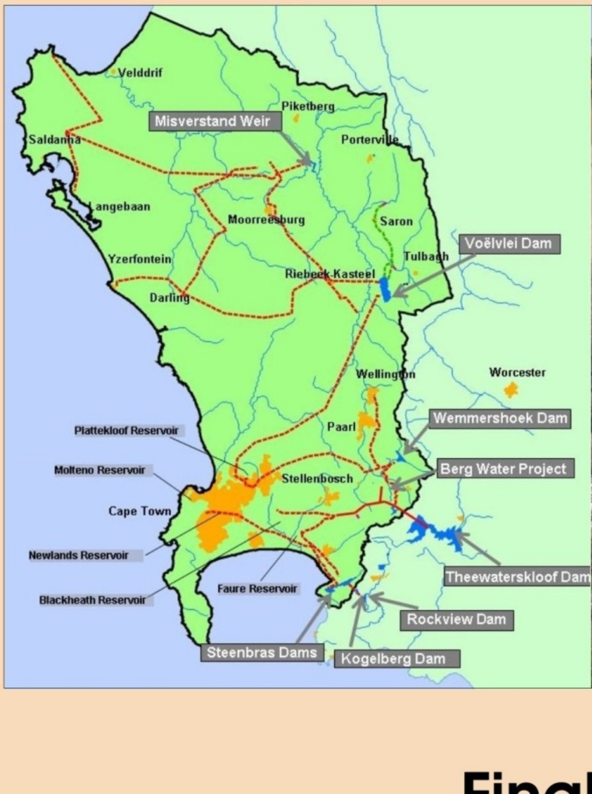
Report No: P WMA 19/G10/00/2413/6

DEPARTMENT OF WATER AFFAIRS
DIRECTORATE : OPTIONS ANALYSIS

PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF FURTHER SURFACE WATER DEVELOPMENTS

Report No 3 : Feasibility Studies
Volume 2 : First Phase Augmentation of Voëlvlei Dam

BREEDE-BERG (MICHELL'S PASS) WATER TRANSFER SCHEME




Final

December 2012

Department of Water Affairs
Directorate: Options Analysis

PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF FURTHER SURFACE WATER DEVELOPMENTS

APPROVAL

Title	:	Feasibility Studies First Phase Augmentation of Voëlvlei Dam Breede-Berg (Michell's Pass) Water Transfer Scheme
Consultants	:	Western Cape Water Consultants Joint Venture
Report status	:	Final
Date	:	December 2012

STUDY TEAM: Approved for the Joint Venture:

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EXECUTIVE SUMMARY

INTRODUCTION

The Western Cape Reconciliation Strategy Study (WCRSS) identified the need for augmentation of the Western Cape Water Supply System (WCWSS) by 2019. In July 2008, the Directorate of National Water Resources Planning (D:NWRP) of the Department of Water Affairs (DWA) appointed the Western Cape Water Consultants Joint Venture (WCWC JV) to undertake pre-feasibility level investigations into six potential surface water development options (Phase 1) and to prioritise these so as to identify the two most viable options for further investigation to feasibility study level in Phase 2 of the Study. The Phase 1 outcome indicated the following two priority schemes.

- Berg River-Voëlvlei Augmentation Scheme, abbreviated as the BRVAS;
- Breede-Berg (Michell's Pass) Water Transfer Scheme, hereinafter referred to as the Breede-Berg Transfer Scheme, abbreviated as the BBTS.

Both schemes would rely on the utilisation of the existing storage capacity in the Voëlvlei Dam, and on the existing capacity of the City of Cape Town's (CCT's) pipeline, from their water treatment works (WTW) at the dam to their Plattekloof reservoir in Cape Town.

These two schemes (BRVAS and BBTS) are likely to be mutually exclusive, unless Voëlvlei Dam is raised and the capacity of the conveyance infrastructure from the CCT WTW to Cape Town is increased. These aspects have been touched on in this study. However the potential to implement both the BRVAS and the BBTS would need to be further investigated, taking the storage and conveyance infrastructure requirements as well as the water requirements into consideration.

This report addresses the BBTS Feasibility Study, for which the scheme location is shown in Figure i. The BRVAS Feasibility Study is reported on independently.

DESCRIPTION OF THE SCHEME

The proposed BBTS would involve the diversion of winter water from the upper Breede River into the catchment of the Klein Berg River. The scheme would comprise the following components shown in Figure ii:

- A new diversion weir immediately downstream of the existing weir H1H001 at Michell's Pass which diverts water into the Artois canal and has supplied the irrigators and Wolseley Municipality for more than 60 years.
- A pressure pipeline of 2000 mm diameter which would deliver water to the adjacent catchment of the Klein Berg River (Berg WMA), from which the water would be diverted into the existing Klein Berg canal to augment the winter flow into the Voëlvlei Dam. The scheme would also supply the summer and winter irrigation requirements of the existing users of the Artois Canal.
- Storage may also be required to supply the Reserve as discussed below.

PRELIMINARY RESERVE AND THE PROVISION OF STORAGE

Assuming that the proposed diversion scheme should be planned to operate so as to meet the Class D flow requirements of the upper Breede River which were recommended in the Preliminary Determination of the Reserve and Resource Class in terms of Section 14(1)(b) and 17(1) of the National Water Act (Act No. 36 of 1998), then this would necessitate the provision of storage so that the summer flows could be released to meet the Reserve requirements of the upper Breede River.

Further investigations and a trial release (if possible from the Koekedouw Dam) should be undertaken to determine whether such Reserve flow releases would restore the summer flows in the upper Breede River. Assuming that these trial releases show that the Reserve flows would be restored then storage could be provided by one of the following options:

- It may be possible to supply the Reserve by releasing water from Koekedouw Dam during the summer months, for which further investigations would be necessary.
- Alternative B would comprise an 8 million m^3 dam on the Boontjies River (the Boontjies Dam) which would be filled in winter and from which water would be pumped in summer to supply the irrigators so that the river flows could supply the Reserve.

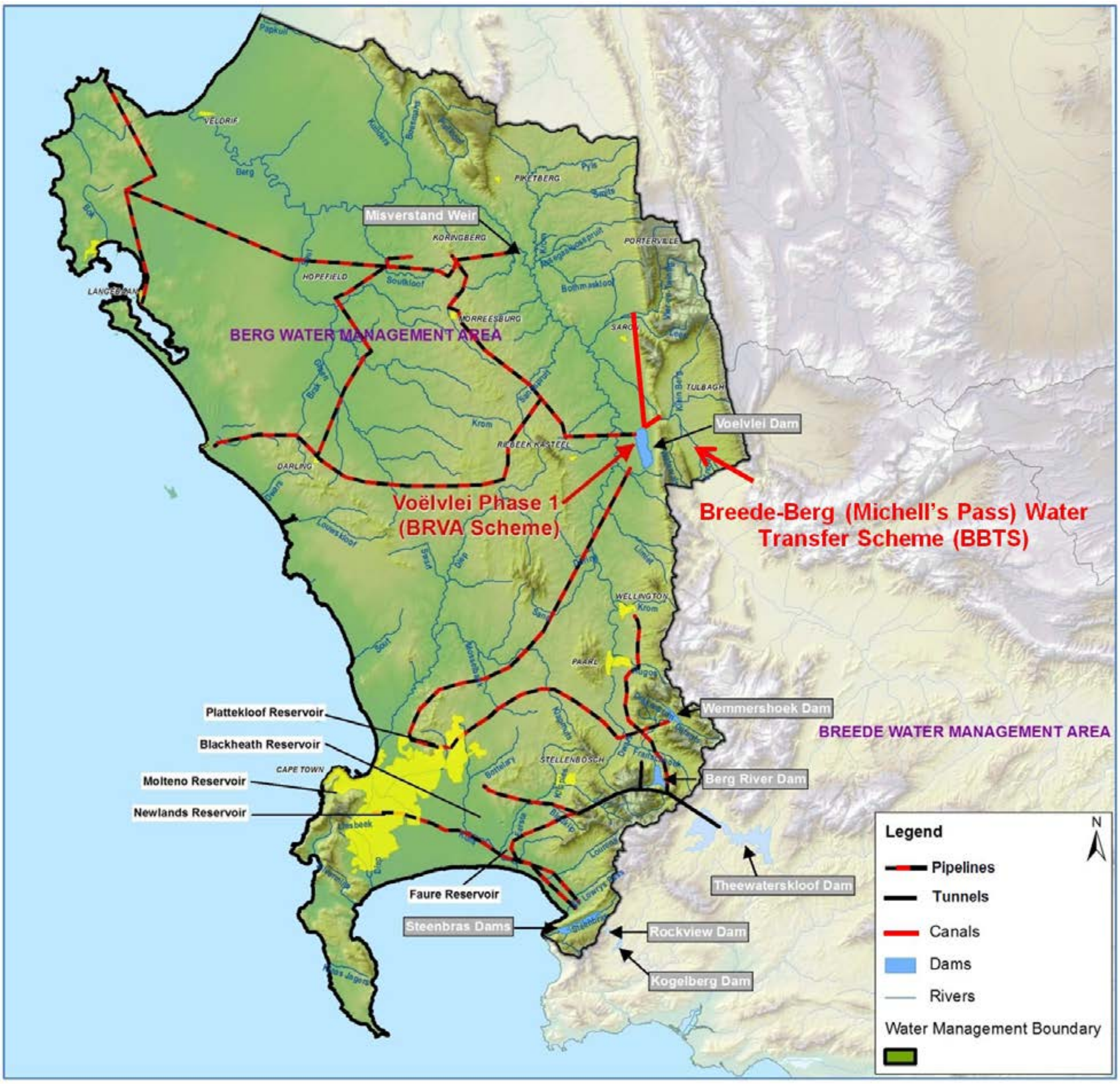


Figure i: **Location of the BRVAS**

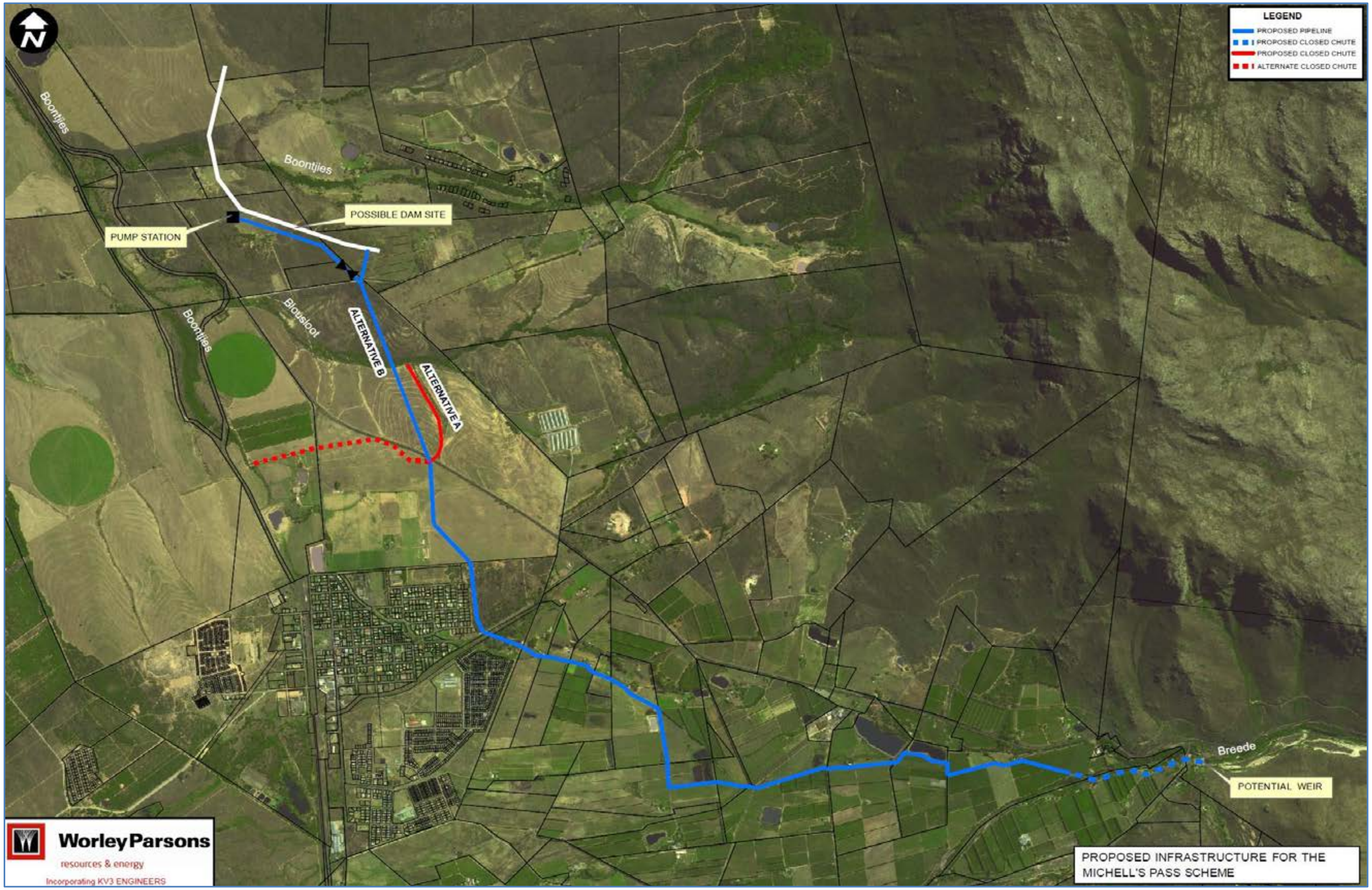


Figure ii: Scheme Layout

PROVISION OF STORAGE, OPERATION AND YIELD

Two options with and without storage were investigated:

- The Alternative A scheme would not meet the summer Reserve flow requirements (unless the summer Reserve flows can be met from Koekedouw Dam):
  - During the summer months water would be diverted from the upper Breede River via the new pipeline to supply the existing users of the Artois furrow, and
  - During the winter months after first meeting the winter requirements of the Artois users via diversions into the pipeline and also the low flow Reserve requirements of the upper Breede River, water would be diverted via the pipeline into the catchment of the Klein Berg River to augment the supply to Voëlvlei.Dam.
- The Alternative B scheme would provide both the summer and winter Reserve flows by utilising storage in the proposed Boontjies Dam as follows:
  - During the summer months:
    - No water would be diverted and the available flows in the upper Breede River would supply the Reserve.
    - The existing users of water from the Artois furrow would be supplied with water pumped from the Boontjies Dam
  - During the winter months, after first meeting the low flow Reserve requirements of the upper Breede River water would be released first to supply the Artois furrow users and then to fill the Boontjies Dam.

Both of these alternatives would augment the 1 in 50 year yield of Voëlvlei Dam by 36 million m^3/annum.

PAPENKUILS PUMP STATION AND IMPACTS ON LOWER BREEDE RIVER

The proposed winter diversions at Michell's Pass would reduce the flows in the river reaches downstream of the proposed new Michell's Pass diversion weir and would necessitate increasing the existing 7 m^3/s pumping capacity of the Papenkuils Pump Station to restore the yield of Brandvlei Dam.

Various pumping capacities (15 m^3/s and 26 m^3/s) and operating rules for the Papenkuils Pump Station were modelled to investigate options for restoring the yield of Brandvlei Dam without impacting unduly on the present ecological status (PES) of the river reaches downstream and of the estuary. It was concluded that

- The capacity and operating rules of the Papenkuils Pump Station could be designed to reinstate the yield of Brandvlei Dam without impacting on the present day ecological status of the Breede River and estuary.
- Other measures would be required to reinstate the Intermediate Reserve requirements of the Breede River downstream of Brandvlei Dam and of the estuary.

The costs estimates were based on increasing the pumping capacity at Brandvlei Dam to 20 m^3/s, for which provision was made when the existing Papenkuils Pump Station was constructed.

INFRASTRUCTURE PRELIMINARY DESIGN

The proposed infrastructure would comprise the following:

- An abstraction weir and diversion works located on the Breede River at Michell's Pass about 30 m downstream of the existing DWA weir H1H006.
- Alternative A with no dam would comprise a 7 600 m long 2 000 mm gravity pipeline would discharge directly into the Blousloot River .
- Alternative B would comprise the 34 m high earth embankment Boontjies Dam, a 9 645 m long 2 000 mm pipeline and a pump station to deliver 1 m^3/s from the dam during the summer months to supply users of the former Artois furrow.

The preliminary designs of the proposed abstraction weir and pipeline were based on a LiDAR survey and geotechnical investigations whereas the design of the proposed Boontjies Dam fell outside the scope of these contracts.

CAPITAL COSTS, OPERATING AND MAINTENANCE COSTS AND UNIT REFERENCE VALUES

i. The capital costs of the alternative schemes are provided in **Table i,** operating and maintenance costs are shown in **Table ii.**

Table i: Capital Costs of Alternatives A and B

Cost Item	5m^3/s Scheme Option: costs in R(millions)	
	Alternative A	Alternative B
Weir at Michell's Pass	50.06	50.06
Gravity main	173.13	230.14
Balancing tank	4.69	4.69
Closed discharge chute	16.28	16.28
Boontjies Dam	not applicable	97.80
Boontjies Dam pump station (Mech/Elec)	not applicable	13.65
Boontjies Dam pump station (Civil)	not applicable	4.38
Rising main: Boontjies Dam to main pipeline	not applicable	14.38
River protection	52.50	42.00
Papenkuils pump station upgrade (Mech/Elec)	78.20	78.20
Papenkuils pump station upgrade (Civil)	11.88	11.88
Contingencies (10% of above, dam = 15%)	38.67	61.23
SUB-TOTAL CONSTRUCTION COST	**425.39**	**624.67**
Professional fees	32.57	45.57
Servitude & property	6.08	19.53
TOTAL CAPITAL COST EXCL. VAT	**464.06**	**689.77**
VAT @ 14%	**64.97**	**96.57**
TOTAL CAPITAL COST INCL. VAT	**529.01**	**786.34**

Table ii: Operating and Maintenance Costs

Operating and Maintenance Cost Items	$5m^3/s$ Scheme Option: Annual Costs in R(million)/a	
	Alternative A without Boontjies Dam	Alternative B with Boontjies Dam
Maintenance Costs		
Civil	1.70	2.06
Dams		0.28
Mechanical and Electrical	3.44	4.04
Electricity Costs		
Boontjies Dam Pump Station (0.86 MW)		
Papenkuils Pump Station (4.1 MW)	2.05	2.55
TOTAL Operating and Maintenance Costs	**7.19**	**8.93**

Table iii: Unit Reference Values (URVs)

Scheme Option	Yield ($m^3 \times 10^6$)	Discount rate (per annum)		
		6%	8%	10%
Alternative A: with no storage	36	R 1.37	R 1.62	R 1.90
Alternative B: with Boontjies Dam	36	R 1.98	R 2.37	R 2.78

The pumping costs for determining these URVs were based on the present day Eskom tariffs which were escalated to take account of the probable future increases in the price of electricity without taking inflation into account. For the Boontjies Dam it was conservatively assumed that the price of electricity would be R1.10 /kWh for pumping year round (although most of the pumping would occur in summer) and at Papenkuils the price was assumed to be R1.30/kWh for pumping during the winter months.

SCHEME INTEGRATION INTO THE WCWSS

The utilisation of the additional water becoming available from the integration of the proposed scheme into the system could be fully utilised within the existing and planned infrastructure. In particular:

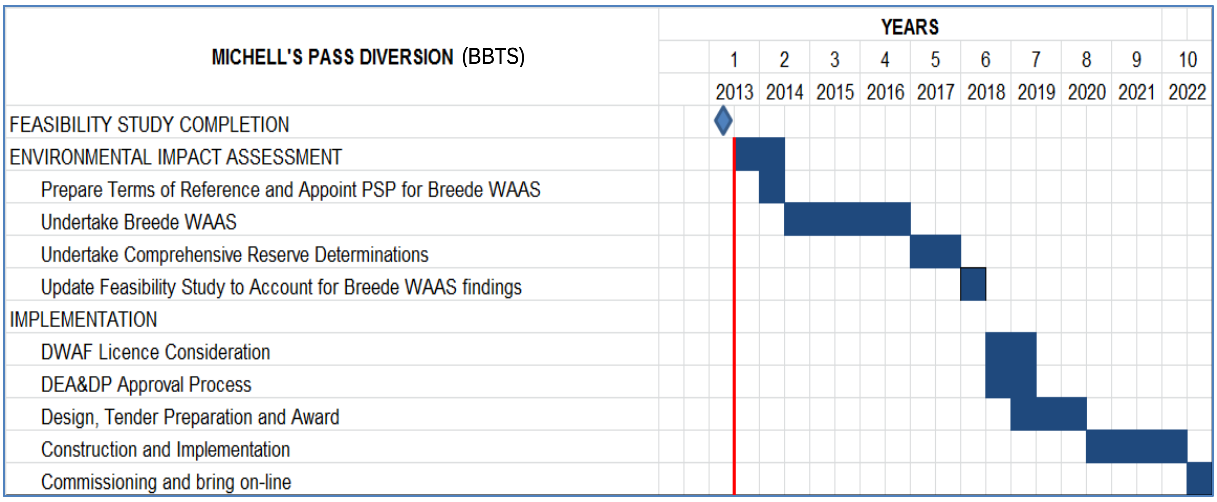
- The CCT has scheduled improvements of its Voëlvlei pipeline system comprising the Spes Bona Reservoir and the Spes Bona to Glen Gary Reservoir pipeline which will extend the footprint of the supply area from the Voëlvlei Dam and enable an additional 23 million m^3/a to be utilised.
- The water requirement projections for the West Coast suggest that by 2020 these will increase by approximately 3 million m^3/a.

The balance of the 36 million m^3/annum yield of the scheme could be beneficially utilised to meet the growing water requirements of Cape Town, however this would require augmentation of the capacity of the Voëlvlei pipeline, which is beyond the scope of this study.

PROGRAM

The earliest possible timeframe for implementation of the BBTS (should it go ahead) is likely to be as indicated in **Figure iii** which shows that water could first be supplied in about 2023, depending on the timing of the further studies which are indicated on the program.

Figure iii: Program for Implementing the BBTS



CONCLUSIONS AND RECOMMENDATIONS

Based on the information presented in this report and its accompanying Appendices, the following conclusions are made in relation to the potential implementation of the BBTS:

1. The **Preliminary Reserve for the upper Breede River** immediately downstream of the proposed Michell's Pass abstraction site **is Category D** based on current available estimates and has been allowed for, as well as maintaining the present ecological status (PES) at some of the sites downstream of the Papenkuils Pump Station. Further investigations and trial releases would be necessary to determine whether such releases would be effective in providing the summer Preliminary Reserve flows in the Breede River downstream of the proposed abstraction site.

2. The proposed Michell's Pass **abstraction site would be located immediately downstream of the existing diversion weir** for the current inter-basin transfer via the Artois Canal scheme (for irrigation and supply to Wolseley). This is the most favourable location for the diversion structure in order to ensure a gravity diversion scheme without the need for supplementary pumping, and to ensure protection from inundation of the ecologically important Witels tributary.

3. Geologically this area is typical of Breede River alluvium which may result in a **weir structure** that leaks to some extent. This would serve towards providing for the summer base flows but may require **measures to seal the foundations as subsurface flows which would contribute to the Reserve** could not be measured.

4. The benefits of the **proposed pipeline** from Michell's Pass to the Boontjies River as a replacement of the Artois canal would be **more efficient control of water distribution to the irrigators and Wolseley** and reduced losses from those currently experienced out of the canal.

5. **The two potential alternatives investigated, with or without the Boontjies Dam, would both yield 36 million m^3/a.**

6. The **Alternative A scheme without the Boontjies Dam is considered to be more easily implemented and operated** and would also have a less disruptive effect on the current users of water

from the Artois canal. This scheme would not provide the summer low flows of the Reserve unless these could be made available from the Koekedouw Dam, the feasibility of which would require further investigation and negotiation with the existing users and the funders of this Dam.

7. The **Alternative B scheme with the Boontjies Dam would require the gravity main to be operated in reverse as a rising main in summer** with pumping facilities provided to deliver water from this Dam to the Artois irrigators and if necessary, back into the Breede River towards meeting the summer Reserve flows.

8. Suitably **accurate survey information is available from this study for the purpose of undertaking detailed design of this scheme, with the exception of the Boontjies Dam** site which fell outside of the survey scope of this study.

9. **Geotechnical conditions at the proposed diversion site are typically alluvial** in nature but are acceptable for accommodating the weir design. Machine excavation is expected to be possible along the pipeline route. Although there is potential for the use of excavated materials for backfilling, the pipe type selection will influence the extent of selected fill material available insitu. Geotechnical investigations for the Boontjies Dam also fell outside the scope of this study.

10. From an integration perspective, the proposed Spes Bona Reservoir and the **linking pipeline to the Glen Gary Reservoir to be constructed by the CCT in the near future would enable most of the** incremental yield of the scheme to be taken up by the CCT. It is also likely that the balance of the **additional yield could be utilised by the WCDM** or alternatively the capacity of the Voëlvlei pipeline could perhaps be increased, however that investigation is beyond the scope of this study.

11. **For the gravity main between the weir and discharge point (9645 m long in the case of the Boontjies Dam and 7600 m long for the alternative without the Boontjies Dam) a 2000 mm dia GRP pipeline** is proposed for both alternatives. Should the DWA opt for ductile iron piping as a preferred pipe material, then it is estimated that the marginal cost increase of ductile iron over GRP pipes would increase the total cost of Alternative A by about 20% and of Alternative B by about 18%. In the case of mild steel pipes as an alternative to GRP, this would increase the capital costs of both alternatives by about 4%, but the maintenance costs in the longer-term would be more significant for mild steel pipes.

12. The **increase in the capacity of the Papenkuils Pump Station to reinstate the current yield of Brandvlei Dam while meeting the Preliminary Reserve flows downstream** would have to be confirmed, however preliminary estimates indicated that the pumping **capacity should be increased from 7 m^3/s to 26 m^3/s although an increase to 15 m^3/s with improved pumping rules may be adequate**. Further investigations would be required however the **cost estimate was based on upgrading the capacity of the pump station to 20 m^3/s for which provision was made when the existing pump station was constructed**.

13. The estimated **capital cost of Alternative A without storage is R 529 million and the capital cost of Alternative B with the Boontjies Dam and Pump Station is R 786 million, both including for increasing the capacity of the Papenkuils Pump Station, with annual operating and maintenance costs of R7.19 million and R8.93 million respectively.** The corresponding **Unit Reference Values are R1.62/m^3 and R2.37/m^3 respectively** (for a discount rate of 8%).

14. All of the above considerations and recommendations are subject to first re-determining and updating the hydrology of the Breede River Basin via a Breede Water Availability Assessment Study (WAAS) so as to provide a reliable basis for making decisions around implementation and water allocation in general from the Breede River. This would have a significant impact on the potential timing of

implementation and as a result, **water could only be expected to come on line from such a scheme by 2023**.

OVERALL RECOMMENDATION OF THE STUDY

The 5m^3/s Michell's Pass Scheme (BBTS), **without** the proposed Boontjies Dam, is the preferred BBTS option. Releases from Koekedouw Dam need to be tested to see if they can achieve the desired effect of providing water for reinstating the summer ecological water requirements downstream of the proposed diversion site. The BBTS appears to be a favourable surface water intervention option from a yield and cost perspective, but would only be able to provide sufficient additional supply to augment the growth in the demands on the WCWSS system by about 3-4 years and would not come on line before 2023.

It is an option which the Western Cape Reconciliation Strategy should retain as a possibility for the future, but only after undertaking a Breede Water Availability Assessment Study (WAAS) to provide updated reliable estimates of water availability. Whist the BBTS remains an option, it is not recommended as the next most suitable surface water intervention for augmenting the Western Cape Water Supply System.

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ABBREVIATIONS

BBTS	Breede-Berg Transfer Scheme
BRVA	Berg River-Voëlvlei Augmentation
BRVAS	Berg River-Voëlvlei Augmentation Scheme
CCT	City of Cape Town
c/kWh	cents per kilowatt.hour
DEA&DP	Department of Environmental Affairs and Development Planning
DWA	Department of Water Affairs
EAP	Environmental Assessment Practitioner
EIA	Environmental Impact Assessment
EWR	Ecological Water Requirements
GN	General Notice
GRP	Glass-fibre Reinforced Polyester
HIA	Heritage Impact Assessment
HWC	Heritage Western Cape
HFY	Historic Firm Yield
I&APs	Interested and Affected Parties
KIB	Koekedouw Irrigation Board
kWh	kilowatt.hour
LiDAR	Light Detection and Ranging
m^3/s	Cubic Metres per Second
m^3/a	Cubic Metres per Annum
MP	Michell's Pass
NEMA	National Environmental Management Act (No. 107 of 1998)
NERSA	National Energy Regulator of South Africa
NPV	Net Present Value
NWA	National Water Act (No. 36 of 1998)
SAHRA	South Africa Heritage Resources Agency
SCADA	Supervisory Control and Data Acquisition
STCC	Short-Term Characteristic Curves
URV	Unit Reference Value
WAAS	Water Availability Assessment Study
WCDM	West Coast District Municipality
WCWSS	Western Cape Water Supply System
WMA	Water Management Area
WCRSS	Western Cape Reconciliation Strategy Study
WRCS	Water Resources Classification System
WRPM	Water Resources Planning Model
WRYM	Water Resources Yield Model
WTW	Water Treatment Works

1. INTRODUCTION

1.1 GENERAL BACKGROUND

The Western Cape Water Supply System (WCWSS) serves the City of Cape Town (CCT), surrounding urban centres and irrigators. It consists of infrastructure components owned and operated by both the CCT and the Department of Water Affairs (DWA). The Western Cape Reconciliation Strategy Study (WCRSS) has investigated a range of bulk water supply schemes that could serve towards meeting the growing water requirements that will need to be supplied from the WCWSS. These include options such as desalination, effluent treatment for re-use, groundwater development and possible (albeit of limited size) surface water augmentation options. Investigations into these options are being embarked on by the CCT and DWA towards ensuring that planning, authorisation processes and implementation are timeously carried out so as to meet the projected water requirements on the WCWSS within a planning horizon to 2030.

In July 2008, DWA appointed the Western Cape Water Consultants Joint Venture (WCWC JV) to undertake pre-feasibility level investigations into the potential development of six surface water options (Phase 1), from which two schemes would be prioritised for further study during Phase 2 to feasibility level. The six potential schemes (as shown on **Figure 1**) investigated to pre-feasibility level were:

i. The Michell's Pass Diversion Scheme
ii. The First Phase Augmentation of Voëlvlei Dam
iii. Further Phases of Voëlvlei Dam Augmentation
iv. The Molenaars River Diversion
v. The Upper Wit River Diversion
vi. Further Phases of the Palmiet Transfer Scheme.

The objective and outcome achieved by the pre-feasibility phase was that all six potential surface development options were investigated and compared at an equivalent level of study detail to enable a recommendation in terms of those options that warranted further investigation to feasibility level study under this project.

Two of the above-mentioned schemes (i and ii) were prioritised for further investigation to feasibility level. As both schemes would involve the storage of water in the existing Voëlvlei Dam, the scheme names have been adapted to suit. Furthermore, in discussion with DWA it was recognised that to avoid potential confusion with existing diversion and supplement schemes of similar names, this study would report on the basis of the following schemes, both representing options for the **First Phase Augmentation of Voëlvlei Dam, namely:**

- **Breede-Berg (Michell's Pass) Water Transfer Scheme,** hereinafter referred to as the Breede-Berg Transfer Scheme, abbreviated as the BBTS.
- **Berg River-Voëlvlei Augmentation scheme,** abbreviated as the BRVA Scheme, which is the subject of its own stand-alone report, also a deliverable under this study.

