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Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area

Final

Reconciliation Strategy Report

June 2012

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water affairs

Department:
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Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area

RECONCILIATION STRATEGY REPORT

FINAL

June 2012

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Directorate National Water Resource Planning

Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area

APPROVAL

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Water Reconciliation Strategy Study for the Large Bulk Water Supply Systems: Greater Bloemfontein Area

Study Reports

Report Name	DWA Report Number	Aurecon Report Number
Inception	P WMA 14/C520/00/0910/01	402992/6231
Preliminary Reconciliation Strategy	P WMA 14/C520/00/0910/02	402992/6232
Interventions Report	P WMA 14/C520/00/0910/03	402992/6233
Water Quality Assessment	P WMA 14/C520/00/0910/04	402992/6234
Reconciliation Strategy	**P WMA 14/C520/00/0910/05**	**402992/6235**

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EXECUTIVE SUMMARY

E1 INTRODUCTION

The Water Reconciliation Strategy Study for the Greater Bloemfontein Area was undertaken by the Department of Water Affairs (the DWA), in cooperation with Bloem Water (BW), the Mangaung Metropolitan Municipality (MMM) and other stakeholders in order to secure a sustainable future water supply for MMM and the other Water Service Authorities served by Bloem Water's regional water supply schemes within the study area. **Figure E1** *shows the extent of the Greater Bloemfontein Water Supply System. A core element of the recommendations presented in this Strategy is Integrated Water Resource Management. Some of the recommendations that are presented in this Strategy are challenging, but they comprise practical and logical next steps to ensure sustainable and improved future management of the BW schemes and local sources of water supply, including the selection of interventions to balance supply and requirements. New approaches are needed to plan and supply urban water needs, including altered consumer behaviour and appreciation of the scarcity of water, and the development and funding of more diversified portfolios of integrated new and alternate water sources, the use of surface and groundwater systems to sustainable levels of abstraction, and new institutional arrangements. Concerted political will is necessary to invigorate water reform in the study area and sustained attention, resources and continued hands-on leadership and action will be necessary to ensure that this Strategy is successfully implemented and continually updated.*

E2 PURPOSE OF THE STRATEGY

The purpose of the Reconciliation Strategy is to determine the current water balance situation and to develop various possible future water balance scenarios up to 2035 and beyond. It aims to describe the proposed strategy, and the associated actions, responsibilities and timing of such actions that are urgently needed to reconcile the supplies and requirements, to enable additional interventions to be timeously implemented.

E3 THE GREATER BLOEM WATER SUPPLY SYSTEM

The Greater Bloemfontein supply system provides the majority of potable water requirements to the larger centers of Bloemfontein, Thaba Nchu and Botshabelo, as well as the smaller towns of Wepener, Dewetsdorp, Reddersburg, Edenburg, and Excelsior, which are also dependent to varying degrees on local water sources. Bloemfontein has been the focus of development in recent years resulting in a decline in many of the small rural towns. Migration from farms to towns by farm workers in search of employment opportunity has further placed increased burden on the water supply to the towns. Currently approximately 66% of the treated water is supplied by Bloem Water, primarily through Welbedacht and Rustfontein Water Treatment Plant (WTP) and the balance via MMM's Maselspoort WTP.

E4 BULK WATER SUPPLY INFRASTRUCTURE

The Caledon – Bloemfontein transfer supplies potable water from the Welbedacht Dam to Bloemfontein, Botshabelo, Thaba Nchu, Dewetsdorp, Reddersburg, and Edenburg ***(****see* **Figure E1)***. Treated water is pumped via a 6.5 km pressure pipeline and a 106 km gravity pipeline to Bloemfontein. Siltation has significantly impacted on the yield of the dam requiring the construction of the Knellpoort off-channel storage dam supplied with transferred water from the Caledon River via the Tienfontein Pump station, enabling year-round abstraction from Welbedacht. The Novo Transfer Pump Station at Knellpoort Dam enables the transfer of water into the Modder River, which supplies the Rustfontein and Mockes Dams. The Maselspoort Scheme (Weir and WTP) on the Modder River supplies approximately 25% of Bloemfontein's water needs.*

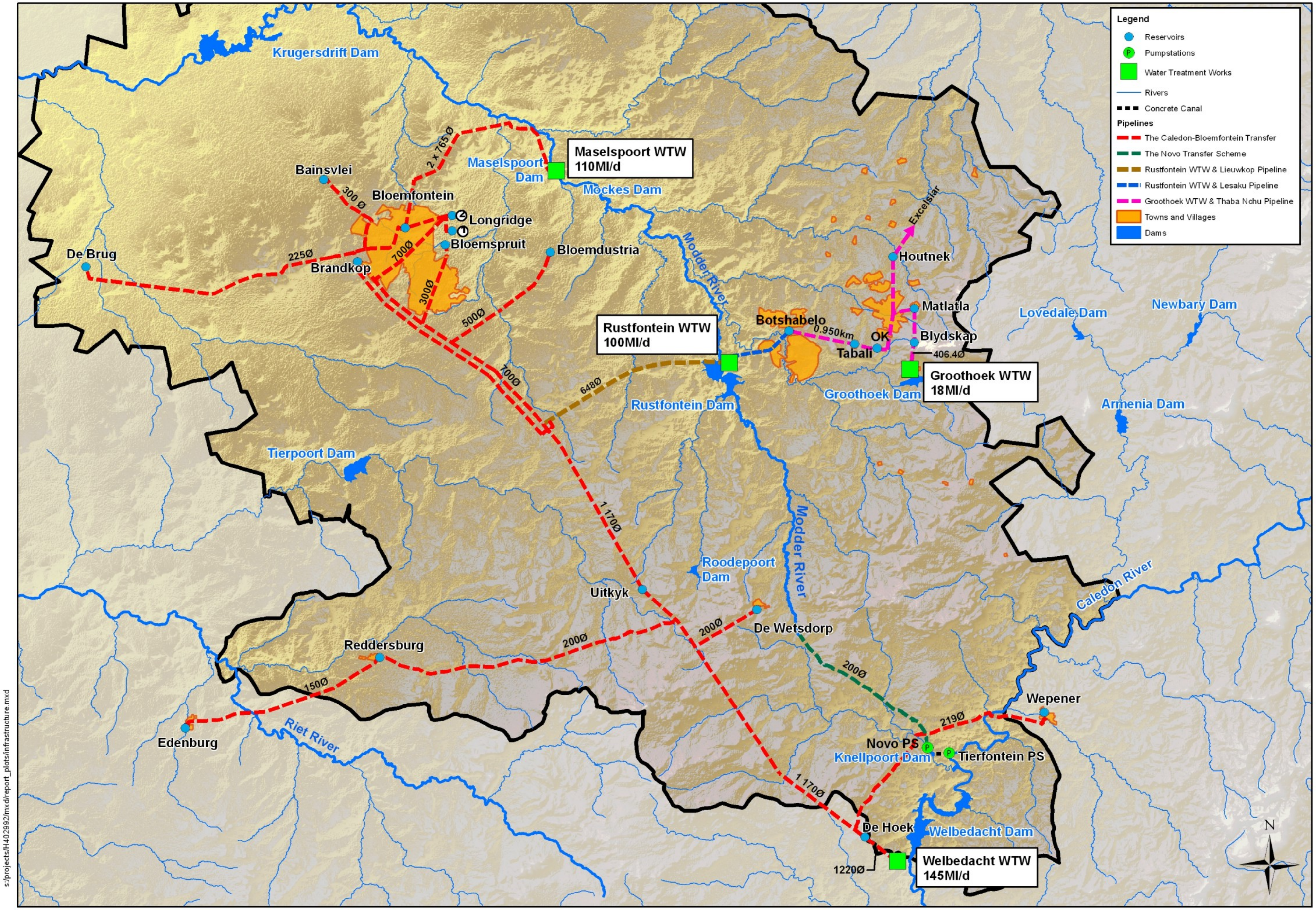

Figure E1: ***The Greater Bloemfontein Bulk Water Supply System***

The Novo Transfer Scheme includes Tienfontein Pump Station, a pipeline and canal from Tienfontein Pump Station to the Knellpoort Dam, Knellpoort Dam, and the Novo Pump Station and pipeline. The Novo pump station transfers water from Knellpoort Dam to the Modder River, via a 20 km pipeline and then via the Modder River to Rustfontein Dam. From the Rustfontein WTP water is pumped to Botshabelo/Thaba Nchu or Bloemfontein.

Groundwater is currently not utilised as a water resource for the supply of potable water to Bloemfontein but the small towns and communities in the vicinity of Bloemfontein are partially dependent on groundwater, and sustainable use of this resource has potential.

E5 INFRASTRUCTURE RELATED CHALLENGES

The current capacity of Bloem Water's potable water reservoirs serving the Mangaung/Bloemfontein area equates to about a single day's storage (average annual daily demand). This is considered acceptable for the present, and is within the desired 1-day limit for Bloem Water. The MMM however should have a 2-day storage capacity but only has 1.5 days at present and augmentation of about 86 Ml is urgently required to remedy the current storage shortfall, and to provide for future growth. Similarly, the Bloem Water reservoirs supplying Botshabelo/Thaba Nchu are adequate but the MMM storage reservoirs provide less than 50% of the required storage and augmentation is of critical importance. Failure of the existing Welbedacht – Bloemfontein pipeline could potentially expose MMM to severe water shortages in the absence of reservoir capacity to support outages of a long duration. A "pro-active" strategy must be put in place to manage the refurbishment of "high risk" infrastructure components and new capital works to limit the risk. The MMM and BW commissioned a study entitled "Joint Bulk Water Services: Infrastructure Challenges" in February 2012. This report summarise the current status of the joint bulk water infrastructure serving the Mangaung Metropolitan area, pointing out the various challenges to both institutions which need to be addressed to ensure uninterrupted and sufficient water supply to the end consumers. Issues which inter alia need to be urgently addressed are: storage capacity, maintenance and upgrading of Maselspoort WTP, additional WTP capacity etc. This report further prioritises the interventions which are required as well as their associated costs. Augmentation of Welbedacht Dam via the Knellpoort off-channel dam has been necessary due to the significant extent of sedimentation in Welbedacht Dam and related operational challenges at the dam and at the critically important Tienfontein Pump Station. These combined components supply 70 % of Bloem Water's bulk water requirements, and downtime in a drought period would place Bloem Water and MMM at risk. Increased flushing of Welbedacht Dam must be considered as well as the recommendations of the 2011 report entitled "Investigation into the Condition of the Caledon River at Welbedacht Dam" (SSI, 2011).

There are a number of siltation challenges associated both with the operation and maintenance of existing infrastructure and with the development of additional augmentation schemes. These challenges are highlighted in detail in Section E13 of this Executive Summary.

E6 WATER AVAILABILITY

The latest water balance from the ***Orange River System*** *indicated a surplus of 274 million m^3/a for the year 2008. Subsequent planning to supply water to emerging farmers and for the growth in water requirements in the Upper Orange, Lower Orange and the Fish to Tsitsikamma WMAs would reduce this surplus to only 40 million m^3 by 2025. Furthermore the proposed developments under Phase 2 of the Lesotho Highlands Water Project would reduce the yield of the Orange River downstream by approximately 283 million m^3/a (proposed Polihali Dam and transfer). Based on a conceptual estimate of the mass balance across the Orange River system, it can be inferred that a system deficit of about 243 million m^3/a could be expected by 2037. It can be concluded that there is currently surplus water available in the Orange River system (including the Caledon River) which can be allocated to the Greater Bloemfontein Area. Other water resource development options on the Orange River will only become feasible after the water requirements from the Vaal WMA have increased to such an extent that they reduce the availability of water in the Orange River, and a new supply intervention is implemented to augment the loss in yield. Such interventions include the utilisation of the lower level storage in Vanderkloof Dam, the construction of*

Bosberg/Boskraai Dams, and the raising of Gariep Dam. It is the intention of the DWA to initiate a separate reconciliation strategy study on the Orange River System, which will draw on the information from the Greater Bloemfontein Reconciliation Strategy Study.

There are a number of factors which can impact on the net available yield of the water resources serving the ***Greater Bloemfontein System.*** *A selection of these factors and their net impact on the available system yield are listed below:*

- *Implementation of Metolong Dam (yield reduction of 1 million m^3/a)*
- *Environmental Water Requirements (yield reduction of 2.21 million m^3/a)*
- *Operate Welbedacht WTP at full capacity throughout the year (yield increase of +4 million m^3/a).*
- *Operation of Tienfontein pump station at 2.5 m^3/s as opposed to 3 m^3/s (yield reduction of 5.2 million m^3/a)*
- *Increase storage capacity of Welbedacht Dam to 13 million m^3 (yield increase of +3 million m^3/a)*
- *Risk of failure (bursts) on the Welbedacht pipeline (dependent on down time, possible yield reduction of 6.8 million m^3/a)*

The impacts of Metolong Dam and the EWRs are inevitable in the short term and the scenario planning should account for this in the baseline yield availability. For planning purposes the historical firm yield of the system with these interventions in place is therefore assumed to be 81 million m^3/a. The current baseline excluding Metolong Dam and implementation of the EWRs is 83.7 million m^3/a.

E7 CURRENT WATER REQUIREMENTS

MMM purchases approximately two thirds of its potable water from Bloem Water. In 2011 the amount of bulk water (excluding groundwater) supplied from the Bloem Water System was 56.8 million m^3, and that supplied from MMM's own sources, 22,7 million m^3. The smaller towns of Excelsior, Wepener, Dewetsdorp, Reddersburg and Edenburg supplement their water supply from local groundwater sources which in 2011 totalled approximately 2.9 million m^3/a. Authorised water consumption has been growing at an average rate of 3% per annum over the period 2007 through to 2010 and on average by 1.7 % over the period 2005 through to 2010. The 2010 population in the Bloemfontein, Botshableo and Thaba Nchu area of supply is estimated to be 630 000 people. The population for the full supply area including the smaller towns is estimated to be 720 000 people.

It is apparent that there is also an increase in unaccounted water which in the Bloemfontein area alone has reached more than 39% of the total annual consumption (Ref: 2006/7 WSDP). Similar levels of unaccounted water are occurring in Botshabelo, and in ***Thaba Nchu, the unaccounted for water is 94%*** *of the total water use.*

Cognisance has also been taken of the agricultural water requirements in those catchments which also supply water to Bloem Water and MMM for potable use. In terms of the yield modelling of the Welbedacht/Knellpoort System, the existing agricultural water requirements along the Caledon River, both upstream and downstream of Welbedacht Dam, and the proposed water requirements of the resource poor farmers, were taken into account.

As part of a Study entitled "Support to Phase II ORASECOM Basin Wide Integrated Water Resources Management Plan (2010)", two Ecological Flow requirement sites were located on the Caledon River, one in the upper and one in the lower Caledon. Based on the Eco-Classification results identified in the abovementioned study, the required flow to support the proposed classifications (long term average flows) would be in the order of 20-26% of the natural Mean Annual Runoff.

E8 FUTURE WATER REQUIREMENT PROJECTIONS

There are uncertainties with the future population growth rate figures which include:

- *Population growth rates vary between various sources of information, ranging from 3.1% per annum down to 1% per annum, and a flat rate of zero % per annum in certain low growth scenarios such as those developed in the All Towns study for Central Region (June 2009).*
- *The effect of migration from the rural into the urban areas is linked to economic growth and the search for improved employment opportunities in the urban centres.*
- *The mortality rates as a result of HIV/Aids have been assumed to be as high as 0.4% for the urban towns, and as high as 0.75% for the rural towns and villages.*

The following assumptions were made for the development of the future water requirement scenarios from the Greater Bloemfontein Water Supply System (see **Figure E2***:).*

- ***A High Growth Water Requirement Scenario** based on the authorised billed and unbilled water consumption figures for the last 3 years and a growth rate of 3% per annum.*
- ***Low Growth Water Requirement Scenario** based on a low population growth and low economic growth, with an effective growth in water requirements of 1% per annum.*

E9 COMPARISON OF REQUIREMENTS AND AVAILABILITY

Figure E2*: illustrates the comparison of available surface water supply and current water requirements for the High and Low water requirement scenarios in the Greater Bloemfontein Area. The current water requirement (based on 2009 data) is approximately 83 million m^3/a, which is in balance with the available supply of 84 million m^3/a (Historical Firm Yield).*

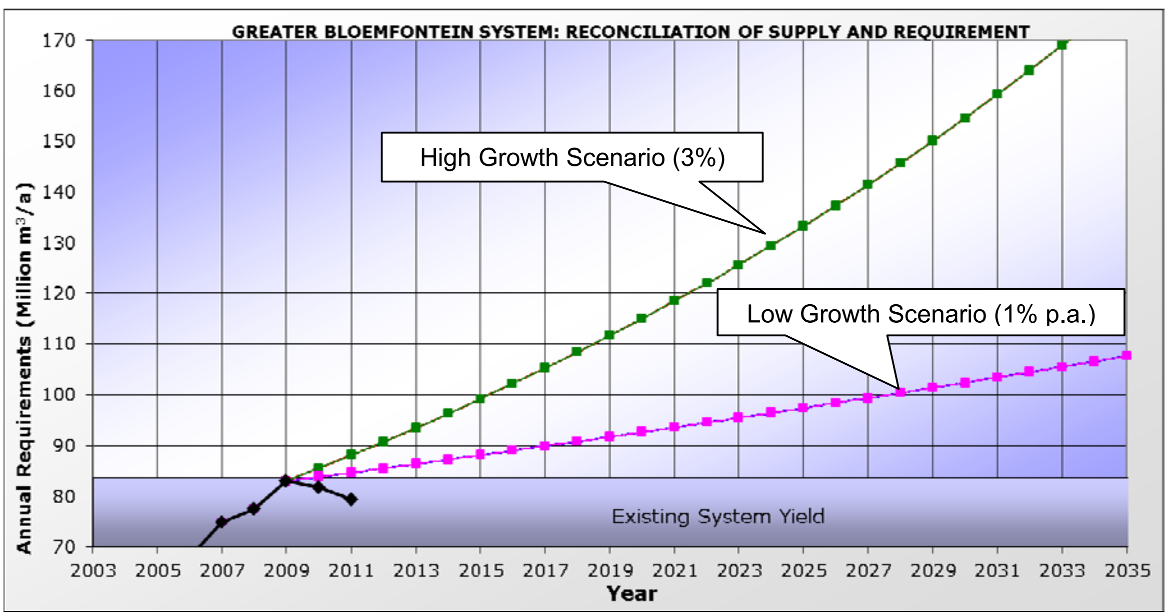

Figure E2: Surface Water Balance for Study Area

It appears that the 2009 water requirement was in balance with available supply (historical firm yield) and any increase in use (as predicted by the high and low water requirement scenarios) would put the system at risk. The higher the growth in water requirements, the higher the risk would be. It is clear that measures to increase the surety of supply need to be implemented as soon as possible. This includes measures to increase the supply of water as well as WC/WDM measures to reduce the demand.

E10 COMPARISON OF REQUIREMENTS AND AVAILABILITY

Thirty-four potential interventions which could contribute to meeting the future water requirements have been identified within the following categories:

- *Urban and agricultural Water Conservation and Water Demand Management (WC/WDM);*
- *Groundwater interventions;*
- *Reuse of treated effluent;*
- *Optimising the efficiency of surface water transfer schemes;*
- *Surface water interventions;*
- *Trading of water use authorisations; and*
- *Other options, such as reuse of mine water and alternate storage in the Caledon River.*

***Table E1** provides a summary of some of the interventions considered for the reconciliation of supply and requirement for the Greater Bloemfontein system.*

Table E1: Detailed Information on Selected Surface Water Interventions

Intervention	Yield Million m^3/a	Capital Cost (R million)	Operating Cost (R million/a)	URV (R/m^3)
Novo Transfer Scheme and obtaining additional water from Welbedacht Dam. Intervention shown based on 2 m^3/s P/S at Weldedacht Dam pumping to Knellpoort Dam.	22.6	374	7.9	1.51
	Yield and Cost dependent of capacity of infrastructure proposed.			
WC/WDM (Most Likely Scenario)	11.5	240		Approx. 1.5
Utilising surplus capacity in Orange River by pumping to Knellpoort Dam from Gariep Dam	20	825	33	6.1
Utilise surplus capacity in Orange River system by pumping to Knellpoort Dam from Van der Kloof Dam	20	1 700	40	10
Planned direct reuse – Bloem Spruit Note 1	10.8	179	4.9	1.56
Treated indirect reuse - Krugersdrift Dam Note 1	10.8	306	9.5	2.83
Bloemfontein aquifer (Bainsvlei aquifer)	28	4743	39	15.58
Thaba Nchu aquifer	0.89	32.7	2.1	5.35

Note 1: Significant uncertainty surrounds the CAPEX and OPEX costs, as costing was undertaken at a very high level.

E11 SCENARIO PLANNING FOR THE BLOEMFONTEIN SYSTEM

For details on the various planning scenarios considered, the reader should refer to the Main Report.
***Table E2**: presents the scenarios which are described in this Executive summary.*

Table E2: Selected Scenarios

Description	*Water Requirement Curve*	*WC/WDM*	*Explanation / Reasoning*
Scenario A	*High*	*Best Case Scenario*	*High growth water requirement scenario assuming that the MMM is able to successfully implement all identified Non Revenue Water (NRW) reduction activities that have been identified as part of its WC/WDM strategy and programme*
Scenario D • *Commissioning of Metolong Dam*	*High*	*Most Probable Scenario*	*This scenario considers what impact the implementation of Metolong Dam would have on the yield of the system.*
Scenario E • *Metolong Dam* • *Implementation of EWR along the Caledon River*	*High*	*Most Probable Scenario*	*This scenario considers what impact the implementation of the EWR requirements d/s of Welbedacht Dam would have on the yield of the system.*

Scenario A (High water requirement, WC/WDM Best Case Scenario)

This assumes the successful implementation of all Non-Revenue Water (NRW) reduction activities identified over a 5 year period giving effect to a 25.2 million m^3/a saving, and that a new supply side intervention would be implemented by 2019. This could entail installing additional capacity at Tienfontein Pump Station, the scouring of Welbedacht Dam and ensuring that the Welbedacht WTP can operate at maximum capacity (estimated cumulative increase in yield from these interventions is estimated to be approximately 12 million m^3/a). Additional interventions such as the Welbedacht Pump Station or further increasing the capacity of Tienfontein/Novo Pump Station would also be available for implementation. **Figure E3** *shows the possible reconciliation of supply and requirement under Scenario A.*

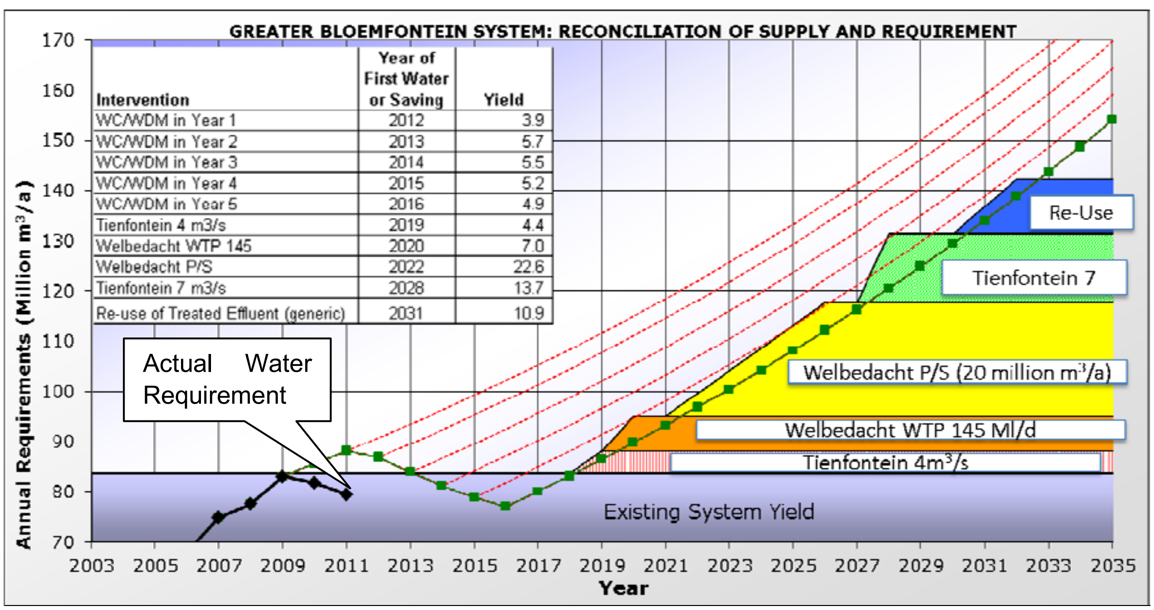

Figure E3*:* ***Water Balance for Scenario A***

Scenario D (High water requirement, WC/WDM Most Probable Scenario, Metolong Dam)

This scenario takes into consideration probable delays in implementation by MMM of successful Non Revenue Water (NRW) reduction activities. It is assumed that a total water savings of 11.2 million m^3/a is achieved (commencing only in 2011/2012). The Metolong Dam is assumed to be completed by July 2012 when it would start to impound water. It is imperative under this scenario that the design capacity of Tienfontein Pump Station is increased to 4 m^3/s in 2012/2013. In addition the scouring of Welbedacht Dam and ensuring that the Welbedacht WTP can operate at maximum capacity are interventions which should be implemented as a matter of priority. Additional augmentation of Knellpoort Dam would then be required be required by 2018. It has been assumed for this scenario that a pump station and pipeline would be constructed between Welbedacht Dam and Knellpoort Dam. ***Figure E4*** *shows the possible reconciliation of supply and requirement under Scenario D.*

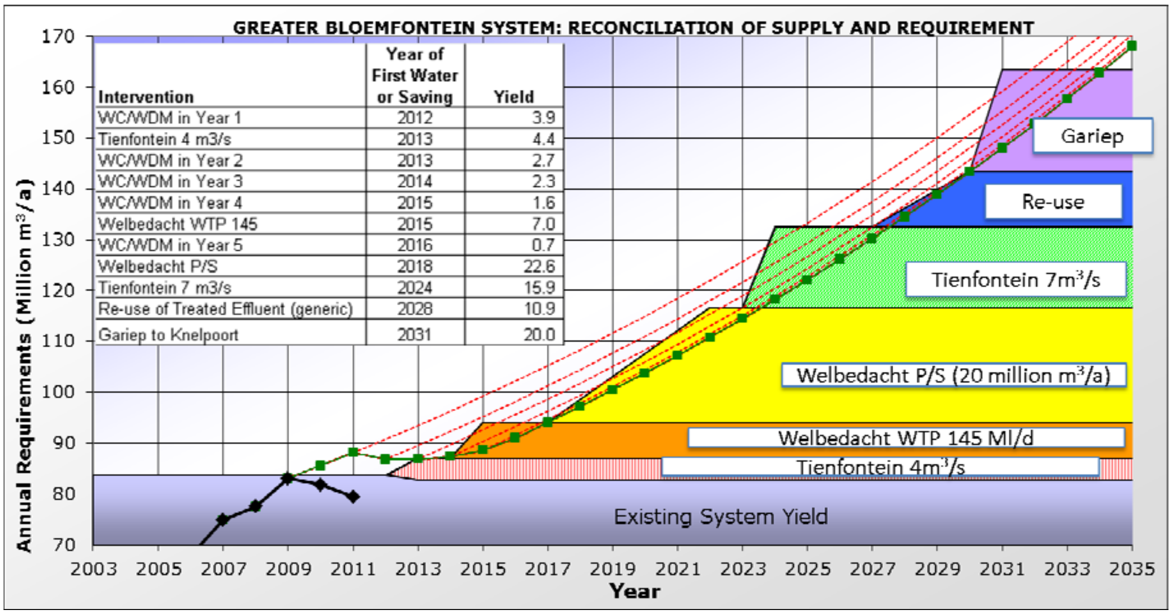

Figure E4*:* ***Water Balance for Scenario D***

Scenario E

Scenario E is the same as Scenario D, but assumes that the Environmental Water Requirements (EWR) is implemented in the Caledon River. The anticipated reduction in yield as a result of the implementation of the EWRs is estimated to be approximately 2.2 million m^3/a. Should the Ecological Reserve be implemented prior to 2018, it would not be possible to implement interventions to offset the loss in yield due to the required environmental flow releases. The implementation of the Ecological Reserve should be phased in, in a planned manner, based on the implementation dates of future water augmentation schemes. ***Figure E5*** *shows the possible reconciliation of supply and requirement under Scenario E.*

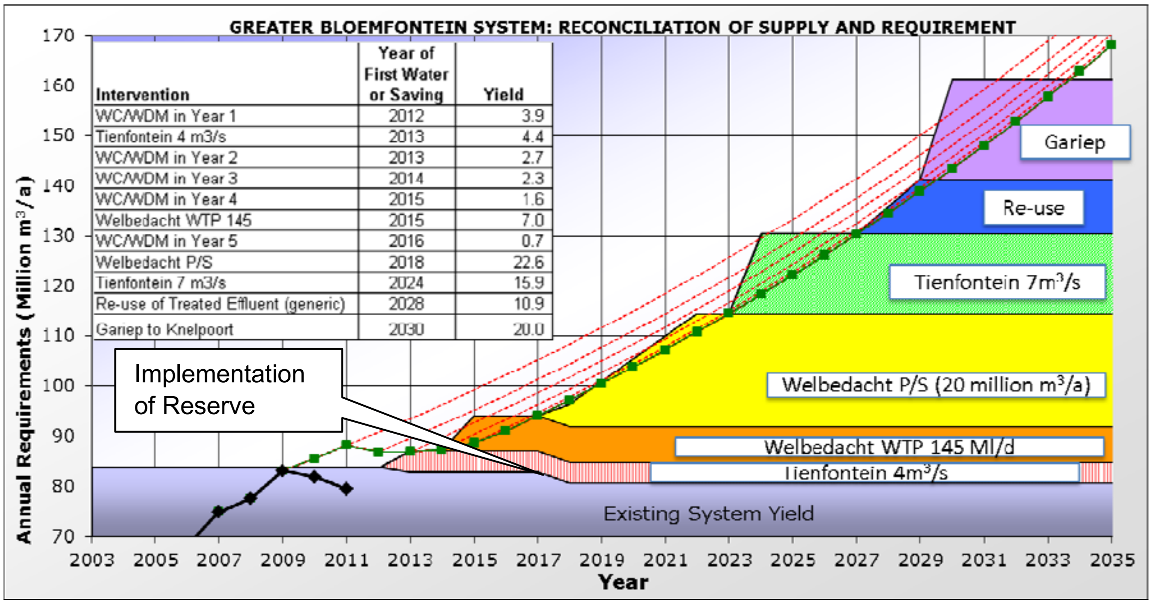

Figure E5*:* ***Water Balance for Scenario E***

E12 SCENARIO PLANNING FOR THE SMALL TOWNS

Wepener

Wepener receives water from Bloem Water's Welbedacht WTP, and utilizes water from its own groundwater source. Based on the total water sales to the town by Bloem Water for the period July 2010-June 2011, the water requirement is estimated to be 0.744 million m^3/a, which includes internal losses within the town's reticulation system. The projected water demands are based on the historical population growth rate increase of close to 1% and this represents the high growth scenario on which this reconciliation strategy is based. This equates to a projected average annual water requirement of 0.934 million m^3/a, and a corresponding annualized peak demand of 1.386 million m^3/a, both up to 2035.

Options for augmenting the supply to Wepener could include further reliance on the Bloem Water System up to the supply capacity of the bulk water pipeline, whereafter consideration could be given to the provision of a booster pump station that could yield an additional 0.87 Ml/day (0.3 million m^3/annum) and a gravity pipeline from the Welbedacht WTP yielding an additional 2.9 Ml/day (1 million m^3/annum). Development of the dolerite dyke groundwater aquifers within a 10–15 km radius of the town also offers significant opportunity.

***Figure E6** shows the possible reconciliation of supply and requirement for Wepener.*

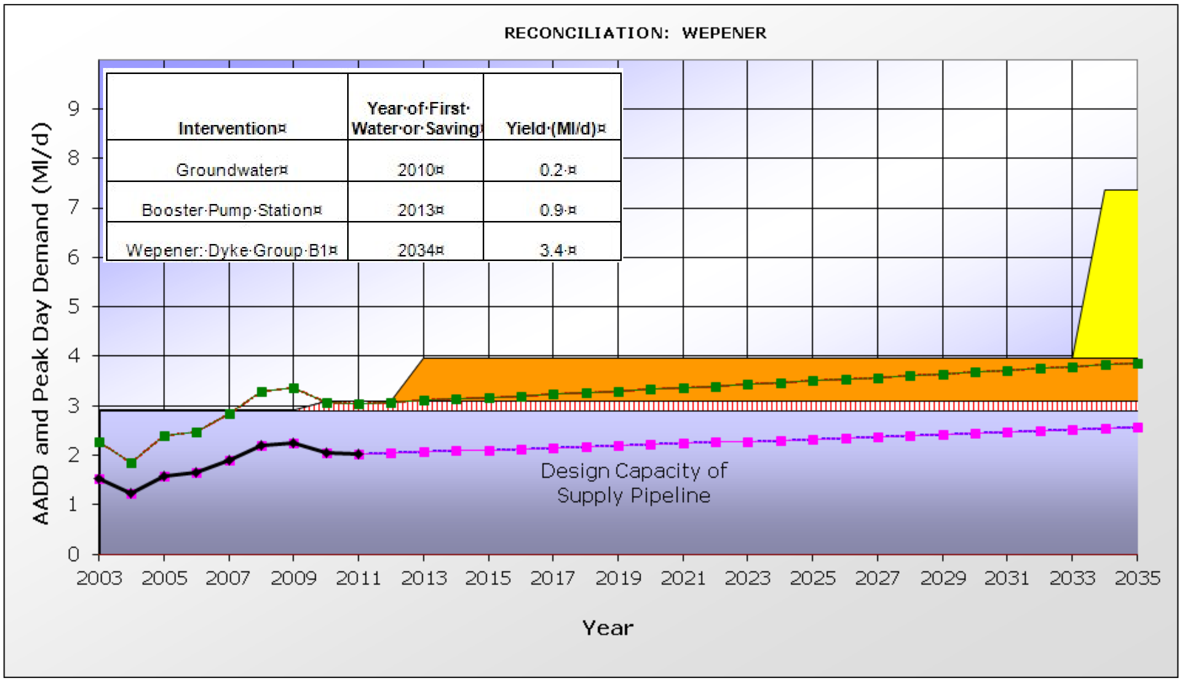

Figure E6*:* ***Water Balance for Wepener***

Reddersburg and Edenburg

Reddersburg and Edenburg are considered together in this report, because they receive water via the same Welbedacht – Bloemfontein pipeline from the Welbedacht WTP, supplemented by local groundwater sources. Neither town has any significant commercial or industrial sectors and water users consist mainly of domestic type users. The estimated combined population of Reddersburg and Edenburg (2009) is 12 627 inhabitants and the total water sales to the towns by Bloem Water for the period July 2010 - June 2011 amounted to 1.247 million m^3/a. The projected average annual water requirement based on the population increase estimate is 1.565 million m^3/a, with an annualized peak demand of 2.321 million m^3/a, both up to 2035.

Options to augment the supply to these towns include:

- *A WTP and a new pipeline from the existing Fouriespruit Dam (capacity of 1.8 million m^3) to Edenburg providing augmentation of 0.13 million m^3/a.*
- *A new gravity pipeline to Reddersburg (34.3 km) and a further 25.4 km pipeline to Edenburg delivering an additional 35 l/s from the Welbedacht scheme pipeline. This equates to an augmentation volume of 1.1 million m^3/a.*
- *The existing Reddersburg Dam could supply Reddersburg town via an existing package plant once refurbished. Existing design reports suggest a possible augmentation of 0,062 million m^3/a. Upgrading of existing pipelines would also be required.*
- *Development of the dolerite dyke structures within a 10–15 km radius of the towns also offers significant opportunity.*

Figure E7 *shows the possible reconciliation of supply and requirement for Reddersburg and Edenburg.*

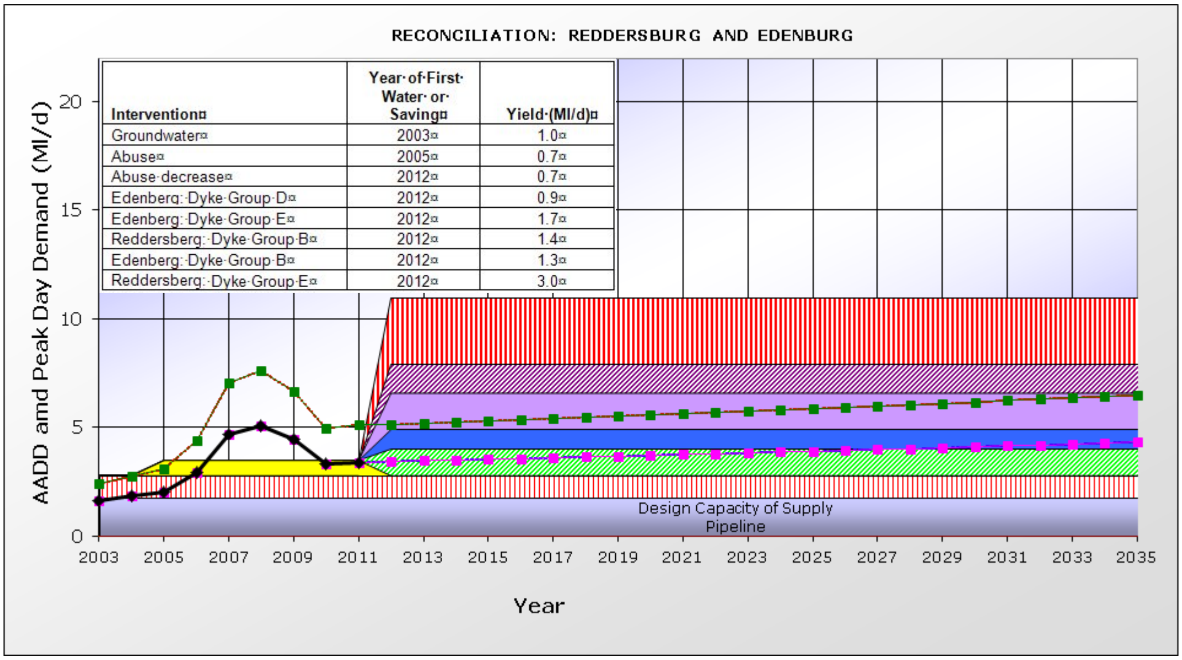

Figure E7*:* ***Water Balance for Reddersburg and Edenburg***

Dewetsdorp

The estimated population of Dewetsdorp (2009) is 9 857 inhabitants. The total water sales to the towns by Bloem Water for the period July 2010-June 2011 amounted to 0.756 million m^3/a, which includes internal losses within the reticulation systems. The anticipated population growth rate for the town is very small resulting in a projected average annual water requirement of 0.768 million m^3/a by 2035 and an annualized peak demand of 1.140 million m^3/a by 2035. As shown in **Figure E8***, the development of the local groundwater resource appears to be the most favorable augmentation option for the town.*

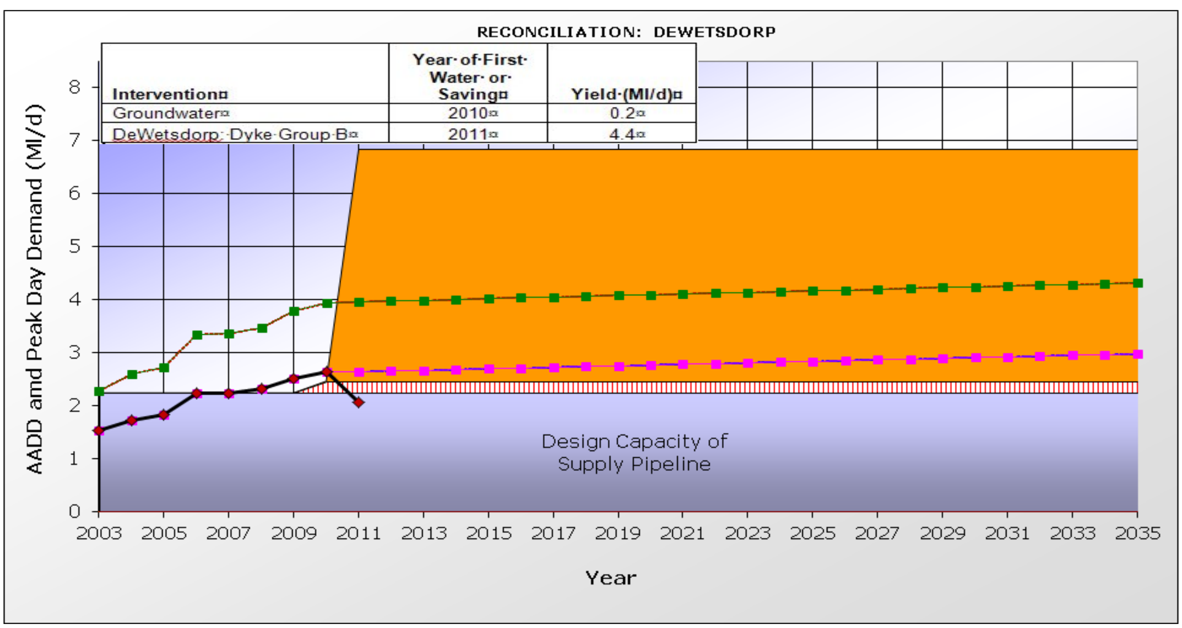

Figure E8*:* ***Water Balance for Dewetsdorp***

Excelsior

Excelsior is supplied with water from local boreholes (0.1 Ml/d) as well as from the Bloem Water system via a pipeline with a capacity of 1,2 Ml/d from the Rustfontein scheme. Furthermore a local run of river scheme is estimated to provide a yield of about 0.5 Ml/d. The available records of Bloem Water's Historical Water Demand Trends suggest that the water supplied to Excelsior from that scheme was 0.167 million m^3/a and the projected increase in water requirements is negligible.

Both the AADD and peak month water requirement of Excelsior is less than the supply capacity of the existing pipeline. It is thought that the reason for this could be the fact that the upstream demands on the supply pipeline to Excelsior are so high that insufficient water reaches Excelsior, hence the occurrence of water shortages in the past.

As shown on **Figure** E9*, groundwater will provide the optimum source for any future augmentation required at Excelsior once the existing supply capacity of the pipeline from Bloem Water is fully utilized.*

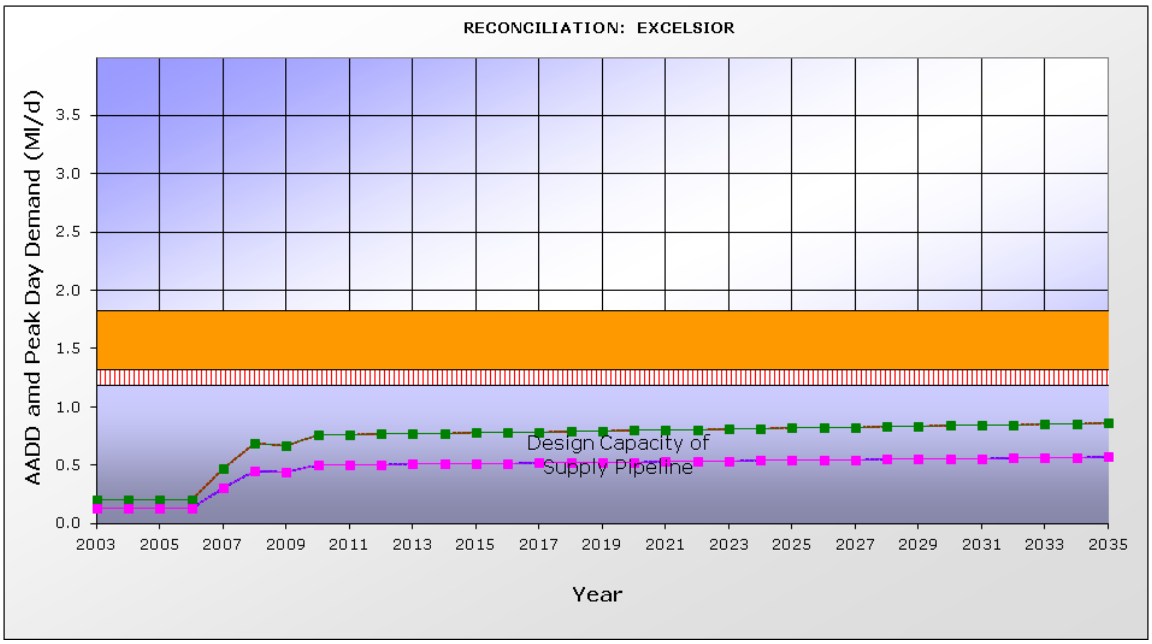

Figure E9*:* ***Water Balance for Excelsior***

E13 EVALUATION OF SCENARIO FINDINGS AND RECOMMENDED INTERVENTIONS

<u>Background</u>

Since its construction in 1973 Welbedacht Dam has lost approximately 95% of its storage capacity. Over the first 18 years of operation the sediment deposition rate was extremely high, but since 1991 scouring of the dam during some of the floods has been intermittently practised. This has reduced the rate of sedimentation but has not stopped the dam from gradually losing almost all of its storage capacity. The flushing operations and on-going sedimentation, however, impact on the quality of the water received at the Welbedacht WTP. The inability of the water treatment plant to deal with high turbidity levels limits the production capacity of the water treatment plant.

Due to the decreasing yield of the Welbedacht Dam as a result of siltation, and the increasing demand on the Caledon-Bloemfontein Regional Water Supply Scheme, DWA supplemented the yield of the Welbedacht Dam by constructing the Knellpoort off-channel storage dam in 1998. Knellpoort Dam which has a gross storage capacity of 137 million m³, is supplied with water from the Caledon River by the Tienfontein Pump Station. Water pumped from the Caledon River into Knellpoort Dam is then released back into the Caledon River during periods of low river flow to allow abstraction at Welbedacht Dam by

Bloem Water all year round. The on-going sediment deposition impacts negatively on the operation and maintenance of Tienfontein Pump Station which is a critical node of the supply system.

A yield analysis of the Caledon system has shown that there is still significant water available in the Caledon River to reconcile water supply and requirement for the Greater Bloemfontein area. The development of the additional yield (which could be as much as 60 million m^3/a) would depend on the capacity of the infrastructure that is constructed to abstract water (and the feasibility thereof given the sediment related problems being experienced) from the Caledon River/Welbedacht Dam. Given the close proximity of the Caledon River to Bloemfontein and the existing infrastructure, it would be considerably less costly to further develop this source than to obtain additional water from the Gariep Dam or from the Van der Kloof Dam (the current cost estimates indicate that it would be in excess of 3 times more expensive to obtain water from the Gariep Dam than from the Caledon River). It must be noted however that in the longer term obtaining additional water from the Gariep Dam (or alternatively the Vander Kloof Dam or the proposed Bosberg/Boskraai Dam) should be weighed up against other potential supply schemes such as water reuse.

The yield of the existing system is currently being negatively impacted by the problems associated with the on-going high siltation experienced at Welbedacht Dam, Welbedacht WTP and Tienfontein Pump Station. The following factors are reducing the current system yield:

- ***Capacity of Tienfontein Pump Station**: Due to on-going operation and maintenance related problems associated with the siltation, the pumps frequently do not operate at their design capacity.*

- ***Capacity of Welbedacht Dam**: Unless Welbedacht Dam is scoured, the capacity of the dam will continue to decrease and this will have a knock-on impact on Welbedacht WTP and the silt profile at Tienfontein Pump Station.*

- ***Capacity of Welbedacht WTP**: The inability of the water treatment plant to deal with high turbidity levels reduces the production capacity of the water treatment plant during the high demand (summer) season.*

In addition, other infrastructure risks pose potential negative impacts on the system's yield:

- ***Integrity of the Welbedacht pipeline:** Should the condition of this pipeline continue to deteriorate there is a risk that more pipe bursts could occur. Any long outages of the pipeline will impact on the yield of the current system (and will impact on the continuity of supply to the user).*

- ***Other Infrastructure Challenges:** The MMM and BW commissioned a study entitled "Joint Bulk Water Services: Infrastructure Challenges" in February 2012. This report summarises the current status of the joint bulk water infrastructure serving the Mangaung Metropolitan area, and points out the various challenges which need to be addressed to ensure uninterrupted and sufficient water supply to the end consumers. This report further prioritises the interventions which are required as well as their associated costs. It is important to note that the identified infrastructure challenges identified in this report (i.e. storage, water treatment plant capacity, upgrading and maintenance of the WTP) will not increase the yield of the system (make more water available), but are critical to implement if Bloem Water and Mangaung Metropolitan Municipality do not want on-going potential interruptions to supply.*

It is imperative that the abovementioned issues are addressed as a matter of priority, as it will allow for <u>maintaining the existing system yield</u> and could also potentially result in an <u>increase in system yield</u> (from that which was modelled) if the full output capacity of the WTP can be restored during the summer months and if the storage capacity of the Welbedacht Dam can be increased (albeit a small increase in storage capacity).

Prior to increasing the capacity of Tienfontien Pump Station the requirement for water will be greater than the historical firm yield. The only intervention which could mitigate this is the implementation of WC/WDM (best case scenario). Under most scenarios evaluated even after increasing the capacity of Tienfontein

Pump Station, addressing the scouring problems at Welbedacht Dam and ensuring that Welbedacht WTP can operate at its design capacity of 145 Ml/d, there will still be an imbalance between supply and requirement until the supply to Knellpoort Dam can be augmented or additional WC/WDM measures implemented. It is important that any long term further augmentation of Knellpoort Dam from the Caledon River be further investigated to ensure that whatever measures are implemented will address the siltation issues and will provide a high reliability of supply.

The prioritised issues, which were highlighted through the Scenario Planning that was undertaken, are discussed in more detail below. These issues should form the basis of any action plan going forward.

Recommended Interventions for the Reconciliation of Supply and Requirement

The following interventions should be prioritised:

a) Implementation of WC/WDM

The projected water requirement (based on the high water requirement curve) is currently in excess of the historical firm yield of the system. Implementation of WC/WDM is critical, as the next supply scheme (under a fast-tracked programme) could only be put in place by 2018 at the earliest. Funds and resources should be allocated by MMM to ensure that MMM achieves at a minimum their "most likely scenario" in terms of WC/WDM savings. MMM should nevertheless strive to achieve the "best case scenario".

Under the "most likely scenario" approximately 11.5 million m^3 of water could be saved at an approximate cost of R 240 million (this equates to a URV of approximately R1.5/m^3).

b) Increase capacity of Tienfontein Pump Station

Tienfontein Pump station is seen as one of the critical components of the existing water supply infrastructure supplying Bloem Water with raw water, as Bloem Water receives approximately 40 % of its water supply via Tienfontein Pump Station and Knellpoort Dam. The other critical component is the Welbedacht Pipeline.

Under sediment equilibrium conditions in Welbedacht Dam, it is estimated that the Tienfontein site will be sedimented to 4 m above the full supply level of the dam, which is approximately 17 m above the original river bed level. Pumping at Tienfontein is therefore not under storage conditions, but under run of river conditions.

Since there is minimal storage capacity in Welbedacht Reservoir, the Tienfontein pumps must operate at a high assurance to supply Knellpoort Dam. The predicted bed level at Tienfontein pump station indicates that the current bed level is near equilibrium, but it should be borne in mind that this is a dynamic equilibrium and during floods scour will occur and deposition after floods. The variability on the equilibrium bed level is in the order of 3 m up or down with which the pump station has to cope. This could lead to sediment build up as high as 4.6 m above the full supply level of the reservoir, at the pump station, and the existing pumps cannot deal with such a scenario.

Tienfontein Pump station currently has a design capacity of 3 m^3/s, but due to the sedimentation related problems and high maintenance requirements delivers on average approximately 2.5 m^3/s. Given that the projected water requirements are currently in excess of the system historical firm yield, it is proposed that two additional (1 m^3/s) pumpsets at Tienfontein Pump Station be implemented. The first pumpset should be utilised to increase the design capacity of the pump station to 4 m^3/s and the second pumpset to provide additional standby capacity. This would provide an additional yield of approximately 4.4 million m^3/a. With an increase in the standby capacity (proposed 50% of design capacity), maintenance of pumps could be more easily facilitated without impacting on the operating capacity of the pump station. The additional yield gained by increasing the capacity of Tienfontein pump station by 1 m^3/s would under most scenarios still *not lead to a balance of supply and requirement, but would reduce the risk of non-supply and having to impose water restrictions.*

Whilst it is accepted that there is sufficient storage capacity in Knellpoort Dam (and also Rustfontein Dam) to allow Tienfontein Pump Station to have downtime for maintenance purposes, a cause of concern is the fact that this downtime may occur during a drought period when it is critical that pumping of available run of river flow should take place. Downtime may also occur as a result of the sediment build up at the Tienfontein Pump Station. Should this happen during a drought, the water supply to Bloem Water and Mangaung Metropolitan Municipality would be put at risk.

It is expected that these types of problems and associated expenditure will continue to persist into the future, unless the pump station is modified/redesigned to cope with the sedimentation problems. With the near equilibrium sediment regime in the Caledon River now being reached, the redesign of Tienfontein pump station should be considered. The following aspects could be taken into consideration in the redesign of Tienfontein pump station:

- *Redesign the forebay with fine screens,*
- *Trash rack opening under water,*
- *Flushing facility,*
- *Hoppers with jet pumps to remove sand,*
- *Investigate pump intake elevation and possibly pump types, sand trap efficiency and flood levels, and*
- *Possible use of a dry well.*

In general the pump station position is, however, ideally located at a river bend.

c) Address the siltation problems at Welbedacht WTP

An analysis of the siltation problems at Welbedacht WTP in the mid 1990's showed that the there was a general increase in average turbidity at Welbedacht WTP from 500 NTU in 1976 to approximately 2300 NTU in 1994. It is possible that the decrease in storage capacity of Welbedacht Dam from 115 million m^3 to approximately 6 million m^3 has resulted in a relatively shallow dam storage and possibly a flow channel which has the effect that high turbidity inflow water passes through the dam, depositing less silt than previously and thus resulting in delivering a more turbid water to the dam wall area and ultimately to the Welbedacht WTP. High silt loads arriving at the dam wall are as a result of scouring and turbulence due to river floods and the resuspension of some of the previously deposited silt.

