements and the implementation of WC/WDM actions as defined for the Core Scenario, form part of this Scenario (ORASECOM, 2020a). The Preliminary Reserve for the Lower Orange as determined by RSA in terms of the NWA in 2018, was used for the modelling of this scenario over the entire analysis period. For the purpose of this test scenario, Polihali Dam start storing water in Nov 2043. (Polihali Dam was artificially brought in late in the analysis period to be able to show the impact of such a large development). No other future large developments upstream of the ORP such as dams, transfer schemes etc were activated in the analysis. The reason for not activating the upstream development options, is that the purpose of this scenario is to evaluate the impact of assurance of water supply on users, and the impact of upstream developments.

**Table 3: Priority Classification for the users in the Orange River Project**

| Sector (Recurrence Interval of a restriction; Assurance of supply) | Priority Categories (Portion of the water requirements %) | | |
|---|---|---|---|
| | High | Medium | Low |
| | 1: 200 year (99.5%) | 1: 100 year (99%) | 1: 20 year (95%) |
| **Irrigation** | **10** | **40** | **50** |
| **Urban** | **50** | **30** | **20** |
| **Operational requirements** | **100** | **0** | **0** |
| **Environmental** | **68** | **0** | **32** |

**Restriction levels: 3 2 1 0**

- Scenario 2: Consider the current system with the alternative priority classification as shown in **Table 4** in the body of the text (alternative priority classification that will result in a lower assurance of supply as promoted in previous studies considering the ORP) The remainder of the Orange System WRPM set up, remains as for Scenario 1.

**Table 4: Orange River Project alternative Project Priority Classification**

| Sector | Priority Categories |
|---|---|

| | **(portions of the water requirements as %)** | | | |
|---|---|---|---|---|
| | **High** | **Medium High** | **Medium Low** | **Low** |
| | **1 : 200 year**<br><br>**(99.5%)** | **1 : 100 year**<br><br>**(99%)** | **1 : 50 year**<br><br>**(98%)** | **1 : 10 year**<br><br>**(90%)** |
| Irrigation | 0 | 20 | 20 | 60 |
| Urban | 30 | 30 | 20 | 20 |
| Operational Requirements | 100 | 0 | 0 | 0 |
| Environmental Requirements | 68 | 0 | 0 | 32 |
| Restriction levels | 4 | 3 | 2 | 1 0 |

Scenario 2c: As Scenario 2, but with some of the irrigation in the low class moved up into the medium low assurance class.

- Scenario 3: As Scenario 2, but with all irrigation allocated to the low assurance class (90%).

The impact of water supply assurance on a water supply system were illustrated by four different key result outputs:

- Looking at ability of the system to adhere to the required assurance of supply: The results from the analyses in the form of the curtailment level plots clearly illustrated the assurance of supply ability of the system. If there was a high number of violation events of the curtailment criteria, it clearly showed that the system was not able to supply the users all the time over the analysis period, at the required assurance levels as defined in the priority classification table and applicable to that specific scenario. From these plots it is also clear at which of the curtailment levels the most violations occur.
- Evaluating the storage projection plots for the different scenarios to assess whether the operating rule that includes the applicable priority classification table for the specific scenario, was able to protect the water supply system from total failure or not: Total failure means the storage dams in the system were completely empty at some time over the analysis period and no water could be supplied to any of the users for some time period.

- Assessing the impact of different priority classifications or assurance levels of water supply on the GDP, as produced from the water supply system: These assessments clearly illustrated the economic impacts of water supply assurance from the system. For these analyses, the reduction in GDP as result of restrictions/curtailments imposed on the system, were determined for the different scenarios considered. The scenario with the lowest reduction (net present value) in GDP, will thus reflect the best scenario from an economic point of view.
- Determining the average water supply over the analysis period: For the irrigators it is very important to know what the overall average water supply from the different scenarios will be. If the average water supply from one scenario is significantly lower than that from the other scenarios, the irrigators will be hesitant to implement that specific option or scenario. It is not possible to look at one of these four key results in isolation to be able to decide which of the scenarios analyzed is providing the best result. One need to assess the related impacts from all four key result components per scenario, and then compare the combined effect with those from the other scenarios. A summary of the four key results per scenario is given in Table 5.

In Table 5 each of the key results are ranked according to color as indicated in the Color Ranking box on the left. The ranking colors are almost like that of a traffic light with green as the best or highest ranking and red the worst or lowest ranking. When considering the average irrigation supply for example, the current system (Scenario 1) was ranked yellow and not red due to the fact that a 94.5% average supply for irrigation is still good for irrigation, although it presents the lowest average water supply of all the scenarios. The color ranking for the reduction in GDP due to water restrictions is fairly straight forward and clearly shows that the reduction in GDP for Scenario 1 is having by far the most severe impact on the GDP produced from the system, with Scenario 3 the lowest reduction in GDP, thus producing the highest GDP.

When considering the color ranking for all four key results as a whole, Scenario 2c stands out as the most favorable option (See Table 5) with all key results ranked from light green to the full green ranking. Although Scenario 3 resulted in the highest average water supply and lowest reduction in GDP, the risk of total dam failure is high, and this scenario significantly impact on the water available from the high assurance class.

**Table 5: Summary of key results per Scenario analyzed**

| Color Ranking | |
|---|---|
| 1 | Highest |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | Lowest |

| Description | Scenario | Average Irrigation (million $m^3$/a) | | Reduction in GDP @ 8% discount rate | Curtailment Levels | Average Dam storage @ exceedance probability (million $m^3$) | | 1 in 200 year (99.5%) curtailment level: Number of curtailment exceedances |
|---|---|---|---|---|---|---|---|---|
| | | Supply | Demand | million Rand | | 99.5% | 95% | |
| As Scenario 2 but all irr at low assurance | 3 | 2,090.21 | 2,174.00 | 1,442.72 | 4 | 2351 | 3853 | 14 small to medium high exceedance |
| | | % supplied | 96.1% | | | | | |
| Adjusted lower assurance with 4 Classes | 2 | 2,080.51 | 2,174.00 | 1,904.18 | 4 | 2533 | 3937 | 5 small to medium exceedance |
| | | % supplied | 95.7% | | | | | |
| As Scenario 2 just slightly higher assurance | 2c | 2,073.39 | 2,174.00 | 2,273.31 | 4 | 2638 | 4011 | Zero exceedance |
| | | % supplied | 95.4% | | | | | |
| Current System - 3 priority classes | 1 | 2,054.42 | 2,174.00 | 3,201.00 | 3 | 2882 | 4183 | Once very small exceedance |
| | | % supplied | 94.5% | | | | | |

Scenario 2c provides several benefits when compared to Scenario 1 (Current assurance of supply) which includes:

- Slight increase in average water supply.
- The reduction in GDP due to restrictions/curtailments is significantly lower.
- The available storage in the system is better utilized.
- It is not impacting negatively on the water allocated to the high assurance class

From results obtained from all the scenarios analysed, it was clear that there are strong indications that irrigation within the ORP is currently supplied at a too high assurance. It will clearly be to the benefit of all the users, for the water supply system as a whole and the GDP generated from this area, to supply irrigation at a lower assurance, more in line with that used for Scenario 2c.

It is important to note that every irrigation or water supply scheme is unique due to the characteristics of the hydrology applicable to the water supply system, the yield capability and its related yield characteristics at different assurance levels, whether the system is over or underutilized, the crop types generally grown and produced from this scheme, etc. The results from this sensitivity analysis carried out for the ORP will not be fully applicable to other schemes, although some guidelines or trends can provide guidance when evaluating other schemes in more detail.

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| | |
|---|---|
| AMD | Acid mine drainage |
| ASM | Assurance of Supply Model |
| B/C RATIO | Benefit-Cost Ratio |

| | |
|---|---|
| BCR | Economic Benefit-Cost Ratio |
| BW | Republic of Botswana |
| CBA | Cost-Benefit Analysis |
| DWA-LS | Department of Water Affairs (Lesotho) |
| DWA-RSA | Department of Water Affairs (RSA) |
| DWAF-NA | Department of Water Affairs and Forestry (Namibia) |
| DWAF | Department of Water Affairs and Forestry (RSA) |
| DWS-BW | Department Water and Sanitation (Botswana) |
| DWS-RSA | Department Water and Sanitation (RSA) |
| EFR | Ecological flow requirements |
| EIRR | Economic Internal Rate of Return |
| ENPV | Economic Net Present Value |
| EWR | Ecological Water Requirement |
| GDP | Gross Domestic Product |
| GEF | Global Environmental Facility |
| IAPP | International Association for Public Participation |
| IRR | Internal Rate of Return |
| IPCC | International Panel for Climate Change |
| IVRS | Integrated Vaal River System |
| IWRM | Integrated Water Resources Management |
| L-BWT | Lesotho Botswana Water Transfer |
| LHDA | Lesotho Highlands Development Authority |
| LHWP | Lesotho Highlands Water Project |
| LS | Kingdom of Lesotho |
| L/S | Litre per second |
| MAFS | Ministry of Agriculture and Food Security (Lesotho) |
| MAP | Mean Annual Precipitation |
| MAR | Mean Annual Runoff |
| MAWF | Ministry of Agriculture, Water and Forestry (Namibia) |
| MC | Management Centre (Botswana) |
| MEWR | Minerals, Energy and Water Resources (Botswana) |
| MM/A | Millimetres per annum |

| | |
|---|---|
| $M^3/S$ | Cubic Meters per second |
| $M^3/A$ | Cubic Meters per annum |
| MW | Megawatts |
| NAP | National Action Programme/Plan |
| NGO | Non-governmental Organisation |
| NWA_RSA | National Water Act (RSA) |
| ORASECOM | Orange Senqu River Commission |
| ORP | Orange River Project (Gariep and Vanderkloof dams and supply area) |
| ORS | Orange River System |
| PES | Present Ecological State |
| PWC | Permanent Water Commission |
| RSA | Republic of South Africa |
| SADC | Southern African Development Community |
| SADC-GIO | Southern African Development Community Groundwater Information Portal |
| SAP | Strategic Action Programme |
| TDA | Transboundary Diagnostic Analysis |
| TTT | Technical Task Team |
| TOR | Terms of Reference |
| UGEP | Utilisable Groundwater Exploitation Potential |
| UNDP | United Nations Development Programme |
| URV | Unit Reference Value |
| VRS | Vaal River System |
| WARMS | Water Authorisation and Registration Management System |
| WASCO | Water and Sewerage Company (Lesotho) |
| WC | Water Conservation |
| WC/WDM | Water Conservation and Water Demand Management |
| WDM | Water Demand Management |
| WIM | Economic Water Impact Model |
| WMA | Water Management Area |
| WRC | Water Research Commission of South Africa |
| WRYM | Water Resources Yield Model |

| | |
|---|---|
| WRPM | Water Resources Planning Model |
| WUC | Water Utilities Company |

# 1 INTRODUCTION

## 1.1 Background to the study area

The Orange-Senqu River Basin is one of the largest river basins south of the Zambezi with a catchment area of approximately 1 million km$^2$. It encompasses all of Lesotho, a significant portion of South Africa, Botswana and Namibia. The Orange-Senqu River originates in the Highlands of Lesotho and flows in a westerly direction, approximately 2,200 km to the west coast of South Africa and Namibia, where the river discharges into the Atlantic Ocean. See **Figure 1-1**

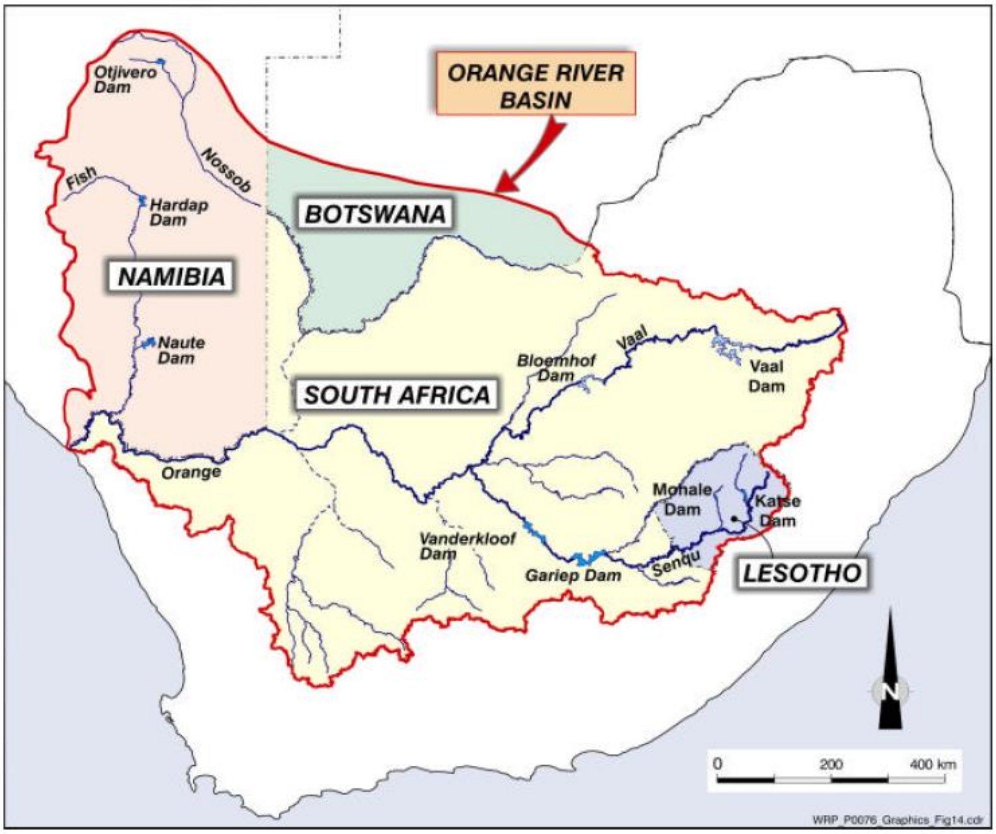



**Figure 1-1: Orange River Basin**

On the part of Lesotho, there are three distinct hydrologically homogenous river basins, where each river basin has its clear source where it originates. These river basins, namely: Senqu, Mohokare and Makhaleng River Basins all flows in the westerly direction and join together outside the border of Lesotho with the Orange River to form one large basin known as the Orange-Senqu River Basin.

It has been estimated that the natural runoff of the Orange-Senqu River Basin is in the order of 11,300 million m$^3$/a, of which approximately 4,000 million m$^3$/a originates in the Senqu River Basin in the highlands of Lesotho, 6,500 million m$^3$/a from the Vaal and Upper Orange River, with approximately 800 million m$^3$/a from the Lower Orange and Fish River in Namibia. The basin also includes a portion in Botswana and Namibia (north of Fish River) feeding the Nossob and Molopo Rivers.

Southern Africa has fifteen (15) transboundary watercourse systems of which thirteen (13) exclusively stretch over the Southern African Development Community (SADC) Member States. The Orange–Senqu is one of these thirteen (13) transboundary water course systems. SADC member states embrace the ideals of utilizing the water resources of these transboundary watercourses for the regional economic integration and for the mutual benefit of the riparian states. The region has demonstrated a great deal of goodwill and commitment towards collaboration on water issues. Thus, SADC has adopted the principle of basin–wide management of the water resources for sustainable and integrated water resources development.

To enhance the objectives of integrated water resources development and management in the region, the Orange–Senqu River Basin Commission (ORASECOM) was established in November 2000.

ORASECOM was established by the Governments of four States, namely, South Africa, Lesotho, Botswana and Namibia, for managing the transboundary water resources of the Orange-Senqu River Basin and promoting its beneficial development for the socio-economic wellbeing and safeguarding the basin environment. This led to the development of a basin level Integrated Water Resources Management (IWRM) Plan adopted in February 2015 by the ORASECOM Member States. The IWRM Plan provides a strategic transboundary water resources management framework and action areas and serves as a guiding and planning tool for achieving the long-term development goals in the basin. A key aspect of the transformative approach for strengthening cooperation has been identified as the need for joint project implementation that provides a mutually inclusive transboundary benefit.

The IWRM Plan recommends strategies and measures for promoting sustainable management of the water resources of the basin and defines strategic actions that will ensure and enhance water security, considering the long term socio-economic and environmental demands on the water resources of the basin. The Lesotho to Botswana Water Transfer Scheme, a major component under this study, was not included in the 2015 IWRM Plan as one of the strategic actions but has lately been identified as a priority project.

The Orange-Senqu River basin is a highly complex and integrated water resource system, characterized by a high degree of regulation and major inter-basin transfers to manage the resource availability between the location of relatively abundant precipitation and the location of greatest water requirements. The infrastructure involves water storage and transmission infrastructure, transmitting water to demand centres that are in some cases located outside of the basin through intra and inter basin transfers. Most of the existing infrastructure are those under the Lesotho Highlands Water Project (LHWP) which transfers water to South Africa and also those for inter basin transfer to the Vaal River Basin.

**Figure 1.2** provides approximate values of the natural run-off in the Orange-Senqu River Basin. These figures highlight the variable and uneven distribution of runoff from east to west in the basin. The figures refer to the natural runoff which would have occurred had there been no developments or impoundments in the catchment. The actual runoff reaching the river mouth is considerably less than the natural values and is estimated to be in the order of half the natural values.

The difference is due mainly to the extensive water utilisation in the Vaal River Basin, most of which is for domestic and industrial purposes. Several major transfer systems are used to bring water into the Upper Vaal River catchment to support the high-water requirements, in particular those within the Gauteng area as well as for several Power Stations.

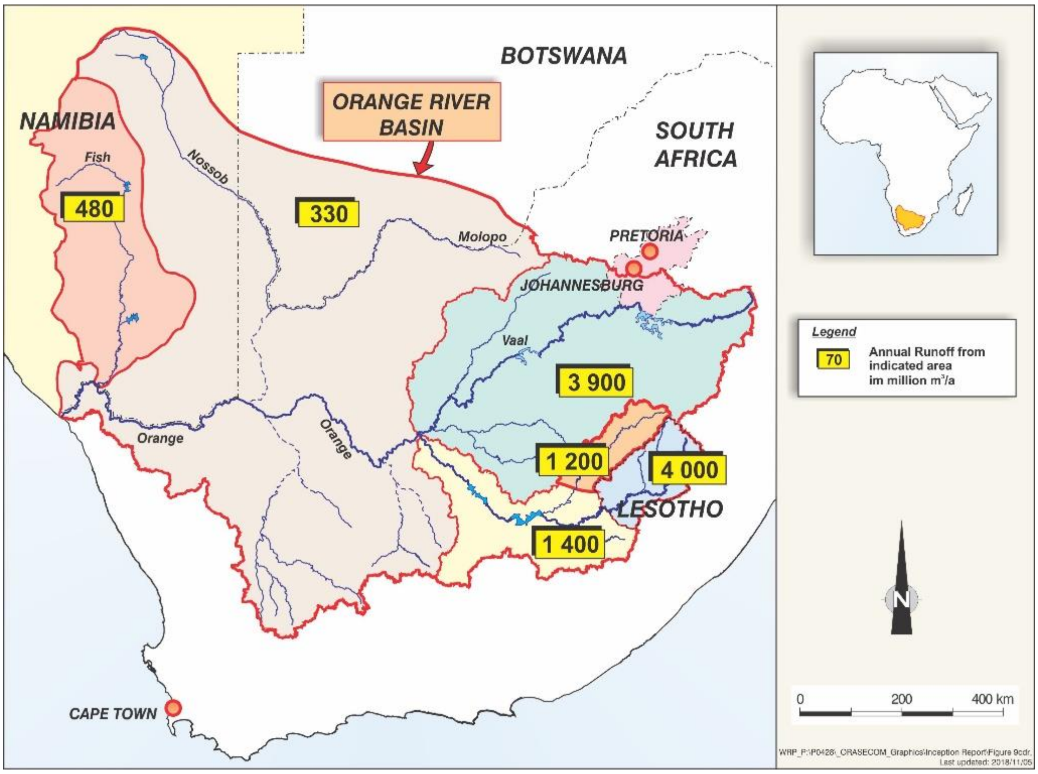



**Figure 1-2: Approximate Natural Run-off in the Basin**

Large volumes of water are also used to support extensive irrigation and some mining demands along the Orange River downstream of the Orange-Vaal confluence, as well as significant irrigation developments in the Eastern Cape in South Africa, supplied through the Orange-Fish Tunnel. In addition to the water demands, evaporation losses from the Orange

River and the associated riparian vegetation that depend on the river account for 500 to 1,000 million $m^3$/a.

As already indicated, there are locations of relatively abundant precipitation and water availability and locations of greatest water requirements. Water scarcity in locations of greatest need is the main challenge in the basin, and this requires a coordinated joint development, management and conservation of the water resources of the River Basin. The climate in the basin varies from relatively temperate in the eastern source areas, to hyper-arid in the western areas. As shown in **Figure 1.3**, average annual precipitation decreases from more than 1,000 mm/a in the source areas of the basin to less than 50 mm/a at the river mouth. This varies considerably from year to year. Much of the rainfall occurs as intense storms, which can be highly localised. The temporal and spatial distribution of precipitation within any particular year can be considerable.

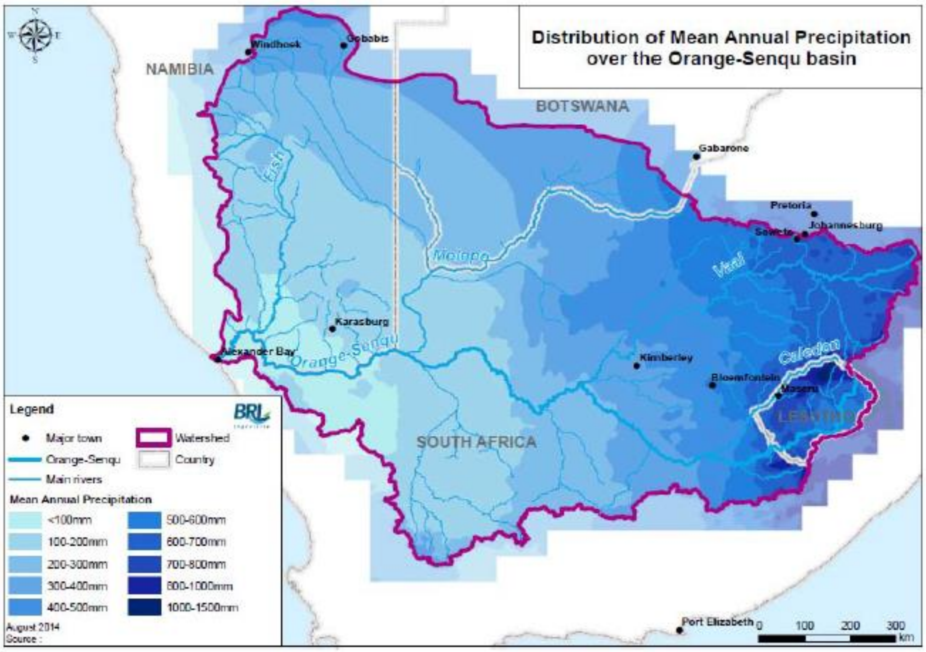
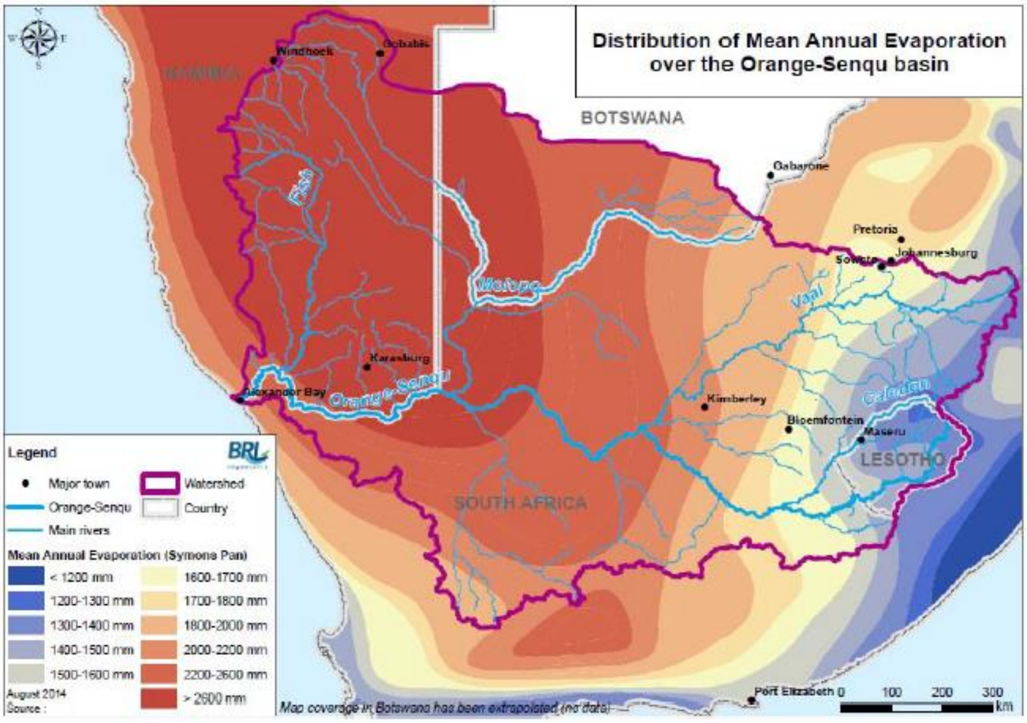



**Figure 1-3: Distribution of Mean Annual Precipitation**

In **Figure 1.4** it is evident that evaporation increases from south-east to north-west reaching a maximum of more than 1,650 mm/a in the west. Even in the cooler and wetter parts of the basin, evaporation in most cases exceeds precipitation. Temperature and evaporation follow a similar distribution with the coolest temperatures in the Lesotho Highlands and the hottest in the western Kalahari.