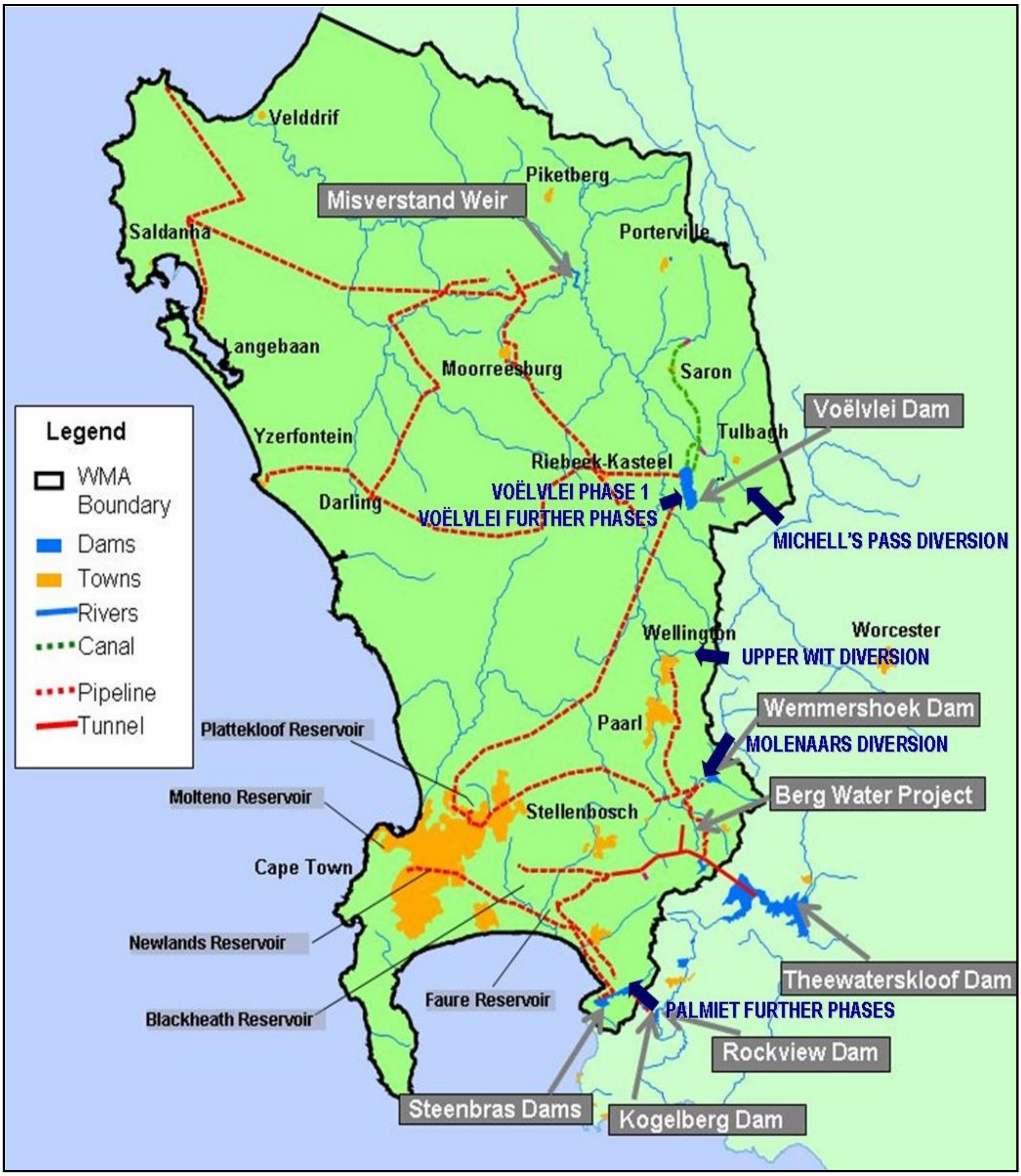
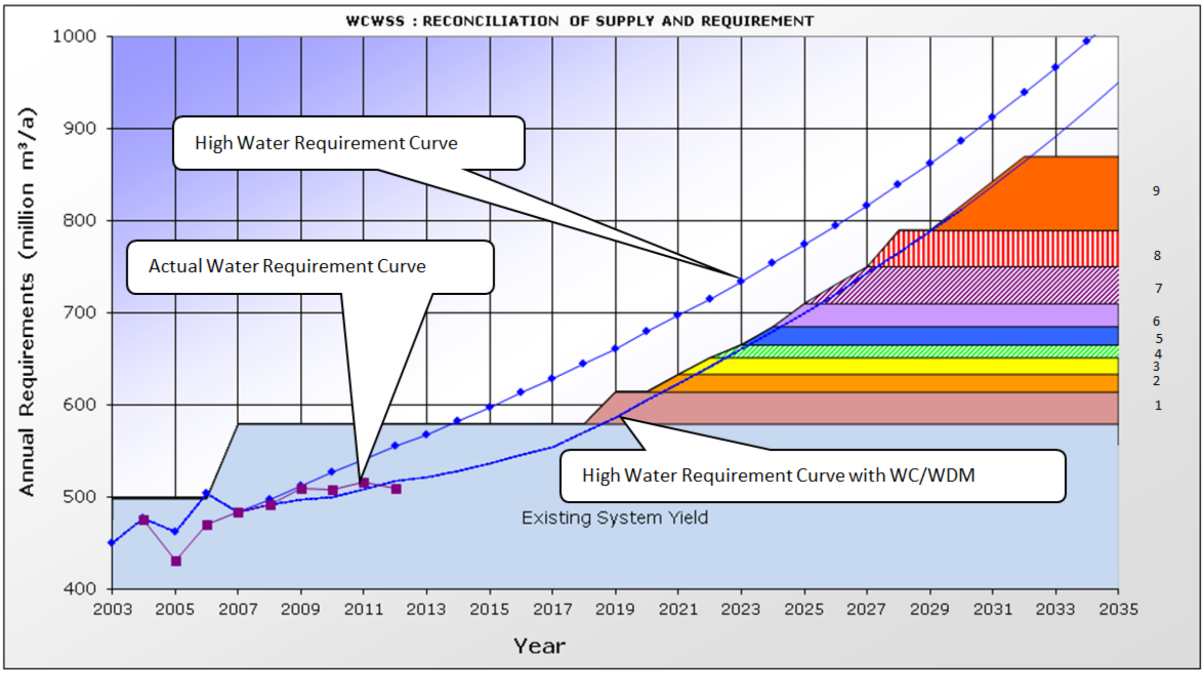


Figure 1: The Six Options Investigated to Pre-Feasibility Level in Phase 1

The WCRSS has identified that small schemes such as the potential BBTS, only yield sufficient additional water to augment the overall system to meet the growth in demand for about another 3 to 4 years at best, dependant also on the CCT achieving the objectives of its Water Conservation and Water Demand Management Strategy. The latest reconciliation of water supply and water requirements based on the WCWSS is shown on **Figure 2.**



No	Intervention	Year of First Water
1	Voëlvlei Phase 1	2019
2	Lourens	2021
3	Cape Flats Aquifer	2022
4	DWAF:ASR: West Coast	2023
5	TMG Scheme 1	2024
6	Raise Lower Steenbras	2025
7	Re-use Generic 1	2026
8	Re-use Generic 2	2028
9	Desalination	2030

Figure 2: Current Planning of Reconciliation of Water Supply and Requirements (WCWSS)

Section 9.6 of this report shows the potential timeframe in which the BBTS could be implemented (on line by 2023 earliest). As shown above, the BBTS does not currently feature as one of the preferred options within the Western Cape Reconciliation Strategy. Furthermore, to meet the next required scheme completion date by 2019, the only possible surface water option is Voëlvlei Phase 1 (BRVA scheme), as its feasibility study and a related Berg Water Availability Assessment Study (WAAS) have been completed. Desalination and water reuse remain possibilities for 2019 as well, although current progress on those two feasibility studies by the CCT will need to be assessed by the Strategy Steering Committee, in order to confirm if 2019 is still realistically achievable.

It is important at the outset of this report to point out that whilst the BBTS remains an option for consideration, its potential inclusion in the Reconciliation Strategy suite will need to be introduced, in addition to the related aspects such as the limitation of the CCT pipeline to Cape Town, as well as the need to possibly also raise Voëlvlei Dam, if both the BRVA and BBTS were to eventually be implemented.

1.2 PURPOSE AND OBJECTIVES OF THE STUDY

The aim of this feasibility study and preliminary design was to confirm the technical, environmental, social, economic and financial viability of this proposed winter abstraction scheme, which would make use of the existing (un-raised) Voëlvlei Dam. The study aims to determine the sustainable optimal diversion capacity from the Upper Breede River, in the vicinity of the existing DWA stream flow gauging station, H1H006. This proposed scheme would operate in winter only, and would only divert water after allowing for downstream winter water requirements, most notably those for meeting Ecological Water Requirements (EWRs) of the Breede River downstream of the diversion site. Options for re-instating the summer EWRs downstream of the diversion site are also investigated as well as the implications for the operation of the downstream Greater Brandlvlei Dam. Possibilities towards addressing the current EWR shortfalls in both summer and winter at a catchment wide scale are also presented.

A Comprehensive Reserve determination for the Breede River and its estuary has not been undertaken, mainly due to the fact that the Breede River hydrology is very variable in its reliability between one reach and the next. With the exception of the upper most reaches of the Breede River, the hydrology of the Breede Basin is outdated. Furthermore, stream flow gauging data in the middle reaches is known to be unreliable.

The importance of undertaking a Breede WAAS is well recognised, and is on the agenda of the DWA Directorate National Water Resource Planning. For the BRVA study, the existing hydrology from the Berg WAAS for the Upper Breede River has been used, in conjunction with previous hydrology for the remainder of the basin (now dating back more than 20 years) to determine the EWRs and the yield assessment of the potential diversion scheme as well as its downstream impacts.

Agriculture represents the largest water user group and is reliant on the Breede River. The Western Cape Water Supply System which primarily supports the neighbouring Berg WMA in which agriculture and urban users are predominant, already receives a significant volume of water each year (almost 30% of the Berg WMA's water requirement) via inter-basin transfers from Riviersonderend in the Breede WMA.

There is increasing conflicting opinion between various stakeholders, across both the Breede and Berg WMAs in relation to the strategic approach to water allocation. Whilst agriculture on the one hand is the predominant economic activity of the region, the growing water requirements of the urban sector (particularly those of the CCT) also need to be met. A public awareness and engagement process therefore formed a key component of this study in order to ensure that interested and affected parties were involved from the start of the study, in its findings and through to its recommendations.

1.3 THE STUDY AREA

The Study area is effectively that of the Berg WMA and the uppermost catchment of the Breede WMA, from where the proposed Michell's Pass inter-basin transfer would augment the supply from the WCWSS sufficiently to meet the future growth in water demand for another 3 to 4 years (see **Figure 3**). The figure also illustrates the extent of the main bulk water supply infrastructure within the WCWSS. It should be noted that the potential for large-scale development of surface water resources in the Western Cape has become very limited. Almost all potential, feasible large dam sites have been developed, and the need to provide water for the riverine environment limits the extent of possible development of the resource. The Breede-Overberg Catchment Management Agency (BOCMA) has set clear goals and objectives in its Catchment Management Strategy (CMS) towards protection of water resources of the Breede and limiting further development thereof.

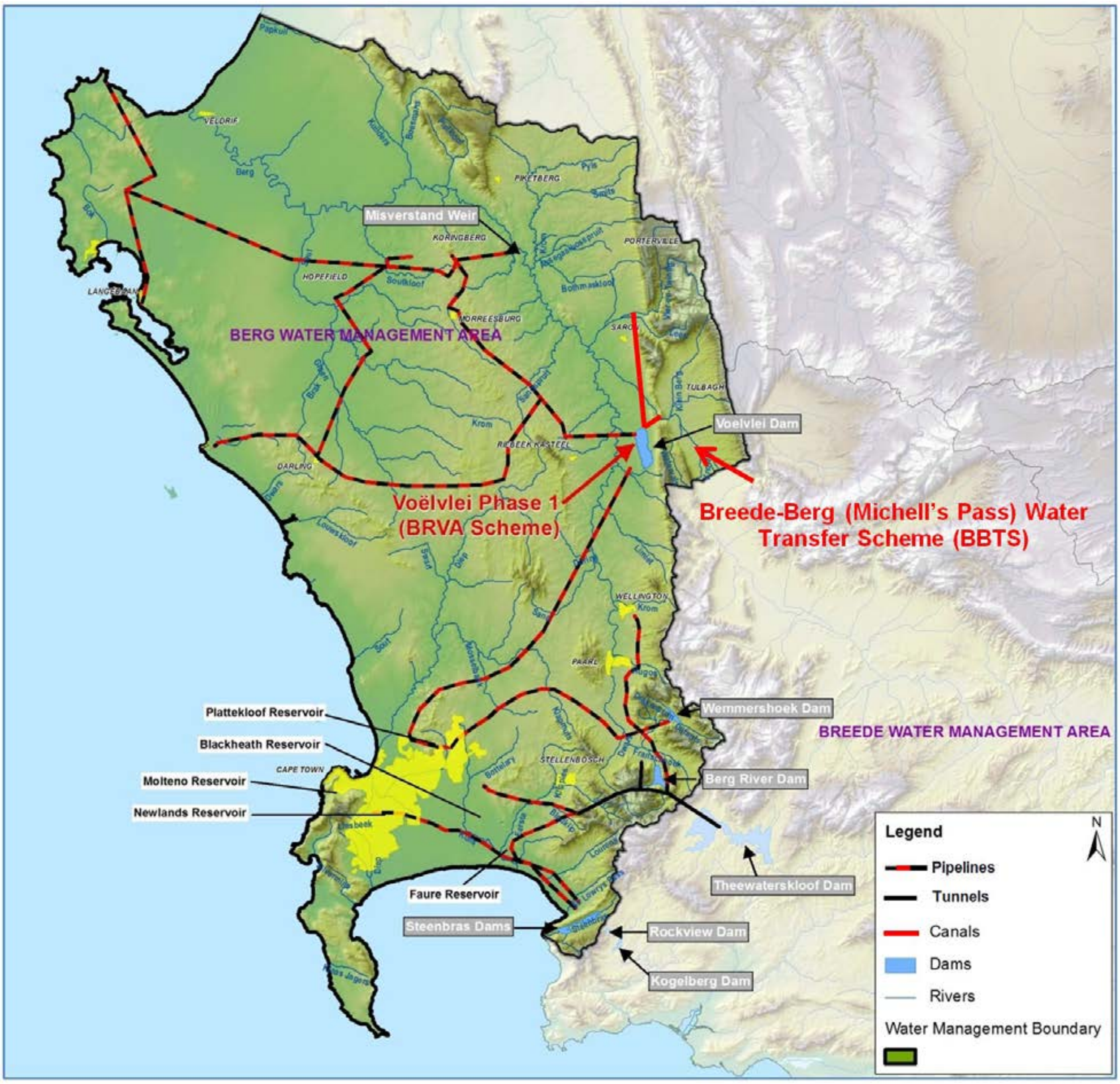


Figure 3: The Western Cape Water Supply System and Proposed BBTS

2. DESCRIPTION OF THE SCHEME

2.1 EXISTING VOËLVLEI GOVERNMENT WATER SCHEME

The proposed BBTS would feed into the existing Voëlvlei Government Water Supply Scheme via the existing diversion weir on the Klein Berg River (see **Figure 4**). This canal and that from the Twenty Four Rivers and the Leeu River divert water into the Voëlvlei Dam which is located in a natural depression between the Voëlvlei Mountain range and the Berg River near Gouda.

Figure 4: The Existing Klein Berg Diversion Weir

Voëlvlei Dam is state owned and is a source of water for the CCT and local authorities, including users in the West Coast District Municipality (WCDM) from Malmesbury to St Helena Bay. Treated water is supplied to these users via the Swartland Water Treatment Works (owned and operated by the WCDM) and to Cape Town via its Voëlvlei Water Treatment Works. Both of these works are situated close to the Voëlvlei Dam. Water is also released from the Voëlvlei Dam via the outlet canal, shown in **Figure 5** to the Berg River from whence abstraction takes place at Misverstand Dam to the Withoogte WTW (also owned and operated by the WCDM) and from the Berg River to irrigators.

Figure 5: The Existing Voëlvlei Dam Outlet Canal to the Berg River

The Voëlvlei Dam has a full supply capacity of 172 million m^3 but has a very small incremental catchment of its own (31 km^2), with water being fed into the dam via the diversions and canals described previously.

Both canals feeding the dam are concrete lined. The Klein Berg Canal (8 km long) which would be used as part of the proposed BBTS, has a capacity of 20 m^3/s whilst that from the Twenty Four Rivers and Leeu (29 km long) has a capacity of 34 m^3/s.

The current assured yield from the Voëlvlei Dam has been estimated to be 105 million m^3/a (ISP, 2005) and indications are that the dam is currently over-allocated.

The CCT owns and operates the Voëlvlei WTW at the Dam (see **Figure 6**) including the raw water abstraction via an intake structure and pump station, a purification plant, and a high lift pump station which pumps treated water through a single pipeline to the CCT's service reservoir at Plattekloof in the Tygerberg Hills. The City's intake and WTW were completed in 1971 and these are located at the southern end of the 6,4 km long reservoir, thus minimising the length of the delivery pipeline to Cape Town. The intake works consist of a reinforced concrete pump station housing five low lift pumps in a dry well which extends well below the minimum water level in the reservoir. The pumps can deliver a maximum of 273 Ml/d through the 1,5 m dia, 0,6 km long pre-stressed concrete pipeline to the treatment plant.


Figure 6: The CCT's Water Treatment Works and Low Lift Pumps at Voëlvlei Dam

The treatment plant makes use of upward flow clarifiers and rapid gravity sand filters and has a maximum output of 273 Ml/d. The treated water is fed into a 9,1 Ml capacity clear water reservoir from whence it is pumped via the conveyance pressure pipeline to Cape Town. The City's high lift pump station is equipped with six pumps each with variable speed motors to enable fluctuations in water requirements to be accommodated. The 80 km pipeline to the Plattekloof reservoir is a 1,5 m diameter pre-stressed concrete pipeline, which has required regular maintenance by the CCT, including repairs due to pipe bursts. The frequency of leaks and bursts has however reduced significantly since the City replaced the vulnerable sections of this pre-stressed concrete pipeline and has a dedicated pipeline maintenance team in place so as to reduce down time of the pipeline due to any bursts or leaks that do occur.

The pipeline integrity is of critical importance to the water supply security of Cape Town. The current spare capacity available in winter only is 3,16 m^3/s, and this equates to 20 million m^3/a. This presents a limitation in terms of the extent to which the water supply to the City from Voëlvlei Dam could be augmented, and either alternative water users that could be supplied directly from the Voëlvlei Dam will need to be considered or the CCT would need to implement increased potable water storage infrastructure as well as increased integration thereof into the existing system. This is further addressed in **Section 4**. Alternative water use could for example include augmentation to the WCDM and the possible alleviation of the perceived over allocation from the Voëlvlei Dam.

2.2 THE EXISTING ARTOIS CANAL DIVERSION SCHEME AT MICHELL'S PASS

Currently diversions at Witbrug into the Artois Canal, which was constructed in about 1950, divert an average annual volume of about 19 million m^3/a. Of this about 15 million m^3/a is utilized by the Artois irrigators and Wolseley town. The remaining 4 million m^3/a flows past these abstractors and into the Klein Berg River. This water transfer occurs year-round from the manually controlled gated canal intake structure at the DWA stream flow gauging station H1H006 (see **Figure 7**), into the Canal and across the catchment divide (from the Breede WMA into the Berg WMA).

Figure 7: The Artois Diversion Structure at Stream flow Gauging Station H1H006

The Artois Canal shown in **Figure 8** has a capacity of 1,13 m^3/s (DWA, ISP, 2004). The Canal offtake is situated on the upper Breede River about 120 m upstream of the Witbrug R43 road bridge and about 2 500 m downstream of the confluence of the Dwars and the Witels Rivers as shown in **Figure 9** and **Figure 20**. The Witels is a pristine river whereas there are extensive irrigation developments and many dams on the Dwars River and its tributaries including the Koekedouw Dam. Downstream of the confluence the name of the river changes from the Dwars River to the Breede River.

Figure 8: The Artois Canal near Wolseley

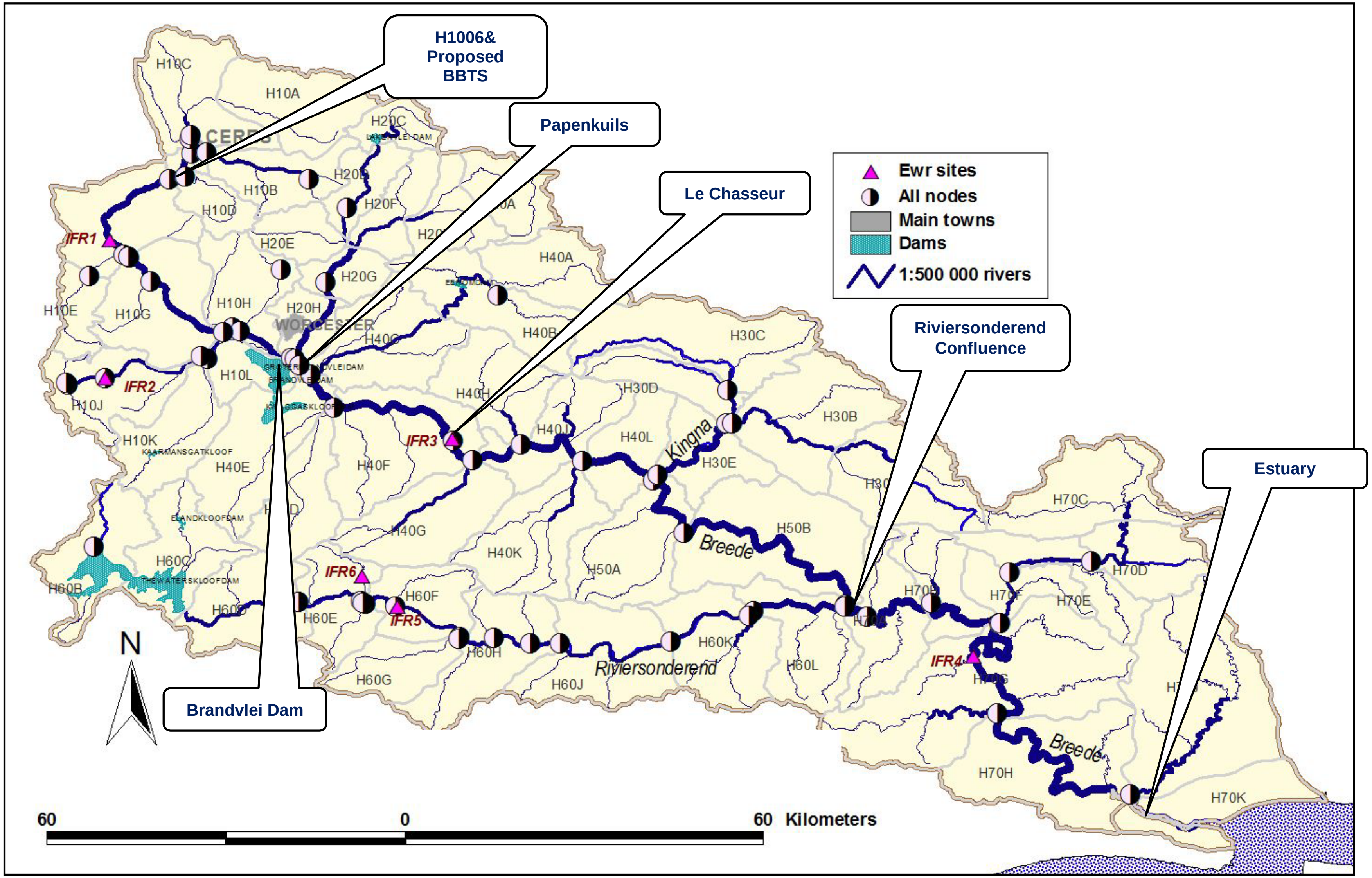


Figure 9: Breede River System

During most of the summer months the entire flow of the Wit River is diverted into the Artois Canal and the upper Breede River immediately downstream which crosses an alluvial fan is dry for many kilometres as shown in **Figure 10**. Groundwater is abstracted from this alluvial fan to supplement the irrigation supplies from the summer diversions into the Artois Canal. This groundwater abstraction may contribute to the lack of summer flow in the upper Breede River.

Figure 10: Upper Breede River in March 2011

2.3 PROPOSED BREEDE-BERG (MICHELL'S PASS) WATER TRANSFER SCHEME

2.3.1 Introduction to Scheme Options

The proposed BBTS would involve the diversion of winter water from the upper Breede River at the same location as that of the current Artois canal diversion (see **Figure 11**). The scheme would involve upgrading the existing diversion weir and the conveyance of the diverted water under gravity, via a pressure pipeline of 2000 mm diameter across the catchment divide into the adjacent catchment of the Klein Berg River (Berg WMA). From there the water would be diverted into the existing Klein Berg canal which feeds the Voëlvlei Dam. The scheme would also supply the summer and winter irrigation requirements of the existing users of the Artois Canal.

Figure 11: The Proposed Location for the BBTS Diversion Weir

The Artois Canal has been in operation for more than 60 years with little or no summer flow downstream of the point of diversion. However the Preliminary Determination of the Ecological Reserve (hereinafter referred to as the Reserve) assessment of the Breede River determined that the present ecological status (PES) of the Breede at this location is Class D and recommended that this should be Class D. Therefore it has been assumed that if the BBTS is constructed future abstractions should be made in such a way that sufficient releases are also made to the river immediately downstream of the weir to comply with both the summer and winter Reserve of the upper Breede River. This recommendation is based on the point of view that it is a requirement of the National Water Act (NWA) that where new water resource schemes are developed, they be designed and operated in such a way that the opportunity be taken to ensure that such schemes will be compliant with the Reserve, in both summer and winter, and that they not be designed to merely maintain the status quo.

Any transfer of water out of the Breede River Basin will impact on downstream water users. In this case the yield of Brandvlei Dam would be reduced unless the capacity of the infrastructure to pump water into the Dam is increased. Therefore the various scheme options investigated include an allowance for maintaining the yield of Brandvlei Dam through an upgrade of the pump station at Papenkuils. The sizing of this upgrade is described in **Section 3** and the design and costing is detailed in **Appendix 10**.

From a geotechnical perspective, the founding conditions at the proposed weir site are typically that of loose alluvial sediments and boulders as shown in the excavated material in **Figure 12.** Along the proposed pipeline route, the geotechnical conditions vary from course alluvium to sandy alluvium towards Wolseley and then to finer alluvium with sandy clay towards the proposed discharge locations. The detailed geotechnical investigation is summarised in **Section 6** and the detailed geotechnical report is provided in **Appendix 8**

.

Figure 12: Typical Alluvial Sediments Excavated to Depths in Excess of 3m at Proposed Weir

The proposed general layout of the BBTS, including the route of the 10760 m long pipeline is shown in **Figure 13.** The scheme options, conveyance infrastructure and preliminary design are described and reported on in detail in **Appendix 11**. A summary of the two potential scheme configurations investigated to preliminary design is provided hereafter.

The possible need to meet the summer Reserve release requirements of the upper Breede River were identified late in the study and therefore the infrastructure facilities to supply the Reserve have only been investigated at prefeasibility level, whereas the other components of the scheme were investigated at feasibility level.

2.3.2 Overview of Scheme Alternative A

This alternative would involve the diversion of surplus winter water via the proposed low weir on the Upper Breede River into a new gravity pipeline which would transfer the water across the catchment divide, into the Berg WMA, discharging into the Boontjies River, a tributary of the Klein Berg River. From here the water would be diverted via the existing Klein Berg Diversion structure and conveyed via the existing canal into the Voëlvlei Dam. Presently, irrigation water is conveyed by means of the open Artois Canal from the current irrigation diversion structure at the DWA stream flow gauging station, H1H006, shown in **Figure 14.** The initial conceptual design for the proposed BBTS was for the proposed new gravity pipeline to follow the existing canal alignment as far as possible. This was however not practically feasible due to strong preferences of the Artois irrigators to take cognisance of their infrastructure and irrigation investments. As such, variations in the proposed horizontal alignments were considered to ensure least possible impact, whilst still offering an optimal design.

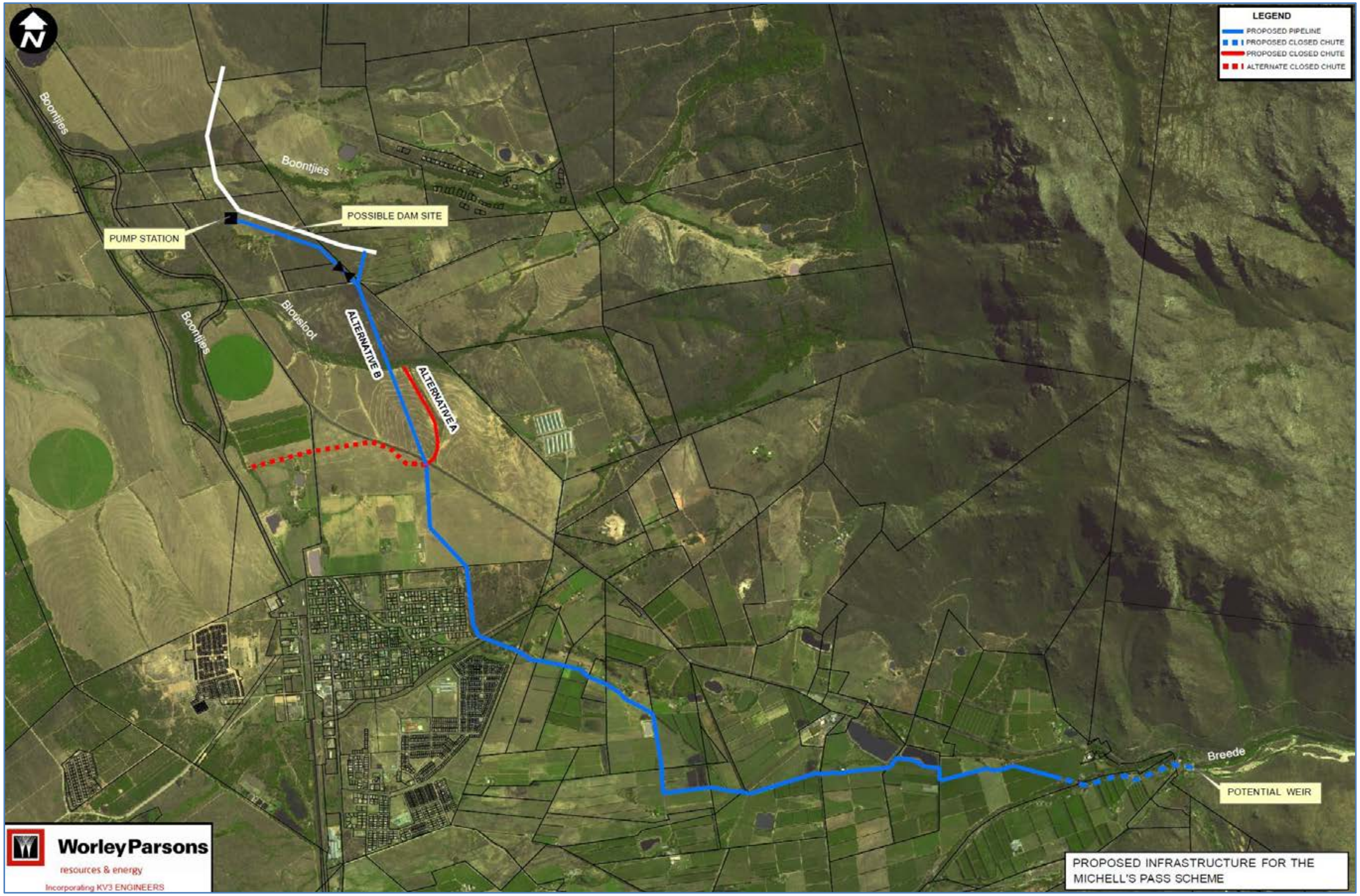


Figure 13: Layout of Alternatives for the Proposed Michell's Pass Scheme

Figure 14: The Existing Artois Canal Intake Structure at the DWA Flow Gauging Station (H1H006)

The proposed gravity pipeline requires route selections that take careful account of the hydraulic gradient, thus limiting the possible pipeline route variations between the points of abstraction and discharge. The proposed pipeline alignment from the intake to the town of Wolseley extends across several farms and agricultural land, consisting mostly of well-established orchards.

Where possible, the pipeline alignment was kept to farm boundaries, farm roads and clearings between agricultural fields. Site visits to all affected farms were conducted and close (one-on-one) engagement undertaken with the individual landowners, particularly those who raised specific objections and concerns. The proposed pipeline route as shown in **Figure 13** and discussed in detail in **Appendix 10** is as agreed to in principle with the relevant existing land owners.

The initial design incorporated a discharge chute that would discharge water directly into the Boontjies River in close proximity to the town of Wolseley. This option was however discarded due to objections from specific land owners on account of the required chute length proposed. The discharge chute was thereafter realigned to discharge water into the Blousloot River (a tributary of the Boontjies River), which entails a shorter discharge chute and an alignment that was preferable to the affected land owners. A balancing reservoir between the gravity pipeline and discharge chute forms part of the proposed scheme design for this alternative.

The re-introduction of the summer Reserve flows into the upper Breede River downstream of the proposed abstraction site would need to be provided from upstream storage, as this alternative would not introduce any substantial carry-over storage between winter and summer. The possible provision of Reserve releases from the existing Koekedouw Dam (Ceres) is one such possibility and **Section 2.3.5** sets out the current commitments required from that dam in terms of its intended provision for downstream ecological flows. This dam will be referred to in this report as the **Koekedouw Dam**, although in other literature it is also known by a number of other names, such as:

- Ceres Dam (current DWA website / Google Earth)
- Greater Ceres Dam (Cape Nature 2009)
- Ceres Koekedouw Dam (SRK report 216111/7, August 2001)

There is concern that any releases from the Koekedouw Dam made in summer could be abstracted by other users upstream of the proposed new diversion weir at the Witbrug. Even if the Reserve releases were to be made from the proposed diversion then the water released to meet the Reserve may simply "disappear" into the Breede alluvium and not make any significant net contribution to the provision of summer Reserve surface water flows in the upper Breede River.

If this option were to be further considered, then it would be strongly advisable to test the feasibility of making summer Reserve releases from Koekedouw Dam on the increased receiving flow at the proposed diversion weir. This release could be gauged at Koekedouw Dam, at the Ceres Golf Club (H1H003, see **Figure 15**) some 8 km downstream, then at the H1H006 stream flow gauging station from which it should be released and measured at a temporary gauge further downstream. In so doing it would be possible to determine the extent of "losses" along the 14 km reach between the dam and the proposed site of the diversion weir as well as in the alluvium in the reach downstream of H1006 where the summer Reserve flows are required.

Figure 15: The Existing Stream Flow Gauging Station, H1H003 at Ceres Golf Club

2.3.3 Overview of Scheme Alternative B

Alternative B differs from Alternative A in that it involves the provision of a new storage dam as part of the BBTS, which would allow for the provision of water towards the summer Reserve flows. This is an alternative to that described above for Alternative A (with possible Reserve releases from Koekedouw Dam). This possibility was identified fairly late during the course of the current study and as such, the potential dam site has neither been surveyed, nor did it fall within the scope of the geotechnical investigations undertaken. Consequently as mentioned above, the option of a new dam on the Boontjies River has only been investigated to pre-feasibility level.

Figure 16 shows the sites that were considered for the proposed dam and **Figure 13** shows the site that was selected for costing purposes (Site 9 in **Figure 16** although Site 2 might be slightly more cost effective). This site selection was based on available 1 in 10 000 ortho-mapping and local geotechnical knowledge. The modelling of, and operation of the proposed scheme is described in detail in **Section 3** and the design and costing is detailed in **Appendix 12**. In summary the concept of the dam on the Boontjies River would be to:

- Provide a discharge facility for winter water diverted under gravity from the Breede River.
- Enable spills and provide releases to the downstream Klein Berg River from where the diversions into the Voëlvlei Dam will take place as described in Alternative A.
- Provide summer releases to current irrigators who are supplied from the Boontjies River.
- Provide for summer irrigation to the current upstream Artois irrigators by pumping water from the dam to these users in summer.
- Facilitate the cessation of the current Artois canal diversions in summer so as to allow water currently flowing in the Breede River in summer to remain undiverted. This towards remedying the current absence of summers Reserve flows downstream of the diversion site.
- Supplement, when necessary, the summer Reserve flows in the Breede River from the stored water in the Boontjies Dam, via pumping.