The inability of the water treatment plant to deal with high turbidity levels currently limits the production capacity of the water treatment plant. Due to the high turbidity of the raw water, especially during flood events it is not possible to operate Welbedacht WTP at full capacity (145 Ml/d) throughout the year. A discussion with the operator of the WTP suggested that the WTP could operate at full capacity (145 Ml/d) in winter, but at times only managed an output of between 90 and 100 Ml/d in summer when the silt load in the river was higher. The yield of the system could therefore potentially increase if the WTP was operated at full capacity all year round.

On average it has been assumed that the yearly output from the WTP is approximately 123 Ml/d. In order to optimise the system yield, Welbedacht WTP should be operated close to 145 Ml/d throughout the year. The peak week water requirements should be absorbed by the Maselspoort WTP and Rustfontein WTP. By operating the Welbedacht WTP at 145 Ml/d as opposed to 123 Ml/d the system yield could be increased by approximately 7 million m^3/a.

In order to address this problem it is proposed that the following issues are further addressed (as part of the design of the WTP or part of further planning studies):

- *The water treatment process required to deal with on-going siltation issues.*
- *The abstraction from Welbedacht Dam. During any scouring of Welbedacht Dam, the water level in the dam would be drawn down and the intake works to the water treatment plant may no longer be able to*

effectively draw water for conveyance to the water treatment plant. Issues surrounding turbidity would also have to be investigated.

Alternative options to supply the water treatment plant during periods of scouring with low turbidity water could be to provde off channel raw water storage or to provide a pipeline linking Knellpoort Dam to Welbedacht Water Treatment Plant.

d) Scouring of Welbedacht Dam

The existing radial gates are situated 15 m above the original river bed. Flushing through the existing gates is therefore not efficient and will not restore any significant lost capacity of the dam. An option would be reconstruct the dam outlets at a lower level which might restore up to approximately 40% of the original storage capacity of Welbedacht Dam if operated appropriately. It is however anticipated that this option would be very costly and for this reason, and the fact that Knellpoort Dam was constructed to replace the lost storage capacity of Welbedacht Dam, this option is not considered a feasible solution.

At the moment sediment flushing from Welbedacht Dam, by means of opening the radial gates, is limited to between 8 to 12 hours. Welbedacht Dam has 5 m radial sluice gates and the opening of these gates creates a suddden drop in water level, causing a sudden outflow of water which induces turbulence in the basin upstream of the dam wall. The turbulence creates a scouring action which churns the deposited sediment loose and the outgoing water would then carries a considerable amount of silt from within the dam basin downstream into the river.

It would be more effective (in terms of sediment removal) to scour Welbedacht Dam for 4 to 7 days continuously by flushing the dam during a flood period. The gates could also be left open prior to the first flood reaching the dam wall. The initial floodwater would therefore be allowed to pass through the dam, at a steeper flow gradient, and thus at higher velocities, which would also induce a scouring action in the basin, scouring some of the previously deposited silt from the dam basin. Longer duration flushing would ensure a deeper channel near the Tienfontein pump station with the hydraulic control remaining at the dam and not controlled by vegetation and sediment upstream of the dam, as is currently happening. Longer duration flushing would also make it possible to release relatively clear water at the end of flushing to limit sediment deposition in the river downstream. In order to ensure good quality water to the Welbedacht WTP during the extended scouring period clear water storage facilities downstream of the dam (or possibly by providing a pipeline link between Knellpoort Dam and Welbedacht WTP) could be constructed.

Alternativel*y it has been proposed by DWA that the operating rules of Welbedacht Dam be modified and that Welbedacht Dam be operated as a barrage during summer months. The gates would be closed during the winter months to provide sufficient storage to feed Welbedacht WTP. The Caledon River would then be operated as a run of river scheme at Welbedacht Dam (within the limitations of the existing gates). This option could also increase the storage capacity of Welbedacht Dam and possibly improve the sedimentation conditions at Tienfontein Pump Station. The disadvantage would be to decrease the head available for Bloem Water to convey raw water to Welbedacht water treatment plant. Issues surrounding dealing with the turbidity would also have to be investigated.*

During the scouring of the dam (for both the extended scouring operation scenario and the modified DWA operating rule scenario), the water level in the dam would be drawn down and the intake works to the water treatment plant may no longer be able to effectively draw water for conveyance to the water treatment plant. Issues surrounding dealing with the turbidity would also have to be investigated.

It must be borne in mind that any storage capacity gained in Welbedacht Dam through scouring reduces the reliance which the system currently places on Tienfontein Pump Station.

e) Integrity of the Welbedacht Pipeline

The Welbedacht-Bloemfontein Pipeline was constructed in the early 1970's (commissioned in 1974) and consists of a 112km long DN1200 pipeline. The pipeline has a maximum capacity of 145Ml/day. Together with Tienfontein Pump Station the Welbedacht pipeline is also regarded as a critical component of the raw water / bulk water supply infrastructure.

The pipeline is a pre-stressed concrete pipeline which is subject to numerous bursts due to the deterioration of the pre-stressed windings which impacts on the structural integrity of the pipeline. Since 2009, seven bursts have occurred on the Welbedacht pipeline. Should the condition of this pipeline continue to deteriorate there is a risk that more pipe bursts could occur (particularly if the pipeline is to be operated at its full capacity of 145 Ml/d) . Any long outages of the pipeline will impact negatively on the yield of the current system. The magnitude of the impact will be directly proportional to the time which the pipeline is taken out of service. (A 20% downtime would result in a decrease in the system yield of approximately 5 million m^3/a). It is therefore important to assess the integrity of the Welbedacht pipeline and to also ensure that any burst on the pipeline can be repaired in as short a time period as possible. In this regard it is also imperative that the in-line control valves be maintained and correctly set, as insufficient attention to these valves could lead to surge pressures with the potential for consequential bursts along the Welbedacht pipeline.

The Welbedacht Pipeline can unfortunately not be taken out of commission to conduct integrity testing. Testing pipeline integrity under flow conditions is very expensive (approx. R 38 million). Bloem Water have therefore opted to relay portions Welbedacht Pipeline which they know to be potentially problematic in lieu of conducting inline pipeline integrity testing.

f) Further Augmentation from the Caledon River

In addition to addressing the siltation problems at Tienfontein Pump Station, Welbedacht Dam and Welbedacht WTP, it is imperative that further long term augmentation of Knellpoort Dam from the Caledon River be investigated to ensure that whatever measures are implemented will also ensure a high reliability of supply. The study should also confirm the amount of water which is available for abstraction from the Caledon River. The two options which have currently been identified are:

- ***Welbedacht P/S (2m^3/s):*** *To augment Knellpoort Dam from a pump station located at Welbedacht Dam itself. If a pipeline is installed between Knellpoort Dam and Welbedacht WTP to address the turbidity at Welbedacht WTP, this pipeline could be used as a bi-directional pipeline to also augment Knellpoort Dam, and*
- ***Tienfontein 7 m^3/s****: To further increase the capacity of Tienfontein Pump Station.*

It is important to address the scouring of Welbedacht Dam and the associated sediment related issues (described above) at Tienfontein Pump Station prior to the development of additional water resource capacity/infrastructure (especially increasing the capacity of Tienfontein Pump Station).

It must be noted that the capacity of the Novo Transfer Scheme will also ultimately have to be increased in order to realise an increase in system yield. Based on the yield analysis undertaken, and contained in ***Appendix B****, it is anticipated that this increased capacity would be required after the Welbedacht P/S (2 m^3/s**)** and before the further increase in capacity of Tienfontein Pump Station to 7m^3/s .*

g) Other Augmentation Interventions

The next most cost effective supply side intervention would be the direct or indirect re-use of treated effluent. Public resistance to this intervention may be encountered, possibly stemming from concerns of poor design or control of processes which may allow sub-standard water to be introduced into the potable water supply system, or for religious reasons. The water to be re-used would only be from that associated with growth after 2009, from the WWTW's in the catchment area. The yield of this option, for the purposes *of the scenario planning, has been assumed to be 10.8 million m3/a, but may ultimately be significantly more, dependent on the growth in water requirement.*

An alternative option would be to transfer water from Gariep Dam, either directly to Bloemfontien or to Knellpoort Dam. It is estimated that this augmentation option would be in excess of 3 times the cost of developing additional water resources from the Caledon River. This option together with water reuse should be further investigated should further studies show that abstraction of additional water from the Caledon river is not feasible (or only partly feasible) due to on-going sediment related issues and concerns.

The ecological Reserve should be implemented in a planned manner, based on the implementation dates of future water augmentation schemes. Based on the scenario planning undertaken, the ecological Reserve should only be implemented when the supply to Knellpoort dam is augmented.

Should groundwater be developed to supply the full current and projected water requirements of Wepener, DeWetsdorp, Reddersburg, Edenburg and Excelsior, then the water demand on the Greater Bloemfontein system would be reduced by approximately 4%. This would reduce the risk of non-supply and also keep the system in balance until 2016 where after a new augmentation scheme would be required.

E15 RECOMMENDED INTERVENTIONS

The following recommendations are made with regard to the implementation of interventions

- *The MMM should implement their WC/WDM strategy which was developed in 2011.*
- *The MMM should strive to achieve the maximum possible water savings through the implementation of their WC/WDM Strategy, namely "the best case savings scenario".*
- *Install two additional (1 m^3/s) Pump Sets at Tienfontein Pump Station. The first pumpset should be utilised to increase the design capacity of the pump station to 4 m^3/s and the second pumpset to provide additional standby capacity. With the implementation of the two additional pumpsets the total standby capacity of the pump station would be increased to 50% (based on the proposed new design capacity). The implementation of this solution would reduce the risk of restrictions and would be a cost effective interim solution to implement at Tienfontein Pump Station*
- *The Welbedacht Dam should be scoured to increase the capacity of the dam and to ensure that the siltation at Tienfontein Pump Station does not further hamper operations and maintenance.*
- *Bloem Water should further investigate the inability of the water treatment plant to deal with high turbidity levels which currently limit the production capacity of the water treatment plant*
- *Urgently initiate a feasibility Study to consider the most appropriate means to scour Welbedacht Dam and to augment Knellpoort Dam. The outcome of the feasibility study will guide the selection of future water resource development interventions. The feasibility study should inter alia address the following:*
  - *incremental yield generated and total yield available;*
  - *synergies with potential supply schemes' e.g. bi-directional pipeline between Knellpoort and Welbedacht;*
  - *the most appropriate intervention to augment Knellpoort Dam (e.g. implement a pump station at Welbedacht Dam and use the bi-directional scour pipeline to pump water into Knellpoort Dam, or further increase the capacity of Tienfontein Pump Station);*
  - *cost estimates; and*
  - *implementation programme.*
- *Bloem Water should take steps to ensure the integrity of the Welbedacht Pipeline. Bloem Water has proposed to relay sections of the Welbedacht pipeline which are considered as high risk.*
- *Mangaung Metropolitan Municipality should construct additional storage reservoir capacity in order to ensure that the network peaks are not transmitted through to the bulk supply infrastructure.*
- *It is expected that maintenance problems and associated expenditure will continue to persist into the future, unless Tienfontein pump station is modified/redesigned to cope with the sedimentation*

problems. With the near equilibrium sediment regime in the Caledon River now being reached, the redesign of Tienfontein pump station should be considered.

- *A Feasibility Study on Water Re-use should be undertaken. The timing of the feasibility study should be recommended by the Strategy Steering Committee.*

E16 SMALL TOWN SPECIFIC RECOMMENDATIONS

Wepener

- *It is imperative that the Naledi Municipality develop a business plan for the implementation of WC/WDM.*
- *Based on the URVs, the booster pump station is the preferred option for implementation at Wepener. However incremental development of the groundwater resource also appears favourable and could be considered as an alternative, introducing some independence of the town on the Bloemfontein system as well as conjunctive use of a local water source.*

Reddersburg and Edenburg

- *It is imperative that Kopanong Municipality develops a business plan for the implementation of WC/WDM.*
- *Develop groundwater interventions to augment the supply to Reddersburg and Edenburg.*

DeWetsdorp

- *It is imperative that Naledi Municipality develops a business plan for the implementation of WC/WDM.*
- *The provision of a new pipeline and pump station from the existing Bloem Water scheme is the most favourable option when comparing the URVs for Dewetsdorp. However if the desire for these smaller towns is that they become less dependent on the Bloem Water System, and more dependent on their own local sources, then groundwater does offer this opportunity, but at a higher financial cost than the potential surface water augmentation.*

Excelsior

- *It is imperative that the municipality develops a business plan for the implementation of WC/WDM.*
- *Undertake a study to investigate the following aspects: (1) the actual extent of water use in Excelsior and (2) the apparent limitations in supply of water during peak periods, and 3) the actual operation of the sources that supply water to the town.*

E17 THE STRATEGY ACTION PLAN

The Strategy Action Plan sets out the Actions, Responsibilities and Time Frames for achieving the following:

- *Implementation of the Reconciliation Strategy*
- *Implementation of Urban Water Conservation and Water Demand Management*
- *Implementation of the necessary studies to investigate surface and groundwater supply augmentation options.*
- *Development Operational Requirements.*

The full plan is set out below.

IMPLEMENTATION OF THE RECONCILIATION STRATEGY

a. ***Action:*** *The Greater Bloemfontein Water Supply (GBWS) Reconciliation Strategy Steering Committee should be formed in order to make recommendations, on a bi-annual basis, on long term planning activities required to ensure reconciliation of requirement and available supply in the GBWS area.*
Responsibility*:* *DWA: NWRP*
Timing: *November (Strategy update) and April (Monitoring of implementation)*

b. ***Action:*** *The GBWS Strategy Steering Committee must ensure that the following monitoring is undertaken in order to be able to ensure the reconciliation of supply and requirement over the longer term:*

i. The success of the WC/WDM interventions implemented. This is of particular importance the projected water requirement is currently higher than historical firm yield of the system.
ii. Actual water use
iii. Population growth and economic growth rate figures in order to be able to develop a better understanding of future water requirements
iv. Reconciliation of requirement and available supply in the GBWS area.

Responsibility: *GBWS Strategy Steering Committee*
Timing: *November (Strategy update) and April (Monitoring of implementation)*

c. ***Action:*** *An Administrative and Technical Support Group should be established to give support to the Strategy Steering, and implement the decisions of the Strategy Steering Committee.*
Responsibility: *DWA:NWRP*
Timing: *October 2012*

d. ***Action:*** *The Scenario Planning process should be updated on a regular basis to cater for:*

i. Revised future water requirement projections.
ii. Updated information on the implementation of the ecological Reserve and the potential for climate change impacts.
iii. Updated information from recently completed studies (reconnaissance level, pre-feasibility level and feasibility level) for WC/WDM and supply-side interventions to feed into the scenario planning process.
iv. Any other changes to the input data.
v. Revision of the MMM WC/WDM strategy.

Responsibility: *Administrative and Technical Support Group*
Timing: *In November of each year*

e. ***Action:*** *The Strategy Steering Committee should distribute at least one newsletter and one news release per year to stakeholders.*
Responsibility: *Strategy Steering Committee*
Timing: *After each November SSC Meeting on an annual basis*

URBAN WATER CONSERVATION AND WATER DEMAND MANAGEMENT

a. ***Action***: *Given the potential water shortages that could be experienced should the water requirements of the Greater Bloemfontein Area continue to grow, it is imperative for MMM to strive to achieve the maximum possible water savings through the implementation of WC/WDM, namely "the best case savings scenario".*
Responsibility: *MMM*
Timing: *2012 and on going*

b. ***Action***: *Appoint appropriate staff/professional service providers to expedite implementation of the MMMs existing WC/WDM Strategy.*
Responsibility: *MMM*
Timing: *2012 and ongoing*

c. ***Action:*** *Wepener, Dewetsdorp, Reddersburg, Edenburg and Excelsior should develop a WC/WDM business plan (strategies, actions plans, and programmes).*
Responsibility: *All Water Service Authorities*
Timing: *2012 and ongoing*

d. ***Action***: *Bloem Water to maintain and verify their bulk water metering system.*
Responsibility: *Bloem Water*
Timing: *Annually*

e. ***Action:*** *DWA's: Water Use Efficiency, to assist and support the WSA in the development and implementation of their WC/WDM strategies.*
Responsibility: *DWA D: WUE NMBM*
Timing: *2012 and on-going*

LOCAL SURFACE WATER SCHEME

a. ***Action***: *Investigate the most appropriate means to scour Welbedacht Dam*
Responsibility: *DWA (in conjunction with Bloem Water)*
Timing: *2012*

b. ***Action:*** *Install two additional (1 m^3/s) Pump Sets at Tienfontein Pump Station. The first pumpset should be utilised to increase the design capacity of the pump station to 4 m^3/s and the second pumpset to provide additional standby capacity.*
Responsibility: *DWA and Bloem Water*
Timing: *2012*

c. ***Action***: *Initiate a feasibility study to investigate the most appropriate means to augment Knellpoort Dam.*
Responsibility: *DWA*
Timing: *2012*

d. ***Action***: *Investigate the treatment process to deal with high turbidity levels which currently limit the production capacity of the water treatment plant*
Responsibility: *Bloem Water (in conjunction with DWA)*
Timing: *2012*

e. ***Action***: *Increase the Capacity of Novo Pump Station to 2.4 m^3/s*
Responsibility: *Bloem Water*
Timing: *2013 or dependent on operational requirements of Bloem Water*

f. ***Action:*** *Initiate a detailed feasibility study into water reuse as a potential supply intervention.*
Responsibility: *MMM*
Timing: *To be determined by the Strategy Steering Committee*

g. ***Action:*** *Initiate a study to investigate feasibility of obtaining additional water from the Orange River.*
Responsibility: *DWA*
Timing: *To be determined by the Strategy Steering Committee*

h. ***Action:*** *Develop additional groundwater resources to supply the shortage in water requirements in Reddersburg and Edenburg.*
Responsibility: *Kopanong Municipality*
Timing: *Study to be initiated in 2012*

i. ***Action:*** *Monitor the growth of water requirements in Wepener. If shortages occur, consider the implementation of a booster pump station on the supply pipeline to Wepener.*
Responsibility: *Naledi Municipality*
Timing: *Study to be initiated in 2012*

j. ***Action:*** *Develop additional groundwater resources to supply the shortage in water requirements in DeWetsdorp.*
Responsibility: *Naledi Municipality*
Timing: *Study to be initiated in 2012*

k. ***Action:*** *Undertake a study to investigate the actual extent of water use in Excelsior, the apparent limitations in supply of water during peak periods, and the actual operation of the sources that supply water to the town.*
Responsibility: *Local Municipality*
Timing: *Study to be initiated in 2012*

OPERATIONAL

a. ***Action:*** *A Technical Operations Committee should be formed between DWA, Bloem Water and Mangaung Metropolitan Municipality to ensure that the system is managed in the most optimal manner.*
Responsibility: *DWA, Bloem Water and Mangaung Metropolitan Municipality*
Timing: *2012 and ongoing*

b. ***Action:*** *Ensure sufficient bulk potable water storage to be able to manage system outages and to ensure that the peak water requirements are not transferred across to the Bloem Water Supply system.*
Responsibility: *Bloem Water and Mangaung Metropolitan Municipality*
Timing: *2012 and ongoing*

c. ***Action:*** *Monitor the growth in water requirement and adjust the water requirement projection scenarios if it becomes evident that the actual water requirements and projected water requirements differ significantly.*
Responsibility: *Strategy Steering Committee*
Timing: *November 2012 and annually thereafter*

d. ***Action:*** *Implement a monitoring system to serve as an early warning system should climate change start impacting on water availability and/or water requirements.*
Responsibility: *Strategy Steering Committee*
Timing: *To be determined by the Strategy Steering Committee*

e. ***Action:*** *Develop a "pro-active" strategy to manage the refurbishment of "high risk" components and the implementation of risk mitigation measures. This would also include new capital works which would enhance system capacity as well as supply flexibility."*
Responsibility: *Bloem Water and MMM*
Timing: *2012 and ongoing*

f. ***Action:*** *Replace pipelines in the high risk areas of the Welbedacht Pipeline*
Responsibility: *Bloem Water*
Timing: *2012 and on-going*

g. ***Action:*** *It is imperative that the Welbedacht Pipeline in-line control valve be maintained and correctly set, as insufficient attention to this valve could lead to surge pressures with the potential for consequent burst along the Welbedacht pipeline.*
Responsibility: *Bloem Water*
Timing: *2012 and on-going*

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TABLES

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ABBREVIATIONS

ACRONYMS

BW	Bloem Water
CBD	Central business district
DWA	Department of Water Affairs
EIA	Environmental Impact Assessment
GIS	Geographical information systems
IDP	Integrated Development Plant
ISP	Internal Strategic Perspective
MMM	Mangaung Metropolitan Municipality
PRVs	Pressure reducing valves
P/s	Pumpstation
RDP	Reconstruction and Development Programme
RO	Reverse Osmosis
RPST	Reconciliation Planning Support Tool
SDF	Spatial Development Plan
UAW	Unaccounted for water
URVs	Unit Reference Values
WC/WDM	Water Conservation and Water Demand Management
WMA	Water Management Area
WSDP	Water Service Development Plan
WTW	Water Treatment Works
WWTW	Wastewater treatment works
NWRP	DWA Directorate: National Water Resource Planning (NWRP)
WARMS	Water Authorisation and Registration Management System
AADD	Average Annual Daily Demand
EFR	Environmental Flow requirements

MEASUREMENTS

million m^3	Million cubic meters
km	Kilometres
m^3/s	Cubic meters per second
m	Meters
Ha	Hectares
mm/a	Millimetres per annum
m^3/d	Cubic metres per day
m^3/a	Cubic metres per annum

GLOSSARY OF TERMS

URV	The Unit Reference Value (URV) provides an indication of the combined capital and operational costs. An evaluation period of 50 years was selected for the determination of URVs for all augmentation schemes. Discount rates of 4%, 6%, and 8% were used in the calculation of URVs to cater for funding by MMM, Bloem Water, and DWA.

1. BACKGROUND

1.1 INTRODUCTION

In the process of compiling the Internal Strategic Perspectives (ISPs) for all the Water Management Areas (WMAs) in the country, the Department of Water Affairs (DWA) identified the need to develop strategies that will ensure adequate future reconciliation of water requirements and water availability in the main metropolitan areas, as well as in smaller municipal areas and towns. Some basic reconciliation options were addressed as part of the ISPs, but at the time it became clear that more detailed strategies needed to be developed. This would ensure effective and efficient management of the water resources supplying the economic hubs and smaller urban areas in the country, while at the same time managing their water requirements to ensure water use efficiency.

In 2004 the DWA Directorate: National Water Resource Planning (NWRP) embarked on a series of reconciliation strategy studies for some of the metropolitan areas and larger cities in the country. The Water Reconciliation Strategy Study for the greater Bloemfontein Supply Area (Mangaung) is one of the Metropolitan Reconciliation Strategies which is being developed.

The Bloemfontein Water Reconciliation Strategy Study was undertaken by DWA in co-operation with Bloem Water, Mangaung Metropolitan Municipality (MMM), and other stakeholders in order to secure a sustainable future water supply for MMM and other smaller towns served by the Greater Bloemfontein System.

The core element of the recommendations of this Strategy is based on the principal of Integrated Water Resource Management, which necessitates that the water supply system is managed collectively by all affected parties working together. In addition, new approaches are needed to manage urban water supply in order to develop an appreciation of the scarcity of water and to develop a diverse portfolio of water supply sources. Ultimately the Strategy will be a living process, to be continuously improved as estimates of water requirements, water availability, and resource development options become more reliable during the planning horizon.

1.2 PURPOSE OF THIS DOCUMENT

The purpose of the Reconciliation Strategy Study is to determine the current water balance situation and to develop various future water balance scenarios up to 2035. The Reconciliation Strategy Study aims to identify actions, responsibility and timing of such actions to ensure adequate and sustainable reconciliation of future water requirements in the Greater Bloemfontein Area so as to prevent the risk of a water shortage becoming unacceptable.

An interim Reconciliation Strategy was completed February 2010 which evaluated a wide range of interventions that could be implemented to meet future water requirements. These interventions include water conservation and water demand management (WC/WDM), groundwater, re-use of treated effluent, and possible future surface water resource development (supply) options. Following the investigations carried out in the interim Reconciliation Strategy, preferred interventions were identified which were further investigated in the Reconciliation Strategy (this document). The Reconciliation Strategy (this document) aims to evaluate a range of interventions and sequences of their implementation that may be necessary to address various future water requirement scenarios up to 2035 and recommends actions for implementation of the Strategy.

1.3 THE GREATER BLOEMFONTEIN WATER RECONCILIATION STRATEGY

1.3.1 The need for the strategy

As a proactive activity to ensure water availability for continued growth and development in the country the Directorate: National Water Resource Planning of the DWA embarked on a number of reconciliation strategy studies of large metropolitan areas. The *Water Reconciliation Strategy Study for the Bulk Water Supply Systems: Greater Bloemfontein Area* covers the area supplied by Bloem Water and MMM.

1.3.2 Strategy objectives

The purpose of the Strategy is to achieve reconciliation of the water supply with the water requirements up to 2035. The Strategy aims to guide the management of the water supply system in a coordinated, efficient, cost effective and environmentally sound manner. Stakeholder consultation with water users, planners, and policy makers is a key component of developing a strategy which is built around the principles of Integrated Water Resource Management. The planning process has involved developing an understanding of the bulk water supply network and its relevant components and the water requirements of the urban, rural, agricultural, and environmental sectors which are all competing for limited water resources. In addition, the demands and future development of the Orange River and the Caledon River were taken into consideration. The overriding principles of sustainability in water supply and management have guided the development of an action plan to provide water for future generations.

Water resource planning cannot rely on the benefit of hindsight, and as such, future water requirements scenarios need to be developed to ensure that sufficient water is provided to meet future water requirements. This in turn is a complex task of unravelling and understanding the range of parameters that affect future water requirements scenarios and the range of potential permutations. The Reconciliation Strategy has been designed to respond to potential future water requirement scenarios (urban and agricultural water requirements) and takes into account the growth in water requirements which are influenced by service delivery and population growth (high and low growth). In addition, surface and groundwater resources, the existing water supply infrastructure, and the management thereof, were taken into consideration to develop practical interventions. In order to facilitate a dynamic Strategy, regular review, supported by monitoring, will need to be undertaken. The Strategy aims for adequate levels of assurance of supply within the constraints of affordability and practical implementation ability, whist ensuring the sustainability of the surface and groundwater resources.

1.4 STRUCTURE OF THIS REPORT

Chapter 1 presents the background to the study and sets the scene for the need for a reconciliation strategy and its objectives. In **Chapter 2**, an Overview of the Study area is provided and this covers aspects such as development trends and climate for the areas of Greater Bloemfontein, Botshabelo, Thaba Nchu, the rural areas as well as the small towns of Reddersburg, Edenburg, Dewetsdorp, Wepener and Excelsior. In **Chapter 3**, the water resources and bulk infrastructure of the associated sub-catchments of the Caledon, Modder, Riet and Upper Orange Rivers is described, as well as that of the relevant areas of neighbouring Lesotho. In particular the Caledon–Bloemfontein transfer, Maselspoort Scheme and the Novo Transfer Scheme are described, with particular emphasis on operational challenges, reservoir storage capacity assessment, and risk related to infrastructure constraints and sedimentation impacts. **Chapter 4** describes the water availability (based on historical firm yield) of the Orange River system as well as that of the Greater Bloemfontein supply system and provides an overview of the factors influencing the yield. The current and future water requirements (urban, agricultural and environmental) are described in **Chapter 5**, which includes the factors influencing the future water requirement projections determined in the study. A comparison of water requirements and availability follows in **Chapter 6**, where after the potential interventions are identified in **Chapter 7**, screened, and a preliminary reconciliation strategy proposed. The selected interventions are described in detail, and the scenario planning process and use of the reconciliation planning support tool is explained. **Chapter 7** further provides the detailed Scenario Planning and consequent water balance outcomes for the Greater Bloemfontein system, with a strong focus on water conservation and demand management as a first step on the demand-side. The chapter concludes with an evaluation of the scenario findings and recommendations for the system. In **Chapter 8**, the water requirements, water availability and reconciliation (as well as indicative cost indications) for the supply to the small towns of Wepener, Dewetsdorp, Reddersburg, Edenburg and Excelsior are addressed, with a very strong focus on water conservation and demand management as well as local water resource development options, primarily that of groundwater development. **Chapter 9** provides the overall recommendations in relation to potential interventions within the study area and is followed by the recommended institutional and administrative arrangements in **Chapter 10**, required to give effect to the Strategy. In **Chapter 11**, a Strategy Action Plan is proposed which includes implementation of the Strategy, responsible authorities, stakeholder participation, and timing of implementation.

2. OVERVIEW OF THE STUDY AREA

The Greater Bloemfontein supply system provides the majority of potable water requirements to Bloemfontein, Thaba Nchu, Botshabelo, Wepener, Dewetsdorp, Reddersburg, Edenburg, and Excelsior. Agricultural water requirements will also form part of this study, as these water requirements may impact on the reconciliation of supply and requirement. The majority of the Greater Bloemfontein supply system is located within the Mangaung Metropolitan Municipality (MMM), which falls within the Motheo District Municipality. As such, the boundary of the ***Primary Study Area*** was defined by the municipal boundary of MMM (**Figure 2.1**). The ***Secondary Study Area*** is defined by the Caledon River, which is the main river system providing surface water to Bloem Water.

2.1 BLOEMFONTEIN

Bloemfontein is the capital of the Free State which is the third largest province covering 10.6% of the country's surface area. Bloemfontein is the judicial capital of the Republic of South Africa, the economic hub of the MMM, and the focal point for future development. The city is centrally located in South Africa and is served by major roads, such as the N1 which links Gauteng with the Southern and Western Cape, the N6 which links Bloemfontein to the Eastern Cape, and the N8 which links Lesotho in the east and Northern Cape in the west. The city has developed around the central business district (CBD) in a sectoral form, with the majority of the poor and previously disadvantaged communities living in the south-eastern section.

Little economic activity has been stimulated recently, despite land being designated for commercial or small industrial activities in new extensions. There has been a major relocation of services to suburbs, which has led to under-utilised office space in the CBD. Commercial and industrial activity in the city centre has also shown a decline.

The community, social, and personal service sector is the strongest economic sector and biggest job provider in the city. Key service sector employers include provincial and local government, education, and health facilities and training institutions, sport and cultural events and facilities, services to the agricultural sector, and financial services (IDP, 2002).

2.2 BOTSHABELO

Botshabelo was established in 1978 as an apartheid-engineered town for displaced people in the Free State. Most of the people who migrated to the town were from rural areas and adjacent towns. The town was spatially designed as a linear development with a small shopping centre in the middle, an industrial area on the northern side next to the N8, and 59 schools. The area is characterised by an over-supply of school sites and public open spaces (IDP, 2002).

There has been a decline in the manufacturing sector, which is largely due to subsidy cuts to industries in Botshabelo. As a result there are limited employment opportunities and many residents have started their own business. Others seek employment opportunities outside of Botshabelo, giving rise to almost 13 000 people commuting on a daily basis between Botshabelo and Bloemfontein.

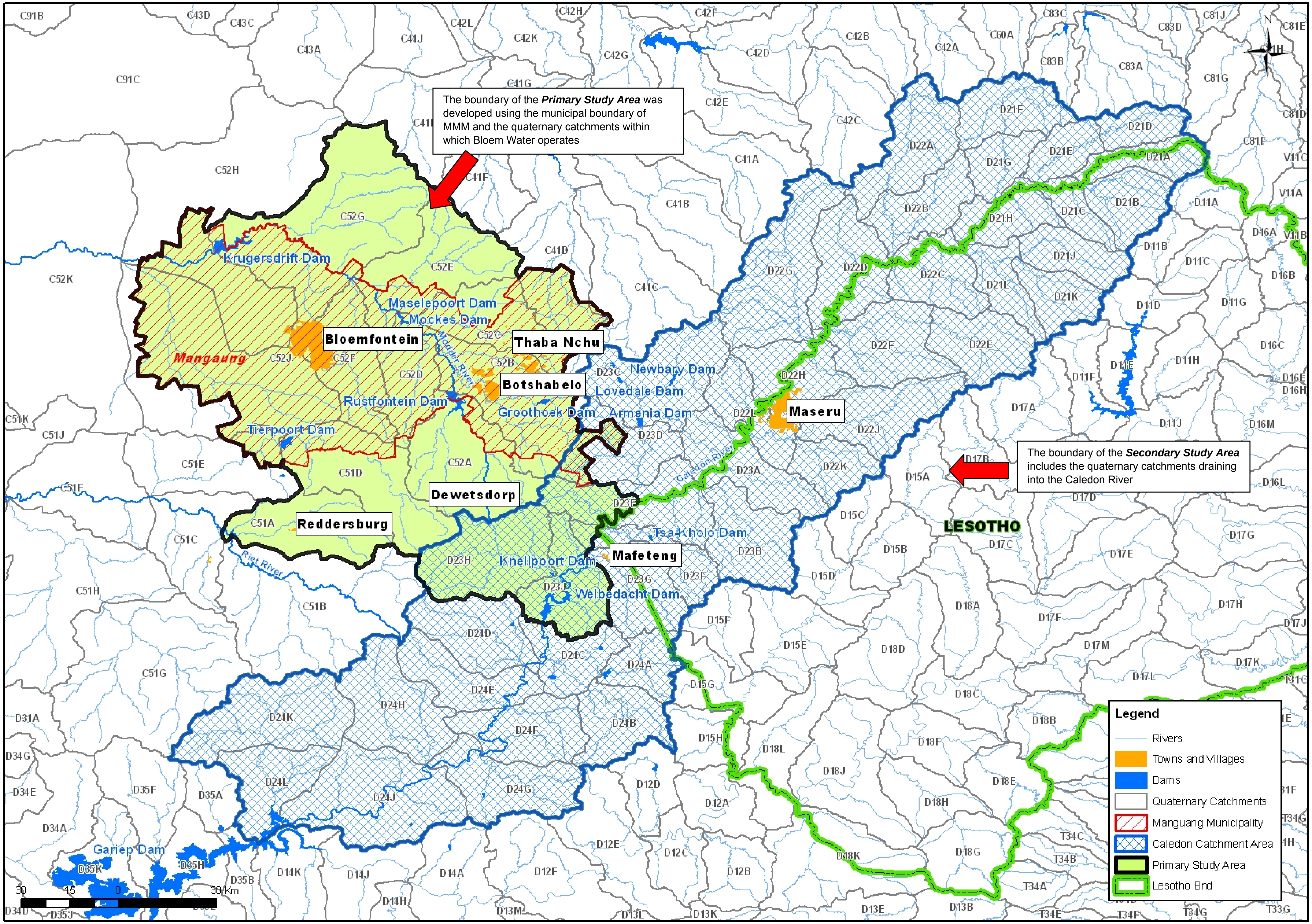

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Figure 2.1: The Greater Bloemfontein Bulk Water Supply System (Primary Study Area) and the Caledon Catchment Area (Secondary Study Area)

2.3 THABA NCHU

Thaba Nchu has a more scattered development pattern with 37 villages surrounding the urban centre, some as far as 35 km from the closest urban centre. Four of these villages have recently been formalised. The area is characterised by vast stretches of communal grazing areas that surround the urban centre. Thaba Nchu has a strong rural character and is mainly a dormitory town for workers in Bloemfontein.

2.4 RURAL AREAS

Approximately 23% of MMM is farmland, with a further 2% covered with smallholdings. The rural area with its commercial farms is a new challenge to the expanded Municipality. Although the area has basic infrastructure like roads, electricity and telephones, the main services are in the urban areas. Approximately 93% of all erven have at least RDP standard of water (access within 200 m radius) but 39% are without water connections on the erf. In terms of sanitation, the biggest problem is the bucket system, with 38% of erven having buckets or own pit latrines (WSDP, 2006/2007).

Commercial livestock farming is the economic backbone of the rural areas. Crops like maize, wheat, and sunflower are also produced. Many farmers have struggled to adapt to open markets, new products, and lack of subsidies from government.

There are small farmers on the former Trust lands around Thaba Nchu and Botshabelo. There has been some land reform but the process has been slow (IDP, 2002).

2.5 SMALL TOWNS

2.5.1 Reddersburg

Reddersburg is located in the southern part of the Free State, approximately 60 km south of Bloemfontein. It was established around the Reformed Church on the farm Vlakfontein bought for 1500 pounds sterling for that purpose on 20 August 1859. The name is Afrikaans and means "Saviour's Town" because God is our Saviour. The town was managed by the church until 1894 when it was handed over to the municipality on agreement that a hereditary tenure of 33 pounds sterling must be paid by the municipality to the church on an annual basis (http://en.wikipedia.org/wiki/Reddersburg).

Reddersburg has no large commercial or industrial sector and water users consist mainly of domestic type users. The town receives bulk water via a pipeline from Bloem Water's Welbedacht – Bloemfontein Pipeline, and from local boreholes.

2.5.2 Edenburg

Edenburg is located in the southern part of the Free State, approximately 75 km south-west of Bloemfontein. Edenburg has no large commercial or industrial sector and water users consist mainly of domestic type users. The economy of the town and surrounding district is based on sheep and cattle ranching (http://www.places.co.za/html/edenburg.html).

Edenburg receives bulk water via a pipeline from Bloem Water's Welbedacht – Bloemfontein Pipeline, and from local boreholes.

2.5.3 Dewetsdorp

Dewetsdorp is located on the R702, some 75 km south-east of Bloemfontein. The district is renowned as prime sheep and cattle ranching country (http://www.places.co.za/html/dewetsdorp.html). Dewetsdorp has no large commercial or industrial sector and water users consist mainly of domestic type users.

Dewetsdorp receives bulk water via a pipeline from Bloem Water's Welbedacht – Bloemfontein Pipeline, and from local boreholes when they are operational.

2.5.4 Excelsior

Excelsior is a small rural town originally established to serve the surrounding farming community. It was formed by farmers in 1910 who wanted a town which was closer to them than Winburg and Ladybrand (http://en.wikipedia.org/wiki/Excelsior,_Free_State). In recent years it has experienced a decline in the local economy as most of the farmers now visit the bigger centers, such as Bloemfontein, for their daily needs and education for their children. In most cases the banks have closed down and very limited services and goods are currently available to the local community (Motheo IDP, 2003).

Excelsior receives bulk water via a pipeline from Bloem Water's Rustfontein WTP. Excelsior also makes use of groundwater and a "run of river scheme" treated at a local water treatment plant.

2.5.5 Wepener

Wepener is located in the south-eastern part of the Free State, close to the border with Lesotho, next to the Caledon River. The town was founded in 1867 on the banks of the Jammersbergspruit, a tributary of the Caledon River. Today, the town is a commercial center for a 1725 square km district where mixed farming is practiced. Farming activities include cattle and sheep ranching, dairy farming, and the cultivation of wheat and maize (http://en.wikipedia.org/wiki/Wepener). Wepener has no large commercial or industrial sector and water users consist mainly of domestic type users. Wepener has the potential to grow, although very limited growth has been experienced in recent years. The small town is vibrant, and offers a range of goods and services to the local community. Tourists particularly favour the town as an overnight destination and a well-established bed and breakfast industry is starting to flourish (Motheo IDP, 2003).

Wepener receives bulk water via a pipeline from Bloem Water's Welbedacht – Bloemfontein Pipeline, and from local boreholes when they are operational.

2.6 DEVELOPMENT TRENDS

Bloemfontein has been the focus of development in recent years which has resulted in the centralisation of services to Bloemfontein and also an increase in population.

Another development trend that is evident in all of the urban nodes of Motheo District Municipality is the increase in immigration to these small towns. This can primarily be attributed to farm workers leaving the farm to settle in town as a result of labour dispute or farmers having had to reduce the number of employees on the farm due to a decline in the agricultural sector. There is thus an increase in the number of informal settlements in these towns with Bloemfontein in particular experiencing high levels of influx (Motheo IDP, 2003).

2.7 CLIMATE

The study area is located within the summer rainfall zone of South Africa, which is classified as a sub-humid, warm zone with annual water deficiency. The mean annual precipitation varies between 500 mm and 600 mm with the mean annual precipitation (MAP) of Bloemfontein being equal to 559 mm. Rainfall during the summer months, October to April, amounts to 86% of the total amount of rainfall, and is mainly in the form of nocturnal thunderstorms. Therefore summer runoff is relatively high and most of the discharge is in the form of storm flow. Air temperatures range from an average maximum of 31°C in January to an average minimum of -2°C in July. Daily temperatures range (for both summer and winter averages) some 16°C. Monthly pan-evaporation rates are highest in summer (December = 323 mm) and lowest in winter (July = 85 mm), with an annual average gross evaporation of approximately 1750 mm.

The rainfall data for the Bloemfontein area is shown in **Figure 2.2** below.

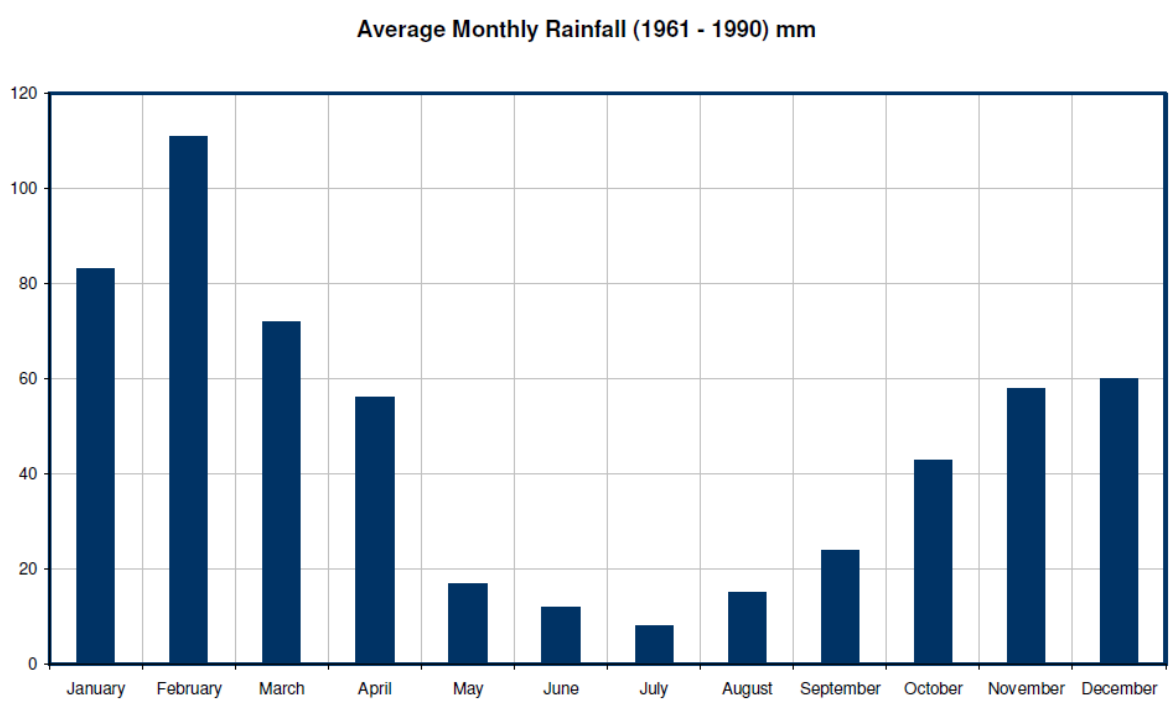

Figure 2.2: Rainfall Data for the Bloemfontein Area

3. WATER RESOURCES AND BULK SUPPLY INFRASTRUCTURE

3.1 SURFACE WATER RESOURCES

Nearly 70% of the total surface runoff, which would flow through the Upper Orange under natural conditions, originates from Lesotho and just more than 30% from within the Upper Orange Catchment within South Africa. The surface water resources, both within the Upper Orange and in Lesotho, are well developed and have a high degree of utilisation.

The two largest dams in the Upper Orange are the Gariep and Vanderkloof dams, which reduce the incidence of floods in the Lower Orange by about 50%. Other major dams are the Welbedacht and Knellpoort dams in the Caledon catchment and the Krugersdrift, Rustfontein, and Kalkfontein dams in the Modder-Riet River catchment. A description of the major dams per sub-catchment is provided in the following sections and the locations of the dams are shown in **Figure 3.1**.

3.1.1 Caledon River Sub-catchment

The *Welbedacht Dam* is situated on the Caledon River and supplies water to urban users in Bloemfontein, Botshabelo, Dewetsdorp, and various smaller users, as well as irrigators downstream of Welbedacht Dam along the Caledon River. The irrigators downstream of Welbedacht Dam have no claim to any water in Welbedacht Dam and only the normal inflow is released for irrigation purposes. The Welbedacht WTW at Welbedacht Dam supplies water via the Caledon-Bloemfontein pipeline to Bloemfontein, Botshabelo, and some minor consumers.

The *Knellpoort off-channel storage dam* was constructed to mitigate the impact of the decreasing yield of the Welbedacht Dam as a result of siltation and the increasing demand on the Caledon-Bloemfontein Regional Water Supply Scheme. Knellpoort Dam is supplied with water from the Caledon River by the Tienfontein Pump station. Water diverted via pumping from the Caledon River into Knellpoort Dam is then released back into the Caledon River under gravity to allow abstraction at Welbedacht Dam by Bloem Water all year round.

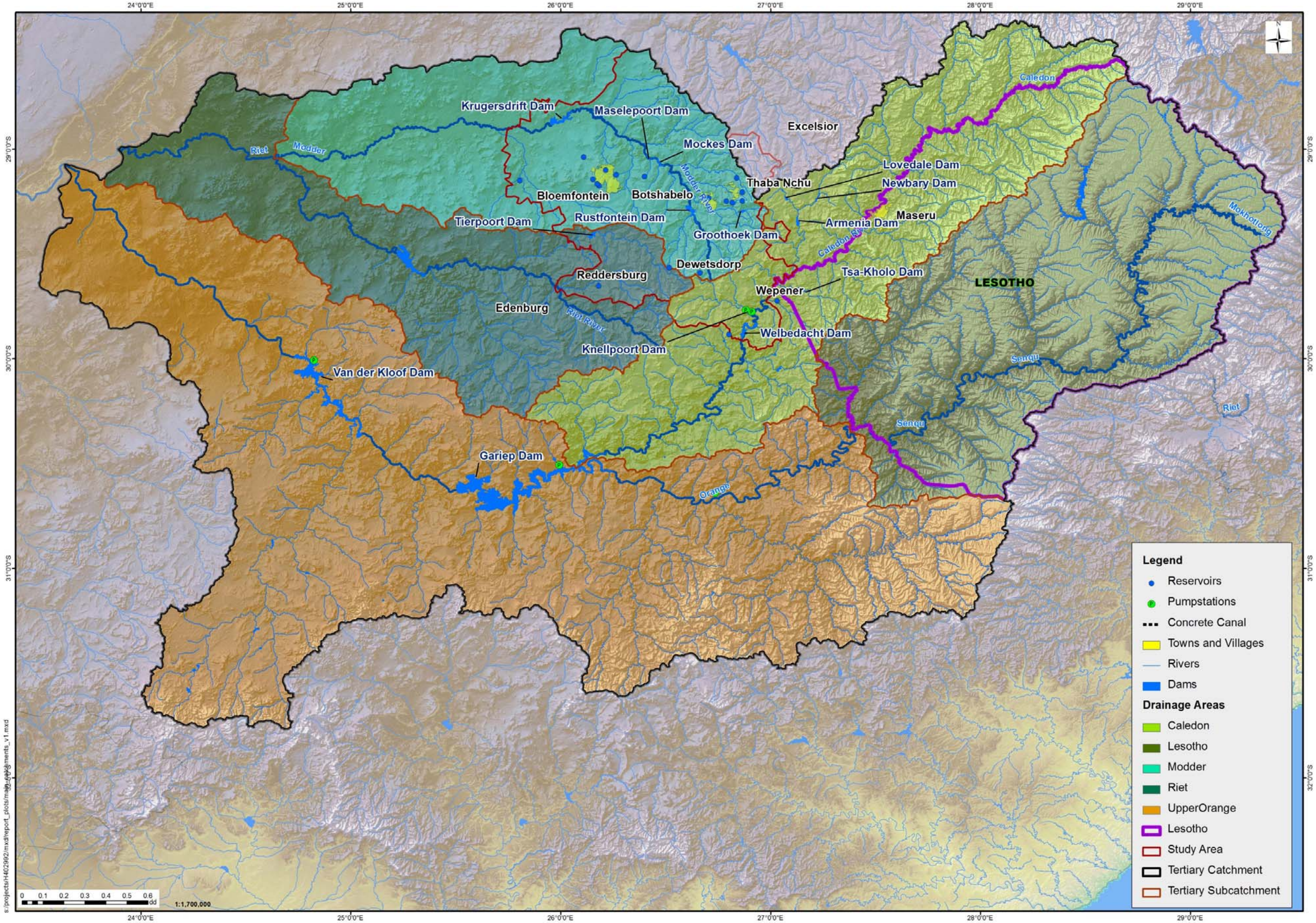

Figure 3.1: **Major Dams per Sub-catchment**

3.1.2 Modder River Sub-catchment

Krugersdrift Dam is located on the Modder River and supplies water for irrigation purposes to the Modder River Government Water Scheme. More than 50 weirs are constructed in the Modder River between the dam wall and the confluence with the Riet River.

Mockes Dam on the Modder River supplies water to Bloemfontein via the Maselspoort WTW. *Groothoek Dam* is located on the Kgabanyane River, a tributary of the Modder River, and supplies water to Thaba Nchu.

Rustfontein Dam is located on the Modder River and forms the major storage reservoir in the Modder River. Water is released from Rustfontein Dam to supplement the abstraction from Mockes Dam and currently provides the major portion of water supplied to Bloemfontein at Maselspoort.

3.1.3 Riet River Sub-catchment

Tierpoort Dam is situated on a tributary of the Riet River upstream of Kalkfontein Dam and supplies water to the Tierpoort Irrigation Board through a network of unlined canals.

Kalkfontein Dam is on the Riet River and supplies water for irrigation through a network of canals and syphons to the Riet River Government Water Scheme. Urban water is also supplied to the towns Koffiefontein and Jacobsdal through the aforementioned canal system.

3.1.4 Upper Orange River

The *Gariep Dam* and the *Vanderkloof Dam* are the two largest reservoirs in South Africa and are both situated on the Upper Orange River. These two reservoirs form the main component of the Orange River Project and are utilised to supply water to urban and irrigation users. They are also used for hydro power generation and flood control.

3.1.5 Lesotho

The *Katse Dam* in the Senqu sub-area is used for transfer of water to the Upper Vaal. *Mohale Dam*, in the same sub-area, is also used to transfer water to the Upper Vaal. Metolong Dam, which is under construction in Lesotho on a tributary of the Caledon River, will be completed in 2013. It will supply water to Maseru and surrounding towns.

3.2 GROUNDWATER

Groundwater is currently not utilised as a water resource for the supply of potable water to Bloemfontein. However, groundwater is used by individuals for irrigation of gardens in residential areas and groundwater is used extensively for agricultural purposes in the Bainsvlei / Kalkveld area and the area to the south-west of Bloemfontein. Groundwater is also utilised by small industries for bottling of water as well as micro-irrigation of vegetables and nurseries (garden centres), which are in close proximity to the city limits.

Small towns and communities in the vicinity of Bloemfontein, such as Dewetsdorp, Reddersburg, Edenburg, Wepener, and Excelsior, are partially dependent on groundwater for drinking and domestic purposes. Groundwater is therefore considered as an essential resource, specifically for the smaller towns. An estimate of the current groundwater yields for the small towns in the vicinity of Bloemfontein is provided in **Table 3.1**. The option of further developing groundwater resources for each of the small towns is discussed in Chapter 8.

Table 3.1: Estimated Groundwater Yields for Small Towns

Town	Estimated Average Yield of Existing Boreholes (million m^3/a)	Number of Boreholes
Wepener	0.071	4
Dewetsdorp	0.080	4
Reddersburg	0.160	9
Edenburg	0.213	12
Excelsior	0	0

3.3 BULK WATER SUPPLY INFRASTRUCTURE

Bloem Water is the main supplier of bulk potable water to urban centres in the Modder / Riet sub-catchment. The other water service provider is MMM which supplies about 25% of Bloemfontein's water requirements via the Maselspoort Scheme. The primary source of water is the Caledon and Orange rivers. As both of these river systems are a great distance from the water demand centres, several transfer schemes have been developed. The main transfer water supply schemes are: (1) the Caledon – Bloemfontein transfer which supplies Bloemfontein, Dewetsdorp, and small users from Welbedacht Dam, (2) the Maselspoort Scheme, and (3) the Caledon – Modder (also known as the Novo Transfer Scheme) which supplies water via the Rustfontein Treatment Works to Bloemfontein, Botshabelo, and Thaba Nchu. A brief description of these transfer schemes is provided in the following sections. The bulk water supply system serving the Greater Bloemfontein Area is shown in **Figure 3.2**.

3.3.1 The Caledon – Bloemfontein transfer

The Caledon-Bloemfontein pipeline was commissioned in 1974 to supply potable water from the Welbedacht Dam on the Caledon River to Bloemfontein, Botshabelo, Thaba Nchu, Dewetsdorp, Reddersburg, and Edenburg. Due to the decreasing yield of the Welbedacht Dam as a result of siltation (gross storage capacity reduced from the original 115 million m^3 to approximately 40 million m^3 in the first nine years of its life and has since reduced to 15,5 million m^3) and the increasing demand on the Caledon-Bloemfontein Regional Water Supply Scheme, the DWA supplemented the yield of the Welbedacht Dam through the construction of the Knellpoort off-channel storage dam on the Rietspruit, a tributary of the Caledon River. Knellpoort Dam is supplied with water from the Caledon River by the Tienfontein Pump station. Water diverted via pumping from the Caledon River into Knellpoort Dam is then released back into the Caledon River to allow abstraction at Welbedacht Dam by Bloem Water all year round. The Novo Transfer Pump Station (discussed in **Section 3.3.3**) is located at the Knellport Dam and is able to transfer water into the Modder River, which supplies the Rustfontein and Mockes Dams.