It is generally accepted that Southern Africa will be highly impacted by climate change. Consequently, there are concerns around the changes in precipitation and temperature due to climate variability and climate change. This study therefore aims to enhance investment in transboundary water security and to build resilience to climate change into the implementation of the strategic projects and actions described in the IWRM Plan.

**Figure 1-4: Distribution of Mean Annual Evaporation**




## 1.2 Objective of the Assignment

The objective of the study is to assist ORASECOM and the riparian countries in operationalizing the IWRM plan developed in 2015. The objective will therefore be met through three outputs:

- A Climate Resilient Investment Plan for the Orange-Senqu River Basin based on the updated Core Scenario (Report 003/2019);
- Operationalization Plan (Report 012/2019) for ten (10) priority actions selected from the updated IWRM Plan; and
- Pre-feasibility level report (Report 015/2019) for the L-BWT Project, and the feasibility level report (Report 017/2019) for a new dam, on Makhaleng River in Lesotho.

The study is divided into two distinct parts:

- Preparation of a Climate Resilient Investment Plan, based on the updated Water Resources Yield and Planning Model and the updated Core Scenario defined in the IWRM Plan of 2015, as Components I & II of the study; and

- The pre-feasibility study of Lesotho-Botswana Water Transfer Project, including the feasibility study of a new dam on Makhaleng River in Lesotho, as Components III & IV of the study.

The four components of the study referred to above are:

- Component I: Climate Resilient Water Resources Investment Plan;
- Component II: Operationalisation of the Integrated Water Resources Management Plan;
- Component III: Pre-feasibility study of the Lesotho to Botswana Water Transfer Project;
- Component IV: Feasibility Study of the Dam on Makhaleng River in Lesotho.

### 1.2.1 Climate Resilient Investment Plan (Components I and II)

The high level of variability in precipitation due to climate variability and change, warrants the need to optimize and implement efficient water resources development and management in the basin. The development of new infrastructure to meet increasing water demands, even if technically and environmentally feasible, is both expensive and complex. Economic considerations of water use have been identified as a key criteria in the planning and optimum use of what will become an increasingly scarce and expensive resource. Projections of future water demand and associated infrastructure development must be based on balanced considerations of economic, social, and environmental factors. The integration of water resources yield analysis, water resources development planning and economic optimization will ensure the development of short, medium- and long-term solutions to address basin water resources needs and development challenges.

The study considers all relevant water resource studies in Botswana, Lesotho, Namibia and South Africa. This will include updating of inputs from the Reconciliation Strategy Studies, updating of inputs with more recent results from the Reconciliation Strategy Maintenance Studies as well as other recent water resource related studies conducted in the basin countries. The study will establish a comprehensive basin wide model which will be integrated with economic analyses to determine the optimized and most efficient development options, as part of setting the long-term development investment strategy and plan for the basin.

Components I & II will thus address the water resources investment plan and the operationalization of the updated IWRM Plan with the following outputs:

- Updated Core Scenario of the IWRM Plan, which would include the Lesotho-Botswana Water Transfer Scheme and any other new projects identified (ORASECOM 003/2019);
- Estimate of the Climate Change Effects on the updated Core Scenario (ORASECOM 007/2019);
- Optimised IWRM Plan Core Scenario through an economic approach (ORASECOM 009/2019);
- Financial Strategy for the Core Scenario (ORASECOM 010/2019);
- Updated Basin Wide Investment Plan approved by ORASECOM, which would include new projects that takes into consideration climate change effects (ORASECOM 010/2019);
- A comprehensive assessment of existing policies, legal and institutional arrangements and structures (ORASECOM 008/2019);
- Selected 10 strategic actions, Terms of Reference and cost estimates for each strategic action (ORASECOM 013/2019); and
- A road map for operationalization of the ten (10) strategic actions contained in the updated Integrated Water Resource Management Plan (ORASECOM 012/2019).

### 1.3 Purpose and Structure of this report

A vital component of Optimizing the Core Scenario involves an assessment of the optimal allocation of water resources across the different categories of water use to prioritise potential investments by assessing their contribution to unlocking value for money i.e. the investment's contribution to socio-economic impact relative to the cost of the investment, the benefit versus the cost. This task may be termed the economic optimization of the Core Scenario.

This report presents the findings of the economic optimisation conducted through an assessment of the economic effectiveness and efficiency of the various project interventions that constitute the updated IWRMP Core Scenario. Optimizing the Core Scenario enables an optimal allocation of water resources across the different categories of water use.

The objective is to inform the process of prioritizing potential investments by assessing their economic effectiveness through the use of Unit Reference Value (URVs). Further each project intervention's economic efficiency to unlocking the socio-economic impact relative to the cost of the investment is determined through the use of a Cost-Benefit Analysis (CBA) model. Both approaches will inform the economic optimisation of IWRMP Core Scenario.

This report has the following sections:

1. **High-level costing of the Core Scenario** – the economic costs of the project are identified and described.
2. **Economic Effectiveness Analysis of the Core Scenario** - The economic efficiency of the Core Scenario’s individual projects is determined through the use of unit reference values (URVs).
3. **Economic Efficiency Analysis of the Core Scenario** - identified economic costs and benefits of the Core Scenario are evaluated to determine the socio-economic impact of the different schemes. The variables are then tested in a sensitivity analysis to determine the robustness of the model.
4. **Conclusion**

**Appendix A**

URV Sensitivity analysis for the L-BWT Scheme

## 2 HIGH-LEVEL COSTING OF THE CORE SCENARIO

The IWRMP Core Scenario was developed for the Integrated Orange-Senqu River system in 2015. The 2015 Core Scenario provides a set of projects/interventions and water requirement projections. The Core Scenario has been updated to reflect all existing and future water requirements from the basin. There are 37 project interventions in the updated Core Scenario that are grouped into nine clustered schemes as shown in **Table 2-1**.

High-level estimates of the Core Scenario capital and operational costs were sourced from existing reports and documents. The key documents used to source the costing data are listed in **Section 7.**

All project intervention costs with a base date before 2018 were escalated to 2018 prices using an average South African inflation rate of 6%[2]. The total economic costs of the IWRMP Core Scenario, in 2018 prices, therefore, amounts to R104 596 million. It is to be noted that the prices summarised in **Table 2-1** have been converted into economic prices using conversion factors (see **Box 1**).

| **Box 1: Conversion Factors** |
| --- |
| Conversion factors are a ratio between the economic price and the financial price for a project output or input. To convert financial prices into economic prices it is necessary to remove market distortions (such as taxes or import duties) so as to determine the true cost of a project. The methodology used in the economic analysis thus applies conversion factors to market prices to correct for market distortions and attain relevant shadow prices of inputs and outputs. If a conversion factor is less than one it indicates that the true value of that price is less than its market price, and vice versa. An example would be an imported product which is subject to exchange rate commissions and VAT. VAT expenditures by the government on a project on these items would be offset by the VAT receipts on the same products. A failure to adjust for this would show the project as being more expensive on a net basis than would actually be the case. |

Based on a technical assessment, the various projects have been allocated into a number of clusters. These clusters align with an overall water balance impact and portfolio of dependent projects. It is important to note that a number of projects cannot be implemented nor assessed

[2] StatsSA

as standalone projects, as their implementation and function is contingent on an adjacent project. This further justifies the clustering approach of the projects.

The clustering approach is critical to the economic analysis, as it forms the basis on which the assessment of the economic costs and benefits can be meaningfully assessed. Given that, as stated above, the implementation of most projects has a direct bearing on the implementation and output of adjacent projects, it will be inept to conduct an economic appraisal of individual projects, without providing a more holistic cluster approach.

The table below also provides a list of the clusters, with their associated costs and projects that make up each cluster. A breakdown of these costs per project, as well as their operational costs and impact on water balance is shown in the table.

Projects with similar characteristics are categorised into four main categories: (1) Dams; (2) Pipeline/Pumping Schemes; (3) Wastewater Treatment; and (4) Integrated Water Management. This is done to align the operational review period of like projects. The assumptions around the operational periods for each project category are indicated in **Table 2-1** below.

**Table 2-1: Summary of Project Interventions and Clustered Schemes (ZAR 2018)**

| | | Project Type | Capital Cost (2018 - R Million) | Operational Cost (2018 - R Million) | Yield or Impact on yield (Million $^3$/annum) | Operational Period |
|---|---|---|---|---|---|---|
| **Cluster 1: Orange River Project Scheme future improvements** | | | 39,822 | 131 | | |
| 1 | Utilise the lower-level storage in Vanderkloof Dam | Dam | 180 | 10 | 137 | 20 |
| 2 | Real Time flow modelling and monitoring in the Lower Vaal downstream of Bloemhof Dam and in the Orange River downstream of Vanderkloof Dam to the Orange River mouth; | Dam Operating Rule | 6 | 1 | 80 | 20 |
| 3 | Polihali Dam (Lesotho Highland Water project (LHWP) Phase II and connecting tunnel to Katse Dam; using new operating rule (net yield). Dam wall height to spill level is 150m with gross storage of 2 322 million $m^3$ | Dam | 31,137 | 96 | 107 | 50 |
| 4 | Noordoewer/Vioolsdrift Dam used as an individual resource. Medium size dam, 36m dam wall height to spill level and gross storage of 650 | Dam | 4,397 | 13 | 280 | 50 |

| | | Project Type | Capital Cost (2018 - R Million) | Operational Cost (2018 - R Million) | Yield or Impact on yield (Million $^3$/annum) | Operational Period |
|---|---|---|---|---|---|---|
| | million $m^3$ (Dam size still to be optimized and finalised) | | | | | |
| M | Construction of the Verbeeldingskraal Dam upstream of Gariep Dam; | Dam | 4,082 | 12 | 200 | 50 |
| 6 | Formally agree Environmental Water Requirements & release to River Mouth | Integrated Water Management | 20 | - | - | 20 |
| **Cluster 2: L-BWT Scheme** | | | 65,611 | 852 | | |
| 7 | Makhaleng Dam | Dam | 6,006 | 23 | 334 | 50 |
| 8 | LBWT pipeline, transfer pipe to Gaberone/Lobatse | Pipeline/Pumping Scheme | 48,251 | 838 | 162 | 30 |
| **Cluster 3: Lesotho Lowlands** | | | 1,381 | 6 | | |
| 9 | Hlotse Dam, dam wall height to spill level 51m and gross storage of 105 million $m^3$: Urban/rural demands plus irrigation developments | Dam | 884 | 3 | 54 | 50 |
| 10 | Ngoajane Dam, dam wall height to spill level 47.5m and gross storage of 36 million m3: | Dam | 497 | 3 | 11 | 50 |

| | | Project Type | Capital Cost (2018 - R Million) | Operational Cost (2018 - R Million) | Yield or Impact on yield (Million $^3$/annum) | Operational Period |
|---|---|---|---|---|---|---|
| | Urban/rural demands plus irrigation developments | | | | | |
| **Cluster 4: IVRS intervention options** | | | 32,739 | 1,603 | | |
| 11 | Thukela transfer further phase | Pipeline/Pumping Scheme | 22,492 | 172 | 522 | 50 |
| 12 | Desalination and re-use of mine water effluent; | Wastewater Treatment | 8,773 | 1,304 | 500 | 30 |
| 13 | Utilise Croc Return Flows in Tshwane to reduce load from Rand Water via Vaal | Pipeline/Pumping Scheme | 1,474 | 127 | 56 | 30 |
| **Cluster 5: Caledon to Greater Bloemfontein transfer** | | | 267 | 11 | | |
| 14 | Tienfontein pump station capacity increase to 7m3/s; | Pipeline/Pumping Scheme | 180 | 7 | 6 | 30 |
| 15 | Increase Tienfontein pumping capacity to 3.87 $m^3/s$ Novo Transfer scheme capacity to 2.2 $m^3/s$; to Rusfontein Dam | Pipeline/Pumping Scheme | 87 | 4 | 5 | 30 |

| | | Project Type | Capital Cost (2018 - R Million) | Operational Cost (2018 - R Million) | Yield or Impact on yield (Million $^3$/annum) | Operational Period |
|---|---|---|---|---|---|---|
| **Cluster 6: Greater Bloemfontein internal resource improvements** | | | 1,638 | 174 | | |
| 16 | Raise Mockes Dam to increase storage capacity | Dam | 120 | 1 | 3 | 50 |
| 17 | Increase Maselport WTW Capacity to 130 Ml/d | Wastewater Treatment | 944 | 68 | 31 | 30 |
| 18 | Planned indirect reuse from the Bloem Spruit WWTW (± 16 million $m^3$/a); Maselspoort | Wastewater Treatment | 322 | 62 | 16 | 30 |
| 19 | Planned direct reuse from the Bloem Spruit WWTW (± 11 million $m^3$/a); Maselspoort | Wastewater Treatment | 252 | 43 | 11 | 30 |
| **Cluster 7: Gariep to Greater Bloemfontein Transfer** | | | 4,300 | 230 | | |
| 20 | Pump station and pipeline from Gariep Dam to Bloemfontein Phase 1 | Pipeline/Pumping Scheme | 3,800 | 171 | 32 | 30 |
| 21 | Pump station and pipeline from Gariep Dam to Bloemfontein Phase 2 | Pipeline/Pumping Scheme | 500 | 59 | 11 | 30 |
| **Cluster 8: Neckartal Scheme** | | | 500 | 14 | | |

| | | Project Type | Capital Cost (2018 - R Million) | Operational Cost (2018 - R Million) | Yield or Impact on yield (Million $^{3}$/annum) | Operational Period |
|---|---|---|---|---|---|---|
| 22 | Neckartal Dam irrigation demands (large schemes) | Dam | 500 | 14 | 90 | 50 |
| 23 | Neckartal Dam hydropower releases | Dam | - | - | 105 | 50 |
| **Cluster 9: Integrated Water management options** | | | 6,394 | 1,276 | | |
| 24 | Removal of unlawful irrigation | Integrated Water Management | 4 | - | 120 | 20 |
| 25 | WC/WDM Irrigation | Integrated Water Management | 199 | 2 | 73 | 20 |
| 26 | WC/WDM Urban and Industrial | Integrated Water Management | 6,115 | 1,274 | 155 | 20 |
| 27 | Increase permit/ licence coverage | Integrated Water Management | 8 | - | - | 20 |
| 28 | Improve assessments of aquifers (storage capacities, recharge rates, sustainable yields and other characteristics) | Integrated Water Management | 5 | - | 40 | 20 |

| | | Project Type | Capital Cost (2018 - R Million) | Operational Cost (2018 - R Million) | Yield or Impact on yield (Million $^3$/annum) | Operational Period |
|---|---|---|---|---|---|---|
| 29 | Manage salinity | Integrated Water Management | 9 | - | - | 20 |
| 30 | Manage eutrophication | Integrated Water Management | 8 | - | - | 20 |
| 31 | Management and control of alien and invasive species and problem pests | Integrated Water Management | 13 | - | 20 | 20 |
| 32 | Set water quality objectives/standards | Integrated Water Management | 5 | - | - | 20 |
| 33 | Consolidation of climate data and extreme event data at Basin leval | Integrated Water Management | 15 | - | - 100 | 20 |
| 34 | Identify priority water needs to support economic development at basin level | Integrated Water Management | 2 | - | - | 20 |
| 35 | Set out guidelines and procedures to improve equitable utilisation and benefit sharing at the basin level | Integrated Water Management | 7 | - | - | 20 |
| 36 | Harmonize policy, legal and institutional frameworks | Integrated Water Management | 5 | - | - | 20 |

# 3 ECONOMIC EFFECTIVENESS ANALYSIS

The first economic analysis undertaken is of the Unit Reference Value (URV) of water supplied by each identified cluster. Unit reference value (URV) is a common measure that provides a ratio of the investment cost of a water intervention relative to the quantity of water supplied. This analysis provides insight into the cost per unit of effectiveness of each cluster in the Core Scenario whereby the effectiveness is the resultant impact of each project intervention on the combined yield impact in this cluster. URVs represent the economic cost effectiveness between water projects and its objective is to provide a unit of comparison across the different schemes in the Updated Core Scenario.

## 3.1 Methodology for calculating URVs

The URV calculation encompasses the cumulative present values (PVs) of the investment costs (i.e., capital and operational costs) over the life of the specific intervention, relative to the cumulative PVs of water volume supplied per project intervention - see URV equation below.

$$URV \frac{PV(capital\ costs)\ +\ PV(operational\ costs)}{PV\ (quantity\ of\ water\ incrementally\ assured)}$$

The operational periods are assumed to be as follows:

- Dams – 50 years
- Pipeline/Pumping Schemes – 30 years
- Wastewater Treatment – 30 years
- Integrated Water Management – 20 years

The applicable social discount rate used is 8%[3]. A URV was calculated for either select interventions and its clustered scheme, or only for the clustered scheme.

The inputs and assumptions underpinning the URV calculations are discussed below.

## 3.2 Inputs and assumptions

The inputs and assumptions that underpin the URV calculation and are discussed in detail below.

### 3.2.1 Base years

[3] Conningarth Economists (2014) A Manual for Cost Benefit Analysis in South Africa with Specific Reference to Water Resource Development. Water Research Commission.

Interventions in the Core Scenario have varying base dates. To ensure consistency in the analysis, costs[4] are escalated to a base year of 2018 at constant price levels based on an average inflation rate in South Africa of 4.7%.

### 3.2.2 Operational cost (Opex) to capital cost (Capex) ratios

Estimated operational cost figures were obtained from source documents and reports on the project interventions. For interventions where operational cost figures could not be sourced, an assumption on the opex to capex ratio was used.

### 3.2.3 Construction and operational period

The Updated Core Scenario has a range of interventions from large dam construction projects to pipeline and pumping schemes. The construction period is project specific, however, the operational period of the various interventions is dependent on the project type - see **Table 2-1** in the previous section. Standard operations periods were applied to similar schemes – for dams – 50 years, pipelines/pumping schemes – 30 years, wastewater treatment – 30 years, integrated water management – 20 years.

### 3.2.4 Impact on water yield

The projected water demand over a project intervention's operations period is used for each intervention.

### 3.2.5 Discount rates

The URV analysis uses the South African standard best practice for water projects discount rate of 8%.

[4] Financial prices are used to determine the URV.

## 3.3 Summary of URVs by Clustered Scheme

As noted at the beginning of this section, the URV calculation aims to assess the cost-effectiveness of a particular intervention, by overlaying an intervention's water yield with its associated costs. In situations where the assessment is of a similar intervention category (e.g. dams), the URV can serve as a basis for comparison of the relative efficiencies of different interventions. However, it must be stated upfront that the URV outcome is dependent on the nuances of a specific intervention. URV calculations are generally used to rank water resource development options that are comparable in that the options serve the same purpose or supply the same area.

It is acknowledged that the different clusters are not comparable and serve different water demand areas, although the projects within a cluster are generally comparable. However, the URV as a single indicator does give the relative cost of each cluster in that it shows that the cluster might be extraordinarily expensive or cheap.

The narrative below summarises the results of the URVs for each clustered scheme and individual project interventions. Given the varying nature of the various interventions, and their associated complexities, the results show a wide range of URVs – these are evaluated in more detail below.

### 3.3.1 Cluster 1: Orange River Project Scheme Future Improvements

The URVs for Cluster 1 range from 0.18 to 28.81 with an overall cluster URV of 6.52. The variability in the URV results is driven by the variation in the investment costs in relation to the water impact for each intervention. A number of the interventions have a relatively small cost when compared to the water impact anticipated for that particular intervention. This yields a much lower URV.

Cluster 1 contains seven interventions. A URV was calculated for each of the interventions with exception to:

- Real Time flow modelling and monitoring in the Lower Vaal downstream of Bloemhof Dam and in the Orange River downstream of Vanderkloof Dam to the Orange River mouth;
- Formally agree Environmental Water Requirements & release to River Mouth.

**Table 3-1: Cluster 1 URV Results**

| | Discount Rates | | | Investment Cost | Yield |
|---|---|---|---|---|---|
| | 8% | | | | |
| | URV | PV Costs | PV Water | | |
| **Project Name** | **R/m³** | **R millions** | **Million m³** | **R millions** | **Million m³** |
| Cluster 1 (ORP) Polihali net yield | 6.52 | 35,869 | 5,501 | 39,808 | 724 |
| Utilise the lower-level storage in Vanderkloof Dam | 0.18 | 308 | 1,676 | 180 | 137 |
| Noordoewer/Vioolsdrift Dam used as an individual resource. Medium size dam, 36m dam wall height to spill level and gross storage of 650 million m3 | 3.43 | 4,217 | 1,230 | 4,397 | 280 |
| Polihali Dam net (Lesotho Highland Water project (LHWP) Phase II and connecting tunnel to Katse Dam; using new operating rule (net yield). Dam wall height to spill level is 150m with gross storage of 2 322 million m3 | 28.81 | 27,717 | 962 | 31,137 | 107 |
| Gross_Polihali Dam (Lesotho Highland Water project (LHWP) Phase II and connecting tunnel to Katse Dam; using new operating rule (Based on the gross yield) | 11.31 | 27,717 | 2,452 | 31,137 | 391 |

### 3.3.2 Cluster 2: L-BWT Scheme

The “L-BWT Scheme” has two components, namely: (1) Makhaleng Dam; and (2) L-BWT pipeline, transfer pipe to Gaborone/Lobatse. A URV was calculated for each individual intervention as well as for the combined scheme. For the URV calculation, the cumulative impact on the water balance and project intervention costs were considered.

The URV calculations in the final draft report delivered in October 2021 used the costing of this water supply scheme as available from the Phase I Pre-feasibility Study. It was requested that this report be finalized once the Phase II Pre-feasibility study was completed, and the final proposed dam site and conveyance system route were determined as well as the related cost for the final agreed options. The URV based on the results from the Phase II Pre-feasibility study was found to be lower at 53.17 R/m$^3$ (Table 3-3) in comparison with the Phase I result of 67.15 R/m$^3$ (Table 3-2).

**Table 3-2: Cluster 2 URV Results based on the Pre-feasibility Phase I results.**

| | **Discount Rates** | | | **Investment Cost** | **Yield** |
|---|---|---|---|---|---|
| | **8%** | | | | |
| | **URV** | **PV Costs** | **PV Water** | | |
| Project Name | **R/m$^3$** | **R millions** | **Million m$^3$** | **R millions** | **Million m$^3$** |
| Cluster 2 L-BWT Scheme | 67.15 | 65,582 | 977 | 65,644 | 150 |
| Makhaleng Dam | 4.41 | 4,305 | 977 | 4,648 | 150 |
| LBWT pipeline, transfer pipe to Gaborone/Lobatse | 62.74 | 61,276 | 977 | 60,963 | 150 |

There are two elements to the project where URV was used. The one forms part of Component III of the study that focus only on the L-BWT Scheme while the other is part of Component I of the study focusing on the entire Orange-Senqu Basin including all possible future developments expected to occur within the basin, also including the L-BWT Scheme. The one was designed to compare options within the L-BWT Scheme and used a shorter evaluation period as well as excluded common cost such as for example, land acquisition and relocation costs. The other one was used in the Economic Report in Component I of the study where totally different schemes were compared. ORASECOM at the time also requested that the full cost be used for the purpose of the Economic Report of Component I of the study.

This resulted in significant differences in the URV as determined from Component I and Component III of the study. Although these URVs are used for different purposes, one is expecting that questions will be raised to understand the reason for the differences. The URV Sensitivity analyses were thus conducted to answer that question and to highlight the factors contributing the most to the observed differences.

The analysis started to first identify the main differences in the approach followed to determine the URV for Component I (entire study basin) versus Component III (L-BWT Scheme). The following important differences in the two approaches were identified as:

- The Pre-feasibility Phase II Study used the gross demand while the net demand was used for the Economic study.
- The Pre-feasibility Phase II Study used a fixed water requirement from the start of the analysis while the Economic study used the expected growth in water requirement over time.
- The Pre-feasibility Phase II Study used a 20-year period for the URV calculation while the Economic Study used a 50-year period.
- The Pre-feasibility Phase II Study presented and used the partial cost of the scheme while the Economic study used the full cost of the scheme in the URV calculations.

Some detailed sensitivity analyses were thus carried out to determine the reasons for the differences as well as the impact of each of the differences given above on the URV. The results further show that the largest impact on the URV was obtained by the partial cost versus full cost of the scheme (Scenario 3 versus Scenario 4 with a difference of 15.6 R/m$^3$ see Appendix A). The second highest impact on the URV was due to the fixed water requirement over time versus the growth in demand over time (Scenario 1 versus Scenario 2 showing a difference of 14.5 R/m$^3$ See Appendix A).