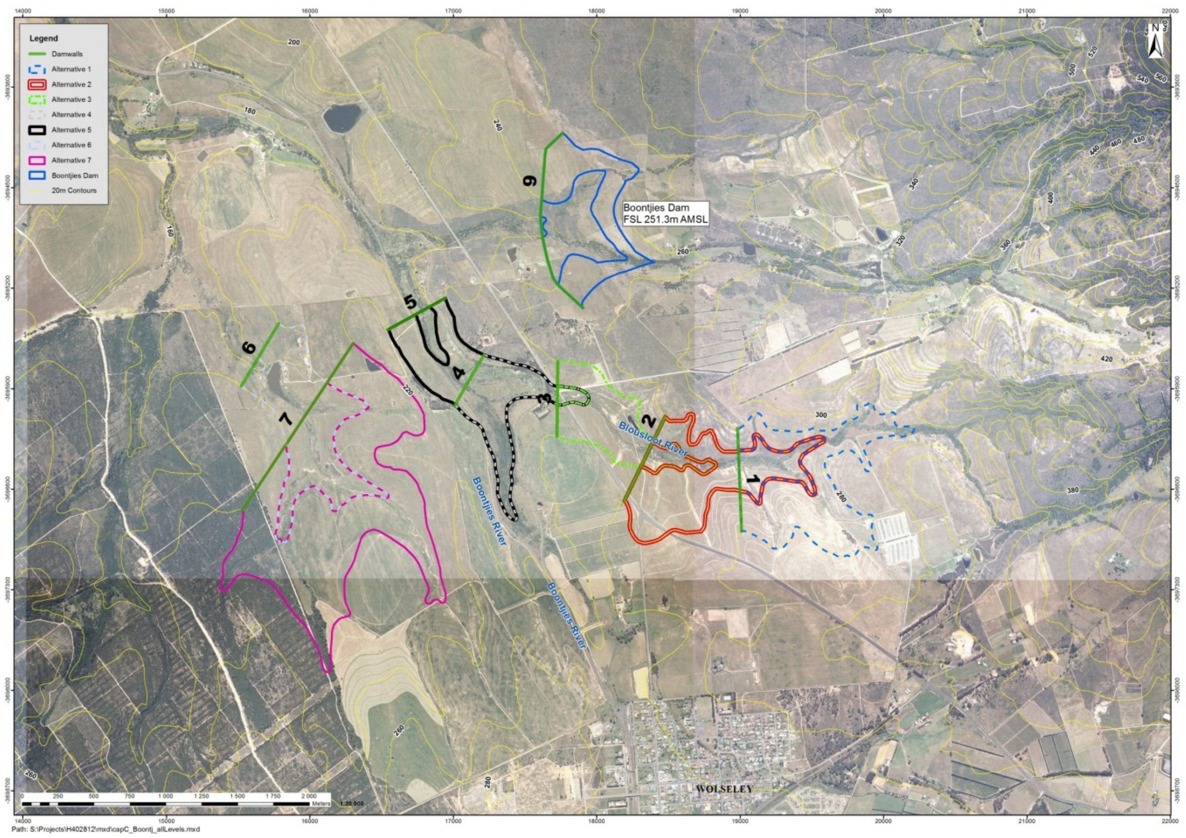


Figure 16: Sites Considered for the Proposed Boontjies Dam

The pipeline route would be slightly longer than for Alternative A in order to reach the proposed dam site on the Boontjies River shown in **Figure 13.** In order to facilitate summer pumping to the upstream water users, and when necessary to the Breede River itself (for supplementing summer Reserve flows) a new pump station is proposed at the toe of the proposed Boontjies Dam. This would include a rising main from the pump station, bypassing the balancing reservoir, and connecting to the gravity pipeline. The proposed gravity pipeline would then be used in reverse as a rising main to pump water to the upstream water users and to the Breede River in summer to supply the Reserve.

A positive spin-off from either of the two proposed BBTS alternatives is a more efficient distribution (than the current Artois canal) of irrigation water during the summer months, either under pressure from the proposed gravity pipeline (Alternative A) or from the Boontjies Dam via the pump station and rising main (Alternative B). An additional positive aspect of Alternative B is that with the proposed dam, the release of Breede River water into the Boontjies and Klein Berg Rivers could be timed so as not to coincide with flood events in the Klein Berg, thus enabling 100% of the diverted flow, other than that stored in the dam, to be diverted into Voëlvlei Dam.

Diversion of water out of the Breede River Basin at Michell's Pass would impact on the yield of Brandvlei Dam. To compensate for this an upgrade in capacity of the Papenkuils Pump Station has been included in the analysis and preliminary designs.

2.3.4 Reserve Requirement Considerations

The Present Ecological Status (PES) of the upper Breede River immediately downstream of the proposed BBTS diversion is Class D and the Preliminary Determination of the Reserve and Resource Class in Terms of Section 14(1)(b) and 17(1) of the National Water Act (Act No. 36 of 1998) also recommends that this should be Class D but with the low flows restored. The PESs of the various river reaches of the Breede River and its tributaries are shown in **Figure 17.**

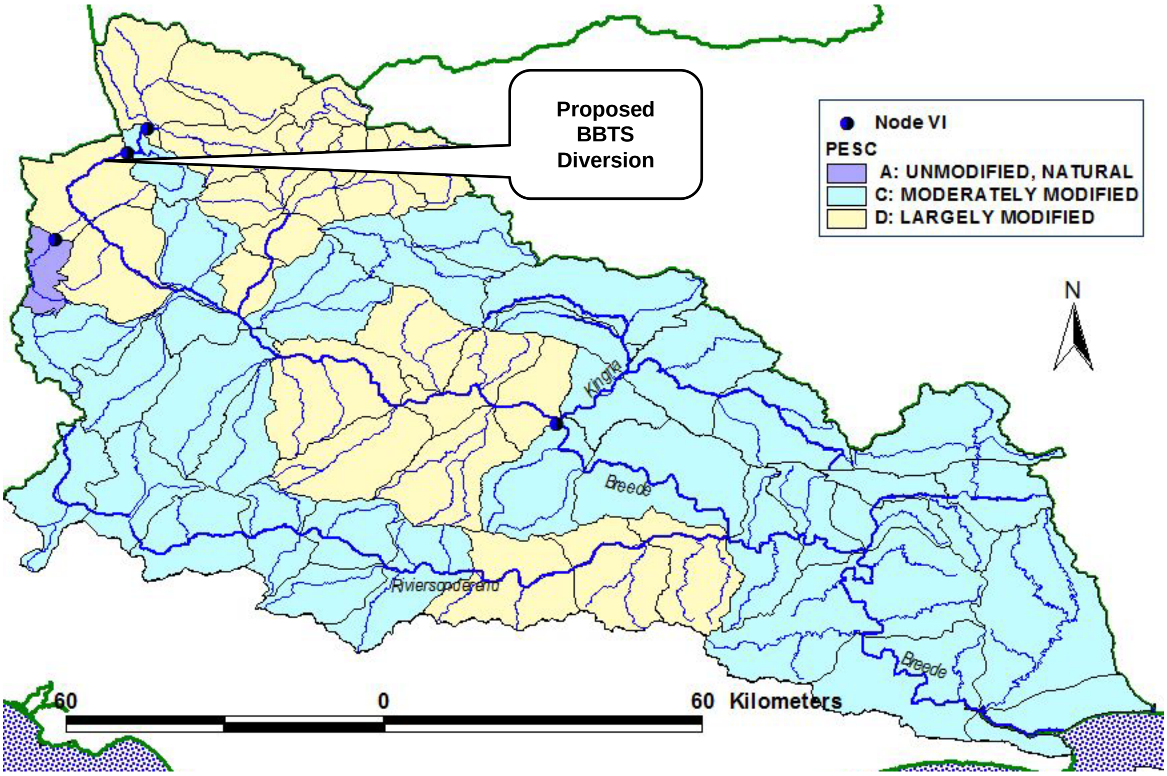


Figure 17: Present Ecological Status of the Breede River and its Tributaries

2.3.4.1 Summary of Current Concerns Regarding Development Options and the Reserve for the Breede River and Estuary

There are two main concerns regarding the provision for the Reserve for the Breede River and its estuary, based on a review of the status quo. These concerns are presented in relation to the proposed BBTS and the need to provide for both summer and winter Reserve flows, after scheme implementation. The concerns are as follows:

1. Implementation of the Class D Ecological Reserve flows in the river reach downstream of Michell's Pass for the full hydrological year, including reinstatement of summer flows downstream of the proposed diversion site at Michell's Pass.
2. Consideration of the Ecological Reserve for the full downstream environment, i.e., the Breede River from Michell's Pass down to and including the Breede River Estuary, based on the present-day water use in the basin.

A verification and validation process of existing water allocations mainly for irrigation is currently being undertaken by the Breede Overberg Catchment Management Agency (BOCMA) which has indicated that it intends to ensure that the Reserve flows will be met in the future. Although this process might result in the existing allocations being revised in the future, for the purpose of this study it has been assumed that the existing allocations will not change and that the proposed BBTS scheme should as far as possible be operated to comply with the recommended Reserve flows as described below.

The Implementation of the Ecological Reserve for the Reach Downstream of Michell's Pass

In the consideration of the proposed scheme, the provision for the Ecological Reserve has been assumed to cover the full hydrological year even if the scheme would operate only during periods of surplus winter flow. It was assumed that this would not obviate the need to meet the Reserve requirements for the full year. The arguments for meeting the Reserve are as follows:

- Unnatural flow cessation during the dry season (as occurs presently) is extremely damaging to the river as riffles, runs and (often) pools dry up, leaving no riverine habitat, and thus should not form part of any recommended flow regime for the river.
- Eco-classification involves the combination of several aspects of the river, e.g., hydrological, geomorphological, chemical and biological aspects, to arrive at a weighted average score for ecosystem health. This means that if one aspect is in poorer condition than others, then the overall condition score for the system will be reduced.
- Removal of the winter flows without re-instating the summer flows would result in a drop in category below the minimum allowable for sustainable development (Category D).
- Failure to provide for the full Reserve, i.e., both summer and winter flows would set a precedent that would irrevocably harm the opportunities available to meet the Reserve in the Western Cape, and as such will compromise sustainability of the water resources of the Western Cape. This is chiefly because, given the climate of the Western Cape, re-instatement of summer flows is a major requirement of many Reserves and most (if not all) new developments will target winter water.

The counter argument to the above is that the Reserve flows are currently not complied with and that it would be unreasonable to expect that the BBTS should bear the fully responsibility for compliance. Never the less for the purpose of this study it has been assumed that the BBTS would as far as possible be operated in such a way as to comply with the recommended Reserve flows as described below.

The Implementation of the Ecological Reserve for the Full Downstream Environment

The following conservative assumptions were made in relation to the Ecological Reserve for the full downstream environment, i.e., the Breede River from Michell's Pass down to and including the estuary, based on present-day water use in the basin:

- Consideration of the cumulative effects of the proposed BBTS should be based on the available Reserve determinations for the Breede River and its estuary.
- Such considerations should take cognisance of present-day water use in the basin.
- According to the present-day recorded stream flow data, flows in the Lower Breede River are currently insufficient to meet the Reserve flows at the following locations:
    a) Summer flows at between Witbrug in Michell's Pass and the confluence of the Wit River.
    b) Summer flows upstream of Brandvlei Dam.
    c) Winter Flows at Le Chasseur in the middle Breede River.
    d) Summer and winter flows upstream of the confluence with the Riviersonderend River.

e) Summer and winter flows downstream of the confluence with the Riviersonderend River.

Present-day flows into the estuary are at the limit of the Class B Reserve flows for winter (see **Figure 18**) and do not meet these requirements in the summer (see **Figure 19**). Therefore water use in the system has already exceeded that needed to ensure that the Reserve is met, without the further inclusion of the BBTS.

2.3.4.2 The BOCMA Catchment Management Strategy Objectives

BOCMA has taken cognisance of the present-day situation described above in its development of the CMS. Furthermore, as has been mentioned, most of the hydrology of the Breede River system requires updating, both from a reliability perspective and in terms of its chronological updating. This introduces a degree of uncertainty into the base information on which to take informed decisions on actual water availability and additional allocation. The CMS has therefore concluded the following:

> The CMA's current process of verification and validation of existing water use will assist in determining whether in fact there is additional water available in the Breede River for further allocation. It is further proposed that the water requirements and hydrology in the Breede River catchment be updated before any new water is allocated (it should be noted that in the Breede system, only the hydrology upstream of Brandvlei Dam was updated to 2004).

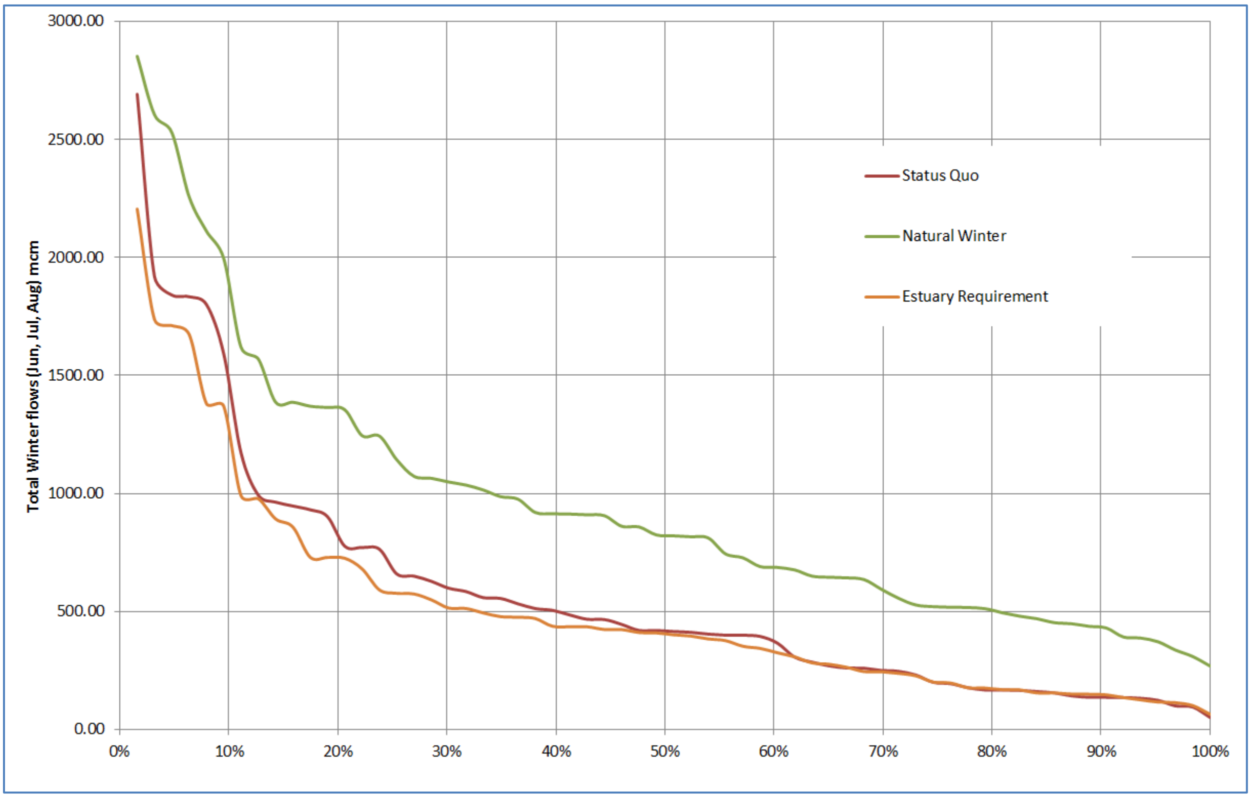


Figure 18: Breede Estuary Inflows – Mid Winter 3 Months (June to August)

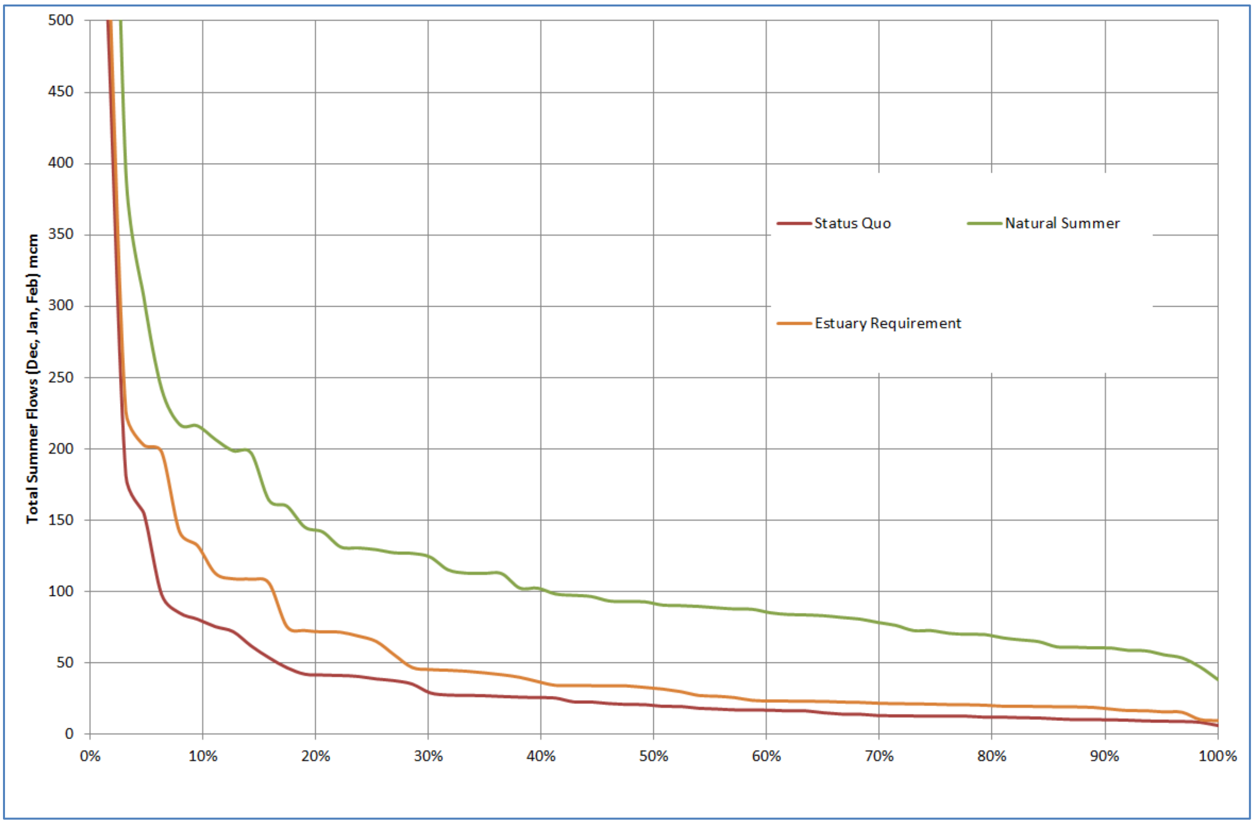


Figure 19: Breede Estuary Inflows – Mid Summer Months (December to February)

2.3.4.3 Preliminary Scheme Design Objectives

Taking into account the current day scenario described above as well as the recommendations of the BOCMA CMA, a cautionary approach has been adopted in the preliminary design of the potential BBTS, so as to take these uncertainties into account. The following scheme design strategies have been used in the overall design objectives:

- Potential releases of water from the upstream **Koekedouw Dam**, towards meeting the Reserve immediately downstream of the proposed diversion site at Michell's Pass are to be investigated.
- Potential development of a dam on the **Boontjies River** (tributary of the Klein Berg), in order to store winter diversions from the BBTS is to be considered. This would allow for summer irrigation requirements to be supplied to the existing Artois Irrigators, in exchange for cessation of the Artois Canal diversion in summer. In so doing, water previously diverted in summer would then be available towards meeting the summer Reserve, immediately downstream of the proposed diversion site at Michell's Pass.

Designs have been undertaken for both options, namely with and without the provision of an off-channel storage dam and with provision for reinstatement of summer base flow downstream of the proposed abstraction. Cost estimates for both options have been determined and are summarised in the economic evaluation in **Section 9**. The detailed cost estimates are provided in **Appendix 10** and **Appendix 12**.

Furthermore, at a wider catchment scale (described in **Section 3**), an estimate has been made of the possible extent to which existing irrigated agriculture within the lower reaches of the Breede River Basin could contribute towards addressing the present-day problems in meeting the Estuarine Reserve, possibly through compulsory licencing.

2.3.5 Potential Koekedouw Dam Contribution to the Reserve

Figure 20 shows the location of the Koekedouw Dam situated upstream of the Michell's Pass abstraction site. As described above, an option towards reinstating the summer Reserve flows immediately downstream of the proposed abstraction site could be to make summer releases from Koekedouw Dam near Ceres. This would be based on the current allocated but unused surplus water stored in the dam. In order to practically implement such a possibility, it would firstly be necessary to understand the current water allocations from the dam, and secondly, it would be necessary to undertake a series of trial releases in summer and perhaps also detailed geohydrological investigations to determine whether these releases are likely to provide the Reserve flows downstream of the proposed Michell's Pass weir or would be "lost" due to infiltration into and abstractions from the Breede alluvium. **Figure 20** shows the relative positions of Koekedouw Dam (from which releases could be considered) in relation to the proposed diversion weir located at H1H006.

2.3.5.1 Current Koekedouw Dam Agreements, Allocations

In consultation with the DWA Regional Office (RO), it has been established that in 1999, just prior to the introduction of the National Water Act, a water use permit was issued to the Koekedouw Irrigation Board (KIB) with a specific provision (part of a Section 9B Permit) for making for water available from the dam for the purpose of providing for the in-stream flow requirements. The details of this requirement are set out in **Section 2.3.5.2** hereafter.

The original cost of the complete scheme was estimated to be R53 million but actual completion costs were R102 million. As such the cost of the water to the irrigators is double what had been previously determined. This led to bankruptcies, leaving fewer remaining farmers to then absorb ever larger proportions of the debt. The irrigators have not taken up their full allocation from the dam, as the water has become unaffordable to expand their irrigation activities up to the full allocation As such the irrigators are only paying a portion of the cost per hectare, namely R4500/ha/annum and not the R11500/ha/annum of actual debt-based cost. The Rand Merchant Bank is financing the scheme and has agreements with various users.

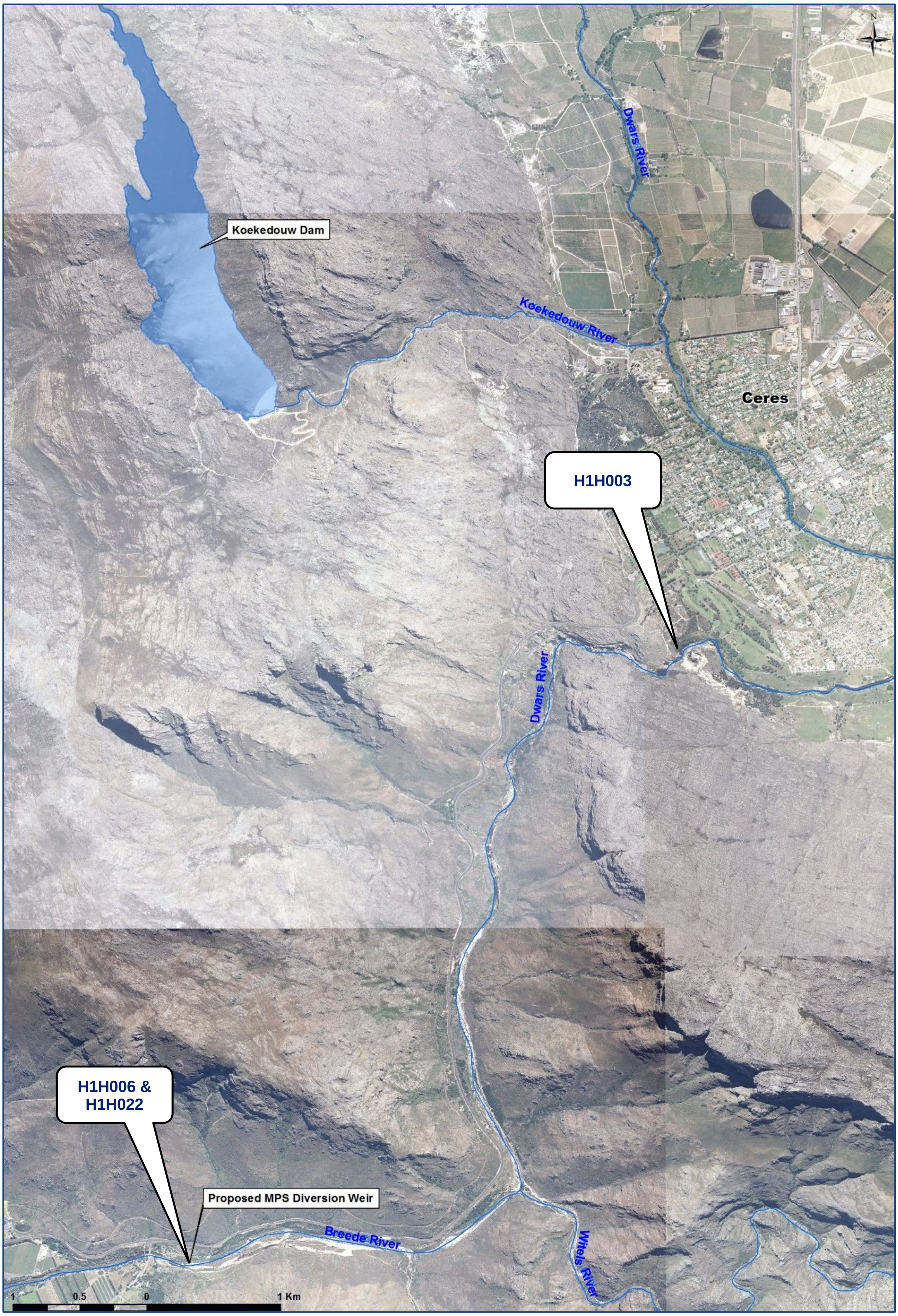


Figure 20: Relative Positions of the Koekedouw Dam and the Proposed BBTS Diversion Weir

The Witzenberg Municipality has entered into an agreement with the KIB for an allocation of water from the dam primarily for water supply to the town of Ceres. In this agreement, a larger proportion of the allocation will ultimately revert to the Municipality in time, as their water requirement increases. However, the Municipality is also under financial pressure to afford the cost of this water. Both entities (the KIB and the Municipality) approached DWA in 2004 to take over the dam, write off the outstanding debt, cover the costs and take over the operation of the dam. This possibility is still being considered by the DWA but to date no decision has been taken.

In addition to the recommendation in Section **2.3.2** that a trial release be made from the Koekedouw Dam as well as the availability of water from the dam, it is also recommended that the financial situation concerning the dam is investigated in order to assess the likely cost of this alternative.

2.3.5.2 Required Ecological Releases from Koekedouw Dam

The 1999 report entitled Ecological Water Requirements of the Koekedouw River (Ninham Shand in association with the Freshwater Consulting Group) reported that in terms of the water permit, an annual release volume of 6,15 million m^3/a in normal years is required, and a reduced volume during drought years. The releases are supposed to be recorded at the downstream low flow gauging station (Bridge 2), adjacent to the Irrigation Board/Witzenberg Municipality pipeline junction. A telemetry system was installed for this purpose and readings can also be taken manually via a gauge plate.

A variety of options and combinations thereof have been prescribed for making these releases from the available outlet infrastructure at the dam, which includes a maximum required flood release of $7m^3/s$ during August.

Low Flow Requirements

Table 1 shows the minimum low flow requirements to be made from the dam into the river during normal and drought years.

Table 1: Low Flow Release Requirements from Koekedouw Dam

Min Low Flows (m^3/s)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Normal Years	0.1	0.1	0.1	0.07	0.06	0.06	0.08	0.2	0.3	0.3	0.3	0.2
Drought Years	0.1	0.05	0.03	0.01	0.01	0.01	0.05	0.08	0.1	0.1	0.1	0.1

Flood Releases

During normal years the prescribed intended release pattern to simulate floods downstream of the dam ranges from creating relatively small events, such as a 1-day flood of 0,5 m^3/s for 24 hours, up to a maximum simulated 6-day flood event in August, with a 2-hour peak of 7 m^3/s. In drought years, the flood release requirements are reduced with a maximum simulated 3-day flood release peak required of 3 m^3/s over a 24 hour duration.

Table 2 shows the flood release requirements that are supposed to be provided from the Koekedouw Dam during both normal and drought conditions.

The above referenced 1999 report also indicates that the provision of flood releases as required is not achievable due the capacity limitations on the outlet infrastructure. The capacity of the 600 mm diameter and 250 mm diameter sleeve valves that are intended for making the Reserve releases are not sufficient to make the larger peak flood releases.

It is understood that flood releases for the environment are currently not being made from the dam in part because of the limited capacity of the outlet works as described above, and as such this portion of water should be available at no cost towards making Reserve releases below the proposed Michell's Pass diversion weir. Over and above this, the extent of any available surplus water from allocations not taken up should also be available towards releases for the environment. However, this will need to be negotiated with the current water users (Witzenberg Municipality and the Koekedouw Irrigation Board) as well as with DWA who has been approached to possibly take over the ownership of this asset.

In view of the uncertainty that it would be possible to provide the Reserve flows for the upper Breede River by releasing water from Koekedouw Dam, the alternative Boontjies Dam scheme was investigated as described below.

Table 2: Flood Release Requirements from the Koekedouw Dam

Flood Releases (m^3/s)	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Normal Years		**A**					**B**		**C**		**D**	
Drought Years							**E**				**F**	
Normal Year Conditions												
A	1-day flood	0.5 m^3/s for 24 hrs										
B	2-day flood	0.5 m^3/s for 48 hrs										
C	3-day flood	1 m^3/s for 24 hrs; 3 m^3/s for 24 hrs; 1 m^3/s for 24 hrs										
D	6-day flood	1 m^3/s for 24 hrs, 2 m^3/s for 24 hrs; 5 m^3/s for 11 hrs, 7 m^3/s for 2 hrs, 5 m^3/s for 11 hrs; 3 m^3 /s for 24 hrs; 1.5 m^3/s for 24 hrs; 1 m^3/s for 24 hrs										
Drought Year Conditions												
E	1-day flood	0.3 m^3/s for 24 hrs										
F	3-day flood	0.5 m^3/s for 12 hrs; 1 m^3/s for 12 hrs; 3 m^3/s for 24 hrs; 1.5 m^3/s for 12 hrs; 1 m^3/s for 12 hrs										

2.3.6 Sizing of Potential Boontjies Dam

2.3.6.1 Inflows at Michell's Pass

In view of the uncertainty that it would be possible to provide the summer Reserve flows of the upper Breeede River below the proposed Michell's Pass diversion at the Witbrug by releasing water from Koekedouw Dam, the alternative Boontjies Dam scheme to supply these releases was investigated as described below.

The diversion at Michell's Pass was modelled on a daily time step based on the observed flows at Department of Water Affairs flow gauges H1H006 (measuring spills from the diversion weir at Michell's Pass) and H1H022 (measuring the flows in the Artois Canal just downstream of the diversion). The sum of the flows observed at these two gauges yields the inflows at the Artois Canal diversion weir at Witbrug. The observed daily flows for 10 years from 1 October 1999 to 10 August 2009 (the last available day with observed data at the time of analysis) are shown in **Figure 21** (note the log scale on the y-axis, to show both the high and low flows).

Figure 21 shows that diversions to the Artois Canal have historically peaked in summer and have drastically reduced in winter. The water users depend on both stored water in their dams and diversions from the Michell's Pass to irrigate during the dry summer months as well as some groundwater abstraction. The first few months of winter are used to fill the dams where after diversions are decreased considerably. In contrast, spills observed at Witbrug (which correlate to periods of increased flow and/or reduced diversions to the Artois Canal) are at their maximum in winter.