Situated just downstream of Welbedacht Dam is the Welbedacht Water Treatment Works (WTW) with a capacity of 145 Ml/day. Due to the high silt concentrations of the raw water abstracted, especially in times of flooding, the output capacity of the Welbedacht Water Treatment Plant is reduced and at times, in summer, the output capacity drops to 100 Ml/d. This water is pumped after purification via a 6.5 km pressure pipeline and a 106 km gravity pipeline to Bloemfontein. The average capacity of the pipeline is 1.7 m^3/s and the maximum capacity 1.85 m^3/s. The existing Welbedacht – Bloemfontein pipeline is a pre-stressed concrete pipeline and has been subject to bursts in the past. Concerns have been raised about the long term structural integrity of the pipeline. If this pipeline were to fail, the MMM could potentially experience severe water shortages, as the MMM does not have surplus reservoir capacity to support outages of a long duration. This infrastructure is owned and operated by Bloem Water.

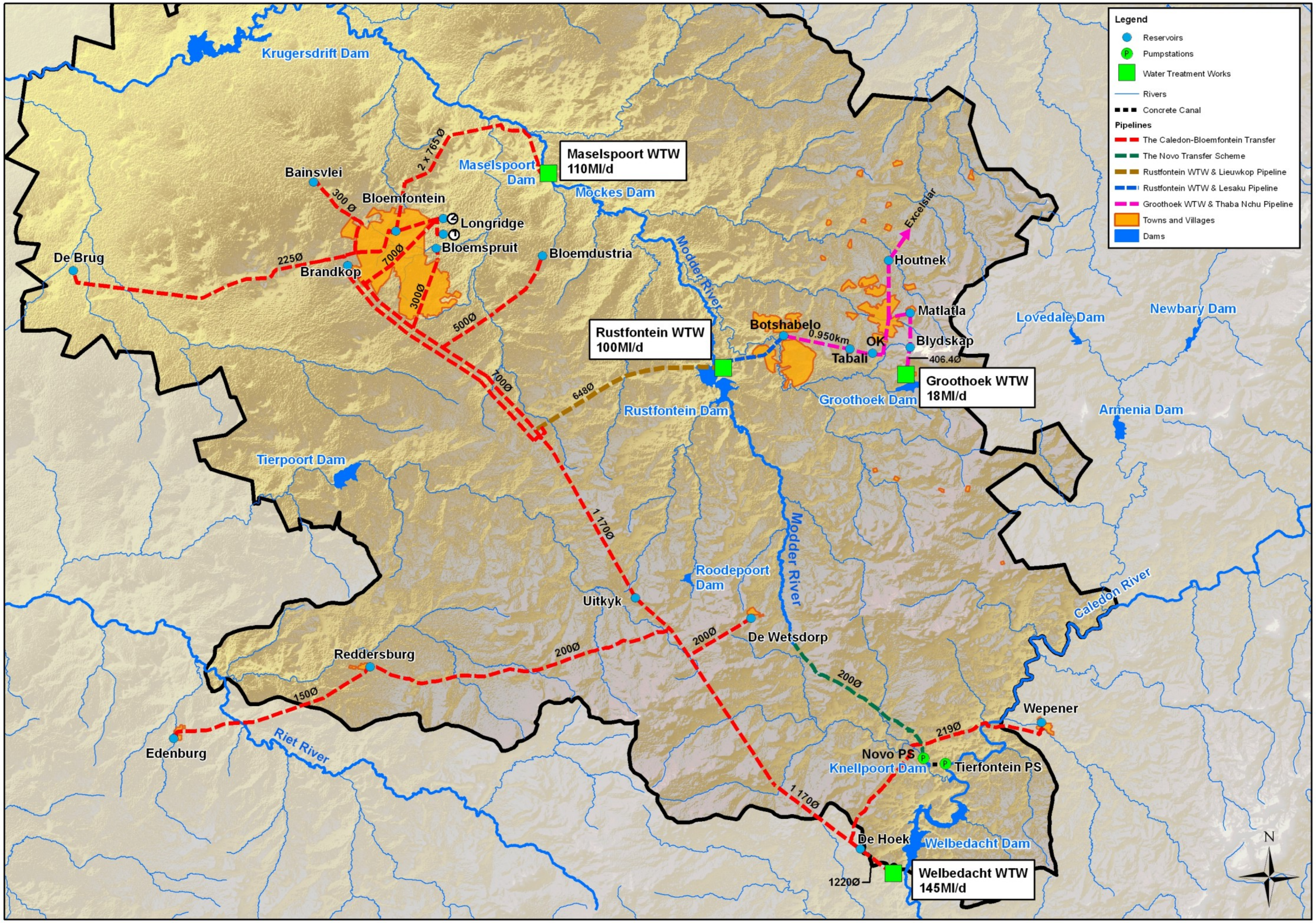

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Figure 3.2: Greater Bloemfontein Bulk Water Supply System

3.3.2 The Maselspoort Scheme

The Maselspoort Scheme includes the Maselspoort WTW (110 Ml/day) and the Maselspoort Weir, which is located on the Modder River downstream of Mockes Dam (which is downstream of the Rustfontein Dam). The Maselspoort WTW supplies approximately 25% of Bloemfontein's water needs and is owned and operated by the MMM.

3.3.3 The Novo Transfer Scheme

The Novo Transfer Scheme, which became operational in 1998, includes Tienfontein Pump Station, a pipeline and canal from Tienfontein Pump Station to the Knellpoort Dam, Knellpoort Dam, and the Novo Pump Station and pipeline. The Novo pump station (current capacity is approximately 1.5 m^3/s), which is situated on the northern side of the Knellpoort Dam, transfers water from Knellpoort Dam to the Modder River, via a 20 km pipeline running from Knellpoort Dam. From the outfall of the Novo pipeline, water flows down the Modder River to Rustfontein Dam, a distance of approximately 50 km. Water stored in Rustfontein Dam is treated at the Rustfontein WTW and pumped to Botshabelo/Thaba Nchu or Bloemfontein. As an alternative, water can be released from Rustfontein Dam to flow downstream into Mockes Dam from where it can be abstracted at the Maselspoort Weir, treated at Maselspoort WTW, and pumped to Bloemfontein. The above infrastructure is owned by DWA and operated by Bloem Water.

3.4 OPERATION OF THE BULK SUPPLY SYSTEM

The Novo Transfer Scheme is aimed at being operated on the basis of maintaining a target water level of approximately 60% in Rustfontein Dam. This is, however, dependent on rainfall. In attempting to achieve the abovementioned target levels, the Novo Pump Station has been run since December 2008 on a virtually continuous basis, pausing in this period for three months only to allow for time to repair the pumps.

Tienfontein Pump Station currently abstracts and pumps the water to Knellpoort Dam for storage, on a virtually continuous basis throughout the year (dependent on water availability). This stored water in Knellpoort Dam is ultimately released back to Welbedacht Dam for abstraction by the Welbedacht WTW or pumped to the upper reaches of the Modder River by Novo Pump Station. The Welbedacht WTW, which abstracts water from Welbedacht Dam, is operated at full capacity throughout the year.

Bloem Water together with MMM own and operate four WTWs (**Figure 3.2**). Details of these WTWs are provided in **Table 3.2.**

Table 3.2: Maximum Capacity of Water Treatment Works (Bloem Water, 2008)

Infrastructure	Capacity (Ml/d)	Owner	Area of Supply
Welbedacht WTW	145	BW	Bloemfontein, Wepener, Dewetsdorp, Reddersburg, and Edenburg
Rustfontein WTW	100	BW	Bloemfontein, Botshabelo, Thaba Nchu, and Excelsior
Maselspoort WTW	110	MMM	Bloemfontein
Groothoek WTW	18	BW	Botshabelo, Thaba Nchu, and Excelsior

The re-use of treated effluent from wastewater treatment works (WWTW) could provide an alternative source to supply water to the Greater Bloemfontein Area in the future. **Table 3.3** lists the current WWTWs which serve Bloemfontein/Mangaung and Botshabelo/Thaba Nchu areas.

Table 3.3: Current Capacity of WWTWs which Serve MMM

Area	WWTWs	Capacity (Ml/d)
Bloemfontein/Mangaung	Bloemspruit	56
	Sterkwater	10
	Welvaart	6
	Bainsvlei	5
	Northern Works	1
	Bloemdustria	< 1
Botshabelo/Thaba Nchu	Botshabelo	20
	Selosesha	6

The geographic location of the WWTWs is provided in **Figure 3.3**.

The MMM is in the design phase to construct the new WWTW (referred to as the North Eastern WWTW), to provide water borne sanitation services for further development in the northern, eastern, and western parts of Bloemfontein.

3.5 RESERVOIR CAPACITY

The current average annual daily demand (AADD) in 2010/2011 for **Mangaung/Bloemfontein** was about **166 Ml/d**. The reservoir storage capacities required for the Mangaung/Bloemfontein area were identified in a previous report (Ninham Shand, Dec. 1994) as being: 1.0 x AADD (Bloem Water) + 2.0 x AADD (Mangaung Municipality), and have been accepted as satisfactory standards for this study. The current capacity of Bloem Water's reservoirs serving the Mangaung/Bloemfontein area is 163.3 Ml. This represents a single day's storage for emergency purposes, and is still acceptable. However, any further increases in the average daily demands will reduce the storage time below one day. Thus, there appears to be the need for Bloem Water to seriously consider constructing new storage for this area. The current capacity of Mangaung Metropolitan Municipality's reservoirs serving the Mangaung/Bloemfontein area is 240 Ml. This represents 1.5 day's storage of the average demand and falls short of the required two days storage. **Thus, it is apparent that network peaks will be transmitted to the bulk supply infrastructure**. It would appear that additional reservoir capacity of about 86Ml is urgently required for Mangaung Metropolitan Municipality to remedy the current storage shortfall, and to include additional storage for future growth.

The current average annual daily demand (2010/2011) for **Botshabelo/Thaba Nchu** is about 45 Ml/d. The current capacity of Bloem Water's reservoirs serving the Botshabelo/Thaba Nchu area is 67.5 Ml. This represents 1.7 day's storage for emergency purposes, and is above the accepted minimum of one day's storage. The current capacity of Mangaung Metropolitan Municipality's reservoirs serving the Botshabelo/Thaba Nchu area is 29.5 Ml. This represents 0.7 day's storage of the average demand and falls well short of the required two days storage**. Thus, it is apparent that network peaks may be transmitted to the bulk supply infrastructure**. It would appear that additional reservoir capacity of about 51 Ml is urgently required for Mangaung Metropolitan Municipality to remedy the current storage shortfall, plus additional storage for future growth.

It must be noted that at the time of drafting this strategy MMM were in the process of increasing the storage capacity of their reticulation system.

Reservoir storage capacity, whether from the Bloem Water System or from MMM's system is further important for the following reasons:

- Storage is required to be allow Bloem Water to effect repairs on the Welbedacht pipeline should it burst and have to be repaired.
- DWA in unable to scour Welbedacht Dam for more that 8 to 9 hours before shortages of supply in Mangaung are experienced. Should additional storage be provided it may help address this problem to some degree (although it will not solve it as Welbedacht Dam would have to be scoured for a number of days for the scouring to be effective).
- The water supply is heavily dependent on pump stations. Should power outages of a significant duration occur it would be important to have sufficient potable water storage capacity.

3.6 INFRASTRUCTURE CAPACITY CONSTRAINTS AND RISKS

The existing Welbedacht – Bloemfontein pipeline is a pre-stressed concrete pipeline and has been subject to bursts in the past. Concerns have been raised about the long term structural integrity of the pipeline. If this pipeline were to fail, the MMM could potentially experience severe water shortages, as Bloem Water and MMM do not have surplus reservoir capacity to support outages of a long duration. Bloem Water is aware of the risk and are in the process of investigating the integrity of the pipeline

Due to the aging and the increased demand on the infrastructure serving Bloemfontein/Mangaung, the risk of non-supply has also increased significantly. Any future upgrading of the supply infrastructure of both Bloem Water and Mangaung Metropolitan Municipality must take consideration of the future risks and should try to mitigate against these potential risks. A study undertaken by Bloem Water in 2007 entitled "Rustfontein Water Treatment Works: Water Supply Options" looked at these potential risks and proposed a capital works programme to address future demands on water supply capacity. One of the general recommendations that came out of the study is given below:

"Ensure that a "pro-active" strategy is in place and is executed with urgency to manage the refurbishment of "high risk" components and the implementation of risk mitigation measures. This would also include new capital works which would enhance system capacity as well as supply flexibility."

A further recommendation that came out of the study was that a future capital works programme should inter alia consider both the **construction of a new Water Treatment Works close to the existing works at Maselspoort weir and the expansion of the existing Rustfontein Water Treatment Works**. The construction of additional water treatment plant capacity at Maselspoort and Rustfontein would also help mitigate some of the non-supply risks associated with the pre-stressed concrete pipeline between Welbedacht WTW and Bloemfontein.

The MMM and BW commissioned a study entitled "Joint Bulk Water Services: Infrastructure Challenges" in February 2012. This report summarises the current status of the joint bulk water infrastructure serving the Mangaung Metropolitan area, and points out the various challenges which need to be addressed to ensure uninterrupted and sufficient water supply to the end consumers. This report further prioritises the interventions which are required as well as their associated costs. It is important to note that the identified infrastructure challenges identified in this report (i.e. storage, water treatment plant capacity, upgrading and maintenance of the WTP) will not increase the yield of the system (make more water available), but are critical to implement if Bloem Water and Mangaung Metropolitan Municipality do not want on-going potential interruptions to supply.

3.7 SEDIMENTATION PROBLEMS

Since 1973, when Welbedacht Dam was completed, the dam has lost about 90 % of its storage capacity. Over the first 18 years of operation the sediment deposition rate was extremely high, but since 1991 when flushing operations during some of the floods commenced, this sediment deposition rate has decreased.

The existing radial gates are located 15 m above the original river bed. The location of these gates limits the extent and also the efficiency of flushing. Tienfontein pump station is situated upstream of the dam basin just above the full supply level of Welbedacht Dam and was designed to be operated as a run-of-river station to augment Knellpoort Dam. Although the pump station was designed for this scenario, there are serious maintenance and operational problems related to the deposited sediment.

The current pumps have a total discharge capacity of approximately 2.5 m^3/s (design 3 m^3/s) and have experienced high maintenance costs. The motors are located at a high level with axial flow type pumps in a wet well. Shafts have been broken due to sedimentation in the past and the pumps at Tienfontein Pump Station had to be overhauled after only 3000 hours of operation. This represented 20% of the expected lifetime of the pumps.

Tienfontein Pump station is seen as the **most critical component** of the water supply infrastructure supplying Bloem Water with raw water, as Bloem Water receives approximately 40% of its water supply via Tienfontein Pump Station and Knellpoort Dam. Whilst it is accepted that there is sufficient storage capacity in Knellpoort Dam (and also Rustfontein Dam) to allow Tienfontein Pump Station to have down time for maintenance purposes, what is a possible cause of concern is the fact that this downtime may occur during a drought period when it may be critical that pumping of available run of river flow should take place.

Down time may also occur as a result of the sediment build up in the Tienfontein Pump Station. Should this happen during a drought, the water supply to Bloem Water and Mangaung Municipality could be put at risk.

Since there is minimal storage capacity in Welbedacht Reservoir, the Tienfontein pumps must operate at a high reliability on a run of river basis to supply Knellpoort Dam. The predicted bed level at Tienfontein pump station indicates that the current bed level is near equilibrium, but it should be borne in mind that this is a dynamic equilibrium and during floods scour will occur and deposition after floods. The variability of the equilibrium bed is in the order of 3 m up or down with which the pump station has to cope. This could lead to sediment build up as high as 4.6 m above the full supply level of the reservoir, at the pump station, and the existing pumps cannot deal with such a scenario.

At the moment sediment flushing of Welbedacht Dam is limited to about 8 to 9 hours. This could be increased to say a week of flushing during a flood period by providing raw water storage facilities downstream of the dam. Longer duration flushing would ensure a deep channel near the Tienfontein pump station with the hydraulic control remaining at the dam and not controlled by vegetation and sediment upstream of the dam as is currently happening. Longer duration flushing would also make it possible to release relatively clear water at the end of flushing so as to limit sediment deposition in the river downstream.

Á report entitled Investigation into the Condition of the Caledon River at Welbedacht Dam (SSI, 2011) investigated the sedimentation problems and potential solutions in more detail. This report contained the following two recommendations:

1) Conduct a detailed investigation and cost estimate to modify the Tienfontein Pump Station to such an extent that the pump station can operate efficiently under the current in-take conditions.
2) Conduct the following investigations to improve the storage capacity of Welbedacht Dam:
    a. Bloem Water and MMM should conduct collectively a detailed investigation and a capital cost estimate to optimize and possibly also to upgrade the existing treatment and supply infrastructure of the entire supply area;
    b. Investigate the possibility of providing off-channel storage at, or close to, the Welbedacht WTW. Carry out a reservoir basin survey, hydrological investigations and geotechnical investigations;
    c. Conduct a detailed investigation and cost estimate to construct a raw water supply line from the Knellpoort Dam to the Welbedacht WTW; and
    d. Conduct a detailed investigation and cost estimate to modify the Tienfontein Pump Station.

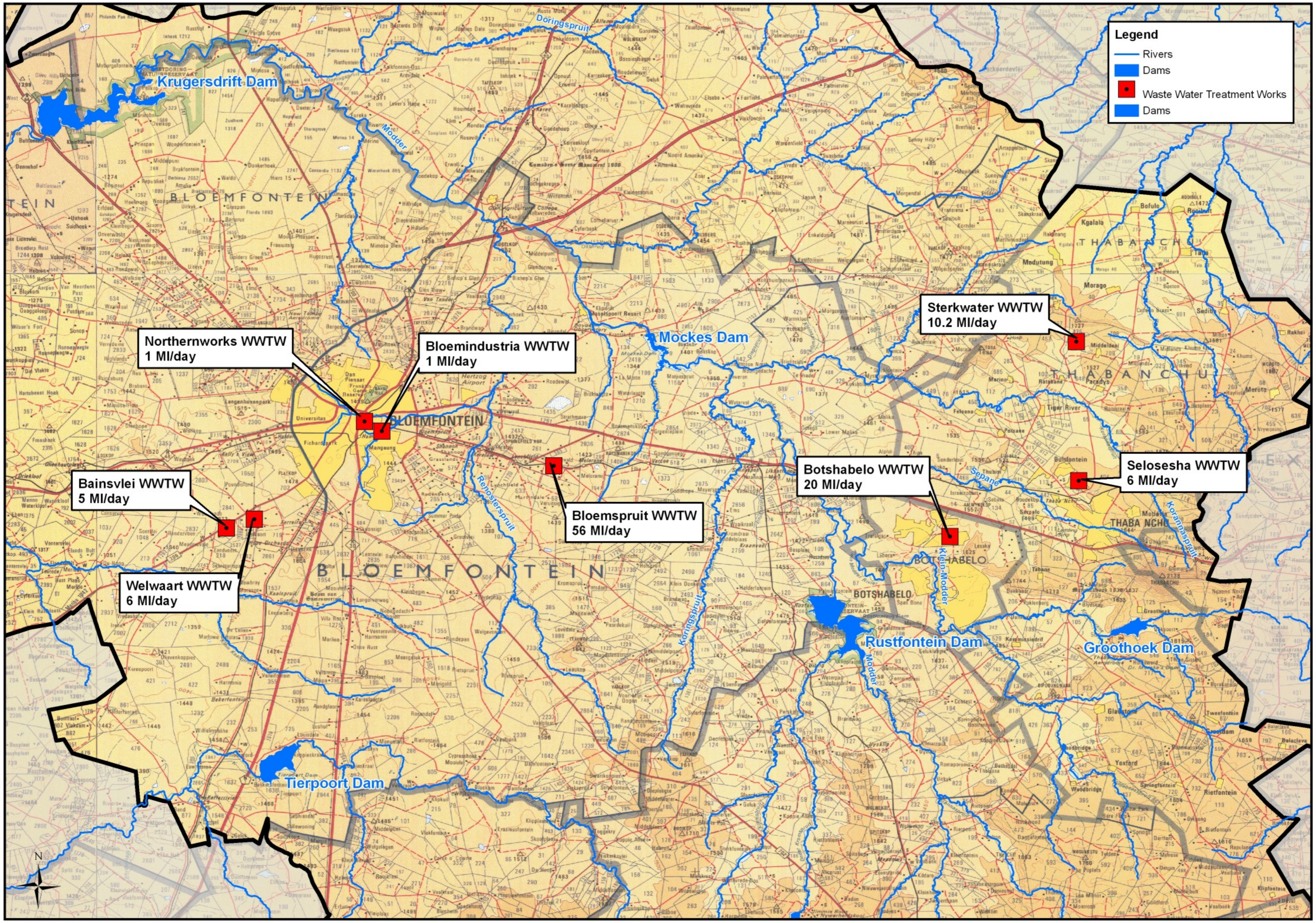

Figure 3.3: WWTWs Located within the Primary Study Area

4. WATER AVAILABILITY

4.1 THE ORANGE RIVER SYSTEM

The Upper Orange is affected by the water requirements and developments in the Orange and Vaal River Systems. These systems have been the subject of various water balance and reconciliation studies. The latest water balance from the Orange River system indicated a surplus of 274 million m^3/a for the year 2008.

When the effect of the 12 000 ha earmarked for resource poor farmers is taken into account, the surplus of 274 million m^3/a will reduce further to only 130 million m^3/a. This net surplus is reserved for the growth in water requirements in the urban, industrial, and mining sectors in the Upper Orange WMA, the Lower Orange, and the Fish to Tsitsikamma WMAs. It was estimated that after the abovementioned water requirements are taken into consideration (estimated to be 90 million m^3/a), that there would be a net surplus in the Orange River system of 40 million m^3 in 2025.

The future Polihali Dam site is situated on the Senqu River approximately 1.5 km downstream of the confluence of the Senqu and Khubelu Rivers. Polihali Dam would increase the water delivered from Lesotho Highlands Water Project to the high value industries in the Vaal catchment, but would, in the long term, result in a reduction in the water available at downstream Gariep and Vanderkloof dams. It is envisaged that the Polihali Dam would reduce the yield of the Orange River downstream by approximately 283 million m^3/a. This is based on the assumption that overall yield of the system increases by 182 million m^3/a but an additional 465 million m^3/a might be transferred to Gauteng, causing a shortfall of 283 million m^3/a (465 – 182 = 283). The anticipated net deficit in 2037 (based on current water requirements and not the anticipated growth in water requirements) will be -243 million m^3/a. **Table 4.1** shows an approximate mass water balance of the Upper Orange WMA.

Based on the mass balance, the following conclusions can be drawn:

- There is currently surplus water available in the Orange River system (including the Caledon River) which can be allocated to the Greater Bloemfontein Area.
- It is most likely that the construction of Boskraai / Bosberg Dam, as well as other water resource development options on the Orange River will only become an option after the water requirements from the Vaal WMA have increased to such an extent that they reduce the availability of water in the Orange River, and a new supply intervention is implemented to augment the loss in yield.

Table 4.1: Orange River Water Balance (ISP, 2004)

Scenario Description	Surplus Yield (million m^3/a)
Year 2008 Surplus Yield*	274
Less allocation to resource poor farmers	-144
Net current yield available for growth in urban water requirements	**130**
Less growth in urban, industrial, and mining sectors in Orange and Eastern Cape	-90
Net yield available in 2025 **	**40**
Less transfer to Gauteng from Polihali Dam (estimated impact on the Orange) ***	-283
Anticipated net deficit in 2037 already (will be higher with additional growth in urban requirements	**-243**

Notes –

* *Based on 2008 WRPM analysis 320 million m^3/a surplus at 1:50 minus 46 million m^3/a deficit mainly in Kraai as from ISP*

** *Net yield available at 2025 as if Polihali Dam is not in place*

*** *From comparative study results the total yield from Polihali will already be utilised in full by the Vaal WMA in 2037*

The Orange River Balance described above is conceptual and has been included for illustrative purposes to demonstrate that there will ultimately be a deficit in the Orange River system and that future water resource developments will have to be put in place in the Orange River. Any future water resource development options along the Orange River could be used to augment the supply to the Greater Bloemfontein area.

The Upper Orange has a large commitment to support the local water requirements and transfers to the Upper Vaal, the Fish to Tsitsikamma, as well as release obligations to the Lower Orange. A number of augmentation interventions have been identified to provide additional yield to the Orange River System to make up the envisaged shortfall caused by transfers from Polihali Dam to the Gauteng area. Some of the interventions identified include: using the lower level storage in Vanderkloof Dam, the construction of Bosberg/Boskraai Dams, and the raising of Gariep Dam.

It is the intention of the DWA to initiate a separate reconciliation strategy study on the Orange River System, which will draw on the information from the Greater Bloemfontein Reconciliation Strategy Study.

4.2 HISTORICAL YIELD OF THE SURFACE WATER SUPPLY SYSTEM

Present Day Yield of the system supplying Bloemfontein, Botshabelo and Thaba Nchu

The modelled present day yield was first compared with the yields determined in earlier analyses and then updated using the more recent operating information and hydrology.

Earlier analysis determined the contribution of the Vaal River portion of this system separately from the contribution from the transfers from the Caledon River.

The Vaal River sub-system used the hydrology from the Vaal River System Analysis Update spanning the period 1920 to 1994. The yield was determined for the system comprising Rustfontein Dam and Mockes Dam, excluding the supply to Thaba Nchu from the Grootfontein Dam of about 3.2 million m^3/a. The losses at the water treatment works (WTW) were assumed to be 5% at Maselspoort near Mockes and the conveyance losses, were assumed to be 5% from Rustfontein Dam to Mockes.

The model used in this study determined a firm yield of 8.2 million m^3/a for the Rustfontein-Mockes sub-system, compared to the 8.5 million m^3/a reported in the earlier analysis titled "Caledon-Modder River System Planning Analysis: Effect of updated water requirement projections based on the National Water Resources Strategy Study".

The Caledon sub-system used the hydrology from the Orange River System Analysis spanning the period 1920 to 1987. The following assumptions were used when initially configuring the model for the current study:

- **Welbedacht**. The live storage capacity of the Welbedacht dam was assumed to be 11.7 million m^3 and the capacity of the water treatment plant at Welbedacht was assumed to be 124 Ml/day
- **Tienfontein/Knellpoort/Novo**. The capacity of the Tienfontein Pump Station transferring water into the Knellpoort Dam was assumed to be 3 m^3/s. The Novo pumpstation transferring water from the Knellpoort Dam to the Rustfontein Dam was assumed to capable of transferring water at 1.67 m^3/s when the water level was above RL1428.61 m. This is less than the pipeline capacity of 2.4 m^3/s
- **Rustfontein WTW.** Rustfontein Water Treatment Works (WTW) only supplies Botshabelo, not Bloemfontein

- **Irrigation d/s Welbedacht**. Irrigation on Caledon d/s Welbedacht was located upstream of Welbedacht, which is one way of ensuring that the irrigation only had access to the inflows into Welbedacht and not the water stored in Welbedacht Dam
- **Losses**. Not all losses in Vaal system were modelled - determined the uniform transfer from the Knellpoort to Rustfontein and from Welbedacht to Bloemfontein, ignoring the smaller losses from Rustfontein to Bloemfontein. Losses at the WTW were assumed to be 10% at Welbedacht. The losses on the pipeline from Welbedacht to Bloemfontein were not modelled. Conveyance losses, were assumed to be 17% from Knellpoort Dam to Rustfontein Dam.

The model used in this study determined a firm yield of 89 million m^3/a for the Caledon transfer, compared to the 88 million m^3/a reported in the earlier analysis titled "Orange River System: Annual Operation Analysis 2008-10". Some details mentioned above, particularly the Nova pipeline and pumpstation capacity, must still be confirmed by WRP Consulting Engineers (Pty) Ltd, but based on the agreement between the results the assumptions seem reasonable.

The combined yield from adding together the yield of the sub-systems supplying Bloemfontein, Botshabelo and Thaba Nchu is 100 million m^3/a (3+8+89). This is the same as the yield from operating the system in an integrated manner. In the integrated system the losses between Rustfontein to Bloemfontein are also applied to water originating from Knellpoort (unlike in the modelling of the Caledon sub-system) and seem to be cancelled by the extra yield from synergistic management of the system. It was difficult to fully optimize the yield of the integrated system because the “equal drawdown” operating rule hung. Instead the following operating rule was adopted:

- **Welbedacht WTW**. Draw constantly from the Welbedacht WTW
- **Rustfontein/Knellpoort Dams**. Water is only transferred from Knellpoort to Rustfontein when Rustfontein's storage drops below 85% (or Knellpoort is full) to leave some space to capture local runoff from the Rustfontein Dam's own catchment. Once the storage in Rustfontein drops below 85% of the full capacity water is transferred from Knellpoort to Rustfontein to try to maintain the level at 85%.
- **Summer peaks**. The summer peak demand of Bloemfontein is met by increasing the supply from the Rustfontein Dam, not necessarily from increasing the transfers from the Knellpoort or Welbedacht Dams
- **Losses.** Losses at the WTW were assumed to be 10% at Welbedacht and 5% at Maselspoort near Mockes. Conveyance losses, were assumed to be 17% from Knellpoort Dam to Rustfontein Dam and 5% from Rustfontein Dam to Mockes. The losses on the pipeline from Welbedacht to Bloemfontein were not modelled

The Water Resource Planning Model (WRPM) has also been used to determine the yield of the current system as part of the Orange River Systems: Annual Operating Analysis. According to the WRPM runs, augmentation of the Bloemfontein System is only required in about 2013 / 2014 where the total demand of Bloemfontein, Botshabelo, Thaba Nchu and the small towns on the Welbedacht pipeline are about 105 million m^3/a. This “yield” is greater than the historical firm yield of 100 million m^3/a, partly because the curtailment options allow 50% curtailment at the 1:200 probability and a 20% curtailment at the 1:100 probability. If such severe curtailments were not possible because of the high proportion of unaccounted for losses (40%) the augmentation of the system might be required earlier and the apparent yield of the system would reduce. This assertion should be tested with an additional demand curtailment scenario.

After verifying the yield of the current system against the earlier yields the system was updated using more recent information, as per **Table 4.2**. The impacts of the changes have been ranked in descending order. The net result of all these changes is a reduction in the integrated system yield of 16 million m^3/a, from 100 million m^3/a to 84 million m^3/a.

Table 4.2: Adjustment of the System to Incorporate Recent Operating Information and Hydrology

Impact on Yield	Model Adjustment
-7	Implement Tienfontein Pump operation described in "Extension of the capacity of the Novo Transfer Scheme - Study (EB/2009/5) by V&V Consulting Engineers. According to this report the pumps transfer 1 m^3/s when the inflow reaches 4 m^3/s, 2 m^3/s when the inflow reaches 6 m^3/s and 3 m^3/s when the inflows reached 10 m^3/s.
-4	Replace Welbedacht's average WTW capacity of 124 Ml/d with the equivalent seasonal capacity that is lower in summer (100 Ml/d due to siltation problems) and higher in winter (145 Ml/d).
-3	Introduce 10% conveyance loss on the pipeline from Welbedacht to Bloemfontein
-3	Reduce Welbedacht live storage from 11.7 to 6.6 million m^3
-3	Replace Caledon System upstream of Welbedacht with a present day streamflow sequence developed during the Orasecom Study - kindly provided by Bennie Haasbroek. The demands downstream of Welbedacht from the Orange River System Analysis were retained while the Orasecom Study was checking why the new demands(14 million m^3/a) were significantly lower than the earlier demands (35 million m^3/a)
3	Implement Knellpoort Pump operation described in "Extension of the capacity of the Novo Transfer Scheme - Study (EB/2009/5) by V&V Consulting Engineers. According to this report the transfer varies from 1.5 m^3/s when the storage level in Knellpoort is above RL1436 m and 1.67 m^3/s at RL1452.1 m.
1	Activate direct line from Rustfontein WTW to Bloem which reduces transmission losses and allow Bloem/Welbedacht to access water in Knellpoort
1	Model 35 million m^3/a irrigation located d/s Welbedacht Dam d/s of the dam (as opposed to u/s) and release all water up to 2 m^3/s flowing into Welbedacht when Knellpoort + Rustenberg Storage > 150 Mm^3, reduce to 25% (0.5 m^3/s) when less
-16	Total net impact

Typical losses reducing the available yield from the system model are summarized in **Table 4.3**. To avoid "double accounting" the demands applied to the system need not be increased to account for these losses.

Table 4.3: Typical Losses Accounted for in the Yield Analysis

Loss Description		Magnitude	
Type	**Location**	**%**	**Million m^3/a**
WTW	Welbedacht	5%	2.3
	Maselspoort near Mockes	5%	0.6
Conveyance	Welbedacht to Bloemfontein	10%	4.5
	Novo pipeline to Rustfontein Dam	17%	6.7
	Rustfontein Dam to Mockes Dam	5%	2.5
Total			16.6

The results on which this analysis is based are summarized in **Appendix A.**

4.3 FACTORS WHICH INFLUENCE THE YIELD OF THE SYSTEM

There are a number of factors which have an influence on the available yield of the Greater Bloemfontein System and therefore will also impact on the water availability and reconciliation of supply and requirement. These factors are shown in **Table 4.4** below together with the potential consequential impact on the available system yield.

Table 4.4: Net System Yields

Factor which influences available yield	Impact of Yield (million m^3/a)
Impact of Metolong Dam. Metolong Dam which is situated on a tributary of the Caledon River will start impounding water in approximately mid-2012. This will have an impact on the flows into the Caledon River and will subsequently reduce the amount of yield available.	**-1**
Impact of Environmental Water Requirement: When the EWR requirements are implemented on the Caledon River, there will be less surplus water available to transfer to Knellpoort Dam and therefore there will be a reduction in the overall yield of the system	**-2.21**
Capacity of Welbedacht WTP: Due to the high turbidity of the raw water, especially during flood events it is not possible to operate Welbedacht WTP at full capacity throughout the year. A discussion with the operator of the WTP suggested that the WTP could operate at full capacity of 145 Ml/d in winter, but only managed an output of between 90 and 100 Ml/d in summer when the silt load in the river was higher. The yield could be increase if the WTP was operated a full capacity all year round	**+4**
Operation of Knellpoort Dam: Due to the high electricity costs of pumping surplus water from the Caledon River into Knellpoort Dam, Knellpoort Dam has in the past been operated up to a maximum capacity of approximately 60%. This operational rule would decrease the available yield of the system	**-3.3**
Risk of non supply as a result of continuous failure (bursts) on the Welbedacht pipeline:	**-6.86**

The impact of Metolong Dam and the implementation of the Environmental Water Requirements are two interventions which will be implemented in the short term. It is therefore proposed that the impact on the yield of these two interventions is factored into the scenario planning and should ultimately form the baseline available yield. For planning purposes the historical firm yield of the system with these interventions in place was therefore assumed to be 81 million m^3/a.

5. WATER REQUIREMENTS

5.1 EXISTING URBAN WATER REQUIREMENTS

Mangaung Metropolitan Municipality purchases approximately two thirds of its potable water form Bloem Water. **Table 5.1** below shows the amount of bulk water which was supplied from the Bloem Water System and from MMM's own sources for the period 2008 through to 2011. From **Table 5.1** it is evident that the water supplied to smaller towns accounts for only 4% of the total bulk water consumption.

Table 5.1: Metered Bulk Water Consumption for Towns Supplied with Water from the Greater Bloemfontein System (Excluding Groundwater)

Year/Supplier	2008			2009			2010			2011		
	BW	MMM	Total	BW	MMM	Total	BW	MMM	Total	BW	MMM	Total
Town	Million m³/a			Million m³/a			Million m³/a			Million m³/a		
Bloemfontein	40.66	20.31	60.97	35.83	30.13	65.97	37.1	27.71	64.82	37.91	22.72	60.63
Botshabelo	8.18		8.18	9.21		9.21	7.87		7.87	10.06		10.06
Thaba Nchu	5.14		5.14	4.64		4.64	6.04		6.04	6.3		6.3
Excelsior	0.17		0.17	0.16		0.16	0.19		0.19	0.17		0.17
Wepener	0.80		0.80	0.82		0.82	0.75		0.75	0.74		0.74
Dewetsdorp	0.84		0.84	0.92		0.92	0.96		0.96	0.76		0.76
Reddersburg	0.85		0.85	0.86		0.86	0.69		0.69	0.43		0.43
Edenburg	0.53		0.53	0.53		0.53	0.53		0.53	0.43		0.43
Total	**57.19**	**20.31**	**77.48**	**52.97**	**30.13**	**83.11**	**54.13**	**27.71**	**81.84**	**56.80**	**22.72**	**79.52**

Smaller towns, by Contractual Agreement, receive between 70 and 80% of their total annual consumption from Bloem Water, with local groundwater supply making up the balance. A summary of the total bulk water consumption for small towns (including groundwater) located within the Primary Study Area is provided in **Table 5.2**.

Table 5.2: Summary of Current Groundwater Supplied to Smaller Towns Year 2011)

Town	Supply from BW (a)	Estimated Groundwater Supply (Million m³/a) (b)	Estimated Average Yield of Existing Boreholes (Million m³/a) [1]	Number of Boreholes	Estimated Total Annual Consumption (a + b)
Excelsior	0.17				0.17
Wepener	0.74		0.071	4	0.74
Dewetsdorp	0.76		0.080	4	0.76
Reddersburg	0.43	0.29	0.160	9	0.72
Edenburg	0.43	0.10	0.213	12	0.53

Figure 5.1 below shows the bulk water supplied from the Greater Bloemfontein System from 1992 through to 2011. With the exception of the period 1999 through to 2001 and the last two years there has been a year on year positive growth in water requirement. **Figure 5.2** below shows the rainfall which was

[1] *It should be noted that the estimated scheme yields were calculated by using the average sustainable yields of the Karoo geology well fields of Petrusburg / Bolokanang, Edenville / Ngwathe, and Ikgomotseng for all the groundwater interventions.*

measured at Rustfontein Dam and at the Bloemfontein Zoo. Whilst this rainfall station is located some 20 km form the metropolitan town itself it does illustrate that there is a potential correlation between rainfall and water requirement. This is particularly noticeable in 2002 and 2011.

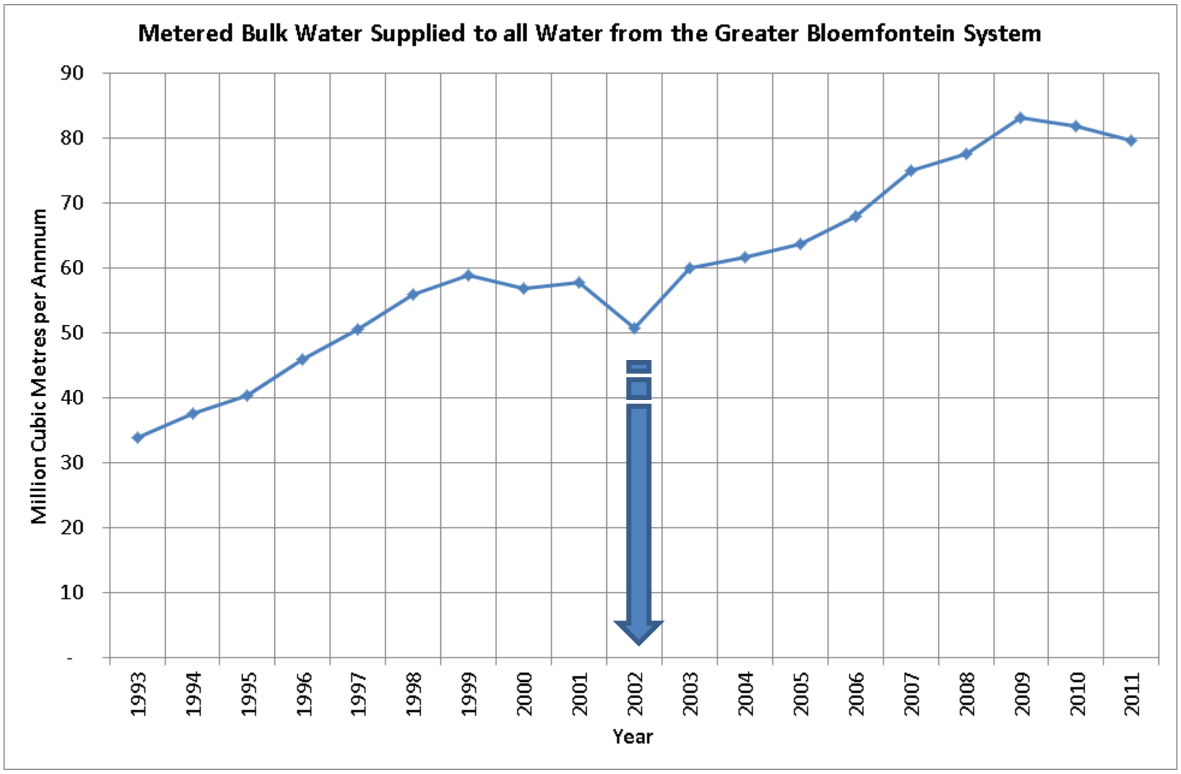

Figure 5.1: Metered Bulk Water Supplied from the Greater Bloemfontein System

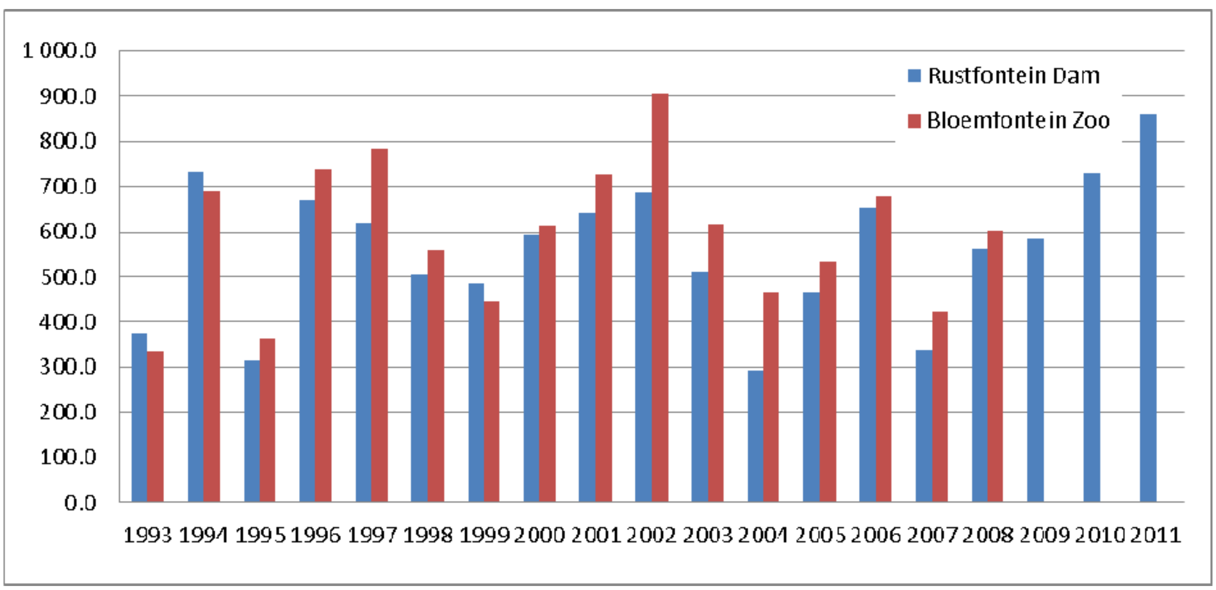

Figure 5.2: Rainfall Data

The following is noted with regard to the historical water consumption for Bloemfontein and surrounds since 1993:

- **Period of 1993 to 1999**: An average annual increase in water consumption of approximately 9% per annum possibly triggered by an improvement in levels of service and delivery of basic services through the Government's various infrastructure programs. In addition, a significant number of people from surrounding areas (urban and rural centres) relocated to Bloemfontein for employment and other economic opportunities.
- **Period of 2003 to 2009:** An average annual increase in water consumption of approximately 5.8% per annum. This could possibly be attributed to a growth in local economy, supported by an improvement in levels of services in the poorer communities through various government projects like the eradication of the bucket system, provision of on-site water projects, and numerous low income housing projects.
- **Period of 2010 to 2011:** A decrease in water requirement possibly due to above average rainfall in the two years, and also potentially the implementation of Water Conservation / Water Demand Management.
- The average long term growth rate in the water requirement for the period **1993 through to 2011** (18 year period) was 5% per annum.

The 2010 population in the Bloemfontein, Botshableo and Thaba Nchu area of supply is estimated to be 630 000 people. The population for the full supply area including the smaller towns is estimated to be 720 000 people.

Figure 5.3 below shows the annual system input volume of MMM (bulk purchases from Bloem Water as well as Maselspoort production) as well as the authorised consumption. The difference between the bulk water purchases and the authorised consumption (billed authorised and unbilled authorised) represents the apparent and real losses in the system. The losses and future potential water savings of MMM are discussed in more detail in **Section 7.5.1** of this Report.

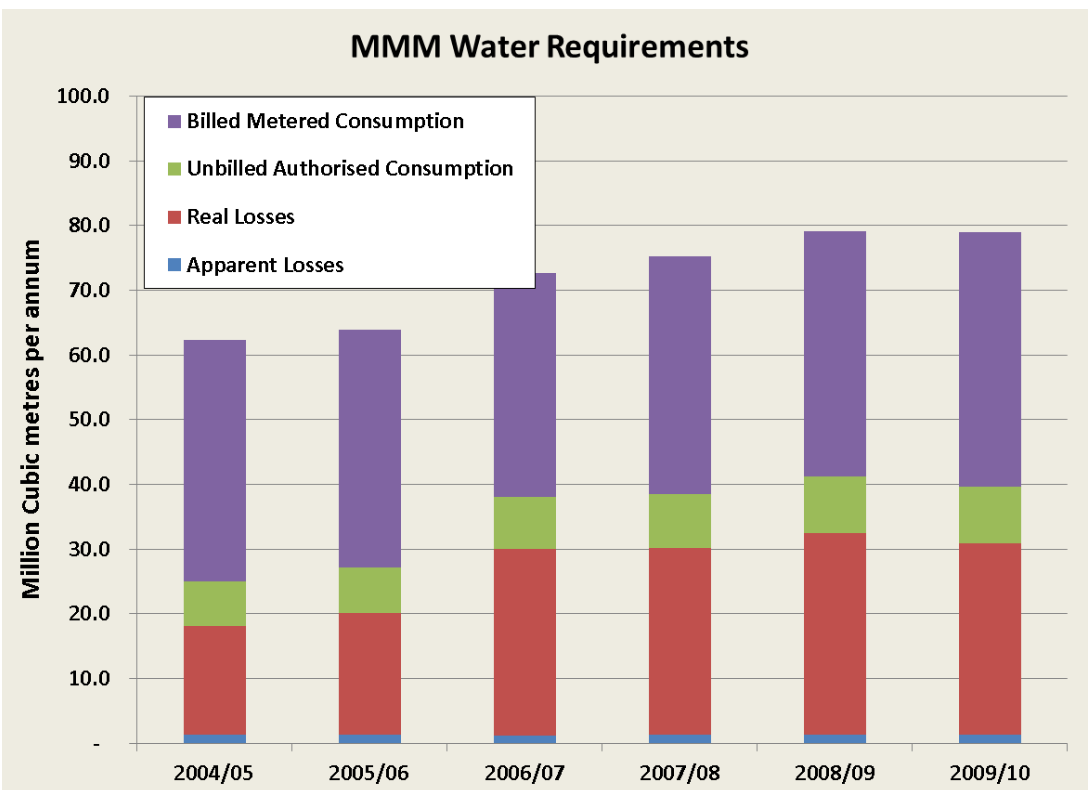

Figure 5.3: MMM Water Consumption

The following conclusions can be drawn from **Figure 5.3:**

1) Losses have increased significantly since 2006.
2) The real and apparent losses in the system are 30 million m^3/a. This represents approximately 37.5% of the annual system input volume.
3) Authorised water consumption has been growing at an average rate of 3% per annum over the period 2007 through to 2010 and on average by 1.7 % over the period 2005 through to 2010.

5.1.1 Breakdown of Urban Consumption

Figure 5.4, Figure 5.5 and **Figure 5.6** provide a breakdown of potable water use as derived from the 2006/07 Water Service Development Plan for Bloemfontein, Botshabelo, and Thaba Nchu. More recent figures were unfortunately not available. In the Bloemfontein area, “unaccounted for water” constitutes 39% of the total annual consumption. The second largest water consumption, accounting for 37% of the total annual consumption, is “residential use”. Thirteen percent of the water is used for commercial purposes, 8.5% is classified as other, and 2% for industrial water.

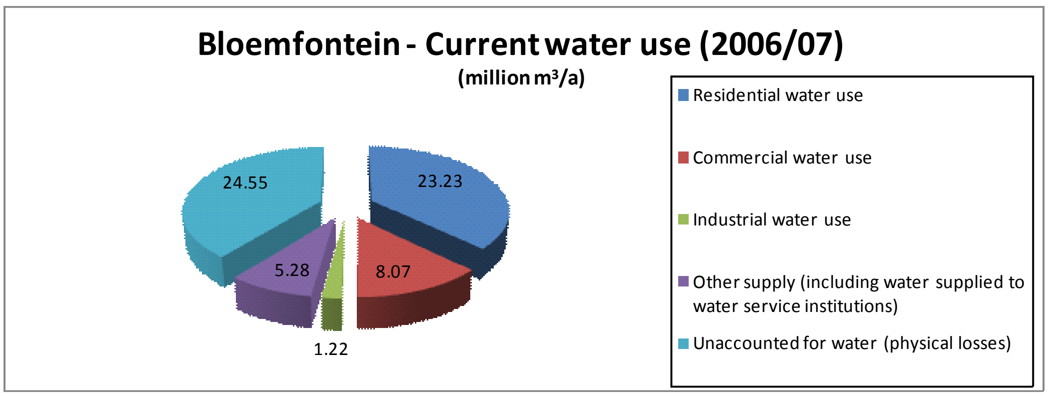

Figure 5.4: Current Water Use for Bloemfontein

In Botshabelo, the largest proportion of the current water use is residential use, representing 40.5% of the total use. “Unaccounted for water” comprises 31% of the total metered bulk water supplied. Commercial use accounts for 20% and other supply accounts for 8%.

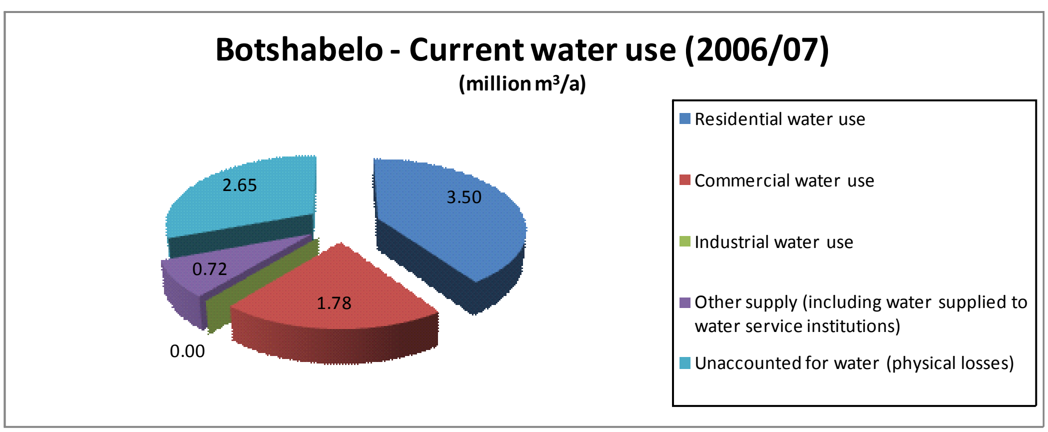

Figure 5.5: Current Water Use for Botshabelo

In Thaba Nchu, physical losses (unaccounted for water) accounts for 94% of the total water use, while residential and commercial use accounts for 3.5% respectively.

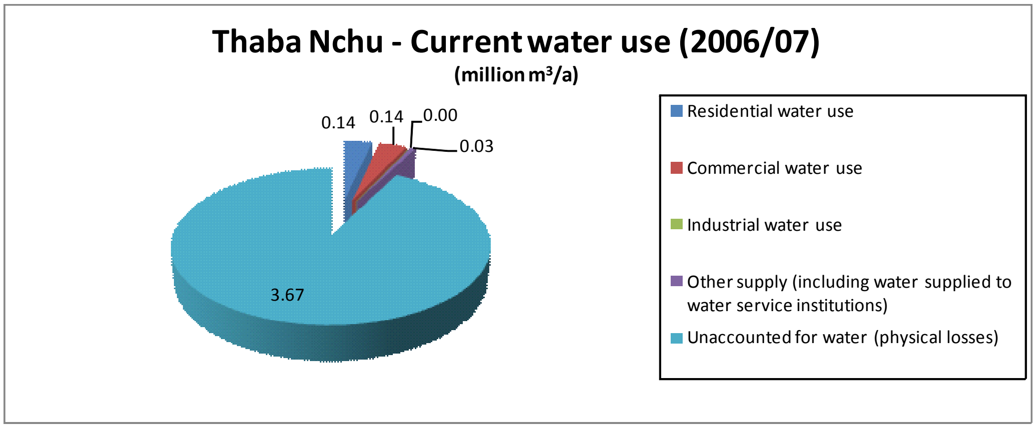

Figure 5.6: Current Water Use for Thaba Nchu

5.1.2 Agricultural Water Requirements

For the purposes of this study, agricultural water requirements were considered in two catchments, namely in the Modder-Riet Catchment upstream of Krugersdrift Dam and along the Caledon River. These catchments were selected as they overlap with the catchments from which Bloem Water and MMM abstract water for potable use.

Figure 5.7 shows the registered water use and resource allocation in the quaternary catchments surrounding the Greater Bloemfontein Area. Based on the allocations to the different water sectors (agriculture and urban) from the different sources of water (surface, groundwater, and scheme) it is evident that the two sectors do not share any allocation from dams situated within the Modder-Riet Catchment upstream of Krugersdrift Dam. For example, in quaternary catchment C52J, the registered agricultural use is 49 million m^3/a, and urban use is 1.3 million m^3/a. 46.1 million m^3/a is abstracted from boreholes, 1.89 million m^3/a is abstracted from schemes, and 0.1 million m^3/a is abstracted from rivers (run-of-river). As there are no towns within this catchment, one can assume that most of the groundwater, water provided by schemes, and run-of-river abstraction is used for agricultural purposes.