**Table 3-3: Cluster 2 URV Results based on Phase2 Pre-feasibility results.**

| | **Discount Rates** | | | **Investment Cost** | **Yield** |
|---|---|---|---|---|---|
| | **8%** | | | | |
| | **URV** | **PV Costs** | **PV Water** | | |
| Project Name | **R/m$^3$** | **R millions** | **Million m$^3$** | **R millions** | **Million m$^3$** |
| Cluster 2 L-BWT Scheme | 53.17 | 54,775 | 1,030 | 54,257 | 162 |
| Makhaleng Dam | 3.55 | 4,566 | 1,286 | 6,006 | 334 |
| LBWT pipeline, transfer pipe to Gaborone/Lobatse | 49.62 | 50,210 | 1,012 | 48,252 | 162 |

For the purpose of the Economic Study Report it was recommended that the URV of 53.17 R/m$^3$ be used which includes the full cost as well as the growth in the transfer volume over time. Details and results of all the scenarios analyzed as part of the sensitivity analysis are given in **Appendix A** of this report.

Although the URV based on the Phase II results (53.17R/m$^3$) is significantly lower than the Phase I URV result (67.15R/m$^3$), it is still high in comparison with all the other development options that form part of the Core Scenario. A high URV does not necessarily mean the scheme is not economically viable. To be able to determine the economic viability of the scheme it will require cost benefit analysis as given in **Appendix A Section 3**.

### 3.3.3 Cluster 3: Lesotho Lowlands

The “Lesotho Lowlands” has two interventions, namely: (1) Hlotse Dam: Urban/rural demands plus irrigation developments; and (2) Ngoajane Dam: Urban/rural demands plus irrigation developments.

**Table 3-4: Cluster 3 URV Results**

| | Discount Rates | | | Investment Cost | Yield |
|---|---|---|---|---|---|
| | 8% | | | | |
| | URV | PV Costs | PV Water | | |
| **Project Name** | **R/m$^3$** | **R millions** | **Million m$^3$** | **R millions** | **Million m$^3$** |
| Cluster 3 Lesotho Lowlands | 1.60 | 1,290 | 806 | 1,381 | 65 |
| Hlotse Dam, dam wall height to spill level 51m and gross storage of 105 million m$^3$: Urban/rural demands plus irrigation developments | 1.44 | 818 | 570 | 884 | 54 |
| Ngoajane Dam, dam wall height to spill level 47.5m and gross storage of 36 million m$^3$: Urban/rural demands plus irrigation developments | 2.00 | 472 | 236 | 497 | 11 |

A URV was calculated for each individual intervention as well as for the combined scheme. This shows that the Hlotse Dam option is more cost efficient than the Ngoajane Dam option.

### 3.3.4 Cluster 4: IVRS intervention options

The “IVRS Cluster ” has three interventions. A URV is calculated for three schemes. They are: (1) Thukela transfer further phase; (2) Desalination and re-use of mine water effluent and (3) Utilise Croc Return Flows in Tshwane to reduce load from Rand Water via the Vaal System. For the URV calculation, the cumulative impact on the water yield and project intervention costs for the three interventions were considered.

**Table 3-5: Cluster 4 URV Results**

| | Discount Rates | | | Investment Cost | Yield |
|---|---|---|---|---|---|
| | 8% | | | | |
| | URV | PV Costs | PV Water | | |
| **Project Name** | **R/m$^3$** | **R millions** | **Million m$^3$** | **R millions** | **Million m$^3$** |
| Cluster 4 IVRS intervention options * | 6.55 | 44,476 | 6,792 | 32,739 | 578 |
| Desalination and re-use of mine water effluent; | 4.97 | 20,717 | 4,172 | 8,773 | 500 |
| Utilise Croc Return Flows in Tshwane to reduce load from Rand Water via Vaal | 4.76 | 2,586 | 544 | 1,474 | 56 |
| Thukela transfer further phase | 10.20 | 21,172 | 2,076 | 22,492 | 522 |

Note *: The yield contribution of the desalination and re-use of mine water was excluded from the combined Cluster 4 calculation as this yield only restored the system yield to the state it was before excessive water was released from Vaal Dam for downstream dilution purposes.

### 3.3.5 Cluster 5: Caledon to Greater Bloemfontein transfer

There are two interventions under the "Caledon to Greater Bloemfontein transfer" scheme. A URV is calculated for the 'Tienfontein pump station capacity increase to 7m$^3$/s' intervention.

**Table 3-6: Cluster 5 URV Results**

| | Discount Rates | | | Investment Cost | Yield |
|---|---|---|---|---|---|
| | 8% | | | | |
| | URV | PV Costs | PV Water | | |
| **Project Name** | **R/ m$^3$** | **R millions** | **Million m$^3$** | **R millions** | **Million m$^3$** |
| Cluster 5 Caledon to Greater Bloemfontein transfer | 4.08 | 253 | 62 | 180 | 6 |
| Tienfontein pump station capacity increase to 7m$^3$/s; | 4.08 | 253 | 62 | 180 | 6 |

The Construction of the 'Increase Tienfontein pumping capacity to 3.87 m$^3$/s Novo Transfer scheme capacity to 2.2 m$^3$/s; to Rustfontein Dam" intervention is already in place and therefore not included in the calculations.

### 3.3.6 Cluster 6: Greater Bloemfontein internal resource improvements

There are four interventions in Cluster 6, of which the increase in the Maselspoort WTW is to accommodate the increase in yield generated by the other three intervention options as shown in the table below.

**Table 3-7: Cluster 6 URV Results**

| | Discount Rates 8% | | | Investment Cost | Yield |
|---|---|---|---|---|---|
| | URV | PV Costs | PV Water | | |
| **Project Name** | **R/ m$^3$** | **R millions** | **Million m$^3$** | **R millions** | **Million m$^3$** |
| Cluster 6 Greater Bloemfontein internal resource improvements* | 10.79 | 3,592 | 333 | 1,638 | 30 |
| Increase Maselspoort WTW Capacity to 130 Ml/d * | 6.03 | 1,704 | 283 | 944 | 31 |
| Planned indirect re-use from Bloemspruit (16 million m$^3$/a) | 5.88 | 1,026 | 174 | 322 | 16 |
| Raise Mockes Dam | 3.73 | 127 | 34 | 120 | 3 |
| Planned direct re-use from Bloemspruit (11 million m$^3$/a) | 5.90 | 736 | 125 | 252 | 11 |

Note *: The yield indicated for the increased Maselspoort WTW is obtained from the two re-use options and the raised Mockes Dam. The yield of the Maselspoort WTW was thus excluded from the combined Cluster 6 calculation The cost of the increased Maselspoort WTW was however included for the combined cluster calculation.

### 3.3.7 Cluster 7: Gariep to Greater Bloemfontein Transfer

A URV is calculated for each of the two interventions, as well as for the clustered Gariep to Greater Bloemfontein Transfer scheme. Phase 2 is dependent on Phase 1 and therefore, the cost incurred as part of Phase 1 of the intervention are necessary for the clustered scheme to be fully operational.

**Table 3-8: Cluster 7 URV Results**

| | Discount Rates | | | Investment Cost | Yield |
|---|---|---|---|---|---|
| | 8% | | | | |
| | URV | PV Costs | PV Water | | |
| **Project Name** | **R/ $m^3$** | **R millions** | **Million $m^3$** | **R millions** | **Million $m^3$** |
| Cluster 7 Gariep to Greater Bloemfontein Transfer | 14.71 | 6,582 | 448 | 4,300 | 43 |
| Pump station and pipeline from Gariep Dam to Bloemfontein Phase 1 | 16.77 | 5,145 | 323 | 3,800 | 32 |
| Pump station and pipeline from Gariep Dam to Bloemfontein Phase 2 | 9.36 | 1,167 | 125 | 500 | 11 |

### 3.3.8 Cluster 8: Neckartal Scheme

No URV was calculated for the clustered or individual interventions of the Neckertal Scheme. The construction of this dam was completed, and the dam already start to inundate water. The irrigation scheme that will receive water from Neckartal Dam still needs to be developed.

### 3.3.9 Cluster 9: Integrated Water management options

URVs are calculated for only two of the interventions under Cluster 9. They are “WC/WDM Irrigation” and “WC/WDM Urban and Industrial”. Again, the WC/WDM Urban and Industrial intervention has a high investment cost and a proportionately small impact on the water balance. The operational cost on the WC/WDM Urban and Industrial intervention is significant and drives the large PV of costs.

**Table 3-9: Cluster 9 URV Results**

| | Discount Rates | | | Investment Cost | Yield |
|---|---|---|---|---|---|
| | 8% | | | | |
| | URV | PV Costs | PV Water | | |
| **Project Name** | **R/ $m^3$** | **R millions** | **Million $m^3$** | **R millions** | **Million $m^3$** |
| Cluster 9 Integrated Water management options | 9.74 | 22,422 | 2,303 | 6,314 | 228 |
| WC/WDM Irrigation | 0.31 | 239 | 768 | 199 | 73 |
| WC/WDM Urban and Industrial | 14.46 | 22,183 | 1,535 | 6,115 | 155 |

## 3.4 Conclusion of URV analysis - Estimation of Value for Money

The table below presents a summary of the URV analysis for the various clusters.

The URV results provide a broad range of outputs, driven by a number of project specific design features, which determine the cost profile and yield impact of the intervention – the two key variables in the URV analysis. The implication of this is that a linear comparison of the URVs across the clusters is quite difficult to establish.

Although the URV figures vary significantly, it is observed that the interventions which involve large transfer schemes and pipelines – clusters 2 and 7 have relatively high URV figures of which cluster 2 is an outlier in comparison with the others. This aligns with the higher upfront costs associated with such large schemes, compared with the other clusters. The intervention with the lowest URV (implying extreme effectiveness) – cluster 1, involves the construction of only a pump station at an existing storage facility indicating a high output (yield impact) for a low input (investment cost).

A further means of assessing the URVs is a comparison across similar project categories, across all the clusters i.e. compare the URV results across dams, pipelines/pumping schemes, and wastewater treatment works for re-use purposes. This allows for further interpretation of the cost effectiveness of each project intervention by project type.

The pipeline/pumping schemes have greater variability in their indicative URVs ranging from 4.08 to 49.62. The L-BWT pipeline intervention option is clearly an outlier having an extremely high, but not unexpected URV figure, given the scale of the project (long distance of the transfer). Other pipeline/pumping options showing higher URV are typical those with long transfer pipelines/canals such as the Gariep to Greater Bloemfontein transfer and the Thukela transfer further phases that also include high pumping requirements.

The wastewater treatment and re-use options provided very similar URV results varying between 4.76 to 5.90, showing no specific outliers.
WC/WDM for irrigation is significantly more cost effective than WC/WDM in the urban/industrial sector, which could be one of the reasons why irrigation farmers rather use these savings to extend their own irrigation areas rather than selling some of their water rights to other users.

**Table 3-10: Summary of Clustered Scheme URVs**

| | **Discount Rates** | | | **Investment Cost** | **Yield** |
|---|---|---|---|---|---|
| | **8%** | | | | |
| | **URV** | **PV Costs** | **PV Water** | | |
| **Cluster Name** | **R/m$^3$** | **R millions** | **Million m$^3$** | **R millions** | **Million m$^3$/a** |
| Cluster 1 ORP intervention options | 6.52 | 35,869 | 5,501 | 39,808 | 724 |
| Cluster 2 L-BWT Scheme | 53.17 | 54,775 | 1,030 | 54,257 | 162 |
| Cluster 3 Lesotho Lowlands | 1.60 | 1,290 | 806 | 1,381 | 65 |
| Cluster 4 IVRS intervention options (includes the Thukela transfer option) | 6.55 | 44,476 | 6,792 | 32,739 | 578 |
| Cluster 5 Caledon to Greater Bloemfontein transfer | 4.08 | 253 | 62 | 180 | 6 |
| Cluster 6 Greater Bloemfontein internal resource improvements | 10.79 | 3,592 | 333 | 1,638 | 30 |
| Cluster 7 Gariep to Greater Bloemfontein Transfer | 14.71 | 6,582 | 448 | 4,300 | 43 |
| Cluster 9 Integrated Water management options * | 9.74 | 22,422 | 2,302 | 6,314 | 228 |

Note *: The calculations for Cluster 9 only include the WC/WDM intervention options

This comparison is presented in Table 3-10. The URVs align with other similar studies conducted.

Out of the six dams, Hlotse Dam offer the best value for money in terms of its cost-effectiveness. Polihali Dam interventions (net yield) has the highest URVs of the rest of the group. The dam options in general provided cost efficient intervention options. Polihali Dam is however an outlier and its lower cost efficiency than other dams is partly due to the transfer tunnel that is included as well as the significant difference between the net and gross yield of this scheme.

The pipeline/pumping schemes have greater variability in their indicative URVs ranging from 4.08 to 49.62. The L-BWT pipeline intervention option is clearly an outlier having an extremely high, but not unexpected URV figure, given the scale of the project (long distance of the transfer). Other pipeline/pumping options showing higher URV are typical those with long transfer pipelines/canals such as the Gariep to Greater Bloemfontein transfer and the Thukela transfer further phases that also include high pumping requirements.

The wastewater treatment and re-use options provided very similar URV results varying between 4.76 to 5.90, showing no specific outliers.

WC/WDM for irrigation is significantly more cost effective than WC/WDM in the urban/industrial sector, which could be one of the reasons why irrigation farmers rather use these savings to extend their own irrigation areas rather than selling some of their water rights to other users.

**Table 3-11: URV Results by Project Type**

| | | | **URV** | **PV Costs** | **PV Water** |
|---|---|---|---|---|---|
| **Project Name** | **Clustered Scheme** | **Project Type** | **R/m³** | **(R) millions** | **Million m³** |
| Building of the Verbeeldingskraal Dam upstream of Gariep Dam; | Orange River Project Scheme future improvements | Dam | 2.22 | 3,627 | 1,633 |
| Noordoewer/Vioolsdrift Dam used as an individual resource. Medium size dam, 36m dam wall height to spill level and gross storage of 650 million m3 | Orange River Project Scheme future improvements | Dam | 3.43 | 4,217 | 1,230 |
| Polihali Dam (Lesotho Highland Water project (LHWP) Phase II and connecting tunnel to Katse Dam; using new operating rule (net yield). Dam wall height to spill level is 150m with gross storage of 2 322 million m³ | Orange River Project Scheme future improvements | Dam and transfer tunnel | 28.81 | 27,717 | 962 |

| | | | | | |
|---|---|---|---|---|---|
| Makhaleng Dam | L-BWT Scheme | Dam | 3.55 | 4,566 | 1,286 |
| Hlotse Dam, dam wall height to spill level 51m and gross storage of 105 million m3: Urban/rural demands plus irrigation developments | Lesotho Lowlands | Dam | 1.44 | 818 | 570 |
| Ngoajane Dam, dam wall height to spill level 47.5m and gross storage of 36 million m3: Urban/rural demands plus irrigation developments | Lesotho Lowlands | Dam | 2.00 | 472 | 236 |
| Raise Mockes Dam to increase storage capacity | Greater Bloemfontein internal resource improvements | Dam | 3.73 | 127 | 34 |
| LBWT pipeline, transfer pipe to Gaberone/Lobatse | L-BWT Scheme | Pipeline/Pumping Scheme | 49.62 | 50,210 | 1,012 |
| Thukela transfer further phase | IVRS intervention options | Pipeline/Pumping Scheme | 10.20 | 21,172 | 2,076 |
| Tienfontein pump station capacity increase to $7m^3/s$; | Caledon to Greater Bloemfontein transfer | Pipeline/Pumping Scheme | 4.08 | 253 | 62 |
| Pump station and pipeline from Gariep Dam to Bloemfontein Phase 1 | Gariep to Greater Bloemfontein Transfer | Pipeline/Pumping Scheme | 16.77 | 5,415 | 323 |
| Pump station and pipeline from Gariep Dam to Bloemfontein Phase 2 | Gariep to Greater Bloemfontein Transfer | Pipeline/Pumping Scheme | 9.36 | 1,167 | 125 |
| Desalination and re-use of mine water effluent; | IVRS intervention options | Wastewater Treatment and re-use | 4.97 | 20,717 | 4,172 |
| Planned indirect reuse from the Bloem Spruit WWTW (± 16 million $m^3/a$); Maselspoort | Greater Bloemfontein internal resource improvements | Wastewater Treatment and re-use | 5.88 | 1,026 | 174 |
| Planned direct reuse from the Bloem Spruit WWTW (± 11 million m3/a); Maselspoort | Greater Bloemfontein internal resource improvements | Wastewater Treatment and re-use | 5.90 | 736 | 125 |
| Utilise Croc Return Flows in Tshwane to reduce load from Rand Water via Vaal | IVRS intervention options | Wastewater Treatment and re-use | 4.76 | 2,586 | 544 |
| WC/WDM Irrigation | Integrated Water management options | Integrated Water Management | 0.31 | 239 | 768 |
| WC/WDM Urban and Industrial | Integrated Water management options | Integrated Water Management | 14.46 | 22,183 | 1,535 |

| | | | | | |
|---|---|---|---|---|---|
| Utilise the lower-level storage in Vanderkloof Dam | Orange River Project Scheme future improvements | Dam, but mainly a change in the operating rule or management of the dam plus pumpstation | 0.18 | 308 | 1,676 |

# 4 COST BENEFIT OR ECONOMIC EFFICIENCY ANALYSIS OF THE CORE SCENARIO

## 4.1 Overview

This chapter evaluates the economic efficiency of the Core Scenario's project interventions on the various beneficiaries across the four Basin Member States. Unlike the URV analysis that looked at the economic cost effectiveness of each intervention on a Rand per $m^3$ of water supplied, a CBA is used to determine the feasibility of a project intervention from a socio-economic perspective, as it is presently designed. It is a framework used to provide an evidence base for the social rationale of the project. A CBA weighs up the overall economic impacts of implementing the various project interventions in the Core Scenario and will therefore provide an indication of whether the project will result in a net cost or benefit to society i.e. whether the project is economically viable.

The main elements of this section include a discussion of the approach and methodology used to evaluate the economic impact associated with implementing the various clustered schemes. The core inputs and assumptions underpinning the CBA are outlined, followed by an analysis of the wider spectrum of costs and benefits compared to the case of pure profit determination of the financial appraisal.

The outcome of the quantitative economic appraisal includes the Economic Net Present Value (ENPV), Economic Benefit-Cost Ratio (BCR), and Economic Internal Rate of Return (EIRR) of the clustered schemes of the Core Scenario. In addition to these quantitative indicators, a description of the qualitative economic impacts serves to inform an understanding of the expected net socio-economic impact of the project to society.

Following the results of the economic appraisal, a sensitivity analysis is conducted to understand the impact of the inputs and assumptions on the main parameters of the project.

## 4.2 CBA Methodology

The economic appraisal is conducted from the perspective of the economy as a whole to assess whether the clustered schemes would have a net positive socio-economic impact. The figure below outlines the approach and methodology used to appraise the Core Scenario.

**Figure 4-1** outlines the process undertaken to conduct a CBA.

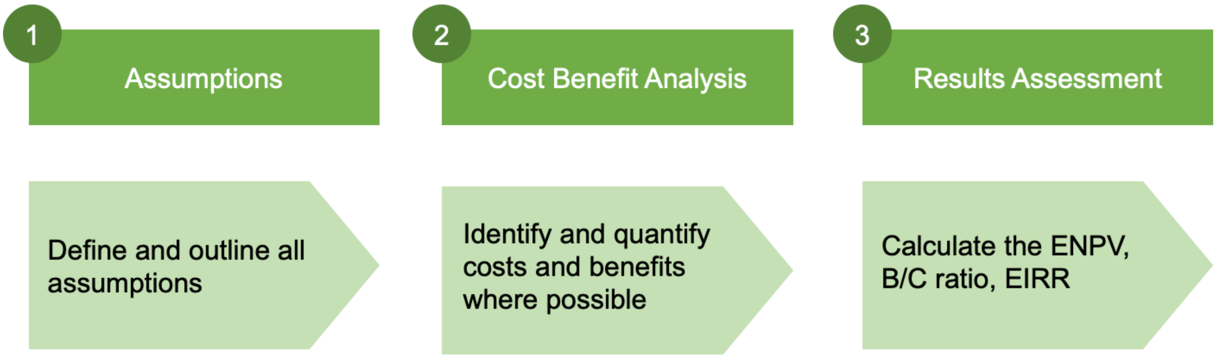



**Figure 4-1: CBA Process**

### 4.2.1 Inputs and Assumptions

This sub-section outlines the data and key assumptions used in the economic appraisal of the clusters. These are discussed in more detail below and underpin the economic model and the results that are obtained.

The CBA analysis is premised on a number of key inputs and assumptions drawn from sourced reports and documents and peer-reviewed publications/international benchmarks.

The tables below provide the details of the inputs and assumptions that frame the CBA analysis.

**Table 4-1: CBA Inputs and Assumptions**

| **General assumptions** | | **Source** |
|---|---|---|
| Social Discount Rate | 8% | Conningarth Economists (2014) A Manual for Cost Benefit Analysis in South Africa with Specific Reference to Water Resource Development. Water Research Commission |
| Exchange Rate | R1.277 to 1 Pula<br>USD 1 to R12.34 | https://ec.europa.eu/info/funding-tenders/procedures-guidelines-tenders/information-contractors-and-beneficiaries/exchange-rate-inforeuro_en<br>(as of 1 January 2018) |
| Prices | Constant 2018 prices | |
| Conversion factors[5] | | |

[5] Refer to section 4.2.2.

| **General assumptions** | | **Source** |
|---|---|---|
| Dam | 0.934 | The conversion factors used in this report are drawn from the report *A Manual for Cost Benefit Analysis in South Africa with Specific Reference to Water Resource Development* by Conningarth Economists and the Water Research Commission. |
| Pipeline/Pumping Scheme | 0.963 | |
| Bulk pipelines | 0.964 | |
| Wastewater Treatment | 0.956 | |
| Integrated Water Management | 1.004 | |

| **Project lifespan (years) Inputs** | |
|---|---|
| Construction period | Project intervention specific |
| Operations period | |
| Dams | 50 |
| Pipeline/Pumping Schemes | 30 |
| Wastewater Treatment | 30 |
| Integrated Water Management | 20 |

| **Basin water requirements per sector at 2018 development level (Million m³/annum)** | | | | |
|---|---|---|---|---|
| Countries | Urban & Industrial | Irrigation | Mining | Source |
| Botswana | 28 | 10 | 8 | ORASECOM water accounts - Database |
| Lesotho | 38 | 7 | - | |
| Namibia | 15 | 108 | 20 | |

| | | | | |
|---|---|---|---|---|
| South Africa | 2,694 | 3,281 | 189 | |
| **ORASECOM GDP per sector (R million, 2018)** | | | | |
| Country | Irrigation | Urban & Industrial | Mining | Source |
| Botswana | 62 | 225 | 522 | Botswana - Bank of Botswana, Economic Statistics Database, 2018<br>ORASECOM water accounts – Database<br>Rapule, P. (2016) Water Cooperation Quotient – ORASECOM. Online: https://strategicforesight.com/conference_pdf/Presentation%20by%20ORASECOM.pdf |
| Lesotho | 1 650 | 3 023 | 1 049 | Reserve Bank of Lesotho, Macroeconomic Outlook, December 2018<br>ORASECOM water accounts – Database<br>Rapule, P. (2016) Water Cooperation Quotient – ORASECOM. Online: https://strategicforesight.com/conference_pdf/Presentation%20by%20ORASECOM.pdf |
| Namibia | 871 | 1 249 | 1 702 | Bank of Namibia, Economic Outlook, 2017-2020<br>ORASECOM water accounts - Database<br>Rapule, P. (2016) Water Cooperation Quotient – ORASECOM. Online: https://strategicforesight.com/conference_pdf/Presentation%20by%20ORASECOM.pdf |
| South Africa | 14 732 | 507 568 | 45 794 | South Africa - STATS SA Q4 2018 GDP report<br>ORASECOM water accounts – Database<br>Rapule, P. (2016) Water Cooperation Quotient – ORASECOM. Online: |

| | | | | |
|---|---|---|---|---|
| | | | | https://strategicforesight.com/conference_pdf/Presentation%20by%20ORASECOM.pdf |

| | | |
|---|---|---|
| **Health Benefit** | | |
| Health cost per capita | USD | Source |
| Botswana | 483 | World Bank. https://data.worldbank.org/indicator/SH.XPD.CHEX.PC.CD |
| Lesotho | 125 | |
| Namibia | 471 | |
| South Africa | 526 | |
| Health benefit: Reduction due to intervention | 25% | SIWI (2014) https://www.who.int/water_sanitation_health/waterandmacroecon.pdf?ua=1 |
| Number of diarrhoea DALYs from inadequate water supply (number) | | WHO: http://apps.who.int/gho/data/view.main.INADEQUATEWATERv?lang=en |
| South Africa | 8 571 | |
| Lesotho | 33 711 | |
| Botswana | 15 411 | |
| Namibia | 270 369 | |

### 4.2.2 Identification and quantification of costs and benefits

The economic costs and benefits of each project intervention include impacts that can be quantified into monetary terms as well as those which can only be captured qualitatively.

The quantitative assessment of the economic costs and benefits involve the calculation and modelling of benefits and cost flows over the project intervention's expected economic lifetime as outlined in an earlier section of the report.

The economic assessment aims to capture both the quantitative and qualitative benefits which stem from the project.