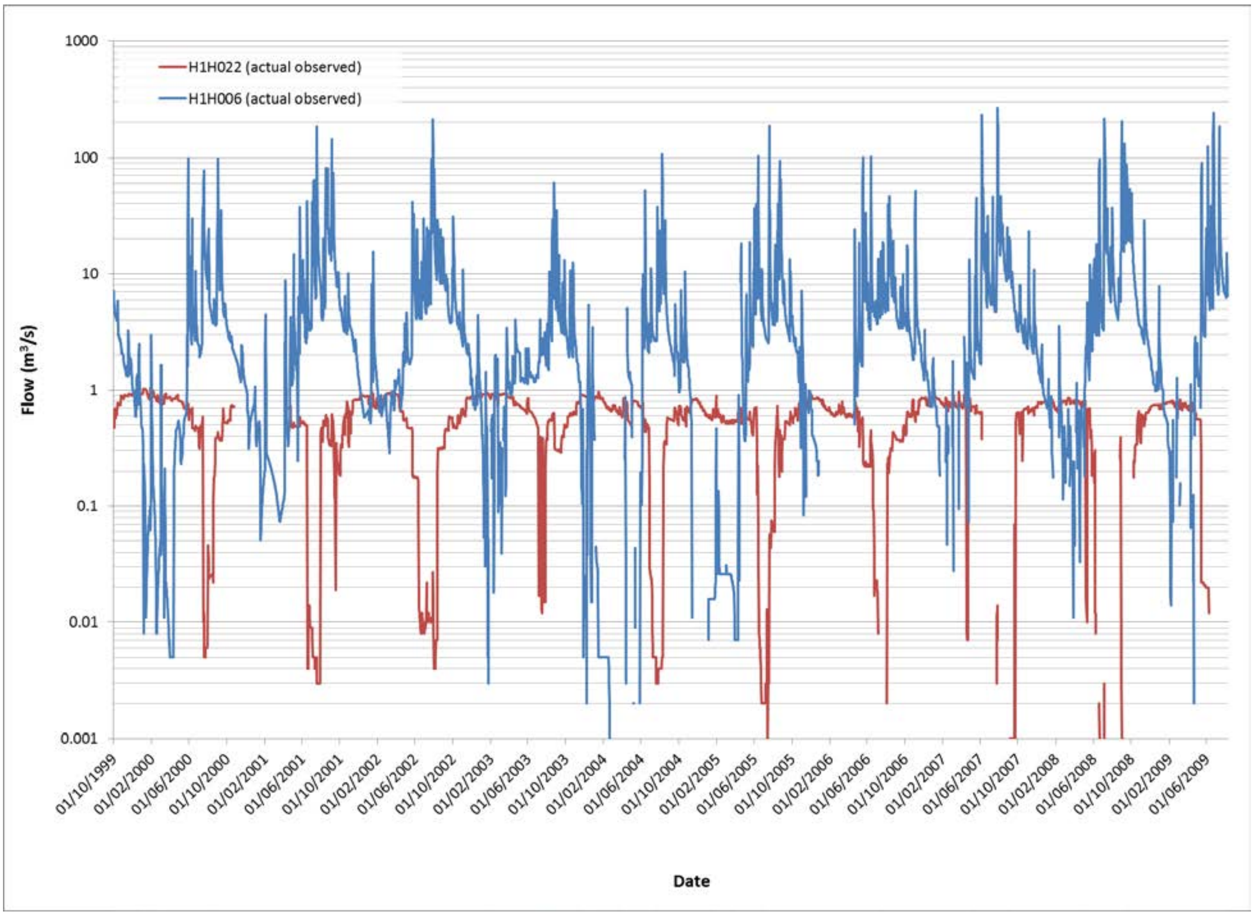


Figure 21: Observed (unpatched) Daily Flows at Witbrug from 1 October 1999 to 10 August 2009

2.3.6.2 Patching of Gaps in the Observed Data

Gaps in the observed daily flow record were patched. The relationship between flows at H1H022 and H1H006 was investigated to enable patching of gaps in the data for H1H022 on the Artois Canal. Unfortunately the correlation between flows from the two stations was very poor, so gaps in the record of H1H022 were patched with the mean monthly flow rate for the relevant month of the gap. The correlation was poor as diversions to the Artois Canal are determined by requirements from the users, in addition to inflows at the diversion structure, and thus the flows in the canal are a function both of inflows and of operation of the structure. The observed and patched flows for the period from 1 October 1959 to 10 August 2009 (the last available day of data) are shown in **Figure 22.** This shows that there was one major continuous gap in the data from May 1979 to October 1991 with various other short gaps scattered across the record.

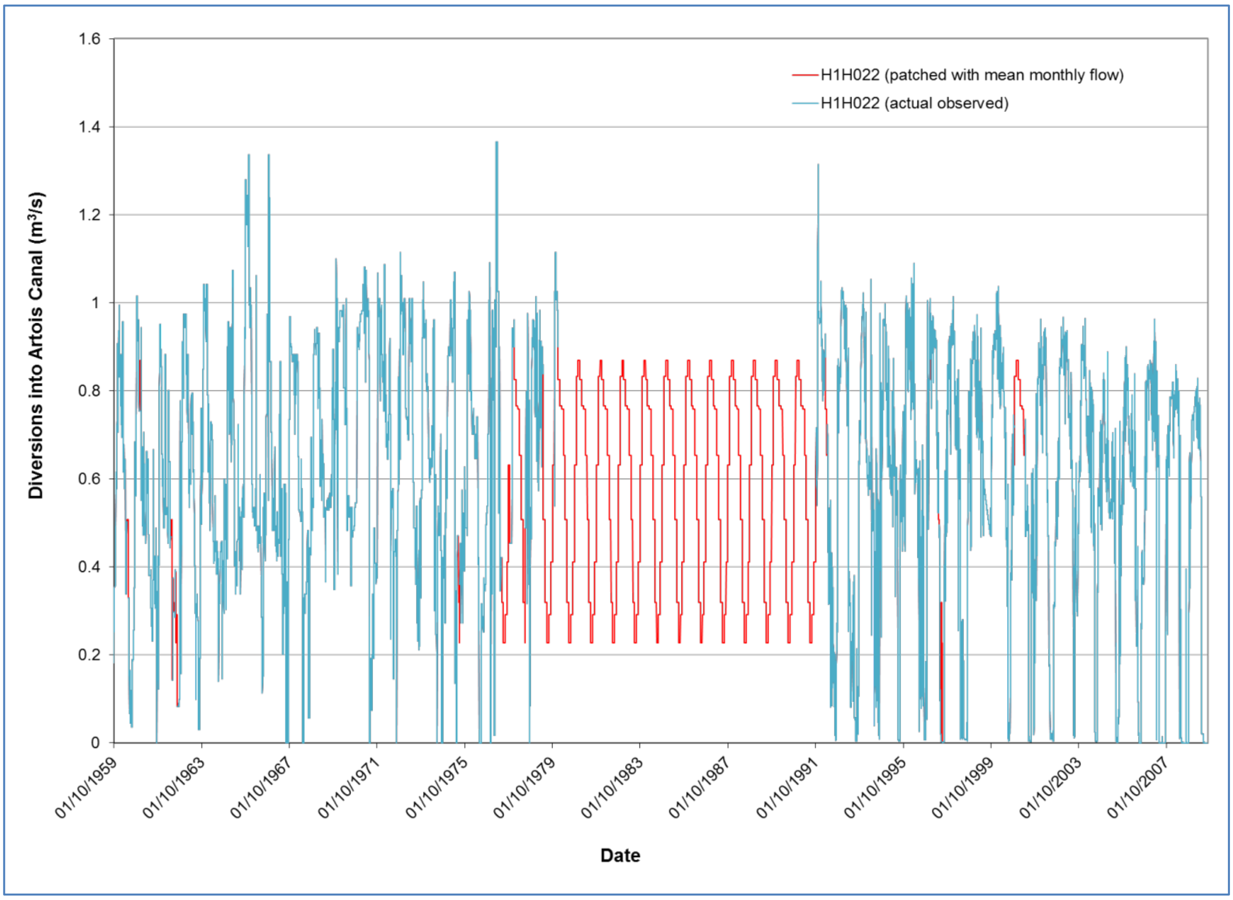


Figure 22: Patching of Daily Flows Diverted to the Artois Canal at Witbrug (patched flows in red)

The patched observed daily flows at H1H022 and the daily flows including gaps at H1H006 were then summed to give a time series of flows at Witbrug representing inflows to the diversion structure. Gaps in this 'inflow' time series were then patched using observed daily flows from H1H003 located just downstream of Ceres on the Dwars River. This gauge lies upstream of H1H006, and upstream of the Witels River confluence which contributes a large proportion of the flow at Witbrug for most of the year.

2.3.6.3 Natural Flow Sequence at Witbrug

A naturalised flow sequence for the Breede River at Witbrug was derived from the monthly natural flows from the Pitman Model for the quaternary catchments upstream. This flow sequence was disaggregated to a daily time-step using the patched observed flow sequence derived above for Witbrug (the sum of the patched observed sequences for H1H006 and H1H022 shown in **Figure 22**).

2.3.6.4 Provision of Ecological Flows

The Reserve flows for the diversion site at Witbrug were then determined using the flow duration curves for the Class D Reserve shown in **Table 8** and the natural flow sequence derived from the Pitman Model (as described above).

In general the Reserve would be satisfied for most of the time by the inflows observed at Witbrug. It was assumed in this exercise that compliance with the Reserve would only be considered immediately downstream of Michell's Pass and not for any other Reserve sites further downstream.

Figure 23 shows the daily flows at the Artois Canal diversion for the natural, present-day, Reserve and the Artois water users' requirements.

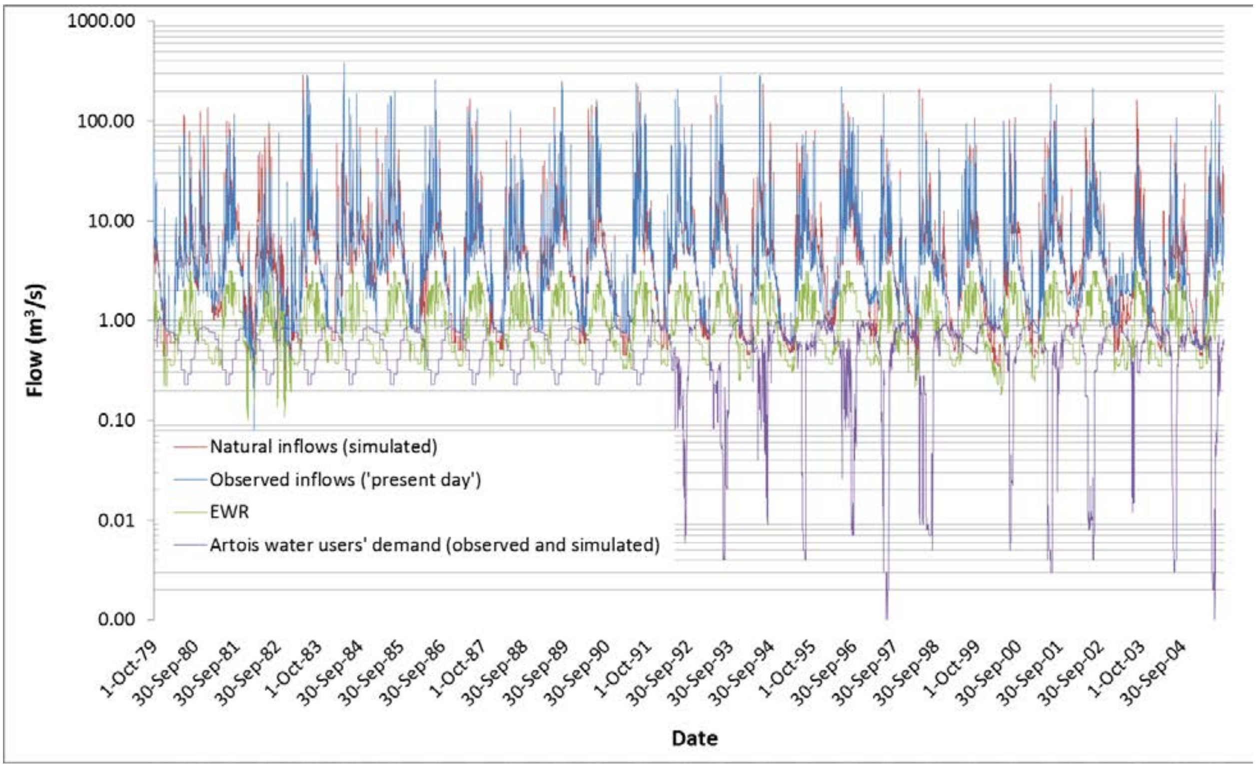


Figure 23: Time Series of Natural Inflows, Observed Inflows, Reserve and Artois Water Users' Requirements

One of the questions that needed to be answered in the yield analysis was whether pumping back from the potential Boontjies Dam would be necessary to supplement the river flows to comply with the Reserve during times when the present-day flows in the river are less than the Reserve requirement. **Figure 24** shows the time series of present-day daily flows less the Reserve requirement at Michell's Pass. The graph indicates that for most of the time, the present-day flows exceed the Reserve requirement. Over the period of 1 October 1979 to 30 September 2005, the Reserve requirement exceeded the present-day flow on 95 days, or for about 1% of the record period. Thus the present-day flows would satisfy the Reserve requirement at Michell's Pass for almost all the time, and it was assumed that the shortfalls would either be accepted or that water would be released from Koekedouw Dam to supplement flow and make up for the Reserve shortfall on the 95 days. This means that the pumping scheme from the Boontjies Dam could then be designed to supply the Artois Canal water users only and would not have to pump water the full distance back up the proposed pipeline to the Breede River at Michell's Pass to provide additional flow to meet the Reserve requirements.

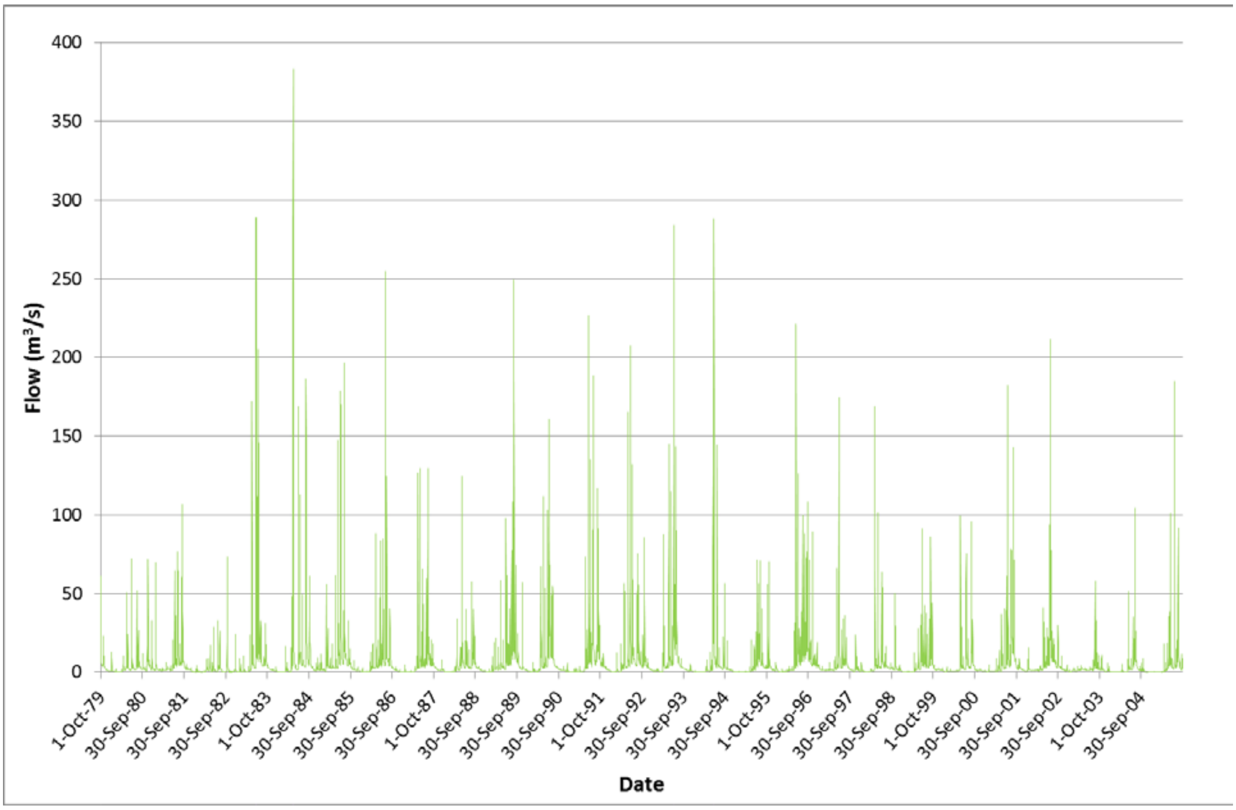


Figure 24: Present-Day Daily Flows Less Reserve Requirements at Michell's Pass

2.3.6.5 Artois Water Users

The water users who depend on water from the Artois Canal need to be catered for in any future scheme at Michell's Pass. Many of them store water in their own farm dams for use during the dry summer months. **Figure 21** above indicates that diversions presently are at their highest in summer and reduce in winter when irrigation water requirements reduce.

It was necessary to estimate the future use of the Artois Canal water users in order to model the diversion scheme and to size the proposed Boontjies Dam and pumping scheme accordingly. **Table 3** details information on the capacity of the Artois Canal from various available sources.

Table 3: Data on the Artois Canal

Information source	Discharge – m^3/s (cusec)
Artois Canal upgrades, dated 1956, on Ninham Shand drawing in Aurecon archives	1.105 (39.04)
Water Court ruling of 1948	1.133 (40)
Sum of allocations off Artois Canal excluding the Tierhoeks River	1.154 (40.75)
Maximum flow recorded at H1H022 on 13 Nov 1991	1.315 (46.44)

The observed discharge record at H1H022 which measures discharge at the intake to the Artois scheme (at the first division box) and was used for the analysis (1 October 1979 to 30 September 2005), had 6 days where a flow of 40 cusecs (1.133 m^3/s) was exceeded and 13 days when a flow of 39.05 cusecs (1.105 m^3/s) was exceeded.

In the absence of better information on the future use of the Artois Canal water users, it was assumed that the use in the future would be equal to that of the past. The flow recorded at H1H022 was therefore used to model the use of the Artois Canal by the water users.

The split in water requirements between the water users in the Wolseley area located upstream of the potential Boontjies Dam and those downstream of the Dam needed to be estimated, in order to allow the determination of the irrigation requirements of the farmers who may require stored water to be pumped to them during the dry summer months.

The Internal Strategic Perspective (ISP) of 2004 states that approximately 4 million m^3/a of water is transferred to the Klein Berg River via the Artois Canal. This is about 21% of the 19.2 million m^3/a that was diverted over the complete record (complete years with reliable data only) from 1958 to 2008. The balance, 79%, is then used upstream of the potential Boontjies Dam.

Information on the various Water Court orders for the Wolseley area is given in **Table 4**.

Table 4: Information from the Various Water Court Orders in the Wolseley Area

Water User	$m/^3s$ (cusec)	
Wolseley Municipality	0.056	(2.000)
Wolseley Municipality which may be supplied from Tierhoks if available	0.035	(1.250)
Dwars River Irrigation Board	0.912	(32.225)
Wolseley Municipality	0.021	(0.750)
Low lying area of the Boontjies River	0.163	(5.775)
Total for all Water Court allocations	**1.187**	**(42.000)**
Total for Water Court allocations excluding the Tierhoks River	**1.154**	**(40.750)**
Total allocation that would need to be pumped back from Boontjies Dam	**0.990**	**(34.975)**
Proportion of the allocation to water users upstream of Boontjies excl. Tierhoks	**86%**	

The split between the water users upstream and downstream of the potential Boontjies Dam based on the ISP and on the Water Court orders is therefore between 79% and 86%. The ISP split was used in the calculations, where it was assumed that 79% of the total Artois Canal water users' requirement would be upstream of the Boontjies Dam and would therefore need to be augmented from the proposed BBTS during times when there are shortfalls.

2.3.6.6 Diversion Calculations

The operation of the proposed diversion structure at Witbrug was modelled in a spreadsheet on a daily time-step, commencing on 1 October 1979 and ending on 30 September 2005. The start date was selected based on the assumption that the level of catchment development at this time remained fairly constant to the present-day. The end date was determined by the availability of the natural flow sequence. The catchment development was therefore assumed to be at present-day levels from 1979 to 2005.

The diversion scheme calculations were then conducted as follows:

- The daily observed inflows (patched observed flows for H1H006 and H1H022, summed together) and daily natural flows (derived as described earlier) were used as inputs.
- The Reserve time series of flows was derived as described earlier.
- At each time-step, the flow available to be diverted into the proposed scheme was calculated by subtracting the Reserve from the 'present-day' inflow. If the Reserve requirement exceeded the 'present-day' flow, then no water was diverted.
- The available flow for diversion was then assumed to be diverted up to the diversion capacity of the diversion structure (capacities from 1 to 10 m^3/s at 1 m^3/s increments were modelled)
- The Wolseley users upstream of the Boontjies Dam were then assumed to be supplied with their share, based on the split of 79% as discussed earlier based on the flow record of the Artois Canal at H1H022. If the requirement for these users exceeded the supply from the Michell's Pass diversion, then all water would be supplied to them and no water would be supplied to the Boontjies Dam. If the supply exceeded the requirement, then the balance would be supplied to the Boontjies Dam.
- The balance of flows was then fed into the Boontjies Dam.

2.3.6.7 Pumping Requirement to the Upstream Artois Canal Water Users

Based on the daily modelling described above with a Michell's Pass diversion capacity of 5 m^3/s, the peak flow that would need to be pumped from the potential Boontjies Dam was 0.666 m^3/s. The annual volumes that would need to be pumped were on average 1.93 million m^3/a, with a minimum year in which no water was required to be pumped, and a maximum year in which 5.35 million m^3/a was required to be pumped. **Figure 25** shows that the pump station would be operated for less than ¼ of the time.

Based on this information, the pump station was designed with a capacity of 1 m^3/s. This is a conservative estimate, but takes into account uncertainty including that the drought of the late 1960's to early 1970's (the critical drought in this region) was not included in the modelling period and that the flow split to the water users upstream of the proposed Boontjies Dam may be less than what was modelled, which would result in a greater pump station capacity being required than 0,666 m^3/s.

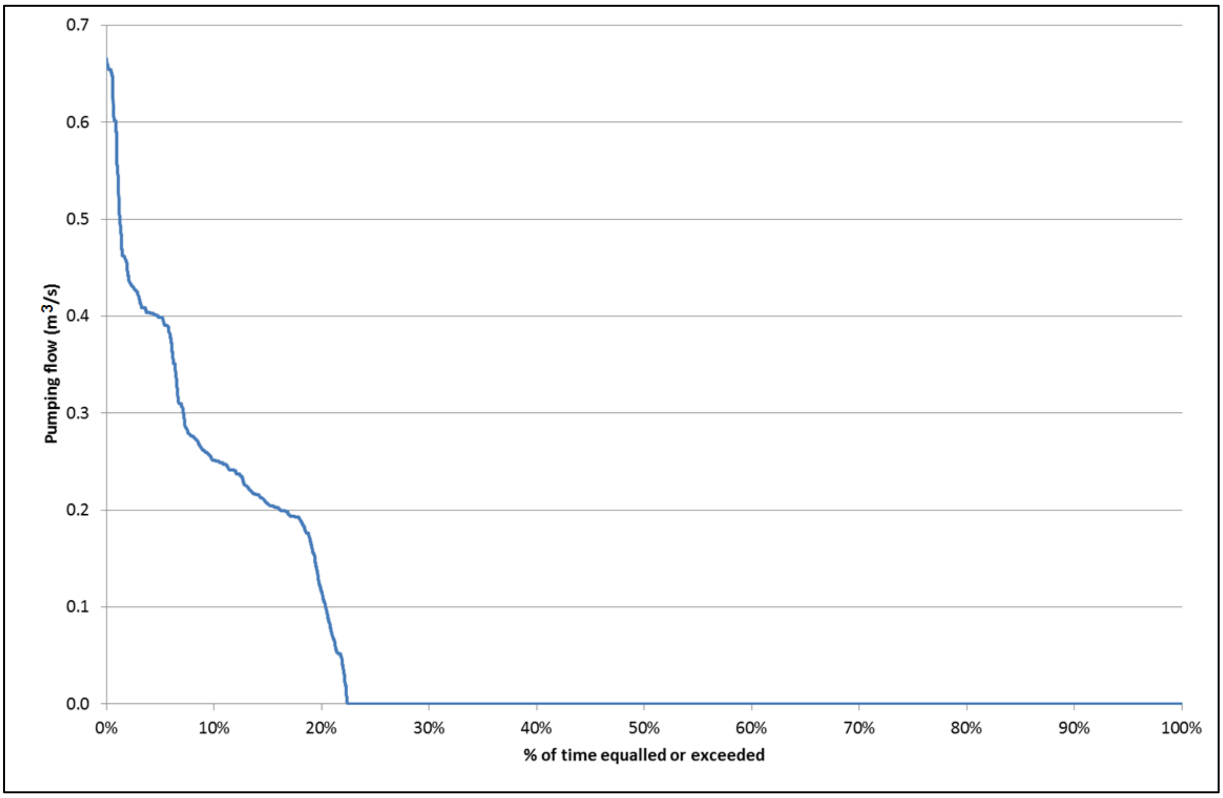


Figure 25: Duration Curve of Pumping from the Boontjies Dam to Supply Deficits in Supply to the Upstream Artois Canal Water Users

2.3.6.8 Boontjies Dam Mass Balance

A dam balance was then conducted on a daily time-step for the Boontjies Dam based on the following operational and modelling assumptions:

- Transfers in from the proposed Michell's Pass diversion.
- Rainfall was added to the dam surface.
- Evaporation was subtracted from the dam surface.
- Releases were made on a continuous basis to the 21% of the Artois Canal water users downstream of the dam, based on the 21% share and the observed Artois Canal flow record at H1H022.
- When a shortfall was experienced by the Artois Canal water users, then water was pumped back to the users from the Boontjies Dam using the gravity pipeline operated in reverse.
- The incremental inflows to the dam from the Boontjies River catchment were ignored, as a proportion of these would need to be released to meet the Reserve requirements.
- The spills from the dam were then assumed to be the flows that would be supplied to the Voëlvlei Dam for supply to the Western Cape Water Supply System. Since the Boontjies Dam would be drawn down every summer while it supplied the local water users, it can therefore be seen that transfers to the Voëlvlei Dam would only occur during the winter months.

The dam was then sized based on the above inflows and outflows so that the level of the dam dropped to dead-storage level (assumed to be 5%, over the required volume) only once during the model period so that a failure in supply would never occur.

2.3.6.9 Results of the Boontjies Dam Assessment

With a 5 m^3/s diversion scheme capacity, the active storage volume required in the Boontjies Dam would be about 7.5 million m^3, and the total storage volume including dead storage of 5% and a slight rounding up in dam wall height would be about 8 million m^3. The dam full supply level required would be to 251.3 masl (a dam wall height of 33.3 m). **Figure 26** shows the dam trajectories for this option together with the pumping time-series and **Figure 27** shows the main components of the dam balance on a log scale.

Table 5 provides the annual water balance for the modelled Boontjies Dam. It can be seen that the average volume available to the Western Cape Water Supply System, before inclusion of losses would vary from 24.6 million m^3/a to 91.1 million m^3/a, with an average over the 26 year period of 57.2 million m^3/a.

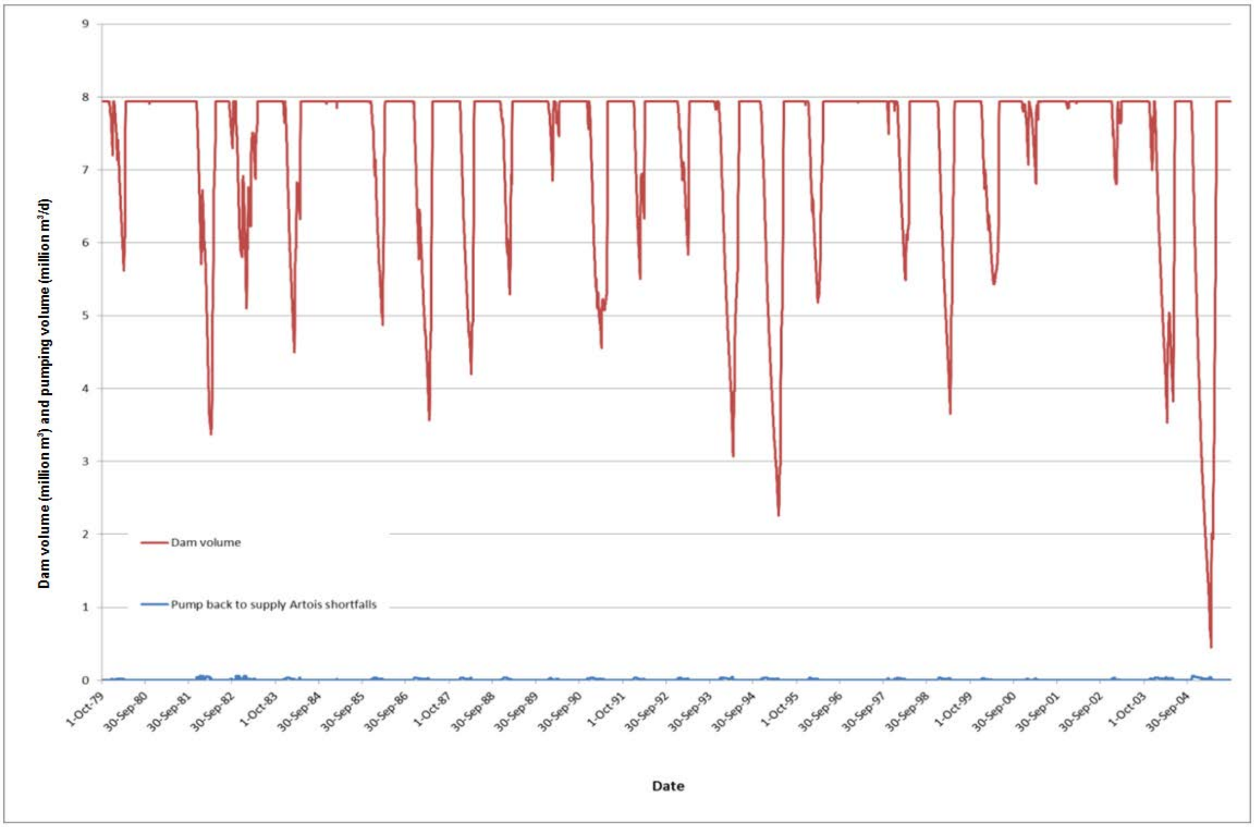


Figure 26: Boontjies Dam Levels and Pumping to the Artois Irrigators Upstream

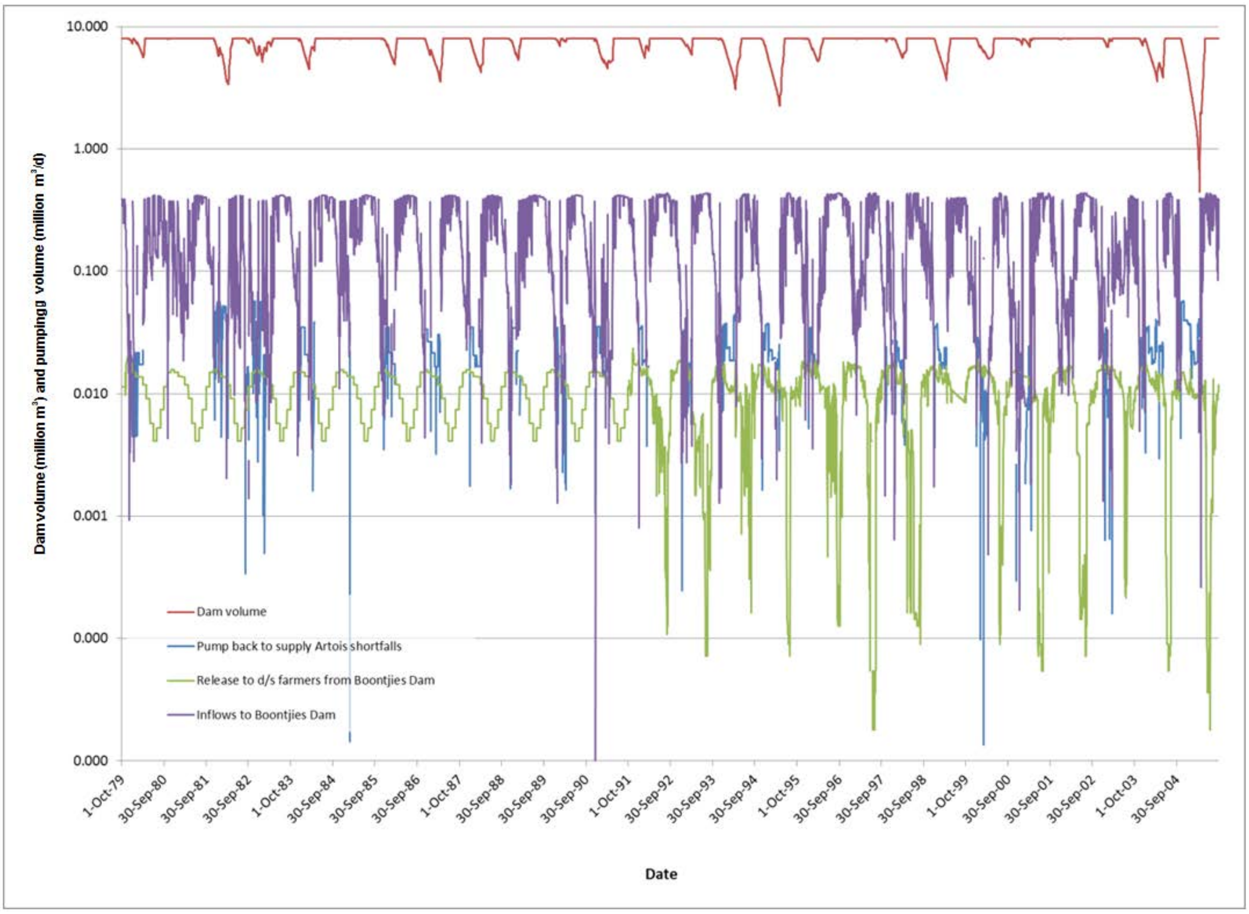


Figure 27: Summary Graph of the Boontjies Dam Water Balance Shown on a Log Scale

Table 5: Annual Water Balance for the Proposed Boontjies Dam

Hydro Year	Inflows to weir @ Michell's Pass (Mill m^3)	Reserve Requirement @ Michell's Pass (Mill m^3)	Diversion @ Michell's Pass @ max 5 m^3/s (Mill m^3)	Spills to Breede @ Michell's Pass weir (Mill m^3)	Artois Canal Users requirement upstream of proposed Boontjies Dam (Mill m^3)	Supply to Artois Canal Users direct from the pipeline under gravity from the Breede River (Mill m^3)	Inflow to proposed Boontjies Dam from pipeline (Mill m^3)	Rain on reservoir surface (Mill m^3)	Evaporation from reservoir surface (Mill m^3)	Pump back to upper Artois farmers to make up for shortfalls in gravity supply from Breede River (Mill m^3)	Releases to lower Artois farmers (Mill m^3)	Spills to Voëlvlei Dam (Mill m^3)	Total flows to Boontjies River (Mm^3)
1979	144.8	29.5	69.1	75.7	15.3	13.9	55.2	0.3	1.0	1.5	4.0	49.0	53.1
1980	253.6	32.7	92.8	160.8	14.7	14.7	78.1	0.7	1.0	0.0	3.9	73.9	77.7
1981	84.6	30.4	43.2	41.4	14.7	10.5	32.7	0.3	0.8	4.2	3.9	24.6	28.5
1982	364.6	30.5	75.6	289.0	14.7	11.3	64.4	0.5	0.9	3.5	3.9	56.1	60.0
1983	354.2	31.7	77.8	276.4	14.8	12.4	65.4	0.5	0.9	2.4	3.9	58.8	62.6
1984	364.4	37.7	110.0	254.4	14.7	14.7	95.3	0.7	1.0	0.1	3.9	91.1	94.9
1985	274.2	35.6	87.6	186.7	14.7	12.9	74.7	0.4	0.9	1.9	3.9	68.4	72.3
1986	233.9	35.4	73.5	160.4	14.7	11.8	61.7	0.4	0.8	3.0	3.9	54.4	58.3
1987	180.8	31.0	75.6	105.2	14.8	12.6	63.0	0.3	0.9	2.2	3.9	56.4	60.2
1988	301.1	35.3	87.9	213.2	14.7	13.1	74.8	0.5	0.9	1.7	3.9	68.9	72.8
1989	303.7	36.0	91.1	212.6	14.7	14.0	77.1	0.5	1.0	0.7	3.9	72.0	75.9
1990	311.7	31.9	70.0	241.7	14.7	12.3	57.7	0.5	0.9	2.4	3.9	51.0	54.8
1991	323.2	36.2	97.5	225.7	14.6	12.9	84.6	0.5	0.9	1.7	3.8	78.6	82.4
1992	388.9	38.6	98.0	290.9	13.7	12.6	85.5	0.5	1.0	1.1	3.6	80.4	84.0
1993	232.3	29.8	56.4	175.8	14.8	11.7	44.7	0.4	0.8	3.1	3.9	37.2	41.1
1994	154.8	34.2	59.8	95.0	15.2	11.8	48.0	0.3	0.8	3.4	4.0	40.1	44.1
1995	351.2	39.1	84.5	266.7	15.5	14.0	70.5	0.6	0.9	1.6	4.1	64.5	68.6
1996	252.8	32.2	101.3	151.5	13.9	13.9	87.4	0.4	1.0	0.0	3.7	83.2	86.8
1997	183.1	28.6	71.0	112.1	13.8	12.2	58.8	0.4	0.9	1.6	3.6	53.0	56.6
1998	188.5	31.3	74.4	114.1	17.3	14.8	59.6	0.4	0.9	2.5	4.5	52.1	56.6
1999	165.6	30.5	66.0	99.5	17.0	15.9	50.2	0.3	0.9	1.1	4.5	44.0	48.5
2000	273.4	37.1	72.2	201.2	14.4	13.7	58.5	0.5	1.0	0.7	3.8	53.5	57.3
2001	232.9	40.3	85.6	147.4	13.7	13.7	71.9	0.6	1.0	0.0	3.6	67.9	71.5
2002	116.4	29.6	62.6	53.7	16.8	16.1	46.5	0.4	1.0	0.7	4.4	40.8	45.3
2003	116.9	28.5	48.4	68.4	15.2	11.3	37.2	0.3	0.8	4.0	4.0	28.6	32.6
2004	168.5	35.9	54.2	114.2	12.6	7.2	47.0	0.4	0.6	5.4	3.3	38.1	41.4
Avg	243.1	33.4	76.4	166.7	14.8	12.9	63.5	0.4	0.9	1.9	3.9	57.2	61.1
Min	84.6	28.5	43.2	41.4	12.6	7.2	32.7	0.3	0.6	0.0	3.3	24.6	28.5
Max	388.9	40.3	110.0	290.9	17.3	16.1	95.3	0.7	1.0	5.4	4.5	91.1	94.9

* The inflows to the Boontjies Dam were modelled as the diverted flows at Michell's Pass less the requirements of the upper Artois Canal water users

2.3.7 Summary of Potential System Yields

The 1:50 year incremental yield that would be added to the Western Cape Water Supply System through the implementation of the BBTS options is described in detail in **Section 3** which follows.