In terms of the yield modelling of the Welbedacht/Knellpoort System, the existing agricultural water requirements along the Caledon River, both upstream and downstream of Welbedacht Dam, and the proposed water requirements of the resource poor farmers, were taken into account.

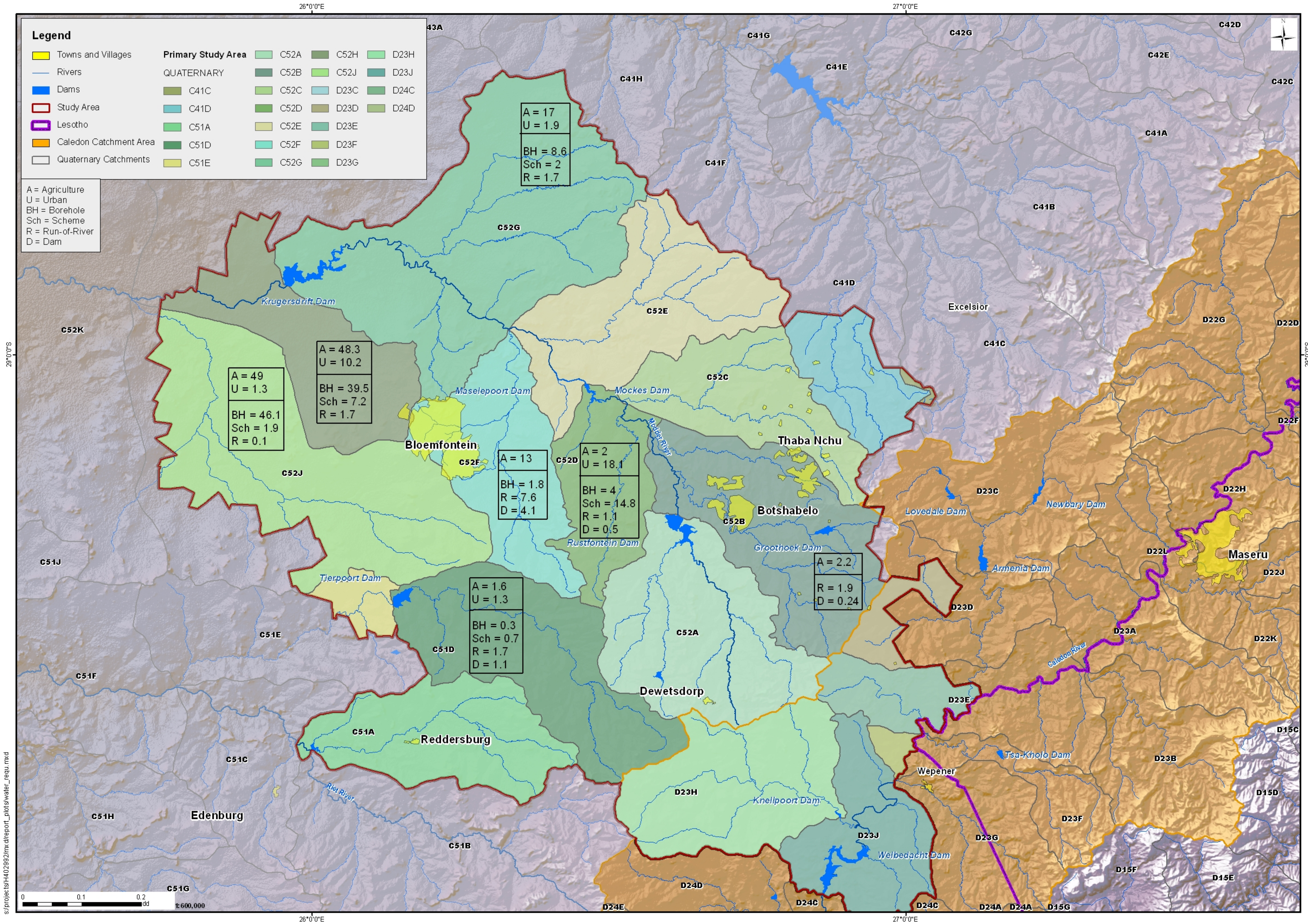

Figure 5.7: Registered Water Use and Resource Allocation Million m³/a in the Quaternary Catchments Surrounding the Greater Bloemfontein Area

5.1.3 Environmental Water Requirements

The work presented in this Report for the Environmental Water Requirements on the Caledon River formed part of study: *Support to Phase II ORASECOM Basin Wide Integrated Water Resources Management Plan.* The main objective of the Environmental Flow requirements (EFR) component of the work was to assess EFRs at selected key areas of the Orange River Basin at an Intermediate Level (DWA RSA criteria). Two EFR sites on the Caledon River were included (see **Figure 5.8**).

Approach

The scoping study for the ORASECOM study (Louw *et al.*, 2010) provided the 'hotspots' which indicated the areas where detailed information, i.e. in this case, detailed EFR studies would be required. The main rivers within these areas were then selected and delineated into Management Resource Units (MRUs) (Louw, 2010). These Resource Units indicate an area for which an EFR will be relevant. Once EFR sites have been selected, field surveys are undertaken at the EFR sites and hydrology is produced for the sites. This leads to the determination of the EcoClassification of the EFR sites and the setting of flow regimes to maintain different ecological states. The table below shows the locality of the EFR sites within the MRUs.

Table 5.3: Locality and Characteristics of EFR Sites on the Caledon River

EFR site number	EFR site name	River	Decimal degrees S	Decimal degrees E	EcoRegion (Level II)	Geozone	Altitude (m)	MRU	Quaternary catchment
EFR C5	Upper Caledon	Caledon	-28.6508	28.3875	15.03	Lower Foothills	1640	MRU Caledon A/B	D21A
EFR C6	Lower Caledon	Caledon	-30.4523	26.27088	26.03	Lowland	1270	MRU Caledon D	D24J

EcoClassification

The result of EcoClassification is shown below for the Caledon EFR sites (Louw and Koekemoer, 2010). EcoClassification refers to the determination and categorisation of the PES (health or integrity) of various biophysical attributes of rivers compared to the natural (or close to natural) reference condition. The state of the river is expressed in terms of biophysical components:

Drivers (physico-chemical, geomorphology, hydrology), which provide a particular habitat template; and
Biological responses (fish, riparian vegetation and aquatic invertebrates).

Different processes are followed to assign a category (A→F; A = Natural, and F = critically modified) to each component. Ecological evaluation in terms of expected reference conditions, followed by integration of these components, represents the Ecological Status or EcoStatus of a river. A general description of the Ecological Categories A to F is provided in **Table 5.4**.

Table 5.4: Summary of Ecological Categories

Ecological Category	Description
A	Unmodified, natural.
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Ref: Kleynhans 1999

Table 5.5: Eco-Classification Results for EFR Sites on the Caledon River

EFR C5 (UPPER CALEDON)

EIS (Ecological Importance and Sensitivity): LOW.
Highest scoring metrices are rare and endangered riparian species, instream biota taxon richness, and sensitive instream habitat (to flow changes).

PES (Present Ecological State): C/D
Grazing and trampling, bank erosion, sedimentation, exotic vegetation and fish species.

REC (Recommended Ecological Category) :C/D
EIS is low - provides no motivation for improvement. The problems are also all non-flow related.

AEC ↓ (Alternate Ecological Category Down): D
Decreased flows due to increased abstraction. Reduced dilatation - impact temperature and oxygen. Increased sedimentation (continued erosion). Habitat loss for a large percentage of time. Vegetation – increased sedges due to increased sedimentation.

Driver Components	PES	Trend	AEC↓
IHI HYDROLOGY	A/B		
WATER QUALITY	B/C		C
GEOMORPHOLOGY	C	-	C/D
INSTREAM IHI	B/C		
RIPARIAN IHI	C		
Response Components	**PES**	**Trend**	**AEC↓**
FISH	D	0	E
MACRO INVERTEBRATES	C	0	C/D
INSTREAM	D	0	D
RIPARIAN VEGETATION	C	0	C
ECOSTATUS	C/D		D
EIS	LOW		

<table>
<tr><th colspan="2">EFR C6 (LOWER CALEDON)</th></tr>
<tr><td>EIS: LOW
The highest scoring matrices are rare and endangered riparian species.

PES:C
Sedimentation (bank erosion), significantly reduced base flows, alien fish species.

REC:C
EIS is low - provides no motivation for improvement.

AEC ↑: B/C
Bottom releases must take place during the wet season and not during low flow conditions. Low flows must be improved. No zero flows or limited duration.</td>
<td>
<table>
<tr><th>Driver Components</th><th>PES</th><th>Trend</th><th>AEC↑</th></tr>
<tr><td>IHI HYDROLOGY</td><td>E</td><td></td><td></td></tr>
<tr><td>WATER QUALITY</td><td>C</td><td></td><td>C(+)</td></tr>
<tr><td>GEOMORPHOLOGY</td><td>C/D</td><td>0</td><td>C</td></tr>
<tr><td>INSTREAM IHI</td><td colspan="3">E</td></tr>
<tr><td>RIPARIAN IHI</td><td colspan="3">B/C</td></tr>
<tr><th>Response Components</th><th>PES</th><th>Trend</th><th>AEC↑</th></tr>
<tr><td>FISH</td><td>D</td><td>0</td><td>C</td></tr>
<tr><td>MACRO INVERTEBRATES</td><td>D</td><td>0</td><td>C</td></tr>
<tr><td>INSTREAM</td><td>D</td><td>0</td><td>C</td></tr>
<tr><td>RIPARIAN VEGETATION</td><td>B</td><td>0</td><td>B</td></tr>
<tr><td>ECOSTATUS</td><td>C</td><td></td><td>B/C</td></tr>
<tr><td>EIS</td><td colspan="3">LOW</td></tr>
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Flow requirements

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O'Keeffe *et al*., 2004), a modification of the Building Block Methodology (BBM; King and Louw, 1998) was used to determine the low (base) flow EFRs. This method is one of the accepted methods applied to determine EFRs at an Intermediate level. The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM.

A summary of the final flow results are provided below as a percentage of the natural Mean Annual Runoff (nMAR) and the volumes.

Table 5.6: Summary of Results as a Percentage of the Natural MAR

EFR Site	EC	Maintenance Low Flows		Drought Low Flows		High Flows		Long Term Mean	
		(%nMAR)	MCM	(%nMAR)	MCM	(%nMAR)	MCM	(% nMAR)	MCM
Virgin MARs									
EFR C5	PES/REC: C/D	13.8	7.85	5.8	3.30	11.4	6.49	26	14.80
EFR C6	PES/REC: D	8.8	118.62	0.3	3.40	10.5	141.54	20.1	270.94
	AEC↑: C	15.5	208.93	2.2	29.66	13.1	176.58	26.1	351.82

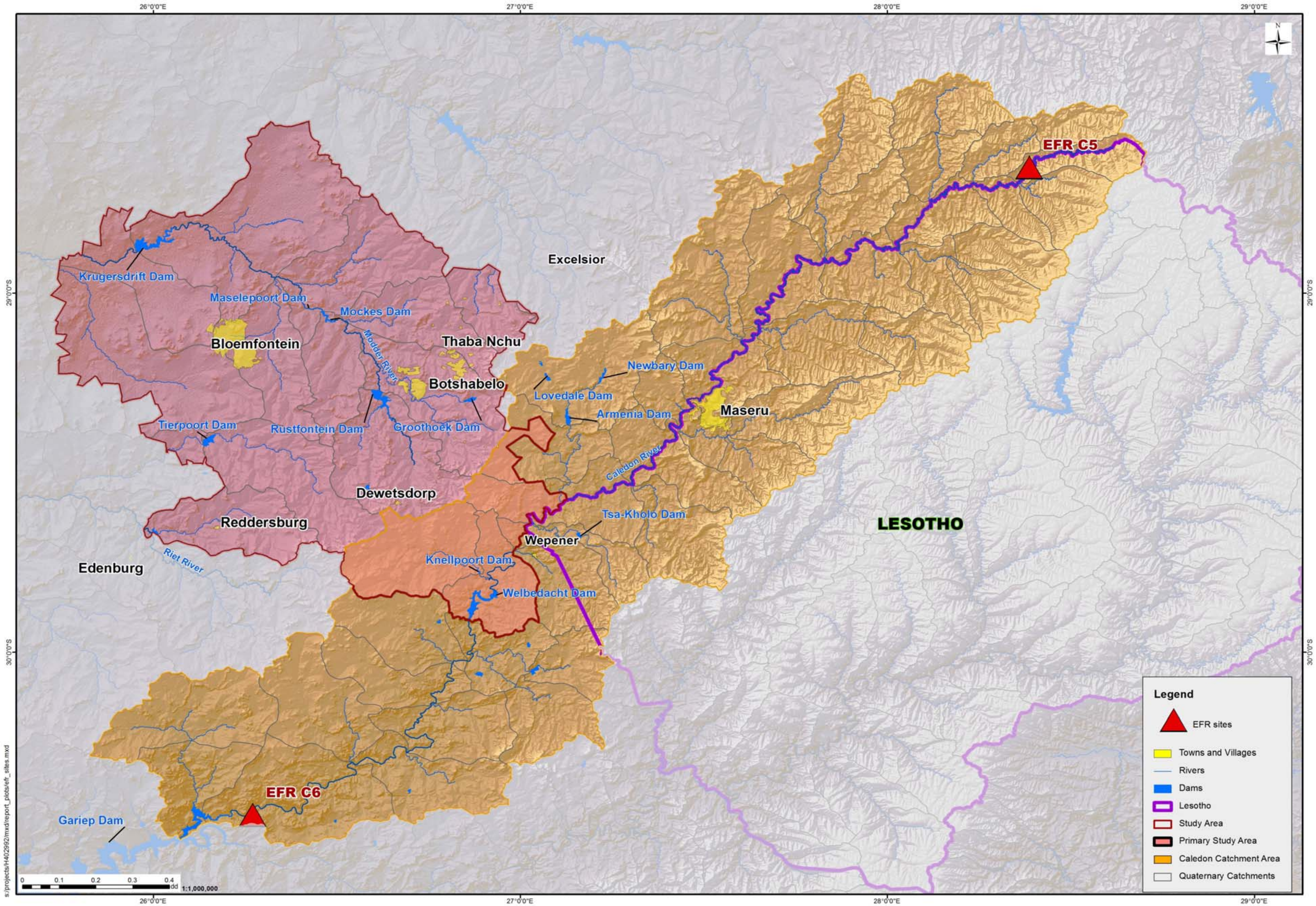

Figure 5.8: Location of the EFR sites

5.2 FUTURE WATER REQUIREMENTS

5.2.1 Understanding growth in water requirements

The prediction of water requirements for master planning purposes, or for a study of this nature, is usually based on the primary drivers of water demand, which are population growth and local economic growth. These two factors are interlinked to some extent, as economic growth may stimulate population growth as a result of migration from the rural areas or other urban area with a poor economy. There are also numerous other factors that can impact future water requirements, and specifically for the Greater Bloemfontein area, these may include:

- Change in the level of service, as improvements in the water services, sanitation, and health awareness will most likely impact on future requirement scenarios. Typical initiatives in the study area include the eradication of water and sanitation backlogs linked to the UN Millennium Goals, as well as the delivery of houses to the poor to meet SA National target with regard to housing.
- The impact of HIV/AIDS is a significant factor, with the highest occurrence in the rural areas of South Africa.
- Improvement in water management in terms of water meter coverage, the extent and accuracy of meter reading and billing, and the effectiveness of credit control policies.

The historic growth in water requirement has not been consistent, and has fluctuated quite significantly. The water growth has included periods of negative or relatively flat growth possibly as a result of above average rainfall being experienced in these specific years.

There are uncertainties, however, associated with the future population growth rate figures as described below.

5.2.2 Population Growth Rates

Population growth rates are based on the birth rate, mortality rate, and migration. The following sources and references were found which described the historic and possible future population growth rates.

- Information taken from the IDP report 2007/2008 for Mangaung Metropolitan Municipality indicates that the future population growth rate for Bloemfontein will be 3.1% per annum. The growth in population between 1996 and 2001 based on 2001 Census figures for the Bloemfontein areas was estimated to be 3.1% per annum.
- A report entitled “Identification of Bulk Engineering Infrastructure in Support of Housing Development in Mangaung” which was a masterplan prepared for Mangaung Metropolitan Municipality determined that the anticipated population growth figures for Bloemfontein up to 2030 would be 1% per annum.
- Population projection scenarios were also developed for the All Towns study for Central Region (June 2009). The high population growth scenario translates to an aggregate population growth rate for Bloemfontein, Botshebelo and Thaba Nchu of 1% per annum, whilst the low population growth scenario translates to an aggregate population growth rate of 0% per annum.
- Migration is proportional to economic growth rate, implying a strong economic growth will result in “immigration” whereas a decline in economic growth will result in “emigration”. Migration figures that could be relevant to the study area were sourced from Provincial trends as abstracted from the “2009 StatsSA Mid-Year Projections for the Orange Free State Province (2006 to 2011 Projection)”. Migration affects the rural and smaller towns more significantly, as a result of people seeking economic and employment opportunities in the larger urban centres. Migration is assumed to vary between 0.00% and 0.25% for Bloemfontein and Botshabelo, assuming more people migrating to, and residing in these towns. For the smaller towns with less economic opportunity, the migration

rates vary from between -0.4% and 0.0%. The assumption is that current residents could be leaving the smaller towns to reside and seek opportunities in the larger centres.

- The impact of HIV/AIDS is a significant factor when estimating population projections, and more specifically, its influence on the mortality rate. The impact of HIV/Aids relevant to the Study area has been based on National statistics, where the highest occurrence is in the rural areas of South Africa. The mortality rate as a result of HIV/Aids has been assumed to be as high as 0.4% for the urban towns, and as high as 0.75% for the rural towns and villages.

5.2.3 Economic Growth Rates

Bloemfontein is currently the largest urban centre, followed by Botshabelo and Thaba Nchu and most public and private investment will be in these areas. The latest Integrated Development Plan (IDP) projects that Bloemfontein will remain the focus for future development as it is predicted that Bloemfontein will house approximately 65% of the total population by 2016.

The economy of the MMM plays a significant role in the Motheo District economy (92,5%) as well as the Free State economy (25,5%), but it is relatively small when compared to the national economy (1,6%).

Of importance is the relatively small share of the local agriculture, mining and manufacturing sectors compared to the province and the country. Mining's small share is understandable as the Mangaung area competes with the Goldfields area, which is very strong in mining, however the share of agriculture and manufacturing is disturbingly low. On the other hand, the tertiary sector of the local economy is very significant within the context of the province.

Approximately 87% of economic production in the MMM area occurs in Bloemfontein while only 7% and 6% respectively occur in Botshabelo and Thaba Nchu.

The overall annual economic growth rate for the Mangaung area was 3.59% between 2001 and 2004 and a significantly higher growth of 9.5% occurred between 2004 and 2007. In Bloemfontein an economic growth rate between 2004 and 2007 of 9.86% was recorded compared with 8.55% in Botshabelo, while that of Thaba Nchu was considerably less at 5.08% per annum. This confirms the fact that the Bloemfontein economy is and will be increasing its proportional share of the economy.

While community services contribute to over a third of Mangaung's economy, other prominent sectors include finance, retail and trade, transport, and manufacturing. The remaining sectors such as agriculture and mining are very small and make a minor contribution to the local economy. Community services contributes 35% to the city's economy, transport 13%, finance 18%, agriculture 4%, manufacturing 8%, trade 16%, utilities 3% and construction 3%.

Growth in the transport sector, given the strategic central location of Bloemfontein, is likely to be stimulated by increasing economic activity elsewhere in the country.

5.2.4 Future Water Requirement Scenarios

The following assumptions were made for the development of the future water requirement scenarios from the Greater Bloemfontein Water Supply System.

- **High Growth Water Requirement Scenario** will take place on account of high population growth rate and high economic growth rates. Given the relatively low population projection growth rates and the contrasting relatively high historic growth in water requirements (the authorised billed and unbilled water consumption figures for the last 3 years have grown at a rate of 3% per annum) it was decided to use long term historical growth rate of 3% per annum as the basis for the high growth scenario.

- **Low Growth Water Requirement Scenario** will take place on account of low population growth and low economic growth. It was decided to base the low growth scenario on a growth in water requirement of 1% per annum.

Figure 5.9 presents the proposed high and low water requirement scenarios. The actual water requirement is also shown on the graph. The high and low water requirement projections have been projected from the 2009 base for the following reasons:

- There were significant summer rains in the 2011 and this may have resulted in a depressed demand.
- It is still too early to ascertain whether or not the drop in 2010 can be ascribed to structural reasons (e.g. improved metering, WC/WDM) or is as a result of climatic influences.
- It is conservative to plan from a higher base. As future years actual water requirements become known, the base from which the projections are made can always be changed and the implementation date of every intervention moved out (this is easier than moving implementation dates forward.).

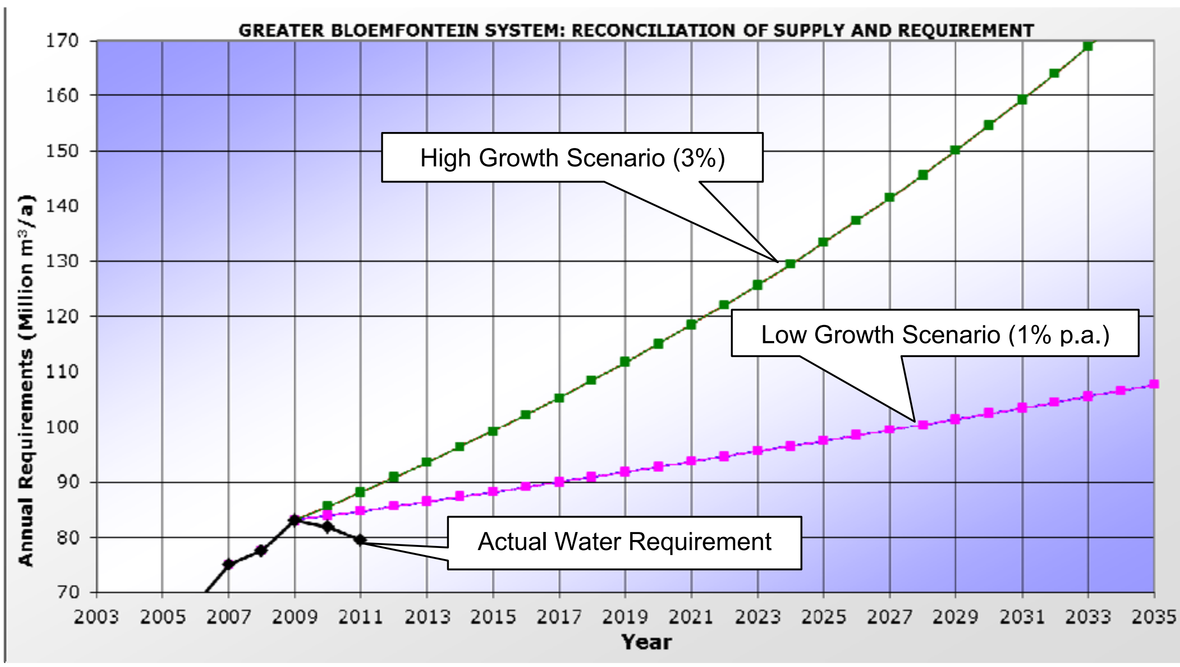

Figure 5.9: Water Requirement Scenarios for the Study Area

Important qualification

It is important to note that the water requirement scenarios presented above were developed during a global economic crisis. The global recession and a slow recovery from this recession are likely to have significant implications for water requirement growth projections for the Greater Bloemfontein Water Supply System.

The implications of the recession for the strategy to meet future water requirements are as follows:

- The economic uncertainty increases uncertainty concerning the growth in water requirements.
- Water use must be continuously and carefully monitored;

- Future scenarios/projections need to be revised frequently, based on updated information;
- Planning to increase water availability needs to be as flexible as possible; and
- Interventions that are more flexible in terms of timing should be favoured, all other considerations being equal.

5.2.5 Agricultural Water Requirements

The only expected growth in irrigation requirements is the allocation of 12 000 ha to resource poor farmers. The effect of the 12 000 ha (4 000 ha for the Upper Orange, 4 000 ha for the Lower Orange, and 4 000 ha for the Fish-Tsitsikamma WMA) is estimated to be in the region of 114 million m^3/a. The Implementation Strategy for the development of 3 000 ha irrigation in the Free State Province indicates that there is ± 200 ha available near Ficksburg (Caledon River) and ± 2 000 ha available next to the Orange-Riet Canal, which starts at the Vanderkloof Dam. The agricultural water requirement for the 200 ha near Ficksburg will be taken into account in the determination of the available yield.

6. COMPARISON OF REQUIREMENTS AND AVAILABILITY

The anticipated surplus yield in the Orange River System (including the Caledon River) is approximately 44 Mm³/a. According to the Internal Strategic Perspective for the Upper Orange River, this surplus is reserved for the growth in demands in the urban, industrial, and mining sectors in the Upper Orange, the Lower Orange, and the Fish to Tsitsikamma WMA.

It is not anticipated that there will be any further growth in agricultural water requirements in the Greater Bloemfontein Area (with the exception of the possible allocation made to the resource poor farmers). As the agricultural sector and urban sector in the Greater Bloemfontein Area and surrounds do not share any yield from a common surface water resource, it is possible to undertake a reconciliation of supply and requirement based on the current urban water requirements and available yield of the surface water schemes serving the Greater Bloemfontein area and surrounds.

Figure 6.1 illustrates the comparison of available surface water supply and current water requirements for the High and Low water requirement scenarios in the Greater Bloemfontein Area. The current water requirement (based on 2009 data) is approximately 83 million m^3/a while the available supply is 84 million m^3/a (Historical Firm Yield).

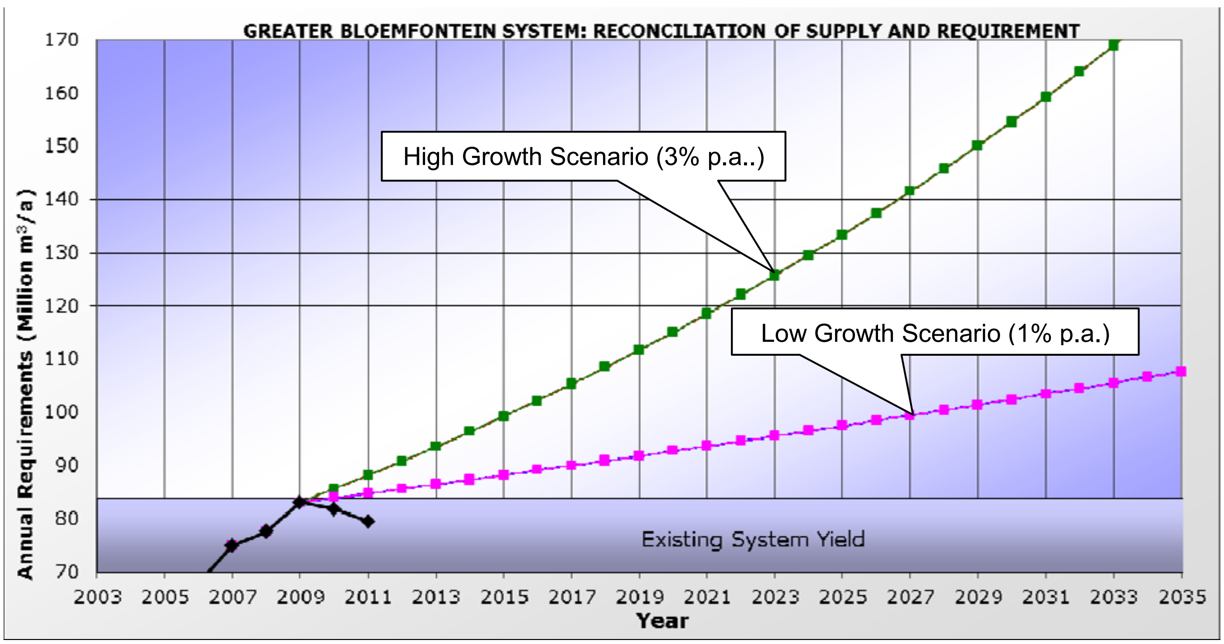

Figure 6.1: Surface Water Balance for Study Area

It appears that the 2009 water requirement was in balance with available supply (historical firm yield) and any increase in use (as predicted by the high and low water requirement scenarios) would put the system at risk. The higher the growth in water requirements, the higher the risk would be. It is clear that measures to increase the surety of supply need to be implemented as soon as possible. This includes measures to increase the supply of water as well as WC/WDM measures to reduce the demand.

7. INTERVENTIONS

Following the determination of the water balance, the Strategy followed a step-wise process to identify the most favourable interventions, or groups of interventions, to meet possible future water requirement scenarios. The reconciliation strategy process is listed below:

Step 1: Identification of interventions
Step 2: Preliminary screening of interventions
Step 3: Key stakeholder review of selected interventions
Step 4: Scenario planning process
Step 5: Review of selected scenarios by the Study Steering Committee[2]
Step 6: Obtaining public feedback on the scenarios
Step 7: Implementing interventions and initiating studies of interventions

7.1 IDENTIFICATION OF INTERVENTIONS

Thirty-four potential interventions which could contribute to meeting the future water requirements were initially identified (**Step 1**). These interventions include those that have been identified in previous and on-going studies and some of which are newly formulated interventions developed collaboratively through the Preliminary Screening Workshop and Study Management and Study Steering Committee Meetings. The following categories of interventions were identified:

- Urban and agricultural Water Conservation and Water Demand Management (WC/WDM);
- Groundwater interventions;
- Re-use of treated effluent;
- Optimising the efficiency of surface water transfer schemes;
- Surface water interventions;
- Trading of water use authorisations; and
- Other options, such as re-use of mine water and alternate storage in the Caledon River.

Interventions that could potentially be implemented within the planning period were selected. These selected interventions were then compared with each other to determine in which order they should be implemented. A Preliminary Screening Document was compiled and discussed at a workshop of stakeholders. A brief description of the interventions is given in **Table 7.1** below.

[2] The **Study Steering Committee** includes representatives from DWA Head Office and DWA Regional Office, Mangaung Metropolitan Municipality, Motheo District Municipality, Naledi Municipality, Bloem Water, Department of Agriculture, Department of Rural Development and Land Reform, and water user associations.

Table 7.1: Interventions Identified in the Preliminary Screening Document

Potential Intervention	Brief Description
Urban Water Conservation and Water Demand Management Interventions	
A1 - Efficient use of water	Improved efficiency of water intensive household appliances, bathroom fittings and focus on water efficient gardens.
A2 - Loss management	Improved loss management in reticulation systems and through billing, leak detection and repair.
Agricultural Water Conservation and Water Demand Management Interventions	
B1.1 - River release management	The timing of irrigation releases from storage dams and the subsequent timing of the uptake downstream is critical to avoid “missing the boat”.
B1.2 - Irrigation Practices	Limited opportunity to firstly, save water (efficient systems already in place) and secondly, to return any saved water to the system, as farmers tend to develop utilizing the water savings they have achieved.
B1.3 - Irrigation Canal Losses	Canal losses of up to 30% have been determined but costs to undertake refurbishment are high. This may not be affordable to the irrigation sector, which is accustomed to inexpensive water.
B1.4 - Farm Dam Losses	Opportunities to line farms dams may offer a benefit but this may not be affordable to the landowner.
B1.5 - Crop Selection	Crop types must be selected to match the soil conditions and water availability, as well as economic viability. Planting low value “thirsty” crops in water scarce areas should be avoided.
B1.6 - Crop Deficit Irrigation	Introduces controlled water stress but requires meticulous monitoring of soil moisture content, well-designed irrigation systems and proper management of pruning and fertilizing.
B1.7 - Metering	Includes the need to meter irrigation releases from source to abstraction to field application. Effective management and efficient water use can only be informed through metering.
Surface Water Interventions	
C1 - Utilising surplus capacity in Orange River by pumping to Knellpoort Dam from Gariep Dam	Surplus could be obtained from utilizing existing dead storage in Gariep Dam (changing operating rules) or via a dam raising of 5-10 m.
C2 - Utilise surplus capacity in Orange River system by pumping to Knellpoort Dam from Vanderkloof Dam	Surplus could be obtained by amending the operating rules of Vanderkloof Dam to access the existing dead storage volume below the existing canal (bottom) inlets.
C3 - Utilise surplus capacity in Orange River system by pumping to Knellpoort Dam from Bosberg/Boskraai Dam	Surplus capacity in the Orange River could be utilized through the construction of two new dams on that river (Bosberg and Boskraai Dams) and then pumping water to Knellpoort Dam.
C4a - Modifications to Welbedacht Dam : Extend scour operations	This option would involve maintaining the available yield from the Welbedacht Dam through extending the scour operation at the dam.
C4b - Modifications to Welbedacht Dam : Lower gates	This would involve lowering of the existing bottom gates at Welbedacht Dam to make better use of the available storage in the dam.
C5a - Modifications to Knellpoort System : Increased abstraction capacity of Novo Pumpstation	Increased abstraction could be considered from Caledon River for transfer to Bloemfontein via the existing Novo Transfer Scheme (owned and operated by Bloem Water).
C5b - Modifications to Knellpoort System : Raising of Knellpoort Dam	The raising of the dam could yield a maximum additional annual volume of about 1,3 million m^3/a.

Potential Intervention	Brief Description
C5c - Modifications to Knellpoort System : Increase capacity of Tienfontein pumpstation	An increase in the capacity of the existing Tienfontein Pumpstation (3 m^3/s) by a further 1 to 3 m^3/s would yield an additional amount of between 12,5 and 27 million m^3/a.
C5d - Modifications to Knellpoort System : New pump station at Welbedacht Dam	A new pumpstation at Welbedacht Dam of between 0,7 and 1,6 m^3/s could yield an additional supply of between 18 and 39 million m^3/a.
C5e - Modifications to Knellpoort System : Combination of options	Combinations of the above options could yield up to an additional amount of 67 million m^3/a.
C6 - Polihali Dam Lesotho Highlands Phase 2	LHWP (Phase II) – this includes the potential Polihali Dam (163 m high) and gravity tunnel to Katse Dam. From here water would be transferred via the existing Transfer and Delivery tunnels. Potential additional yield would be 14,75 m^3/s (465 million m^3/a)
Water Re-use Interventions	
D1 - Planned direct reuse - new North Eastern WWTW	A new WTW at the new North Eastern WWTW, from where the treated water could be pumped to the existing reservoir at Maselspoort. Estimated yield of 10,8 million m^3/a (30 Ml/d).
D2 - Planned indirect reuse - Transfer to upstream of Mockes Dam	Abstraction at the new North Eastern WWTW, and pumping to a stream feeding the existing Mockes Dam. The WTW at the Maselspoort Weir would be extended. Yield as above.
D3 - Treated indirect re-use - Krugersdrift Dam	Treating surplus surface runoff which accumulates in the dam and pumping the treated water back to the main Bloem Water reservoir at Brandkop. A booster pump station 35 km rising main to Bloemfontein is also required. The yield would be about 10,8 million m^3/a (30 Ml/d). .
D4 - Planned direct re-use - Bloemspruit	Treated wastewater from the Bloemspruit WWTW would be purified and pumped over 3.8 km into the Greater Bloemfontein supply area after blending. The estimated yield would also be about 10,8 million m^3/a (30 Ml/d).
D5 - Re-use of treated effluent - Direct use: Irrigation	The direct use of treated wastewater from any WWTW via a dedicated additional distribution system in the city for “in-city” irrigation purposes or extended to agricultural and industrial uses. A reuse volume of about 6.5 Ml/day is possible.
Groundwater Interventions	
E1 - Ikgomotseng aquifer	Development large dolerite sill structures on the community trust property of Ikgomotseng could produce an estimated additional sustainable yield of up to 177 million m^3/a.
E2 - Bloemfontein aquifer (Bainsvlei aquifer)	This involves the provision of groundwater to Bloemfontein from the Bainsvlei area (Kalkveld region) to provide a sustainable yield of 28 Mm^3/a.
E3 - Thaba Nchu aquifer	This option provides for groundwater supply to small communities equipped with 50 boreholes and pumpstations on the outskirts of the settlements. About 0,89 million m^3/a is estimated as being a sustainable yield.

Potential Intervention	Brief Description
E4 - Reddersburg Aquifer	The dolomitic aquifers in the vicinity of these four towns (and at Excelsior) offer significant opportunity for further sustainable development of the local groundwater resource. This is further described in detail in the Small Towns Strategies.
E5 - Edenburg Aquifer	
E6 - Dewetsdorp Aquifer	
E7 - Wepener Aquifer	
E8 - Well-field developments along the route of the existing pipelines : De Hoek Reservoir	Possible exploitation of potential dolerite intrusions in the vicinity of the De Hoek reservoir have been identified that could sustainably yield approximately 0.43 Mm^3/a via development of a 28 borehole wellfield.
E9 - Well-field developments along the route of the existing pipelines : Lieukop Off-take Chamber	Possible exploitation of potential dolerite intrusions in the vicinity of the Lieukop off-take chamber could sustainably yield approximately 0.43 Mm^3/a via development of a 27 borehole wellfield.
Water Trading Opportunities	
F1 - Water Trading	There is potential for purchasing unused water rights from agricultural users along the Caledon River (u/s and d/s of Welbedacht Dam), from the Modderrivier and Kalkveld WUAs, and from Orange-Riet and Vanderkloof WUAs.
Other Options	
G1 - Tunnel from Caledon to the Modder	A previously identified option but unlikely to be feasible due to the subsequent development Welbedacht and Knellpoort Dams, as well as the Novo Transfer scheme.
G2 - New dam on the Caledon River	Perhaps theoretically feasible but not practical due to the sedimentation load in the Caledon River and complicated international obligations between South Africa and Lesotho.
G3 - Transfer of mine water	This scheme entails abstracting water from closed gold mines, treating the water to an acceptable standard and then pumping the water to the Greater Bloemfontein Area. A possible yield of 20 million m^3/a is estimated as being feasible.

7.2 PRELIMINARY SCREENING OF INTERVENTIONS

The selection of interventions, either to study further or to implement, to reconcile water availability with the requirement for the Greater Bloemfontein Area is a complex task, with many diverse criteria to consider.

In order to compare interventions with one another, information was drawn from various existing reports as well as from expert knowledge. The evaluation was done at desktop level utilising the latest available information for each intervention. Each intervention was evaluated (**Step 2**) based on the following criteria:

- Potential Yield
- Lowest cost based on Unit Reference Value (URV);
- Potential Socio-economic impacts
- Potential Ecological Impacts

The interventions that were considered for the Strategy following the preliminary screening are summarised in **Appendix C** of this Report.

A summary of selected surface water interventions, water re-use interventions and groundwater interventions considered, as well as estimated capital, cost operating cost and Unit Reference Value (URV) is given in **Table 7.2** below

Table 7.2: Detailed Information on Selected Surface Water Interventions

Intervention	Yield Million m^3/a	Capital Cost (R million)	Operating Cost (R million)	URV (R/m^3)
Utilising surplus capacity in Orange River by pumping to Knellpoort Dam from Gariep Dam	20	825	33	6.1
Utilise surplus capacity in Orange River system by pumping to Knellpoort Dam from Van der Kloof Dam	20	1 700	40	10
Planned direct reuse – Bloem Spruit *(Note 1)*	10.8	179	4.9	1.56
Treated indirect reuse - Krugersdrift Dam (Note 1)	10.8	306	9.5	2.83
Bloemfontein aquifer (Bainsvlei aquifer)	28	4743	39	15.58
Thaba Nchu aquifer	0.89	32.7	2.1	5.35
Novo Transfer Scheme and obtaining additional water from Welbedacht Dam	Not calculated as infrastructure costs not available at time of preliminary screening workshop, but it was estimated that the URV's would be in the vicinity of $R1/m^3$. Estimated URVs are presented in Section 7.5 of this report.			

Note 1: Significant uncertainty surrounds the CAPEX and OPEX costs, as costing was undertaken at a very high level.

7.3 PRELIMINARY RECONCILIATION STRATEGY

A Preliminary Options Workshop was held in November 2009 to specifically address the potential interventions and actions to achieve a water balance. Following the preliminary screening workshop a preliminary Reconciliation Strategy was drafted. The Preliminary Reconciliation Strategy included a preliminary scenario planning evaluation to identify the most favourable interventions or groups of interventions that could be implemented to meet the potential supply shortfalls for selected water requirement scenarios, in order to prevent the imminent risk of shortages in water supply.

The primary recommendation which came out of the preliminary strategy is highlighted below:

- It is imperative that MMM and the other WSA implement WC/WDM measures to reduce the risk of having to impose water restrictions and to ensure the longer term reconciliation of supply and requirement.

- Additional water could be abstracted from the Caledon River to meet the short, medium and long term water requirements of the Greater Bloemfontein Area. This would however require that additional infrastructure be implemented.
- The most favourable interventions, with the lowest URVs, are the interventions related to increasing the capacity of existing infrastructure associated with the Novo Transfer Scheme.

The outcome of the Preliminary Strategy was presented to the Study Steering Committee (**Step 5**). Thereafter, a Newsletter highlighting the findings and recommendations of the Preliminary Reconciliation Strategy was circulated to Interested and Affected Parties (**Step 6**).

Subsequent to the development of the Preliminary Strategy further important information with regard to potential interventions became available to the Study from mid-2011. These new reports are listed below:

- ***Reduction of Unaccounted-for Water and Non-Revenue Water Master Plan*** for Mangaung Metropolitan Municipality,
- ***Technical Report in Support of Application for Funding for Non-Revenue Water Reduction Programme*** for Mangaung Municipality, and
- ***Extension of the Capacity of the Novo Transfer Scheme*** for Bloem Water
- ***Investigation into the Condition of the Caledon River at Welbedacht Dam*** for Bloem Water
- ***Joint Bulk Water Services: Infrastructure Challenges*** for MMM and Bloem Water (February 2012).

This new information has been incorporated into this Strategy Report and is also presented in more detail below under **Section 7.5** (Selected Interventions) of this Report.

7.4 THE SCENARIO PLANNING PROCESS

The objective of the Water Balance Scenario Planning Process is to identify, evaluate and assess alternative groupings and phasing of interventions to determine the most appropriate combination of interventions that should be implemented to reconcile water supply and water requirements. The combination of interventions selected to meet the future water requirement (based on low, medium, or high population growth curve) is terms a scenario.

The scenario planning process considers a range of possible scenarios to reconcile water supply and requirements. Due to the lead times required for feasibility studies, interventions need to be identified well in advance so that they are ready for implementation within the required time frame. While conducting the feasibility studies, some interventions may be found not to be suitable for implementation. For that reason, the scenario planning process considers a range of possible scenarios to reconcile water supply and requirement. The objective is not to select one “favourable” scenario, but rather to identify and prioritize which interventions should be further investigated. This will allow the DWA, and other stakeholders, such as MMM and Bloem Water, the maximum amount of flexibility in making informed decision on which interventions to implement. The outcome of the process will be a list of interventions that should be studied, by specific dates, so as to facilitate the implementation of a range of reconciliation scenarios.

7.5 SELECTED INTERVENTIONS

Based on the evaluation of the interventions, a review of available literature, and the risk that any significant increase in water requirements may not be met by the current bulk water supply system, a number of groupings of interventions were identified as priority for implementation. It is anticipated that the implementation of these interventions would allow for the reconciliation of supply and requirement for the Greater Bloemfontein Area for the short, medium and long term. These groupings of interventions are:

- Water conservation and water demand management;
- Increasing the capacity of Tienfontein Pump Station (and ultimately the Novo Transfer Scheme);
- The scouring/flushing of Welbedacht Dam, and
- A new pump station at Welbedacht Dam (to pump water to Knellpoort Dam).

These interventions would be the most cost effective interventions to implement and could also be implemented in the shortest possible time.

7.5.1 Water conservation and water demand management

For the purposes of this Reconciliation Strategy, the WC/WDM interventions have been divided up into two categories, namely:

- Reduction in Bloem Water UAW
- Reduction in MMM UAW

(a) Reduction in Bloem Water UAW

The bulk water losses for Bloem Water have been calculated as the difference between the volume of water abstracted from the various sources and the volume of water sold to consumers. Representatives from Bloem Water have indicated that their total overall losses are in the vicinity of 12% of the bulk water treated. **Table 7.3** unpacks the water losses in the bulk water system network of Bloem Water.

Table 7.3: Detailed Breakdown of Water Losses in the Bulk System Network of Bloem Water (BW) (Million m^3/a)

	Financial Year				
	2005	**2006**	**2007**	**2008**	**2009**
Bulk water supplied from BW's WTWs	53.13	55.27	59.33	62.40	54.82
Less: Bulk meters to MMM	46.20	49.24	52.05	53.99	49.68
Less: Supply to other Local Authorities	2.01	2.34	3.01	3.20	3.29
Bloem Water Conveyance loss downstream of WTW	**4.93**	**3.69**	**4.27**	**5.21**	**1.85**
% water loss downstream of WTW	**9.6%**	**7.0%**	**7.6%**	**8.8%**	**3.6%**
Bloem Water abstraction from Source	54.91	58.01	62.60	65.87	57.13
Loss in WTW	1.78	2.74	3.25	3.47	2.30
% water loss in WTW	3.2%	4.7%	5.2%	5.3%	4.0%
Bloem Water Total water loss	6.71	6.43	7.52	8.68	4.15
% Total water loss	**12.2%**	**11.1%**	**12.0%**	**13.2%**	**7.3%**

It would appear that conveyances losses are in the order of 7% to 9% per annum. Bloem Water has an active database monitoring system, where the water losses of the different supply systems are monitored and respective reports are generated. Each of the regional managers within Bloem Water is responsible for managing their system water losses. The current levels of water losses do not appear inordinately high. A significant portion of this water loss could also be attributed to the regular bursts which occur on the Caledon-Bloemfontein pipeline, which is approximately 50 years old.

The water loss in the WTWs is in the order of 4% to 5% of the source abstracted volume. The most significant part of this loss can be attributed to the high sediment loads in the Caledon River, abstracted at Welbedacht Dam and treated at Welbedacht WTW.

For the purposes of this study it was assumed that no significant water saving could be made through targeting water losses in the Bloem Water's supply system.

(b) Reduction in MMM UAW

In spite of the preparation of a number of reports addressing various aspects of water loss in the Mangaung area, the implementation of water loss management strategy largely remained as a reactive rather than a proactive programme. In the year 2005 and 2006 Mangaung initiated a project aimed at reduction of leakages on private properties and with assistance from DWA and broadened the scope of the project to cover the four strategic pillars of Water Conservation and Water Demand Management, namely:

- Network Losses Strategy
- System Losses Strategy
- Behind Water Meter Losses Strategy, and
- Willingness to Pay Strategy.

In 2010/2011 the MMM developed a Master Plan for the Implementation of a Water Loss Management Strategy. Specific attention was to be directed towards the particular problems experienced in the Mangaung, Botshabelo and Thaba Nchu areas of supply. The master plan included strategies for both consumption (billing database) as well as physical losses from the water distribution system up to the point of sale to consumers.

In terms of the President's State of the Nation address, the MMM is obligated to reduce its water losses by 50% by 2014. This directive was prepared by the DWA which has prepared the National WC/WDM Strategy. The strategy as developed by MMM focuses on the need to reduce non-revenue water (NRW), which currently accounts for 50% of all potable water supplied to the Municipal area of jurisdiction. The implementation of any WC/WDM programme is a multi-phased strategy, with the ultimate objective being the need to reduce unnecessary distribution losses to an economical minimum while maximising revenues from customers.

A breakdown of the authorised consumption and water losses within the Bloemfontein/Mangaung area, for the 2009/2010 financial year, is given in **Table 7.4**. The total bulk water supplied to the Bloemfontein/Mangaung area was 79 million m^3/a. The water losses amounted to 29 million m^3/a (or 37% of total bulk water supplied to this area).

Table 7.4: Unaccounted for Water – Bloemfontein/Mangaung Area (2009/2010 FY)

<table>
<tr><td rowspan="10">Input volume
79.09 million m^3/a</td><td rowspan="4">Authorised consumption (estimated)
48 million m^3/a
60.7%</td><td rowspan="2">Billed authorised consumption
39.31 million m^3/a
49.7%</td><td>Billed metered connections</td><td rowspan="2">Revenue generating water
39.31 million m^3/a
49.7%</td></tr>
<tr><td>Billed unmetered connections</td></tr>
<tr><td rowspan="2">Unbilled authorised consumption
8.7 million m^3/a
11%</td><td>Unbilled metered connections (Free Basic Water)</td><td rowspan="8">Non-revenue generating water
39.78 million m^3/a
50.3%</td></tr>
<tr><td>Unbilled unmetered connections (communal taps)</td></tr>
<tr><td rowspan="6">Water losses (unaccounted for water)
31.08 million m^3/a
39.3%</td><td rowspan="3">Apparent losses
1.38 million m^3/a
1.7%</td><td>Unavoidable losses</td></tr>
<tr><td>Illegal connections</td></tr>
<tr><td>Metering inaccuracies</td></tr>
<tr><td rowspan="3">Real losses
29.55 million m^3/a
37.4%</td><td>Main leaks</td></tr>
<tr><td>Reservoirs overflows</td></tr>
<tr><td>Service connection leaks</td></tr>
</table>

The MMM has kept fairly regular records in terms of the annual water balances for their entire area of supply. The annual water balances by volume for the 2004/05 to 2009/10 financial years are given in **Table 7.5** below.

Table 7.5: Annual Water Balance for MMM

Water Balance Component	Financial Year (Volumes million m^3/year)					
	2004/05	**2005/06**	**2006/07**	**2007/08**	**2008/09**	**2009/10**
System Input Volume	62.33	63.96	72.70	75.44	79.29	79.09
Billed Metered Consumption	37.36	36.86	34.68	36.86	37.91	39.31
Unbilled Authorised Consumption	6.86	7.04	8.00	8.30	8.72	8.70
Apparent Losses	1.31	1.29	1.21	1.29	1.33	1.38
Real Losses	16.80	18.78	28.80	28.84	31.17	29.55
Non-Revenue Water	24.97	27.11	38.01	38.59	41.38	39.78
Inefficiency of Use (%)	27.0%	29.4%	39.6%	38.2%	39.3%	37.4%
NRW by Volume (%)	40.1%	42.4%	52.3%	51.1%	52.2%	50.3%

The following important observations can be made from **Table 7.5**:

- The system input volume (of bulk water purchases) increased at an average of 4,5% per annum over the last six years
- The billed metered consumption remained relatively constant at 107 Ml/day (in effect, sales have increased an average of 0,9% per annum over the last six years)
- The sum of the billed metered consumption and unbilled authorised consumption grew at a rate of approximately 3% per annum over the last 3 year period.
- Apparent losses remained relatively constant at 3,7 Ml/day

Real losses increased at an average of 12,6% per annum over the last six years, which is an indication that the rate of system attrition (the worsening condition of infrastructure over time) is higher than expected (roughly double an acceptable value) and is the key driver for increased System input volume

- Non-revenue water increased at an average of 9,9% per annum over the last six years

The MMM has developed 3 alternative potential water demand projection scenarios based on alternative saving projections. These projection scenarios are described in **Table 7.6** below.

Table 7.6: Water Demand Projection Scenarios

Scenario	Description
Do Nothing Approach	Water requirement and sales projections should nothing be done by MMM to stop or slow the current trends of bulk water purchases, consumer sales and system attrition
Best-Case Scenario	This scenario represents what would happen should all the identified Non Revenue Water Reduction Activities that have been identified be implemented by MMM. This scenario represents the current full potential for WC/WDM
Most-Probable Scenario	This scenario is closely aligned to the best-case scenario, but taking into consideration probable delays in implementation, alignment and processes within the MMM

The anticipated water saving which will be achieved under each scenario is given in **Table 7.7** below.

Table 7.7: Anticipated Water Saving for Each Water Demand Projection Scenario

Scenario	Anticipated Saving (million m^3/a)
Do Nothing Approach	0
Best-Case Scenario	25.2
Most-Probable Scenario	11.2

7.5.2 Increase in Capacity of the Novo Transfer Scheme

Tienfontein Pump station is seen as the most critical component of the water supply infrastructure supplying Bloem Water with raw water, as Bloem Water receives approximately 40 % of its water supply via Tienfontein Pump Station and Knellpoort Dam. Since there is minimal storage capacity in Welbedacht Dam, the Tienfontein pumps must operate at a high reliability on a run of river basis to supply Knellpoort Dam. The predicted bed level at Tienfontein pump station indicates that the current bed level is near equilibrium, but it should be borne in mind that this is a dynamic equilibrium and during floods scour will occur and deposition after floods. The variability of the equilibrium bed is in the order of 3 m up or down with which the pump station has to cope. This could lead to sediment build up as high as 4.6 m above the full supply level of the reservoir, at the pump station, and the existing pumps cannot deal with such a scenario.

At the moment sediment flushing of Welbedacht Dam is limited to about 8 to 9 hours. This could be increased to say a week of flushing during a flood period by providing raw water storage facilities downstream of the dam. Longer duration flushing would ensure a deep channel near the Tienfontein pump station with the hydraulic control remaining at the dam and not controlled by vegetation and sediment upstream of the dam as is currently happening. Longer duration flushing would also make it possible to release relatively clear water at the end of flushing so as to limit sediment deposition in the river downstream.

Following an analysis of the Novo Transfer Scheme it became apparent that significant additional yield could be made available from this system with limited additional infrastructure requirements in comparison to the other water augmentation interventions. **It is important, however, to note** that if the continued and on-going sedimentation of Welbedacht Dam is not addressed through a longer scouring/flushing duration of the dam, then any increase in the capacity of Tienfontein Pump Station may not lead to an increased system yield due to the operational problems of managing silt at Tienfontein Pump Station.