**Economic Costs**

High-level cost estimates for each project intervention were obtained from various source documents. These are representative of financial costs which for the purposes of the economic appraisal should be converted to economic costs. Conversion of costs into "economic prices" or shadow prices includes removing price distortionary measures such as expenditure on imports, taxes, subsidies, and varying skills levels where applicable. Conversation factors are the ratio between the economic price and the financial price for a project output or input, which can be used to convert the financial values of project costs and benefits to economic values.

A conversion factor lower than one suggests that the market price is higher than the true value of that input. Conversely, if the conversion factor is greater than one, then the observed price is lower than the shadow price, meaning that the opportunity cost of that good is higher than that captured by the market.[6]

In order to calculate the total economic costs, the financial costs are multiplied by a conversion factor (dependent on the project type – see Table 4-2). The capital expenditure amount is equally distributed across the construction period for each project. In addition, the operational expenditure is spread evenly over the entire operational period. The discount rate is applied to the discounted cash flow in order to obtain the present value of the capital and operational expenditure. Subsequently, the capital and operational expenditures for each project intervention were summed to get the total economic costs for each clustered scheme.

**Quantitative Economic Benefits**

There are two broad economic benefits that were considered for the CBA analysis:

- the impact on economic activity;
- decrease in the Basin State's incidence of disease due to increased access to water.

[6] European Commission (2014) Guide to Cost-Benefit Analysis of Investment Projects. Online: http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

The economic benefits are quantified using proxies and other indicators to monetise intervention impacts that are typically not captured through the financial discounted cashflows of a project.

The benefits that relate to a decrease in incidence of disease and impact on the economic activity of the Basin States are quantified and assigned a monetary value in order to estimate the real economic value of the project.

These economic benefits are described in more detail below.

**An impact on economic activity**

Water is key to economic growth. Through the improvement of water resources development and management, there are likely impacts to the economies of the Basin States. As such, this benefit was quantified using proxies to estimate the GDP benefit for each project intervention.

The first proxy, a GDP to water ratio (in Rand per $m^3$ per annum), is the ORASECOM GDP contribution per sector per country (in Rand millions) divided by the water use per sector per country (in million $m^3$/annum).

The realised impact from each project intervention on the economy is not 100%. Therefore, the second proxy used was the water balance ratio per intervention, which was the ratio of a project intervention's impact on water balance divided by the total water balance in the project intervention country.

Three broad economic sectors are identified to be impacted by the project interventions. They are: (1) urban and industrial, (2) irrigation and (3) mining sectors.

For each project intervention, a water-use ratio split assumption.

The benefit of increased economic activity was determined by applying the impact on the water balance for each project intervention to the water-use ratio split for each sector and GDP-water ratio for each sector, and the water balance ratio.

The table below summarizes the valuation method.

**Table 4-2: Impact on economic output valuation method**

| Illustration of Benefit/Cost | Proxy / Inputs / Assumptions Used | | Quantification approaches |
|---|---|---|---|
| Impact on economic output (ZAR million, 2018) | | | = (a)*(b)*(c) * (f) |
| Intervention's impact on water balance (million $m^3/a$) | | (a) | |
| Water use ratio by beneficiary (%) | | (b) | |
| GDP-water ratio | | (c) = (d) / (e) | |
| ORASECOM GDP per sector (ZAR million, 2018) | | (d) | |
| National water use per sector (million $m^3$) | | (e) | |
| Water balance ratio per intervention | | (f) | |

## Health benefits

There are health benefits associated with the improvements in water resources and infrastructure including increased access to clean water and reduced illness. Decreasing a population's incidence of disease can be interpreted as a cost avoidance on the national health expenditure.

To quantify the health benefits, the national health cost per capita in each Basin State is used as a proxy of cost of the burden of disease on population. Through the various intervention, it is assumed that there will be a reduction in incidences of disease burden on the Basin State population. However, to reflect the subset of the population afflicted by the water borne disease burden, the number of diarrhea cases are used as proxy for the disease burden on the Basin State population.

**Table 4-3: Health benefit valuation method**

| Illustration of Benefit/Cost | Proxy / Inputs / Assumptions Used | | Quantification approaches |
|---|---|---|---|
| Health benefit | | | = (g) * (h) * (i) |
| Population (number of diarrhoea cases from inadequate water supply) | | (g) | |
| National health cost per capita | | (h) | |
| Reduction due to intervention | | (i) | |

**Qualitative Economic Benefits**

Water supply has knock-on effects on people's livelihoods. Water in the system plays a vital role in supporting the livelihoods of more than 14 million people within the system.

The four Basin States are water scarce regions. The intra-basin transfers are aimed at reallocating water across the different river systems to regions that are identified to be in greatest need of water supply.

The basin within Botswana is very sparsely populated with no major urban centres. As a result, there is a lower water demand that is almost entirely fed by locally developed groundwater sources but persistent changes in climate change are driving increased water scarcity. For Botswana's Molopo River the water requirements are predominantly for urban/rural water users, diffuse irrigation and stock watering, as well as some mines.

Lesotho water requirements are primarily used for urban and rural water supply, with a substantial portion being utilised for industrial applications.

Irrigation plays an important economic role in Namibia. The north eastern part of the basin in Namibia is largely given over to stock farming, dependent on rainfall and groundwater. Namibia's Fish, Nossob, Auob and Lower Orange River form part of the ORASECOM basin with its water use sectors ranging from urban, rural, tourism, livestock watering, irrigation and mining. A number of mines also depend on the basin's water resources.

The Basin is of major economic importance to South Africa, supporting both the urban/industrial heartland of Gauteng and large areas of irrigation, producing crops for local consumption and some export. South Africa has two main river systems that form part of the Orange-Senqu Basin - the Integrated Vaal River System (IVRS) and the Orange- River System (ORS), both of which supply major power stations, petro-chemical plants, urban developments and strategic industries which are all located in their supply areas.

Households depend on safe and reliable access to water to be able to engage in various activities that would improve their livelihoods in two main ways: poverty reduction and a reduction in the incidence of disease burden. The latter was discussed quantitatively above.

Typical urban households use water for household activities such as drinking, cooking and sanitation, and garden irrigation whereas rural households have a wider range of uses for water that may include small-holder farming of crops for consumption and for sale. Rural households typically travel longer distances in search of water sources. This represents an opportunity cost of lost wages.

### 4.3 Cost-Benefit Analysis Results

This section presents the results of the CBA and the potential economic impact of the investment for the updated Core Scenario. The criteria used in the evaluation of the economic model include the following indicators:

**Economic Net Present Value (ENPV):** is the present value of project's benefits minus present value of the project's costs. A positive ENPV indicates a net benefit associated with the project intervention and therefore economic viability and rationale for implementing the intervention.

The formula is shown below:

$$NPV = CF_0 + \frac{CF_1}{(1+r)^1} + \frac{CF_2}{(1+r)^2} + \cdots + \frac{CF_n}{(1+r)^n}$$

Where:

$CF_0$ – initial investment

$CF_1$ - $CF_n$ – cash flows over project period

r – social discount rate

n – number of periods

**Benefit/Cost Ratio (BCR):** This indicator is the ratio between benefits and costs of the Project. The present value of project's benefits is divided by the present value of project's costs. A project is interpreted as economically viable and worth implementing if the BCR is greater than 1; that is, the discounted benefits are greater than the discounted costs.

**Economic Internal Rate of Return (EIRR):** Relates to the ENPV but it is expressed as a percentage. The EIRR is an indication of a project intervention's rate of return at which the NPV will be zero. For a project to be acceptable, the ERR should be greater than the discount rate.

The key measure in the CBA is the BCR. The interpretation of CBA results is therefore outlined as follows:

- A BCR below 1 implies the project is not economically viable and may require a further assessment of the project's structure/design and/or outputs to enhance its economic benefits;
- A BCR marginally above 1 implies that while the project is deemed to be economically viable, it is susceptive to the factors driving the benefits, and a change in the underlying

assumptions/features of the benefits could negatively impact the BCR, potentially resulting the in project not being economically viable;

- A BCR well over 1 demonstrates that the project is strongly economically viable.

**Table 4-4** summarises the results of the CBA model. The results indicate that four out of the seven clustered schemes are economically viable project interventions, with the associated economic benefits exceeding the economic costs of the project. That is, the schemes with a NPV greater than zero, as currently designed, yield a net positive socio-economic impact. The benefits were discounted, at a rate of 8%, over the operational period of the clustered scheme to arrive at a net benefit.

The Orange River Project Scheme future improvements scheme is an aggregation of five interventions: (i) Utilise the lower level storage in Vanderkloof Dam; (ii) Real Time flow modelling and monitoring in the Lower Vaal downstream of Bloemhof Dam and in the Orange River downstream of Vanderkloof Dam to the Orange River mouth; (iii) Construction of the Verbeeldingskraal Dam upstream of Gariep Dam; (iv) Formally agree Environmental Water Requirements & release to River Mouth; and (v) Vioolsdrift Dam. It is to be noted that the Polihali Dam (Lesotho Highland Water project (LHWP) Phase ll and connecting tunnel to Katse Dam intervention is clustered under the ORP scheme, however, its economic impact is realizable under the IVRS scheme. Therefore, the economic costs and benefits are accounted for under the IVRS scheme.

**Table 4-4: CBA Results**

Discount rate 8%

| | Cluster 1: Orange River Project Scheme future improvements | Cluster 2: L-BWT Scheme | Cluster 3: Lesotho Lowlands | Cluster 4: IVRS intervention options | Cluster 5: Caledon to Greater Bloemfontein transfer | Cluster 6: Greater Bloemfontein internal resource improvements | Cluster 7: Gariep to Greater Bloemfontein Transfer |
|---|---|---|---|---|---|---|---|
| E-NPV | 6,469 | -22,994 | 200 | 119,783 | 2,093 | 6,723 | -1,006 |
| E-IRR | 10.7% | 0.8% | 5.0% | 13.6% | 38.7% | 22.6% | 1.9% |
| BCR | 2.63 | 0.46 | 1.20 | 3.43 | 10.92 | 3.72 | 0.80 |
| **NPV (R millions)** | | | | | | | |
| **Total Economic Costs** | 3,969 | 42,248 | 1,008 | 49,342 | 211 | 2,468 | 5,001 |
| Capital Cost | 3,743 | 37,840 | 966 | 37,606 | 149 | 1,105 | 3,312 |
| Operational Cost | 227 | 4,408 | 42 | 11,736 | 62 | 1,363 | 1,689 |
| **Total Economic Benefits** | 10,439 | 19,254 | 1,208 | 169,125 | 2,304 | 9,191 | 3,995 |
| Increase in economic activity | 5,000 | 18,483 | 660 | 161,889 | 25 | 725 | 747 |
| Urban & Industrial | 3,290 | 5,992 | 89 | 161,889 | 25 | 725 | 747 |
| Irrigation | 1,089 | 226 | 571 | - | - | - | - |
| Mining | 620 | 12,264 | - | - | - | - | - |
| Health benefit | 5,439 | 771 | 548 | 7,236 | 2,279 | 8,466 | 3,247 |

Note: Polihali Dam (Lesotho Highland Water project (LHWP) Phase II and connecting tunnel to Katse Dam intervention is clustered under the ORP scheme, however, its economic impact is realizable under the IVRS scheme. Therefore, the economic costs and benefits are accounted for under the IVRS scheme.

In the ORP Scheme, the irrigation sector accounts for the largest water user in this scheme[7]. However, the urban & industrial sector contributes significantly more to economic output.

That is, there is greater productive use of water in the urban & industrial sectors compared to the irrigation sectors. The total impact on economic activity equates to approximately 0.7% of

[7] With exception to Polihali Dam – urban & industrial sector is the main water user.

the total ORASECOM Basin GDP. Overall, the scheme's economic benefits outweigh the economic costs resulting in a positive NPV, an EIRR of 10.7%, and a BCR of 2.63.

Botswana, Lesotho and South Africa are the beneficiary Basin States of L-BWT Scheme. The largest water user is the urban & industrial sector followed by the mining sector. The economic costs of the project are significantly higher than the economic benefits resulting a negative NPV and EIRR (0.8%), and a low BCR or 0.46.

The Lesotho Lowlands scheme has two interventions. The irrigation and urban and industrial sectors are both water users in the two interventions. Lesotho's irrigation sector has a greater GDP to water ratio than the urban and industrial sector which is driving the larger impact on economic output. While this results in a positive NPV and a BCR marginally greater than one (1.20), the EIRR (5%) is lower than the primary discount rate of 8%.

The IVRS scheme falls within South Africa and the urban & industrial sector is the only water user. South Africa accounts for the largest share of the ORASECOM GDP contribution. The scheme has a significant impact on the Basin's water balance which is compounded by the urban & industrial sector's productive use. This results in a significant impact on economic activity on the Basin (equivalent of 24.2% of ORASECOM Basin GDP). The IVRS Scheme has a strong BCR of 3.43 and an EIRR of 13.6%.

The economic benefits outweigh the economic costs for Caledon to Greater Bloemfontein transfer scheme with a BCR of 10.92. The economic benefits are mainly driven by the realisable health benefits (the scheme lies in South Africa which has the highest Basin population). The relatively lower impact on economic activity is due to the scheme's low impact on the Basin's water balance – only 11 million $m^3$ per annum.

Similar to the Caledon to Greater Bloemfontein transfer scheme, the Greater Bloemfontein internal resource improvements are mainly drive by the realisable health benefits with a good BCR of 3.72 and an EIRR of 22.6%.

The results for the Gariep to Greater Bloemfontein Transfer schemes is also similar to that of the Caledon to Greater Bloemfontein transfer scheme. However, its economic costs outweigh the economic benefits. The schemes costs, relative to their low impact on the Basin's water balance, are contributing to the negative NPV and BCR of 0.80 as shown in **Table 4-4**.

# 5 SENSITIVITY ANALYSIS

## 5.1 CBA Model related sensitivity analysis

A sensitivity analysis is an important way to analyse the robustness of a model by testing whether key inputs have a material impact on the output. The objective is to identify the factors that have the biggest impact on the project's sustainability and returns. The sensitivity assessment looks at the main factors that could impact the project's costs, as well as the factors affecting the project's benefits over the lifetime of the project intervention. A sensitivity analysis was carried out for each clustered scheme where economic costs and benefits were tested.

The CBA model indicators were tested for sensitivity using a 6% and 10% discount rate against the primary discount rate of 8% used for the model. The discount rate is the percentage that is used to determine the present value of future cost and benefit streams. In the economic appraisal a discount rate is used to measure a society's willingness to trade present for future consumption. Different institutions usually use a base rate across different projects. The World Bank and European Bank for Research and Development use 10% as a standard conventional cut-off rate for water and power projects in Southern Africa.[8]

The Water Research Commission (WRC) of South Africa recommends for South African water projects to be assessed with an 8% discount rate with possible variation between 6% and 10%. This rate conforms to the discount rate recommended by major international development institutions whilst taking into account the macro-economic context of the country.[9]

The impact of the sensitivity analysis is summarised in the tables below.

**Table 5-1** provides the results of the sensitivity test on the two quantitative benefits - an impact on economic activity and health benefit by -10% and 10% and the sensitivity test of the primary discount rate. The results indicated that the CBA model was sensitive to variability in the discount rate particularly for the clustered schemes with a larger NPV (i.e. where benefits outweigh costs more significantly). Whereas the variability in the model was limited in the case of quantitative benefits inputs. Overall, the sensitivity test indicated a robust model.

[8] Economic Commission for Africa (2012) Cost-Benefit Analysis for Regional Infrastructure in Water and Power Sectors in Southern Africa. ECA Publications, Addis Ababa
[9] Conningarth Economists (2014) A Manual for Cost Benefit Analysis in South Africa with Specific Reference to Water Resource Development. Water Research Commission

**Table 5-1: Sensitivity analysis on the discount rate and quantitative benefits (Rand, BCR)**

| | Discount rate | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 6.00% | | | 8% | | | 10% | | |
| | NPV | **IRR** | **BCR** | **NPV** | **IRR** | **BCR** | **NPV** | **IRR** | **BCR** |
| Orange River Project Scheme future improvements | 10,532 | 10% | 3.18 | 6,469 | 11% | 2.63 | 4,248 | 12% | 2.29 |
| L-BWT Scheme | -22,994 | 1% | 0.46 | -22,994 | 0.8% | 0.46 | -25,256 | 1% | 0.34 |
| Lesotho Lowlands | 645 | 5% | 1.59 | 200 | 5% | 1.20 | -58 | 5% | 0.94 |
| IVRS intervention options | 186,739 | 13% | 4.24 | 119,783 | 14% | 3.43 | 78,655 | 14% | 2.82 |
| Caledon to Greater Bloemfontein transfer | 2,745 | 38% | 12.69 | 2,093 | 39% | 10.92 | 1,633 | 39% | 9.46 |
| Greater Bloemfontein internal resource improvements | 9,336 | 22% | 4.17 | 6,723 | 23% | 3.72 | 4,987 | 23% | 3.35 |
| Gariep to Greater Bloemfontein Transfer | -263 | 2% | 0.95 | -1,454 | 2% | 0.67 | -1,454 | 2% | 0.67 |

| | Impact on economic activity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | -10.00% | | | 0% | | | 10% | | |
| Discount rate = 8% | NPV | **IRR** | **BCR** | **NPV** | **IRR** | **BCR** | **NPV** | **IRR** | **BCR** |
| Orange River Project Scheme future improvements | 5,969 | 10% | 2.50 | 6,469 | 11% | 2.63 | 6,969 | 11% | 2.76 |
| L-BWT Scheme | -24,842 | 0% | 0.41 | -22,994 | 0.8% | 0.46 | -21,146 | 1% | 0.50 |
| Lesotho Lowlands | 134 | 5% | 1.13 | 200 | 5% | 1.20 | 266 | 5% | 1.26 |
| IVRS intervention options | 103,594 | 13% | 3.10 | 119,783 | 14% | 3.43 | 135,972 | 15% | 3.76 |
| Caledon to Greater Bloemfontein transfer | 2,090 | 39% | 10.90 | 2,093 | 39% | 10.92 | 2,095 | 39% | 10.93 |
| Greater Bloemfontein internal resource improvements | 6,650 | 22% | 3.69 | 6,723 | 23% | 3.72 | 6,795 | 23% | 3.75 |
| Gariep to Greater Bloemfontein Transfer | -1,081 | 2% | 0.78 | -1,454 | 2% | 0.67 | -931 | 2% | 0.81 |

| | Health benefit | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | -10.00% | | | 0% | | | 10% | | |
| Discount rate = 8% | NPV | **IRR** | **BCR** | **NPV** | **IRR** | **BCR** | **NPV** | **IRR** | **BCR** |
| Orange River Project Scheme future improvements | 6,469 | 11% | 2.63 | 6,469 | 11% | 2.63 | 6,469 | 11% | 2.63 |
| L-BWT Scheme | -22,994 | 1% | 0.46 | -22,994 | 1% | 0.46 | -22,994 | 1% | 0.46 |
| Lesotho Lowlands | 200 | 5% | 1.20 | 200 | 5% | 1.20 | 200 | 5% | 1.20 |
| IVRS intervention options | 119,783 | 14% | 3.43 | 119,783 | 14% | 3.43 | 119,783 | 14% | 3.43 |
| Caledon to Greater Bloemfontein transfer | 2,093 | 39% | 10.92 | 2,093 | 39% | 10.92 | 2,093 | 39% | 10.92 |
| Greater Bloemfontein internal resource improvements | 6,723 | 23% | 3.72 | 6,723 | 23% | 3.72 | 6,723 | 23% | 3.72 |
| Gariep to Greater Bloemfontein Transfer | -1,006 | 0% | 0.80 | -1,454 | 2% | 0.67 | -1,006 | 2% | 0.80 |

# 6 ASSURANCE OF WATER SUPPLY SENSITIVITY ANALYSIS

The purpose of this task is to evaluate the assurance of supply to users on an economic basis. Work was in this regard for the first time carried out in 2017 for the Water Research Commission of RSA. The Water Research Commission study was specifically focused on the assurance of irrigation supply versus the related economic impacts. The goal of this assessment is to determine whether irrigation in some areas could not be optimized by supplying water at lower assurances than the existing norm currently applicable.

The assurance of water supply is a very important component of water supply to users that are taken into account in water resource modeling, planning and management of the water resources. Although the assurance of water supply can be modelled in detail by both the Water Resources Yield Model (WRYM) and the Water Resources Planning Model (WRPM), these results are seldom taken forward into economic assessments.

The WRPM makes provision for priority classification inputs such as the required assurance of water supply to different users and in most cases also includes different assurance levels of supply, within a single user sector. A typical example is the water supply for urban/domestic supply purposes, where say 30% of the total requirement is supplied at a low assurance, which represents the water used for garden irrigation purposes, car washing, swimming pools etc. another 20% at a slightly higher assurance used for washing and sanitation purposes etc. and the last 50% at a high assurance for drinking, cooking and minimum washing and sanitation purposes.

For irrigation purposes it will make sense to supply high-income, long-term crops such as vineyards at a higher assurance and the normal cash crops at a lower assurance. During very severe droughts one would at least want to keep long term investments such as vineyards and orchards alive with the minimum water, although no or very little crop production will take place in such times. This small amount of water would then be made available at a high assurance to protect these investments.

Many of the existing water supply systems in the Orange-Senqu basin are based on the principle to supply water to the users at agreed assurance levels. These assurances are not linked to the water license as no assurance of supply is given by DWS RSA for any license granted to a water user. The operating rules developed for these sub-systems include the ability to operate or manage these sub-systems to ensure the supply of water at the required assurance level. To be able to define the combinations of the different supply assurance levels, a priority classification table is used, as given in **Table 6-1.** The information in this table represents the priority classification as currently in use for the water supplied from the Orange River Project (Gariep and Vanderkloof dams) to its users.

From **Table 6-1** it is for example evident that 50% irrigation is supplied at a low assurance of 95%, 40% at median assurance (99%) and 10% at a high assurance (99.5%). During severe droughts when restrictions need to be imposed, the water supply allocated to the low assurance class will first be curtailed or restricted, followed by the medium and finally by the high assurance class.

**Table 6-1: Orange River Project Priority Classification**

| Recurrence Interval of a restriction<br>**Sector**<br>Assurance of supply | **Priority Categories (Portion of the water requirements %)** | | |
|---|---|---|---|
| | **High** | **Medium** | **Low** |
| | **1: 200 year (99.5%)** | **1: 100 year (99%)** | **1: 20 year (95%)** |
| **Irrigation** | **10** | **40** | **50** |
| **Urban** | **50** | **30** | **20** |
| **Operational requirements** | **100** | **0** | **0** |
| **Environmental** | **68** | **0** | **32** |

**Restriction levels: 3 2 1 0**

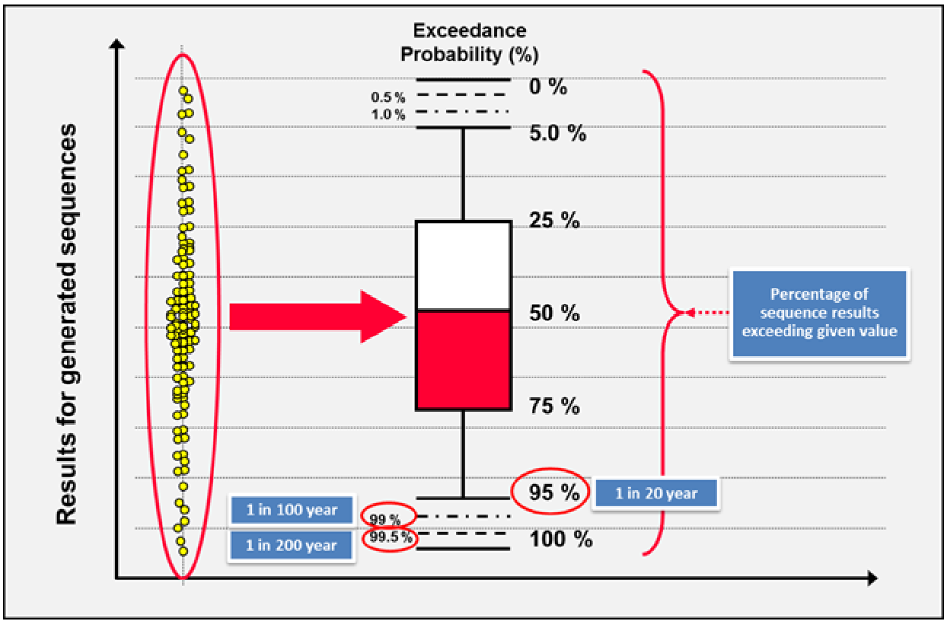



**Figure 6-1: Probability distribution boxplot definition.**

Restriction level 1 refers to the restrictions imposed on the low assurance class with level 2 on the medium assurance class and level 3 restrictions imposed on the high assurance class.

When risk analyses are carried out using stochastic flow sequences in the WRPM, a 1000 or more flow sequences are in general analysed. To be able to give meaning to the 1000 different results obtained from each of the 1000 flow sequences, box plots are used, expressing the results in terms of exceedance probability, as shown in **Figure 6-1**.

Results from a risk analysis relating to the restrictions imposed on a system during drought periods, or when the demand imposed on the system is starting to exceed the yield capability of the system, are displayed by means of an example curtailment plot, as shown in **Figure 6-2**. Curtailment level 1 refer to level 1 restrictions.