In summary the increased system yield for either of the two alternatives (ie with Boontjies River Dam or without) is **36 million m^3/a**.

The reason for both schemes providing the same yield is that the Boontjies Dam does not significantly affect the diversions out of the Breede River. For both options, as much water is taken as possible after the Reserve at Michell's Pass is met, and until Voëlvlei Dam is full.

2.4 SUMMARY OF ANALYSES OF DIVERSION SCHEMES

The analyses of the proposed Michell's Pass Diversion Scheme show the following:

- A new weir on the upper Breede River sited immediately downstream of the existing weir (H1H001) could divert up to 5 m^3/s into a new gravity pipeline to supply the existing irrigators that are supplied by the Artois furrow and to augment the flow in the Klein Berg River for diversion into Voëlvlei Dam.
- It would be possible to supply the existing and proposed users after releasing the Class D Reserve flows to the upper Breede River.

- Trial releases should be made from Koekedouw Dam to determine the following:
  - Whether such releases could supply the summer Reserve requirements and
  - If such releases did reach the diversion weir, site whether they would be effective in restoring the EWR flows in the Upper Breede River.

- Both schemes for diverting water from the Breede River to Voëlvlei would be feasible:
  - Alternative A would divert water after meeting the winter Reserve requirements and would supply the Artois furrow users from the Breede River during the summer months without meeting the Reserve unless water is supplied from Koekedouw Dam (the feasibility of which would require further investigation and negotiation with the existing users and the funders of this Dam).
  - Alternative B would only divert water after meeting both the summer and winter Reserve requirements. Winter diversions would first fill the Boontjies Dam and this stored water would be pumped from the dam in summer to supply the Artois furrow users.

Section 3 describes the determination of the 1 in 50 year incremental yield that would be added to the Western Cape Water Supply System through the implementation of the BBTS options with and without the Boontjies Dam.

In increased 1 in 50 year yields of both alternatives (i.e. with or without storage provided by the Boontjies Dam) would be **36 million m^3/a**.

The reasons for the scheme without storage providing the same yield as that with storage are that both options would divert as much winter water as possible after meeting the Reserve at Michell's Pass until Voëlvlei Dam would be full.

3. YIELD AND SYSTEM ANALYSIS

3.1 YIELD ANALYSIS FOR THE MICHELL'S PASS SCHEME

3.1.1 Natural Stream flows Adopted

In the Inception Report it was stated that the yield analysis for the BBTS would be conducted using the natural stream flows from the Breede River Basin Study (BRBS) (DWAF, 2002), given that the Berg WAAS of 2007 only developed stream flows for the main Breede River upstream of H4H006 (Lower Brandvlei - Papenkuils). However, for the Michell's Pass analysis stream flows would be required down to the estuary of the Breede River to determine the impact of diversions on downstream reaches. Also, the Berg WAAS (which included the upper Breede catchments) concluded that gauge H4H006 appeared to be highly unreliable and stream flows based on that gauge would be of low confidence.

Comparing the WAAS stream flows with those of the BRBS, it was found that the WAAS MAR at H1H006, the stream flow gauging station at the BBTS site, was about 12% less than the BRBS stream flows, although the MARs at H4H006 further downstream were almost identical (see **Table 6**, column c). As an interim, conservative measure, pending the possible re-evaluation of the hydrology for the entire Breede River Basin (Breede WAAS) in the future, a decision was taken to shift about 34 million m^3/a (18.5%) of the incremental stream flow from sub-catchment H1H006 to downstream of H1H006.

The record at H1H006 has a large number of missing / under-recorded values. This is illustrated in **Figure 28**, which compares the patched stream flows from the Berg WAAS study (blue) with the corresponding stream flows from the BRBS study, with all under-recorded / doubtful values removed prior to patching (red). Where accepted values exist in the BRBS stream flow series, these correspond well with the WAAS values.

Table 6: Comparison of the Contribution of Natural MARs from Incremental Sub-Catchments Upstream of H4H006 in the BRBS and the Berg WAAS

Incremental sub-catchments	BRBS	Berg WAAS	BRBS Adjusted
	Million m^3/a	**Million m^3/a**	**Million m^3/a**
	(1927-90)	**(1927-2004)**	**(1927-90)**
a	**b**	**c**	**d**
H1H013	31	34	31
H1H003	83	82	83
H1H006	184	150	150
Michells Pass Sub-total	298	266	
H1H006 stream flows moved d/s			34
H1H007	127	132	127
H1H018	145	62	145
H1H012	298	99	298
H1H033		87	
H4H006		215	
TOTAL up to H4H006	867	861	867

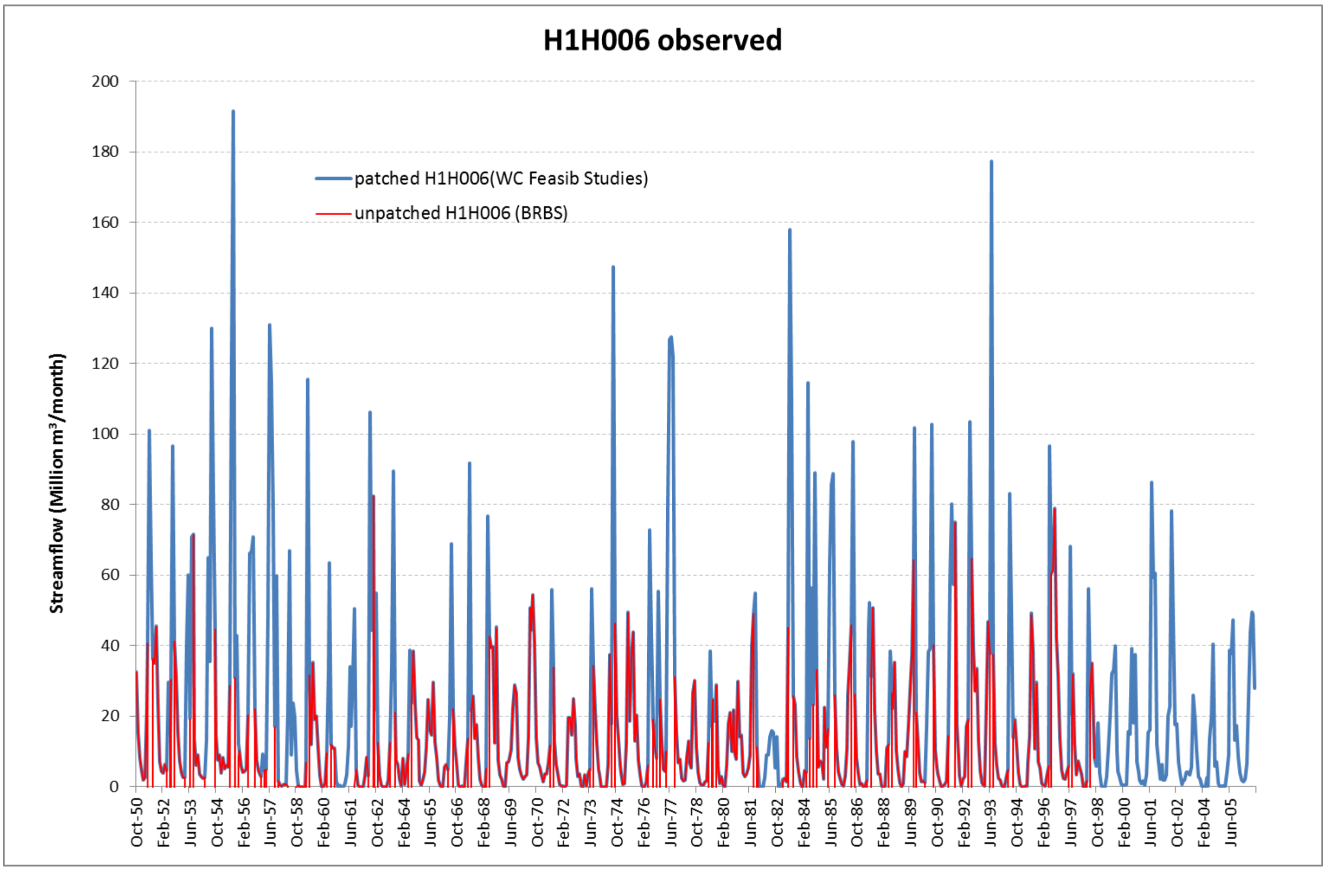


Figure 28: Comparison of Patched Stream Flows at H1H006 from the Berg WAAS with Unpatched Stream Flows at the Same Site from the BRBS to Illustrate the Extent of the Patching Required

3.2 YIELD MODELLING

3.2.1 System Overview

A simplified conceptual layout of the proposed BBTS is illustrated in **Figure 29**. It was assumed that the demands on the Koekedouw Dam would be equal to the maximum planned demands which would reduce the flows reaching the BBTS as spillages from the dam would reduce.

At present the stream flow remaining in the Breede River after the abstraction by the existing Artois canal does not satisfy the recommended summer Reserve flows of the upper Breede River. Therefore as discussed in **Section 2.3.6** the yield modelling was based on first providing the Reserve flows of the upper Breede River before diverting water into the proposed Boontjies Dam with a capacity of 8 million m^3. When transfers from the BBTS would fill the proposed Boontjies Dam, the additional diversions would flow down the Klein Berg River from where they would be diverted via the existing Klein Berg canal into Voëlvlei Dam. Should both the Boontjies Dam and the Voëlvlei Dam be full, then the transfers from the Breede would be halted.

The BBTS diversions would reduce the flows in the upper Breede River below the BBTS diversion. This means that less flow would be available for pumping into Brandvlei Dam at the Papenkuils pump station. In order to restore the yield of Brandvlei, the pumping capacity would need to be increased. Effectively a greater abstraction rate over a shorter pumping period than the current operation at Papenkuils would be required.

The critical characteristics of the BBTS were assumed to be as follows:

- a 5m^3/s transfer capacity from Michell's Pass,
- a potential new dam on the Boontjies River with a net capacity of 8 million m^3, and
- the Papenkuils pump station increased to 26 m^3/s from its current installed capacity of 7 m^3/s.

The stream flows in the Breede River with the BBTS in place, were compared with the stream flows for the recommended Ecological categories at five sites down the Breede River as shown in **Figure 9** and **Figure 29**, namely:

- Immediately downstream of the Michell's Pass diversion,
- At Le Chasseur,
- Just upstream of the confluence with the Riviersonderend River,
- The Reserve riverine site upstream of the estuary, and
- At the estuary itself.

The following sections describe the modelling of the BBTS, Papenkuils pump station and Klein Berg River canal in more detail and describe the determination of the abstraction functions required to approximate the behaviour of run-of-river schemes in the Water Resources Yield Model (WRYM).

The updated abstraction functions were incorporated into the WRYM system originally developed as part of the BRBS and used to determine the overall system yields.

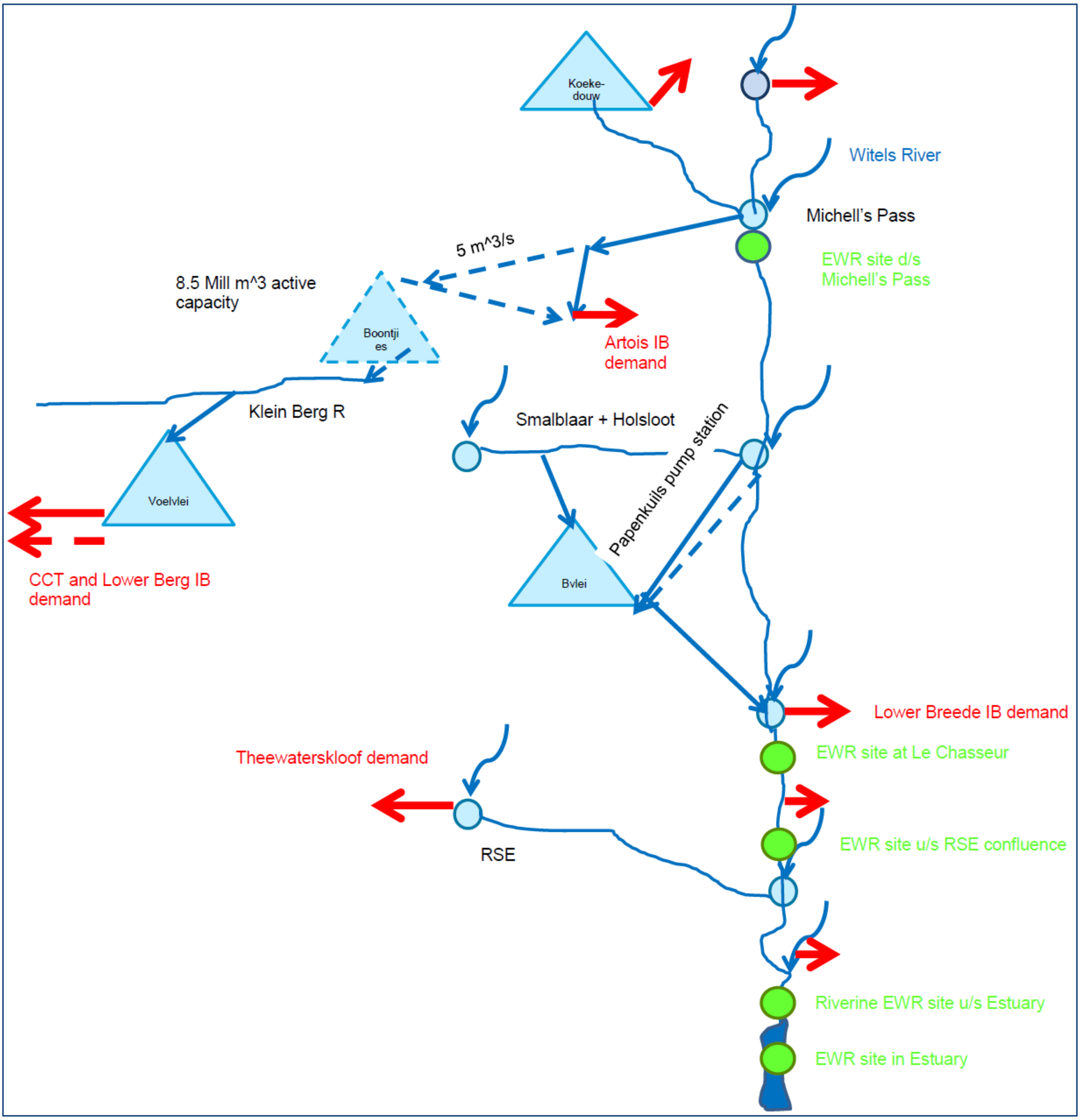


Figure 29: Simplified Schematic Showing the Major Components of the Breede River System and the Proposed Michell's Pass Scheme

3.2.2 Modelling the BBTS Operations

The Koekedouw Dam is located about 14 km upstream of the Michell's Pass abstraction site and will affect the available stream flows downstream.

The proposed BBTS would replace the current Artois diversion scheme with a larger abstraction capacity. This enlarged scheme would need to supply the requirements of both the existing irrigators (currently supplied from the Artois canal) and the additional water to be released into the Klein Berg River for transfer into the Voëlvlei Dam via the Klein Berg River canal. A diversion capacity of 5 m^3/s has been found to be optimum; hence, this capacity was adopted for the yield analysis.

The BBTS has been conceptualised to be a run-of-river scheme. Hence, given that no storage would be available, the abstraction rate would vary in accordance with variations in the available stream flow. Therefore, the operation of the scheme needed to be modelled with a daily time-step to establish the abstraction efficiency of the scheme. The inflows available for diversion were estimated by adding together the recorded abstraction by the Artois irrigators (H1H022) and the spill over the flow-gauging weir at Michell's Pass (H1H006). As noted in **Section 3.1.1** the gauging station, H1H006, appears to have frequently underestimated the stream flow. Also, recorded abstractions at H1H022 are missing for long periods. The periods with reasonable data adopted for analysis of the proposed diversion are from October 1964 to April 1977 and from November 1991 to September 2005 and are illustrated in **Figure 30.**

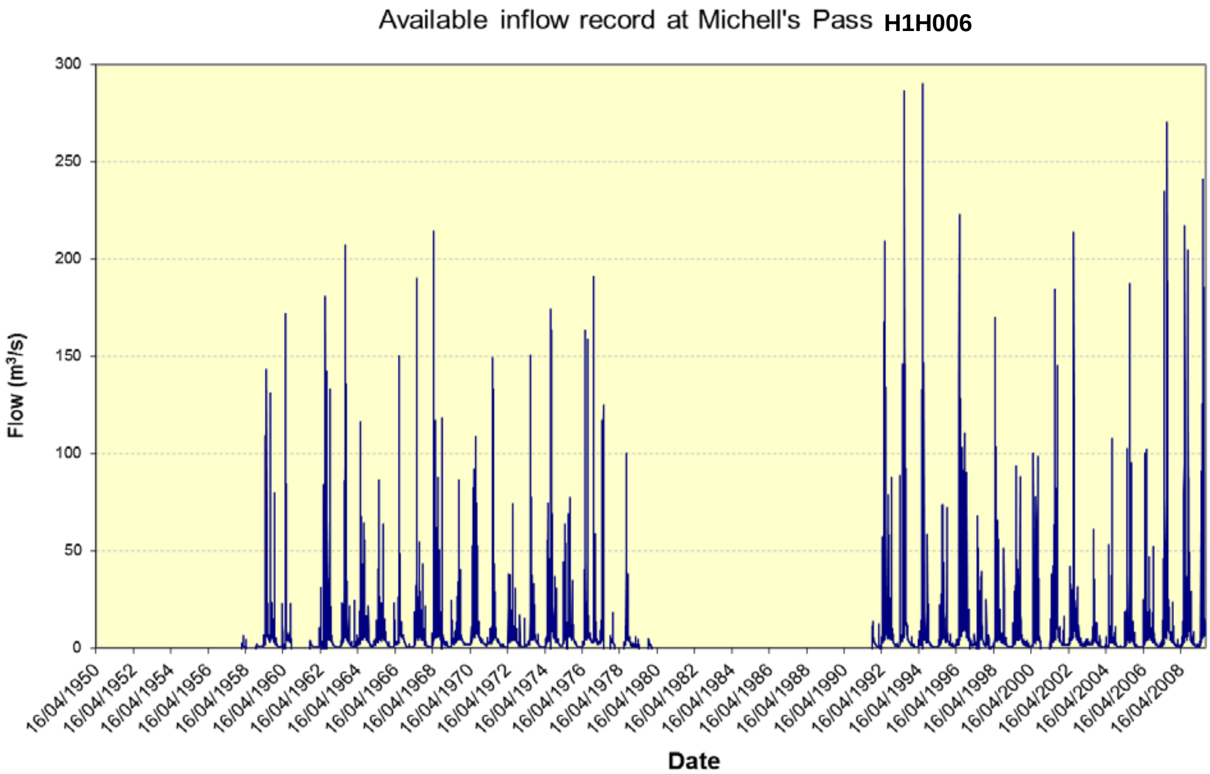


Figure 30: Available Inflow Record at Michell's Pass Gauge H1H006

The earlier stream flows shown in **Figure 30** do not reflect the potential impacts of the raised Koekedouw Dam constructed between 1996 and 1998. The observed stream flows also do not reflect the dam's ultimate impacts when operating at its planned yield. Therefore the modelling analyses to determine the reduction in stream flows at Michell's Pass and further downstream were performed assuming that the dam would be operated to supply its intended yield. In adopting this conservative approach, the baseflow Reserve recommended in the Water Permit issued by DWA was included in the analysis so that the impacts of Koekedouw Dam would be mitigated by the proposed Reserve base flows shown in **Table 7**. However, any freshettes were omitted from the modelling of releases from the dam, because of their submonthly duration and, also, because they would often correspond with higher flows from elsewhere in the catchment, such as those from the Witels River tributary, just upstream of the proposed diversion site.

Table 7: Baseflows Required from the Koekedouw Dam According to the Water Licence Issued by the DWA (Cape Nature 2009)

Baseflow Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	m^3/s											
Normal baseflows	0.1	0.1	0.1	0.07	0.06	0.06	0.08	0.2	0.3	0.3	0.3	0.2
Drought baseflows	0.1	0.05	0.03	0.01	0.01	0.01	0.05	0.08	0.1	0.1	0.1	0.1

Not all stream flows arriving at Michell's Pass would be available for abstraction, given the Reserve requirements. The river downstream of the abstraction site has been allocated the Ecological Class D. The environmental releases from the BBTS were determined using the estimated natural stream flow at the site and a relationship between the natural stream flow and the environmental water requirements for any month.

The relationship used and presented in **Table 8** was developed during the earlier phases of the study and is slightly more conservative than the Preliminary Determination of the Reserve. For discussion purposes three values in the table have been highlighted. The first value of 28.11 million m^3 for October is the natural flow in October with a 20% exceedence probability. The corresponding total Reserve stream flow requirements (i.e. with 20% exceedence in October) for a Class D is 6.61 million m^3 and the corresponding baseflow stream flow Reserve requirements (i.e. also with 20% exceedence in October) is 5.39 million m^3. Where the natural stream flow in a month does not correspond exactly with the tabulated exceedance values, the Reserve requirements need to be interpolated.

The Reserve requirements provided are monthly values. For the purposes of this analysis the stream flows were converted to m^3/s and the baseflow Reserve was used in the daily analysis to determine the stream flow that should be released before abstraction can commence.

Table 8: Reserve Rules for a Class D just Downstream of the Michell's Pass Abstraction Site

Desktop Version 2, Generated on 2009/08/06

Summary of IFR rule curves (Desktop Version 2) for :

Total Runoff : RCSS extra N

Regional Type : W.Cape(wet)

Ecological Category = D

Data are given in million m^3 per month

Natural Duration curves

	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	37.750	28.111	20.860	18.128	16.950	15.131	13.092	11.808	10.689	6.857
Nov	17.955	14.824	10.497	9.248	7.499	6.810	6.125	5.358	4.488	2.798
Dec	8.129	5.679	4.980	4.079	3.405	2.799	2.554	2.320	2.009	1.470
Jan	6.018	3.359	2.408	1.890	1.780	1.649	1.410	1.257	1.180	0.783
Feb	5.648	2.941	1.988	1.673	1.278	1.232	1.098	0.932	0.742	0.285
Mar	7.555	4.439	3.041	1.834	1.349	1.142	1.079	0.780	0.690	0.290
Apr	24.430	15.154	13.154	9.112	6.518	4.688	3.699	1.750	1.079	0.640
May	89.694	56.421	39.475	26.152	21.662	17.760	14.662	8.942	6.297	0.640
Jun	138.759	76.793	63.799	48.361	33.917	27.811	22.235	20.239	11.529	1.150

Jul	110.464	90.198	65.239	55.210	48.416	38.565	28.849	22.967	17.032	9.533
Aug	106.778	82.700	59.516	53.307	47.706	38.820	36.688	32.532	25.695	15.273
Sep	70.250	48.519	42.822	36.882	32.386	28.393	22.895	20.118	16.983	11.495

Reserve flows with High Flows

	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	6.615	6.615	6.575	6.485	6.294	5.916	5.244	4.210	2.962	2.158
Nov	3.241	3.241	3.222	3.180	3.091	2.915	2.601	2.119	1.537	1.162
Dec	1.703	1.703	1.690	1.659	1.589	1.456	1.242	0.968	0.717	0.601
Jan	1.560	1.560	1.548	1.517	1.449	1.319	1.109	0.841	0.595	0.482
Feb	1.024	1.024	1.015	0.992	0.941	0.844	0.688	0.488	0.304	0.220
Mar	0.993	0.993	0.986	0.972	0.940	0.879	0.769	0.601	0.397	0.266
Apr	1.894	1.894	1.880	1.851	1.787	1.663	1.441	1.100	0.688	0.423
May	2.866	2.866	2.849	2.811	2.729	2.567	2.280	1.839	1.305	0.640
Jun	9.291	9.291	9.245	9.150	8.959	8.583	7.865	6.562	4.436	1.150
Jul	6.245	6.245	6.219	6.168	6.063	5.858	5.465	4.753	3.591	2.399
Aug	47.530	43.449	39.815	36.598	33.603	27.814	25.274	20.668	13.149	5.436
Sep	23.417	21.197	19.280	17.606	16.005	13.226	11.450	8.720	5.423	3.299

Reserve Flows without High Flows

	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	5.393	5.393	5.363	5.295	5.151	4.867	4.361	3.584	2.645	2.040
Nov	3.241	3.241	3.222	3.180	3.091	2.915	2.601	2.119	1.537	1.162
Dec	1.703	1.703	1.690	1.659	1.589	1.456	1.242	0.968	0.717	0.601
Jan	1.560	1.560	1.548	1.517	1.449	1.319	1.109	0.841	0.595	0.482
Feb	1.024	1.024	1.015	0.992	0.941	0.844	0.688	0.488	0.304	0.220
Mar	0.993	0.993	0.986	0.972	0.940	0.879	0.769	0.601	0.397	0.266
Apr	1.894	1.894	1.880	1.851	1.787	1.663	1.441	1.100	0.688	0.423
May	2.866	2.866	2.849	2.811	2.729	2.567	2.280	1.839	1.305	0.640
Jun	5.218	5.218	5.196	5.151	5.060	4.880	4.538	3.916	2.901	1.150
Jul	6.245	6.245	6.219	6.168	6.063	5.858	5.465	4.753	3.591	2.399
Aug	8.515	8.515	8.479	8.406	8.260	7.972	7.422	6.423	4.793	3.121
Sep	6.318	6.318	6.283	6.203	6.033	5.699	5.103	4.187	3.081	2.369

Ref (Volume No. 1: EWR data for the Breede River prepared as part of this study)

All of the stream flows remaining after making the Class D baseflow Reserve (Reserve flow without high flow) releases, up to the 5 m^3/s capacity of the abstraction works, is available for transfer by the BBTS. To determine the efficiency of the diversion scheme, the inflows and the transferred water modelled for each day were aggregated into monthly averages and plotted. **Figure 31** shows the scatter of the monthly inflows and corresponding monthly abstractions over the modelled periods. As the Water Resources Yield Model (WRYM) operates on a monthly time-step, it requires a monthly diversion function, i.e. a relationship of average monthly inflow (which is determined in the WRYM) to monthly abstraction. This relationship was determined for the BBTS from the scattered points in **Figure 31** and is shown as the dashed line on that figure, and is presented in **Table 11.** The relationship was checked to ensure that the long term abstraction volume (simulated using a daily time-step) matched the volumes generated by the applying the diversion function to the monthly inflow sequence over the same period.

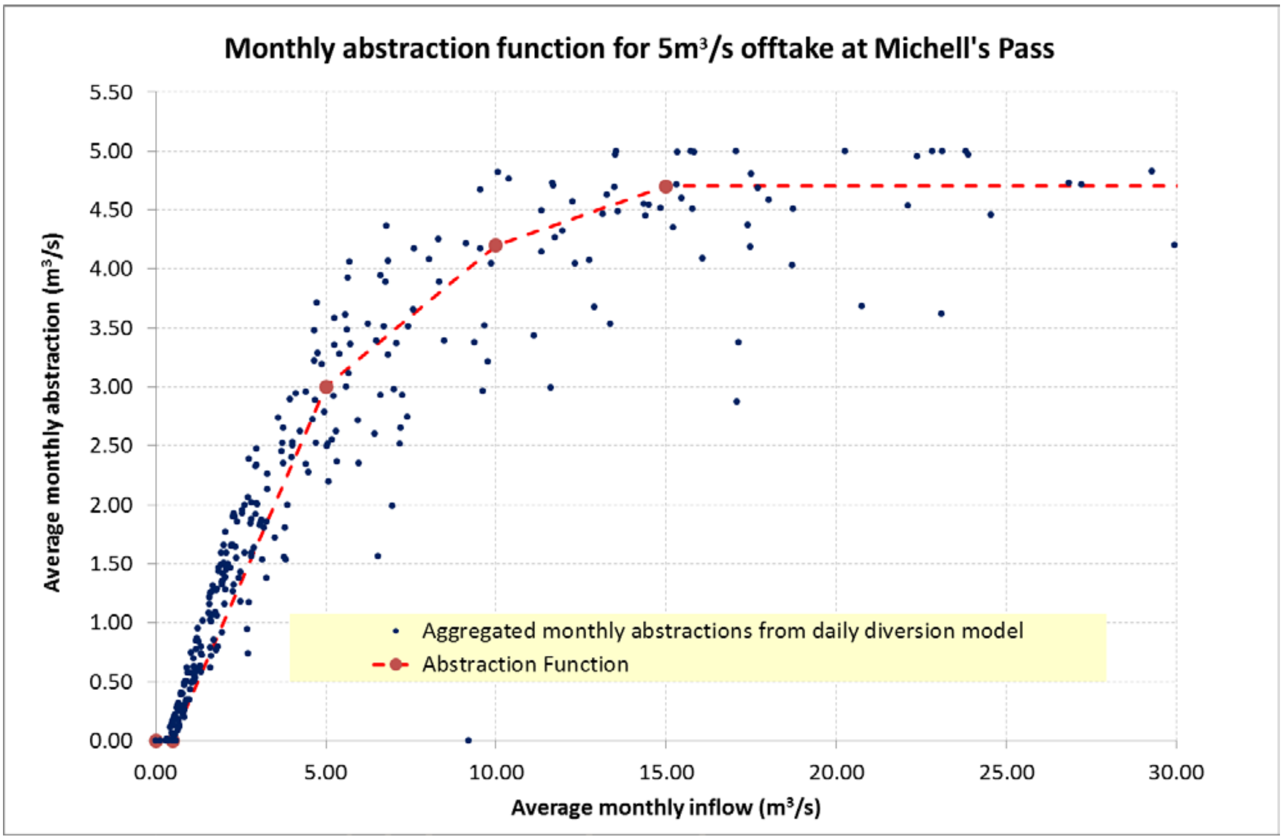


Figure 31: Monthly Diversion Function for the 5m^3/s Daily Diversion at Michell's Pass

Table 9: Diversion Function for Michell's Pass with an Abstraction Capacity of 5m^3/s

Average monthly inflow (m^3/s)	0.0	0.5	5.0	10.0	15.0	100.0
Average monthly diversion (m^3/s)	0.0	0.0	3.0	4.2	4.7	4.7

3.2.3 Modelling the Papenkuils pump station supplying the Brandvlei Dam

3.2.3.1 Alternative schemes investigated by the Breede River Basin Study (BRBS)

The yield of the Brandvlei Dam will be reduced by the proposed diversion at Michell's Pass and additional measures would be required to restore the yield to its current level.