The yield of the Novo Transfer Scheme can be increased by one, many or a combination of interventions (**Figure 7.1**). These are listed below:

1) Increase capacity of Novo Pump Station (P/S)
2) The raising of Knellpoort Dam
3) Increasing the Capacity of Tienfontein (TFT) Pump Station
4) Implementing a pump station and pipeline between Welbedacht Dam and Knellpoort Dam
5) A combination of the abovementioned interventions

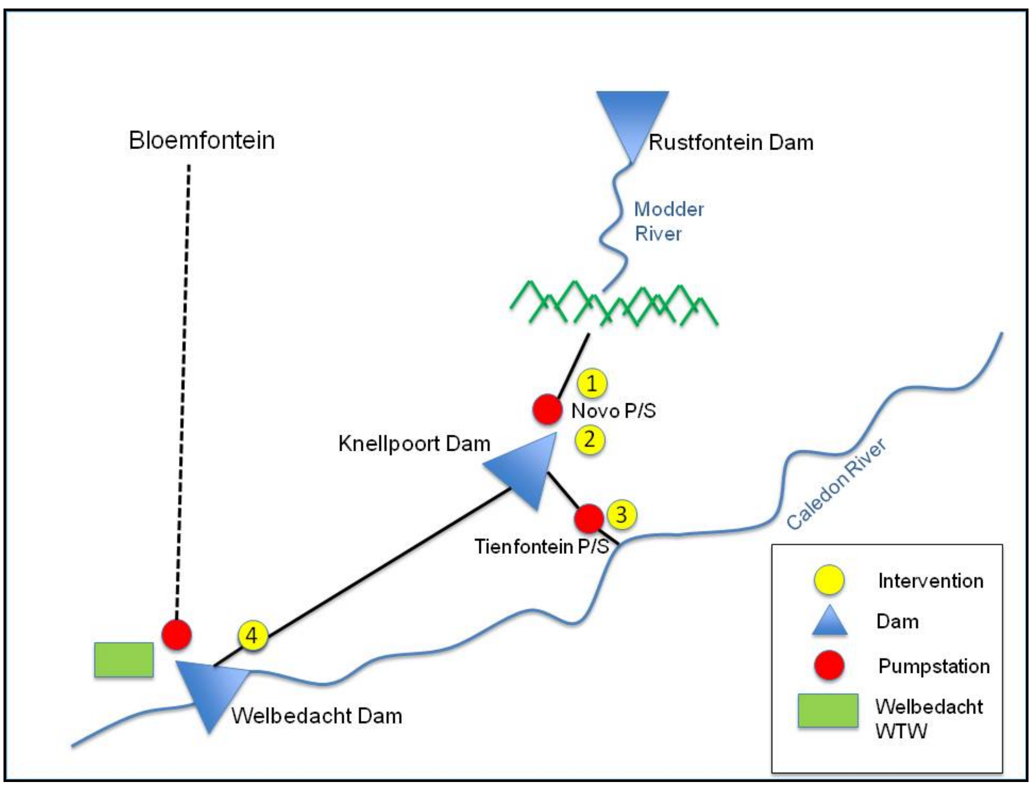

Figure 7.1: Caledon-Bloemfontein Transfer Scheme Interventions

1) **Novo Pump Station:** The civil structure of Novo Pump Station was initially constructed to house pumps with a capacity of 4.8 m^3/s. The current installed capacity of Novo Pump Station is 1.5 m^3/s. The pipeline from Novo pump station to the head waters of the Modder River has a capacity of 2.4 m^3/s. If the capacity of Novo Pump Station is increased beyond 2.4 m^3/s, an additional pipeline from Novo Pump Station would have to be constructed.
2) **Knellpoort Dam:** The possibility of raising Knellpoort Dam was investigated. An analysis of the historical firm yields showed that raising the dam by 1 to 4 m would not increase the yield of the system significantly. This option was not considered further.
3) **Tienfontein Pump Station:** The existing civil structure of Tienfontein Pump Station consists of 7 pump bays of which 4 of the bays currently have pump sets each with an installed capacity of 1 m^3/s. There are currently 3 vacant bays. The design capacity of the pump station is currently 3 m^3/s with 1 m^3/s standby capacity.
4) **Welbedacht Pump Station:** This is a possible future intervention which would pump directly from Welbedacht Dam to Knellpoort Dam. (Refer to **Sections 7.5.3** and **7.5.4**).

The phasing and implementation of the pumping infrastructure comprising the Novo Transfer Scheme is an important consideration. Whilst it may not make sense to increase the pumping capacities of the Tienfontein and Novo Pump Stations incrementally, it must be understood that in terms of the yield determinations "yield bottlenecks" may occur as a result of pumping/conveyance infrastructure capacity constraints.

The study undertaken by Bloem Water to investigate the extension of the capacity of the Novo Transfer Scheme identified a number of Interventions which should be implemented.

An Intervention is seen as an action or group of actions that are applied to the Novo Transfer Scheme at a set time to enhance the transfer capacity of the system. Each ***Intervention*** is a phased approach to be implemented according to timeframes as determined and discussed under the following sections.

The interventions as proposed by the Bloem Water Report are outlined below:
Intervention 1: This intervention entails operating all 4 pumps at the existing Tienfontein Pump Station simultaneously (i.e. with no standby capacity). Should water levels in the Caledon River permit, the full utilisation of the existing pump station capacity would enable 3.5 m^3/s to 4 m^3/s to be transferred to Knellpoort Dam via Tienfontein Pump Station.
Intervention 2: This intervention entails the installation of three new high capacity pump sets at Tienfontein pump station, each with a capacity of 2 m^3/s. In addition, a duplicate steel rising main is required from the Tienfontein pump station to the sand traps with surge chamber and additional sand traps to be constructed. To make full use of the 2.4 m^3/s capacity of the existing steel rising main between Knellpoort Dam and the upper reaches of the Modder River, it is recommended that a pumpset with a capacity of 1.6 m^3/s capacity, similar to existing pumpsets, be installed at Novo Pump Station. The newly installed pump set, operating in parallel with one of the existing pump sets could deliver ± 2.3 m^3/s. The electricity supply to Novo Pump Station would also need to be upgraded.
Intervention 3: This intervention entails the installation of a second new high capacity pump set at Novo pump station to transfer an additional 1.67 m^3/s via a new parallel installed steel rising main from the Novo pump station through to the upper reaches of the Modder River.

Table 7.8 below summarises the Interventions together with the required pumping infrastructure capacities and associated incremental yields.

Table 7.8: Caledon Bloemfontein Transfer Scheme Interventions

Intervention	Tienfontein P/S Capacity (m^3/s)	Novo P/S (m^3/s)	Novo/Modder Rising Main (m^3/s)
Intervention 1	4 (by utilising standby capacity)	1.5	2.4
Intervention 2	7	2.4	2.4
Intervention 3	7	4.8	4.8

Whilst the interventions described above target increasing the capacity of the existing supply infrastructure they are not necessarily the best interventions to implement to increase the available yield of the system and do also not address the underlying risks associated with sedimentation. **Table 7.9** below shows the incremental yield (determined from the water resources yield model) associated with each intervention, and highlights risk/concerns from a longer term reconciliation of supply and requirement point of view.

Table 7.9: Incremental Yield Associated with Each Intervention Listed in Table 7.8

Intervention	Incremental Yield (million m^3/a)	Comments
Intervention 1	4.4	Intervention 1 is not seen as a permanent solution, as given the historical sediment related problems experienced at Tienfontein Pump Station and the very high operating and maintenance costs utilising the standby capacity may be impractical to do on a sustained basis. This also poses additional risks in terms of breakdowns and maintenance.
Intervention 2	11.5 (15.9 including the yield from Intervention 1)	The full implementation of Intervention 2 should be subject to the scouring/flushing limitations on Welbedacht Dam being addressed and a workable solution found. If these problems are not addressed the siltation problems at Tienfontein Pump Station may limit the usage of the increased capacity
Intervention 3	0	Additional yield will only re realised with an increased inflow in Knellpoort Dam

Tienfontein Pump station currently has a design capacity of 3 m^3/s, but due to the sedimentation related problem and high maintenance requirements delivers on average approximately 2.5 m^3/s. It is proposed that as an interim solution those two additional (1 m^3/s) Pump Sets at Tienfontein Pump Station be implemented. The first pumpset should be utilised to increase the design capacity of the pump station to 4 m^3/s and the second pumpset to provide additional standby capacity. This would provide an additional yield of approximately 4.4 million m^3/a. With an increase in the standby capacity (proposed 50% of design capacity), maintenance of pumps could be more easily facilitated without impacting on the operating capacity of the pump station.

7.5.3 Scouring/flushing of Welbedacht Dam

Due to the high turbidity of the raw water, especially during flood events it is not possible to operate Welbedacht WTW at full capacity throughout the year. A discussion with the operator of the WTW suggested that the WTW could operate at full capacity (145 Ml/d) in winter, but only managed an output of between 90 and 100 Ml/d in summer when the silt load in the river was higher. The yield of the system could therefore potentially increase if the WTW was operated a full capacity all year round.

The possibility to supply raw water to Welbedacht WTW from a source other than the Welbedacht Dam was recently investigated by Bloem Water and the DWA. The report, which was entitled "Investigation into the Condition of the Caledon River at Welbedacht Dam" (SSI, 2011) investigated the sedimentation problems and potential solutions in more detail. This report contained the following two recommendations:

1) Conduct a detailed investigation and cost estimate to modify the Tienfontein Pump Station to such an extent that the pump station can operate efficiently under the current in-take conditions
2) Conduct a detailed feasibility study to improve the storage capacity of Welbedacht Dam, through the scouring/flushing of Welbedacht Dam.

The report found that Welbedacht Dam could be scoured for a period of 4 days continuously during times of floods in the Caledon River if either:

1) an off-channel storage dam was constructed to supply Welbedacht WTW, or
2) a supply pipeline was laid between Knellpoort Dam and Welbedacht WTW.

The yield analysis undertaken (refer to Section 4.2) found that by operating Welbedacht WTW at 145 Ml/d throughout the year and by increasing the storage capacity of Welbedacht Dam to approximately 13 million m^3, the incremental historical firm yield of the system could be increased by approximately 4 million m^3/a and 3 million m^3/a respectively. The scouring operation with alternative feed to Welbedacht WTW could therefore increase the historical firm yield of the system by approximately 7 million m^3/a. The capital cost of the two alternatives together with the associated URVs is given in **Table 7.10** below.

Table 7.10: Capital Costs and URVs Associated with the Scouring/Flushing of Welbedacht Dam

Intervention	Incremental Yield (Million m^3/a)	Capital Cost (R Million) [1]	URV (R/m^3)
Off channel storage dam to supply Welbedacht WTW	7	270	2.54
Raw Water Supply from Knellpoort Dam to Welbedacht WTW	7	297	2.79

[1] Cost taken from report entitled "Investigation into the Condition of the Caledon River at Welbedacht Dam" (SSI, 2011)

7.5.4 Welbedacht Pump Station

In addition to the interventions proposed to increase the capacity of the Novo Transfer Scheme, this intervention entails the construction of a new pump station at Welbedacht Dam with a capacity of approximately 2 m^3/s (although this could be increased to obtain additional system yield) to pump water to Knellpoort Dam. There is potential synergy between this intervention and the interventions described in Section 7.5.3 above. Should a pipeline be constructed between Knellpoort Dam and Welbedacht WTW to facilitate the scouring of Welbedacht Dam by providing a continuous supply of water to Welbedacht WTW, then this pipeline could be used in reverse as a rising main and pump water from Welbedacht Dam to augment the supply to Knellpoort Dam. The pipeline could only be used when Welbedacht Dam was not being scoured. For the purposes of the yield calculations, it was assumed that the Welbedacht Dam would not be scoured for more than a 4 day duration and not more than 4 to 5 times per year. The indicative yields, capital costs, operating costs and URVs associated with this intervention are given in **Table 7.11** below. The URV calculations have been worked out firstly assuming a new pipeline would need to be implemented between Welbedacht Dam and Knellpoort Dam, and then assuming that the pipeline could be used as a bi-directional pipeline to facilitate the scouring of Welbedacht Dam (Integrated Solution). **Appendix B contains a range of yields dependant on which infrastructure configuration is chosen to augment the supply to Knellpoort Dam from the Caledon River**

Table 7.11: Welbedacht Pump Station Interventions

Intervention	Incremental Yield (Million m^3/a)	Capital Cost (R Million)	Operating Cost (R Million)	URV (R/m^3)
Welbedacht P/S with raw water pipeline to Knellpoort Dam.	22.6	374	7.9	1.51

7.5.5 Other Supply Side Interventions

A number of other possible water supply interventions were investigated (See **Sections 7.1** and **7.2** of this report). These supply options may need to be further investigated at pre-feasibility/feasibility level should no practical and sustainable solution be found to address the following:

- The scouring/flushing of Welbedacht Dam;
- The on-going sedimentation problems at Tienfontien Pump Station;
- The further augmentation of Knellpoort Dam from the Caledon River; and
- The integrity of the Welbedacht Pipeline – this could entail relaying sections of the Welbedacht pipeline

It is recommended that the Strategy Steering Committee give guidance on the need and timing of additional pre-feasibility/feasibility studies.

7.6 THE SCENARIO PLANNING PROCESS

The objective of the Water Balance Scenario Planning Process is to identify, evaluate and assess alternative groupings and phasing of interventions to determine the most appropriate combination of interventions that should be implemented to reconcile water supply and requirements in the Greater Bloemfontein System. The combination of interventions selected to meet the selected water requirement scenario, is termed a scenario.

The scenario planning process considers a range of possible scenarios to reconcile water supply and requirements. The objective is not to select one ‘favourable scenario’ but rather to identify which interventions should be studied to allow consideration of a range of possible scenarios. This will allow the DWA, Bloem Water, the MMM, and other stakeholders the maximum amount of flexibility in making informed decisions on which interventions to implement. The outcome of the process is a list of interventions that should be studied by specific dates, so as to meet implementation requirements of a range of reconciliation scenarios. This evaluation involves the use of the Reconciliation Planning Support Tool (RPST) to evaluate the identified reconciliation scenarios.

7.7 THE RECONCILIATION PLANNING SUPPORT TOOL (RPST)

The selection of interventions, to be studied further or to be implemented, to reconcile water availability with `water requirements, is a complex task, with many diverse issues and criteria to consider. A graphical support tool, which was developed for the Western Cape Water Supply System Reconciliation Strategy Study, to aid the process of scenario planning, was customised for the Bloemfontein Reconciliation Strategy Study and used for developing the different water balance scenarios.

7.8 SCENARIO PLANNING

7.8.1 Factors that impact on the water balance

There are a number of factors which could impact on the potential water balance and therefore need to be taken into account in the scenario planning process. These factors are listed below:

- Future Water Requirements
- Impact of WC/WDM:
- Capacity of Welbedacht WTP
- Impact of Metolong Dam.
- Impact of Environmental Water Requirement
- Operation of Knellpoort Dam
- Capacity of Tienfontein Pump Station
- Storage capacity of Welbedacht Dam
- Water supply to additional 23 000 erven
- Risk of non-supply as a result of continuous failure (bursts) on the Welbedacht pipeline
- Supply to smaller towns

In order to assess the impacts of all these variables, the Water Resource Planning Model (WRPM) was used where one variable was changed at a time in order to ascertain what the associated impact on the yield of the system would be. The results of the WRPM runs are contained in **Appendix A**. The results of the analysis have also been used as the basis for the various scenarios which were developed and which are described below.

Table 7.12 below lists all the scenarios that have been considered as part of this Reconciliation Strategy Study.

Table 7.12: Scenarios Considered most Feasible in the Reconciliation Strategy Study

Description	Water Requirement Curve	WC/WDM	Explanation/Reasoning
Scenario A	High	Best Case Scenario	High growth water requirement scenario assuming that the MMM is able to successfully implement all identified Non Revenue Water (NRW) reduction activities that have been identified as part of its WC/WDM strategy and programme
Scenario B	High	Most Probable Scenario	High growth water requirement scenario taking into consideration probable delays in implementation, alignment and process within the MMM to be able to successfully implement WC/WDM.

Description	Water Requirement Curve	WC/WDM	Explanation/Reasoning
Scenario C • Un-optimal operation of Knellpoort Dam	High	Most Probable Scenario	This scenario considers what impact the operation of Knellpoort Dam to a maximum level of 60% would have on the yield of the system.
Scenario D • Commissioning of Metolong Dam	High	Most Probable Scenario	This scenario considers what impact the implementation of Metolong Dam would have on the yield of the system.
Scenario E • Metolong Dam • Implementation of EWR along the Caledon River	High	Most Probable Scenario	This scenario considers what impact the implementation of the EWR requirements d/s of Welbedacht Dam would have on the yield of the system.
Scenario F • Metolong Dam • Additional erven	High	Most Probable Scenario	This scenario considers what impact the servicing of an additional 23 000 erven with water would have on the yield of the system.
Scenario G • Metolong Dam • Groundwater supply to meet future requirements in small towns • All supply of bulk water to small towns sourced from groundwater	High	Most Probable Scenario	This scenario considers what the impact of: 1) supplying the growth in water requirements of small towns from groundwater, and 2) supplying all small towns water requirements from groundwater, would have on the yield of the system.
Scenario H • Metolong Dam • 80% risk of failure of the Caledon-Bloemfontein pipeline	High	Most Probable Scenario	This scenario considers what the impact of the Welbedacht pipeline having a 20% downtime would be on the yield of the system.
Scenario I • Metolong Dam	Low	Most Probable Scenario	This scenario considers the impact of the low water requirement curve on the reconciliation of supply and requirement.

7.8.2 Water Balance Scenario A: High water requirement, WC/WDM Best Case Scenario

This assumes the successful implementation of all Non-Revenue Water (NRW) reduction activities identified over a 5 year period giving effect to a 25.2 million m^3/a saving, and that a new supply side intervention would be implemented by 2019. This could entail installing additional capacity at Tienfontein Pump Station, the scouring of Welbedacht Dam and ensuring that the Welbedacht WTP can operate at maximum capacity (estimated cumulative increase in yield from these interventions is estimated to be approximately 12 million m^3/a). Additional interventions such as the Welbedacht Pump Station or further increasing the capacity of Tienfontein/Novo Pump Station would also be available for implementation.

Dependent on the availability of surplus water from the Caledon River, water re-use may have to be considered as a supply intervention to balance supply and requirement in the longer term.

A possible reconciliation of supply and requirement based on lowest Unit Reference Value (URV) is shown in **Figure 7.2** below, taking into account those interventions that could potentially be implemented in time.

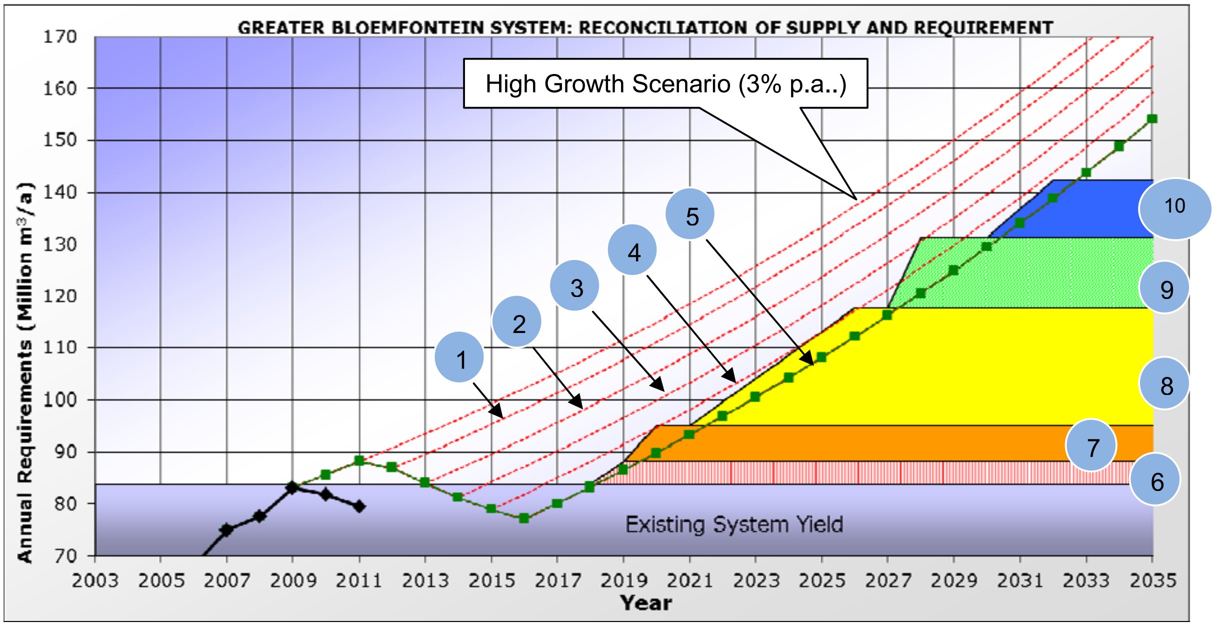

Figure 7.2: Water Balance Scenario A

The interventions which have been utilised for the reconciliation of supply and requirement in **Figure 7.2** are contained in **Table 7.13** below.

Table 7.13: Water Balance Scenario A: Interventions to be Implemented

No	Intervention	Year of First Water or Saving	Yield (Million m^3/a)
1	WC/WDM in Year 1	2012	3.9
2	WC/WDM in Year 2	2013	5.7
3	WC/WDM in Year 3	2014	5.5
4	WC/WDM in Year 4	2015	5.2
5	WC/WDM in Year 5	2016	4.9
6	Tienfontein 4 m^3/s	2019	4.4
7	Welbedacht WTP 145 (includes scouring of Welbedacht Dam)	2020	7.0
8	Welbedacht P/S (2m^3/s)	2022	22.6
9	Tienfontein 7 m^3/s	2028	13.7
10	Re-use of Treated Effluent (generic)	2031	10.9

7.8.3 Water Balance Scenario B: High water requirement, WC/WDM Most Likely Scenario

This Scenario which is closely aligned to Scenario A takes into consideration probable delays in implementation, alignment and process within the MMM to be able to successfully implement all the identified Non Revenue Water (NRW) reduction activities. The total water savings through the implementation of WC/WDM over the 5 year period under the most likely WC/WDM implementation scenario is 11.2 million m^3/a. This scenario assumes that the planned water savings only commence in the 2011/2012 financial year. The actual year on year saving of the 5-year period will be dependent on the annual approved budget allocations and availability of funds to implement WC/WDM. Under this scenario, a shortfall in supply would exist until a new supply side intervention could be implemented.

Implementation of WC/WDM is critical, as the first supply scheme can only be put in place by the end of 2013 at the earliest. Funds and resources should be allocated to ensure that MMM moves from the most likely WC/WDM savings scenario to the “best case scenario”. The first supply scheme proposed is the implementation of two additional pump sets at Tienfontein Pump Station. This would increase the design capacity of Tienfontein Pump Station from 3 m^3/s to 4 m^3/s and the standby capacity from $1m^3/s$ to 2 m^3/s. It is proposed that this intervention is implemented first for the following reasons:

- The intervention can be implemented reasonably quickly
- Provides incremental yield of approximately 4 million m^3/a and reduces the risk of non supply
- Does not require a significant capital expenditure due to existing infrastructure already being in place

Should the capacity of Tienfontein Pump Station be increased, the next supply side intervention would be required by 2015. It is proposed that the next intervention would be a combination of the scouring of Welbedacht Dam (to increase the storage capacity) and ensuring that the Welbedacht WTP can operate at maximum capacity (estimated combined increase in yield from these two interventions is estimated to be approximately 7 million m^3/a). In 2018 it is proposed that a pump station and pipeline be constructed between Welbedacht Dam and Knellpoort Dam (pipeline could be used as a bi-directional pipeline to assist with feeding the Welbedacht WTP whilst Welbedacht Dam is being scoured). Additional interventions to ensure the reocnciliaiton of supply and requirement over the longer term could include: 1) further increasing the capacity of Tienfontein Pump Station, 2) direct or indirect re-use with Mangaung Metropolitan Municipality, and 3) possibly augmenting the supply by means of a pipeline from Gariep Dam (although this is a very expensive supply intervention).

A possible reconciliation of supply and requirement based on first fully utilising the spare capacity if the already installed civil infrastructure is shown in **Figure 7.3** below.

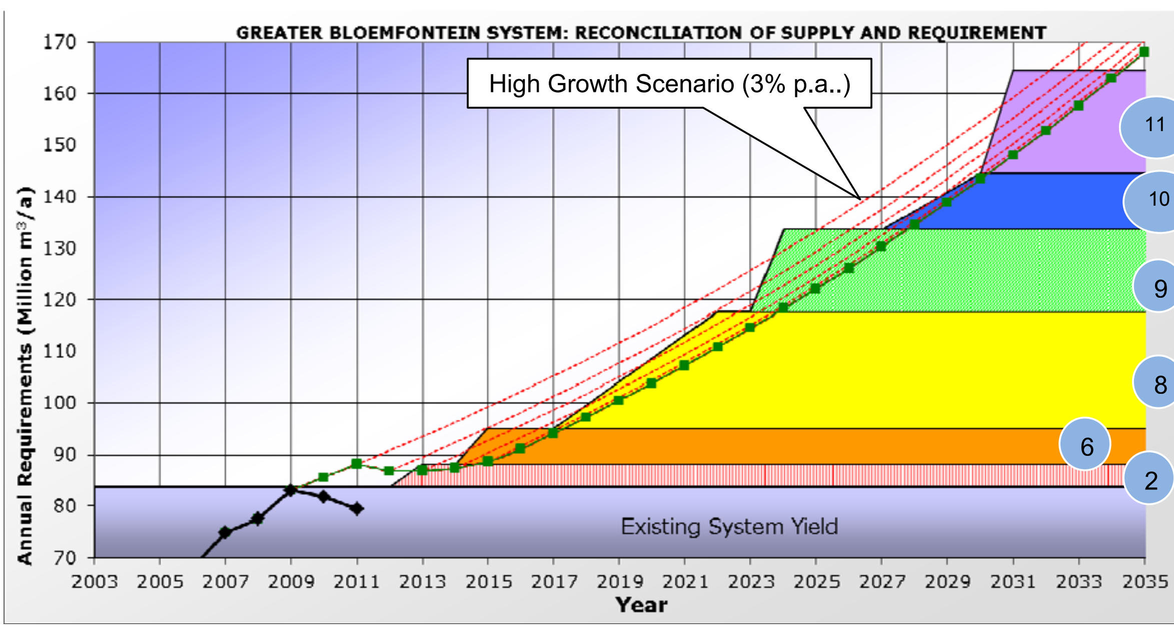

Figure 7.3: Water Balance Scenario B

The interventions which have been utilised for the reconciliation of supply and requirement in **Figure 7.3** are contained **Table 7.14** below.

Table 7.14: Water Balance Scenario B: Interventions to be Implemented

No	Intervention	Year of First Water or Saving	Yield Million m^3/a
1	WC/WDM in Year 1	2012	3.9
2	Tienfontein 4 m^3/s	2013	4.4
3	WC/WDM in Year 2	2013	2.7
4	WC/WDM in Year 3	2014	2.3
5	WC/WDM in Year 4	2015	1.6
6	Welbedacht WTP 145	2015	7.0
7	WC/WDM in Year 5	2016	0.7
8	Welbedacht P/S ($2m^3/s$)	2018	22.6
9	Tienfontein 7 m^3/s	2024	15.9
10	Re-use of Treated Effluent (generic)	2028	10.9
11	Gariep to Knelpoort	2031	20.0

7.8.4 Water Balance Scenario C: High water requirement, WC/WDM Most Likely Scenario, Un-optimal operation of Knellpoort Dam

Scenario C is the same as Scenario B, but assumes that Bloem Water maintains the level of Knellpoort Dam (via pumping at Tienfontein Pump Station) up to a maximum level of 60%. This scenario has been developed to illustrate the importance of maximising the supply from Tienfontein pump station and optimally managing the level of the water in Knellpoort Dam. Should Knellpoort Dam be operated so as to maintain a maximum operating level of 60%, the overall historical firm yield of the system would drop from 83.7 million m^3/a to 80.4 million m^3/a. Given that the system is already in a slight deficit under Scenario B, it is extremely important that the level of Knellpoort Dam and the supply from Tienfontein pump station is optimally managed and maximised.

A possible reconciliation of supply and requirement based is shown in **Figure 7.4** below. This reconciliation scenario assumes that an intervention is required to ensure that the level in Knellpoort Dam is optimally managed.

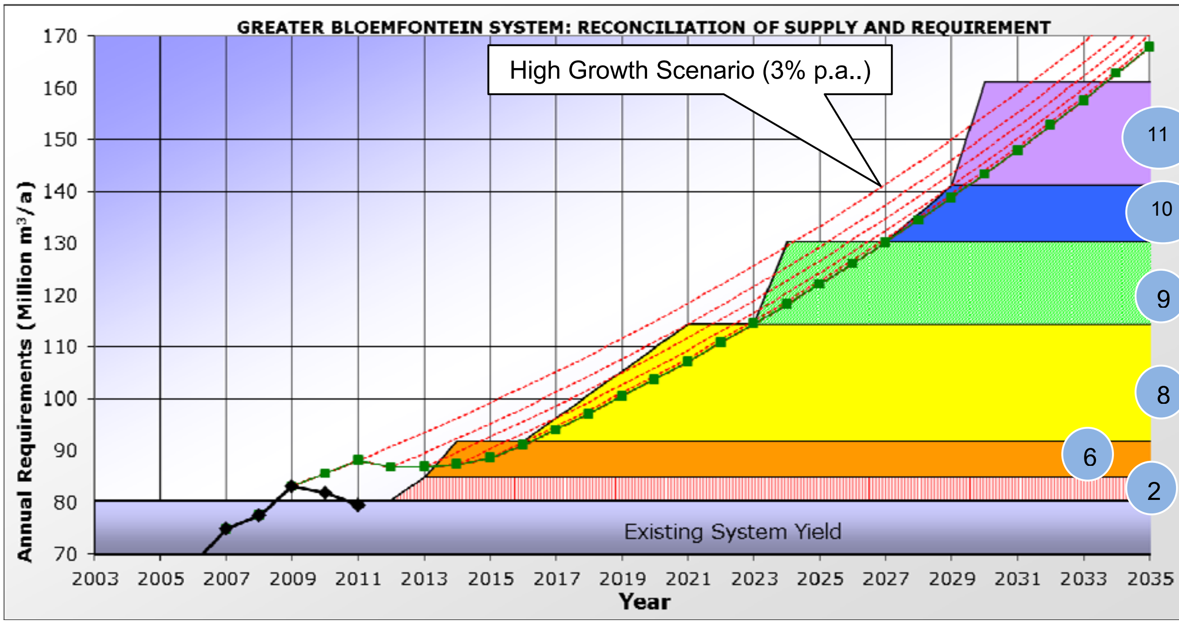

Figure 7.4: Water Balance Scenario C

The interventions which have been utilised for the reconciliation of supply and requirement in **Figure 7.4** are contained in **Table 7.15** below.

Table 7.15: Water Balance Scenario C: Interventions to be Implemented

No	Intervention	Year of First Water or Saving	Yield Million m^3/a
1	WC/WDM in Year 1	2012	3.9
2	Tienfontein 4 m^3/s	2013	4.4
3	WC/WDM in Year 2	2013	2.7
4	WC/WDM in Year 3	2014	2.3
5	WC/WDM in Year 4	2015	1.6
6	Welbedacht WTP 145	2014	7.0
7	WC/WDM in Year 5	2016	0.7
8	Welbedacht P/S ($2m^3/s$)	2017	22.6
9	Tienfontein 7 m^3/s	2024	15.9
10	Re-use of Treated Effluent (generic)	2028	10.9
11	Gariep to Knelpoort	2030	20.0

7.8.5 Water Balance Scenario D: Reference Scenario: High water requirement, WC/WDM Most Likely Scenario, Metolong Dam

Scenario D is the same as Scenario B, but assumes that the construction of Metolong Dam will have been completed.

This scenario takes into consideration probable delays in implementation by MMM of successful Non Revenue Water (NRW) reduction activities. It is assumed that a total water savings of 11.2 million m^3/a is achieved (commencing only in 2011/2012). The Metolong Dam is assumed to be completed by July 2012 when it would start to impound water. It is imperative under this scenario that the design capacity of Tienfontein Pump Station is increased to 4 m^3/s in 2012/2013. In addition the scouring of Welbedacht Dam and ensuring that the Welbedacht WTP can operate at maximum capacity are interventions which should be implemented as a matter of priority. Additional augmentation of Knellpoort Dam would then be required be required by 2018. It has been assumed for this scenario that a pump station and pipeline would be constructed between Welbedacht Dam and Knellpoort Dam.

A possible reconciliation of supply and requirement is shown in **Figure 7.5** below.

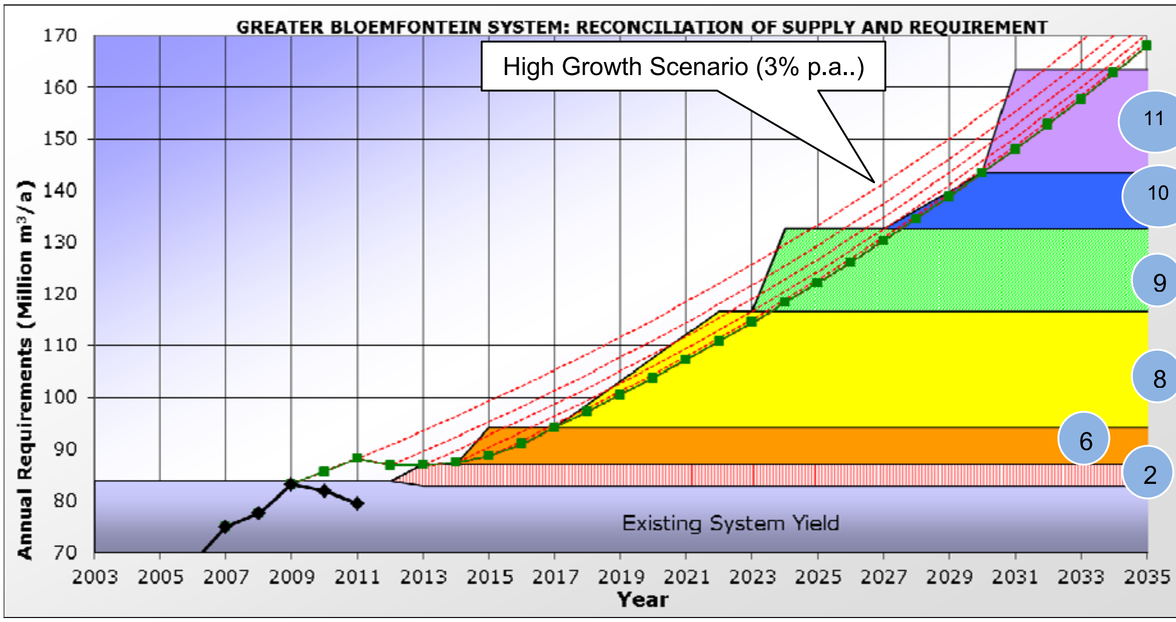

Figure 7.5: Water Balance Scenario D

The interventions which have been utilised for the reconciliation of supply and requirement in **Figure 7.5** are contained **Table 7.16** below.

Table 7.16: Water Balance Scenario D: Interventions to be Implemented

No	Intervention	Year of First Water or Saving	Yield Million m^3/a
1	WC/WDM in Year 1	2012	3.9
2	Tienfontein 4 m^3/s	2013	4.4
3	WC/WDM in Year 2	2013	2.7
4	WC/WDM in Year 3	2014	2.3
5	WC/WDM in Year 4	2015	1.6
6	Welbedacht WTP 145	2014	7.0
7	WC/WDM in Year 5	2016	0.7
8	Welbedacht P/S (2m^3/s):	2017	22.6
9	Tienfontein 7 m^3/s	2024	15.9
10	Re-use of Treated Effluent (generic)	2028	10.9
11	Gariep to Knelpoort	2030	20.0

7.8.6 Water Balance Scenario E: High Water Requirement, WC/WDM Most Likely Scenario, Metolong Dam, Implementation of EWR Requirements

Scenario E is the same as Scenario D, but assumes that the Environmental Water Requirements (EWR) is implemented in the Caledon River. The anticipated reduction in yield as a result of the implementation of the EWRs is estimated to be approximately 2.2 million m^3/a.

Should the Reserve be implemented prior to 2018, it would not be possible to implement interventions to offset the loss in yield due to the required environmental flow releases. The implementation of the Reserve should be phased in, in a planned manner, based on the implementation dates of future water augmentation schemes. Figure 7-6 illustrates a possible scenario for the implementation of the Reserve after 2019.

A possible reconciliation of supply and requirement is shown in **Figure 7.6** below.

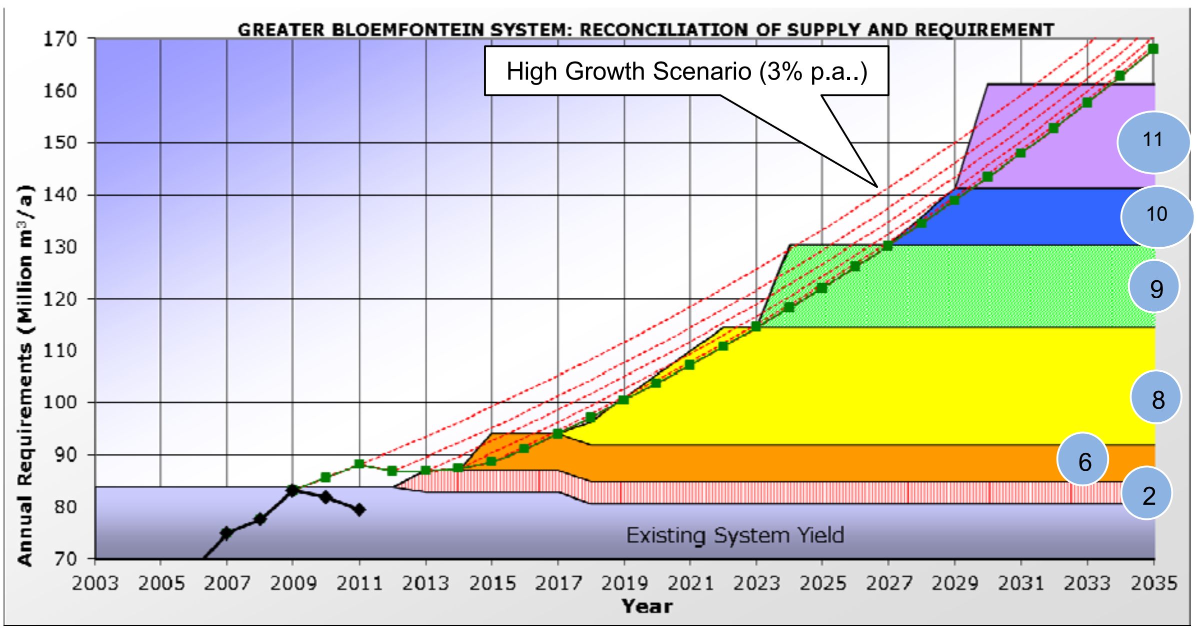

Figure 7.6: Water Balance Scenario E

The interventions which have been utilised for the reconciliation of supply and requirement in **Figure 7.6** are contained in **Table 7.17** below.

Table 7.17: Water Balance Scenario E: Interventions to be Implemented

No	Intervention	Year of First Water or Saving	Yield Million m^3/a
1	WC/WDM in Year 1:	2012	3.9
2	Tienfontein 4 m^3/s	2013	4.4
3	WC/WDM in Year 2	2013	2.7
4	WC/WDM in Year 3	2014	2.3
5	WC/WDM in Year 4	2015	1.6
6	Welbedacht WTP 145	2015	7.0

No	Intervention	Year of First Water or Saving	Yield Million m^3/a
7	WC/WDM in Year 5	2016	0.7
8	Welbedacht P/S ($2m^3/s$)	2018	22.6
9	Tienfontein 7 m^3/s	2024	15.9
10	Re-use of Treated Effluent (generic)	2028	10.9
11	Gariep to Knelpoort	2030	20.0

7.8.7 Water Balance Scenario F: High water requirement, WC/WDM Most Likely Scenario, Metolong Dam, Additional 23 000 Erven

Scenario F is the same as Scenario D, but assumes that an additional 23 000 additional erven will need to be serviced in terms of water supply. This additional water requirement has been superimposed on the high water requirement curve. It was assumed for this scenario that the additional water requirement resulting from the additional erven would be phased in over a 4 year period

The servicing of an additional 23 000 erven will increase the water requirement of Mangaung Metropolitan Municipality by approximately 4.2 million m^3/a. It is assumed that the additional services will be implemented within a 4 year period from 2012. The additional water requirement is based on a per capita consumption of 100 litres/person/day. Under this scenario it is even more important to increase the capacity of Tienfontein Pump Station by an additional 1 m^3/s in order to reduce the risk of having to impose water restrictions.

A possible reconciliation of supply and requirement is shown in **Figure 7.7** below.

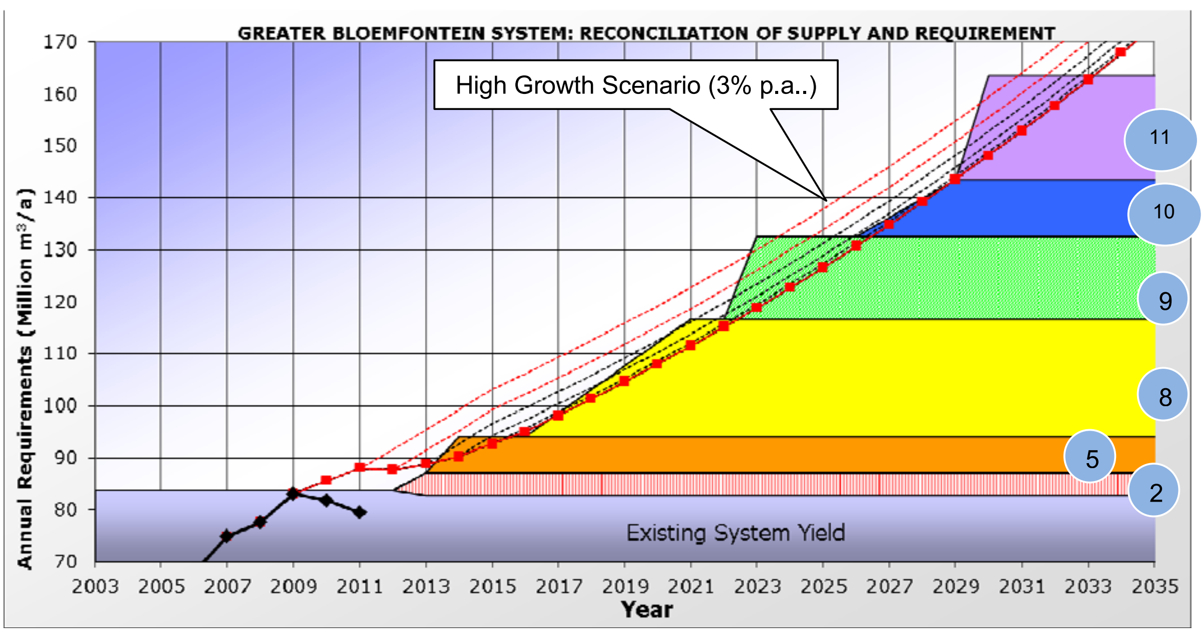

Figure 7.7: Water Balance Scenario F

The interventions which have been utilised for the reconciliation of supply and requirement in **Figure 7.7** are contained in **Table 7.18** below.

Table 7.18: Water Balance Scenario F: Interventions to be implemented

No	Intervention	Year of First Water or Saving	Yield million m^3/a	Fast-tracked Yes/No
1	WC/WDM in Year 1	2012	3.9	
2	Tienfontein 4 m^3/s	2013	4.4	
3	WC/WDM in Year 2	2013	2.7	
4	WC/WDM in Year 3	2014	2.3	
5	Welbedacht WTP 145	2014	7.0	
6	WC/WDM in Year 4	2015	1.6	
7	WC/WDM in Year 5	2016	0.7	
8	Welbedacht P/S (2m^3/s)	2017	22.6	Yes
9	Tienfontein 7 m^3/s	2023	15.9	
10	Re-use of Treated Effluent (generic)	2027	10.9	
11	Gariep to Knelpoort	2030	20.0	

7.8.8 Water Balance Scenario G: High Water Requirement, WC/WDM Most Likely Scenario, Metolong Dam, Smaller Towns Supplied Entirely from Groundwater

Scenario G considers what the impact would be on the water balance should the water requirements of the smaller towns off the Bloem Water supply System be supplied solely through groundwater. The smaller towns utilise about 4% of the supply from the system. Whilst there is a small decrease in the overall water requirement, it is still necessary to implement the first supply augmentation intervention as soon as possible. In this regard it is proposed that the design capacity of Tienfontein Pump Station be increased from 3 m^3/s to 4 m^3/s. Thereafter it is a requirement to implement the next supply side intervention (following upgrading the capacity of Tienfontein Pump Station) by 2017.

A possible reconciliation of supply and requirement based is shown in **Figure 7.8** below.

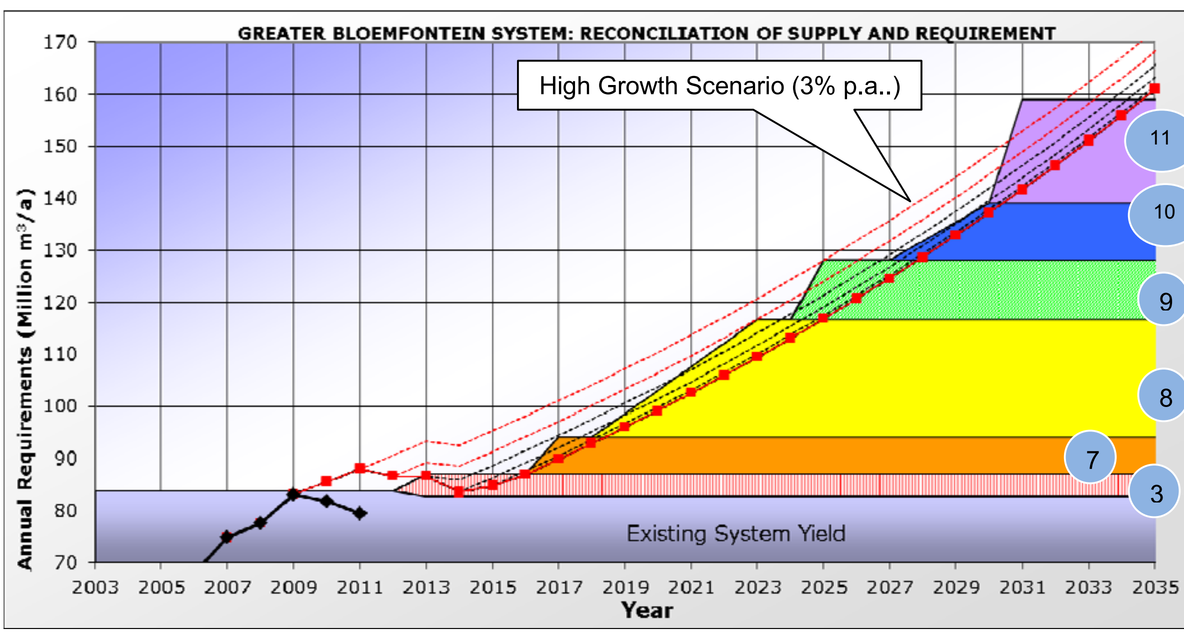

Figure 7.8: Water Balance Scenario G

The interventions which have been utilised for the reconciliation of supply and requirement in **Figure 7.8** are contained in **Table 7.19** below.

Table 7.19: Water Balance Scenario G: Interventions to be implemented

No	Intervention	Year of First Water or Saving	Yield million m^3/a
1	WC/WDM in Year 1	2012	3.9
2	WC/WDM in Year 2	2013	2.7
3	Tienfontein 4 m^3/s	2013	4.4
4	WC/WDM in Year 3	2014	2.3
5	WC/WDM in Year 4	2015	1.6
6	WC/WDM in Year 5	2016	0.7
7	Welbedacht WTP 145	2017	7.0
8	Welbedacht P/S (2m^3/s)	2019	22.6
9	Tienfontein 7 m^3/s	2025	11.5
10	Re-use of Treated Effluent (generic)	2028	10.9
11	Gariep to Knelpoort	2031	20.0

7.8.9 Water Balance Scenario H: High water requirement, WC/WDM Most Likely Scenario, Metolong Dam, Welbedacht pipeline having 20% downtime.

There is a concern about the integrity of the Welbedacht supply pipeline. The pipeline is a pre-stressed concrete pipeline and has in the past been subject to numerous bursts. It is anticipated the condition of the pipeline may continue to deteriorate in the future. This scenario assumes that the Welbedacht Pipeline will only be available for use 80% of the time on an annual basis. The remaining 20% will be used to repair leaks and relay sections of the pipeline. As a result of the decrease in utilisation of the pipeline there is an associated decrease in system yield of 6.8 million m^3/a.

A possible reconciliation of supply and requirement is shown in **Figure 7.9** below. It can be seen from the graph below that the Welbedacht WTW and pipeline contribute significantly to the overall system yield and that any long term outages of the Welbedacht pipeline will increase the risk of non-supply and the risk of having to impose water restrictions. Should regular outages occur on the Welbedacht pipeline, it is imperative that the design capacity of Tienfontein Pump Station be increased to 4 m^3/s and that an additional supply intervention is implemented as soon as possible thereafter.

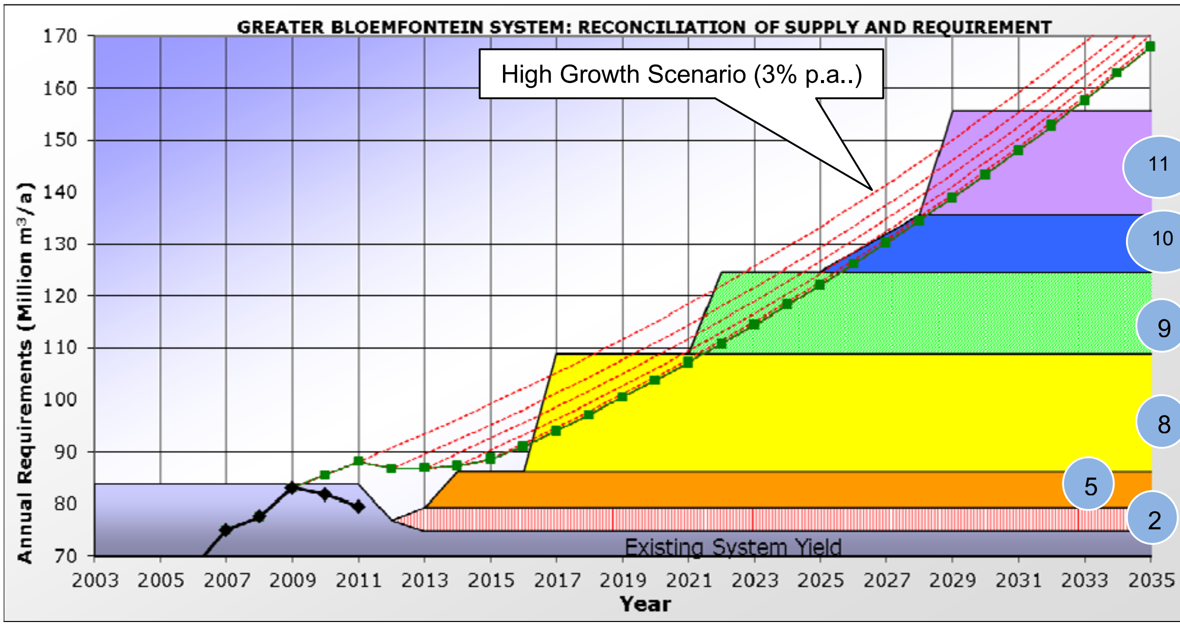

Figure 7.9: Water Balance Scenario H

The interventions which have been utilised for the reconciliation of supply and requirement in **Figure 7.9** are contained in **Table 7.20** below.

Table 7.20: Water Balance Scenario H: Interventions to be implemented

No	Intervention	Year of First Water or Saving	Yield Million m^3/a	Fast-Tracked Yes/No
1	WC/WDM in Year 1	2012	3.9	
2	Tienfontein 4 m^3/s	2013	4.4	
3	WC/WDM in Year 2	2013	2.7	
4	WC/WDM in Year 3	2014	2.3	
5	Welbedacht WTP 145	2014	7.0	
6	WC/WDM in Year 4	2015	1.6	
7	WC/WDM in Year 5	2016	0.7	
8	Welbedacht P/S (2m^3/s)	2017	22.6	Yes
	Tienfontein 7 m^3/s	2022	15.9	
	Re-use of Treated Effluent (generic)	2026	10.9	
	Gariep to Knelpoort	2029	20.0	

7.8.10 Water Balance Scenario I: Low Water Requirement, WC/WDM Most Likely Scenario, Metolong Dam

Scenario I is the same as Scenario D, but assumes that the growth in water requirement follows the Low Water Requirement Curve and not the High Water Requirement Curve. The Low Water requirement curve is based on a population growth rate of approximately 1% per annum.

Under this scenario with the most likely WC/WDM implementation savings being achieved a new supply side intervention will not be required before 2022. This would allow for a detailed feasibility study and implementation solution to be found to augment the supply to Knellpoort Dam.

A possible reconciliation of supply and requirement based is shown in **Figure 7.10** below.