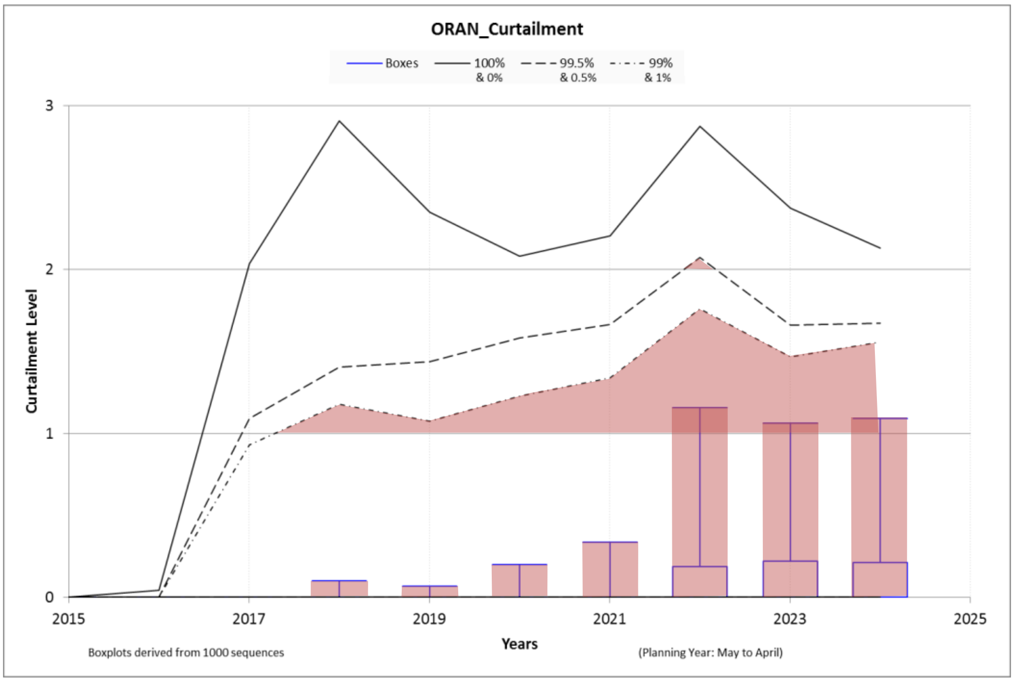



**Figure 6-2: Orange System Curtailment plot**

When the 5% exceedance probability show up in curtailment level 1 (red highlighted bars), it means that the restriction criteria for the users in the low class were violated. The 1% exceedance probability entering in curtailment level 2 zone implies that the restriction criteria for the medium class assurance users was violated (red highlighted area) and similar for the 0.5% exceedance probability entering in curtailment level 3 zone. When the restriction criteria for a given assurance class is violated, it indicates that the sub-system is no longer able to supply the demands imposed on the system at its required assurance. It will thus be necessary to bring in an intervention option to either increase the yield of the sub-system, or decrease the demand imposed on the sub-system.

The operation of sub-systems using the approach described above is thus based on the principle that demands are restricted during severe droughts.

- The objective is to reduce water supply to less essential use, to be able to protect the assurance of supply to more essential use.
- The basis on which restrictions are implemented, is defined by means of a user priority classification definition and the short-term yield characteristics.

Priority classifications used for the different sub-systems is not always the same, as it depends on the yield characteristics of the sub-system, the type of user or combination of users to be supplied from the resource, losses within the system, types of crops or crop combinations that need to be irrigated, the strategic importance of the user, etc.

Priority classifications are not fixed and can be changed by agreement with the users for various reasons.

Transfers are in some cases also linked to a specific assurance level. A good example is the transfer from The LHWP in Lesotho to the IVRS in the RSA. This transfer volume is fixed and represent an assurance of approximately 98% (failure in full supply on average 1 in 50 years).

It will not be possible to carry out the sensitivity analysis relating to the assurance of water supply for all the water supply systems within the Orange Senqu basin, as the amount of work involved will be far outside the scope of this study. For the purpose of this sensitivity analysis the ORP water supply system was selected, as this is the largest single water supply system in the basin, which includes a large amount of irrigation water use. Irrigation is quite flexible regarding the assurance of supply and significant amounts of water from a system can be made available when irrigation is supplied at slightly lower assurance levels.

## 6.1 Sensitivity analysis Scenarios for the ORP

It is important to take note of the typical yield characteristics from a water resource to better understand the purpose of this sensitivity analysis. The long-term yield for the current ORP is given in **Figure 6-3**.

From the long-term stochastic yield curve, it is evident that at a risk of failure of 1 in 50 year the firm yield that can be supplied by the ORP is just over 3 400 million $m^3$/a. If one need to supply the users at a very high assurance or risk of failure of only 1 in 200 years, the firm yield available from the ORP reduces to just over 3000 million $m^3$/a, thus a reduction of approximately 400 million $m^3$/a. The important characteristic to note, is that the lower the assurance of the supply, the higher the volume of water that can be supplied from the ORP.

Along the Orange River one can irrigate approximately between 30 000 to 40 000 ha with the 400 million $m^3$/a, which is quite significant. A typical question can be, would one rather irrigate 30 000 to 40 000ha more from the dam, or would one prefer to have the irrigation water at a much higher assurance and which assurance of supply will provide the optimal option from an economical point of view?

To be able to take an informed decision it will be necessary to carry out an economic analysis to show which of the possible options produce the highest economic benefit. In reality it is however not that simple, as single users are supplied at different assurance levels as shown in **Tables 6-1** and **6-2.**

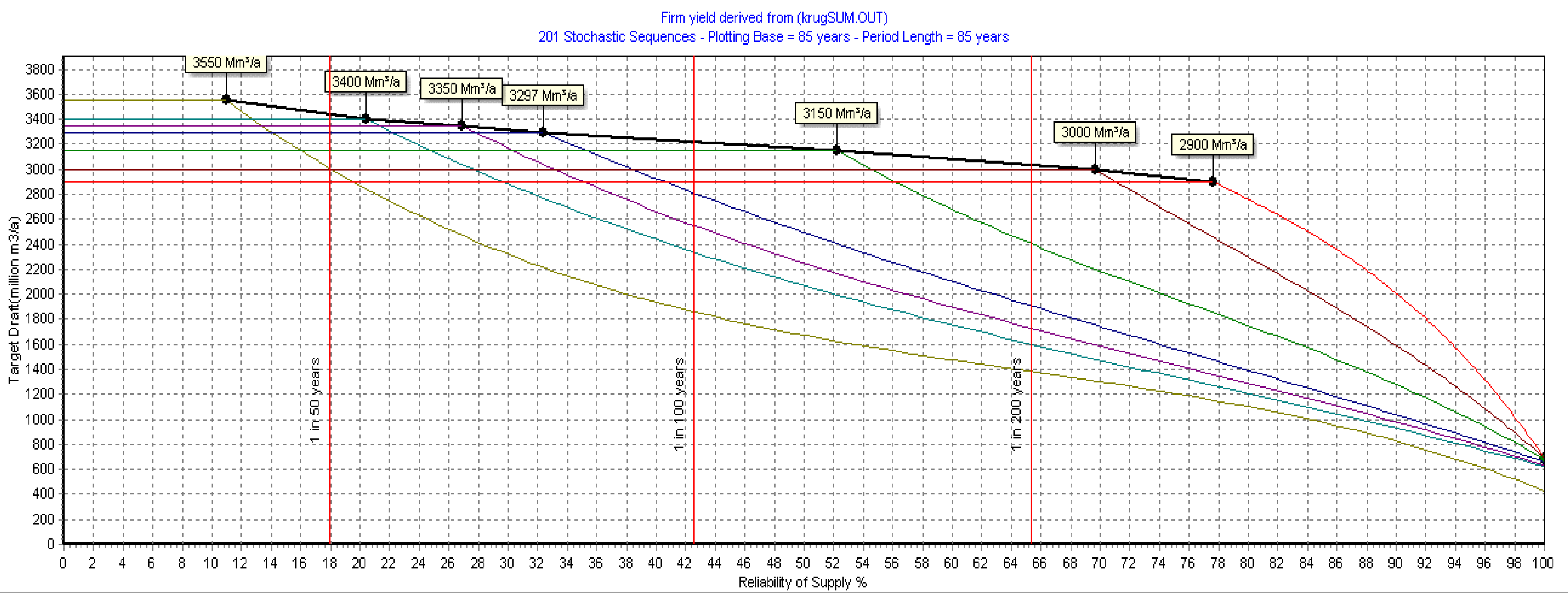



**Figure 6-3:Orange River Project long-term stochastic yield curve at 2030 development level**

The following scenarios were considered for the assurance of water supply sensitivity analysis, considering the ORP.

- Scenario 1: Consider the current system with the priority classification as shown in **Table 6-1** (existing priority classification as currently used for the ORP); Expected growth and WC/WDM included with Preliminary Reserve in place. Polihali Dam start storing water in Nov 2043 (Polihali Dam was artificially brought in late in the analysis period to show the impact of such a large development).
- Scenario 2: Consider the current system with the alternative priority classification as shown in **Table 6-2** (alternative priority classification that will result in a lower assurance of supply as promoted in previous studies considering the ORP). The remainder of the system set up remains as for Scenario 1.
- Scenario 2c: As Scenario 2, but with some of the irrigation in the low class moved up into the medium low assurance class.
- Scenario 3: As Scenario 2, but with all irrigation allocated to the low assurance class (90%).

**Table 6-2: Orange River alternative Project Priority Classification – Scenario 2**

| **Sector** | **Priority Categories (Portions of the water requirements as %)** | | | |
|---|---|---|---|---|
| | **High** | **Medium High** | **Medium Low** | **Low** |
| | **1 : 200 year (99.5%)** | **1 : 100 year (99%)** | **1 : 50 year (98%)** | **1 : 10 year (90%)** |
| Irrigation | 0 | 20 | 20 | 60 |
| Urban | 30 | 30 | 20 | 20 |
| Operational Requirements | 100 | 0 | 0 | 0 |
| Environmental Requirements | 68 | 0 | 0 | 32 |
| Restriction levels | 4 | 3 | 2 | 1 0 |

The only difference between scenario 1 and 2 is the priority classification, the rest are exactly the same, infrastructure development, water requirements, operating rules, etc.

Restrictions or curtailments were imposed on the ORP system when required, for all the scenarios analyzed.

To be able to obtain meaningful results from analysis, no infrastructure changes were included in the system for most of the analysis period. Polihali Dam was however included towards the end of the analysis period by 2045, only to illustrate the impact of such a development on the water supply system. Although this is not what would occur in reality, it is important to note, that the purpose of this analysis is to determine the impact of the assurance of supply on the economic benefit or disbenefit for the system.

### 6.1.1 Methodology

Until recently, decisions concerning water supply as allocated at different assurance levels or classes to the different water user sectors in water resource systems, have not been scientifically established. A methodology to establish this was fairly recently developed as part of a WRC project completed in 2017 (Economic Study of Assurance of Supply Requirements for Water Resource Management with Reference to Irrigation Agriculture, Report K5/2517).

The research work thus developed a decision support tool for assessing the assurance of water supply requirements of various water user sectors. This was based on economic indicators, by utilizing and coupling existing water resource models with an economic model. The following models formed part of the research:

- The water resource yield model (WRYM);
- The water resource planning model (WRPM);
- The economic water impact model (WIM).

The main economic indicators that were included in the analyses were the gross domestic product (GDP), employment, and household income. The main input variable to the WRPM used for this analysis is the User Priority Classification (risk criterion). As part of this research work the assurance of supply model (ASM) was developed which serves as a decision support tool that can be used to improve the assurance of water supply criteria.

A schematic representation is given in **Figure 6-4**, of the overall process of how the different models were applied, the related information flow linkages and the key results that can be supplied from the various analysis steps. An alphabetic letter in the schematic is used to indicate each of the elements in the analysis.

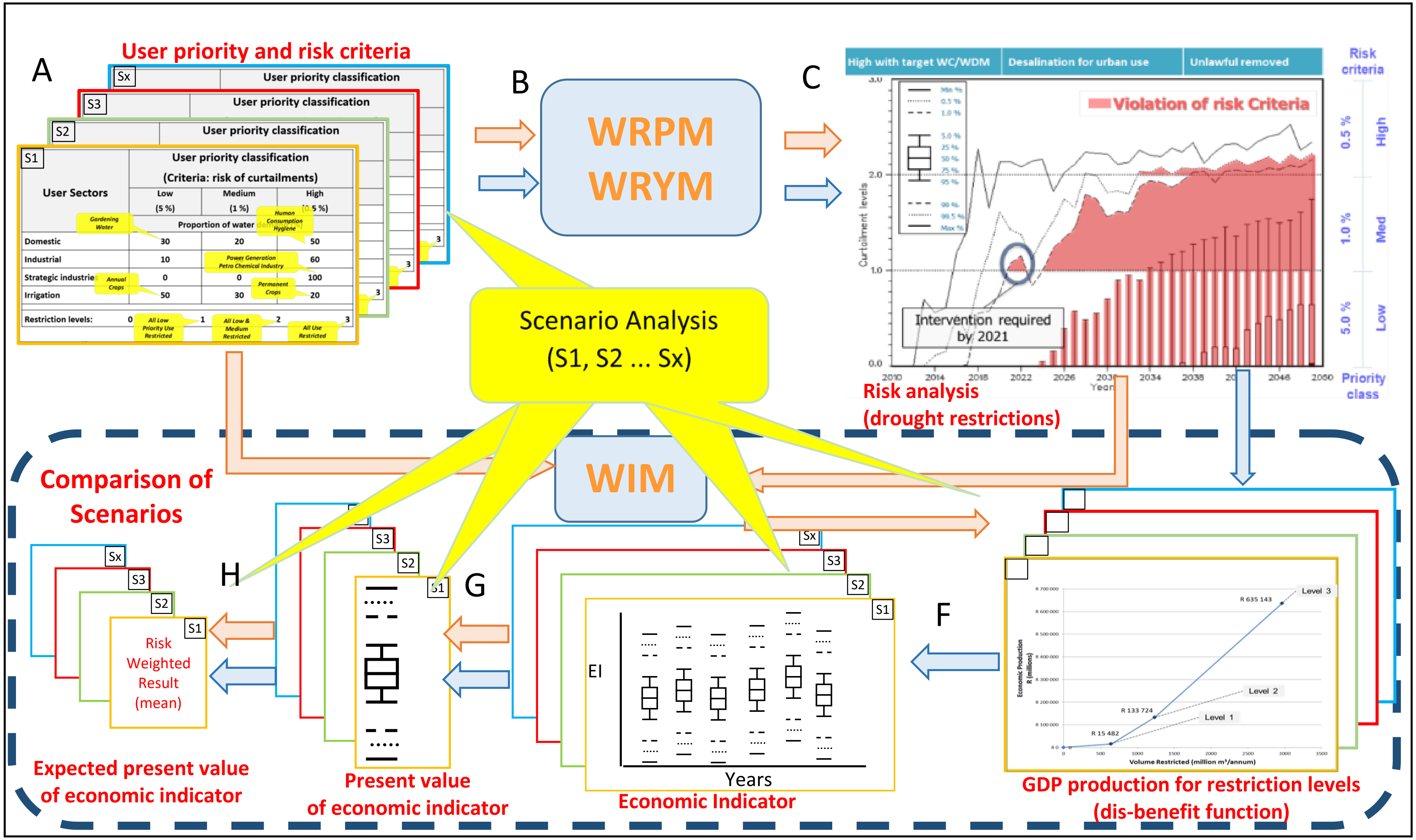



**Figure 6-4: Schematic representation of the proposed analysis processes**

The flow of information or data is indicated by the blue and red arrows. Brief descriptions of each of the process elements are included in the order of the sequence in which they were applied.

### A. User priority and risk criteria

The user priority classification data or risk criteria as applicable to different scenarios (See Section 6.1) is the primary input data that will be varied as defined per scenario. The aim is to determine and evaluate the economic implications of alterative priority classification data sets.

### B. WRPM

The WRPM will be used to carry out the water resource system analysis with different user priority classification data sets included as input. Restrictions will be simulated and implemented by the WRPM as required over the analysis period. The analyses will be carried out for a 1000 stochastic flow sequences.

### C. Risk analysis (results from WRPM)

The restriction levels as determined by the WRPM for the 1000 stochastic flow sequences, is the key output from the WRPM to be used for the economic analyses. This output directly relates with the priority classification data as defined in (A). The volumetric magnitude of the restrictions for each of the risk levels as applicable to the different users, is represented by the restriction level scale as produced from the WRPM output.

### D. Water impact model (WIM)

The WIM requires the water supply volumes that include the impacts due to restrictions, as obtained from the WRPM as well as the specific production budgets for each crop which are made up from the variable costs and fixed costs in order to determine the gross income for each of the crops. It further includes the labour requirements per hectare, as well as the current crop yield at a 100% water supply.

### E. GDP versus restriction relationship

Output from the WIM can typically be used to determine the relationship between the level of restriction and an economic indicator such as GDP. For the purpose of the sensitivity analysis this information was obtained from a recent study carried out by Conningarth Economists in 2018, where the WIM was already applied to the ORP supply area (Socio-economic Impact of Water Restrictions in the Orange River basin) (see **Figure 6-5**).

The information from **Figure 6-5** was then used to derive the relationship between the volume of water supplied to the users and the related GDP impact (see **Figure 6-6**). As part of the sensitivity analysis different restriction levels, as well as combinations of restriction levels will be evaluated. The graph as given in **Figure 6-6** will thus provide very useful information to be utilized for the purpose of the scenario sensitivity analyses to be carried out as part of this study. .

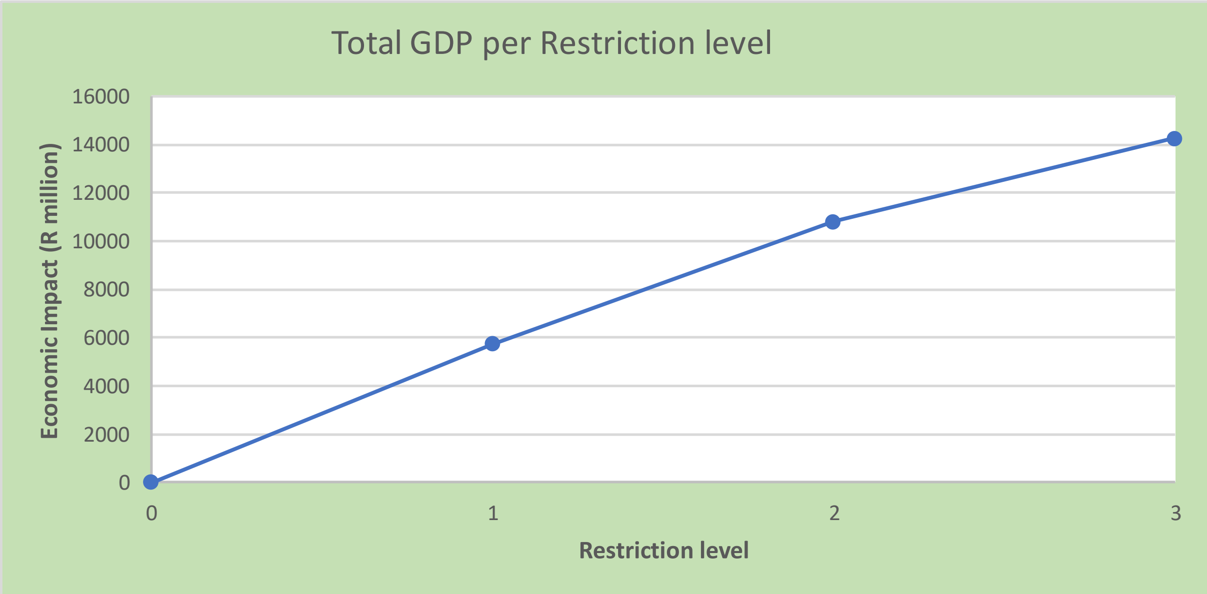



**Figure 6-5: ORP System: GDP vs. the indicated restriction levels**

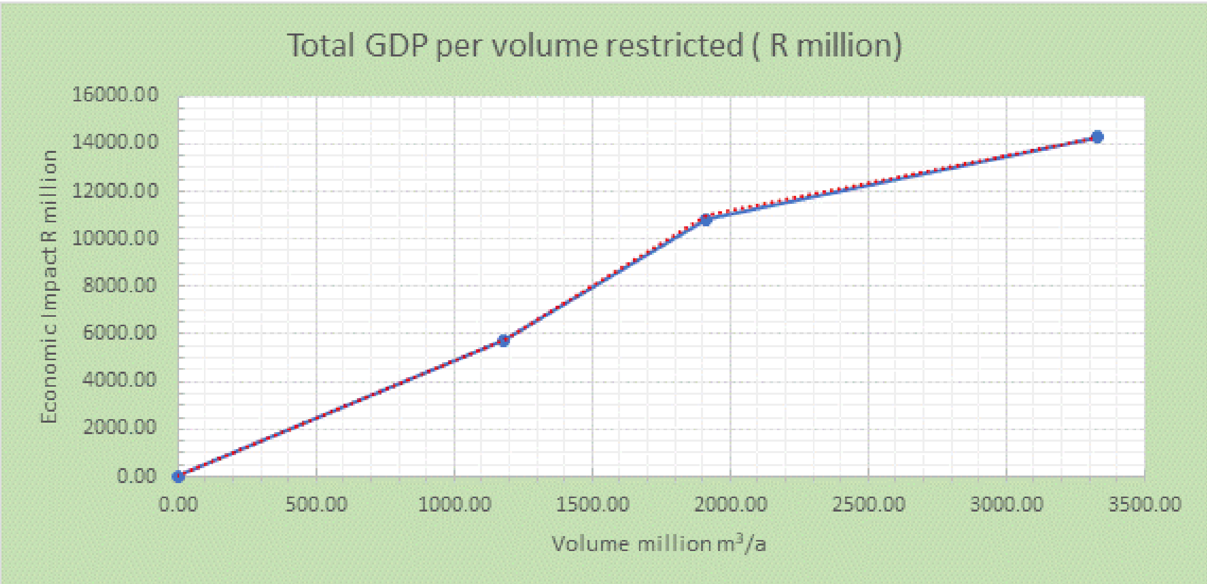



**Figure 6-6:ORP System: GDP vs. the restricted volume**

**F. Economic indicators (GDP, Employment & Household income)**

The WIM is used to determine the economic impact of crops under irrigation. The model requires the following input data:

- The volumes of water supplied to the various crops (as received from the WRPM)
- Production budgets that consist of variable and fixed costs to be able to determine the gross income for each of the crops.
- The production budgets also include the labour requirements per hectare as well as the crop yield at a 100% water supply.

From the WIM, annual time series of economic indicators are produced for each of the 1000 sequences analyzed. The WIM provides outputs in the form of GDP and employment for the representative economic regions, as well as household income within the selected water supply area. The impact on the GDP is one of the key outputs from the WIM and reflects the magnitude of the values added to the regional and wider economy from activities using the water.

**G. Present value of economic indicator (GDP)**

The present value of the GDP for each of 1000 sequences was determined which were then used to provide a probability distribution of the present value for each of the scenarios to be analyzed. The probability distribution was determined for 17 exceedance probabilities for three different discount rates.

**H. Expected value (average or mean) of the economic indicator (GDP)**

For comparison purposes between scenarios, the average present-day value as produced by all 1000 sequences were determined at the three different discount rates. The gain or loss in GDP can then easily be determined by comparing these results as derived for the different scenarios analyzed.

### 6.1.2 Results from the analyses

The results from the WRPM are used to show how well the water was supplied to the users and also to show the behavior of the storage in the ORP system over the analysis period. **Figures 6-7** and **6-8** show the **curtailment plots** as obtained for the first two scenarios analyzed.

From **Figure 6-7** it is evident that for Scenario 1, the ORP system was for most of the time not able to supply the users at the required assurance levels (red highlighted areas) as specified in **Table 6-1**. Curtailment levels were already exceeded from 2021 onwards and increased significantly by 2046 onwards due to the inclusion of Polihali Dam.

At curtailment level 3 (99.5% assurance) the curtailment level criteria were exceeded slightly, and only once over the analysis period in the year 2046 and was due to the inclusion of Polihali Dam.