The BRBS (DWAF 2003) evaluated a number of alternative schemes for increasing the yield of the Brandvlei Dam including:

- Increasing the capacity of the Papenkuils pump station.
- Constructing a high level canal from the Smalblaar and Holsloot feeder canals that can help fill the Brandvlei Dam under gravity.
- Increasing the capacity of the existing feeder canals as well as constructing a pump station to help fill the Brandvlei Dam.
- Constructing a new pump station at Riverside on the Breede River.

- Constructing a high level canal/pipeline from Michell's Pass that can help to fill the Brandvlei Dam under gravity.
- Constructing a proposed Ouplaas Dam on the Molenaars River to help regulate the stream flow in the canals supplying the Brandvlei Dam.

The incremental yields, URV's and unit costs have been extracted from the BRBS reports and are presented in **Table 10**.

Table 10: Incremental Yields, URV's and Unit Costs of Schemes that could Potentially Augment the Yield from the Brandvlei Dam from the BRBS (DWAF 2003)

Scheme	Diversion/pump capacity	Incremental yield (million m^3/a)	URV	unit cost
Papenkuils pump station	Pumps at 20 m^3/s, run-of-river	44.2	0.15	0.23
	Pumps at 20 m^3/s, 7.8 million m^3 storage	49	0.18	0.3
	Pumps at 20 m^3/s, 20 million m^3 storage	52.5	0.18	0.3
	Pumps at 20 m^3/s, 27.8 million m^3 storage	58.4	0.18	0.28
High level canal from Smalblaar and Holsloot	5 m^3/s capacity	7	0.48	0.93
	10 m^3/s capacity	14.6	0.26	0.5
	25 m^3/s capacity	23.2	0.22	0.42
Riverside pump station	Pumps at 20 m^3/s, 7.8 million m^3 storage	81.8	0.38	0.65
	Pumps at 20 m^3/s, 20 million m^3 storage	83.7	0.39	0.67
	Pumps at 20 m^3/s, 27.8 million m^3 storage	88	0.38	0.65
increased capacity of existing feeder canals plus pump station about RL207.12m	Increased by 10 m^3/s	16.9	0.68	1.19
	Increased by 25 m^3/s	23.2	0.67	1.18
Ouplaas Dam on Molenaars regulating stream flow in the canals supplying Brandvlei Dam	30 million m^3 dam	24.8	0.83	1.54
High level pipeline from Michell's Pass	8 m^3/s capacity pipeline	20.9	2.45	4.8
	8 m^3/s capacity canal	20.9	1.04	2.04

As part of the BRBS, a multi criteria decision (MCD) approach, that included environmental and socio-economic criteria as well as financial criteria, was used to evaluate these schemes. The option of increasing the 7 m3/s capacity of the Papenkuils pump station was the recommended preferred option from that study, as can be seen in **Figure 32**. Consequently it was assumed that the option of increasing the Papenkuils pump station would be used to restore the yield lost as a result of abstracting additional water from Mitchell's Pass further upstream.

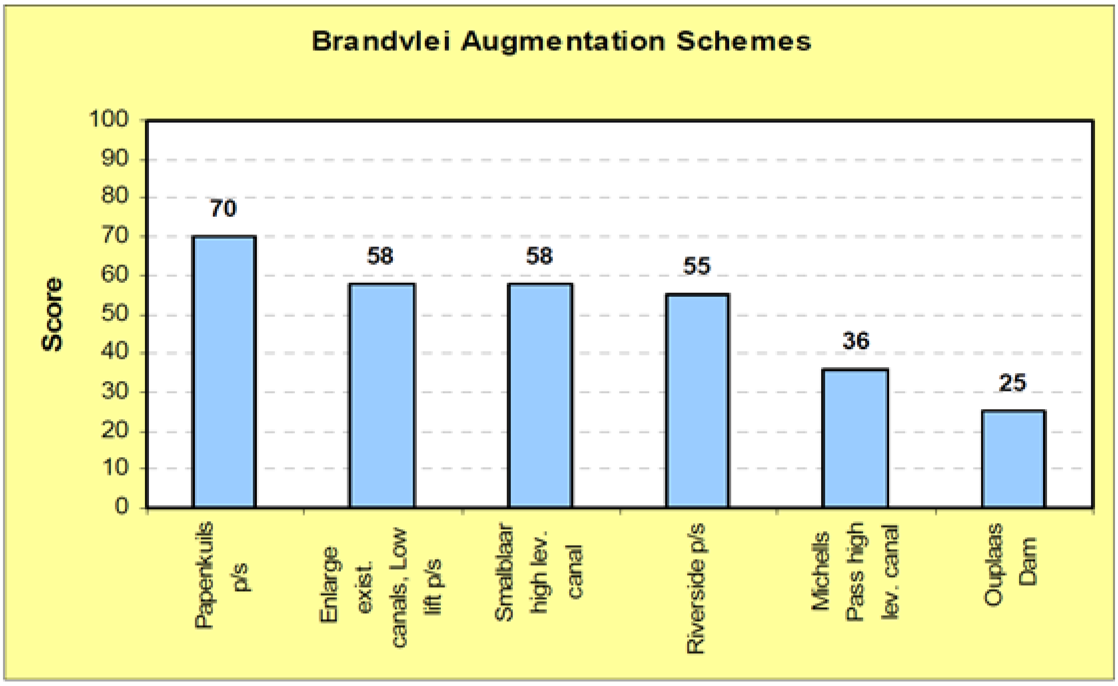


Figure 32: Ranking of the Proposed Schemes for Augmenting the Brandvlei Dam Using a MCD Approach (Ref: BRBS DWAF 2003)

3.2.3.2 Modelling the operation of the Papenkuils Pump Station with the BBTS

The existing Papenkuils Pump Station shown in **Figure 9** has a capacity of 7 m^3/s with all three pumps in operation. The original design made provision for two identical pump stations to be constructed adjacent to the existing pump station which would increase the pumping capacity to about 20 m^3/s with all nine pumps in operation. The pump station delivers water to Brandvlei Dam with a full supply level of 210.5 m and a bottom water level of approximately 195 m. The original crest level of the proposed concrete weir in the Breede River at Papenkuils was 192.5 m however this was not constructed and instead a rubble weir was built.

Transfers from the existing 7 m^3/s pump station at Papenkuils will be affected by the proposed year round diversion at Michell's Pass after meeting the Class D Reserve. Abstraction functions enabling the modelling of these impacts in the monthly WRYM were prepared in a similar manner to those for the BBTS described above. These abstraction functions were also based on daily modelling, with the following considerations taken into account:

- Reduction in stream flows due to the presence of Koekedouw Dam.
- Reduction in stream flows at Papenkuils due to the BBTS.
- The stepped operation of the Papenkuils pump station, whereby the first 2.5 m^3/s pump is switched on when the incoming stream flow is 5 m^3/s and the second 2.5 m^3/s pump is switched on when the incoming stream flow is 7.5 m^3/s, etc. With each increase of inflow of 2.5 m^3/s an additional pump is switched on until the capacity of the pump station is reached. It was also assumed that the pumps would switch off at the same flows.
- The analysis period spans the period 1992 to 2005. The stream flows prior to the establishment of the Greater Brandvlei Dam in about 1989 were ignored.

Figure 33 shows the scatter of average monthly inflows and corresponding monthly abstractions over the modelled periods for the current situation. The relationship of average monthly inflow to monthly abstraction derived from the scattered points for the WRYM is shown by the dashed line in **Figure 33**. **Figure 34** presents similar information for the proposed BBTS scheme, where the proposed Michell's Pass diversion capacity is 5 m^3/s and the Papenkuils pump station capacity is increased to 20 m^3/s in order to develop the extended diversion function.

Table 11 presents the winter abstraction relationships from **Figure 33** and **Figure 34** for the different scenarios analysed. The relationships were checked to see that the long-term simulated abstraction volume matched the volume generated by the abstraction functions over the same period.

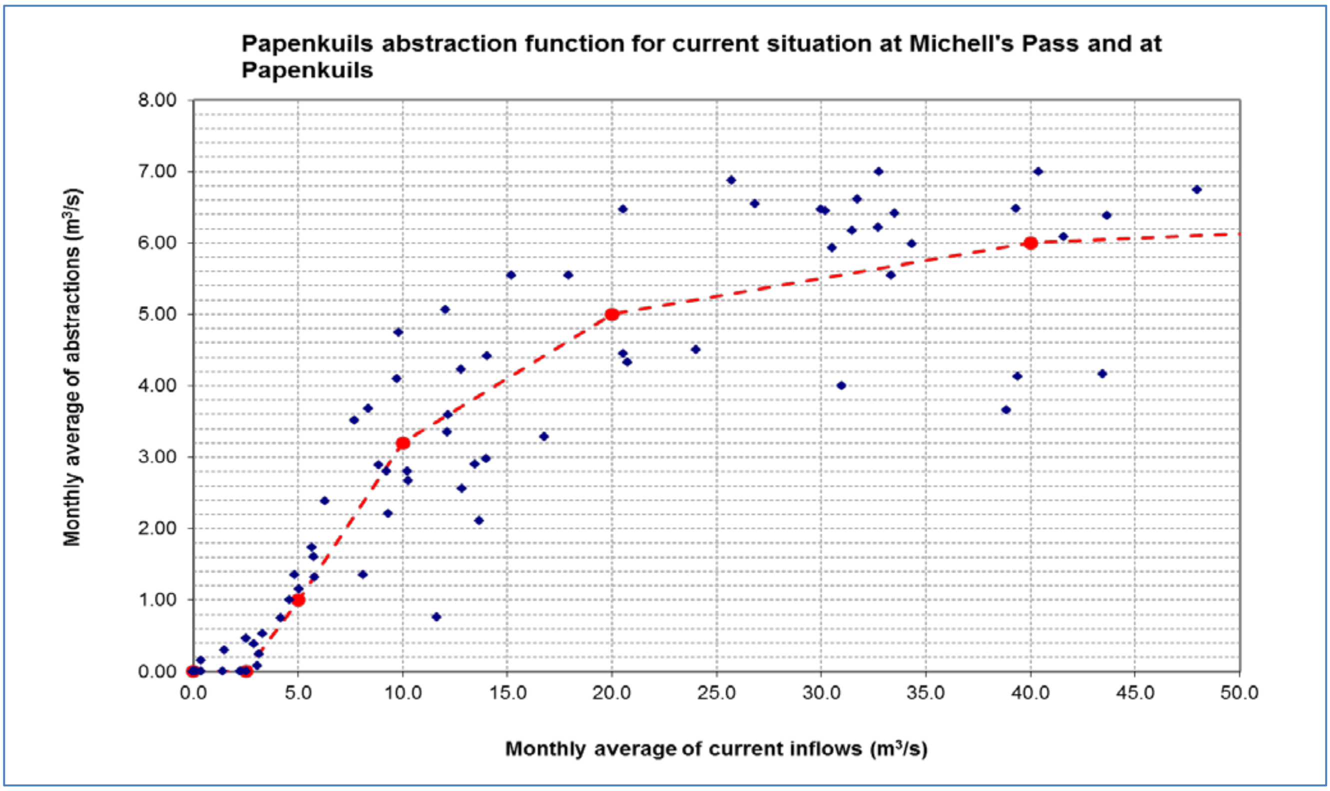


Figure 33: Relationship of Average Inflows to Abstracted Flows at Papenkuils for the Current Situation - Assuming Current Abstractions at Michell's Pass and that the Papenkuils Pump Station Capacity Remains at 7m^3/s

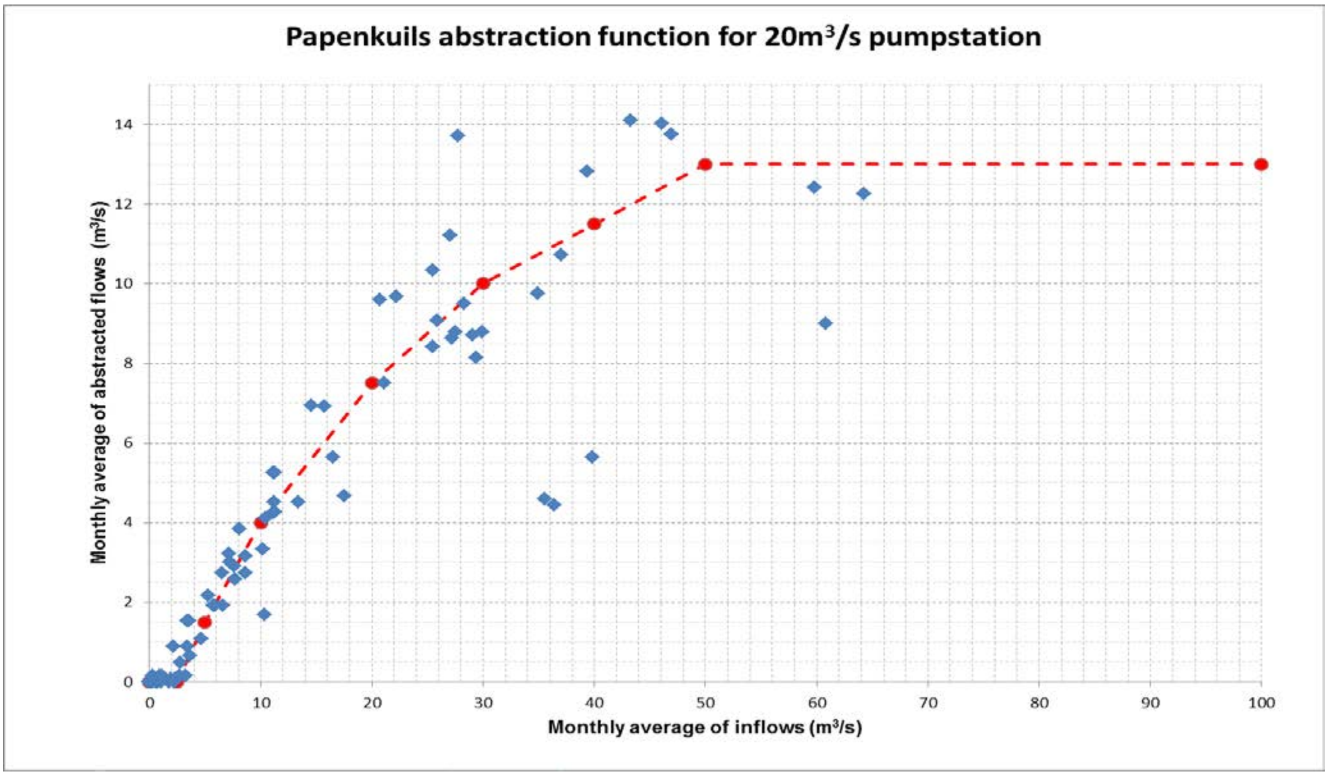


Figure 34: Relationship of Average Inflows to Abstraction at Papenkuils Assuming that Michell's Pass Abstracts 5m³/s Upstream and that the Papenkuils Pump Station has Been Increased to 20m³/s.

Table 11: Relationships of the Average Monthly Inflow to Monthly Abstraction at the Papenkuils Pump Station for the Current Situation and for Various Papenkuils Pump Station Capacities Assuming that the Michell's Pass Diversion has been Increased to 5m³/s

Current Michell's Pass Abstraction												
Inflow (m³/s)	0	2.5	5	10	20	40	80	90	100	110	120	200
Average monthly abstraction for 7 m³/s Papenkuils pump station	0	0	1	3.2	5	6	6.5	6.5	6.5	6.5	6.5	6.5
Michell's Pass Operated at 5 m³/s												
Inflow (m³/s)	0	2.5	5	10	20	30	40	50	100	200	300	400
Average monthly abstraction for 7 m³/s Papenkuils pump station	0	0	0.9	1.9	3.5	4.5	5.25	5.75	5.75	5.75	5.75	5.75
Average monthly abstraction for 12 m³/s Papenkuils pump station	0	0	1.5	3	5	7	8.5	9	9	9	9	9
Average monthly abstraction for 20 m³/s Papenkuils pump station	0	0	1.5	4	7.5	10	11.5	13	13	13	13	13

The winter abstraction at Papenkuils under future conditions was also managed to maintain the baseflow component of the stream flows at current levels at le Chasseur which is shown in **Figure 9.** This was modelled in the WRYM by extracting the baseflow component of the Reserve flows for the present-day simulation. This stream flow was then placed as a "demand" at le Chasseur. This "demand" was supplied before water could be pumped into Brandvlei Dam at Papenkuils. The abstraction at Papenkuils needed to be increased to compensate both for the increased abstraction at Michell's Pass and to try to maintain the baseflow at le Chasseur.

Due to the elevation of the dam the upper 30% of the Brandvlei Dam capacity cannot be filled by the canals from the Smalblaar and Holsloot Rivers and can only be filled using the pump station located at Papenkuils (see **Table 12)**.

This means that if the pump station capacity is increased, more water is pumped into the dam from the Breede River during the earlier months, which shortens the period suitable for filling by the gravity-fed canals. Hence the pumping costs increase more than would otherwise be expected. In order to maintain the yield of Brandvlei and to maintain the baseflow at le Chasseur it would be necessary to increase the capacity of the pump station to 26 m^3/s.

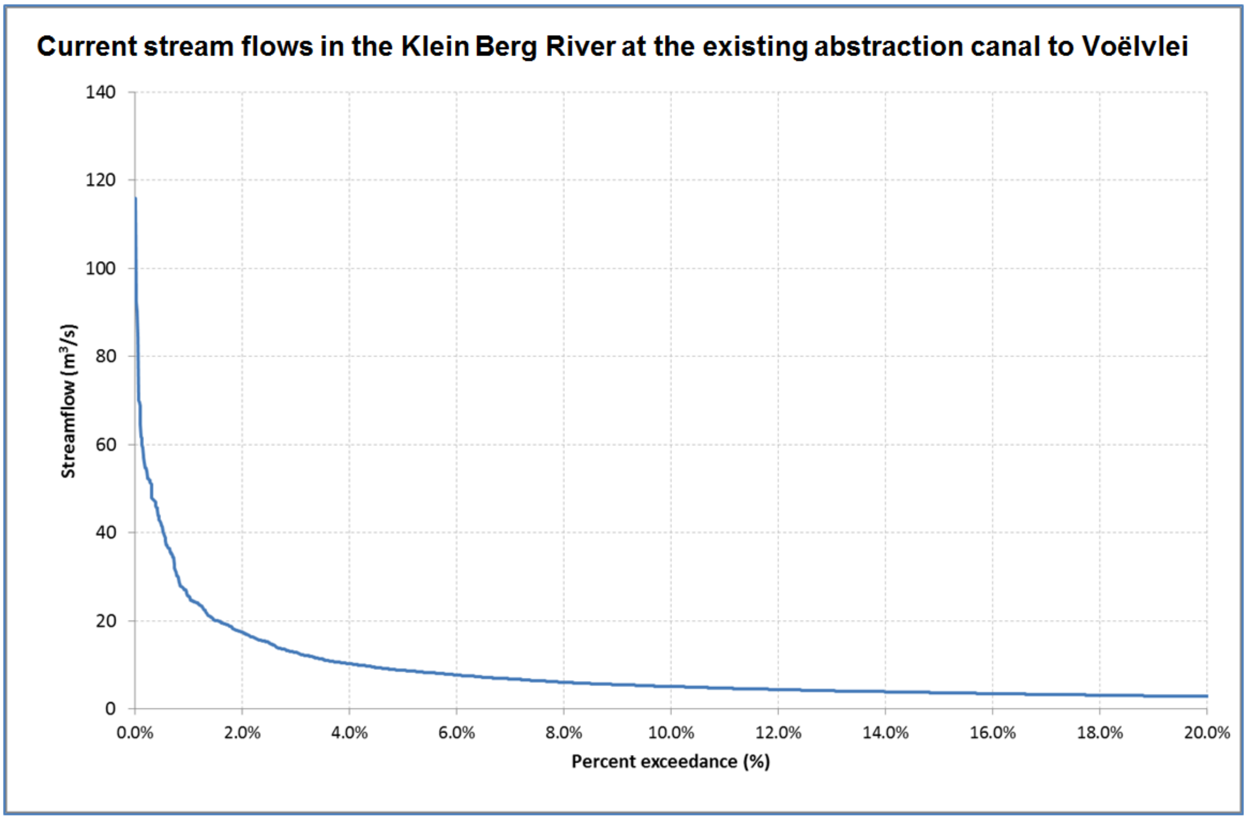
Table 12: Storage Zones in Brandvlei Dam

Total storage above reservoir bottom (million m^3)	Storage above underlying zone (million m^3)	% Active storage in zone
Full supply capacity (RL 210.5 m)		
472	133	30%
Maximum level supplied by canals (RL 207.12 m)		
338	311	70%
Dead storage level (RL 195 m)		
28	28	

3.2.4 Modelling the Boontjies Dam Operation

The capacity of the existing canal from the Klein Berg River to the Voëlvlei Dam is 19.8 m^3/s and the current annual stream flows in the Klein Berg River exceed this capacity about 1.3% of the time (see **Figure 35)**.

Figure 35: Current Annual Stream Flows in the Klein Berg River at the Existing Diversion to Voëlvlei



The proposed diversion of stream flow from the Breede River into the Boontjies Dam would increase the stream flows in the Klein Berg River and result in slightly more spillage at the existing Klein Berg River canal diversion. The abstraction functions used in the WRYM to model the current situation and the transfer of the combined stream flows from the Klein Berg and the proposed Michell's Pass transfer are presented in **Table 13**. This table shows the relationship between the mean monthly inflow and the corresponding mean monthly abstraction.

Table 13: Monthly Abstraction Functions for the Klein Berg River Canal

Current situation without the Michell's Pass transfer												
Average monthly inflow (m^3/s)	0.0	2.9	5.9	8.7	11.6	14.5	20.3	26.1	29.0	31.9	38.0	max
Average monthly abstraction (m^3/s)	0.0	2.9	5.1	6.8	8.3	9.7	12.5	15.4	16.6	17.4	18.6	19.8
Including 5m^3/s Michell's Pass transfer into Klein Berg River												
Average monthly inflow (m^3/s)	0	6.5	10.5	13.6	20.8	40	max					
Average monthly abstraction (m^3/s)	0	6.5	9.9	11.2	14.7	19.8	19.8					

It might be possible to increase the yield of the system slightly if the upper zone of the Boontjies Dam would be actively used to hold water from Michell's Pass for a few days until the peak flows in the Klein Berg River have subsided to 5 m^3/s below the capacity of the canal into the Voëlvlei Dam. However, this was not attempted in this analysis as the yield benefit is not significant in relative terms.

3.2.5 BBTS Yield Analysis Results

The results of the yield analyses are presented in **Table 14** and are discussed below:

- Increasing the capacity of the Michell's Pass abstraction to 5 m^3/s increases the historical firm yield (HFY) of the Western Cape System by 36 million m^3/a.
- If the capacity of the Papenkuils pump station is not increased, this would cause a decrease in the HFY available from the Brandvlei Dam of 16 million m^3/a.
- If the pump station capacity at Papenkuils is increased to 20 m^3/s then the decrease in the historical firm yield would reduce to about 7 million m^3/a.
- Increasing the pump station capacity by 19 m^3/s to 26 m^3/s would fully compensate for the loss of yield in the Brandvlei Dam, from impact of the BBTS.

The incremental 1:50 year stochastic yield from the 5m^3/s BBTS is also 36 million m^3/a, which is the same as the incremental HFY as shown in **Table 14.**

Table 14: Yield Analysis Results

Total Capacity of BBTS (replacing existing Artois canal)	Change in yield of the integrated WCWSS	Total capacity of Papenkuils pump station pumping into Brandvlei Dam	Change in HFY measured at Brandvlei Dam
m^3/s	Million m^3/a	m^3/s	Million m^3/a
HFY Analyses			
5	36	7	-16
		20	-7
		26	0
Stochastic Analyses (1 in 50 year assurance)			
5	36	7	

The further analyses undertaken to refine the operating rules for a 26 m^3/s pump station so as to minimise the impacts on the river downstream are described below.

An alternative stepped operating rule for a 15 m^3/s pump station which would also not affect the yield of Brandvlei Dam and have similar downstream impacts was also assessed, however the more conservative 26 m^3/s option was utilised for the cost estimates.

3.2.6 Ecological Water Requirement (EWR) Impacts

The following section describes the impact of the proposed BBTS (5 m^3/s abstraction at the Michell's Pass and up to 26 m^3/s pumping capacity at Papenkuils) on the ability of the Breede River stream flows to satisfy the recommended EWRs for the Reserve. Stream flows at the five sites shown in **Figure 9** were analysed, namely:

- Immediately downstream of the Michell's Pass diversion.
- Le Chasseur.
- Just upstream of the confluence with the Riviersonderend River.
- The riverine site upstream of the estuary.
- The estuary itself.

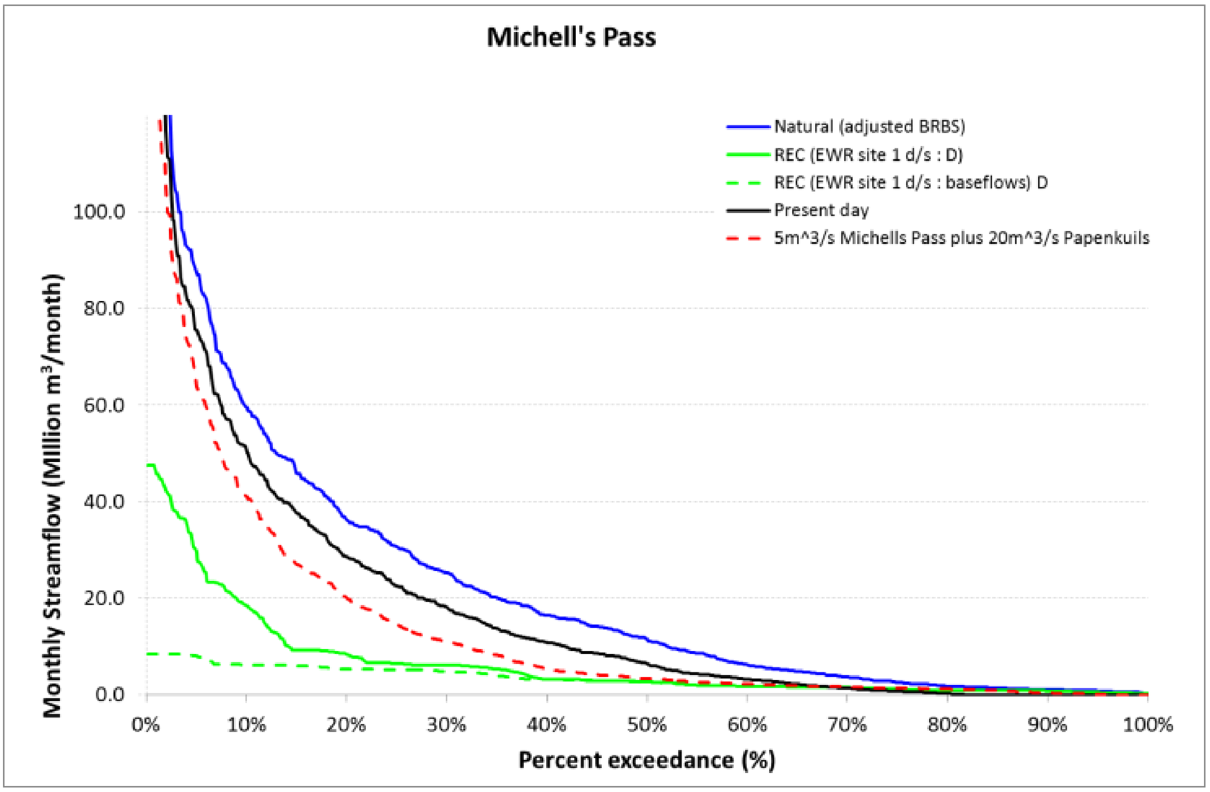
To assess whether there was a decrease in current and future stream flows with respect to the natural stream flows or the recommended ecological stream flows at each of these sites, various stream flow scenarios were compared, namely:

- natural stream flows;
- recommended total ecological stream flows;
- recommended baseflow ecological stream flows (with the exception of the estuary);
- present-day stream flows; and
- stream flows associated with the proposed schemes.

The comparison was done by juxtaposing the percentage exceedence curves, also known as flow duration curves, for the various scenarios. **Figure 36** presents such a comparison of the annual flow duration curves for the Michell's Pass site. The low-flow zoomed version with larger vertical scale (for the lower graph) indicates that for about 15% of the months the "Present Day" stream flow (black line) is below both the total EWR "REC (EWR site 1 d/s : D)" (solid green line), and below the total EWR without high flows "REC (EWR site 1 d/s : baseflows D)" (dashed green line), for both the present-day (black line) and the proposed BBTS scenario (dashed red line). This shows that the BBTS transfer (dashed red line) would improve the situation and would comply with the EWR requirements except for exceedences of more than about 85% when there would be a deficit in low flows.

To investigate the above potential future low flow deficit at the Michell's site in more detail comparisons based on separate flow duration curves for each month were prepared. A sample plot is included in **Figure 37** which shows that the shortfalls identified in **Figure 36** occur in February and March when the present-day stream flows (blue line) drop below the ecological requirements (green line). **Table 15** lists the full set of shortfalls/surpluses at the various EWR sites and **Appendix 5** shows the results for each of the selected EWR sites.

A summary of the plots for the five sites is included in **Figure 36.**



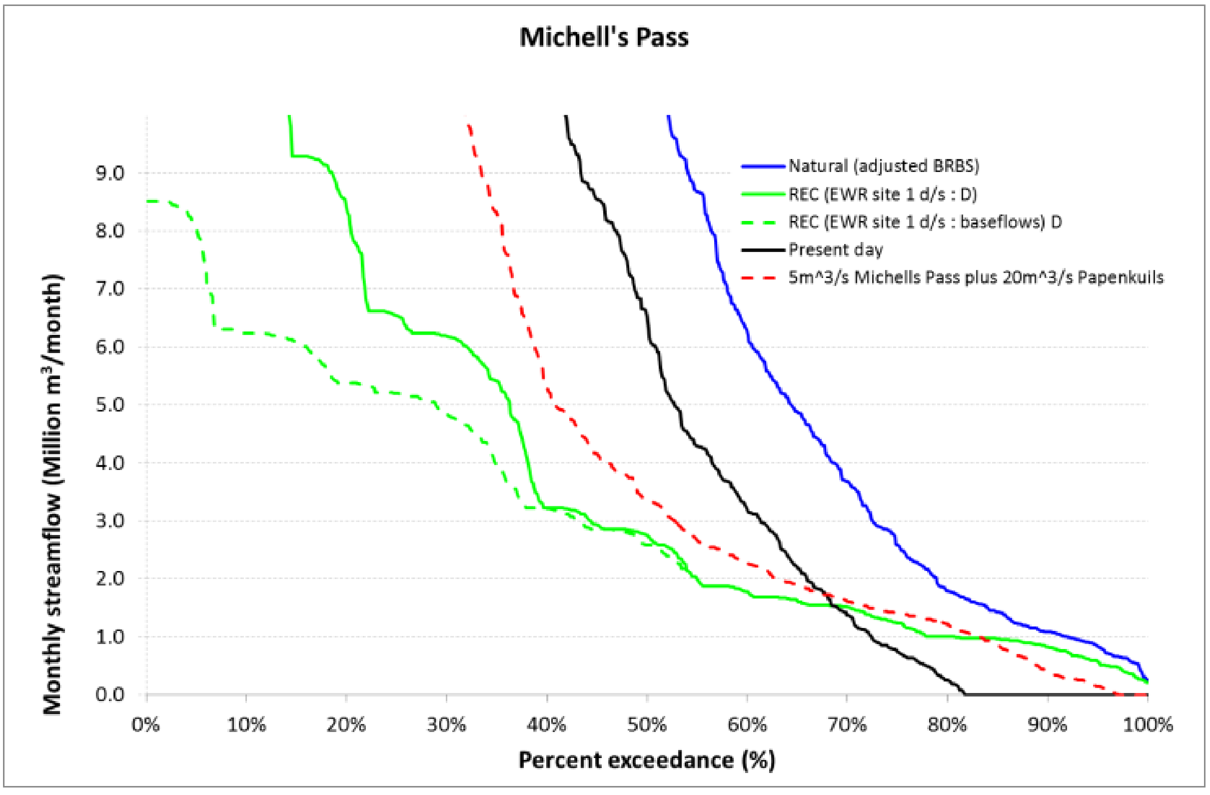


Figure 36: Examples of Monthly Stream Flow Shortfalls Relative to Total EWR (upper graph shows total flow and lower graph shows total flow at expanded scale to identify shortfalls at EWR Site 1)

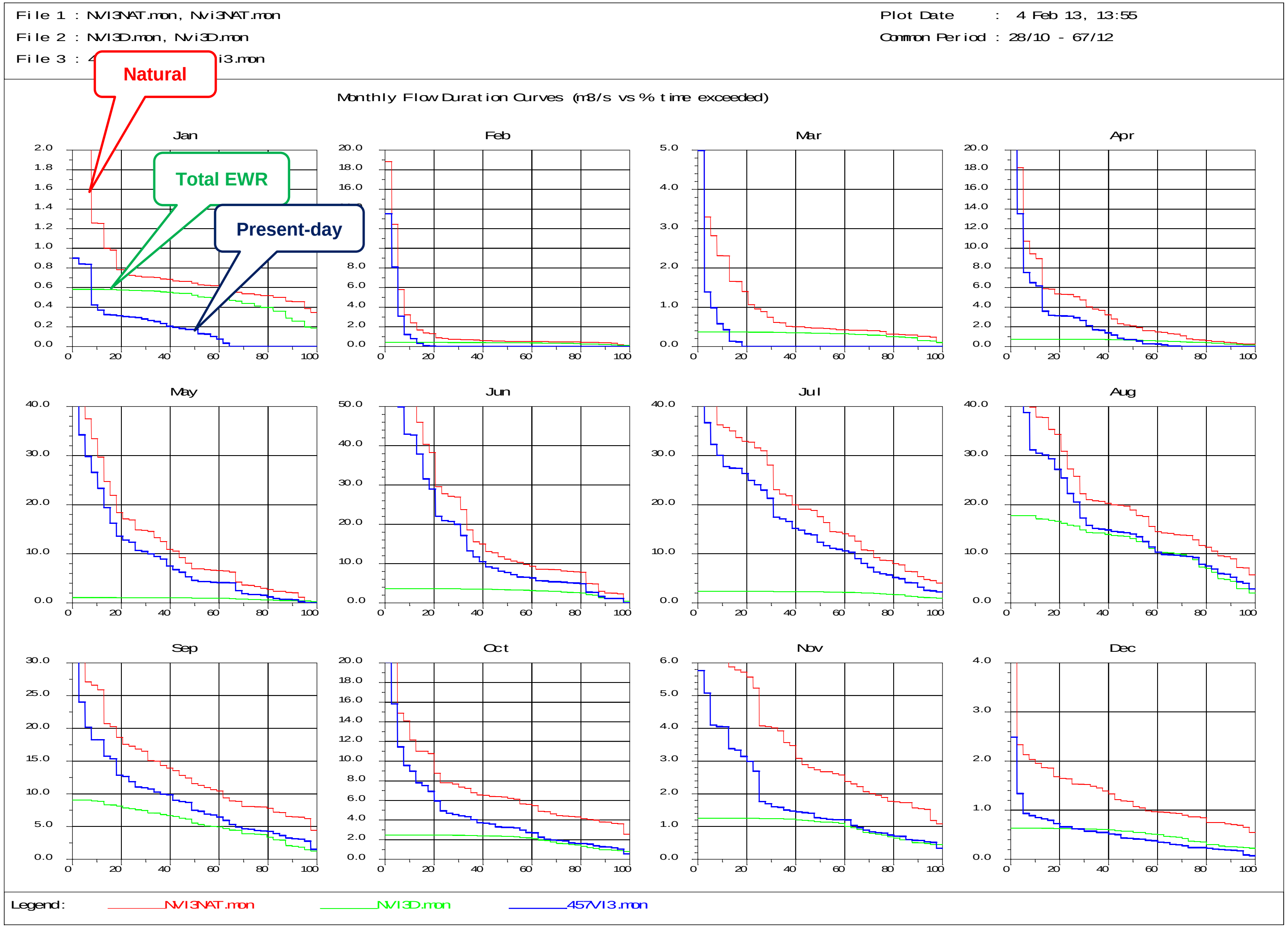


Figure 37: Monthly Natural and Present-Day Stream Flows Relative to Total Monthly EWRs at H1H006 Michell's Pass

The information in the plots provided in **Figures A3 to E3 of Appendix 5** shows the annual flow duration curves for the other IFR sites on the Breede River and estuary in order to compare the shortfalls in EWRs at all the sites. For selected exceedence percentages in each of the annual flow duration plots (such as), the differences between the actual present-day stream flow and the EWR were calculated. The shortfalls associated with the future BBTS were determined in a similar manner and the process was repeated for all the sites of interest and is presented in **Figure 38** allows comparisons to be made between the EWR shortfalls at different sites shown in **Figure 9:**

- Note how at Le Chasseur, downstream of Brandvlei, the present day releases for agriculture during the dry months elevate the stream flows (solid blue line) above the EWR requirements.
- Further downstream, just above the confluence with the Riviersonderend River, the agricultural releases have been largely consumed and the stream flows (violet line) are no longer significantly elevated with respect to the EWRs.
- The shortfalls at the site just upstream of the Breede River Estuary (red line) are very high. This is partly because the recommended Ecological Class of this reach is B/C, which increases the EWRs significantly. The reason for this high classification will need to be investigated when the Breede River Basin hydrology is updated in the future, as it could significantly reduce the water available upstream if releases are made to meet this EWR.
- The shortfalls at the estuary (green lines) are in the order of 5 m^3/s and the present-day (solid green line) and BBTS (dashed green line) scenarios are very similar for exceedences over 60%. It is possible that the exceedences of over 60% would preclude the development of the Michell's Pass diversion scheme and the increased abstraction at the Papenkuils pump station. This would also imply that no further development of the water resources of the Breede River could take place.