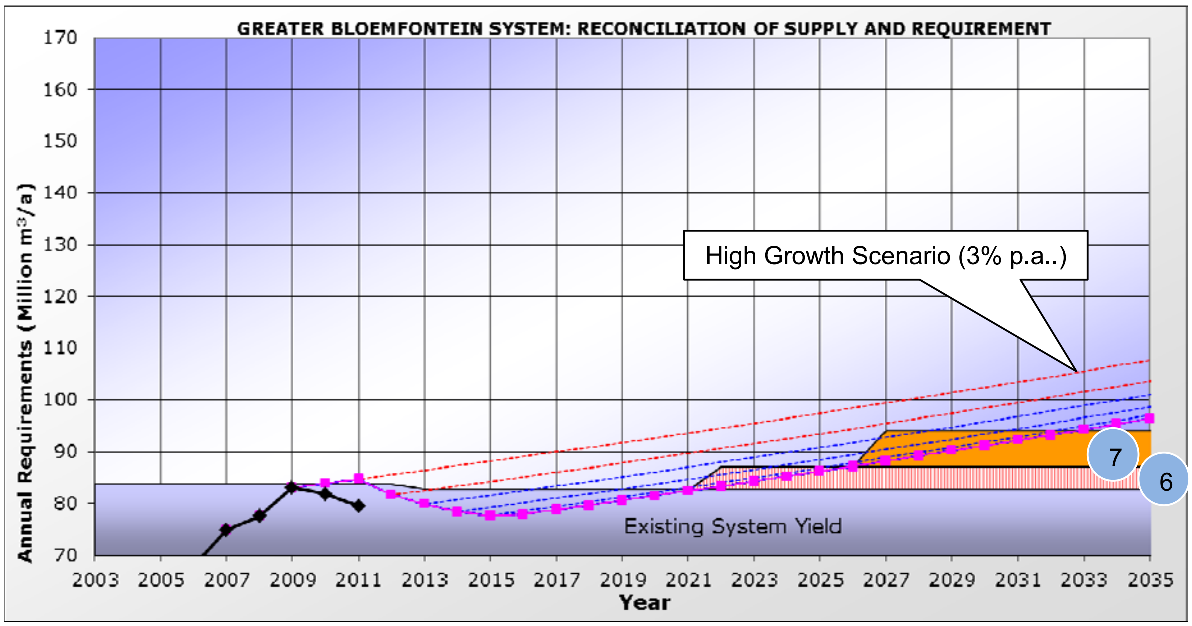

Figure 7.10: Water Balance Scenario I

The interventions which have been utilised for the reconciliation of supply and requirement in **Figure 7.10** are contained in **Table 7.21** below.

Table 7.21: Water Balance Scenario I: Interventions to be Implemented

No	Intervention	Year of First Water or Saving	Yield million m^3/a
1	WC/WDM in Year 1	2012	3.9
2	WC/WDM in Year 2	2013	2.7
3	WC/WDM in Year 3	2014	2.3
4	WC/WDM in Year 4	2015	1.6
5	WC/WDM in Year 5	2016	0.7
6	Tienfontein 4 m^3/s	2022	4.4
7	Welbedacht WTP 145	2027	7.0

7.9 EVALUATION OF SCENARIO FINDINGS / RECOMMENDATIONS

7.9.1 Background

Since its construction in 1973 Welbedacht Dam has lost approximately 95% of its storage capacity. Over the first 18 years of operation the sediment deposition rate was extremely high, but since 1991 scouring of the dam during some of the floods has been intermittently practised. This has reduced the rate of sedimentation but has not stopped the dam from gradually losing almost all of its storage capacity. The flushing operations and on-going sedimentation, however, impact on the quality of the water received at the Welbedacht WTP. The inability of the water treatment plant to deal with high turbidity levels limits the production capacity of the water treatment plant.

Due to the decreasing yield of the Welbedacht Dam as a result of siltation, and the increasing demand on the Caledon-Bloemfontein Regional Water Supply Scheme, DWA supplemented the yield of the Welbedacht Dam by constructing the Knellpoort off-channel storage dam in 1998. Knellpoort Dam which has a gross storage capacity of 137 million m^3, is supplied with water from the Caledon River by the Tienfontein Pump Station. Water pumped from the Caledon River into Knellpoort Dam is then released back into the Caledon River during periods of low river flow to allow abstraction at Welbedacht Dam by Bloem Water all year round. The on-going sediment deposition impacts negatively on the operation and maintenance of Tienfontein Pump Station which is a critical node of the supply system.

A yield analysis of the Caledon system has shown that there is still significant water available in the Caledon River to reconcile water supply and requirement for the Greater Bloemfontein area. The development of the additional yield (which could be as much as 60 million m^3/a) would depend on the capacity of the infrastructure that is constructed to abstract water (and the feasibility thereof given the sediment related problems being experienced) from the Caledon River/Welbedacht Dam. Given the close proximity of the Caledon River to Bloemfontein and the existing infrastructure, it would be considerably less costly to further develop this source than to obtain additional water from the Gariep Dam or from the Van der Kloof Dam (the current cost estimates indicate that it would be in excess of 3 times more expensive to obtain water from the Gariep Dam than from the Caledon River). It must be noted however that in the longer term obtaining additional water from the Gariep Dam (or alternatively the Vander Kloof Dam or the proposed Bosberg/Boskraai Dam) should be weighed up against other potential supply schemes such as water reuse.

The yield of the existing system is currently being negatively impacted by the problems associated with the on-going high siltation experienced at Welbedacht Dam, Welbedacht WTP and Tienfontein Pump Station. The following factors are reducing the current system yield:

- **Capacity of Tienfontein Pump Station**: Due to on-going operation and maintenance related problems associated with the siltation, the pumps frequently do not operate at their design capacity.
- **Capacity of Welbedacht Dam**: Unless Welbedacht Dam is scoured, the capacity of the dam will continue to decrease and this will have a knock-on impact on Welbedacht WTP and the silt profile at Tienfontein Pump Station.
- **Capacity of Welbedacht WTP**: The inability of the water treatment plant to deal with high turbidity levels reduces the production capacity of the water treatment plant during the high demand (summer) season.

In addition, other infrastructure risks pose potential negative impacts on the system's yield:

- **Integrity of the Welbedacht pipeline:** Should the condition of this pipeline continue to deteriorate there is a risk that more pipe bursts could occur. Any long outages of the pipeline will impact on the yield of the current system (and will impact on the continuity of supply to the user).
- **Other Infrastructure Challenges:** The MMM and BW commissioned a study entitled "Joint Bulk Water Services: Infrastructure Challenges" in February 2012. This report summarises the current status of the joint bulk water infrastructure serving the Mangaung Metropolitan area, and points out the various challenges which need to be addressed to ensure uninterrupted and sufficient water supply to the end consumers. This report further prioritises the interventions which are required as well as their associated costs. *It is important to note that the identified infrastructure challenges identified in this report (i.e. storage, water treatment plant capacity, upgrading and maintenance of the WTP) will not increase the yield of the system (make more water available), but are critical to implement if Bloem Water and Mangaung Metropolitan Municipality do not want on-going potential interruptions to supply.*

It is imperative that the abovementioned issues are addressed as a matter of priority, as it will allow for <u>maintaining the existing system yield</u> and could also potentially result in an <u>increase in system yield</u> (from that which was modelled) if the full output capacity of the WTP can be restored during the summer months and if the storage capacity of the Welbedacht Dam can be increased (albeit a small increase in storage capacity).

Prior to increasing the capacity of Tienfontien Pump Station the requirement for water will be greater than the historical firm yield. The only intervention which could mitigate this is the implementation of WC/WDM (best case scenario). Under most scenarios evaluated even after increasing the capacity of Tienfontein Pump Station, addressing the scouring problems at Welbedacht Dam and ensuring that Welbedacht WTP can operate at its design capacity of 145 Ml/d, there will still be an imbalance between supply and requirement until the supply to Knellpoort Dam can be augmented or additional WC/WDM measures implemented. It is important that any long term further augmentation of Knellpoort Dam from the Caledon River be further investigated to ensure that whatever measures are implemented will address the siltation issues and will provide a high reliability of supply.

The prioritised issues, which were highlighted through the Scenario Planning that was undertaken, are discussed in more detail below. These issues should form the basis of any action plan going forward.

7.9.2 Recommended Interventions for the Reconciliation of Supply and Requirement

The following interventions should be prioritised:

a) Implementation of WC/WDM

The projected water requirement (based on the high water requirement curve) is currently in excess of the historical firm yield of the system. Implementation of WC/WDM is critical, as the next supply scheme (under a fast-tracked programme) could only be put in place by 2018 at the earliest. Funds and resources should be allocated by MMM to ensure that MMM achieves at a minimum their "most likely scenario" in terms of WC/WDM savings. MMM should nevertheless strive to achieve the "best case scenario".

Under the "most likely scenario" approximately 11.5 million m^3 of water could be saved at an approximate cost of R 240 million (this equates to a URV of approximately R1.5/m^3).

b) Increase capacity of Tienfontein Pump Station

Tienfontein Pump station is seen as one of the critical components of the existing water supply infrastructure supplying Bloem Water with raw water, as Bloem Water receives approximately 40 % of its water supply via Tienfontein Pump Station and Knellpoort Dam. The other critical component is the Welbedacht Pipeline.

Under sediment equilibrium conditions in Welbedacht Dam, it is estimated that the Tienfontein site will be sedimented to 4 m above the full supply level of the dam, which is approximately 17 m above the original river bed level. Pumping at Tienfontein is therefore not under storage conditions, but under run of river conditions.

Since there is minimal storage capacity in Welbedacht Reservoir, the Tienfontein pumps must operate at a high assurance to supply Knellpoort Dam. The predicted bed level at Tienfontein pump station indicates that the current bed level is near equilibrium, but it should be borne in mind that this is a dynamic equilibrium and during floods scour will occur and deposition after floods. The variability on the equilibrium bed level is in the order of 3 m up or down with which the pump station has to cope. This could lead to sediment build up as high as 4.6 m above the full supply level of the reservoir, at the pump station, and the existing pumps cannot deal with such a scenario.

Tienfontein Pump station currently has a design capacity of 3 m^3/s, but due to the sedimentation related problems and high maintenance requirements delivers on average approximately 2.5 m^3/s. Given that the projected water requirements are currently in excess of the system historical firm yield, it is proposed that two additional (1 m^3/s) pumpsets at Tienfontein Pump Station be implemented. The first pumpset should be utilised to increase the design capacity of the pump station to 4 m^3/s and the second pumpset to provide additional standby capacity. This would provide an additional yield of approximately 4.4 million m^3/a. With an increase in the standby capacity (proposed 50% of design capacity), maintenance of pumps could be more easily facilitated without impacting on the operating capacity of the pump station. The additional yield gained by increasing the capacity of Tienfontein pump station by 1 m^3/s would under most scenarios still not lead to a balance of supply and requirement, but would reduce the risk of non-supply and having to impose water restrictions.

Whilst it is accepted that there is sufficient storage capacity in Knellpoort Dam (and also Rustfontein Dam) to allow Tienfontein Pump Station to have downtime for maintenance purposes, a cause of concern is the fact that this downtime may occur during a drought period when it is critical that pumping of available run of river flow should take place. Downtime may also occur as a result of the sediment build up at the Tienfontein Pump Station. Should this happen during a drought, the water supply to Bloem Water and Mangaung Metropolitan Municipality would be put at risk.

It is expected that these types of problems and associated expenditure will continue to persist into the future, unless the pump station is modified/redesigned to cope with the sedimentation problems. With the near equilibrium sediment regime in the Caledon River now being reached, the redesign of Tienfontein pump station should be considered. The following aspects could be taken into consideration in the redesign of Tienfontein pump station:

- Redesign the forebay with fine screens,
- Trash rack opening under water,
- Flushing facility,
- Hoppers with jet pumps to remove sand,
- Investigate pump intake elevation and possibly pump types, sand trap efficiency and flood levels, and

- Possible use of a dry well.

In general the pump station position is, however, ideally located at a river bend.

c) Address the siltation problems at Welbedacht WTP

An analysis of the siltation problems at Welbedacht WTP in the mid 1990's showed that the there was a general increase in average turbidity at Welbedacht WTP from 500 NTU in 1976 to approximately 2300 NTU in 1994. It is possible that the decrease in storage capacity of Welbedacht Dam from 115 million m^3 to approximately 6 million m^3 has resulted in a relatively shallow dam storage and possibly a flow channel which has the effect that high turbidity inflow water passes through the dam, depositing less silt than previously and thus resulting in delivering a more turbid water to the dam wall area and ultimately to the Welbedacht WTP. High silt loads arriving at the dam wall are as a result of scouring and turbulence due to river floods and the resuspension of some of the previously deposited silt.

The inability of the water treatment plant to deal with high turbidity levels currently limits the production capacity of the water treatment plant. Due to the high turbidity of the raw water, especially during flood events it is not possible to operate Welbedacht WTP at full capacity (145 Ml/d) throughout the year. A discussion with the operator of the WTP suggested that the WTP could operate at full capacity (145 Ml/d) in winter, but at times only managed an output of between 90 and 100 Ml/d in summer when the silt load in the river was higher. The yield of the system could therefore potentially increase if the WTP was operated at full capacity all year round.

On average it has been assumed that the yearly output from the WTP is approximately 123 Ml/d. In order to optimise the system yield, Welbedacht WTP should be operated close to 145 Ml/d throughout the year. The peak week water requirements should be absorbed by the Maselspoort WTP and Rustfontein WTP. By operating the Welbedacht WTP at 145 Ml/d as opposed to 123 Ml/d the system yield could be increased by approximately 7 million m^3/a.

In order to address this problem it is proposed that the following issues are further addressed (as part of the design of the WTP or part of further planning studies):

- The water treatment process required to deal with on-going siltation issues.
- The abstraction from Welbedacht Dam. During any scouring of Welbedacht Dam, the water level in the dam would be drawn down and the intake works to the water treatment plant may no longer be able to effectively draw water for conveyance to the water treatment plant. Issues surrounding turbidity would also have to be investigated.

Alternative options to supply the water treatment plant during periods of scouring with low turbidity water could be to provde off channel raw water storage or to provide a pipeline linking Knellpoort Dam to Welbedacht Water Treatment Plant.

d) Scouring of Welbedacht Dam

The existing radial gates are situated 15 m above the original river bed. Flushing through the existing gates is therefore not efficient and will not restore any significant lost capacity of the dam. An option would be reconstruct the dam outlets at a lower level which might restore up to approximately 40% of the original storage capacity of Welbedacht Dam if operated appropriately. It is however anticipated that this option would be very costly and for this reason, and the fact that Knellpoort Dam was constructed to replace the lost storage capacity of Welbedacht Dam, this option is not considered a feasible solution.

At the moment sediment flushing from Welbedacht Dam, by means of opening the radial gates, is limited to between 8 to 12 hours. Welbedacht Dam has 5 m radial sluice gates and the opening of these gates creates a suddden drop in water level, causing a sudden outflow of water which induces turbulence in the basin upstream of the dam wall. The turbulence creates a scouring action which churns the deposited sediment loose and the outgoing water would then carries a considerable amount of silt from within the dam basin downstream into the river.

It would be more effective (in terms of sediment removal) to scour Welbedacht Dam for 4 to 7 days continuously by flushing the dam during a flood period. The gates could also be left open prior to the first flood reaching the dam wall. The initial floodwater would therefore be allowed to pass through the dam, at a steeper flow gradient, and thus at higher velocities, which would also induce a scouring action in the basin, scouring some of the previously deposited silt from the dam basin. Longer duration flushing would ensure a deeper channel near the Tienfontein pump station with the hydraulic control remaining at the dam and not controlled by vegetation and sediment upstream of the dam, as is currently happening. Longer duration flushing would also make it possible to release relatively clear water at the end of flushing to limit sediment deposition in the river downstream. In order to ensure good quality water to the Welbedacht WTP during the extended scouring period clear water storage facilities downstream of the dam (or possibly by providing a pipeline link between Knellpoort Dam and Welbedacht WTP) could be constructed.

Alternatively it has been proposed by DWA that the operating rules of Welbedacht Dam be modified and that Welbedacht Dam be operated as a barrage during summer months. The gates would be closed during the winter months to provide sufficient storage to feed Welbedacht WTP. The Caledon River would then be operated as a run of river scheme at Welbedacht Dam (within the limitations of the existing gates). This option could also increase the storage capacity of Welbedacht Dam and possibly improve the sedimentation conditions at Tienfontein Pump Station. The disadvantage would be to decrease the head available for Bloem Water to convey raw water to Welbedacht water treatment plant. Issues surrounding dealing with the turbidity would also have to be investigated.

During the scouring of the dam (for both the extended scouring operation scenario and the modified DWA operating rule scenario), the water level in the dam would be drawn down and the intake works to the water treatment plant may no longer be able to effectively draw water for conveyance to the water treatment plant. Issues surrounding dealing with the turbidity would also have to be investigated.

<u>It must be borne in mind that any storage capacity gained in Welbedacht Dam through scouring reduces the reliance which the system currently places on Tienfontein Pump Station.</u>

e) Integrity of the Welbedacht Pipeline

The Welbedacht-Bloemfontein Pipeline was constructed in the early 1970's (commissioned in 1974) and consists of a 112km long DN1200 pipeline. The pipeline has a maximum capacity of 145Ml/day. Together with Tienfontein Pump Station the Welbedacht pipeline is also regarded as a critical component of the raw water / bulk water supply infrastructure.

The pipeline is a pre-stressed concrete pipeline which is subject to numerous bursts due to the deterioration of the pre-stressed windings which impacts on the structural integrity of the pipeline. Since 2009, seven bursts have occurred on the Welbedacht pipeline. Should the condition of this pipeline continue to deteriorate there is a risk that more pipe bursts could occur (particularly if the pipeline is to be operated at its full capacity of 145 Ml/d) . Any long outages of the pipeline will impact negatively on the yield of the current system. The magnitude of the impact will be directly proportional to the time which the pipeline is taken out of service. (A 20% downtime would result in a decrease in the system yield of approximately 5 million m^3/a). It is therefore important to assess the integrity of the Welbedacht pipeline and to also ensure that any burst on the pipeline can be repaired in as short a time period as possible. In this regard it is also imperative that the in-line control valves be maintained and correctly set, as insufficient attention to these valves could lead to surge pressures with the potential for consequential bursts along the Welbedacht pipeline.

The Welbedacht Pipeline can unfortunately not be taken out of commission to conduct integrity testing. Testing pipeline integrity under flow conditions is very expensive (approx. R 38 million). Bloem Water have therefore opted to relay portions Welbedacht Pipeline which they know to be potentially problematic in lieu of conducting inline pipeline integrity testing.

f) Further Augmentation from the Caledon River

In addition to addressing the siltation problems at Tienfontein Pump Station, Welbedacht Dam and Welbedacht WTP, it is imperative that further long term augmentation of Knellpoort Dam from the Caledon River be investigated to ensure that whatever measures are implemented will also ensure a high reliability of supply. The study should also confirm the amount of water which is available for abstraction from the Caledon River. The two options which have currently been identified are:

- **Welbedacht P/S (2m^3/s):** To augment Knellpoort Dam from a pump station located at Welbedacht Dam itself. If a pipeline is installed between Knellpoort Dam and Welbedacht WTP to address the turbidity at Welbedacht WTP, this pipeline could be used as a bi-directional pipeline to also augment Knellpoort Dam, and
- **Tienfontein 7m^3/s**: To further increase the capacity of Tienfontein Pump Station.

It is important to address the scouring of Welbedacht Dam and the associated sediment related issues (described above) at Tienfontein Pump Station prior to the development of additional water resource capacity/infrastructure (especially increasing the capacity of Tienfontein Pump Station).

It must be noted that the capacity of the Novo Transfer Scheme will also ultimately have to be increased in order to realise an increase in system yield. Based on the yield analysis undertaken, and contained in **Appendix B**, it is anticipated that this increased capacity would be required after the Welbedacht P/S (2 m^3/s**)** and before the further increase in capacity of Tienfontein Pump Station to 7m^3/s .

Appendix B contains a range of yields dependant on which infrastructure configuration is chosen to augment the supply to Knellpoort Dam from the Caledon River

g) Other Augmentation Interventions

The next most cost effective supply side intervention would be the direct or indirect re-use of treated effluent. Public resistance to this intervention may be encountered, possibly stemming from concerns of poor design or control of processes which may allow sub-standard water to be introduced into the potable water supply system, or for religious reasons. The water to be re-used would only be from that associated with growth after 2009, from the WWTW's in the catchment area. The yield of this option, for the purposes of the scenario planning, has been assumed to be 10.8 million m3/a, but may ultimately be significantly more, dependent on the growth in water requirement.

An alternative option would be to transfer water from Gariep Dam, either directly to Bloemfontien or to Knellpoort Dam. It is estimated that this augmentation option would be in excess of 3 times the cost of developing additional water resources from the Caledon River. This option together with water reuse should be further investigated should further studies show that abstraction of additional water from the

Caledon river is not feasible (or only partly feasible) due to on-going sediment related issues and concerns.

The ecological Reserve should be implemented in a planned manner, based on the implementation dates of future water augmentation schemes. Based on the scenario planning undertaken, the ecological Reserve should only be implemented when the supply to Knellpoort dam is augmented.

Should groundwater be developed to supply the full current and projected water requirements of Wepener, DeWetsdorp, Reddersburg, Edenburg and Excelsior, then the water demand on the Greater Bloemfontein system would be reduced by approximately 4%. This would reduce the risk of non-supply and also keep the system in balance until 2016 where after a new augmentation scheme would be required.

8. STRATEGY DEVELOPMENT AND SCENARIO PLANNING FOR THE SMALL TOWNS

8.1 INTRODUCTION

The small towns considered in this reconciliation strategy are those supplied from Bloem Waters' Greater Bloemfontein Water Supply System (see **Figure 8.1)**. These include:

- Wepener (Naledi Local Municipality – FS 164),
- Dewetsdorp (Naledi Local Municipality – FS 164),
- Edenburg (Kopanong Local Municipality – FS 162), and
- Reddersburg (Kopanong Local Municipality – FS 162)

All of the above lie within the Xhariep District Municipality (DC 16). The small town of Excelsior which lies in the Thabo Mofutsanyane District Municipality (DC19) (Mantsopa Local Municipality - FS 196) is also included. This town is linked to Groothoek and Rustfontein water supply schemes, also as part of the Greater Bloemfontein Bulk Water Supply System.

Figure 8.1 shows the positions of the small towns relative to the bulk water supply infrastructure and **Figure 8.2** shows the extent of the Xhariep and Thabo Mofutsanyane District Municipalities and the relative location of the small towns.

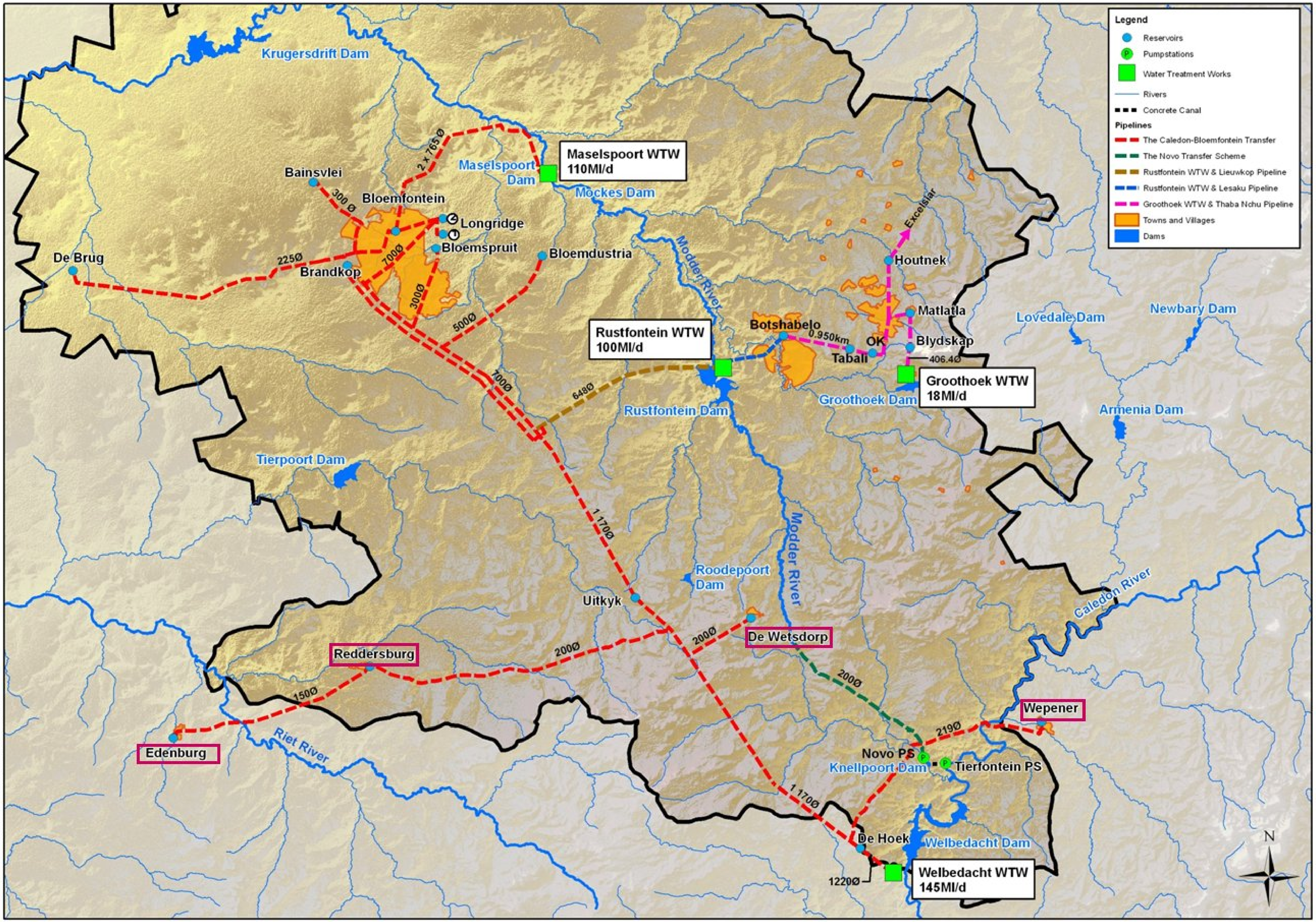

Figure 8.1: Greater Bloemfontein Bulk Water Supply Scheme (showing smaller towns)

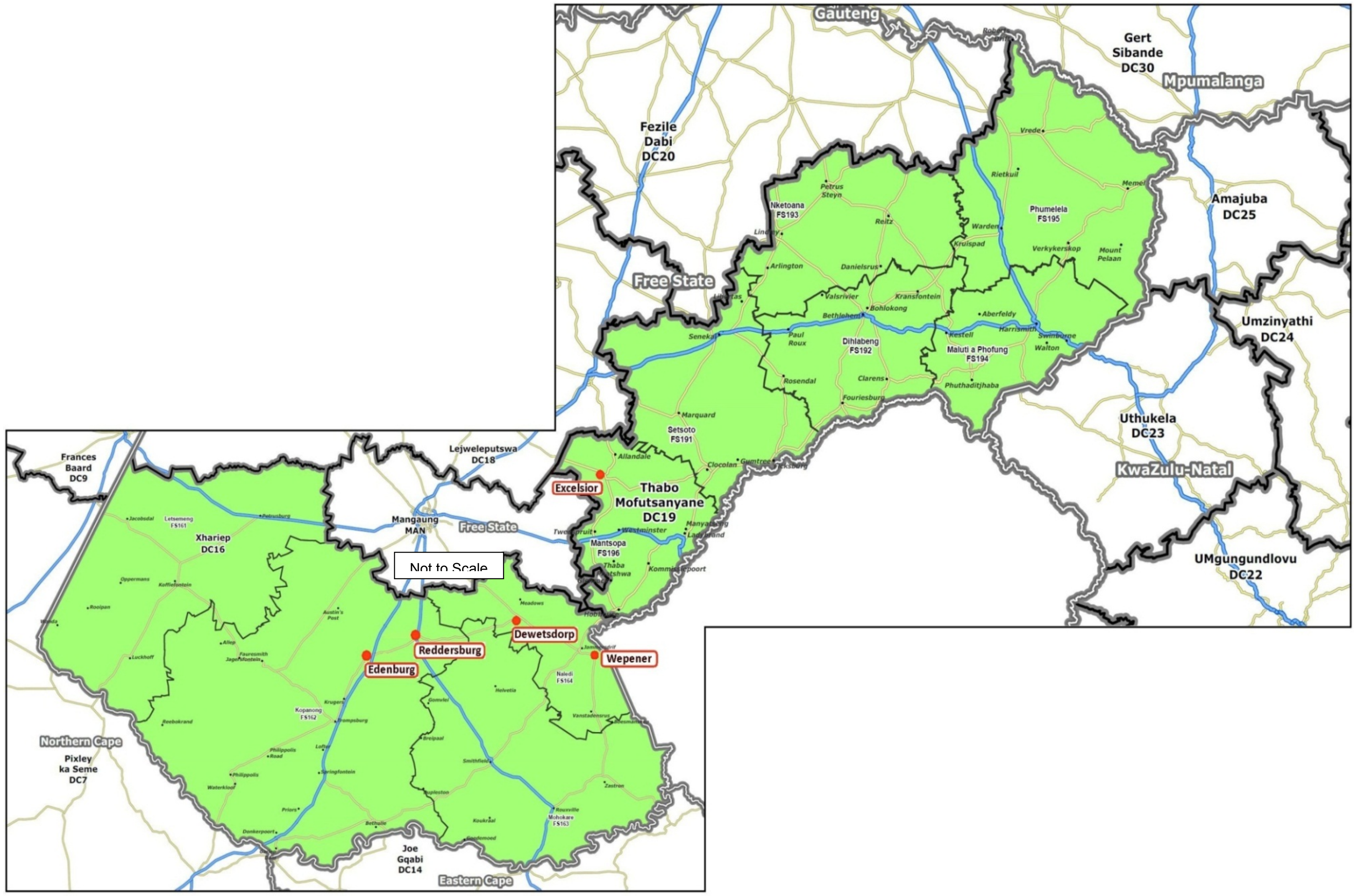

Figure 8.2: Xhariep and Thabo Mofutsanyane District Municipalities Showing the Small Towns (ref: www.demarcation.org.za)

8.2 APPROACH TO THE PROJECTED WATER REQUIREMENTS

The approach adopted in evaluating the water requirements for the five small towns was to utilize Bloem Water's bulk water meter records as well as estimates of groundwater use, where applicable. Actual water consumption figures from 2003 to 2011 have been utilised, with the exception of Excelsior, where water consumption data is only from 2006 to 2011.

The All Towns Strategy (DWA, October 2009) has presented estimates of population increase for various growth scenarios. For this water requirement analysis, the high population growth scenario from that Study has been adopted for the purpose of projecting the future water requirements for each of the five small towns. The growth in water requirements is assumed to be directly proportional to the projected population increase at each town, and on this basis future water requirements to 2035 have been estimated. This is further described for each town in **Sections 8.3** to **8.6**.

The current combined estimate of the water supplied to the small towns from Bloem Water and from local groundwater sources is indicated in **Table 8.1**

Table 8.1: Summary of Water Supply from Bloem Water and Groundwater Sources to Smaller Towns (year 2011)

Town	Supply from Bloem Water (Million m^3/a) (a)	Estimated Groundwater supply (Million m^3/a) (b)	Estimated Average Yield of Existing Boreholes (Million m^3/a) [3]	Number of Boreholes	Estimated Total Annual Consumption (a + b)
Excelsior	0.17				0.17
Wepener	0.74		0.071	4	0.74
Dewetsdorp	0.76		0.080	4	0.76
Reddersburg	0.43	0.29	0.160	9	0.72
Edenburg	0.43	0.10	0.213	12	0.53

Table 8.1 summarizes the water requirements for each of the small towns. Edenburg and Reddersburg are supplied and metered from the same bulk supply line and as such, their combined water consumption estimate is also presented in the table. The current estimates of local groundwater use are also included for the relevant towns.

[3] *It should be noted that the estimated scheme yields were calculated by using the average sustainable yields of the Karoo geology well fields of Petrusburg / Bolokanang, Edenville / Ngwathe, and Ikgomotseng for all the groundwater interventions.*

Table 8.2: Summary of Actual 2011 Water Sales Requirements and Projections to 2035

Town	Actual Water Consumption 2011 (ML/year)	Population Growth			Projected Consumption 2035 (ML/year)	Consumption (l/c/d)
		2010	2030	% Growth per annum		
Dewetsdorp	756	9 777	9 910	0.067%	768	212
Edenburg	531	8 207	9 934	0.959%	668	177
Excelsior	167	6 689	7 619	0.653%	195	68
Reddersburg	716	4 684	5 641	0.934%	895	419
Wepener	744	11 153	13 483	0.953%	934	183
Edenburg and Reddersburg	1 247	12 891	15 575	0.950%	1 565	265

It would appear that Reddersburg, in comparison to the other towns is either experiencing significant losses downstream of the Bloem Water bulk meter or is experiencing metering problems within its distribution network. Similarly the per capita consumption for Excelsior appears to be too low. The possible explanation for this is given **Section 8.4**.

8.3 WEPENER

Wepener is located in the south eastern part of the Free State, close to the border with Lesotho, and adjacent to the Caledon River. Other than acting as a commercial center for a 1 725 km^2 district where mixed farming is practiced, the town has no large commercial or industrial sector, and water uses consist mainly of domestic type users.

8.3.1 Existing Water Supply at Wepener

Wepener receives water via a pipeline from Bloem Water's Welbedacht WTW, and has also previously been supplied from boreholes. However, the current WARMS data base does not reflect any groundwater use by the town and it appears that the usage of boreholes has diminished over the years, with the town becoming increasingly more reliant on the Bloem Water supply.

8.3.2 Wepener Water Requirements

The estimated population of Wepener (2009) is 10 946 inhabitants (All Towns Study data). The total water sales to the town by Bloem Water for the period July 2010-June 2011 amounted to 0.744 million m^3/a, which includes internal losses within the town's reticulation system. This implies an average per capita consumption of 183 l/c/d.

Table 8.3: Summary of Water Supply from Bloem Water and Groundwater Sources to Wepener (2011)

Town	Supply from Bloem Water (a)	Estimated Groundwater Supply (Million m^3/a) (b)	Estimated Average Yield of Existing Boreholes (Million m^3/a) [4]	Number of Boreholes	Estimated Total Annual Consumption (a + b)
Wepener	0.74		0.071	4	0.74

As was shown in **Table 8.2,** the population growth rate increase of close to 1% represents the high growth scenario from the All Towns Study. This equates to a projected average annual water requirement of 0.934 million m^3/a and an annualized peak demand of 1.386 million m^3/a, both up to 2035. **Table 8.4** and **Figure 8.3** show the projected water requirements for Wepener in Ml/day.

Table 8.4: Wepener Water Requirements to 2035 (Ml/day)

Town	Water Requirements			
	Average Annual (Ml/day)		Within Allowance for Peak (Ml/day)	
	2011 Actual	2035	2011 Actual	2035
Wepener	2.038	2.559	3.024	3.797

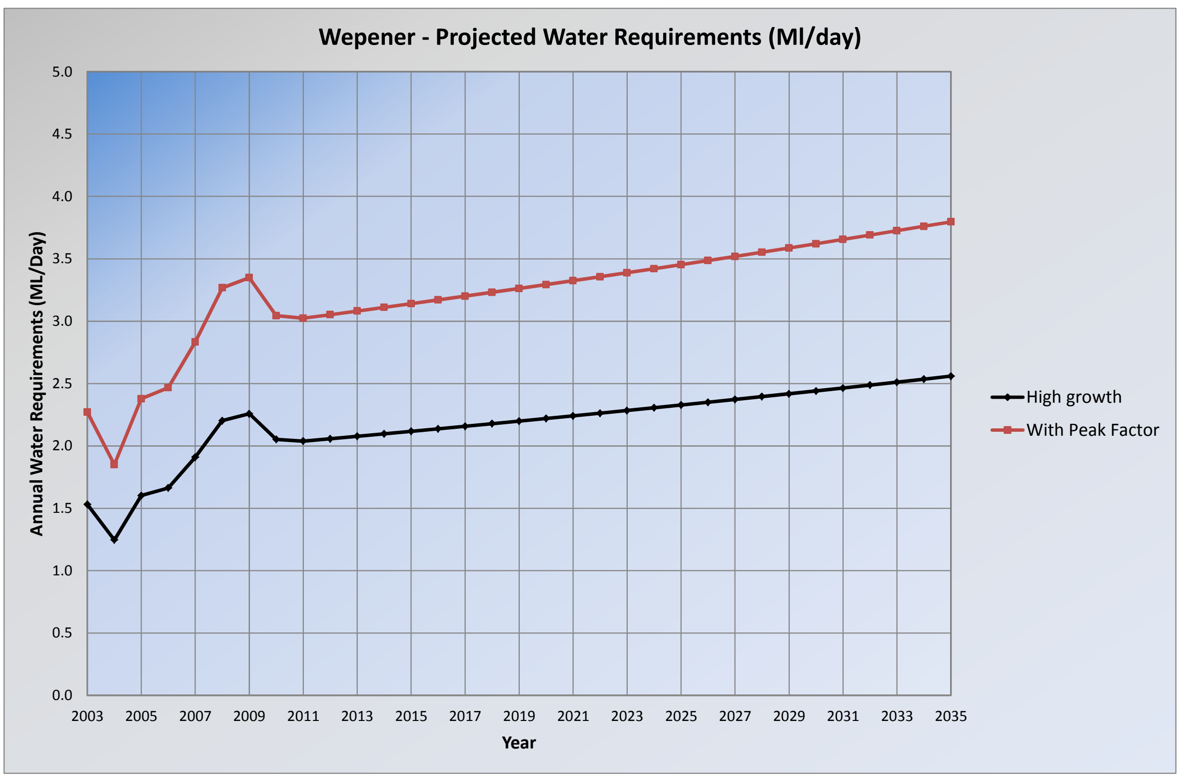

Figure 8.3: Water Requirement Projections for Wepener

[4] *It should be noted that the estimated scheme yields were calculated by using the average sustainable yields of the Karoo geology well fields of Petrusburg / Bolokanang, Edenville / Ngwathe, and Ikgomotseng for all the groundwater interventions.*

8.3.3 Opportunity for Water Conservation and Water Demand Management

As part of the All Towns Study, theoretical water demands for Wepener were estimated, based on the assumed average per capita requirements from that study, which amounted to a consumption of 506 Ml/year. If a nominal allowance of 20% were to be assumed as "acceptable" internal losses then the theoretical water requirement would be in the order 607 Ml/year. Thus, it appears that a water saving of about 137 Ml/year could possibly be achieved. This equates to about 18% of current bulk water sales to the town. However, the theoretical assumptions made for the town's water demands might be too low, and as such it is proposed that planning be based on the actual 2010/11 water sales of 744 Ml/year. Based on the above calculations, the water saving potential for this town is estimated as being **low**. This however needs to be confirmed and the Municipality needs to prepare a WC/WDM business plan.

8.3.4 Potential Surface Water Augmentation Options for Wepener

Options to augment the supply to Wepener could include further reliance on the Bloem Water System up to the supply capacity of the bulk water pipeline, whereafter consideration could be given to the provision of a booster pumpstation on that pipeline or provision of a new gravity pipeline.

A booster pumpstation of 44 l/s capacity has been sized for location at chainage 25,1 km and could yield an additional 0.868 Ml/day (316 937 m^3/annum). The gravity pipeline option from the Welbedacht Water Treatment Works involves a new 200 mm dia, 32.5 km pipeline, capable of delivering 34 l/s. This could potentially yield an additional 2.938 Ml/day (1 072 224 m^3/annum).

Taking into account that the current capacity of the existing pipeline from the Bloem Water scheme is about 2.95 Ml/d, the extent of augmentation that would be required to meet the peak water requirement by 2035 of 3.797 Ml/d would be 0.847 Ml/d.

8.3.5 Wepener Potential Groundwater Augmentation Options

An alternative to Wepener becoming more reliant on Bloem Water would be for the local groundwater sources to be developed so as to augment the supply once the current capacity of the Bloem Water pipeline has been reached.

The DWA Report on the ***Groundwater Potential for Small Towns*** within the Greater Bloemfontein area has identified thirty-one potential dolerite dyke structures within a 10–15 km radius of Wepener. These dolerite dykes were grouped into four potential development regions (A, B, C and D) for the purposes of calculating the theoretical sustainable yield volumes for the Wepener area (see **Figure 8.4**).

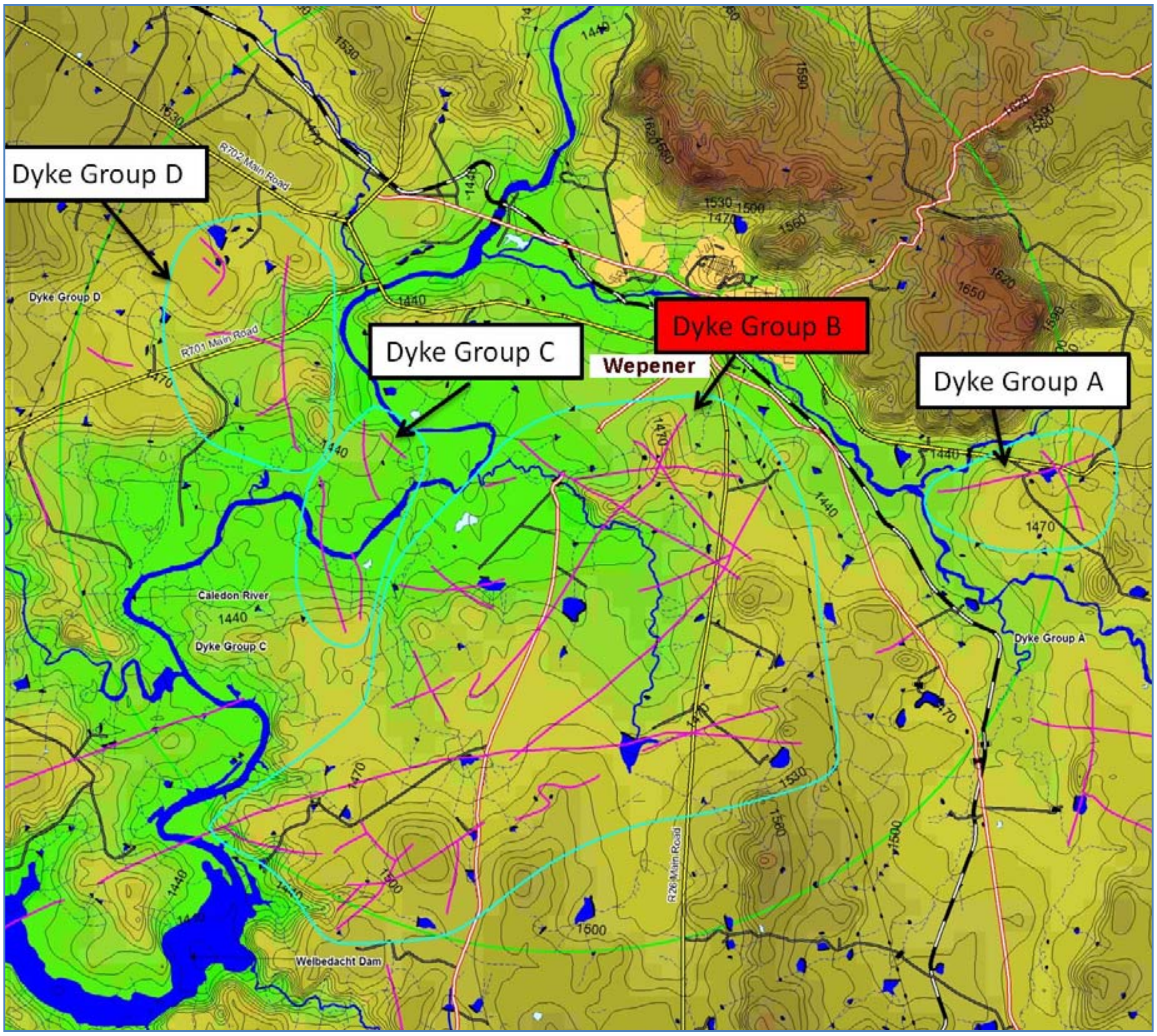

Figure 8.4: Potential Dolerite Dyke Intrusions Close to Wepener

It is important to note that although there are irrigation pivots situated next to the Caledon River, it is probable that these irrigation pivots utilise surface water and not groundwater. In the review of the latest available WARMS data for this region, no groundwater use is registered in WARMS within quaternary catchment D23G, in which Wepener lies. Small-scale groundwater use (Schedule 1) is utilised by many farmers for domestic purposes at their farmsteads. This may include uses such as drinking water purposes, washing of clothes and food preparation as well as watering of the farmstead gardens.

Groundwater Resource Potential

Estimates of groundwater resource potential (sustainable yield) from each of the four Dyke Group areas were determined. These estimates were based on two approaches, namely a groundwater recharge based estimation (providing a lower limit of sustainable yield) and a geometric mean estimation which provides an upper limit of sustainable yield. The latter was based on the assumptions that:

- The potential dolerite dykes are water bearing;
- An average sustainable yield of 2,1 l/s (60,5 m^3/d) per borehole can be achieved;
- An 8-hour pumping schedule is assumed and a 14 hour recovery period;
- Boreholes would be spaced at 250 m centres along the dolerite dyke structure.

The outcomes of the sustainable yield estimates for both approaches are summarised in **Table 8.5**.

Table 8.5: Summary of the Estimated Sustainable Groundwater Yield in the Wepener Area

Dyke Group	Estimates of Sustainable Groundwater Yield (Ml/day)		
	Recharge Approach	Geometric Mean Approach	Average (Ml/day)
A	0.658	0.847	0.752
B	7.651	12.761	10.206
C	0.743	1.210	0.977
D	1.331	1.370	1.350

From **Figure 8.4** and **Table 8.5** it can be seen that in terms of both proximity to the town and yield potential, the Dyke Group B offers the most favourable option for groundwater development at Wepener. The average of the two approaches suggests that a sustainable yield potential from the development of Dyke Group B alone, could yield up to 10.200 Ml/d.

A sustainable groundwater yield potential of 10.200 Ml/d equates to almost four times the projected AADD for the town in 2035 (2.559 Ml/d) and more than twice the 2035 peak water requirement of 3.797 Ml/d. Consequently it can be concluded that groundwater has significant potential as an augmentation option for the town.

Taking into account that the current capacity of the existing pipeline from the Bloem Water scheme is about 2.95 Ml/d, the extent of augmentation that would be required to meet the peak water requirement by 2035 of 3.797 Ml/d would be 0.847 Ml/d.

8.3.6 Wepener Cost Estimates

Surface Water Options

The yields, costs and Unit Reference Values (URVs) for the two potential surface water augmentation options are summarized in **Table 8.6**.

Table 8.6: Potential Surface Water Augmentation Options for Wepener

Item	New Booster Pump Station	New Gravity Pipeline
Yield (m^3/a)	316 937	1 072 244
Yield (Ml/day)	0.868	2.938
Capital costs (R mill)	3. 04	44. 85
O&M Annual (R mill)	0.52	0.97
URV (at 6%) (R/m^3)	2.26	3.65

From the above it can be seen that the booster pumpstation provides the most favorable surface water development option for augmenting the future water supply to Wepener

Groundwater Options

The costs for developing the proposed boreholes are based on the findings of the ***Groundwater Potential for Small Towns*** report, in which indicative cost estimates for wellfield development are provided, based on a unit cost per borehole of about R205 000 (including VAT). Further allowance for other infrastructure requirements, including collector pipework, storage reservoirs, delivery pipelines, and pumpstations were also applied, in addition to energy costs and operation and maintenance costs.

Table 8.7**Table 8.7** provides a comparative summary of the yields, cost estimates and URVs for the potential development of Dyke Groups A, B, C and D.

Table 8.7: Yield and Cost Summary of the Potential Wepener Groundwater Scheme

Item	Dyke Group					
	A	B1	B2	B3	C	D
Yield (m^3/a)	274 663	1 235 845	1 324 120	1 165 225	356 423	492 933
Yield (Ml/day)	0.753	3.386	3.628	3.193	0.977	1.351
Capital costs	R 12 650 327	R 42 195 594	R 56 455 747	R 55 341 074	R 19 674 098	R 23 321 655
O&M Annual	R 225 735	R 846 119	R 1 041 757	R 869 078	R 352 249	R 350 506
URV (at 6%)(R/m^3)	3.75	2.85	3.50	3.76	4.50	3.89

(1) O&M includes energy costs at 70c/Kw h

From the above it can be seen that the development of Dyke Group B1 offers the most favourable groundwater development option for augmenting the future water supply to Wepener.

8.3.7 Wepener Water Balance

The booster pumpstation intervention (0,868 Ml/day) and the potential development of Dyke Groups B1, B2 and B3 (3,386 Ml/day) have been shown on **Figure 8.5** as possible implementation options for Wepener. As can be seen from the graph, the Average Annual Daily Demand (AADD) of Wepener can be met through the existing supply infrastructure. The existing infrastructure has insufficient capacity to meet the peak month water requirement. Unless sufficient potable water storage is provided within the town of Wepener itself, it is most likely that water shortages will occur during the summer months.

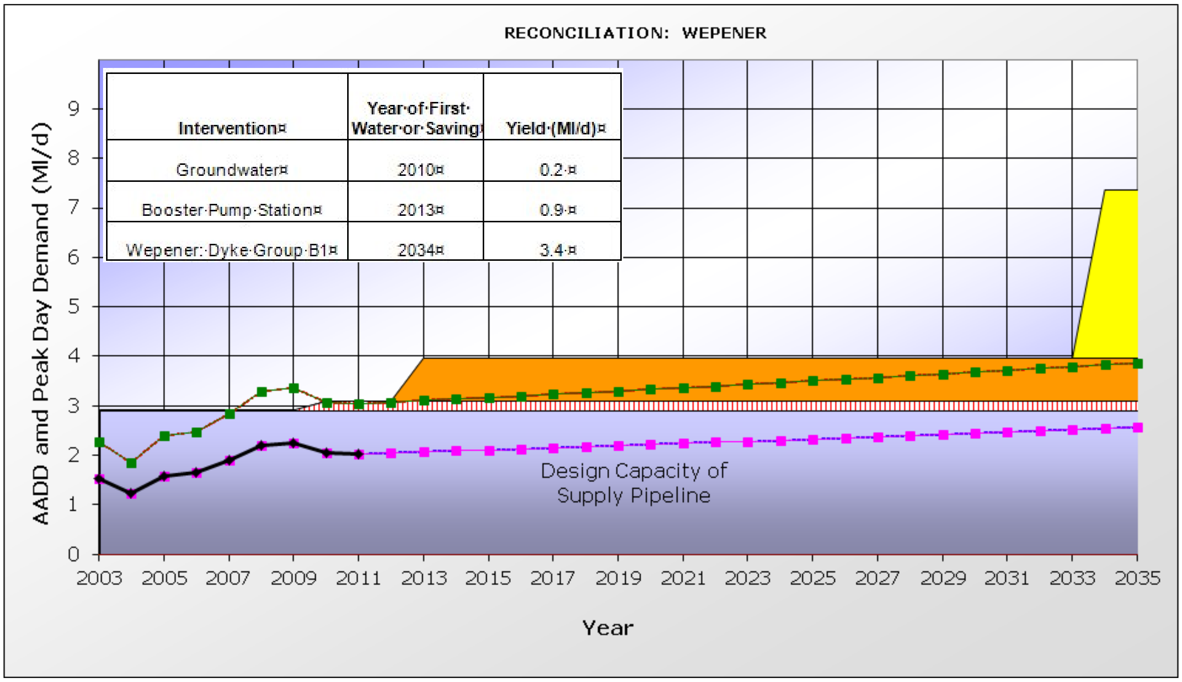

Figure 8.5: Reconciliation of Water Requirements and Availability

8.3.8 Recommendations for Wepener

It is imperative that the Naledi Municipality develop a business plan for the implementation of WC/WDM. Based on the URVs, the booster pumpstation is the preferred option for implementation at Wepener. However incremental development of the groundwater resource also appears favourable and could be considered as an alternative, introducing some independence of the town on the Bloemfontein system as well as conjunctive use of a local water source.

8.4 REDDERSBURG AND EDENBURG

Reddersburg and Edenburg are located about 60 km and 75 km, respectively, to the south of Bloemfontein. For the purpose of this report, these two towns are being considered together, due to the fact that they receive water via the same Welbedacht – Bloemfontein pipeline from the Welbedacht water treatment works, supplemented by local boreholes. Neither towns have any significant commercial or industrial sectors and water users consist mainly of domestic type users.

8.4.1 Existing Water Supply to Reddersburg and Edenburg

These towns both receive water from the Welbedacht – Bloemfontein pipeline and from local groundwater sources. The current WARMS data base shows that two boreholes are registered, one for Reddersburg and one for Edenburg. The details are shown in **Table 8.8**.

Table 8.8: Edenburg and Reddersburg Registered Groundwater Use

Town	Registered User	Quaternary Catchment	Registered Volume (m^3/annum)	Use Start Date
Reddersburg	Kopanong Local Municipality	C51A	2000	1990
Edenburg		C51C	25000	1985

8.4.2 Reddersburg and Edenburg Water Requirements

The estimated combined population of Reddersburg and Edenburg (2009) is 12 627 inhabitants (All Towns Study data). The total water sales to the towns by Bloem Water for the period July 2010 - June 2011 amounted to 1247 Ml/year, which includes internal losses within the reticulation systems. This equates to an average per capita consumption of 265 l/c/d.

Table 8.9: Summary of Water Supply from Bloem Water and Groundwater Sources to Reddersburg and Edenburg (2011)

Town	Supply from Bloem Water (a)	Estimated groundwater supply (million m^3/a) (b)	Estimated average yield of existing boreholes (million m^3/a)	Number of boreholes	Estimated total annual consumption (a + b)
Reddersburg	0.43	0.29	0.160	9	0.72
Edenburg	0.43	0.10	0.213	12	0.53

As was shown in **Table 8.2**, the population growth rate increase of close to 1% represents the high growth scenario from the All Towns Study. This equates to a projected average annual water requirement of 1 565 Ml/yr and an annualized peak demand of 2 321 Ml/yr, both up to 2035.

Table 8.10 and **Figure 8.6** show the projected combined water requirements for Reddersburg and Edenburg in Ml/day.