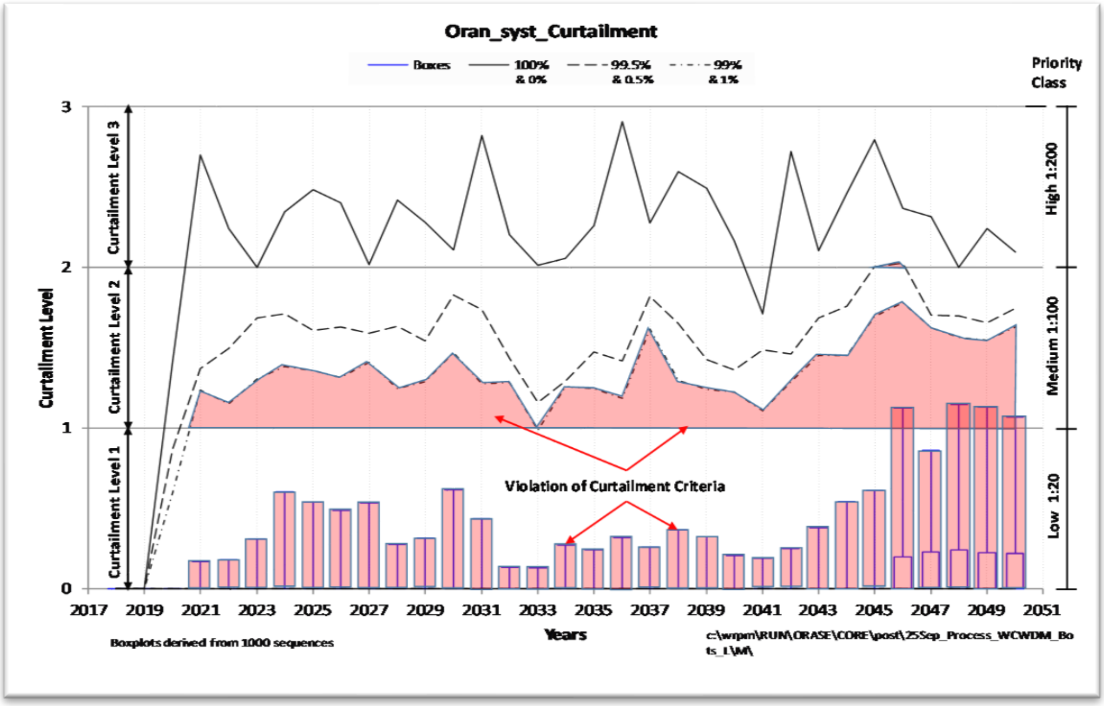



**Figure 6-7: Scenario 1 – ORP curtailment level plot using existing priority classification.**

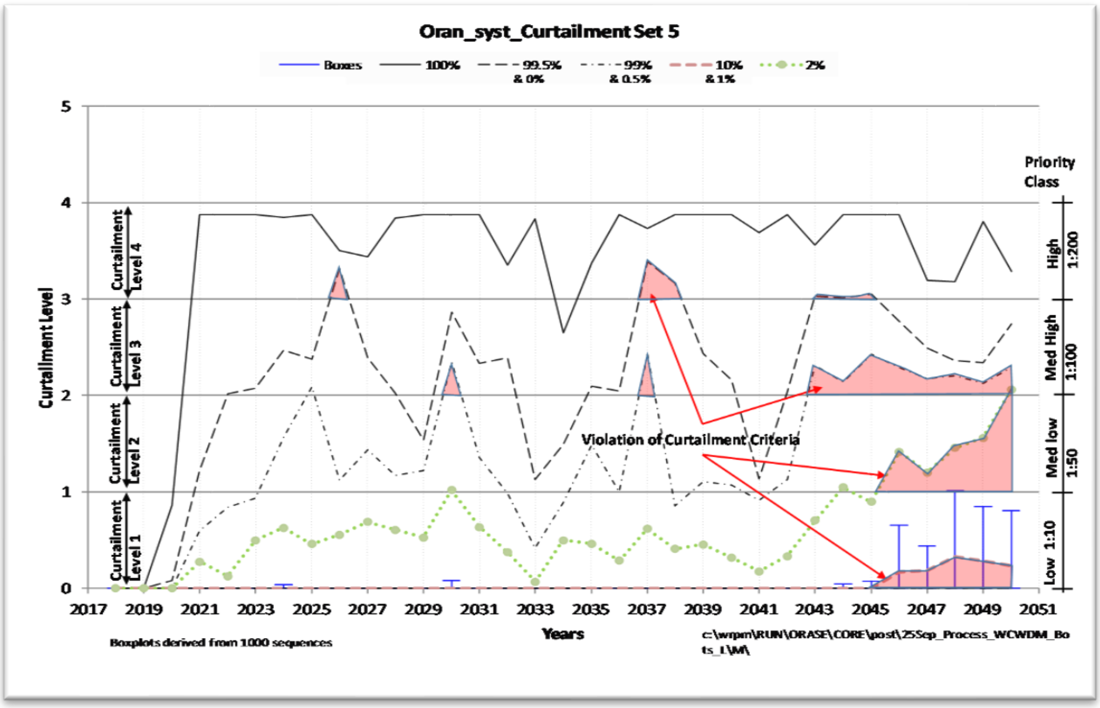



**Figure 6-8:Scenario 2– ORP curtailment level plot with alternative priority classification.**

From **Figure 6-8** it is clear that with the users being supplied at a lower assurance, based on the Priority Classification as given in **Table 6-2,** the water supply did improve significantly in comparison with Scenario 1 regarding the low, medium low and medium high assurance classes. Before the inclusion of Polihali Dam curtailment levels on the low and medium low assurance classes for Scenario 2 were hardly exceeded. It was only after the inclusion of Polihali Dam that the curtailments levels on the low and medium low assurance were exceeded on a continuous basis (red highlighted areas). For Scenario 1 however, the curtailment level for high assurance class was only once slightly exceeded at the time when Polihali Dam was activated. For Scenario 2 the high assurance class did not perform that well, as curtailment levels were exceeded for a few stand-alone events (see red highlighted areas), but not on a continuous basis.

The ORP system was thus for Scenario 2 able to supply the users at the required assurance levels, for most of the time over the analysis period, until the inclusion of Polihali Dam.

One would however prefer not to exceed the curtailment criteria when moving into the high assurance level (curtailment level 4) as the users will at that stage already be at very severe stress conditions regarding water supply and irrigation will receive no water. Not receiving the water allocated to curtailment level 3 and 4 can also lead to the total loss of long-term investments such as orchards and vineyards. It is also not acceptable that the improved water supply to irrigation at the medium low and low assurance levels should impact negatively on the high assurance supply used to support only basic needs. For this reason, a slight change was made in the **Table 6-2** priority classification by reducing the irrigation in the low class from 60% to 45% and increasing the irrigation in the medium low class from 20% to 35%. The aim of this change is to have as little as possible violation of the curtailment criteria in the high assurance class. The results from this analysis are shown in **Figure 6-9**.

Scenario 2c clearly succeeded in eliminating any exceedance of curtailment levels in the high assurance class as well as reducing it in the medium high assurance class. The exceedance of curtailment levels however slightly increased in the low and medium low assurance classes, which is more acceptable.

Results from Scenario 2 and 2c clearly illustrate the advantage of supplying irrigation in general at a lower assurance (also see the economic results in **Tables 6.4** and **6.5**). This raised the question if a further lowering in the assurance of supply would benefit the water supply from the ORP even more, or would there be a turning point where a further lowering in the assurance of supply is rather a disbenefit to the ORP water supply system.

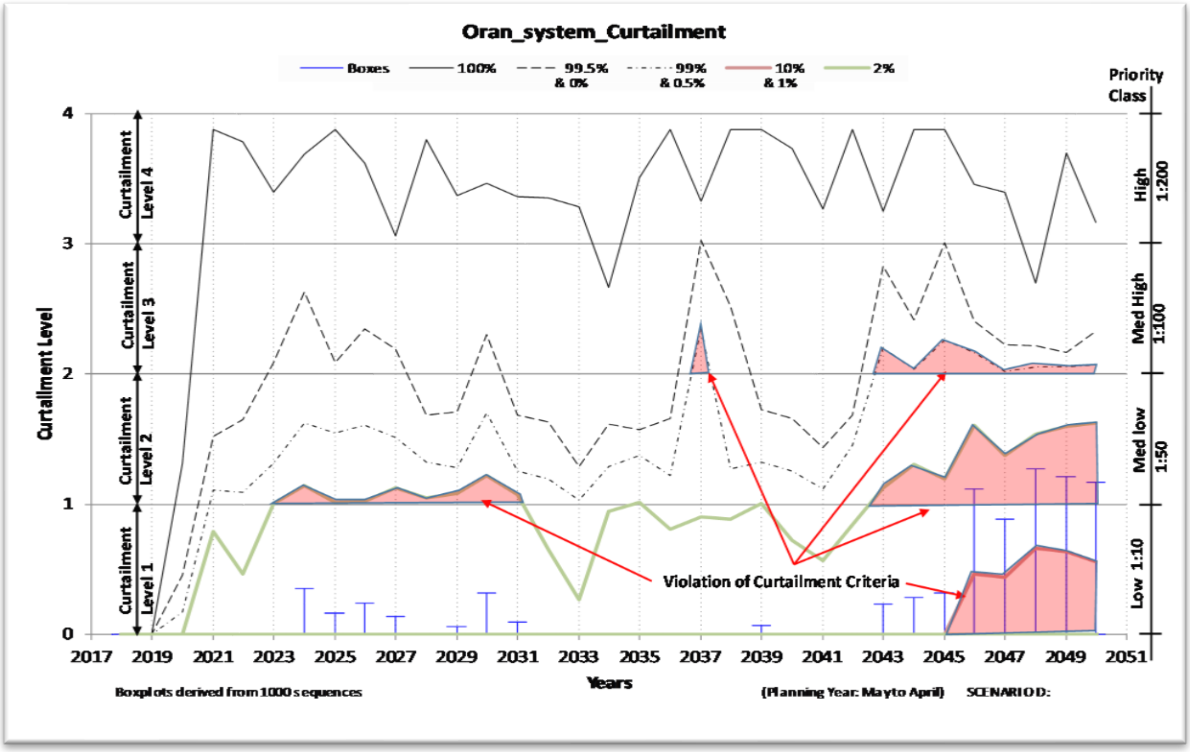



**Figure 6-9: Scenario 2c– ORP curtailment level plot with adjusted alternative priority classification.**

For this reason, Scenario 3 was defined with the alternative priority classification (**Table 6-2**) used as basis, with the only difference that all the irrigation was allocated to the lowest assurance class.

The results from Scenario 3 as given in **Figure 6-10** showed that the supply to the Low and Medium Low assurance classes improved even more than that obtained from Scenario 2 and 2c. The water supply to the Medium High assurance class was for Scenario 3 in some years worse than that obtained from Scenario 2 and in other years better. The high assurance class however did perform worse for Scenario 3 than that evident from the Scenario 2 results. It thus seems that the positive water supply achieved at the lower assurance classes in general results in a negative impact on the high assurance classes. This was also noticed when comparing Scenario 2c with Scenario 2.

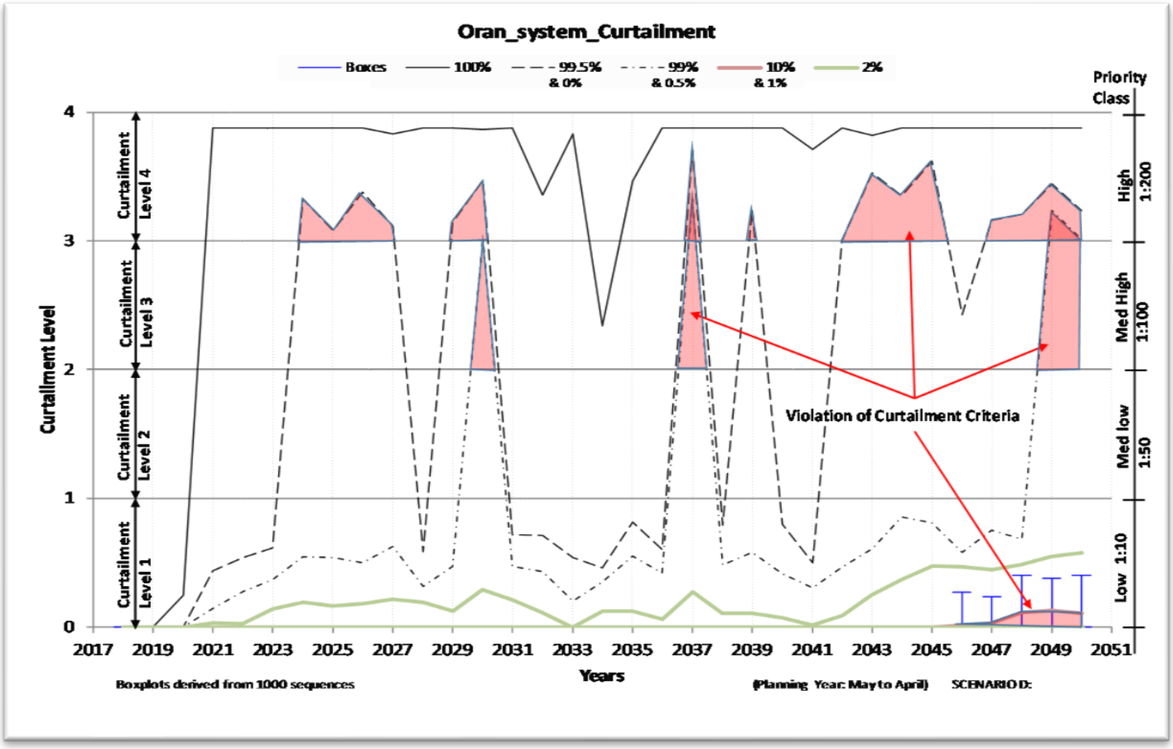



**Figure 6-10: Scenario 3 – ORP curtailment level plot with all irrigation at low assurance.**

For Scenario 3 the exceedance of curtailment criteria for the high assurance class (99.5% assurance curtailment level 4) occurred even more frequently than for Scenario 2 (see red highlighted areas). As explained before, this is not acceptable as it impacts negatively on the high assurance supply used to support only basic needs during severe drought periods and can also lead to the total loss of long-term investments such as orchards and vineyards.

<u>**The storage projection**</u> plots of the ORP for Scenario 1 and Scenario 2 are given in **Figures 6-11** and **6-12** respectively. For both scenarios, the curtailment rule functioned well, and the dams were protected, thus dams never over the analysis period ran empty (99.5% exceedance probability never reached the minimum operating level). When the dams do run empty, it would result in a total failure in water supply to the users. The purpose of the curtailments and related operating rules are to avoid such a situation.

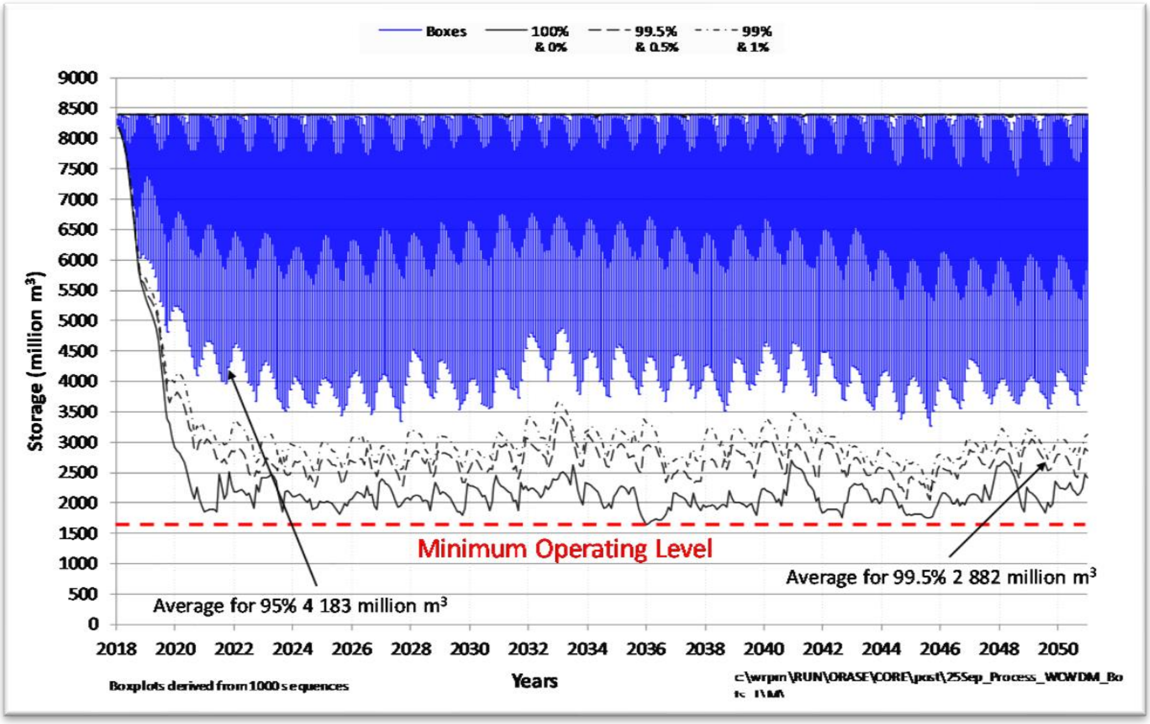



**Figure 6-11: Scenario 1 – ORP Storage Projection**

For Scenario 2, where the users were in general supplied at a lower assurance, it is evident that the storage levels in the ORP were slightly lower than those from Scenario 1.

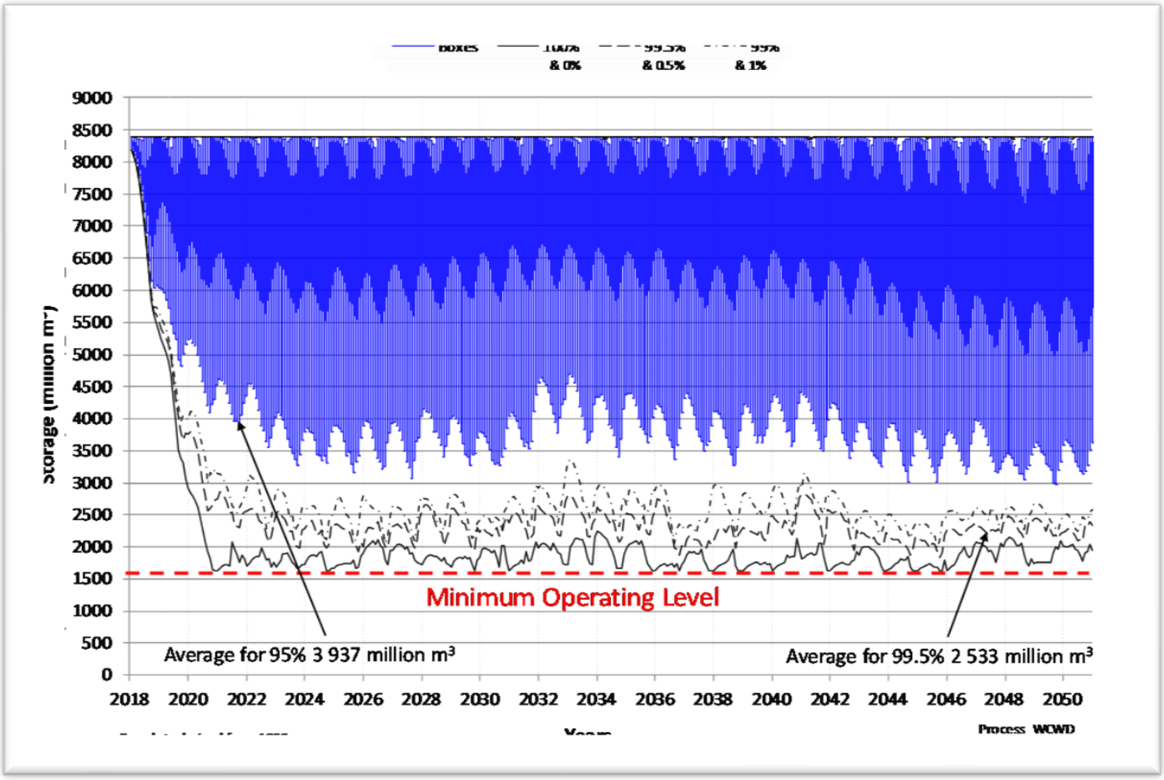


**Figure 6-12: Scenario 2 – ORP Storage Projection**

This is to be expected, as due to the lower assurance of supply, restrictions will start to be imposed at lower storage levels, than would be the case for Scenario 1.

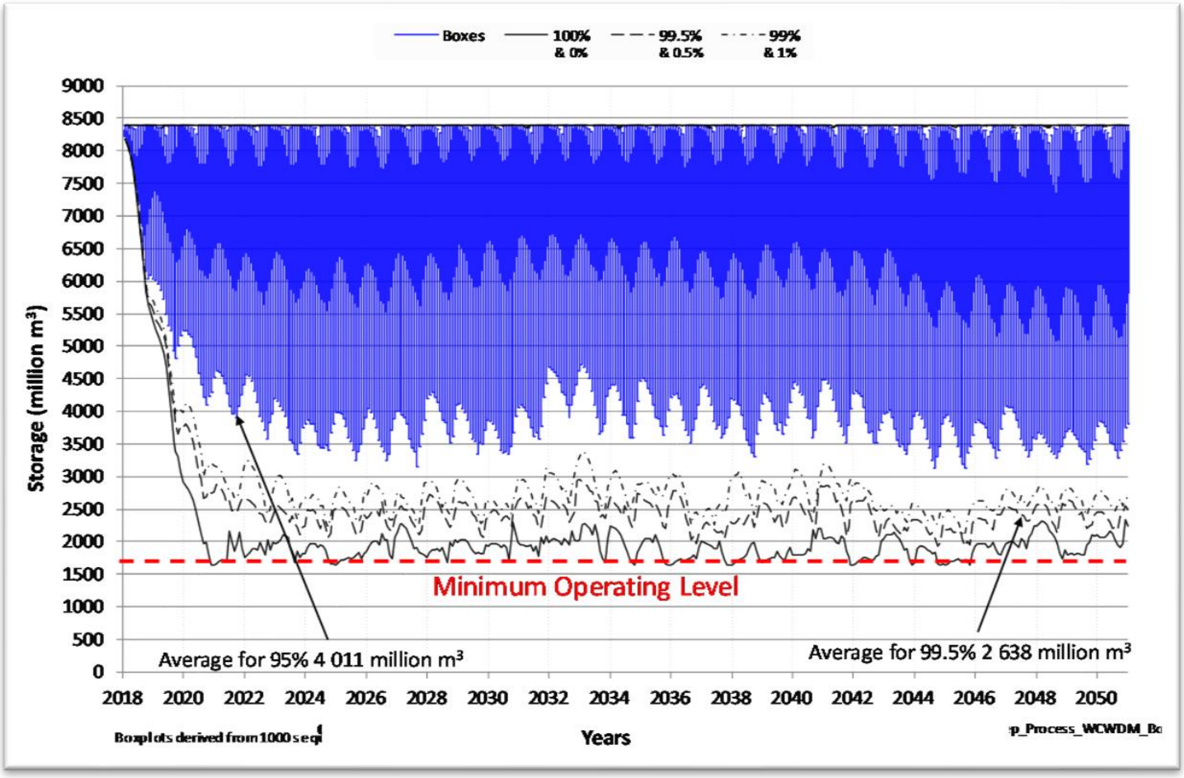



**Figure 6-13: Scenario 2c – ORP Storage Projection**

For Scenario 2c the users were supplied at a slightly higher assurance than for Scenario 2, but at a lower assurance than for Scenario 1. It is thus evident that the average storage levels for Scenario 2c lies between those of Scenarios 1 and 2. The Scenario 2c operating rule as in the Case of the other two scenarios protected the dam against total failure.

Of all the scenarios analyzed, the Scenario 3 operating rule result in the lowest assurance of supply to the users. The average storage levels from the Scenario 3 storage projection plots thus resulted in the lowest average storage levels. Between 2037 and 2038 the 99.5% exceedance probability level ( 1 in 200 year recurrence interval) almost reaches the minimum operating level of the ORP system (Gariep and Vanderkloof dam combined storage). This means that the system almost would experience a total failure in water supply during that time. Lowering the assurance of supply further might very well result in a total failure of the water supply system over the analysis period.

The operating rule and related priority classification used for scenario 3 still succeeded to prevent the system from total failure by imposing restrictions in time.

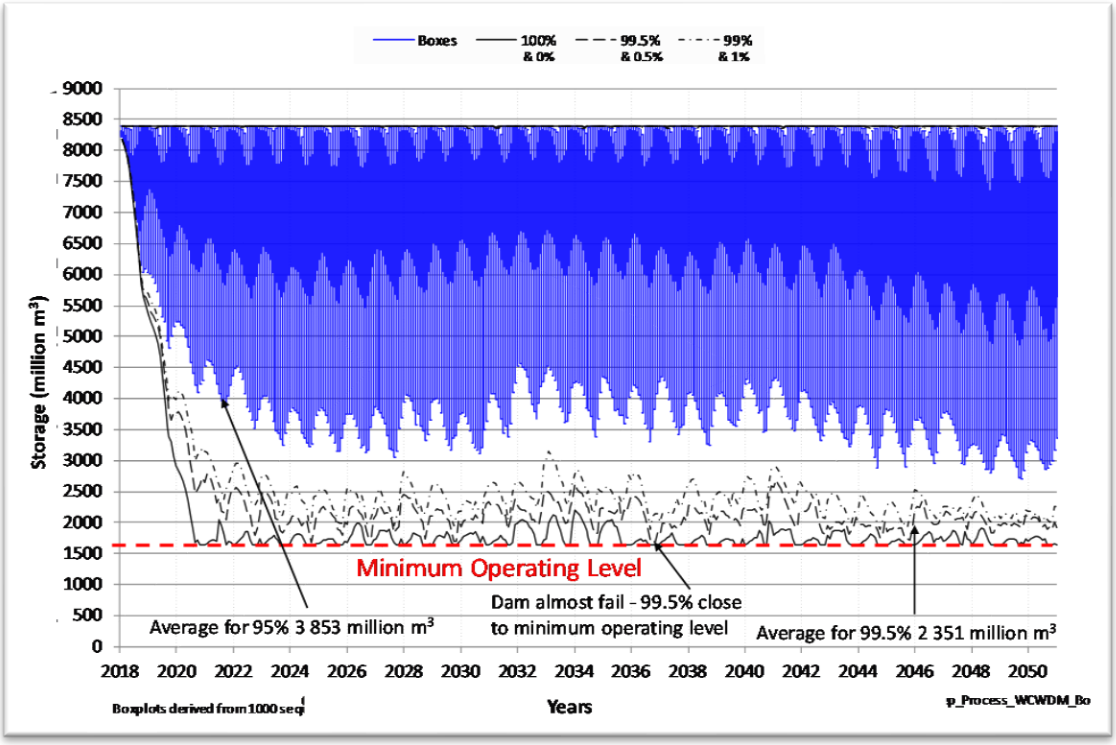



**Figure 6-14: Scenario 3 – ORP Storage Projection**

From the water resource models the most important output that need to be used as input to the assurance of supply model (ASM) are the curtailment levels or restrictions that were imposed on the users from the water supply system as already discussed, based on the results shown in **Figures 6-7** to **6-10**.