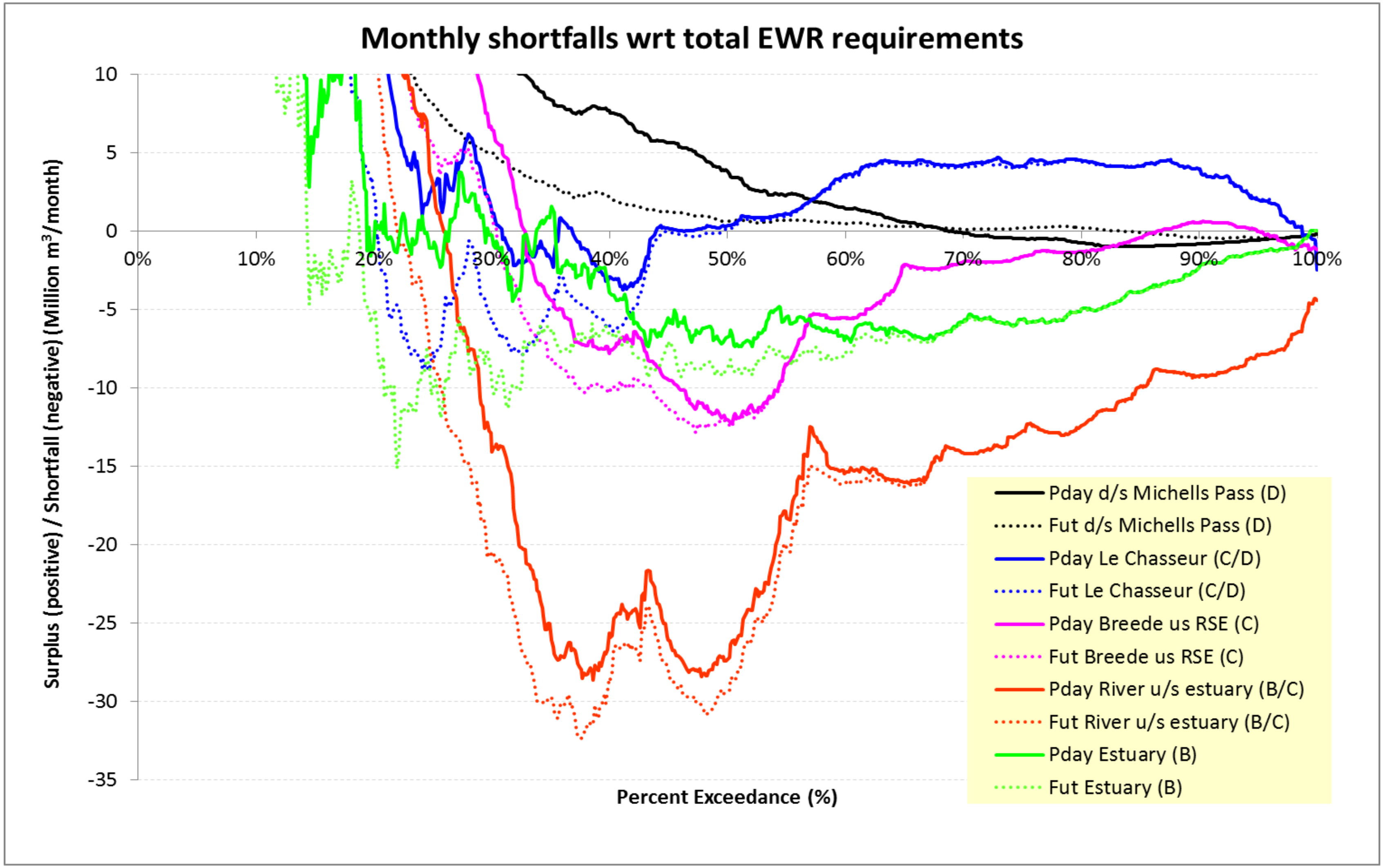


Figure 38: Monthly Shortfall in EWR with Respect to the Total EWRs

3.2.7 Potential impact of Reserve EWRs on yields

It is difficult to assess the potential impacts of restoring the stream flow at the various sites along the Breede River because, determining the actual shortfall itself, is not easily undertaken on unregulated stretches of river.

In the Breede, the EWR sites are not immediately downstream of an in-channel dam that could completely regulate the stream flows immediately downstream (except when such dam would be spilling), and thus release the specified EWRs. Instead, the EWR sites along the Breede River are much affected by upstream regulation that is focused on irrigation and other water supply needs and not on the EWR maintenance per se.

Comparing the annual stream flow at a site with the annual EWR helps to identify sites which are receiving too little water on an annual basis. If the annual stream flows exceed the EWR then at least the site is receiving sufficient water although the distribution of the stream flow throughout the year may not be ideal. **Figure 39** indicates the average annual surplus / shortfall at each of the EWR sites. Note that the largest annual shortfalls occur at the riverine site just upstream of the estuary (red lines), and at the estuary itself (green lines). Shortfalls occur at the other sites as well and additional analysis would be required to determine how the shortfalls are distributed on a seasonal or monthly basis.

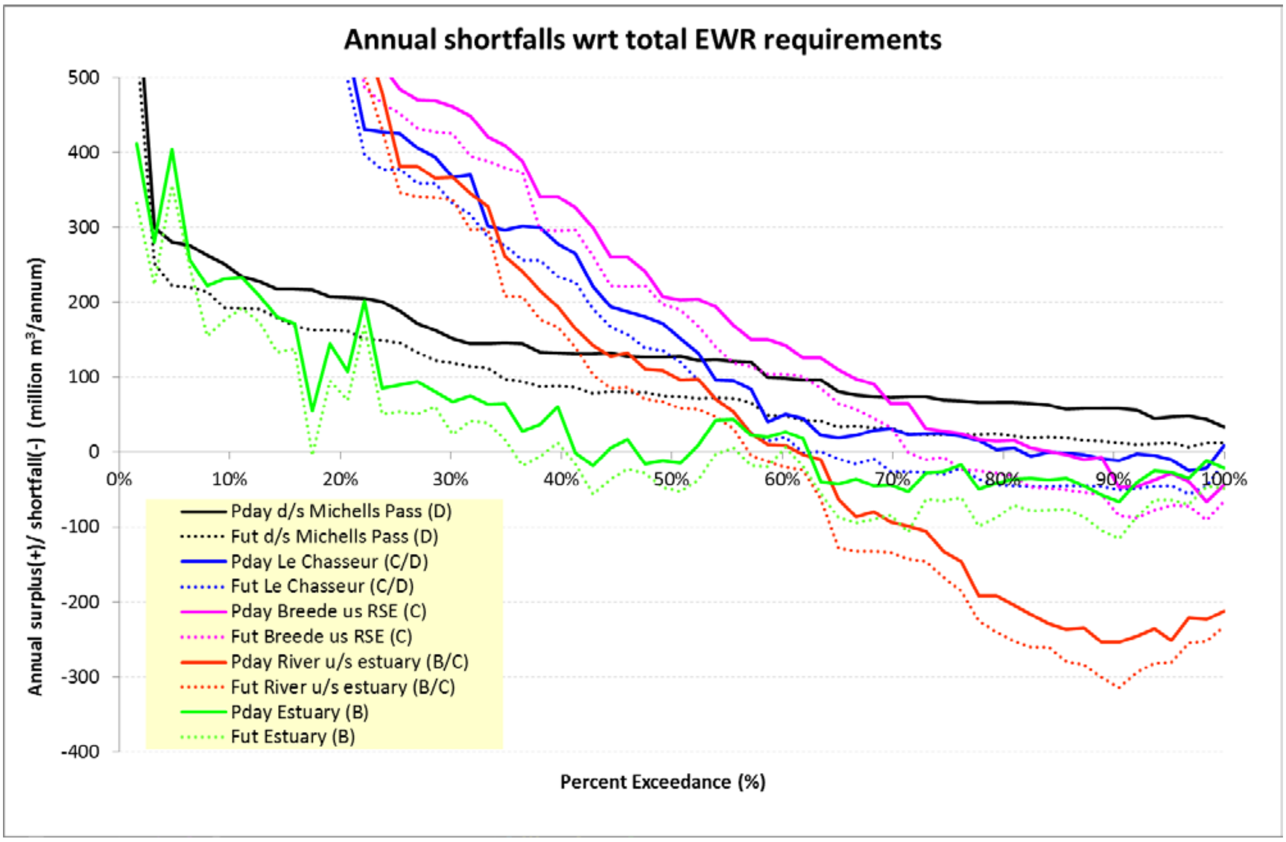


Figure 39: Annual Shortfall in EWR with Respect to the Total EWR Requirements

To assess the shortfalls on a seasonal basis the stream flows from **Figure 38** ("Monthly shortfall in EWR with respect to the total EWR requirements") were subdivided into four categories according to their exceedence percentages:

- 0% - 25% (representing the wettest three months of the year on average);
- 25% - 50% (the next wettest three months on average);
- 50% - 75% (second driest quarter of the year on average); and
- 75% - 100% (representing the driest three months of the year on average).

Because of the highly seasonal nature of the rainfall in the Breede, the driest quartile coincides mainly with late summer and the wettest quartile coincides with mid-winter.

To estimate the indicative yield reduction through meeting the EWR shortfalls, the shortfalls were summed for each of the four ranges of exceedence percentages. Negative values represent a shortfall and positive values a surplus. The total annual value was determined by combining the values for the four quarters. The annual shortfall, if quarters with surpluses were ignored, was also determined. The details of this analysis are included in **Table 15** and summarized in **Table 16**. As shown in the **Table 16** summary, if the impact of the riverine site upstream of the estuary is ignored, then restoring the EWR just upstream of the RSE confluence and at the estuary might reduce the yield by roughly 50 million m^3/a. The proposed Michell's Pass abstraction scheme would increase the shortfall at the estuary by about 20 million m^3/a.

Table 15: Order of Magnitude of the Shortfall (negative) / Surplus (positive) at Different EWR Sites (Figure 9)

Periods			Order of magnitude of shortfall (negative) or surplus (positive) at different sites (million m^3) for the different periods for present-day and future conditions										
			Site	d/s Michells Pass		Le Chasseur		Breede us RSE		River u/s estuary		Estuary	
			EWR REC	D		C/D		C		B/C		B	
			Development	Pday	Future	Pday	Future	Pday	Future	Pday	Future	Pday	Future
Driest 25% months	Million m^3/3-month period	0-25%		-2	0	11	10	-2	-2	-31	-31	-11	-11
Second driest quartile	Million m^3/3-month period	25-50%		9	2	4	3	-22	-24	-61	-65	-18	-23
Second wettest quartile	Million m^3/3-month period	50-75%		26	9	0	-12	-5	-18	-60	-75	-9	-24
Wettest quartile	Million m^3/3-month period	75-100%		112	83	285	256	406	378	410	386	88	66
Total (Million m^3/a)	Million m^3/a			145	94	300	258	377	334	257	215	50	8
Only considering shortfalls	Million m^3/a			-2	0	0	-12	-29	-44	-152	-171	-38	-58

Table 16: Indicative Impacts of Potentially Meeting Shortfalls at Different EWR Sites on Upstream Yields

Site	Recommended Ecological Class	Present-day (million m^3)	Future (million m^3)
d/s Michells Pass	D	-2	0
Le Chasseur	C/D	0	-12
Breede u/s RSE	C	-29	-44
River u/s estuary	B/C	-152	-171
Estuary	B	-38	-58

3.2.8 Proposed operation of the BBTS to meet the Reserve EWRs

This section summarizes how the BBTS would be operated.

Michell's Pass Weir

The ecological base flow releases at the proposed BBTS diversion weir would be adjusted on a weekly or monthly basis using a function based on the inflows to the BBTS weir. This function would be derived using the natural duration curves shown previously in **Table 8**. The function would be as simple as is acceptable to the ecological scientists to simplify the management of the system. These inflows would include the largely unimpacted contribution of the Witels River. If the dams used to store this water (the Voëlvlei Dam and possibly the Boontjies Dam) would be full, then no transfers would be made from the Breede River.

Boontjies Dam

If the BBTS is constructed and releases are made at the diversion weir during the summer months as described above, then insufficient flow would be diverted to meet the irrigation requirements of the Artois irrigation farmers. In order to supply this irrigation deficit during the summer months water would be pumped from the proposed Boontjies Dam.

During the winter months when irrigation demands reduce and the flow in the Breede River is surplus to the Reserve requirements water would be diverted to fill the proposed 7.5 million m^3 (active storage) Boontjies Dam as described in **Section 2.3.6**. After the dam has filled the river flows that would be additional to the Reserve requirements would be released down the Klein Berg River from where they would be diverted via the existing canal into Voëlvlei Dam.

The current stream flows (from its own incremental catchment) into the proposed Boontjies Dam (as opposed to the additional water diverted from Michell's Pass) would be released from the dam as compensation to the downstream users. If a relationship could be developed between these inflows and the stream flows already measured at other sites in the Klein Berg (Watervals : G1H011 or Mountain View : G1H021) then the releases could be a function of these existing stream flows. If an acceptable relationship could not be developed, then a new gauge should be constructed to measure the inflow into the proposed Boontjies Dam from its catchment area.

Option without Boontjies Dam

Should the Boontjies Dam not be constructed, then the new scheme would be used to supply water to the existing irrigators and the surplus would be released into the Klein Berg catchment. In this case, the option of providing increased releases from Koekedouw Dam was considered as described in **Section 2.3.5.2**. Other options that could be considered might be to reduce upstream abstractions, and the removal of invasive alien plants (or combinations thereof).

3.2.9 Proposed operation of the Papenkuils Pump Station toward Meeting the Reserve EWRs

The Papenkuils pump station is currently operated in a step-wise manner. When the stream flow downstream of the pump station reaches 5 m^3/s an additional 2.5 m^3/s pump is switched on until the pump station is operating at full capacity. This allows minimum flows of between 2.5 m^3/s and 5 m^3/s to bypass the pump station. If the abstraction at Michell's Pass is increased to 5 m^3/s then the stream flows at Papenkuils further downstream would decrease. This reduction would in turn reduce the volume that could be pumped into the Brandvlei Dam.

As described in **Section 3.2.5** it was determined that the capacity of the Papenkuils pump station capacity should be increased from 7m^3/s to 26 m^3/s after the proposed BBTS is constructed in order to maintain the present day yield of Brandvlei Dam and the low flow component of the EWR at Le Chasseur (**Figure 9**), which is currently met. It was also determined that if the Papenkuils pump station was instead operated using a stepped pumping rule (whereby the first 2.5 m^3/s pump was switched on when the inflow was 5 m^3/s and additional 2.5 m^3/s pumps were switched on every time the inflow increased by a further 2.5 m^3/s until all the available pumps of the pump station were operational) then a smaller pump station of about 15m^3/s would be required.

This section discusses how the 26 m^3/s pump station would be operated in practice and compares the downstream stream flows for this scenario with the present-day stream flows and with the other future scenario having a 15 m^3/s pump station operated in a stepped manner.

As previously discussed, the 26 m^3/s pump station capacity was derived from a theoretical approach, and the required pump station capacity estimated to maintain the present-day stream flows contributing to the low flow EWR at Papenkuils. However, this operating rule cannot be used in practice and instead a more practical operating rule to benefit the environment and maintain the yield for the irrigators, was derived for the operation of the 26 m^3/s Papenkuils pump station.

The present day stream flows downstream of Papenkuils were compared with the ecological requirements to determine the months with the largest shortfalls (see **Figure 40**). It was determined that the largest shortfalls would occur in May, June, July and October however it was decided to assess rules for operating the pump station to improve the ecological stream flows in May and June. This could be achieved by only commencing pumping in May and June when the inflows at Papenkuils increase to 32.5 m^3/s. For the rest of the year, up until October, the pump station would be operated using the stepped pumping rule with pumping commencing when the inflows reach 5 m^3/s.

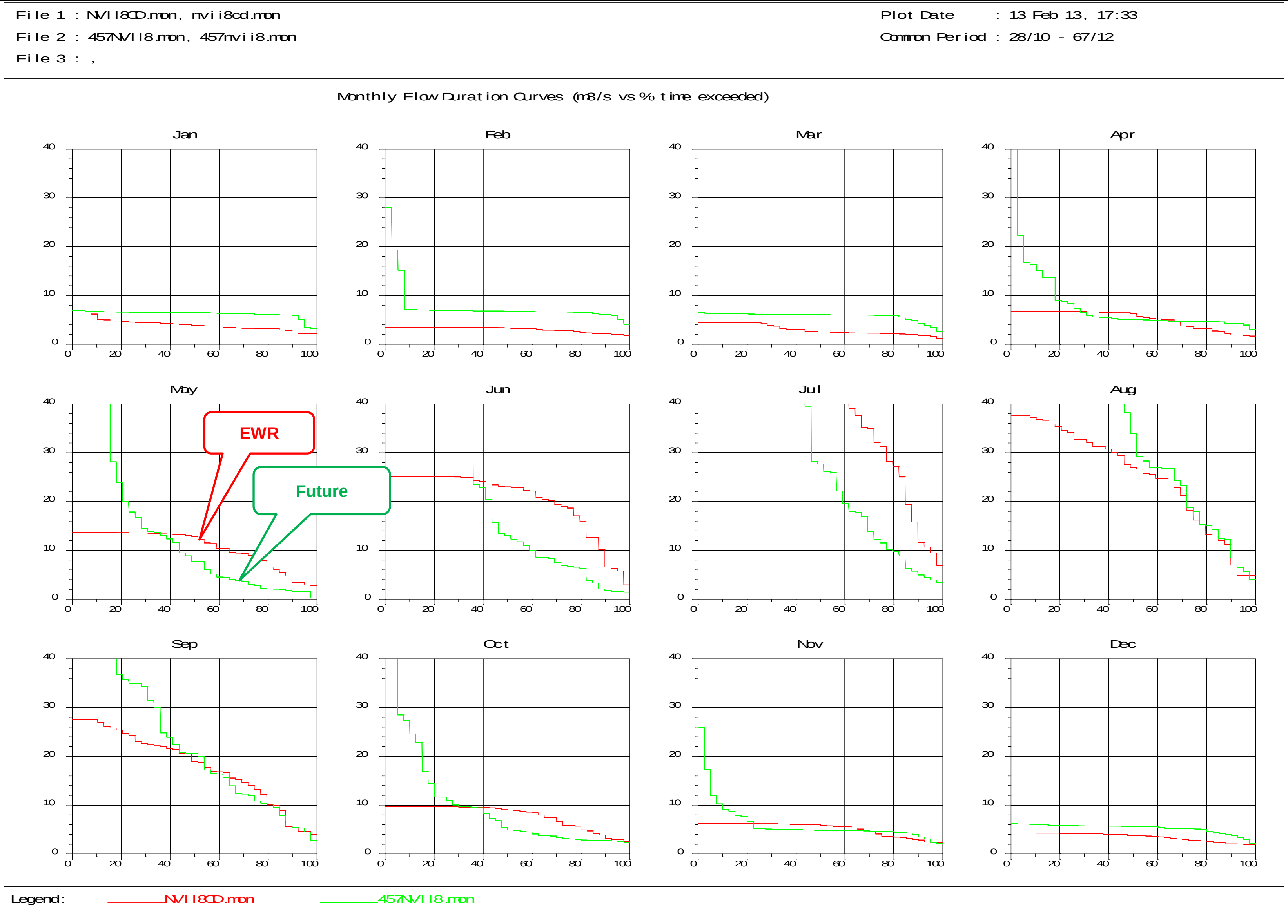


Figure 40: Comparison of the Recommended Ecological Requirement and the Present Day Stream Flows at le Chasseur

With this operating rule there is a risk that, if in any particular year most of the stream flows occur in June, then less water would be pumped into Brandvlei Dam. However, this risk is mitigated to a certain extent because Brandlvei is largely filled by canals in early winter, and their operation would not be affected by this pumping rule. Also, because Papenkuils would start pumping when the stream flows reach 32.5 m^3/s, some of the water from a large flow in June would be abstracted. A daily spreadsheet model was used to compare the annual volumes that could be abstracted assuming that the existing Papenkuils pump station has a capacity of 7 m^3/s and that when the 5 m^3/s diversion scheme is implemented at Michell's Pass the capacity of the Papenkuils pump station would be increased to 26 m^3/s. The results of this modelling of the 14 year flow record indicate that if a 30 m^3/s baseflow is provided at Papenkuils before pumping commences in May and June, then the volume that could be pumped in future would exceed the volume that is pumped under present conditions in all years as shown in **Table 17**. Note that although the volume that can be pumped is sometimes over 200% of the present transfer volume, this larger volume would not be used if Brandvlei Dam has already filled.

Table 17: Comparison of Annual Volumes that could Potentially be Pumped at Papenkuils Under Present and Future Conditions

Calendar year	Current conditions: 7 m^3/s at Papenkuils with current abstractions at Michell's Pass million m^3/a	Future scenario : 26 m^3/s at Papenkuils with 5 m^3/s abstractions at Michell's Pass and baseflow of 30m^3/s past Papenkuils in May and June million m^3/a	Ratio of available water under the present day and the future scenario million m^3/a
1992	90.0	136.8	152%
1993	73.2	124.3	170%
1994	50.5	78.3	155%
1995	58.0	97.6	168%
1996	88.8	202.6	228%
1997	52.8	78.9	149%
1998	51.9	54.3	105%
1999	63.3	89.8	142%
2000	48.2	76.6	159%
2001	72.6	139.3	192%
2002	77.9	114.2	147%
2003	26.2	37.1	142%
2004	29.2	50.6	173%
2005	76.2	98.1	129%

This modified pumping rule was included in the WRYM by using two diversion functions, one for the period from May to June where a 30 m^3/s baseflow was allowed to bypass the pump station, and one from July to October where a stepped pumping rule with a 2.5 m^3/s baseflow was implemented. The relationships for incorporation in the WRYM are presented in the first four rows of **Table 18.**

For comparison, the system was also modelled with a 15 m^3/s pump station at Papenkuils releasing a minimum baseflow of 2.5 m^3/s. The relationship of inflow to abstraction is presented in the bottom two rows of **Table 18.**

The two future scenarios with the 26 m^3/s and the 15 m^3/s both give the same firm yield at Brandvlei Dam as for the present day condition.

Table 18: Relationships Between Average Monthly Inflow and Average Monthly Abstraction that were Incorporated into the WRYM

26 m^3/s pump starting leaving 30 m^3/s baseflow - May-Jun	Inflow (m^3/s)	0	2.5	5	10	20	30	40	50	70	170	270	370
	abstraction (m^3/s)	0	0	0	1.5	3.2	4.3	5.5	6.5	9	9	9	9
26 m^3/s pump starting leaving 2.5 m^3/s baseflow - Jul-Aug	Inflow (m^3/s)	0	2.5	5	10	20	30	45	50	100	200	300	400
	abstraction (m^3/s)	0	0	1.5	4.5	8.5	12	18	18	18	18	18	18
15 m^3/s pump starting leaving 2.5 m^3/s baseflow - May-Aug	Inflow	0	2.5	5	10	20	30	40	50	100	200	300	400
	abstraction (m^3/s)	0	0	1.5	3.3	6	8	10	11	11	11	11	11

Figure 41 shows monthly flow duration curves upstream of the Breede Riviersonderend confluence and compares the ecological stream flow requirements (**green**), present day stream flows (**black**) and stream flows for two future scenarios (the first (**solid red**) assuming 15 m^3/s stepped abstraction at Papenkuils and the second (**dashed red**) assuming 26 m^3/s stepped abstraction but allowing a 30 m^3/s baseflow in May and June. **Figure 41** shows that the operating rule for the 26 m^3/s pump station would help to preserve the low flows so that they remain similar to the present day stream flows while the low flows for the 15 m^3/s pump station would decrease relative to the present day stream flows.

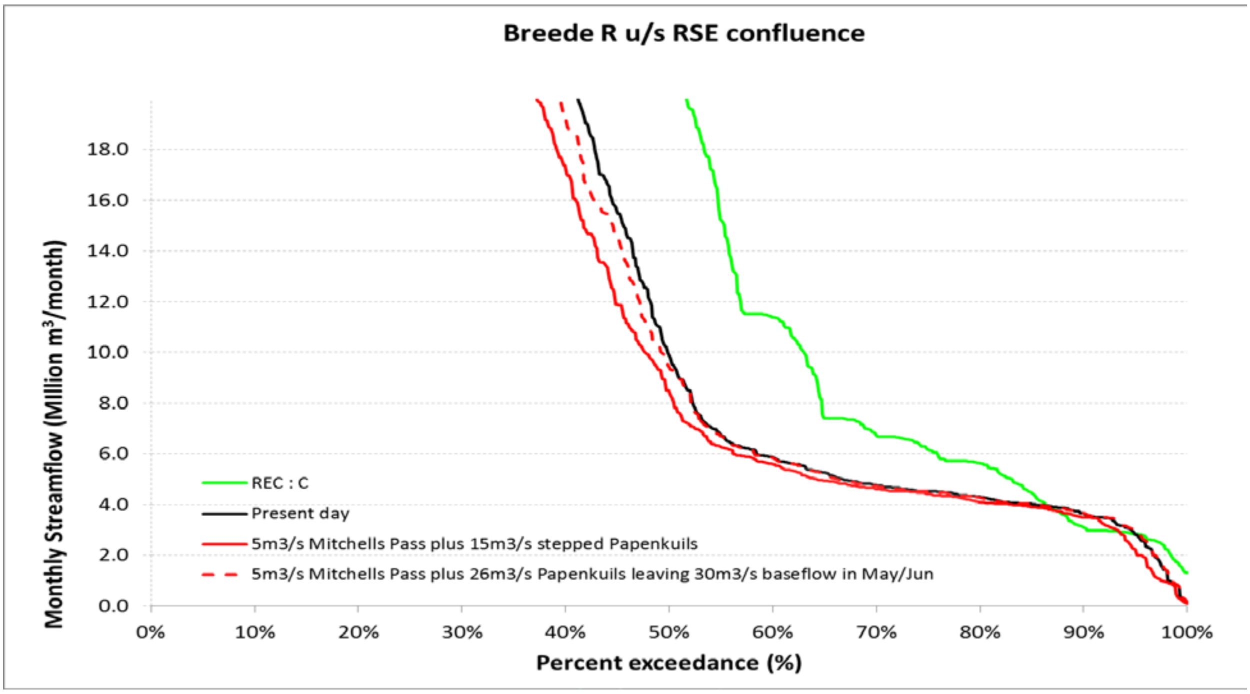


Figure 41: Flow Duration Curves above Breede Riviersonderend Confluence for 15 m^3/s Stepped and 26 m^3/s Pumping Rules at Papenkuils Leaving 30 m^3/s base Flow in May and June

Figure 42 shows the flow duration curves at the Papenkuils site and compares the ecological stream flow requirements (**red**), present day stream flows (**green**) and future stream flows (**blue**), assuming a 26 m^3/s abstraction capacity at Papenkuils and allowing a 30 m^3/s baseflow in May and June. On a month-by-month basis **Figure 42** shows that the operating rule for the 26 m^3/s pump station would also help to preserve the low flows in May, June and October. During July, for exceedances greater than 70% the 26 m^3/s pump station stream flows would be similar to the present day condition. The biggest reduction in stream flows with respect to the present day condition would occur in July, August and September which would be less stressed ecologically than May. Similar trends can be seen in **Figure 43** which compares the present day stream flows and the two future scenarios directly.

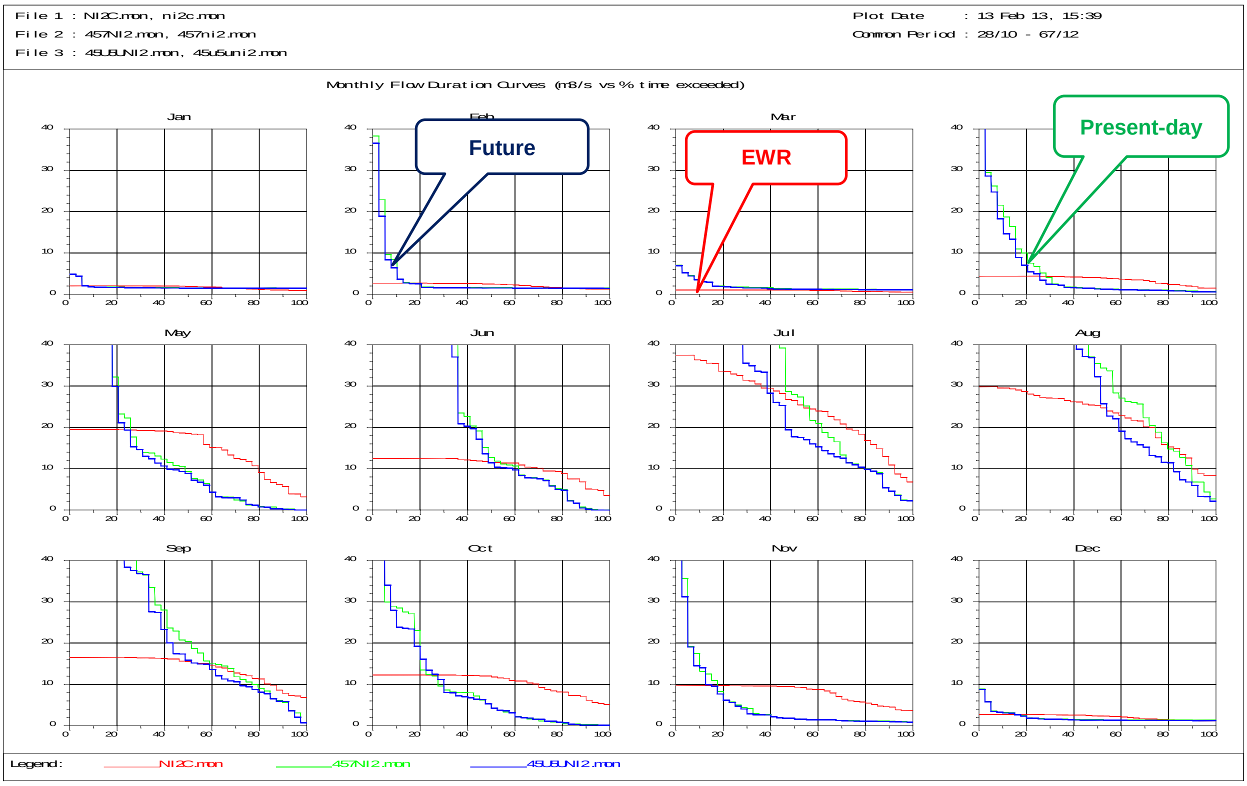


Figure 42: Month by Month Flow Duration Curves for Stream Flows at Papenkuils Site for 26 m^3/s Abstraction Capacity at Papenkuils and Allowing 30 m^3/s Base Flow in May and June

Figure 43 compares the present day monthly flow duration curves at Papenkuils showing stream flows (red) and two future stream flows: one assuming a 15 m^3/s abstraction capacity at Papenkuils following the stepped pumping rule [green] and the other assuming 26 m^3/s abstraction capacity at Papenkuils allowing a 30 m^3/s base flow in May and June [blue]). **Figure 42** and **Figure 43** show that both rules would cause similar reductions in the flow duration curves compared with the present day stream flows.