Table 8.10: Reddersburg and Edenburg Combined Water Requirements to 2035 (Ml/day)

Town	Water Requirements			
	Average Annual (Ml/day)		Within Allowance for Ppeak (Ml/day)	
	2011 Actual	2035	2011 Actual	2035
Edenburg and Reddersburg	3.416	4.287	5.068	6.359

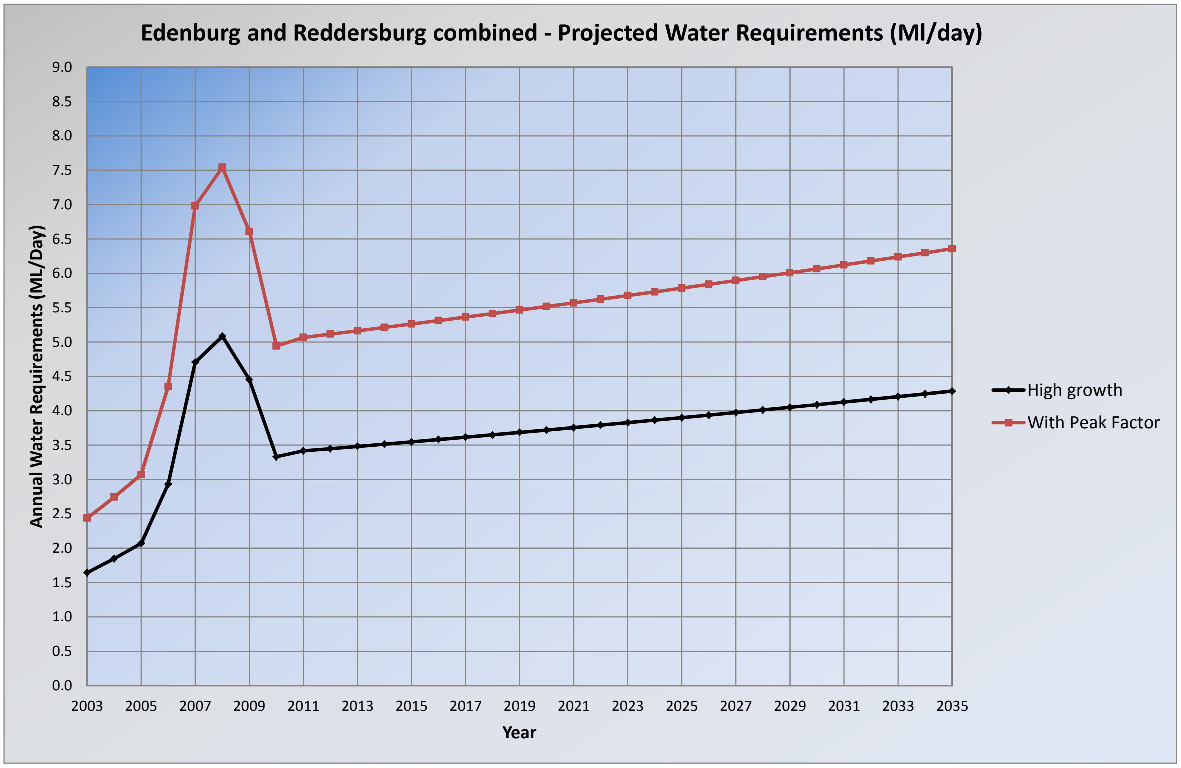

Figure 8.6: Combined Water Requirement Projections for Reddersburg and Edenburg

8.4.3 Opportunity for Water Conservation and Water Demand Management

As part of the All Towns Study, theoretical water demands for Reddersburg and Edenburg were estimated, based on the assumed average per capita requirements from that study, which amounted to a consumption of 280 and 368 Ml/year respectively, totaling 648 Ml/yr. If a nominal allowance of 20% were to be assumed as "acceptable" internal losses then the combined theoretical water requirement would be in the order 778 Ml/year. Thus, it appears that a water saving of about 469 Ml/year could possibly be achieved, i.e. 37% of current bulk water sales to the town. This significant discrepancy suggests that there may be an error in metering of water sales to these towns, rather than being attributed entirely to water losses. This apparent anomaly should be further investigated. The water saving potential for this town is estimated as being **high**. This however needs to be confirmed and the Municipality needs to prepare a WC/WDM business plan.

8.4.4 Potential Surface Water Augmentation Options for Reddersburg and Edenburg

Three potential surface water development options to augment the supply to these two towns have been identified. These include:

- A WTW and a new pcpeline from the existing Fouriespruit Dam (capacity of 1,8 million m^3) to **Edenburg** is a possible intervention. The pipeline would be about 13 km long and of 100 mm diameter, capable of delivering an estimated 4.3 l/s (16 m^3/hr). This equates to an augmentation volume of 135,605 m^3/a or 0.372 Ml/day. The embankment dam is currently under the control of Nature Conservation but is has been established that they may not wish to retain control or responsibility for it. This dam could therefore serve as a source of water for the town, in addition to the boreholes and the existing Uitkijk-Edenburg Pipeline.

- A new gravity pipeline (of 200-300 mm diameter) from to Reddersburg (34.3 km) and a further 25.4 km to Edenburg, totaling 59,7 km and delivering and additional 35 l/s from the Welbedacht scheme pipeline. This equates to an augmentation volume of 1,103,760 m3/a or 3.024 Ml/day.
- The existing Reddersburg Dam could supply Reddersburg town via an existing package plant, which is currently not fully operational. This dam could serve as a source of water for the town, in addition to the boreholes and the Uitkijk-Edenburg Pipeline. The dam has a capacity of 730 000 m3. Design reports indicate that the sustainable yield would be about 62 000 m^3/yr (an average of about 170 m^3/d). The intervention would entail the upgrading of existing pipelines and the rehabilitation of the existing Water Treatment Package Plant at Reddersburg.

Existing groundwater sources and the current capacity of the existing pipeline from the Bloem Water scheme (1.7 Ml/d) currently supplies about 2.85 Ml/d to these towns. The extent of augmentation that would be required to meet the peak water requirement by 2035 of 6.359 Ml/d would therefore be about 3.5 Ml/d.

8.4.5 Potential Groundwater Augmentation Options for Reddersburg and Edenburg

An alternative to Reddersburg and Edenburg becoming more reliant on Bloem Water would be for the local groundwater sources to be further developed so as to augment the supply once the current capacity of the Bloem Water pipeline has been reached.

The DWA Report on the ***Groundwater Potential for Small Towns*** within the Greater Bloemfontein area has identified the potential dolerite dyke structures within a 10–15 km radius of both towns. These dolerite dykes were grouped into six potential development regions (A, B, C, D, E and F) for the purposes of calculating the theoretical sustainable yield volumes for the Reddersburg (see **Figure 8.7**) and for Edenburg (**Figure 8.8**).

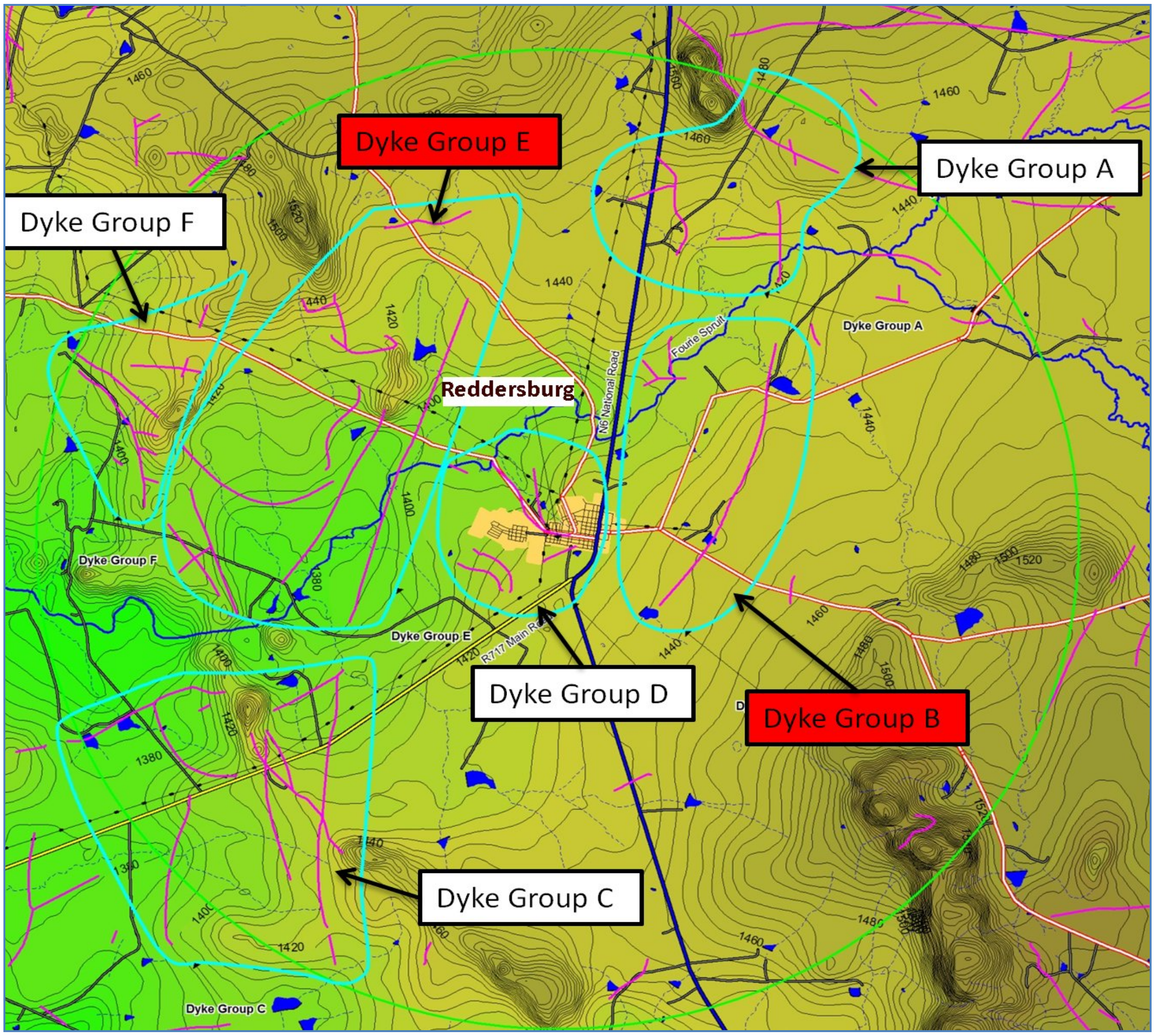

Figure 8.7: Potential Dolerite Dyke Intrusions Close to Reddersburg

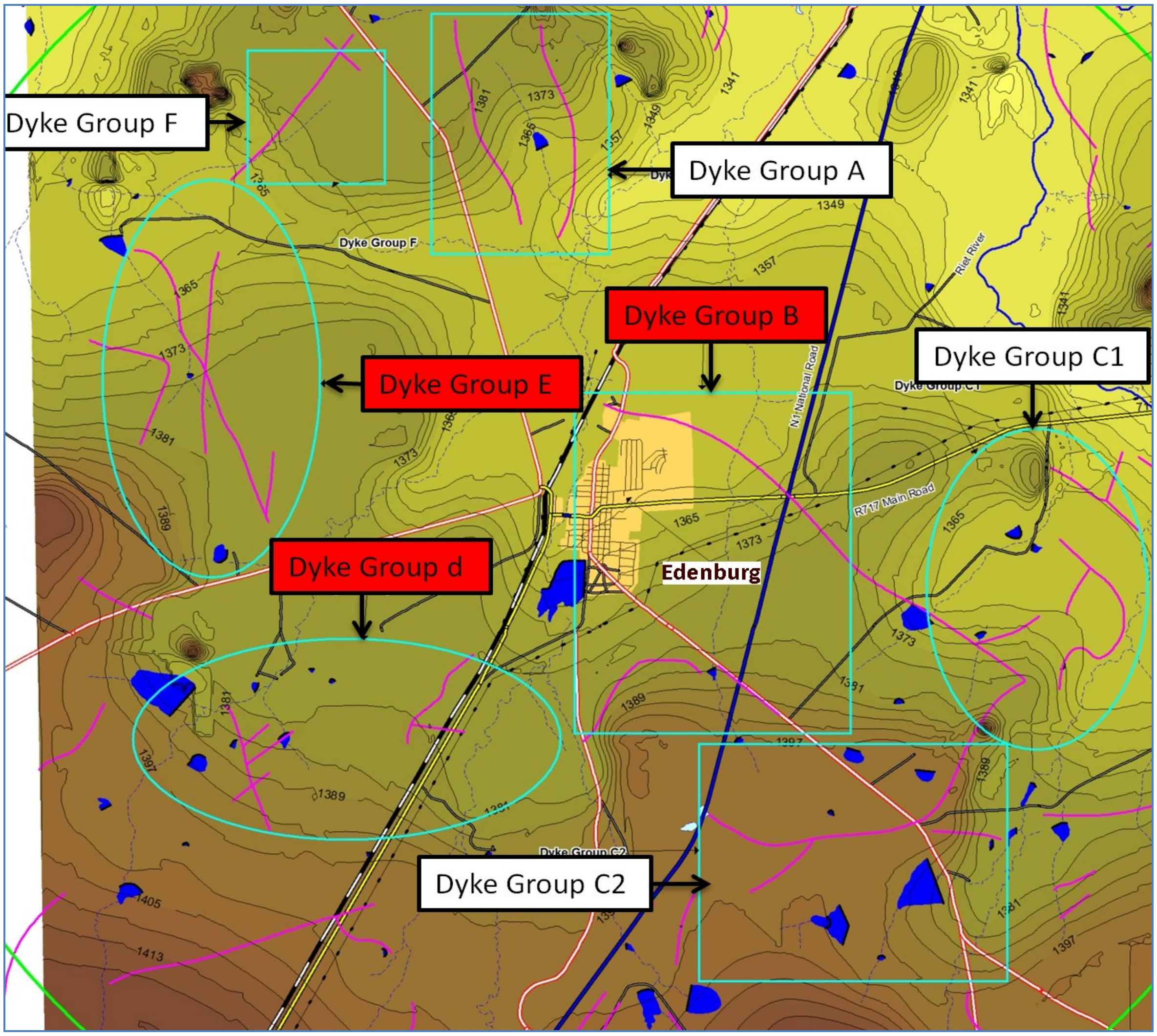

Figure 8.8: Potential Dolerite Dyke Intrusions Close to Edenburg

Groundwater Resource Potential

Estimates of groundwater resource potential (sustainable yield) from each of the four Dyke Group areas were determined. These estimates were based on two approaches, namely a groundwater recharge based estimation (providing a lower limit of sustainable yield) and a geometric mean estimation which provides an upper limit of sustainable yield. The latter was based on the assumptions that:

- The potential dolerite dykes are water bearing;
- An average sustainable yield of 2,1 l/s (60,5 m^3/d) per borehole can be achieved;
- An 8-hour pumping schedule is assumed and a 14 hour recovery period;
- Boreholes would be spaced at 250 m centres along the dolerite strike structure.

The outcomes of the sustainable yield estimates for both approaches are summarised in **Table 8.11.**

Table 8.11: Summary of the Estimated Sustainable Groundwater Yield in the Reddersburg and Edenburg Areas

Dyke Group	Estimates of Sustainable Groundwater Yield (Ml/day)		
	Recharge Approach	**Geometric Mean Approach**	**Average (ML/day)**
REDDERSBURG			
A	0.966	1.633	1.300
B	1.211	1.512	1.361
C	1.936	4.657	3.297
D	0.628	0.968	0.798
E	2.414	3.629	3.022
F	0.597	1.210	0.904
EDENBURG			
A	0.567	1.270	0.918
B	1.110	1.391	1.250
C1 & C2	1.708	2.964	2.336
D	0.765	0.986	0.876
E	1.135	2.217	1.676
F	0.395	0.544	0.470

When referring to **Figure 8.7, Figure 8.8,** and **Table 8.11** it can be seen that in terms of both proximity to the towns and yield potential, the Dyke Groups B and E offer the most favourable option for groundwater development at Reddersburg. At Edenburg, the Dyke Groups B, D and E appear to be most favourable for development. The average of the two approaches used to determine the sustainable yield potential from the development of these preferred dyke groups, could yield up to:

- Reddersburg: 4.383 Ml/d (B and E).
- Edenburg: 3.802 Ml/d (B, D and E)
- Total: 8.185 Ml/d

8.4.6 Reddersburg and Edenburg Cost Estimates

Surface Water Options

The yields, costs and Unit Reference Values (URVs) for the three potential surface water augmentation options are summarized in **Table 8.12**.

Table 8.12: Potential Surface Water Augmentation Options for Reddersburg and Edenburg

Item	New Gravity Pipeline to Reddersburg and Edenburg	Edenburg: Pipeline from Fouriespruit Dam and new WTW	Reddersburg: Upgrade Package Plant and Pipeline from Reddersburg Dam
Yield (m^3/a)	1,103,760	135,605	63,072
Yield (Ml/d)	3.024	0.372	0.173
Capital Costs	R 67,375,000	R 7,850,000	R 2,500,000
O&M Annual	R 336,875	R 327,998	R 168,301
URV (at 6%)(R/m^3)	4.44	6.09	5.18

From the above it can be seen that a new gravity pipeline to Reddersburg and Edenburg provides the most favorable surface water development option for augmenting the future water supply to these towns.

Groundwater Options

The same approach used for Wepener for costing the proposed boreholes, collector pipework, storage reservoirs, delivery pipelines and pumpstations has been applied, as well as energy costs and operation and maintenance costs. **Table 8.13** provides a comparative summary of the yields, cost estimates and URVs for the potential development of Dyke Groups A to F for both towns.

Table 8.13: Yield and Cost Summary of the Potential Reddersburg and Edenburg Groundwater Scheme

EDENBURG						
Item	Dyke Group					
	A	B	C	D	E	F
Yield (m^3/a)	335 353	456 433	852 640	316 273	593 490	171 368
Yield (Ml/d)	0.919	1.251	2.336	0.867	1.626	0.470
Capital Costs	R 17 786 829	R 18 559 394	R 42 633 072	R 14 355 718	R 24 778 446	R 10 374 799
O&M Annual	R 307 636	R 257 801	R 656 063	R 209 963	R 437 698	R 135 497
URV (at 6%)(R/m^3)	4.29	3.15	3.95	3.55	3.39	4.64
REDDERSBURG						
Item	Dyke Group					
	A	B	C	D	E	F
Yield (m^3/a)	474 318	496 948	1 203 223	291 270	1 102 848	329 778
Yield (Ml/d)	1.300	1.362	3.297	0.798	3.022	0.904
Capital Costs	R 26 658 514	R 22 948 828	R 68 157 602	R 16 110 377	R 50 394 617	R 25 834 444
O&M Annual(1)	R 381 983	R 358 932	R 1 135 255	R 253 290	R 934 532	R 343 995
URV (at 6%)(R/m^3)	4.38	3.66	4.54	4.38	3.75	6.02

(1) *O&M includes energy costs at 70c/Kwh*

From **Table 8.13** it can be seen that for augmenting the supply to Edenburg, Dyke Groups B, E and D offer the most favourable groundwater development options. At Reddersburg, the development of Dyke Groups B and E appear to be the most favourable groundwater options.

8.4.7 Reddersburg and Edenburg Water Balance

The surface water development options do not appear to be favourable for these towns. This is as result of the extensive distances (and related costs) over which new pipelines would be required. **Figure 8.9** shows the reconciliation of water requirements and water availability for Reddersburg and Edenburg combined. The AADD and Peak month water requirements are both greater than the sum of the design capacity of the existing pipeline and yield of the existing boreholes. It is therefore anticipated that water shortages should exist on a regular basis in summer. The extent of the shortages and risk of non-supply will be dependent on the available potable water storage within the two towns. It is currently thought that the settings on the flow control valve downstream of the connection to the Bloem Water System have been adjusted to allow a great flow rate through the existing pipeline to Reddersburg and Edenburg. This could potentially put the supply pipeline at risk as the design pressures in the pipeline may be exceeded. There is sufficient groundwater supply to supply both the current water requirements and future water requirements of Reddersburg and Edenburg.

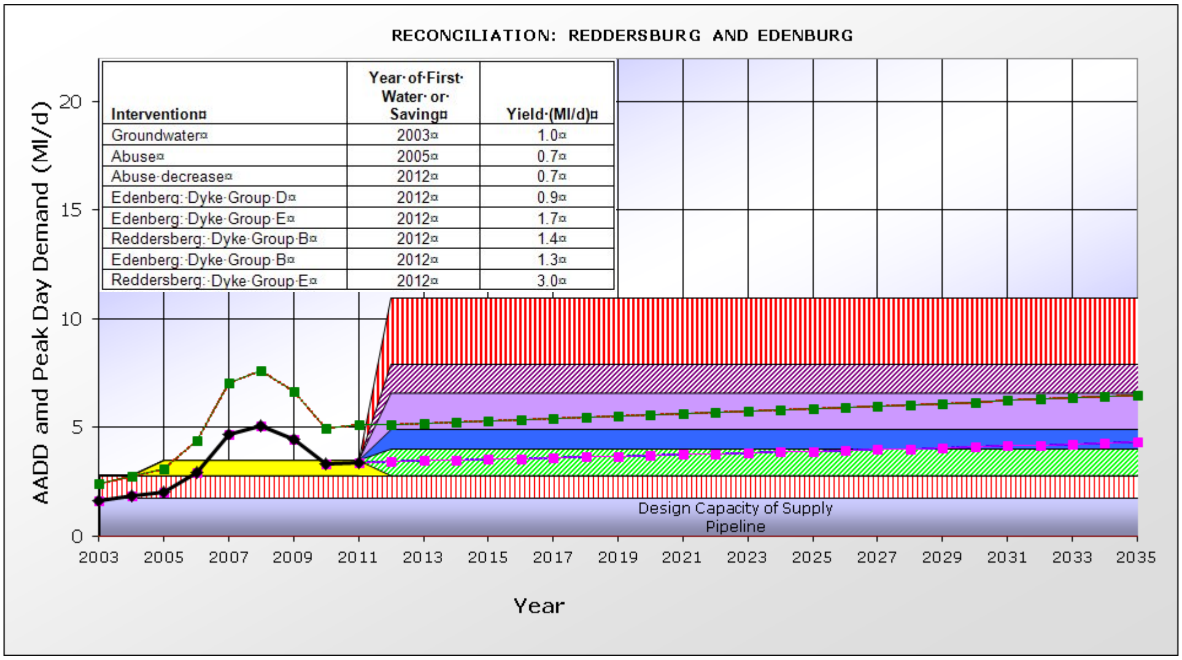

Figure 8.9: Reconciliation of Water Requirements and Availability for Edenburg and Reddersburg

8.4.8 Recommendations for Reddersburg and Edenburg

It is imperative that Kopanong Municipality develops a business plan for the implementation of WC/WDM. Although there remains some uncertainty regarding the actual water requirements at both of these towns, verbal discussions with Kopanong Municipality confirms that both Edenburg and Reddersburg are experiencing daily water shortages in summer (but not in winter). Therefore, it is recommended that interventions for these towns (WC/WDM and supply side interventions) be implemented as a matter of **priority**. The extent of the apparent metering problems must however also be addressed so as to confirm the projected water requirements to 2035.

Based on the URVs, the incremental development of the groundwater resource from Dyke Groups B, E and D at Edenburg, and from Dyke Groups B and E at Reddersburg is recommended. The extensive distances required for pipelines makes the development of surface water augmentation schemes less favourable than groundwater for these two towns.

8.5 DEWETSDORP

Dewetsdorp is located in the south eastern part of the Free State, between Bloemfontein and Wepener. The outfall of the Novo Transfer Scheme into the upper reaches of the Modder River is located approximately 7 km to the east of to the town. Dewetsdorp has no large commercial or industrial sector and water users consist mainly of domestic type users.

8.5.1 Existing Water Supply to Dewetsdorp

Dewetsdorp receives water via a pipeline from Bloem Water's Welbedacht – Bloemfontein Pipeline and from local boreholes. However, it appears that the usage of boreholes has diminished over the years and the town is increasingly reliant on the Bloem Water supply. The WARMS database shows the following groundwater use registered for the town.

Table 8.14: Dewetsdorp Registered Groundwater Use

Town	Registered User	Quaternary Catchment	Registered Volume (m^3/annum)	Use Start Date
Dewetsdorp	Naledi Local Municipality	C52A	2,848,539	1972

8.5.2 Dewetsdorp Water Requirements

The estimated population of Dewetsdorp (2009) is 9 857 inhabitants (All Towns Study data). The total water sales to the towns by Bloem Water for the period July 2010-June 2011 amounted to 756 Ml/year, which includes internal losses within the reticulation systems. This equates to an average per capita consumption of 212 l/c/d.

Table 8.15: Summary of Water Supply from Bloem Water and Groundwater Sources to Dewetsdorp (2011)

Town	Supply from BloemWater (a)	Estimated groundwater supply (million m^3/a) (b)	Estimated average yield of existing boreholes (million m^3/a)	Number of boreholes	Estimated total annual consumption (a + b)
Dewetsdorp	0.76		0.080	4	0.76

As was shown in **Table 8.2**, the population growth rate for Dewetsdorp is very small (less than 0,1%) resulting in a projected average annual water requirement of 768 Ml/yr and an annualized peak demand of 1 140 Ml/yr, both up to 2035. **Table 8.16** and **Figure 8.10** show the projected water requirements for Dewetsdorp in Ml/day.

Table 8.16: Dewetsdorp Water Requirements to 2035 (Ml/day)

Town	Water requirements			
	Average annual (Ml/day)		Within allowance for peak (Ml/day)	
	2011 Actual	2035	2011 Actual	2035
Dewetsdorp	2.071	2.105	3.072	3.122

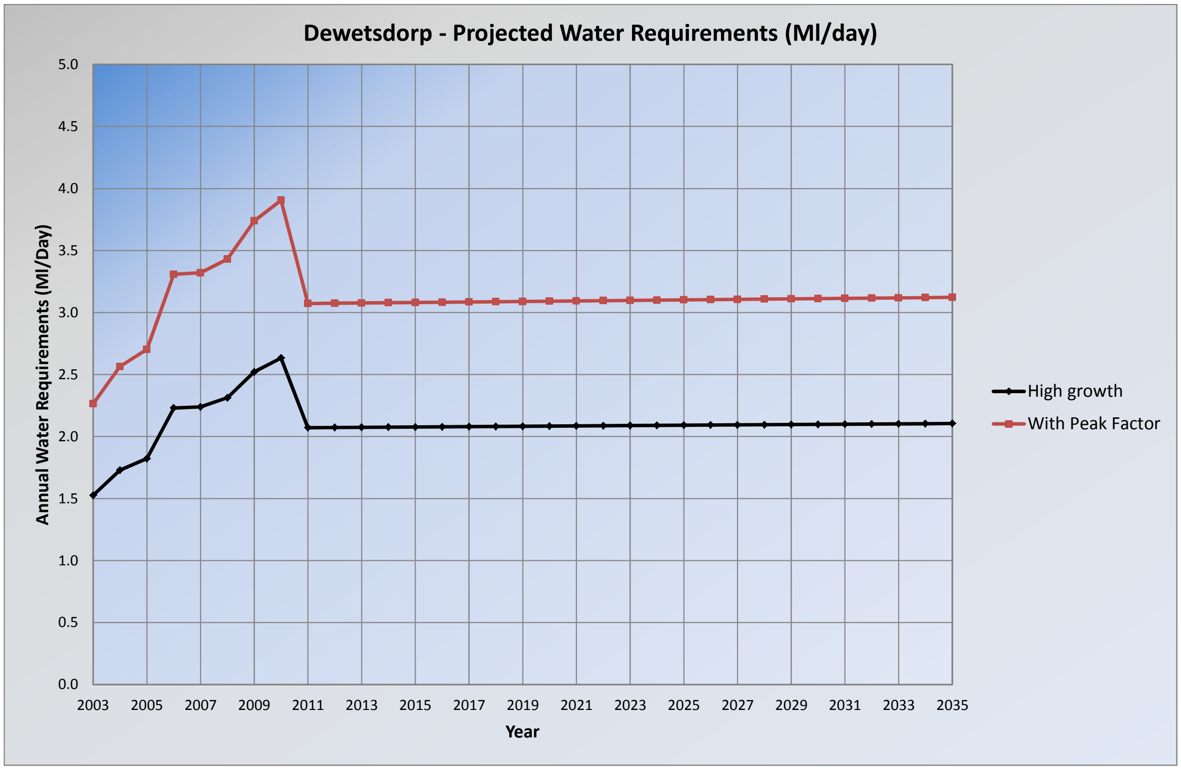

Figure 8.10: Water Requirement Projections for Dewetsdorp

8.5.3 Opportunity for Water Conservation and Water Demand Management

As part of the All Towns Study, theoretical water demands for Dewetsdorp were estimated, based on the assumed average per capita requirements from that study. This amounted to a theoretical consumption of 473 Ml/year. If a nominal allowance of 20% were to be assumed as "acceptable" internal losses then the combined theoretical water requirement would be in the order 577 Ml/year. Thus, it appears that a water saving of about 179 Ml/year could possibly be achieved, i.e. 24% of current bulk water sales. The water saving potential for Dewetsdorp is estimated as being **high**. This however needs to be confirmed and the Municipality needs to prepare a WC/WDM business plan.

8.5.4 Potential Surface Water Augmentation Options for Dewetsdorp

In order to increase the potable supply to Dewetsdorp, an additional pipeline from the Welbedacht-Bloemfontein Pipeline could be constructed. It is foreseen that a 13.2 km (DN 200 mm) pipeline would need to be built, together with a pump station to supply some 30 l/s for this intervention, which equates to 946 080 m^3/a (2.592 Ml/day). The current capacity of the existing pipeline from the Bloem Water scheme to Dewetsdorp is 2.2 Ml/d. The extent of augmentation that would be required to meet the peak water requirement by 2035 of 3.122 Ml/d would therefore be about 0.53 Ml/d.

8.5.5 Dewetsdorp Potential Groundwater Augmentation Options

An alternative to Dewetsdorp becoming more reliant on Bloem Water would be for the local groundwater sources to be developed so as to augment the supply once the current capacity of the Bloem Water pipeline has been reached.

The DWA Report on the ***Groundwater Potential for Small Towns*** within the Greater Bloemfontein area has identified the potential dolerite dyke structures within a 10–15 km radius of Dewetsdorp. These dolerite dykes were grouped into six potential development regions (A, B, C, D, E and F) for the purposes of calculating the theoretical sustainable yield volumes for the Dewetsdorp area (see **Figure 8.11**).

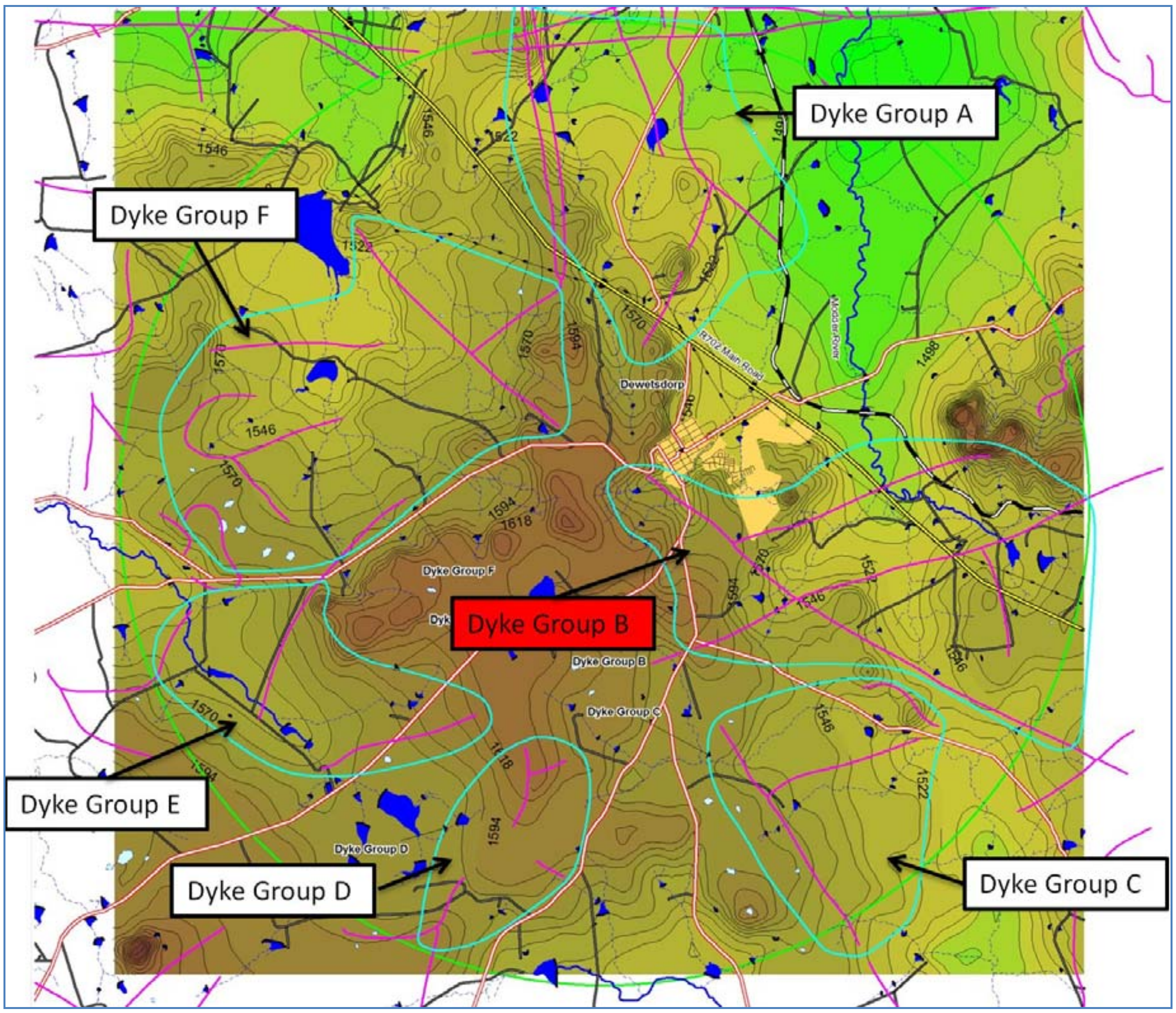

Figure 8.11: Potential Dolerite Dyke Intrusions Close to Dewetsdorp

Groundwater Resource Potential

Estimates of groundwater resource potential (sustainable yield) from each of the six Dyke Group areas were determined. These estimates were based on two approaches, namely a groundwater recharge based estimation (providing a lower limit of sustainable yield) and a geometric mean estimation which provides an upper limit of sustainable yield. The latter was based on the assumptions that:

- The potential dolerite dykes are water bearing;
- An average sustainable yield of 2,1 l/s (60.5 m^3/d) per borehole can be achieved;

- An 8-hour pumping schedule is assumed and a 14 hour recovery period; and
- Boreholes would be spaced at 250 m centres along the dolerite strike structure.

The outcomes of the sustainable yield estimates for both approaches are summarised in **Table 8.17**.

Table 8.17: Summary of the Estimated Sustainable Groundwater Yield in the Dewetsdorp Area

Dyke Group	Estimates of Sustainable Groundwater Yield (Ml/day)		
	Recharge Approach	Geometric Mean Approach	Average (Ml/day)
A	1.845	5.867	3.856
B	2.570	6.169	4.370
C	1.057	2.177	1.617
D	0.647	0.786	0.716
E	1.072	1.452	1.262
F	2.469	4.657	3.563

From **Table 8.17** t can be seen that for augmenting the supply to Dewetsdorp, Dyke Groups B, F and A offer the most favourable groundwater development options in terms of sustainable yield estimates. Based on the average of the two approaches used to determine the sustainable groundwater yield potential, an average yield of up to 4.300 Ml/d is estimated as being available from Dyke Group B alone.

8.5.6 Dewetsdorp Cost Estimates

Surface Water Options

The yields, costs and URVs for the potential 13.2 km pipeline and pumpstation that would need to be built are summarized in **Table 8.18.**

Table 8.18: Potential Surface Water Augmentation Option for Dewetsdorp

Item	New 13.2 km pipeline and pumpstation to Dewetsdorp
Yield (m^3/a)	946 080
Yield (Ml/d)	2.592
Capital Costs	R 15 193 750
O&M Annual[(1)]	R 1 043 019
URV (at 6%) (R/m^3)	2.12

[(1)] O&M includes energy costs at 70c/Kwh

Groundwater Options

As for all previous towns, the same approach used for costing the proposed boreholes, collector pipework, storage reservoirs, delivery pipelines and pumpstations has been applied, as well as energy costs and operation and maintenance costs.

Table 8.19 provides a comparative summary of the yields, cost estimates and URVs for the potential development of Dyke Groups A to F for in the vicinity of Dewetsdorp.

Table 8.19: Yield and Cost Summary of the Potential Dewetsdorp Groundwater Scheme

Item	Dyke group					
	A	B	C	D	E	F
Yield (m^3/a)	1 407 440	1 594 868	590 205	261 523	460 630	1 300 495
Yield (Ml/d)	3.856	4.370	1.617	0.717	1.262	3.563
Capital Costs	R 76 061 155	R 76 702 284	R 35 005 331	R 17 202 057	R 28 152 184	R 69 230 659
O&M Annual(1)	R 1 711 614	R 1 789 041	R 671 795	R 263 425	R 444 782	R 1 286 695
URV (at 6%) (R/m^3)	4.65	4.18	4.91	5.19	4.85	4.37

(1) O&M includes energy costs at 70c/Kwh

From the above it can be seen that the development of Dyke Group B would be the most cost effective groundwater development option for Dewetsdorp.

8.5.7 Dewetsdorp Water Balance

In view of the relatively short pipeline of 13 km, the surface water development option for Dewetsdorp may be a favourable option as it has a URV of almost half that of the most favourable groundwater development option. Strategically and from a diversification of water resources perspective, it may more advisable to develop local groundwater resources for the area in lieu of laying a parallel pipeline. **Figure 8.12** shows the reconciliation of water requirements and water availability for Dewetsdorp, based on groundwater development. Planning projections have been based on the 2010 water requirement, as the reasons for the sharp drop in 2011 could be linked to an exceptionally wet summer month being experienced. Both the AADD and Peak week demands are in excess of the design capacity of the existing infrastructure. It is therefore likely that water shortages are being experienced by the residents of Dewetsdorp during the summer months.

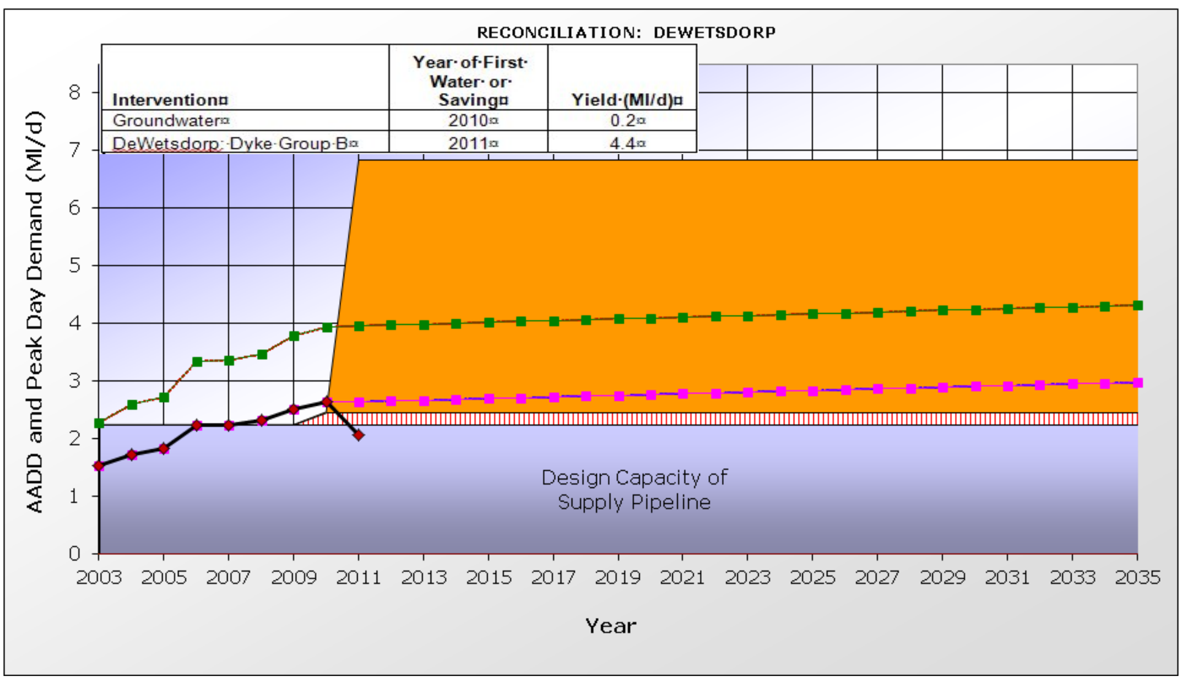

Figure 8.12: Reconciliation of Water Requirements and Availability for Dewetsdorp

8.5.8 Recommendations for Dewetsdorp

It is imperative that Naledi Municipality develops a business plan for the implementation of WC/WDM. The provision of a new pipeline and pumpstation from the existing Bloem Water scheme is the most favourable option when comparing the URVs for Dewetsdorp. However if the desire for these smaller towns is that they become less dependent on Bloem Water, and more dependent on their own local sources, then groundwater does offer opportunity here, but at a higher financial cost than the potential surface water augmentation.

8.6 EXCELSIOR

Excelsior, like Dewetsdorp, is a small rural town originally established to serve the surrounding farming community. However, in recent years it has experienced a decline in the local economy as most of the farmers now visit the bigger centers, such as Bloemfontein, for their daily needs and education for their children. Most of the banks have closed down and very limited service and goods are currently available to the local community. It is primarily the poor that remain in in towns such as Excelsior.

8.6.1 Existing Water Supply to Excelsior

Excelsior is supplied with water from local boreholes (0.1 Ml/d) as well as from the Bloem Water system via a pipeline of capacity of 1.2 Ml/d from the Rustfontein scheme. Furthermore a local run of river scheme is estimated to provide a yield of about 0.5 Ml/d.

8.6.2 Excelsior Water Requirements

The available records of Bloem Water's Historical Water Demand Trends suggest that the water supplied to Excelsior from that scheme was 167 Ml/yr (0.46 Ml/d) in 2011. In considering that the town's population in 2010 is estimated at 6 689, this equates to a per capita demand from the scheme of only 68 l/c/d. This does not seem to be representative of the equivalent figures for the other small towns.

8.6.3 Opportunity for Water Conservation and Water Demand Management

Due to the uncertainty regarding actual water consumption in Excelsior, it is not possible to make a recommendation in terms of the water saving potential that could be achieved through WC/WDM. Implementation of metering of bulk water supply and water use by consumers is the first step towards addressing such uncertainty. This however needs to be confirmed and the Municipality needs to prepare a WC/WDM business plan.

8.6.4 Potential Surface Water Augmentation Options for Excelsior

No further development options for surface water have been considered for Excelsior.

8.6.5 Excelsior Potential Groundwater Augmentation Options

An alternative to Excelsior becoming more reliant on Bloem Water is for the further development of local groundwater sources to be implemented. The DWA Report on the ***Groundwater Potential for Small Towns*** within the Greater Bloemfontein area has identified the potential dolerite dyke structures within a 10–15 km radius of Excelsior. These dolerite dykes were grouped into four potential development regions (A, B, C and D) for the purposes of calculating the theoretical sustainable yield volumes for the Excelsior area (see **Figure 8.13**).

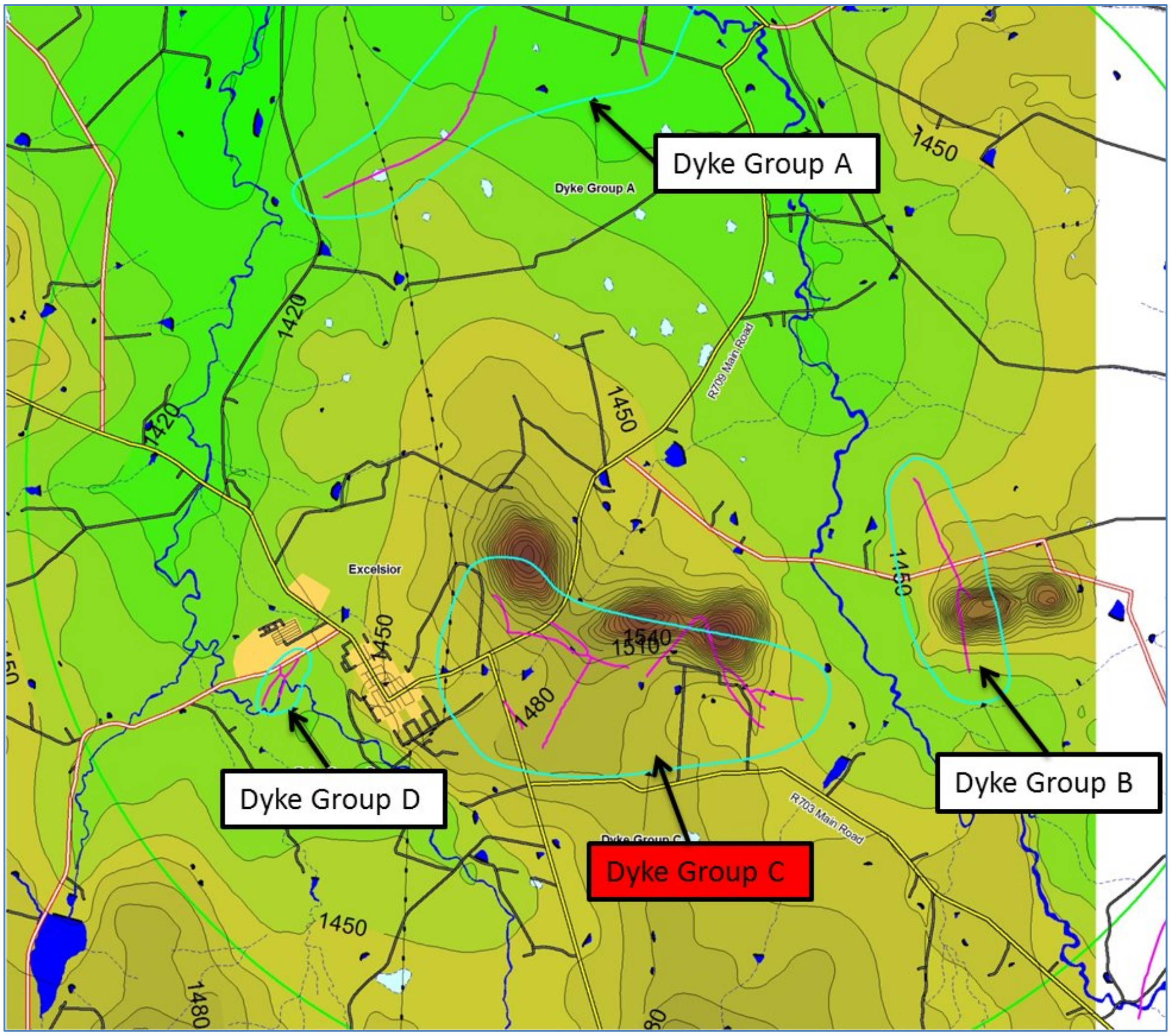

Figure 8.13: Potential Dolerite Dyke Intrusions Close to Excelsior

Groundwater Resource Potential

Estimates of groundwater resource potential (sustainable yield) from each of the four Dyke Group areas were determined. These estimates were based on two approaches, namely a groundwater recharge based estimation (providing a lower limit of sustainable yield) and a geometric mean estimation which provides an upper limit of sustainable yield. The latter was based on the assumptions that:

- The potential dolerite dykes are water bearing;
- An average sustainable yield of 2,1 l/s (60,5 m^3/d) per borehole can be achieved;
- An 8-hour pumping schedule is assumed and a 14 hour recovery period; and
- Boreholes would be spaced at 250 m centres along the dolerite strike structure.

The averages of the two approaches are summarised in **Table 8.20.**

Table 8.20: Summary of the Estimated Sustainable Groundwater Yield in the Excelsior Area

Dyke Group	Average Estimates of Sustainable Groundwater Yield (Ml/day)
A	1.064
B	0.440
C	1.351
D	0.280

From **Figure 8.3** and **Table 8.20** it can be seen that Dyke Group C offers the optimum potential for groundwater development for the town, with a potential sustainable yield of over 1.3 Ml/d.

8.6.6 Excelsior Cost Estimates

Groundwater Options

As for all previous towns, the same approach used for costing the proposed boreholes, collector pipework, storage reservoirs, delivery pipelines and pumpstations has been applied, as well as energy costs and operation and maintenance costs. **Table 8.21** provides a comparative summary of the yields, cost estimates and URVs for the potential development of Dyke Groups A to D for in the vicinity of Excelsior.

Table 8.21: Yield and Cost Summary of the Potential Excelsior Groundwater Scheme

Item	Dyke Group			
	A	B	C	D
Yield (m^3/a)	392,923	124,465	577,613	95,265
Yield (Ml/d)	1.077	0.341	1.583	0.28'
Capital Costs (R mill)	R 21,857,936	R 7,305,136	R 21,282,098	R 4,634,116
O&M Annual (R mill) (1)	R 323,209	R 92,164	R 373,973	R 74,765
URV (at 6%)	4.36	4.47	2.99	3.88
(1) O&M includes energy cost at 70c/Kw h				

The above table shows that the development of Dyke Group C for the Excelsior area is the most favorable of the groundwater development options.

8.6.7 Excelsior Water Balance

Despite the apparent surplus of existing supply from available water sources (see Reconciliation **Figure 8.14**), peak day and peak week shortages are known to occur.

Both the AADD and peak month water requirement of Excelsior is less than the supply capacity of the existing pipeline. It is thought that the reason for this could be the fact that the upstream demands on the supply pipeline to Excelsior are so high that insufficient water reaches Excelsior. This is further substantiated by the fact that water shortages have been experienced in Excelsior in the past. The reason for the low per capita consumption calculated is that the water sales to Excelsior do possibly not reflect the actual "water demand". Dividing the metered consumption by the population would therefore give an artificially low figure.

Excelsior also makes use of groundwater and a "run of river scheme" treated at a local water treatment plant. Information pertaining to the operation of this scheme was not available.

It would appear that sufficient resources (including additional groundwater resources are available to Excelsior. **Figure 8.14** shows the reconciliation of water requirements and water availability for Excelsior.

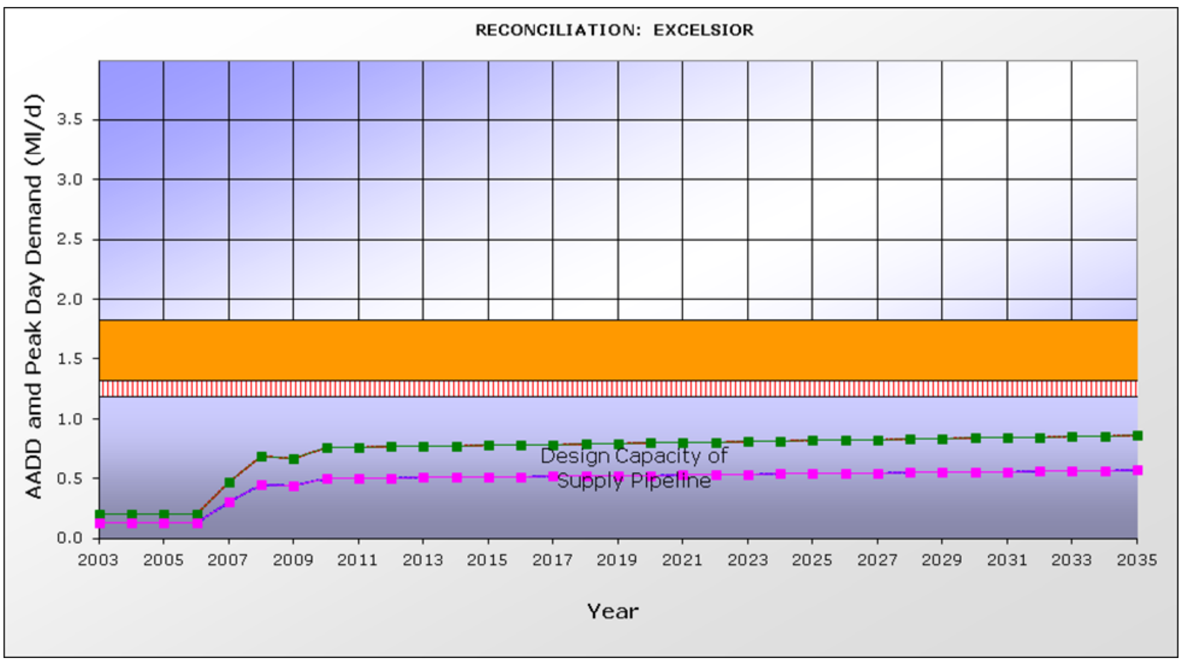

Figure 8.14: Reconciliation of Water Requirements and Availability for Excelsior

8.6.8 Recommendations for Excelsior

Before any decisions are taken on the potential for water resource development to Excelsior, clarity is required on the actual extent of water use, on the apparent limitations in supply of water during peak periods, and on the actual operation of the sources that supply water to the town. From the limited information available, it is however apparent that the development of local groundwater sources would be the most likely intervention in the future.

9. RECOMMENDED INTERVENTIONS

The following recommendations are made with regards the implementation of interventions

- The MMM should implement their WC/WDM strategy which was developed in 2011.
- The MMM should strive to achieve the maximum possible water savings through the implementation of their WC/WDM Strategy, namely “the best case savings scenario”.
- Install two additional (1 m^3/s) Pump Sets at Tienfontein Pump Station. The first pumpset should be utilised to increase the design capacity of the pump station to 4 m^3/s and the second pumpset to provide additional standby capacity. With the implementation of the two additional pumpsets the total standby capacity of the pump station would be increased to 50% (based on the proposed new design capacity). The implementation of this solution would reduce the risk of restrictions and would be a cost effective interim solution to implement at Tienfontein Pump Station
- The Welbedacht Dam should be scoured to increase the capacity of the dam and to ensure that the siltation at Tienfontein Pump Station does not further hamper operations and maintenance.
- Bloem Water should further investigate the inability of the water treatment plant to deal with high turbidity levels which currently limit the production capacity of the water treatment plant
- Urgently initiate a feasibility Study to consider the most appropriate means to scour Welbedacht Dam and to augment Knellpoort Dam. The outcome of the feasibility study will guide the selection of future water resource development interventions. The feasibility study should inter alia address the following:
  - incremental yield generated and total yield available;
  - synergies with potential supply schemes’ e.g. bi-directional pipeline between Knellpoort and Welbedacht;
  - the most appropriate intervention to augment Knellpoort Dam (e.g. implement a pump station at Welbedacht Dam and use the bi-directional scour pipeline to pump water into Knellpoort Dam, or further increase the capacity of Tienfontein Pump Station);
  - cost estimates; and
  - implementation programme.
- Bloem Water should take steps to ensure the integrity of the Welbedacht Pipeline. Bloem Water has proposed to relay sections of the Welbedacht pipeline which are considered as high risk.
- Mangaung Metropolitan Municipality should construct additional storage reservoir capacity in order to ensure that the network peaks are not transmitted through to the bulk supply infrastructure.
- It is expected that maintenance problems and associated expenditure will continue to persist into the future, unless Tienfontein pump station is modified/redesigned to cope with the sedimentation problems. With the near equilibrium sediment regime in the Caledon River now being reached, the redesign of Tienfontein pump station should be considered.
- The Novo Pump Station be increased to a capacity of 2.4 m3/s. This will match the conveyance capacity of the transfer pipeline and will also give Bloem Water more flexibility to transfer water from Knellpoort Dam to Rustfontein Dam.
- A Feasibility Study on Water Re-use should be undertaken. The timing of the feasibility study should be recommended by the Strategy Steering Committee.