The input to the assurance of supply model (ASM) regarding the expected reduction in GDP due to water restrictions, was obtained from a recent study carried out by Conningarth Economists in 2018. In the Conningarth study the WIM was already applied to the ORP supply area (Socio-economic Impact of Water Restrictions in the Orange River basin). Also see **Figures 6-5 & 6-6** in **Section 6.1.1**.

**The reduction in GDP** as applicable to Scenarios 1 to 3 were obtained from the Conningarth Economists 2018 study for the different restriction levels and are given **Table 6-3.** This was then used as input to the ASM for the purpose of the scenario analyses carried out for the ORASECOM study (See also **Figures .6.5** and **6.6**).

**Table 6-3: Reduction in GDP at given restriction levels per Scenario**

| Restriction level | Scenario 1 | Scenario 2 | Scenario 2c | Scenario 3 |
|---|---|---|---|---|
| | GDP reduction R million | | | |
| 0 | 0 | 0 | 0 | 0 |
| 1 | 5,635 | 6,617 | 4,869 | 11,447 |
| 2 | 11,462 | 10,223 | 10,223 | 11,679 |
| 3 | 14,281 | 12,028 | 12,804 | 12,028 |
| 4 | | 14,281 | 14,281 | 14,281 |

The NPV of the reduction in the GDP due to water restrictions imposed on the ORP was determined at three different discount rates of 6%, 8% & 10%. These average NPV as determined for scenarios 1 & 2 are given in **Table 6-4**.

**Table 6-4:The NPV of the reduction in GDP for Scenarios 1 & 2**

| Description | Average water supply (million $m^3/a$) | Net Present GDP Value at the given discount rate<br>Average Reduction in GDP in R million | | |
|---|---|---|---|---|
| | | 6% | 8% | 10% |
| **Scenario 1** | 2,054 | 4,306.61 | 3,200.55 | 2,461.41 |
| **Scenario 2** | 2,080 | 2,570.08 | 1,904.18 | 1,458.12 |
| **Difference** | **26** | **1,736.53** | **1,296.38** | **1,003.28** |

The difference in the average NPV reduction in GDP between Scenario 1 & 2 at the different discount rates is significant and clearly shows that the reduction in GDP due to restrictions is for Scenario 2 is much lower than that for Scenario 1. From an economic point of view, it is thus more beneficial to allocate a large portion of the irrigation water requirements to a lower assurance of supply, given that total demand imposed on the system remains the same for both scenarios. It is further important to note that although the users are supplied at a lower assurance for Scenario 2, Scenario 2 over the total analysis period of 33 years supplied on average slightly more water to the users than received from Scenario 1. There are thus two advantages for Scenario 2 above Scenario 1:

- Scenario 2 on average supplied more water to the crops than Scenario 1.
- Scenario 2 at all three discount rates produced a higher GDP than Scenario 1.

The differences in the NPV of the reduction in GDP between Scenarios 1 and 2c are lower than those evident between Scenarios 1 and 2, but still significant. The average water supply to the users from Scenario 2c over the 33 year period is slightly higher than that supplied from Scenario 1.

**Table 6-5:The NPV of the reduction in GDP for Scenarios 1 & 2c**

| Description | Average water Supply (million $m^3/a$) | Net Present GDP Value at the given discount rate Average Reduction in GDP in R million | | |
|---|---|---|---|---|
| | | 6% | 8% | 10% |
| **Scenario 1** | 2,054 | 4,306.61 | 3,200.55 | 2,461.41 |
| **Scenario 2c** | 2,073 | 3,060.00 | 2,273.31 | 1,745.98 |
| **Difference** | **19** | **1,246.62** | **927.24** | **715.43** |

The differences in the NPV between Scenarios 2 and 2c are much lower than those between Scenario 1 and 2 and Scenarios 1 and 2c.

Very little difference is evident in the average water supply between Scenarios 2 and 2c.

The assurance of supply to irrigation for Scenario 3 was further reduced with all the irrigation supplied at 90%.

**Table 6-6: The NPV of the reduction in GDP for Scenarios 2c & 2**

| Description | Average water Supply (million $m^3/a$) | Net Present GDP Value at the given discount rate Average Reduction in GDP in R million | | |
|---|---|---|---|---|
| | | 6% | 8% | 10% |
| **Scenario 2c** | 2,073 | 3,060.00 | 2,273.31 | 1,745.98 |
| **Scenario 2** | 2,081 | 2,570.08 | 1,904.18 | 1,458.12 |
| **Difference** | 7 | **489.91** | **369.13** | **287.86** |

From both **Tables 6-7** & **6-8** it is clear that the average reduction in GDP has again reduced with a reduction in assurance of supply. It is however important to note that it is for the case where the total demand imposed on the ORP was the same for all three scenarios.

**Table 6-7: The NPV of the reduction in GDP for Scenarios 1 & 3**

| Description | Average water Supply | Net Present GDP Value at the given discount rate Average Reduction in GDP in R million | | |
|---|---|---|---|---|
| | (million $m^3/a$) | 6% | 8% | 10% |
| **Scenario 1** | 2,054 | 4,306.61 | 3,200.55 | 2,461.41 |
| **Scenario 3** | 2,090 | 1,954.35 | 1,442.72 | 1,100.41 |
| **Difference** | **36** | **2,352.26** | **1,757.84** | **1,361.00** |

The reduction in GDP for Scenario 3 due to restrictions imposed on the system is the smallest of all scenarios analyzed. In comparison with the current conditions (Scenario 1) the largest increase in GDP can thus be achieved by Scenario 3. Although relatively small, Scenario 3 resulted in the highest increase in the average water supply to users over the analysis period.

**Table 6-8: The NPV of the reduction in GDP for Scenarios 2 & 3**

| Description | Average water Supply | Net Present GDP Value at the given discount rate Average Reduction in GDP in R million | | |
|---|---|---|---|---|
| | (million $m^3/a$) | 6% | 8% | 10% |
| **Scenario 2** | 2081 | 2,570.08 | 1,904.18 | 1,458.12 |
| **Scenario 3** | 2090 | 1,954.35 | 1,442.72 | 1,100.41 |
| **Difference** | **9** | **615.73** | **461.46** | **357.71** |

The differences between the average water supply and GDP reduction for Scenarios 2 and 3 are relatively small and are more or less in line with that obtained when comparing Scenarios 2 and 2c.

As previously explained, a water supply system can supply more water per annum to users when water is supplied at a lower assurance and less water if the users require that water be supplied at a higher assurance. This is one of the reasons why Scenarios 2, 2c and 3 provided a lower reduction in the GDP in comparison with Scenario 1. For all three these scenarios the total demand imposed on the ORP remained the same. From the ORP long-term yield curve it is evident that the lower assurance of supply as defined for Scenario 2, will allow an increase in water supply of about 285 million $m^3/a$ to obtain the same water supply-water assurance balance as for Scenario 1. This increase in the available yield at a lower assurance therefore becomes available when the users are supplied at lower assurances and reduces the number of curtailment violations.

The impact of water supply assurance on a water supply system were in this section illustrated by four different key result outputs:

- Looking at ability of the system to adhere to the required assurance of supply: The results from the analyses in the form of the curtailment level plots clearly illustrated this ability of the system. If there were a high number of violation events of the curtailment criteria, it clearly showed that the system was not able to supply the users all the time over the analysis period at the required assurance levels as defined in the priority classification table and applicable to that specific scenario. From these plots it is also clear at which of the curtailment levels the most violations did occur.
- Evaluating the storage projection plots for the different scenarios to assess whether the operating rule that includes the applicable priority classification table for the specific scenario, were able to protect the water supply system from total failure or not. Total failure means the storage dams in the system were completely empty at some time over the analysis period and no water could be supplied to any of the users for some time period.
- Assessing the impact of different priority classifications or assurance levels of water supply on the GDP as produced from the water supply system: These assessments clearly illustrated the economic impacts of water supply assurance from the system. For these analyses, the reduction in GDP as result of restrictions/curtailments imposed on the system were determined for the different scenarios considered. The scenario with the lowest reduction (net present value) in GDP will thus reflect the best scenario from an economic point of view.
- Determining the average water supply over the analysis period: For the irrigators it is very important to know what the overall average water supply from the different scenarios will be. If the average water supply from one scenario is significantly less than that from the other scenarios, the irrigators will be hesitant to implement that specific option or scenario.

It is not possible to look at one of these four key results in isolation to be able to decide which of the scenarios analyzed is providing the best result. This will be addressed in detail in **Section 6.1.3**

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### 6.1.3 Evaluation of overall results

One needs to assess the related impacts from all four of the key result components per scenario and then compare the combined effect with those from the other scenarios. A summary of the four key results per scenario is given in **Table 6-9**

**Table 6-9: Summary of key results per Scenario analyzed**

| Description | Scenario | Average Irrigation (million $m^3$/a) | | Reduction in GDP @ 8% discount rate | Curtailment Levels | Average Dam storage @ exceedance probalility (million $m^3$) | | 1 in 200 year (99.5%) curtailment level: Number of curtailment exceedances |
|---|---|---|---|---|---|---|---|---|
| | | Supply | Demand | million Rand | | 99.5% | 95% | |
| As Scenario 2 but all irr at low assurance | 3 | 2,090.21 | 2,174.00 | 1,442.72 | 4 | 2351 | 3853 | 14 small to medium high exceedance |
| | | % supplied | 96.1% | | | | | |
| Adjusted lower assurance with 4 Classes | 2 | 2,080.51 | 2,174.00 | 1,904.18 | 4 | 2533 | 3937 | 5 small to medium exceedance |
| | | % supplied | 95.7% | | | | | |
| As Scenario 2 just slightly higher assurance | 2c | 2,073.39 | 2,174.00 | 2,273.31 | 4 | 2638 | 4011 | Zero exceedance |
| | | % supplied | 95.4% | | | | | |
| Current System - 3 priority classes | 1 | 2,054.42 | 2,174.00 | 3,201.00 | 3 | 2882 | 4183 | Once very small exceedance |
| | | % supplied | 94.5% | | | | | |

| Color Ranking | |
|---|---|
| 1 | Highest |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | Lowest |

In **Table 6-9** each of the key results are ranked according to color as indicated in the Color Ranking box on the left. The ranking colors is almost like that of a traffic light with green as the best or highest ranking and red the worst or lowest ranking. When considering the average irrigation supply for example, the current system (Scenario 1) was ranked yellow and not red due to the fact that a 94.5% average supply for irrigation is still good for irrigation, although it presents the lowest average water supply of all the scenarios. The color ranking for the reduction in GDP is fairly straight forward and clearly shows that the reduction in GDP for Scenario 1 is having by far the most severe impact on the GDP produced from the system, with Scenario 3 the lowest reduction in GDP, thus producing the highest GDP.

When ranking the dam storage, one need to consider a balance between two indicators:

- Did the dam at the 99.5% exceedance probability drop to the minimum operating level over the analysis period? As described before this will result in no water supply to users leading to a disaster, in particular for large water supply schemes.
- Was the storage in the dam fully utilized or did the operating rule overprotect the resource so that storage levels seldom came close to the minimum operating level?

The storage at the minimum operating level in the ORP system is at 1 640 million $m^3$. This is a fairly high storage and is as result of the outlets to the hydropower turbine inlets at the two dams. Considering the average dam storage at the 99.5% exceedance storage level over the analysis period, all the scenarios seem to be above the minimum operating level. When assessing the storage projection plot for Scenario 3 in more detail (See **Figure 6-14**) it is evident that the 99.5% level almost touched the minimum operating level more than once over the analysis period, which means the system was very close to a total failure in water supply during a severe drought. This is showing up a red flag and therefore a ranking of yellow was used for Scenario 3, although this scenario utilized the available storage the best. On the other extreme, the storage projection plot for Scenario 1 showed that the 99.5% storage level was for most of the time quite above the minimum operating level (See **Figure 6-11**), starting to show clear signs of underutilizing the available storage in the system, and Scenario 1 was thus ranked by the light red color. The other scenarios performed reasonably well in this category.

The exceedance of curtailment levels is to some extent already captured in the economic analysis but need to be assessed in further detail. As part of this assessment, it is important to take note of the following:

- For scenarios 2, 2c & 3, no water from the high assurance class was allocated to irrigation. This means that when curtailment level 4 restrictions are imposed on the system, no water will be available for irrigation purposes. If violation of curtailment criteria in level 4 do not occur, it means that on average this will only happen once in 200 years.
- The water allocated to the high assurance for scenarios 2, 2c & 3 is meant to only supply water for the basic domestic/industrial needs.
- The water allocated to the medium high assurance for irrigation purposes in scenarios 2, 2c & 3 is meant to at least keep the long-term investments, such as orchards and vineyards alive during the severe 1 in 100 year droughts, with maybe some crop production depending on the severity of the restriction.

- For Scenario 1 the high assurance volume is meant to supply the basic domestic/industrial needs as well as to at least keep the orchards and vineyards alive during the severe 1 in 200 year drought events.

When assessing the assurance of supply key result from the curtailment level plots, taking into account the four notes listed above it is evident that:

- for Scenario 3 violation of the curtailment criteria occurs quite a number of times during severe droughts (1 in 100 and 1 in 200 year). This Scenario was thus not able to fully protect the high assurance use component, which is not acceptable. This will also result in zero water for irrigation more often than once in 200 years.
- For Scenario 2 violation of the curtailment criteria occurs only a few times during severe droughts (1 in 100 and 1 in 200year). This Scenario was thus able to provide reasonable protection to the high assurance use. Zero water for irrigation should thus occur slightly more than once in 200 years.
- For Scenario 2c no violation of the 1 in 200 year and almost none for the 1 in 100 year assurance occurred. This scenario was thus able to protect the high assurance use and zero supply to irrigation should not occur more than once in 200 years.
- For Scenario 1 basically no violation of the curtailment criteria occurred at the high assurance (1 in 200 year). Violation of the curtailment criteria occurred almost every year at the low assurance (1 in 20 year) and medium assurance (1 in 100 year). The violation of the curtailment criteria at the low assurance is most probably the reason why a higher reduction in GDP is evident for this Scenario. The high assurance of 1 in 200 years however was very well protected.

Regarding the curtailment criteria Scenario 2c is thus providing the best result. For scenarios 2 and 3 the allocation of more irrigation to the lower assurance classes started to impact on the assurance of the water to be supplied from the high assurance class, which should not be allowed. For Scenario 3 the violation of the curtailment criteria at the high assurance occurred 14 times over the analysis period, and in most cases quite severely as well, therefore the red color ranking. The violation of the curtailment criteria at the low assurance almost every year for Scenario 1 is most probably the main reason why a higher reduction in GDP is evident for this Scenario.

When considering the color ranking for all four key results as a whole, Scenario 2c stands out as the most favorable option (See **Table 6-9**) with all key results ranked from light green to the full green ranking. Although Scenario 3 resulted in the highest average water supply and lowest reduction in GDP, the risk of total dam failure is high, and this scenario significantly impact on the water available from the high assurance class.

Scenario 2c provides several benefits when compared to Scenario 1 (Current assurance of supply) which includes:

- Slight increase in average water supply.
- The reduction in GDP due to restrictions/curtailments is significantly lower.
- The available storage in the system is better utilized.

Scenario 2c is also not impacting negatively on the water allocated to the high assurance class.

From the scenarios analyzed Scenario 2c is thus clearly the best option. Further optimization should still take place in combination with the consultation of stakeholders. See further conclusions in Section 7.

# 7 CONCLUSION

## 7.1 Economic Assessments

The purpose of this economic assessment was to provide crucial information regarding the relative economic viability of the Core Scenario to empower a sponsor and investors with an understanding of the overall impact of the project.

This economic assessment determined the economic effectiveness and efficiency of the Core Scenario. The URV analysis provided an indicative value for money of each clustered scheme and individual project intervention. While some schemes do not reflect cost effectiveness, there are identified cost efficiencies realized as indicated by the results of the CBA. The key factor to note in the URV analysis is the wide range of results, driven by the differing nature of the various interventions that make up the clusters.

The CBA provided a socio-economic rationale for the Core Scenario by weighing up the economic costs and benefits of the clustered schemes. The CBA results indicate that overall, five out of the eight schemes will result in a positive net benefit to the ultimate beneficiaries, and one is a marginally net negative outcome. The results reflect healthy BCRs and economic rates of return.

As mentioned in the introduction, the CBA produces 3 important outcomes, the ENPV, BCR and EIRR. The ENPV describes the present value of the economic costs and benefits for the Core Scenario, where a positive ENPV suggests that the investment is worthwhile. The BCR further elaborates on the ENPV. This ratio shows the relationship between the costs and benefit of the Core Scenario. The third outcome is the economic IRR which is a profitability estimate for each clustered scheme.

The economic benefits were a summation of the estimates of the impact on economic activity and health benefit. As seen in the CBA results in Section 4.3 most clustered schemes produced positive economic outcomes, which suggests that most are worthwhile to invest in. Only two clustered schemes yielded (Cluster 2: L-BWT Scheme and Cluster 7: Gariep to Greater Bloemfontein Transfer) weak economic benefits, which as result contributed to negative ENPVs, BCR of below 1 and low EIRRs.

The L-BWT Scheme will provide climate change resilience to Gaborone and its surrounding areas, and although based on the CBA results it turns out not to be economically viable, it may be the only option Botswana has.

Subsequent to the CBA, a sensitivity test was conducted and showed that the CBA model assumptions were robust.

It is important to note that further work will be carried out to determine in more detail the costs and benefits of the L-BWT Scheme. For that purposes a financial assessment was contracted separately from this study. This assessment and analysis will look at the cost and benefit for the “with and without” project situations for the L-BWT Scheme. This is required to establish the incremental net benefit arising from this transfer project over a long-term time horizon. The estimates of the project benefits include direct and indirect benefits, tangible and intangible benefits and secondary benefits related to the project as well as externalities. Benefits associated with hydropower production will also be considered. Indirect costs and externalities, such as the impact of possible reduction of the water allocation to the Orange systems, will also be quantified. A key consideration of the assessment is the climate resilience benefits that the scheme provides to Botswana which cannot be properly quantified in monetary terms.

### 7.2 Assurance of Supply Sensitivity analysis

It is a well-known fact that more water can be made available from a resource when the users are supplied at a lower assurance. The question was always whether it will make economic sense to supply, in particular irrigation at lower assurances. Results from the sensitivity analysis revealed the following:

- When the demand imposed on the ORP is kept the same, but the supply to the users are provided at a lower assurance, the reduction in GDP due to restrictions are, resulting in an increase in the GDP when users are supplied at a lower assurance. This is most probably due to the surplus yield available at the lower assurance, which is then utilised to reduce the number and severity of restrictions.
- The average water supply to the irrigators in general slightly increased over the analysis period when irrigation is supplied at a lower assurance. The irrigators should thus not be concerned that a lower assurance will result in less water being available over time.
- Providing users at a too high assurance can easily result in the water resource being under-utilised. A balance should thus be obtained in the water supply to different levels of assurance within each of the water use sectors.
- The reduction in GDP as used in this analysis does not fully represent the effect of severe droughts such as the 1 in 100 year and 1 in 200-year drought events. One thus needs to consider the impacts of the different scenarios analysed on the high and medium high assurance classes. The curtailment criteria, in particular the high assurance class should not be violated, as it is of extreme importance to have the minimum water supply available for survival during the extreme drought events and to avoid total system failure (no water supply from the system). The Scenario with the highest GDP (lowest reduction in GDP) does not necessarily reflect the best option.

- Based on the result evaluation as given in **Section 6.1.3** it was clear that Scenario 2c provides the best-balanced result between the four key result indicators, although it did not provide the highest GDP (lowest reduction in GDP).
- From results obtained from all the scenarios analysed, it was clear that irrigation within the ORP is currently supplied at a too high assurance level. It will clearly be to the benefit of all the users, for the water supply system as a whole and the GDP generated from this area, to supply irrigation at a lower assurance more in line with that used for Scenario 2c.
- It is important to note that every irrigation or water supply scheme is unique due to the characteristics of the hydrology applicable to the system, the yield capability, and its related characteristics, whether the system is over or underutilised, the crop types generally grown and produced in this scheme, etc. The results from this sensitivity analysis carried out for the ORP will not be fully applicable to other schemes, although some guidelines or trends can provide guidance when evaluating other schemes in more detail.
- Endless number of options or scenarios can be analysed like those carried out. Due to budget and time constraints, it was decided to focus on those currently most relevant and important to the ORP and irrigation schemes in general with input data requirements that are readily available. To be able to compare apples with apples, the total demand on the ORP was kept the same for all scenarios analysed, with only changing the assurance of supply. Other options can also be analysed and evaluated such as increasing the demand imposed on the system as well as changing the assurance of supply, for example to ensure a combined demand water supply assurance balance on the water resource system. Although an attempt was made as part of this sensitivity analysis to analyse such options, it was clear that this was much more complicated and required specific economic inputs that were not generally available. This is something that can be addressed in future as part of the improvement on the effective utilisation of irrigation water use from water supply schemes.
- It is recommended that further optimization should still take place in combination with the consultation of stakeholders.

# 8 REFERENCES

The key documents leveraged were:

South Africa, Department of Water and Sanitation (2014). Bloemfontein Reconciliation Strategy Accelerated Action Plan to Augment Bloemfontein's Water Supply. Prepared by Aurecon South Africa.

South Africa, Department of Water Affairs (2014). Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River Final Reconciliation Strategy. Prepared by WRP Consulting, Aurecon, Golder Associates Africa, and Zitholele Consulting.

South Africa, Department of Water Affairs (2014). Development of Reconciliation Strategies for Large Bulk Water Supply Systems: Orange River Review of Screened Options and Cost Estimates. Prepared by WRP Consulting Engineers, Aurecon, Golder Associates Africa, and Zitholele Consulting.

South Africa, Mangaung Metropolitan Municipality (2018). Mangaung Gariep Water Augmentation Project: Scenario Analyses Greater Bloemfontein. Prepared by Bigen and WRP Consulting.

South Africa, Department of Water Affairs (2010). Vaal River WRDP: Comparative Study between LHWP Phase 2 and Thukela Water Project: Costing Report. Prepared by Acer (Africa), BKS, DMM Development Consultants, Golder Associates Africa, and WRP Consulting.

South Africa, Department of Water Affairs (2010). Vaal River WRDP: Comparative Study between LHWP Phase 2 and Thukela Water Project: Economic Comparison Report. Prepared by Acer (Africa), BKS, DMM Development Consultants, Golder Associates Africa, and WRP Consulting.

South Africa, Department of Water Affairs (2012). Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area Final Interventions Report. Prepared by Aurecon.

South Africa, Department of Water Affairs (2012). Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area Final Reconciliation Strategy Report. Prepared by Aurecon.

The Orange-Senqu River Commission (2018). Preparation of Climate Resilient Water Resources Investment Strategy and Plan and Lesotho-Botswana Water Transfer

Multipurpose Transboundary Project: Pre-Feasibility Report Phase 1: Component III. Prepared by WRP Consulting.

Mosaka Economic Consultants: Socio-Economic Impact of Water restrictions in the Orange River Basin Prepared by William Mullens from Conningarth Economists January 2018

ORASECOM 2020a: Preparation of Climate Resilient Water Resources Investment Strategy & Plan and Lesotho-Botswana Water Transfer Multipurpose Transboundary Project. Core Scenario Update Report Component I, Report no. ORASECOM 003/2019. February 2020

WAVES, Government of Botswana (2015) Botswana Water Accounting Report 2015. Online: https://www.car.org.bw/wp-content/uploads/2016/05/Botswana-WA-report-2015.pdf

Conningarth Economists (2014) A Manual for Cost Benefit Analysis in South Africa with Specific Reference to Water Resource Development. Water Research Commission.

AfDB & OECD (2007) African Economic Outlook. Online: https://www.oecd.org/countries/namibia/38562952.pdf

Lesotho, Ministry of Water (2018) State of Water Resources Report 2015/16.

South Africa, Department of Water and Sanitation (2018) Annual Report 2017/18

Glenn-Marie, et.al., (2006) Water accounting for the Orange River Basin: An economic perspective on managing a transboundary resource.

Namibia, Department of Water Affairs and Forestry (2006) Technical Summary of Water Accounts.