9.1 SMALL TOWN SPECIFIC RECOMMENDATIONS

9.1.1 Wepener

- It is imperative that the Naledi Municipality develop a business plan for the implementation of WC/WDM.
- Based on the URVs, the booster pump station is the preferred option for implementation at Wepener. However incremental development of the groundwater resource also appears favourable and could be considered as an alternative, introducing some independence of the town on the Bloemfontein system as well as conjunctive use of a local water source.

9.1.2 Reddersburg and Edenburg

- It is imperative that Kopanong Municipality develops a business plan for the implementation of WC/WDM.
- Develop groundwater interventions to augment the supply to Reddersburg and Edenburg.

9.1.3 DeWetsdorp

- It is imperative that Naledi Municipality develops a business plan for the implementation of WC/WDM.
- The provision of a new pipeline and pumpstation from the existing Bloem Water scheme is the most favourable option when comparing the URVs for Dewetsdorp. However if the desire for these smaller towns is that they become less dependent on the Bloem Water System, and more dependent on their own local sources, then groundwater does offer this opportunity, but at a higher financial cost than the potential surface water augmentation.

9.1.4 Excelsior

- It is imperative that the Municipality develops a business plan for the implementation of WC/WDM.
- Undertake a study to investigate the following aspects: (1) the actual extent of water use in Excelsior and (2) the apparent limitations in supply of water during peak periods, and 3) the actual operation of the sources that supply water to the town.

10. INSTITUTIONAL ARRANGEMENTS

Any strategy is as good as its practical implementation, which can only be achieved through alignment and cooperation of key role-players and continuous monitoring of the implementation strategy to ensure compliance in meeting the objectives of the strategy and reconciling future water requirements and supply. The strategy is thus kept active by a decision support framework which would enable timely decisions to be made on water resource interventions. A technical support team would need to monitor water requirements and the implementation programmes for all interventions to ensure that the programmes meet the necessary implementation dates. The technical support team will also provide the technical expertise and support throughout the implementation of the strategy.

The planning scenarios presented in the strategy only provide guidance based on future estimated scenarios and rely on certain assumptions and generalisations of water requirements. In reality, there are often deviations from the planning scenarios, which may be as a result of temporary changes in the historical water requirement trend (i.e. due to weather patterns) or permanent changes to the supply network (i.e. implementation of the Ecological Water Requirements), adaptation to climate change, or the introduction of more efficient technologies. The planning scenarios thus need to be flexible enough to allow adaptation to meet unknown future challenges.

In order to maintain the strategy, keep it relevant, and adapt it in response to changing external factors regular revision and adequate financing will be necessary. A number of institutions, including the DWA, MMM, and Bloem Water, will need to co-operate and to create an environment where partnerships can be formed to tackle specific recommended actions. These institutions need to take part in the strategy implementation process and should take responsibility to steer the strategy implementation in the right direction. Co-operation of all the institutions responsible for the entire water supply chain is essential to achieve the intended objectives.

10.1 STRATEGY STEERING COMMITTEE

It is recommended that a Greater Bloemfontein area Strategy Steering Committee (SSC) is established towards the end of the Reconciliation Strategy Study. Key role-players, organisations involved in the planning and operation of the system, and major water users (such as agriculture) need to be represented on the SSC would be requested to nominate representatives to attend the SSC.

The main functions and objectives of the SSC would be:

a. To ensure that the strategy remains relevant and is regularly updated;
b. To monitor and co-ordinate the implementation of the relevant actions identified in the strategy; and
c. To make recommendations on long-term planning activities required to ensure reconciliation of requirements and supply in the Greater Bloemfontein area.

SSC Meetings would be held on a six-monthly basis.

10.2 ADMINISTRATIVE AND TECHNICAL SUPPORT GROUP

The Administrative and Technical Support Group (ATSG) will be responsible for general administrative and technical support and will arrange and facilitate the SSC Meetings. Representative on the ATSG will be confirmed at the first SSC Meeting. The ATSG would be responsible for updating the planning scenario as new information relating to revised yields, water requirements, and the benefits of WC/WDM interventions implemented by MMM becomes available. The ATSG would further assist with the drafting of press releases and newsletters and any technical tasks required by the SSC.

10.3 SUGGESTED FUNCTIONS OF THE STRATEGY STUDY STEERING COMMITTEE AND THE ADMINISTRATIVE AND TECHNICAL SUPPORT GROUP (NOTE: THIS SECTION NEEDS TO BE UPDATED AFTER DISCUSSIONS WITH DWA)

The suggested functions of the SSC and the ATSG are listed in **Table 10-1** and **10-2** respectively.

Table 10.1: Suggested Functions of the Strategy Steering Committee

Strategy Steering Committee activities	
1	Monitor how closely the relevant WC/WDM targets and objectives are met
2	Be informed on changes in the system yield
3	Provide updates on the strategy as required
4	Draft and distribute briefing notes on proposed interventions to the MEC's office
5	Liaise with departments involved in developing provincial strategies and provide agreed input
6	Provide annual updates to all local authorities on the strategy
7	Brief relevant local and district Municipalities on imminent decisions
8	Inform politicians of press releases prior to release
9	Provide and update information for MMM, Bloem Water, and DWA websites
10	Liaise with relevant Bloem Water and MMM Committees as appropriate
11	Make recommendations on activities required to ensure long-term reconciliation of requirements and supply
12	Review and revise the Reconciliation Strategy to ensure monitoring and co-ordination of implementation

Table 10.2: Suggested functions of the Administrative and Technical Support Group

Administrative and Technical Support Group activities	
1	Review and update requirement scenarios based on findings of further studies
2	Update water requirement scenarios
3	Compare recently recorded requirements with scenarios to guide the choice of scenarios for future planning purposes
4	Decided on comparison population growth (low, medium, high) scenario(s) to be used for planning of future interventions
5	Investigate the flexibility of the system in terms of changes in water usage patterns
6	Interpret and clarify the way the system is operated
7	Ensure that the way in which the requirements and availability is compared is user friendly and easy to understand

Administrative and Technical Support Group activities	
8	Compile appropriate press releases and newsletters.
9	Set up and keep updated a list of all media contacts
10	Set up and maintain an efficient system to distribute information
11	Brief relevant municipalities on imminent decisions
12	Provide annual updates on the Strategy to all local authorities
13	Liaise with departments involved in developing provincial strategies and provide agreed SSC input
14	Draft and distribute briefing notes on proposed interventions to the MEC's office
15	Provide updates of the Strategy as required
16	Provide and update information for the websites of MMM, Bloem Water, and DWA
17	Facilitate the identification and gathering of data and information from other government agencies and sectors which influence with Greater Bloemfontein area bulk water supply network

Table 10.3 contains a list of the proposed institutions / agencies to be represented on the SSC.

Table 10.3: Proposed Institutions/Agencies to be Represented on the Strategy Steering Committee

Free State Provincial Government: • Department of Agriculture • Department of Rural Development and Land Reform

Local authorities:
• SALGA
• Mangaung Metropolitan Municipality:
  o Bulk water
  o Water demand management
• Naledi Municipality
• Kopanong Municipality
• Mantsopa Local Municipality

Department of Water Affairs:
• Free State Regional Office:
  o Options Analysis
  o Institutional support
  o Water sector support
• Integrated Water Resource Planning:
  o National Water Resource Planning
  o Options Analysis
  o Water Resource Planning Systems
  o Water Use Efficiency

Water service provider: • Bloem Water
Water User Associations / Irrigation Boards: • Orange-Riet WUA and Lower Modder WUA
Organised industry / commerce
Provincial representative

The institutions / agencies that are proposed to be represented on the ATSG are listed in **Table 10.4.**

Table 10.4: Proposed institutions / agencies to be represented on the Administrative and Technical Support Group

Free State Provincial Government: • Department of Agriculture

Local authorities:
• Mangaung Metropolitan Municipality:
    o Bulk water
    o Water demand management

Department of Water Affairs:
• Free State Regional Office:
    o Options Analysis
    o Institutional support
    o Water sector support
• Integrated Water Resource Planning
    o National Water Resource Planning
    o Options Analysis
    o Water Resource Planning Systems
    o Water Use Efficiency

Water service provider: • Bloem Water

11. STRATEGY ACTION PLAN

The Strategy Action Plan identified the actions to be taken, the responsible authorities, and the timing.

11.1 IMPLEMENTATION OF THE RECONCILIATION STRATEGY

a. **Action:** The Greater Bloemfontein Water Supply (GBWS) Reconciliation Strategy Steering Committee should be formed in order to make recommendations, on a bi-annual basis, on long term planning activities required to ensure reconciliation of requirement and available supply in the GBWS area.

Responsibility: DWA: NWRP

Timing: November (Strategy update) and April (Monitoring of implementation)

b. **Action:** The GBWS Strategy Steering Committee must ensure that the following monitoring is undertaken in order to be able to ensure the reconciliation of supply and requirement over the longer term:

i. The success of the WC/WDM interventions implemented. This is of particular importance the projected water requirement is currently higher than historical firm yield of the system.
ii. Actual water use.
iii. Population growth and economic growth rate figures in order to be able to develop a better understanding of future water requirements.
iv. Reconciliation of requirement and available supply in the GBWS area.

Responsibility: GBWS Strategy Steering Committee

Timing: November (Strategy update) and April (Monitoring of implementation)

c. **Action:** An Administrative and Technical Support Group should be established to give support to the Strategy Steering, and implement the decisions of the Strategy Steering Committee.

Responsibility: DWA:NWRP

Timing: October 2012

d. **Action:** The Scenario Planning process should be updated on a regular basis to cater for:

i. Revised future water requirement projections.
ii. Updated information on the implementation of the ecological Reserve and the potential for climate change impacts.
iii. Updated information from recently completed studies (reconnaissance level, pre-feasibility level and feasibility level) for

WC/WDM and supply-side interventions to feed into the scenario planning process.

iv. Any other changes to the input data.

v. Revision of the MMM WC/WDM strategy.

Responsibility: Administrative and Technical Support Group

Timing: In November of each year

e. **Action:** The Strategy Steering Committee should distribute at least one newsletter and one news release per year to stakeholders.

Responsibility: Strategy Steering Committee

Timing: After each November SSC Meeting on an annual basis

11.2 URBAN WATER CONSERVATION AND WATER DEMAND MANAGEMENT

a. **Action**: Given the potential water shortages that could be experienced should the water requirements of the Greater Bloemfontein Area continue to grow, it is imperative for MMM to strive to achieve the maximum possible water savings through the implementation of WC/WDM, namely “the best case savings scenario”.

Responsibility: MMM

Timing: 2012 and on going

b. **Action**: Appoint appropriate staff/professional service providers to expedite implementation of the MMMs existing WC/WDM Strategy.

Responsibility: MMM

Timing: 2012 and ongoing

c. **Action:** Wepener, Dewetsdorp, Reddersburg, Edenburg and Excelsior should develop a WC/WDM business plan (strategies, actions plans, and programmes).

Responsibility: All Water Service Authorities

Timing: 2012 and ongoing

d. **Action**: Bloem Water to maintain and verify their bulk water metering system.

Responsibility: Bloem Water

Timing: Annually

e. **Action:** DWA’s: Water Use Efficiency, to assist and support the WSA in the development and implementation of their WC/WDM strategies.

Responsibility: DWA D: WUE NMBM

Timing: 2012 and on-going

11.3 LOCAL SURFACE WATER SCHEME

a. **Action**: Investigate the most appropriate means to scour Welbedacht Dam
Responsibility: DWA (in conjunction with Bloem Water)
Timing: 2012

b. **Action:** Install two additional (1 m^3/s) Pump Sets at Tienfontein Pump Station. The first pumpset should be utilised to increase the design capacity of the pump station to 4 m^3/s and the second pumpset to provide additional standby capacity.
Responsibility: DWA and Bloem Water
Timing: 2012

c. **Action**: Initiate a feasibility study to investigate the most appropriate means to augment Knellpoort Dam.
Responsibility: DWA
Timing: 2012

d. **Action**: Investigate the treatment process to deal with high turbidity levels which currently limit the production capacity of the water treatment plant
Responsibility: Bloem Water (in conjunction with DWA)
Timing: 2012

Action: Increase the Capacity of Novo Pump Station to 2.4 m^3/s
Responsibility: Bloem Water
Timing: 2013 or dependent on operational requirements of Bloem Water

e. **Action:** Initiate a detailed feasibility study into water reuse as a potential supply intervention.
Responsibility: MMM
Timing: To be determined by the Strategy Steering Committee

f. **Action:** Initiate a study to investigate feasibility of obtaining additional water from the Orange River.
Responsibility: DWA
Timing: To be determined by the Strategy Steering Committee

g. **Action:** Develop additional groundwater resources to supply the shortage in water requirements in Reddersburg and Edenburg.
Responsibility: Kopanong Municipality
Timing: Study to be initiated in 2012

h. **Action:** Monitor the growth of water requirements in Wepener. If shortages occur, consider the implementation of a booster pump station on the supply pipeline to Wepener.
Responsibility: Naledi Municipality
Timing: Study to be initiated in 2012

i. **Action:** Develop additional groundwater resources to supply the shortage in water requirements in DeWetsdorp.
Responsibility: Naledi Municipality
Timing: Study to be initiated in 2012

j. **Action:** Undertake a study to investigate the actual extent of water use in Excelsior, the apparent limitations in supply of water during peak periods, and the actual operation of the sources that supply water to the town.
Responsibility: Local Municipality
Timing: Study to be initiated in 2012

11.4 OPERATIONAL

a. **Action:** A Technical Operations Committee should be formed between DWA, Bloem Water and Mangaung Metropolitan Municipality to ensure that the system is managed in the most optimal manner.
Responsibility: DWA, Bloem Water and Mangaung Metropolitan Municipality
Timing: 2012 and ongoing

b. **Action:** Ensure sufficient bulk potable water storage to be able to manage system outages and to ensure that the peak water requirements are not transferred across to the Bloem Water Supply system.
Responsibility: Bloem Water and Mangaung Metropolitan Municipality
Timing: 2012 and ongoing

c. **Action:** Monitor the growth in water requirement and adjust the water requirement projection scenarios if it becomes evident that the actual water requirements and projected water requirements differ significantly.
Responsibility: Strategy Steering Committee
Timing: November 2012 and annually thereafter

d. **Action:** Implement a monitoring system to serve as an early warning system should climate change start impacting on water availability and/or water requirements.
Responsibility: Strategy Steering Committee
Timing: To be determined by the Strategy Steering Committee

e. **Action:** Develop a "pro-active" strategy to manage the refurbishment of "high risk" components and the implementation of risk mitigation measures. This would also include new capital works which would enhance system capacity as well as supply flexibility."
Responsibility: Bloem Water and MMM
Timing: 2012 and ongoing

f. **Action:** Replace pipelines in the high risk areas of the Welbedacht Pipeline
Responsibility: Bloem Water
Timing: 2012 and on-going

g. **Action:** It is imperative that the Welbedacht Pipeline in-line control valve be maintained and correctly set, as insufficient attention to this valve could lead to surge pressures with the potential for consequent burst along the Welbedacht pipeline.
Responsibility: Bloem Water
Timing: 2012 and on-going

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Appendix A

Yield Analysis Data

Annexure A : Summary of Present Day Yield Analyses

Scenario	Hydrology		Demands						Welbe-dacht		Tienfontein/ Knellpoort/ Novo			Operating details		Losses					Yields				Dataset	Notes	Change in yield
			Urban		Agric							Novo				WTW		Conveyance									
	Vaal	Caledon	Lesotho	RSA	Lesotho	RSA u/s Welbedacht	RSA d/s Welbedacht	Farm dams u/s Welbedacht	Storage	WTP (after losses)	Tienfontein Pump Station	pump station	pipeline	Rustfontein WTW	Irrigation on Caledon d/s Welbedacht	Wellbedacht	Maselspoort near Mockes	Wellbedacht - Bloem	Novo - Rustfontein	Rustfontein - Mockes	Bloem	Thaba Nchu	Botshabelo	Total			
			m^3x10^6/a	m^3x10^6/a	m^3x10^6/a	m^3x10^6/a	m^3x10^6/a	m^3x10^6	m^3x10^6	Ml/d	m^3/s	m^3/s	m^3/s			%:(m^3x10^6/a for "refo" scenario)	%:m^3x10^6/a	%:m^3x10^6/a	%:m^3x10^6/a	%:m^3x10^6/a	ch77	ch85	ch75				
Caledon transfers																					88					Caledon sub-system from WRP Scenario : "Orange River System: Annual Operation Analysis 2008-10", Need confirmation that used Nova Pumpstorage capacity of 1.67 m^3/s (not 2.4 m^3/s) and assumed losses from Welbedacht WTW were 0% (not 10%). The volume transferred, ignoring losses from Rustfontein to Bloemfontein in the Vaal sub-system.	
Rustfontein-Mockes sub-system																							9			Rustfontein-Mockes sub-system from WRP Scenario : "Caledon-Modder River System Planning Analysis: Effect of updated water requirement projections based on the National Water Resources Strategy Study"	
Caledon + Modder Riet											3						5%			5%	88	3.2	8.5	99		Estimated combined yield, from combining an assumed yield 3.2 million m^3/a for Thaba Nchu with values for the Caledon and Rustfontein-Mockes sub-systems. According to the WRPM runs of WRP curtailment of the Bloem System is only required in about 2013 / 2014 where the total demand of Bloem, Botshabelo, Thaba Nchu and small towns on the Welbedacht pipeline are about 105 million m^3/a (Bloemwater (3).xls from email on 3 Aug 2011. This may be partly because of the curtailment options adopted which allows 50% curtailment at the 1:200 probability and 20% curtailment at the 1 in 100. If the 1 in 200 was 72% and the 1 in 100 was 87% as per the Western Cape would this change the need for curtailments (my email of 8 August 2010).	
Caledon transfers										124		1.67 (above RL1428.61)				10%					89				ymb/cal	Caledon sub-system assuming using a uniform target demand distribution because the demand can peak on the Rustfontein Dam during summer. The volume transferred, ignoring losses from Rustfontein to Bloemfontein in the Vaal sub-system.	
Modder/Riet without Thaba / Nchu									11.7						model u/s of Welbedacht								8.2		ymb/mod	Rustfontein-Mockes sub-system without Thaba Nchu	
Thaba / Nchu from Groothoek Dam														Supplies Botshabelo only				0%				3				Thaba Nchu from Grootfontein Dam	
Caledon + Modder Riet																					89	3	8	100		Caledon-Modder (combining yields from above three scenarios)	
Integrated Caledon + Modder Riet		Orange River System Analysis hydrology (1920-1987)	11	4.2	8.6	32		60													82	3	15	100	ymb/leg0	Integrated system.	
Revised Tienfontein pumpstation	Vaal River System Analysis Update hydrology (1920-1994)						35						2.4						17%: 6.7		74	3	15	93	ymg/t1	Tienfontein Pump operation described in "Extension of the capacity of the Novo Transfer Scheme - Study (EB/2009/5) by V&V Consulting Engineers. According to this report the pumps transfer 1 m^3/s when the inflow reaches 4 m^3/s, 2 m^3/s when the inflow reaches 6 m^3/s and 3 m^3/s when the inflows reached 10 m^3/s.	-7
Revised Nova operation																					77	3	15	95	ymg/t2	Knellpoort Pump operation described in "Extension of the capacity of the Novo Transfer Scheme - Study (EB/2009/5) by V&V Consulting Engineers. According to this report the transfer varies from 1.5 m^3/s when the storage level in Knellpoort is above RL1436m and 1.67 m^3/s at RL1452.1m.	3
Revised Welbedacht WTW operation																	5%: 0.6			5%: 2.5	73	3	15	92	ymg/t3	Replace Welbedacht's average WTW capacity of 124Ml/d with the equivalent seasonal capacity that is lower in summer(100Ml/d due to siltation problems) and higher in winter(145Ml/d).	-4
Revised irrigation d/s Welbedacht																					74	3	15	92	ymg/t4	Model 35million m^3/a irrigation located d/s Welbedacht Dam d/s of the dam (as opposed to u/s) and release all water up to 2m^3/s flowing into Welbedacht when Knellpoort + Rustenberg Storage > 150 Mm^3, reduce to 25% (0.5 m^3/s) when less	1
Revised Welbedacht storage										100Ml/d (Oct-Mar) remainder 145Ml/d	3 new div fn (pump 1 m^3/s when streamflow reaches 4m^3/s; 2m^3/s @ 6m^3/s; 3 m^3/s @ 10m^3/s	1.5 (from 30% / RL1436) to 1.67 (RL1452.1)									71	3	15	89	ymg/t5	Reduce Welbedacht storage from 11.7 to 6.6 million m^3	-3
Revised Welbedacht - Bloem conveyance losses															Model d/s of Welbedacht and release inflows of up to 2m^3/s when the combined storage of Knellpoort and Rustfontein exceeds 150 million m^3, otherwise release inflows of up to 0.5 m^3/s. Don't release from Welbedacht's storage	5% 2.3					67	3	15	86	ymg/t7	Introduce 10% conveyance loss on the pipeline from Welbedacht to Bloemfontein	-3
Supply Bloemfontein from Rustfontein WTW									6.6												68	3	15	86	ymg/ta	Activate direct line from Rustfontein WTW to Bloem which reduces transmission losses and allow Bloem/Welbedacht to access water in Knellpoort	1
Reference scenario with legacy hydrology														Model 100 Ml/d WTW supplying Botshabelo and Bloemfontein				10%: 4.5			68	3	15	86	yme/refl	Same as ta	0
Reference scenario with updated hydrology		ORASE COM	13	7.3	56.25			74													65	3	15	84	yme/refo	Replace Caledon System upstream of Welbedacht with a present day streamflow sequence developed during the Orasecom Study - kindly provided by Bennie Haasbroek. The demands downstream of Welbedacht from the Orange River System Analysis were retained while the Orasecom Study was checking why the new demands(14 million m^3/a) were significantly lower than the earlier demands (35million m^3/a)	-3

"I:\Hydro\402992\ymf\Model Runs to be undertaken rev2_ymfv3.xlsx" sheet "PDayScenarios"

Tienfontein pumpstation

As part of this reconciliation study the modelling of the Tienfontein Pumpstation was revised using the latest available streamflow sequences describing the daily inflow at the pumpstation information on the operation of the pumpstation.

Streamflow sequences

The streamflow in the Caledon River are currently measured at Wilgedraai (D2H022) and downstream of the Welbedacht Dam (D2H033) and the monthly streamflows at these two sites were compared with the most recent estimate of the streamflows arising out of the Orasecom study (see **Figure 1**). A detailed evaluation of the hydrology was outside the scope of this study but this figure indicates that the gauge at Wilgedraai (red line) appears to get stuck during periods of low flow which can result in the streamflow being overestimated. It also underestimates the peak streamflows. For this reason the gauge at Welbedacht was selected for analysing the Tienfontein pumpstation.

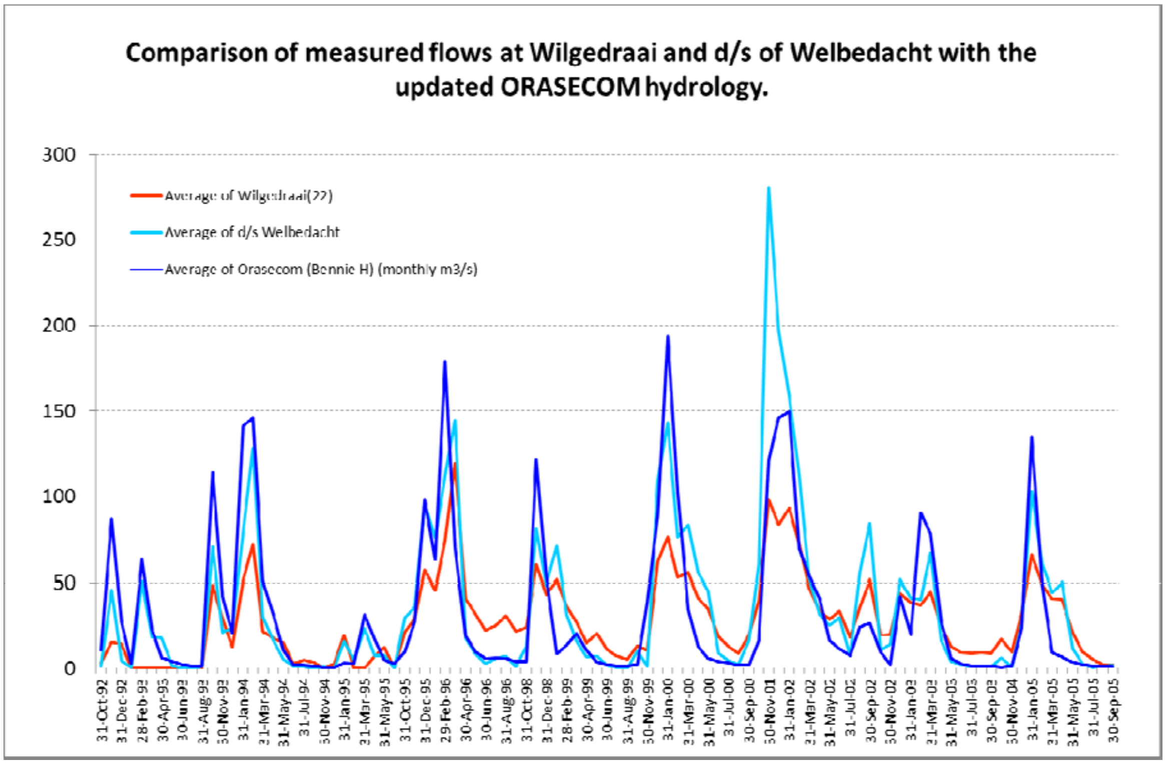

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Figure 1 : **Monthly Streamflows at Wilgedraai(D2H022), Downstream of Welbedacht (D2H033) and the Present Day Streamflows at Tienfontein from the Orasecom Study**

The daily streamflow at Welbedacht (D2H033) was adjusted to estimate the streamflow at Tienfontein :

- Adding increases in storage in Welbedacht Dam (D2R004) and deducting decreases
- Adding back the transfer to Bloemfontein (D2H027-M01) and to Knellpoort (D2H031)
- Deducting releases from Knellpoort (D2H028)

Pumpstation operation

According to the report titled "Extension of the capacity of the Novo Transfer Scheme - Study (EB/2009/5) by V&V Consulting Engineers the first pump of the Tienfontein pumpstation is only switched on when the upstream streamflow reaches 4 m^3/s and that pump transfers 1 m^3/s to Knellpoort Dam. Similarly, when the streamflow reaches 6 m^3/s the second pump starts to pump so that 2 m^3/s is transferred to Knellpoort Dam. The third pump only switches on when the streamflow reaches 10m^3/s. More aggressive pumping operating rules, which tried to pump all water above 3 m^3/s were developed but not used for the yield analyses.

Relationship of monthly inflows to pumped volumes

The daily streamflow at Tienfontein (derived from the streamflow at Welbedacht) and the updated operating rules were used to simulate the volume pumped to Knellpoort Dam on a daily basis. The inflows and pumped volumes were then aggregated into monthly flows to develop a relationship between the monthly streamflows and the pumped volumes (see **Figure 2** below).

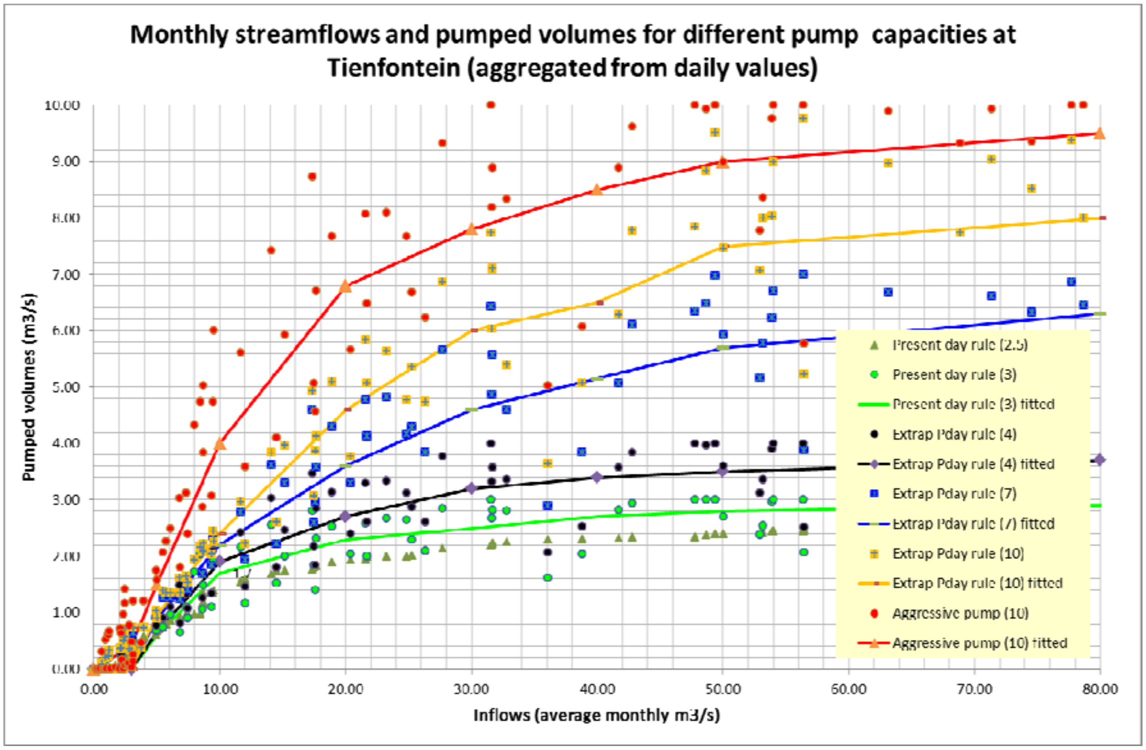

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Figure 2: Relationship of Average Monthly Streamflows to Pumped Volumes at Tienfontein (before taking sand-trap losses into account)

Subsequently, the losses occurring at the sandtrap, where about 6% of the pumped water is used to flush the trap and returns back to the Caledon River, were incorporated by factoring the pumped volumes by 94% (see **Table 1**).

Table 1: Relationship of average monthly streamflows to pumped volumes at Tienfontein (after taking sand-trap losses into account)

Scenario		Average monthly pumped volumes for different average streamflows (m^3/s)										
Capacity	Operating Rule											
Streamflows (m^3/s) -->		0	3	5	10	20	30	40	50	80	150	999
2.5	Present day	0	0.00	0.52	1.32	1.79	2.07	2.16	2.26	2.35	2.35	2.35
3	Present day	0	0.00	0.56	1.60	2.16	2.35	2.54	2.63	2.73	2.73	2.73
3	Aggressive	0	0.24	0.66	2.07	2.16	2.35	2.54	2.63	2.73	2.73	2.73
4	Present day	0	0.00	0.61	1.79	2.54	3.01	3.20	3.29	3.48	3.71	3.71
7	Present day	0	0.00	0.85	2.07	3.38	4.32	4.84	5.36	5.92	6.30	6.30
10	Present day	0	0.00	0.89	2.26	4.32	5.64	6.11	7.05	7.52	8.46	8.46
10	Aggressive	0	0.38	1.41	3.76	6.39	7.33	7.99	8.46	8.93	8.93	8.93

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Acknowledgements

The assistance of Manie Mare (WRP Consulting Engineers), Bennie Haasbroek (Hydrosol), Delarey Bakkes (V&V Consulting Engineers) and Delana Louw (Rivers 4 Africa) in providing data for this study is gratefully acknowledged.

Appendix B

Infrastructure Options and Associated Yields

Abstraction from Caledon River

Welbedacht Storage	Welbedacht pipeline	Welbedacht WTP	Tienfontein Pump Station	Novo Pump Station	Novo pipeline	EWR Req.	Upstream Dev.	New totals	Total	Notes
million m^3	m^3/s	Ml/d	m^3/s	m^3/s	m			Million m^3/a	Million m^3/a	
6.6		**100-145Ml/d**	3	1.5-1.67	2.4		N		84	1
6.6		123	3	1.5	2.4		N			
13		145	3	1.5-1.67	2.4		N	**93**	93	
6.6		123	4	1.5-1.67	2.4		N	**88**	88	
6.6		123	4	2.4	2.4			**88**	88	2
6.6		123	2.5	2.4	2.4			**78**	78	
6.6		123	3	2.4	2.4			**84**	84	
6.6	1	123	4	1.5-1.67	2.4		N	**103**		
	2							**111**		
	3							**113**		
6.6	1	123	4	2.4	2.4		N	**103**		
	2							**111**		3
	3							**113**		
	1			4.8				**101**		
	2							**113**		
	3							**123**		
	4							**128**		
	5							**133**		
	6							**137**		
6.6		123	7	2.4	2.4		N		100	
6.6		123	10	2.4	2.4		N		104	
6.6		123	7	4.8	4.8		N		100	
6.6		123	10	4.8	4.8		N		106	
6.6		145	3	1.5-1.67	2.4		N		91	
13		123	3	1.5-1.67	2.4		N		86	
6.6		123	3	1.5-1.67	2.4		N		80	
6.6		123	3	1.5-1.67	2.4		Metolong		83	
6.6		123	3	1.5-1.67	2.4	EWR	N		81	

Welbedacht Storage	Welbedacht pipeline	Welbedacht WTP	Tienfontein Pump Station	Novo Pump Station	Novo pipeline	EWR Req.	Upstream Dev.	New totals	Total	Notes
million m^3	m^3/s	Ml/d	m^3/s	m^3/s	m			Million m^3/a	Million m^3/a	
6.6		123	3	1.5-1.67	2.4		N		82	
6.6		123	3	1.5-1.67	2.4		N		75	
6.6	1	123	7	4.8	4.8		N	**111**	114	
	2							**121**	125	4
	3							**129**	132	
	4							**134**	138	
	5							**138**	141	
	10							**150**	154	
6.6	1	123	10	4.8	4.8		N	**118**		
	2							**126**		
	3							**133**		
	4							**138**		
	5							**141**		
	10							**151**		
13	1	145	7	4.8	4.8		N	**117**	124	
	2							**127**	137	
	3							**133**	144	
	4							**138**	149	
	5							**141**	153	
	10							**154**	164	
13	1	145	10	4.8	4.8		N	**124**	129	
	2							**132**	141	
	3							**138**	147	
	4							**142**	152	
	5							**146**	156	
	10							**156**	167	
6.6		80/116	3	1.5	2.4		N		76.8	
6.6		123	3	1.5	2.4		N		83.7	

Welbedacht Storage	Welbedacht pipeline	Welbedacht WTP	Tienfontein Pump Station	Novo Pump Station	Novo pipeline	EWR Req.	Upstream Dev.	New totals	Total	Notes
million m^3	m^3/s	Ml/d	m^3/s	m^3/s	m			Million m^3/a	Million m^3/a	
6.6		1.267	3	1.55-1.67	2.4		N			
Notes										
1	Baseline Yield									
2	Tienfontein 4 m^3/s									
3	Welbedacht P/S 2 m^3/s									
4	Tienfontein 7 m^3/s									

Appendix C

Recommendations of Preliminary Options Workshop held on 29 October 2009

water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

DEVELOPMENT OF RECONCILIATION STRATEGIES FOR LARGE BULK WATER SUPPLY SYSTEMS: GREATER BLOEMFONTEIN AREA

PRELIMINARY OPTIONS WORKSHOP RECOMMENDATIONS

Held on 29 October 2009

November 2009

OPTIONS WORKSHOP ATTENDEES

Mr Seef Rademeyer (DWA: NWRP) (SR)
Ms Dragana Ristic (DWA: NWRP) (DR)
Mr Peter Pyke (DWA: Central) (PP)
Ms Lerato Bapela (DWA) (LB)
Mr Louis van Oudtshoorn (Bloem Water) (LvO)
Mr Steve Naude (Mangaung Municipality) (SN)
Mr Dries Visser (DWA: Free State) (DV)
Mr Roelf Jacobs (Free State Agriculture) (RJ)
Mr Nic Knoetze (Orange-Riet Water User Association) (NK)
Mr John Kegakilwe (Motheo DM – Department of Agriculture) (JK)
Ms Patience Hadebe (Motheo DM – Department of Agriculture) (PH)
Ms Andrea van Gensen (Eskom Distribution) (AvG)
Ms Puleng Mofokeng (Department of Agriculture, Forestry and Fishery) (PM)
Mr Mxolisi Mabindisa (Eskom Distribution) (MM)
Mr Charles Wessels (Kalkveld Water User Association) (CW)
Mr Hennie Grobler (Free State Department of Agriculture) (HG)
Mr Tendayi Makombe (DWA: NWRP) (TMak)
Mr Jurgo van Wyk (DWA: Water Resources Planning System) (JvW)
Mr Richard Tloubatla (DWA: Free State) (RT)
Mr Thabo Masike (DWAF: WUE) (TMas)
Mr Mabuti Moloi (Motheo District Municipality) (MM)
Mr Edwin Mofokeng (Naledi Municipality) (EM)
Mr Thulo Mohapi (DWA: Free State) (TMoh)
Mrs Molly Ntwaeaborwa (DWA: FS) (MN)
Mr Tebogo Mothwa (Free State: Department of Agriculture) (TMot)
Dr Johan van der Merwe (Bloem Water) (JvdM)
Mr Mike Killick (Aurecon) (MK)
Ms Karen Versfeld (Aurecon) (KV)
Mr Graeme Evers (Aurecon) (GE)
Ms Terry Baker (ILISO Consulting) (TB)
Mr Jaco Hough (GHT Consulting Scientists) (JH)
Mr Sarel de Wet (Sarel de Wet Consulting Services) (SdW)
Ms Bhavani Daya (ILISO Consulting) (BD)

WELCOME AND OPENING

TB welcomed everyone to the workshop and allowed each attendee to introduce themselves.

SR relayed Mr Johan van Rooyen's apologies for not being able to attend the workshop. On behalf of Mr van Rooyen, SR provided a brief background to this study.

SR explained that the National Water Act, which was promulgated in 1998; requires the establishment of a National Water Resource Strategy (NWRS). The purpose of the NWRS is to provide a framework within which the water resources of the country will be managed. South Africa is a water scarce country and water resources are under stress. In order to make provision for current and future water requirements, the Department of Water Affairs (DWA) are currently developing strategies, such as the Reconciliation Strategy Study, to enhance the water supply.

PRESENTATIONS

The Preliminary Screening Workshop Starter Document was sent to all attendees from the week of the 2 October 2009. The purpose of the Preliminary Screening Workshop Starter Document was to provide attendees with an over-view of the study area, including bulk infrastructure, current and future water requirements, and a water balance. In addition, information on all interventions which have been identified were described in the Preliminary Screening Workshop Starter Document.

The purpose of the Preliminary Screening Workshop was thus to provide attendees with the opportunity to discuss the interventions that have been identified, screen out unfeasible interventions, and identify new interventions which were not included in the Preliminary Screening Workshop Starter Document.

MK presented on the following topics discussed in more detail in the Preliminary Screening Workshop Starter Document:

- Scope of the study;
- Description of the Current Infrastructure;
- Available Supply
- Water Requirements;
- Water Balance
- Reconciliation Interventions;
- Other issues which could have an impact on Reconciliation; and
- Issues impacting on Reconciliation Options.

WATER REQUIREMENTS SCENARIOS

In order to prevent the anticipated shortages in water supply to the Greater Bloemfontein Area, the DWA has initiated a Reconciliation Strategy Study to explore supply and demand side interventions that can be implemented to meet anticipated future water requirements.

In terms of urban requirements, there is limited information currently available on the losses for bulk water transmission losses and water treatment losses. Agricultural water requirements for this study were considered in two areas, namely the Modder-Riet Catchment and along the Caledon River.

Other important comments from delegates:

The following comments refer to **Table 4.1** of the Preliminary Screening Workshop Starter Document:

- GE: Not all the water provided to the towns listed in **Table 4.1** is provided by Bloem Water (BW) and Mangaung Local Municipality (MLM). Some of the water provided to these towns is supplied from boreholes within the area.
- MK: Groundwater is used to augment supply to some towns within the study area, but that the yields from these are very small.
- PP: Utilising other water resources, such as groundwater, may be a cheaper source of water to some towns than obtaining water from Bloem Water.
- LvO: In 2009, the figures provided by BW and MLM may be skew, as ± 30% of the water was provided from alternative resources (such as boreholes) and the rest by BW. The figures in the table are not incorrect just that there was a mismanagement issue at that time in terms of recording water sources at the MLM.

The following comment refers to **Section 4.1.1** of the Preliminary Screening Workshop Starter Document:

- LvO: An allowance of 8.5% has been added to the historical bulk water requirements to calculate the bulk losses from the system. This should be increased to 12%.

The following comment refers to **Figure 4.1** of the Preliminary Screening Workshop Starter Document:

- In 2002 the water consumption drops and then increased in the following year. LvO explained that this was as a result of the high rainfall experienced during that year. As such, the historical data presented in **Figure 4.1** is influenced by climate.

The following comment refers to **Figures 4.2** and **4.3**:

- PP: Concerned about using the term ‘residential uncontrolled water use’, as it implies that it is unmetered or unregistered water. A definition of ‘residential uncontrolled water use’ will be provided in the document.

General comments:

- LvO stated that the situation facing Mohale Dam is a reality, in terms of the surplus yield.
- JH: Has global warming been taken into account and its influence on rainfall? MK responded that climate change would be taken into account in the scenario planning.
- LB asked how the options are compared. MK explained that a Unit Reference Value (URV) per m^3 of water that can be used to compare options is calculated. This value took the cost of developing the resource and providing the bulk water as well as the quantity of water that can be supplied and time-period over which it will be available into account.
- MM queried the use of scenario planning to predict the future water requirements, as the use of a trend-line based on historical data can provide an indication of future requirements. PP responded that historical trends provide information on only one possible future requirement. The benefit of using scenario planning is that it takes into account multiple factors which can influence the future water requirements.
- LB queried whether the various scenarios considered the recession as a factor in the scenario analysis in terms of a demand for water. MK responded that the impact of the recession will be factored into the scenario planning in terms of population growth. DR added that migration rates can also be used as an indicator of the recession.

PRELIMINARY OPTIONS WORKSHOP RECOMMENDATIONS

a. Urban Water Conservation and Demand Management

i. Efficient use of Water and Loss Management

Recommendation:
The MLM has developed a Water Conservation and Water Demand Management (WC/WDM) Strategy which should be referred to in the Preliminary Screening Workshop Starter Document. Institutional arrangements, however, have not been defined in the WC/WDM Strategy. The implementation of WC/WDM must be the major “intervention” recommended by this Study. If the MLM cannot manage their current supply of water then future schemes will not be supported by the DWA.

Other important comments from delegates:
TMas: The MLM has essential information and that needs to be shared with Government Departments, such as DWA Regional Office, to ensure implementation of this intervention.

TMas: Metered information needs to be included in this Study. The person responsible for MLM's Water Conservation Management should be contacted and be involved in this process.

LvO stated that if the Local Municipality is involved perhaps an extension of infrastructure may not be needed as investigated in this assessment; perhaps another form of using current infrastructure can be investigated.

ACTION ITEM: SR suggested that TMas should assist the project team to ensure that these responsible persons are identified and included in the study.

b. Agricultural Water Conservation and Demand Management

Recommendation:
It is important to initiate metering (both surface and groundwater abstractions) in the study area to identify illegal water use. In addition, metering also provides essential information to understand the yield of the system.

Other important comments from delegates:
NK: The DWA needs to ensure that the NWA is implemented, in terms of controlling and monitoring abstractions within the catchment management areas.

CW stated that it is sad that the Water User Associations are not being used more efficiently as the National Water Act states as they could assist in the controlling of water use in their catchment; the lack of service delivery from DWAF has led to the theft and abuse of water. The illegal use of water needs to be monitored and metered by Municipalities.

LvO queried whether there will be a direct pipeline to Bloemfontein.
MK re-iterated that the point of the workshop is to screen out the options which will not be feasible.

RJ stated that he had worked at the Tienfontein pump station and had noted the impact of the high sediment load on the pump station resulting in increased wear-and-tear on the equipment and high maintenance costs. As a result of the high sediment load, the Knellpoort Dam channel from Welbedacht Dam to Bloemfontein is deteriorating, and it is essential that it is rebuilt.

TB queried if the assumption has been made that there is no unlawful use.
SR stated that in terms of addressing unlawful water use, if the information is available regarding it then measures will be undertaken to eradicate it.
MK clarified that all requirement figures used in the study exclude all unlawful use. The assumption is that the unlawful use of water will be dealt with and no longer take place in future.

c. Surface Water Interventions

ii. Utilising Surplus Capacity in the Orange River by Pumping to Knellpoort Dam from Gariep Dam

Recommendation:

This intervention must be further investigated and the description of this intervention must be amended to reflect the actual scheme proposed.

iii. Utilising Surplus Capacity in the Orange River by Pumping to Knellpoort Dam from Vanderkloof Dam

Recommendation:

The URV for this intervention is based on a 200 km pump system, which includes a pump station and rising main, from Vanderkloof Dam to Knellpoort Dam. This intervention will be further investigated. However the high pumping costs will probably exclude this intervention.

iv. Utilising Surplus Capacity in the Orange River by Pumping to Knellpoort Dam from Bosberg / Boskraai

Recommendation:

The URV for this intervention is based on a 100 km pump system, which includes a pump station and rising main. The cost of land acquisition and construction of the dam have been excluded. This intervention will be further investigated. However the high pumping costs will probably exclude this intervention.

v. Modifications to Welbedacht Dam: Extend Scour Operations and Lower Outlets

Recommendation:

Alternative 1: Extended scour operations
- This will be required to maintain the existing yield of Welbedacht Dam

Alternative 2: Lower outlets
- This intervention is fatally flawed as it would require that the entire dam wall be rebuilt.

vi. Modifications to the Caledon-Modder System

Recommendation:

Include an additional option, namely the construction of a canal to transfer water upstream of Tienfontein Pump Station (close to Jammersdrift Weir) to Knellpoort Dam.

vii. Polihali Dam – Lesotho Highlands Phase 2

Recommendation:

The URV is based on the incorrect tariff. The URV should be based on the Vaal prices for water.

d. Re-Use of Treated Effluent

viii. Planned Indirect Re-Use – New North Eastern WWTW

Recommendation:

The URV includes treatment and operating costs, as such the URVs cannot be compared with our surface water interventions.

This option needs to be further investigated.

ix. Planned Indirect Re-Use – Transfer to Upstream of Mockes Dam

Recommendation:

This option needs to be further investigated.

x. Planned Indirect Re-Use – Krugersdrift Dam

Recommendation:

This option needs to be further investigated.

xi. Planned Indirect Re-Use – Bloemspruit

Recommendation:

This option needs to be further investigated.

xii. Re-Use of Treated Effluent – Direct Use: Irrigation

Recommendation:

This option needs to be further investigated.

e. Groundwater

xiii. Ikgomotseng Aquifer

Recommendation:

These groundwater schemes provide local solutions, which may be more cost effective for local use than bringing water from the BW supply scheme.

xiv. Bloemfontein (Bainsvlei Aquifer)

Recommendation:

This option has been screened out due to the high socio-economic costs associated with land expropriation, the cessation of farming activities in this area, and loss of jobs.

xv. Thaba Nchu Aquifer

Recommendation:

This option has been screened out as a result of poor groundwater quality.

xvi. Town Groundwater Interventions (Reddersburg, Edenburg, Dewetsdorp, and Weppener)

Recommendation:

This option needs to be further investigated.

xvii. Groundwater Interventions based on Well Fields next to / in the Vicinity of Pipelines – De Hoek Reservoir

Recommendation:

This option has been screened out.

xviii. Groundwater Interventions based on Well Fields next to / in the Vicinity of Pipelines – Lieukop off-Take Chamber

Recommendation:

This option has been screened out.

f. Water Trading

Recommendation:

There is potential for this option to be developed in future, however there are a number of socio-economic issues that need to be taken into consideration, namely loss of jobs and food security.

g. Other Options

xix. Tunnel from Caledon

Recommendation:

This option has been screened out due to the impact that this option will have on the yield of existing infrastructure.

xx. New Dam on the Caledon River

Recommendation:

This option has been screened out due to the high sediment loads of the Caledon River.

xxi. Transfer of Mine Water

Recommendation:

This option should be further investigated. However, there is currently a demand for the mine water in the Welkom area and the water quality is a concern.

NOTE: A summary of all the interventions and URVs is included in the following section.

GENERAL DISCUSSION

In order to determine the impact of the increasing electricity costs on the proposed interventions, a sensitivity analysis will be conducted.

ACTION ITEM: MK to conduct a sensitivity analysis to determine the impact of electricity costs on the URVs.

WAY FORWARD

TB stated that the proceedings from this meeting would be sent to all present at the Workshop for comment, and that the comments raised from this Workshop would be used in the assessment of options.

MK stated that a second Workshop would be held later in the project to present the findings of the detailed assessment of each Intervention.

CLOSURE

TB thanked everyone for attending the Workshop and for their contributions to the study. The meeting was closed at 14:00.

Table 1: Summary of all interventions considered at the Preliminary Screening Workshop

Option	Yield (Mm^3/a)	URV (R/m^3)	Socio - Economic	Ecological	Warrants further study? Yes / No / & Comment
A - URBAN WATER CONSERVATION AND DEMAND MANAGEMENT					
A1 - Efficient use of water	0	0	1	1	Yes. There will be no augmentation of bulk services without WC/WDM being addressed first
A2 - Loss management	0	0	1	1	Yes. There will be no augmentation of bulk services without WC/WDM being addressed first
B - AGRICULTURAL WATER CONSERVATION AND DEMAND MANAGEMENT					
B1.1 - River release management	0	0	1	1	No
B1.2 - Irrigation Practices	0	0	1	1	No
B1.3 - Irrigation Canal Losses	0	0	1	1	No
B1.4 - Farm Dam Losses	0	0	1	1	No
B1.5 - Crop Selection	0	0	1	1	No
B1.6 - Crop Deficit Irrigation	0	0	1	1	No
B1.7 - Metering	0	0	1	1	No
C - SURFACE WATER DEVELOPMENT OPTIONS					
C1 - Utilising surplus capacity in Orange River by pumping to Knellpoort Dam from Gariep Dam	10	5.3	2	2	Yes
C2 - Utilise surplus capacity in Orange River system by pumping to Knellpoort Dam from Vanderkloof Dam	10	6.7	2	2	Yes
C3 - Utilise surplus capacity in Orange River system by pumping to Knellpoort Dam from Bosberg/Boskraai Dam	10	4.2	2	2	Yes
C4a - Modifications to Welbedacht Dam : Extend scour operations	0	0	1	1	Yes
C4b - Modifications to Welbedacht Dam : Lower gates	0	0	1	1	No

Option	Yield (Mm^3/a)	URV (R/m^3)	Socio - Economic	Ecological	Warrants further study? Yes / No / & Comment
C5a - Modifications to Knellpoort System : Increased abstraction capacity of Novo Pumpstation	4.5	0	1	1	Yes
C5b - Modifications to Knellpoort System : Raising of Knellpoort Dam	5.8	0	1	1	Yes
C5c - Modifications to Knellpoort System : Increase capacity of Tienfontein pumpstation	27	0	1	1	Yes
C5d - Modifications to Knellpoort System : New pump station at Welbedacht Dam	39	0	1	1	Yes
C5e - Modifications to Knellpoort System : Combination of options	67	0	1	1	Yes
C6 - Polihali Dam Lesotho Highlands Phase 2	10	3.38	1	1	Yes. The URVs are incorrect as they are based on the incorrect tariff structure
D - REUSE OF TREATED EFFLUENT					
D1 - Planned direct reuse - new North Eastern WWTW	10.8	4.1	2	2	
D2 - Planned indirect reuse - Transfer to upstream of Mockes Dam	10.8	4.8	1	2	Yes
D3 - Treated indirect re-use - Krugersdrift Dam	10.8	5	1	2	Yes
D4 - Planned direct re-use - Bloemspruit	10.8	3.7	1	2	Yes
D5 - Re-use of treated effluent - Direct use: Irrigation	0	0	1	1	Yes
E - GROUNDWATER DEVELOPMENT OPTIONS					
E1 - Ikgomotseng aquifer	0.21	5.08	2	2	Yes
E2 - Bloemfontein aquifer (Bainsvlei aquifer)	28	15.58	3	2	No
E3 - Thaba Nchu aquifer	0.89	5.35	1	2	Yes
E4 - Reddersburg Aquifer	0.24	9.22	1	2	Yes
E5 - Edenburg Aquifer	0.3	10.08	1	2	Yes
E6 - Dewetsdorp Aquifer	0.17	7.35	1	2	Yes
E7 - Wepener Aquifer	0.16	7.52	1	1	Yes
E8 - Well-field developments along the route of the existing pipelines : De Hoek Reservoir	0.43	9.42	1	1	No

Option	Yield (Mm^3/a)	URV (R/m^3)	Socio - Economic	Ecological	Warrants further study? Yes / No / & Comment
E9 - Well-field developments along the route of the existing pipelines : Lieukop Off-take Chamber	0.43	10.3	1	1	No
F - WATER TRADING					
B1 - Water Trading			3	0	No
G - OTHER OPTIONS					
G1 - Tunnel from Caledon to the Modder	0	0	0	0	No
G2 - New dam on the Caledon River	0	0	0	0	No
G3 - Transfer of mine water	4.6	4.6	1	1	Yes
G4 - Canal option (to be developed still)					