Statistics South Africa, GDP report Q4 2018

Reserve Bank of Lesotho, Macroeconomic Outlook, December 2018

Bank of Botswana, Economic Statistics Database 2018

Bank of Namibia, Economic Outlook 2017-2020

European Commission (2014) Guide to Cost-Benefit Analysis of Investment Projects. Online: http://ec.europa.eu/regional policy/sources/docgener/studies/pdf/cba_guide.pdf

# Appendix A

## URV Sensitivity analysis for the L-BWT Scheme

# 1 CLUSTER 2: L-BWT SCHEME URV SENSITIVITY ANALYSIS

## 1.1 Background

The URV calculations in the final draft report delivered in October 2021 used the costing of the L-BWT scheme as available at the time from the Phase I Pre-feasibility Study. It was requested that this report be finalised once the Phase II Pre-feasibility study had been completed, and the final proposed dam site and conveyance system route had been determined as well as the related cost for the final agreed options. The URVs based on the results from the Phase II Pre-feasibility study were found to be lower at 53.17 R/m$^3$ (Table 1-2) in comparison with the Phase I result of 67.15 R/m$^3$ (Table 1-1).

**Table 1-1: Cluster 2 URV Results based on the Pre-feasibility Phase I results.**

| | Discount Rates | | | Investment Cost | Yield |
|---|---|---|---|---|---|
| | 8% | | | | |
| | URV | PV Costs | PV Water | | |
| Project Name | R/m$^3$ | R millions | Million m$^3$ | R millions | Million m$^3$ |
| Cluster 2 L-BWT Scheme | 67.15 | 65,582 | 977 | 65,644 | 150 |
| Makhaleng Dam | 4.41 | 4,305 | 977 | 4,648 | 150 |
| LBWT pipeline, transfer pipe to Gaborone/Lobatse | 62.74 | 61,276 | 977 | 60,963 | 150 |

The URV for the "L-BWT Scheme" as obtained from the Pre-feasibility Phase I results indicated that the Scheme is very expensive in comparison with the other schemes as there is a marginal impact on the net yield balance in relation to the large investment cost.

The most important differences between the proposed L-BWT Scheme from the Phase I and Phase II pre-feasibility studies include the following:

- Dam Site:
    - Phase I study used the downstream site at S2.
    - Phase II study used the upstream site referred to as the N1a site.
- The dam size and yield.
    - For the Phase 1 study a dam hight of 128m was considered with a gross storage capacity of 1 319 million m$^3$ and a gross historic firm yield of 389 million m$^3$/a.

  - For the Phase II study a lower dam hight of 126m was considered with a gross storage capacity of1 133 million $m^3$ and a gross historic firm yield of 334 million $m^3$/a.

- Utilisation of the available yield from the dam on the Makhaleng River.
  - The Phase 1 study used the yield to supply water to Botswana, Lesotho and the RSA as well as to provide mitigation releases to the Orange River Project to eliminate the negative yield impact on the Orange River Project caused by the large upstream dam on the Makhaleng River.
  - The Phase 2 study used the yield to supply water to Botswana, Lesotho and the RSA, but supplied no mitigation releases in support of the Orange River Project.

- Gross versus the net yield.
  - Phase 1 study used the net yield of 150 million $m^3$/a from the lower dam for the water supply to Botswana, Lesotho and the RSA and for the calculation of the URV for the L-BWT Scheme.
  - Phase 2 study used the gross yield of 334 million from the upper dam for the water supply to Botswana, Lesotho and the RSA and for the calculation of the URV for the dam. For the conveyance system the maximum transfer capacity of 162 million $m^3$/a was used.

- Conveyance system.
  - Phase 1 study used the central fully piped option with a high-water requirement of 150 million $m^3$/a as limited by the net yield.
  - Phase 2 study used the central fully piped option with a high-water requirement of 162 million $m^3$/a based on the full high-water requirement as determined for the transfer system.

The lower URV as obtained from the Pre-feasibility Phase II Study results is mainly due to the following:

- The lower cost estimation of the conveyance system.
- The gross yield available from the storage dam on the Makhaleng River in comparison with the incremental or net yield used previously. It was assumed that the surplus yield from the dam estimated in the order of 134 million $m^3$/a will also be utilised which could be irrigations in Lesotho or urban/Industrial requirements within RSA and Lesotho.

In the Pre-feasibility Phase I Study, it was shown that the dam on the Makhaleng River will significantly reduce the yield currently available from the Orange River Project (Gariep and Vanderkloof dams combined). Mitigation releases were then made from the dam on the Makhaleng River to restore the yield balance in the Orange River Project. This resulted in the incremental yield available from the lower dam on the Makhaleng River of only 150 million $m^3$/a.

The Polihali Dam, which is currently under construction and forms part of the Lesotho Highlands Phase II development, will result in a similar reduction in yield of the Orange River Project. It was suggested by ORASECOM that a separate reconciliation strategy study be undertaken to identify options to restore the water balance of the Orange River Project due to the combined impact of Polihali Dam and the proposed dam on the Makhaleng River, as both these developments are planning to utilise the gross yield from the dams and not the incremental yield. Due to this suggested approach, the upper dam on the Makhaleng River has been assessed on the basis of its gross yield of 334 million $m^3$/a of which 162 million $m^3$/a is to be transferred to Botswana and the RSA via the conveyance system. The 334 million $m^3$/a gross yield as used from the Pre-feasibility Phase II Study is significantly higher than the net yield as used during the Pre-feasibility Phase I Study. The volume to be transferred to Botswana and the RSA has therefore been increased from the 150 million $m^3$/a used from the Phase I study to 162 million $m^3$/a used for the Phase II study.

**Table 1-2: Cluster 2 URV Results based on the Pre-feasibility Phase II results.**

| | Discount Rates | | | Investment Cost | Yield |
|---|---|---|---|---|---|
| | 8% | | | | |
| | URV | PV Costs | PV Water | | |
| Project Name | R/$m^3$ | R millions | Million $m^3$ | R millions | Million $m^3$ |
| Cluster 2 L-BWT Scheme | 53.17 | 54,775 | 1,030 | 54,257 | 162/334 |
| Makhaleng Dam | 3.55 | 4,566 | 1,286 | 6,006 | 334 |
| LBWT pipeline, transfer pipe to Gaberone/Lobatse | 49.62 | 50,210 | 1,012 | 48,252 | 162 |

The Phase II Pre-feasibility Study Report the URVs were only used to compare different possible options with each other and thus did not include all the costs which will be common in all option such as for example land acquisition. Results from the Phase II Pre-feasibility Study Report therefore showed a lower URV for the L-BWT scheme of only 24.30 R/$m^3$. For this report ORASECOM requested that all costs need to be included in these calculations. Although it was not necessary for comparison purposes in the Pre-feasibility study. This however resulted in the URV given in the Phase II Pre-feasibility Study Report to be less than half of the 53.17 R/m$^3$ as given in this report (Table 1-2) which has raised some concerns. A URV sensitivity analysis was therefore undertaken to provide clarity on this issue (See Section 2). The purpose of the sensitivity analysis was to better understand the impact of the different components added or not added to the equation on the final URV.

One of the main differences between the URV calculations carried out as part of the Phase II Pre-feasibility Study Report and those carried out as part of this report is the total cost considered for the L-BWT Scheme. The purpose of the URV calculations in the Pre-feasibility study report was mainly to compare different possible dam and conveyance systems that were considered in the Phase II Pre-feasibility work and used the partial cost of the schemes as input to the URV calculations. The partial costs excluded the following cost components.

- VAT and other taxes
- Engineering fees.
- Electricity transmission and sub-station infrastructure for the dams and hydro-power plants.
- Land acquisition.
- Environmental and social costs
- Relocation costs
- Pre-operation testing and commissioning costs

The partial versus the full cost for different dam types at the final N1A proposed dam site as determined from the Pre-feasibility Phase 2 study are summarized in Table 1-3.

**Table 1-3: Makaleng Dam partial versus full cost – Pre-feasibility Phase 2**

| Site → | N1A | | |
|---|---|---|---|
| Option → | CFRD | Gravity Dam | Arch Dam |
| **Partial Cost** | | | |
| Total Capital Cost (million R) (excl. VAT) | R4,747.35 | R5,359.00 | R4,060.43 |
| Operational Cost per Annum (million R) | R23.74 | R26.80 | R20.30 |
| Annual Revenue Hydropower (million R) | R79.69 | R79.69 | R79.69 |
| | | | -R59.39 |
| **Full cost** | | | |
| Total Capital Cost (million R) (incl. VAT) | R7,021.52 | R7,926.17 | R6,005.54 |
| Operational Cost per Annum (million R) | R27.30 | R30.81 | R23.35 |
| Annual Revenue Hydropower (million R) | R91.64 | R91.64 | R91.64 |
| | | | |
| **Dam Yield (Miilion m$^3$/annum)** | **334** | **334** | **334** |
| | | | |

An estimate of the full cost was made by using the following factors based on sound engineering judgment and experience on similar projects.:

- Land acquisition (5%) Factor 1.05
- Relocation (5%) Factor 1.05
- Secondary infrastructure (5) Factor 1.05
- Engineering fees (10%) Factor 1.10
- Insurance cost (1%) Factor 1.01
- VAT (15%) Factor 1.15

The combined factor used was thus 1.479 for the capital cost and 1.15 for the operational cost as only VAT is impacting on the operational cost.

These factors were applied to both the dam and the conveyance system. See Table 1-4 for the details on the partial versus full cost for the conveyance system. The Central route fully piped option was recommended from the Pre-feasibility Phase 2 study. There is, however, still the option to include Bloemfontein as one of the demand centers within the RSA as well as the option to construct the conveyance system in two phases. The initial phase will include a conveyance system with a capacity of 100 million $m^3$/a for the second phase another pipeline with a capacity of 63 million $m^3$/a will be added.

The significant difference between the partial and full cost of the L-BWT Scheme will thus be one of the key items to be considered in the sensitivity analysis described in Section 2.

**Table 1-4: Conveyance Pipeline partial versus full cost – Pre-feasibility Phase 2**

| Route → | CENTRAL ROUTE | | | |
|---|---|---|---|---|
| Option → | High Scenario | High Scenario + Bloemfontein | High Scenario Phase 1 | High Scenario Phase 2 |
| **Partial Cost** | | | | |
| Capital Cost (million R) | R32,623.52 | R35,367.67 | R26,741.66 | R19,228.58 |
| Energy Cost per Annum (million R) | R729.02 | R833.72 | R572.15 | R146.30 |
| | | | | |
| **Full Cost** | | | | |
| Capital Cost (million R) | R48,251.47 | R52,310.18 | R39,551.98 | R28,439.83 |
| Energy Cost per Annum (million R) | R838.37 | R958.77 | R657.98 | R168.24 |
| | | | | |
| Net Water Transfer (Million m3/a) | 162 | 200 | 100 + 63 = 163 | |

# 2 URV SENSITIVITY ANALYSIS

## 2.1 Scenarios analysed

There are two elements to the project where URV was used. The one forms part of Component III of the study that focus only on the L-BWT Scheme while the other is part of Component I of the study focusing on the entire Orange-Senqu Basin including all possible future developments expected to occur within the basin, also including the L-BWT Scheme. The one was designed to compare options within the L-BWT Scheme and used a shorter evaluation period as well as excluded common cost such as for example, land acquisition and relocation costs. The other one was used in the Economic Report in Component I of the study where totally different schemes were compared. ORASECOM at the time also requested that the full cost be used for the purpose of the Economic Report of Component I of the study.

This resulted in significant differences in the URV as determined from Component I and Component III of the study. Although these URVs are used for different purposes, one is expecting that questions will be raised to understand the reason for the differences. The URV Sensitivity analyses were thus conducted to answer that question and to highlight the factors contributing the most to the observed differences.

The analysis started to first identify the main differences in the approach followed to determine the URV for Component I (entire study basin) versus Component III (L-BWT Scheme). The following important differences in the two approaches were identified as:

- The Pre-feasibility Phase II Study Report considered the gross demand while the net demand was used for the Economic Study Report.
- The Pre-feasibility Phase II Study Report used a fixed water requirement from the start of the analysis while the Economic Study Report used the expected growth in water requirement over time.
- The Pre-feasibility Phase II Study Report used a 20-year period for the URV calculation while the Economic Study Report used a 50-year period.
- The Pre-feasibility Phase II Study Report used the partial cost of the scheme, while the Economic Study Report used the full cost of the scheme in the URV calculations (see details in Section 1.1).

Detailed sensitivity analyses were thus carried out to determine the reasons for the differences as well as the impact of each of the differences given above on the URV. The following scenarios were analyzed.

- Scenario 1: This is also referred to as the Base Scenario and represents the lowest URV and includes the following:

  - Use of a 30-year period for the URV calculation as typically used for conveyance systems.
  - Use of an Arch Dam option.
  - Use of the full yield and full conveyance capacity from day one of the analysis.
  - Assumed that hydro-power generation at the dam will be at full capacity from day one.
  - The net demand was used as the volume delivered to the users through the conveyance system.
  - The partial cost of the L-BWT system was used as given in the Pre-feasibility Phase 2 Report.
  - An 8% discount rate was used.
  - It was assumed that construction starts in 2028 and operation starts in 2033.
- Scenario 2: This is the same as Scenario 1 with the following differences:
  - The growth in demand over time was considered. This means the initial transfer volume and demand supplied from the dam will be significantly less than that used in Scenario 1 (60 million $m^3$/a versus 162 million $m^3$/a in 2033) The conveyance system was assumed to reach full capacity by 2047 and the full yield of the dam was assumed to be utilised by 2059.
- Scenario 3: This is the same as Scenario 2 with the following differences:
  - A 50-year period for the URV calculation was used for both the dam and the conveyance system.
  - After 30 years, it was assumed that some components within the conveyance system will need to be replaced. An allowance of 30% of the initial capital expenditure was included in the calculations.
- Scenario 4: This is the same as Scenario 3 with the following difference:
  - The full cost of both the dam and the conveyance system are used as given in Tables 1.3 and 1.4.
- Scenario 5: This will be the same as Scenario 4 with the following differences:
  - The conveyance system will be constructed in two phases.
    - Phase 1 will have a capacity of 100 million $m^3$/a with construction starting in 2028 and operation in 2033 as given for Scenario 1.
    - Phase 2 will have a capacity of 63 million $m^3$/a. To enable the system to supply in the expected growth in demand Phase 2 will need to start delivering water by 2041. Construction was assumed to commence in 2038.
    - The cost for the phased scheme is provided in Table 1-4.

- Scenario 6: This will be the same as Scenario 5 with the following differences:
    - Only Phase 1 will be considered, having a capacity of 100 million $m^3$/a with construction starting in 2028 and operation in 2033 as given for Scenario 1.
    - The cost for Phase 1of the scheme is provided in Table 1-4.

## 2.2 Results from the sensitivity analysis

The results from the sensitivity analysis are summarised in Table 2-1 providing a range of URV results from as low as 26.6 R/$m^3$ (Scenario 1) to as high as 56.7 R/$m^3$ (Scenario 5).

The Phase ll Pre-feasibility study report provides a URV for the L-BWT scheme of 24.30 R/$m^3$ which is slightly lower than the lowest URV from the sensitivity analysis. The reason for this difference is due the slight difference in the scenario definitions which included the following:

- Scenario 1 used a 30-year analysis period while a 20-Year period was used in the Phase ll Pre-feasibility Report.
- Scenario 1 used the net demand while the gross demand was used in the Phase ll Pre-feasibility Report.

The URV for the dam on its own is reasonably low in all cases. The URV for the conveyance system is generally a magnitude or more greater than that of the dam in all cases.

**Table 2-1: URV Scenario sensitivity analysis**

| Scenario | Description | URV (R/m$^3$) | Investment Cost (R million) | Yield million m$^3$/a |
|---|---|---|---|---|
| 1: Partial cost, 30year | L-BWT Scheme URV | **26.59** | 36,684 | 163/334 |
| period & fixed demand | Makkhaleng Dam URV | 1.1 | 4,060 | 334 |
| | Transfer System URV | 25.49 | 32,624 | 163 |
| 2: Partial cost, 30 year | L-BWT Scheme URV | **41.05** | 36,684 | 163/334 |
| period & ***demand growth*** | Makkhaleng Dam URV | 2.9 | 4,060 | 334 |
| | Transfer System URV | 38.15 | 32,624 | 163 |
| 3:Partial cost, ***50 year*** | L-BWT Scheme URV | **37.58** | 36,684 | 163/334 |
| period & demand growth | Makkhaleng Dam URV | 2.59 | 4,060 | 334 |
| | Transfer System URV | 34.99 | 32,624 | 163 |
| 4: ***Full cost*** , 50 year | L-BWT Scheme URV | **53.17** | 54,257 | 163/334 |
| period & demand growth | Makkhaleng Dam URV | 3.55 | 6,006 | 334 |
| | Transfer System URV | 49.62 | 48,251 | 163 |
| 5: Full cost, 50 year | L-BWT Scheme URV | **56.99** | 73,997 | 163/334 |
| period & demand growth | Makkhaleng Dam URV | 3.55 | 6,006 | 334 |
| ***with phased conveyance*** | Transfer System URV | 53.44 | 67,992 | 163 |
| 6: Full cost, 50 year | L-BWT Scheme URV | **54.49** | 45,558 | 100/334 |
| period & demand growth | Makkhaleng Dam URV | 3.55 | 6,006 | 334 |
| ***with only phase 1 conveyance*** | Transfer System URV | 50.94 | 39,552 | 100 |

The second highest impact on the URV was due to the fixed water demand over time versus the growing water demand over time. The impact on the URV between Scenario 1 and Scenario 2 equals an increase of 14.5 R/m$^3$. Scenario 2 resulted in some reduction in cost, as reduced operational cost will be required when less water is pumped in the initial years before the full demand is taken up. This advantage is however totally dominated by the large volumes transferred in the initial years when a fixed transfer volume over time is considered. This is why the URV for the growing demand option is significantly higher than for the fixed demand option. The high transfer volumes will, in reality, not take place in the initial years, as the water will be wasted together with the associated high pumping costs.

The results also show that the largest impact on the URV was due to the partial cost versus full cost of the scheme i.e. Scenario 3 versus Scenario 4 with an increase of 15.6 R/m$^3$.

By only developing Phase 1 of the transfer scheme, the overall investment cost for the transfer scheme was reduced from R 48 241million to R 39 552 million. This was not sufficient to counter the reduction in the annual transfer volume from 160 million m$^3$/a to 100 million m$^3$/a and thus resulted in a slightly higher URV of 54.49 in comparison with the full transfer scheme with a URV of 53.17.

An 8% discount rate was used in all the scenarios analysed. To provide some sensitivity analysis around the discount rate used, Senario 4 was selected and URVs were determined for discount rates of 6%, 8% and 10% as shown in Table 2-2.

**Table 2-2: URV discount rate sensitivity analysis – Scenario 4**

| Scenario | Description | URV (R/m$^3$) 6% | URV (R/m$^3$) 8% | URV (R/m$^3$) 10% |
|---|---|---|---|---|
| ***Full cost*** , 50 year | L-BWT Scheme URV | **39.38** | **53.17** | **69.88** |
| period & demand growth | Makkhaleng Dam URV | 2.23 | 3.55 | 5.25 |
| | Transfer System URV | 37.16 | 49.62 | 64.63 |

The sensitivity analysis indicates that the transfer system URV is relatively sensitive to the different discount rates.

Scenario 4 represents the most realistic scenario, and it is thus recommended that the URV of 53.17 R/m$^3$ be used for further evaluation and comparison purposes. This URV based on the Pre-feasibility Phase II results is significantly lower (14 R/m$^3$) than the URV of 67.15 R/m$^3$ from the Pre-feasibility Phase I results. The lower URV is mainly due to the fact that, for Phase 2, the dam on the Makhaleng River was not utilised to provide mitigation releases as well as the lower capital investment cost (21% less) for the conveyance system as given in the Phase II Pre-feasibility Study Report. The O&M cost on the conveyance system for Phase II increased by approximately 2.4% but was dominated by the lower capital cost and higher transfer volume and yield.

Although the URV based on the Phase II results is significantly lower than the Phase I URV result, it is still high in comparison with all the other development options that form part of the Core Scenario. A cost-benefit analyses was carried out to provide a more robust indicator of the economic viability of the scheme (See Section 3).

It should be noted that the URVs were in all cases given for the total scheme as well as for the dam and the conveyance system separately. The URV of this scheme as applicable to each country sharing in this scheme, will also be different. It is, however, not possible to determine the URVs per country as the countries must first reach agreement on how the costs and water supplied will be shared. The sharing of the costs will most probably also include royalties to be paid to Lesotho.

# 3 COST BENEFIT OR ECONOMIC EFFICIENCY ANALYSIS OF THE L-BWT

From Section 2.2, it is clear that the URVs for the L-BWT Scheme significantly improved when considering the Pre-feasibility Phase II results. The URV results are, however, still high, indicating that it is a very expensive scheme. Some cost benefit scenarios were thus analysed to provide more clarity around the economic viability of the project.

The scenarios considered were based on Scenario 4 as defined in the previous section and included the following:

- Scenario 4: As Scenario 4 with no changes
- Scenario 4a: As in Scenario 4 with the following changes:
  - Full demand from day 1 of the analysis over the analysis period.
  - Full hydro-power generation from day 1.
- Scenario 4b: As in Scenario 4a with the following change:
  - The partial cost of the L-BWT system to be used as given in the Pre-feasibility Phase 2 Report.

The schemes that are economically viable, are those with the associated economic benefits exceeding the economic costs of the project. The benefits were discounted, at a rate of 8%, over the operational period of the scheme to arrive at a net benefit.

The Benefit/Cost Ratio (BCR) is the ratio between benefits and costs of the project. The present value of the project’s benefits is divided by the present value of project’s costs. A project is interpreted as economically viable and worth implementing if the BCR is greater than 1; that is, the discounted benefits are greater than the discounted costs.

The key measure in the CBA is the BCR. The interpretation of CBA results is therefore outlined as follows:

- A BCR below 1 implies the project is not economically viable and may require a further assessment of the project’s structure/design and/or outputs to enhance its economic benefits.
- A BCR marginally above 1 implies that while the project is deemed to be economically viable, it is susceptible to the factors driving the benefits, and a change in the underlying assumptions/features of the benefits could negatively impact the BCR, potentially resulting the in project not being economically viable.
- A BCR well over 1 demonstrates that the project is strongly economically viable.

The results from the scenarios analysed as well as the previous result based on the result from the Pre-feasibility Phase I study are summarised in Table 3-1.

Although the BCR has increased from the Pre-feasibility Phase I result of 0.13 to as high as 0.58 for the Pre-feasibility Phase II scenarios analysed, they are all still below 1, implying that the project is not economically viable.

The EIRR is an indication of a project's rate of return at which the NPV will be zero. For a project to be acceptable, the EIRR should be greater than the discount rate. For all the scenarios analysed the EIRR were still below the discount rate of 8% indicating that the project is not financially viable.

**Table 3-1: The Benefit/Cost Ratio (BCR) analysis results for different scenarios**

| | Pre-feasibility Phase I: L-BWT Scheme | Pre-feasibility Phase II: L-BWT Scheme Scenario 4 | Pre-feasibility Phase II: L-BWT Scheme Scenario 4a | Pre-feasibility Phase II: L-BWT Scheme Scenario 4b |
|---|---|---|---|---|
| E-NPV | -44,238 | -22,994 | -9,432 | 3,426 |
| E-IRR | -5.5% | 0.8% | 2.3% | 4.5% |
| BCR | 0.13 | 0.46 | 0.78 | 1.12 |
| **NPV (R millions)** | | | | |
| **Total Economic Costs** | **50,667** | **42,248** | **42,248** | **29,390** |
| Capital Cost | 45,616 | 37,840 | 37,840 | 25,584 |
| Operational Cost | 5,051 | 4,408 | 4,408 | 3,806 |
| **Total Economic Benefits** | **6,429** | **19,254** | **32,815** | **32,815** |
| Increase in economic activity | 5,658 | 18,483 | 31,981 | 31,981 |
| Urban & Industrial | 5,575 | 5,992 | 12,263 | 12,263 |
| Irrigation | 82 | 226 | 668 | 668 |
| Mining | - | 12,264 | 19,050 | 19,050 |
| Health benefit | 771 | 771 | 834 | 834 |

The mining benefit from the transferred water to Botswana seemed to have been overlooked as part of the Pre-feasibility Phase I results. This benefit was included in the cost benefit analysis carried out for the Pre-feasibility Phase II results.

Although the BCR values increased based on the results from the Phase II Pre-feasibility study the BCR values for scenarios 4 and 4a are still below 1 indicating that the project is not economically viable.

For Scenario 4b where the partial cost of the L-BWT was used instead of the full cost a BCR value of above 1 was for the first time evident. The E-IRR value of 4.5% should preferably be above the discount rate of 8% which is not the case. Scenario 4b can thus be regarded as marginal with regard to its economically viability.

It is important to note that further work will be carried out to determine in more detail the costs and benefits of the L-BWT Scheme. For that purposes a financial assessment was contracted separately from this study. This assessment and analysis will look at the cost and benefit for the "with and without" project situations for the L-BWT Scheme. This is required to establish the incremental net benefit arising from this transfer project over a long-term time horizon. The estimates of the project benefits include direct and indirect benefits, tangible and intangible benefits and secondary benefits related to the project as well as externalities. Benefits associated with hydropower production will also be considered. Indirect costs and externalities, such as the impact of possible reduction of the water allocation to the Orange systems, will also be quantified. A key consideration of the assessment is the climate resilience benefits that the scheme provides to Botswana which cannot be properly quantified in monetary terms.