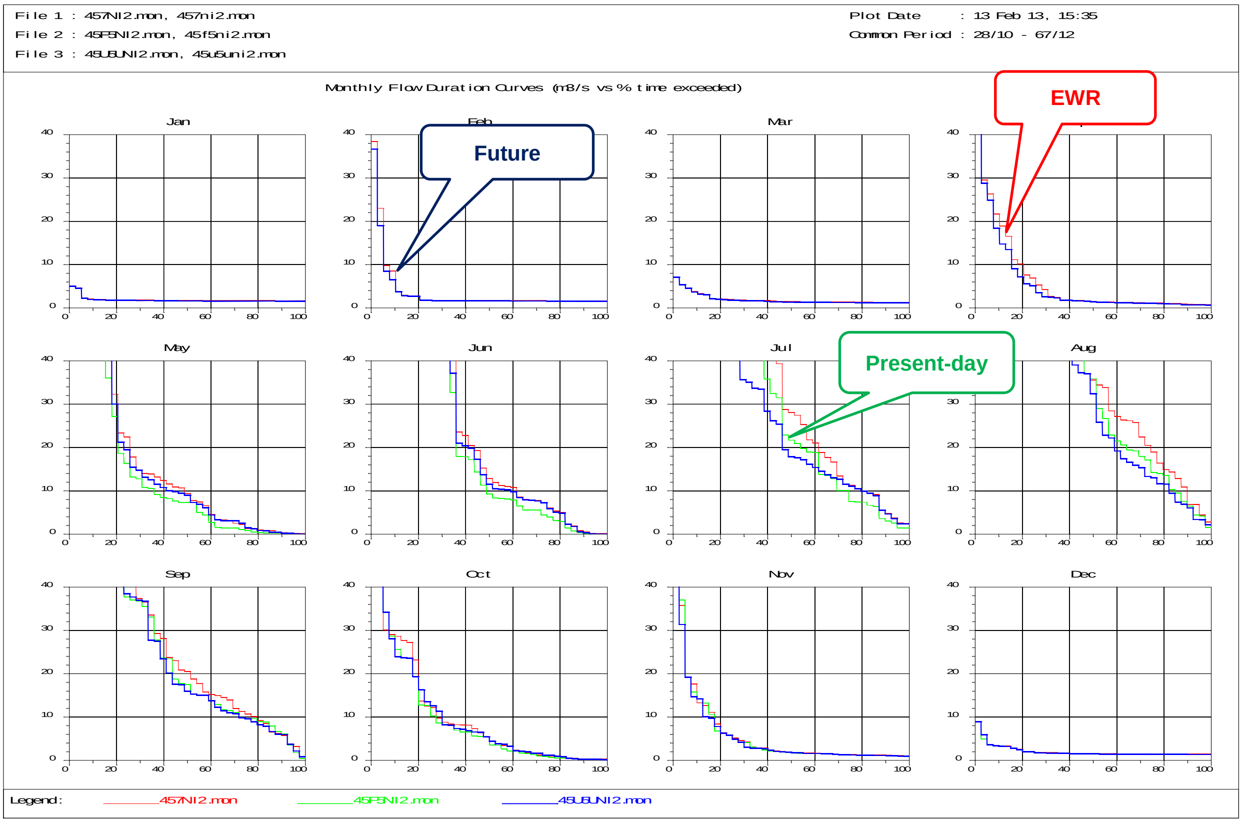


Figure 43: Comparison of Present Day Stream Flows at Papenkuils Site with Future 26 m^3/s Pumping Rule and 15 m^3/s Stepped Pumping Rule

Appendix 5 shows the monthly stream flow sequences for the other sites for which the flow duration plots for the two abstraction rules at Papenkuils are compared. **Table A1** of **Appendix 5** provides a list of the sites that are compared and the corresponding figure numbers.

The following conclusions can be drawn from the analyses:

a) Both the 26 m^3/s and the 15 m^3/s stepped pumping rules allowing a baseflow of 30 m^3/s to bypass the Papenkuils pump station in May / June before pumping commences would help to mitigate the impact of the Michell's Pass abstraction and still maintain the same firm yield at Brandvlei Dam.

b) The daily stream flows at Papenkuils on which these analyses were based are uncertain as they were obtained by factoring stream flows at Michell's Pass and Molenaars which may be attenuated by the time they reach Papenkuils. If flow records were available at Papenkuils pump station, then it might be possible to determine more conservative ecological releases, for example:

- Initially allowing a baseflow of 15 m^3/s (instead of 30 m^3/s) to bypass the pump station.
- Enforcing the high baseflow for May and the first half of June (instead of for the full June month).

The cost estimates have been based on increasing the capacity of the existing Papenkuils Pump Station by 19 m^3/s from the existing capacity of approximately 7 m^3/s to 26 m^3/s, as this would seem to have less impact on downstream reaches, as indicated in **Figure 41** and **Figure 43** than the 15 m^3/s stepped pumping rule. Accurate measurement of the flows at Papenkuils would enable the assessment of future operating rules to be improved.

3.3 CONCLUSIONS AND RECOMMENDATIONS OF THE YIELD ANALYSIS

The Yield and Stochastic Analyses show the following:

- The 1:50 year incremental yield that would be added to the Western Cape Water Supply System through the implementation of the BBTS options after providing for the Class D Reserve requirements of the upper Breede River would be as follows:

> The increased system yield for either of the two alternatives (ie with or without the Boontjies River Dam or without) would **36 million m^3/a** while meeting the Class D intermediate Reserve.

- The diversions at Michell's Pass would reduce the flows in the river reaches downstream and would necessitate increasing the existing 7 m^3 pumping capacity to restore the yield of Brandvlei Dam.
- Various pumping capacities (15 m^3/s and 26 m^3/s) and operating rules for the Papenkuils Pump Station were modelled to restore the yield of Brandvlei Dam without impacting unduly on the present day ecological status (PES) of the river reaches downstream and the estuary. It was concluded that:

> - The capacity and operating rules of the Papenkuils Pump Station could be designed to reinstate the yield of Brandvlei Dam without impacting on the present day ecological status of the Breede River and estuary.
> - Other measures would be required to reinstate the intermediate Reserve requirements of the Breede River downstream of Brandvlei Dam and of the estuary.

The costs estimates in **Section 9** were based on increasing the pumping capacity at Brandvlei Dam to 20 m^3/s, for which provision was made when the existing pump station was constructed.

4. DISTRIBUTION AND POTENTIAL UTILIZATION OF ADDITIONAL WATER - SCHEME INTEGRATION

4.1 INTRODUCTION

The proposed BBTS would augment the supply of the Western Cape Water Supply System (WCWSS) by 36 million m^3/a to enable the system to meet the future growth in the water demands which could not be met by the existing sources of supply. **Figure 44** indicates that even if water conservation and demand management is very successful, augmentation of the WCWSS will be required by about 2020, at latest.

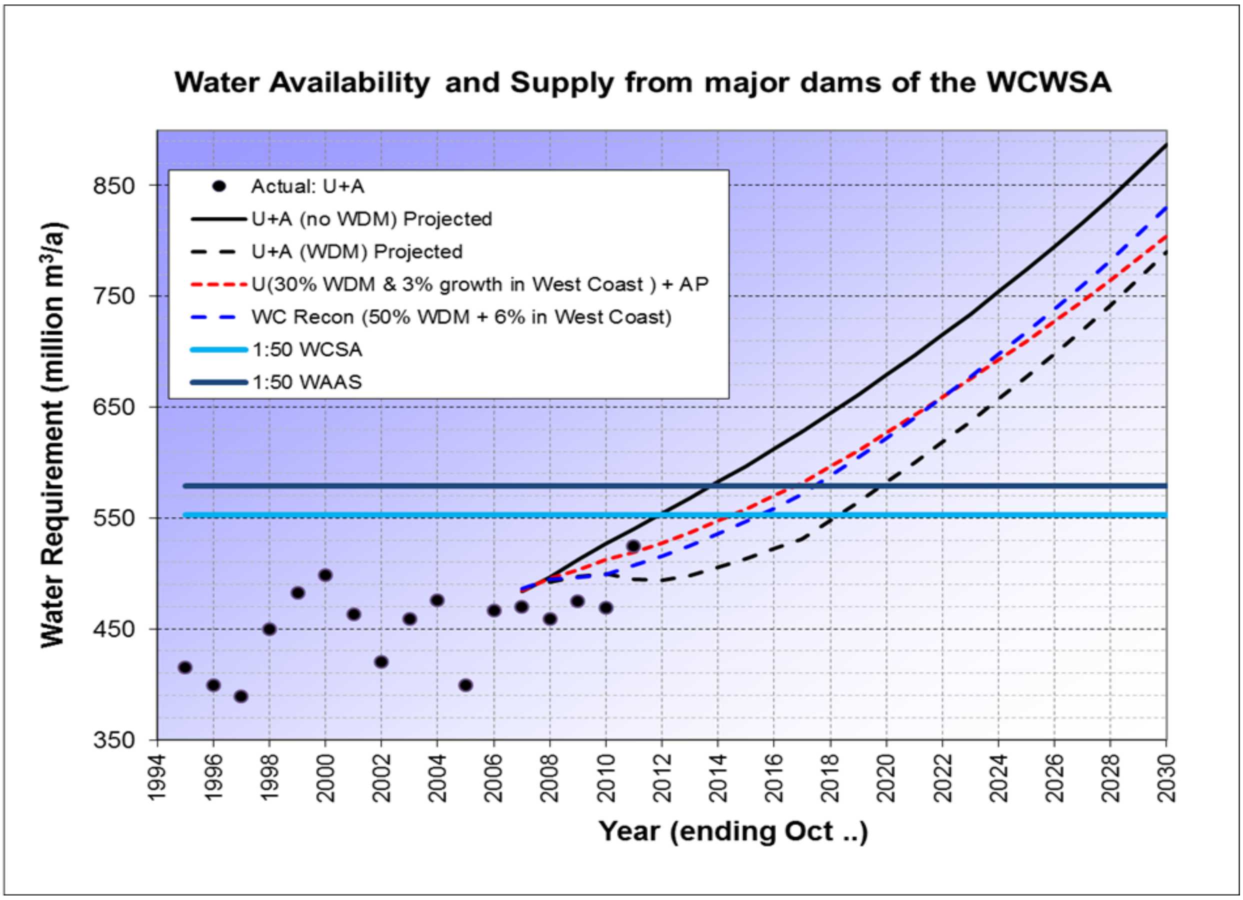


Figure 44: Water Requirement Projection for the Total Supply from the Major Dams

The urban water requirements of the WCWSS that are supplied from the Voëlvlei Dam are those requirements of the CCT which are treated at the Voëlvlei Water Treatment Works and then pumped to the City via the Voëlvlei Pipeline, and the water requirements of the West Coast District Municipality (WCDM). The water requirements of the WCDM comprise water that is piped from the dam to the nearby Swartland Water Treatment Works and water that is released from the dam into the Berg River for abstraction at Misverstand Dam and treatment at Withoogte to supply the Saldanha Bay area.

About 18.1 million m^3/a of water is also released from the Voëlvlei Dam into the Berg River to supply the Lower Berg irrigators downstream of Sonquasdrift.

4.2 CITY OF CAPE TOWN

The existing Voëlvlei Water Treatment Works of the CCT (shown previously in **Figure 6**) has a peak capacity of 273 Ml/day, however routine cleaning of the clarifiers reduces the capacity to about 75% of the peak capacity for 21 days per year. Therefore if operated at maximum capacity, the works could supply 273 Ml/day for 344 days per annum and 205 Ml/day for 21 days per annum, providing a theoretical maximum output of 98.2 million m^3/a.

Very few leaks and bursts of the Voëlvlei Pipeline have occurred since the City replaced the vulnerable sections of this prestressed concrete pipeline. The City also employs a pipeline maintenance team that is permanently on standby to expeditiously repair any pipe breaks or leaks. Thus down time of the pipeline due to breaks such as that shown in **Figure 45** has been minimised.

Figure 45: Typical Pipe Burst on the CCT's Potable Water Pipeline from the Voëlvlei Dam

It is not anticipated that there would be any problems in treating additional water that would be diverted into the Voëlvlei Dam via the existing Klein Berg diversion, or that there would be problems in operating the pumps at the treatment works on a continuous basis. On the other hand power supply interruptions might be experienced and therefore it has been assumed that the maximum output capacity would be about 88 million m^3/a.

The City has determined that the winter requirements on the Plattekloof Reservoir, which is supplied by the Voëlvlei Pipeline, would be insufficient to fully utilise the potentially available supply. However the City is planning the following works which will probably be commissioned by about 2019 or 2020, well before the BBTS could be implemented to augment the supply:

- The construction of a large reservoir at Spes Bona which would be supplied from the Voëlvlei pipeline by the existing link pipeline.

- The construction of a second link pipeline from the proposed Spes Bona Reservoir to Glen Garry Reservoir which would enable an augmented supply of 89 million m^3/a from Voëlvlei to be fully utilized during both the summer and winter months.

The City is also considering the possibility of constructing a reservoir at Koeberg to the North East of Melkbos. This reservoir would enable the Voëlvlei pipeline to serve the growing water requirements of the West Coast, and by reversing the flow in this pipeline it could also serve a desalination plant sited in the vicinity of Melkbos.

It is concluded that if the proposed BBTS is implemented (only possible by 2023) and the proposed Spes Bona Reservoir and the Spes Bona to Glen Gary pipeline are also constructed then a continuous requirement of about 88 million m^3/a could be supplied from the Voëlvlei Dam to Cape Town. **Figure 46** indicates that since 1998 the average annual requirements of the CCT on the Voëlvlei Dam have not exceeded about 60 million m^3/a and therefore with the proposed modifications to the bulk supply system the City could probably utilise about 28 million m^3/a of additional yield becoming available from the BBTS (36 million m^3/a). It is also likely that the balance of the additional yield of about 8 million m^3/a could be utilised by the WCDM or alternatively the capacity of the Voëlvlei pipeline could perhaps be increased, however that investigation is beyond the scope of this study.

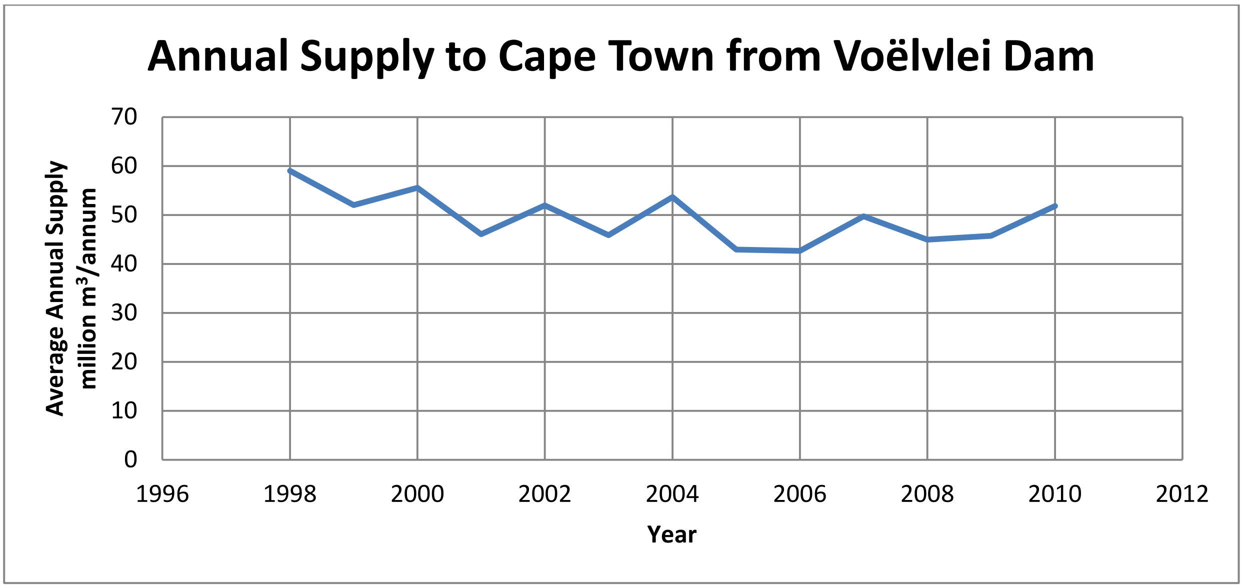


Figure 46: Average Annual Supply to Cape Town from Voëlvlei Water Treatment Works

4.3 WEST COAST GROWTH AND DEVELOPMENTS

It is anticipated that during the hydrological year that commenced in November 2011 the WCDM will utilise about 25.8 million m^3 of water. Some of this water is supplied to the Swartland Water Treatment Works by a short pipeline from the Voëlvlei Dam, and the larger proportion is treated at the Withoogte Water Treatment Works which abstracts runoff in the Berg River at Misverstand Dam during the winter months and releases from the Voëlvlei Dam during the summer months. Assuming that 60% of the demands of the WCDM must be met by releases from the Voëlvlei Dam and that these requirements are growing at the average rate of about 2% per annum then by 2020 the West Coast's requirements on the Voëlvlei Dam will increase by about 3 million m^3/a to approximately 18 million m^3/a and will continue to grow thereafter.

4.4 IRRIGATION REQUIREMENTS

The allocation to the Lower Berg River irrigators is 7 000 m^3/ha/a of which 3 000 m^3/ha/a is released from the Voëlvlei Dam, amounting to 18.1 million m^3/a including provision for losses. The balance of the allocation of 4 000 m^3/ha/a was to be provided by summer run-of-river flows in the Berg River and its main tributaries, namely the Klein Berg River, the Leeu River and the Twenty Four Rivers.

The DWA endeavours to manage irrigation releases from the Theewaterskloof and Berg River Dams to provide a minimum summer flow at Sonquasdrift of about 0.5 m^3/s which provides about 1000 m^3/ha/a to the Lower Berg River irrigators. However to date these flows have averaged between 1.0 and 1.5 m^3/s but may be more closely controlled in the future when the Department's new decision support system is installed. A very small proportion of the summer flows in the tributaries reaches and contributes to the flow in the Lower Berg River and together probably amount to about 500 or 1 000 m^3/ha/a. Therefore the Lower Berg River irrigators currently experience shortfalls in the supply of the balance of their allocation of 4 000 m^3/ha/a as it seems that the Lower Berg has been over allocated.

If the DWA proceeds with the proposed BBTS then it is a possibility that that the Lower Berg Irrigators may wish to contribute financially to the proposed scheme in order to augment their present limited allocation to closer to their scheduled allocation from the rivers, of 4 000 m^3/ha/a.

DWA is currently undertaking verification and validation of existing water allocations from the Berg River which may clarify the situation regarding the existing irrigation allocations.

5. TOPOGRAPHICAL SURVEY INFORMATION

5.1 INTRODUCTION

Preliminary design associated with this feasibility study required more accurate survey data than was available for the study area at the commencement of the project. The preliminary investigations during Phase 1 of the project were based on readily available information such as 1: 10 000 orthophotos, which provided contour information at 5 m intervals. DWA had made provision for undertaking a topographical survey as part of this study so as to obtain the necessary level of survey information to support preliminary design. Contour intervals of a minimum accuracy of 0,5 m were envisaged as being adequate for this purpose.

A LiDAR survey (with the Fli-Map LiDAR System) and aerial photography using a Digital Mapping Camera (DMC) was undertaken by Fugro Maps South Africa. This spatial data processing company had a proven track record on other projects in which members of this Western Cape Water Consultants Joint Venture had been involved.

The resulting report entitled 'Voëlvlei Dam, Final Report, Fli-Map Aerial Survey/DMC Camera' dated March 2011 is contained in **Appendix 9**, including the digital survey information and output data on DVD. The surveyed area covers both the potential Berg River-Voëlvlei Augmentation (BRVA) scheme and this BBTS.

5.2 AERIAL SURVEY

5.2.1 Description of area surveyed

The Fli-Map LiDAR acquisition was undertaken on 9th January 2011. The coverage of the surveyed area is shown on **Figure 46.** It should be noted that the survey for both the potential BBTS and the BRVA Scheme potential was undertaken at the same time, covering a total surveyed area of 1217 ha. The latter scheme forms the subject of its own feasibility study report.

The area surveyed was selected based on the most likely extent of the corridor into which the proposed scheme alignments would be located.

The aerial survey is only suitable for those areas which lie above water surfaces and it is not possible to obtain bathymetric information (survey levels below water surfaces) in this way. However, at the time of the aerial survey, the water levels in the Breede River at the proposed diversion weir site were very low. As such the results of the LiDAR survey at the site are such that they are adequate for determining river cross sections and therefore no further topographical survey of the river section at the weir or upstream of it was necessary.

5.2.2 Accuracy of the Aerial Survey

Fugro Maps initially indicated a guaranteed vertical accuracy of within 15 cm. On completion and after analysis of the survey results, it was concluded that the vertical accuracy achieved was in fact within 3 cm (root mean square of the z value is 3 cm). Details of the specific values pertaining to data resolution and accuracy are enclosed in the aerial survey report in **Appendix 9**.

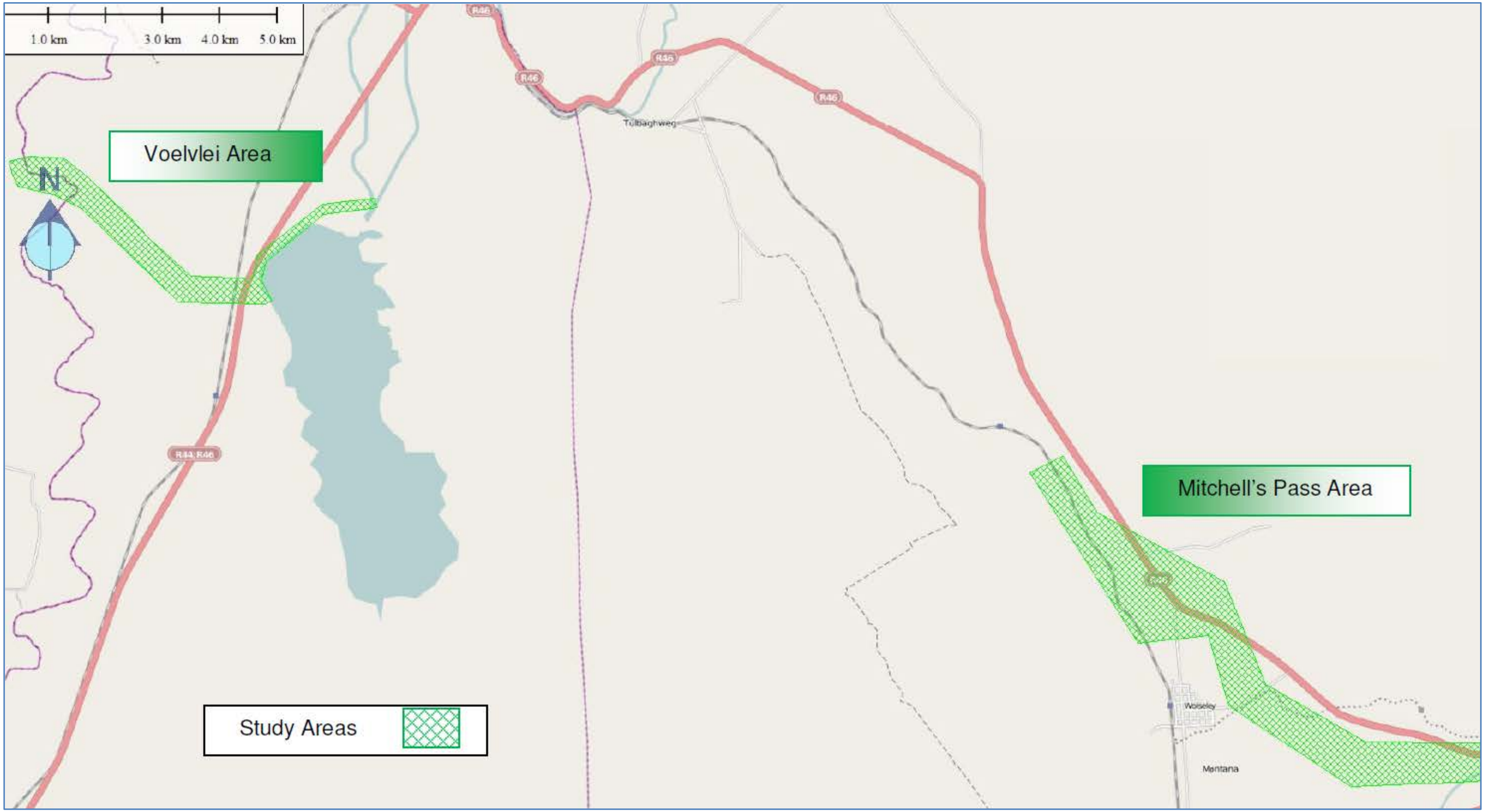


Figure 47: Extent of the LiDAR Aerial Survey Undertaken

5.2.3 Survey Deliverables

The main deliverables of the Michells Pass component of the survey is a set of 58 maps at a scale of 1:1000 with contours at intervals of 0.5 m. These are available in digital format, and are included on the DVD accompanying this report.

The following information and topographical features are indicated on each of the 1:1000 maps:

- trees,
- cultivation,
- rivers,
- main, secondary and farm roads,
- erf boundaries,
- areas of cut and fill adjacent to roads,
- buildings,
- railways,
- power line infrastructure,
- pipelines, pump stations,
- irrigation furrows and canals,
- direction of river flow,
- manholes,
- irrigated and other lands,
- erosion features,
- level crossings, and
- X and Y co-ordinate grid lines at 200 m intervals.

The following deliverables from the survey are captured on the DVD that accompanies this report:

- 0.5 m contour intervals in DSF, DGN and DWG format;
- LiDAR (Ground) in an X,Y,Z format
- Imagery (set of 1:1000 aerial photographs) in a Tiff and ECW format (0.15 m resolution)
- 2D Line Mapping (DGN, DWG and DXF format)
- 2D Line Mapping Plans at 1:1 000 scale (DGN, DWG, DXF and PDF files)

At the time that the LiDAR survey was flown, the concept of a potential dam on the Boontjies River to assist towards the provision of water for the EWRs had not been part of the study scope. As such, the dam site has not been captured in the survey results. Consequently, the potential Boontjies Dam has been investigated at a pre-feasibility study level only making use of existing 1:10 000 orthophotos (5m contours) and this will need to be investigated to feasibility level if this scheme option is ever implemented.

6. GEOTECHNICAL INVESTIGATIONS

6.1 INTRODUCTION

DWA had allowed for geotechnical investigations to be undertaken in order to provide support to the preliminary design of the proposed BBTS diversion, the gravity main and the related energy dissipation structures, erosion protection measures and ancillary structures in the receiving catchment. The investigations were undertaken by Fairbrother Geotechnical Engineering cc (FGE) on the basis of a scope of work and pricing schedule developed by the WCWC JV. FGE subsequently appointed R.A. Bradshaw & Associates cc, Consulting Engineering Geologists as the specified independent Professional Service Provider to provide professional services related to the interpretation of the drilled boreholes, excavation of trial pits, laboratory testing, administration of the geotechnical investigations, reporting and liaison with the WCWC JV.

The feasibility level investigations were conducted in May, June and July 2011. For the BBTS they comprised mapping of the bedrock and the excavation of thirteen trial pits along the proposed pipeline route from the proposed diversion weir site to the potential discharge locations in the adjacent Berg WMA (Boontjies and Blousloot Rivers). Due to the alluvial nature of the geology at the proposed weir site (verified in the geotechnical investigations undertaken for the widening of the bridge at Witbrug during the upgrading of the Michell's Pass), no drilling was considered necessary at the weir site.

As was the case for the survey information, at the time that the geotechnical investigations were undertaken, the concept of a potential dam on the Boontjies River to assist towards the provision of water for the EWRs had not been part of the study scope. As such, the potential Boontjies Dam site has not been investigated to the level of geotechnical detail that would be required to support a preliminary design, and the dam has been investigated at a pre-feasibility study level only.

The full geotechnical report is enclosed in **Appendix 8** and a summary of the investigation is provided in the following sections.

6.2 TRIAL PITTING

Thirteen trial pits were excavated at the designated positions along the proposed BBTS gravity pipeline route. The positions of these trial pits are shown in **Figure 48** and were based on an approximate spacing of 1 every 500 m, sited to have least impact on existing infrastructure and on private land. A wheel-mounted excavator was used instead of a track-mounted excavator because of landowner objection to potential damage caused by a track-mounted machine. The pits were extended to the practical limit of excavation or refusal. The limit was either at approximately 3 m depth, or at depths at which massive collapse of the sidewalls of the pits prevented deeper excavation without excessive lateral extension of the pits. The soils exposed in the sidewalls of the pits were described according to standard South African practice and the descriptions of the soil profiles are presented in the geotechnical report enclosed in **Appendix 8**.

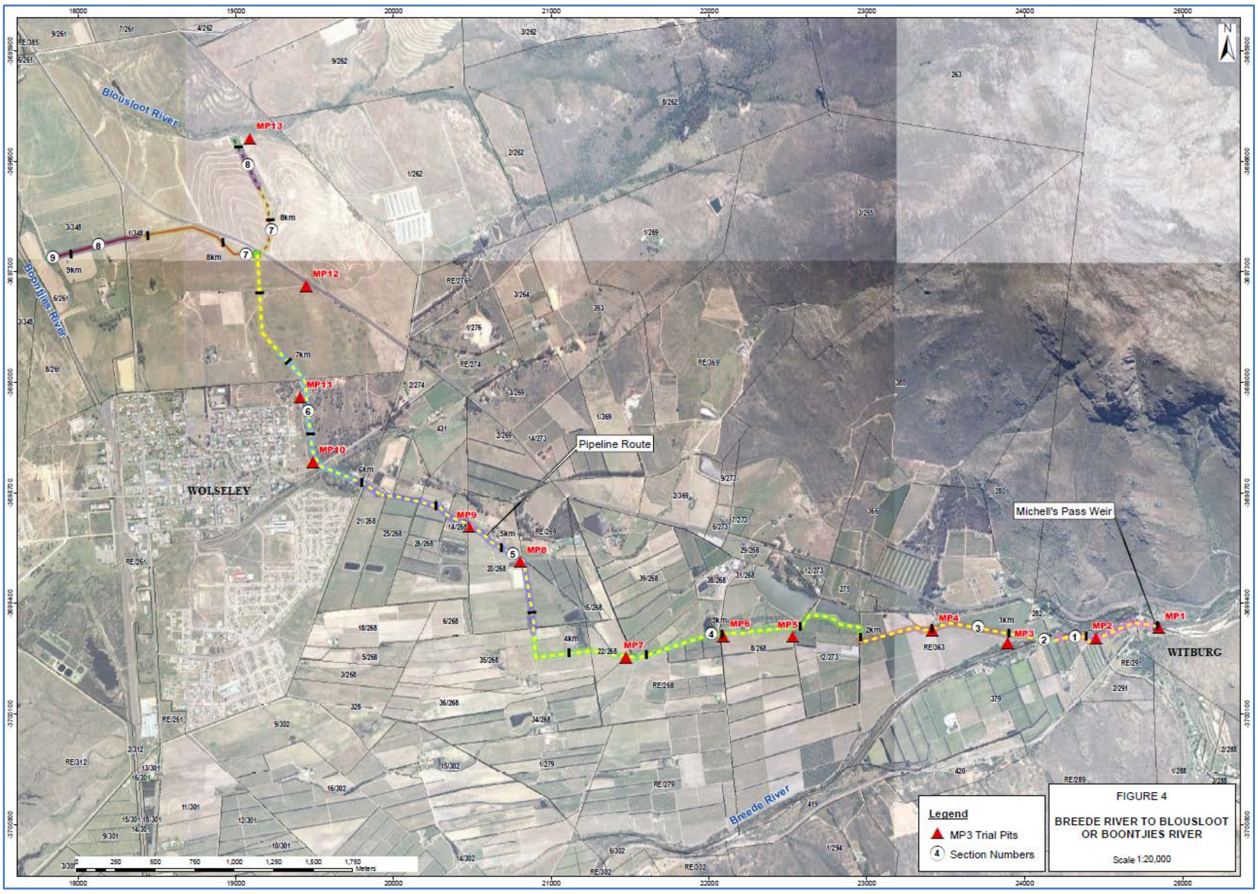


Figure 48: Approximate Locations of the Trial Pits for the BBTS

6.3 MAPPING AND LABORATORY TESTING

Disturbed samples were taken from representative soil layers in the trial pits along the pipeline route. Foundation indicator tests were undertaken on certain of these samples, and grading analyses to 0.075 mm sieve size were undertaken on certain other samples. Testing was undertaken by Geoscience Laboratory (Pty) Ltd. The laboratory test sheets are presented in the geotechnical report in **Appendix 8**.

6.4 FINDINGS AND RECOMMENDATIONS OF THE GEOTECHNICAL INVESTIGATIONS

An independent review of the Geotechnical Report was undertaken by the JV's independent geotechnical engineering specialist in order to consider the outcomes, results and conclusions. The result of that review was that the geotechnical investigation and its report are considered to be "*very thorough and provides an excellent basis for proceeding to the design and costing of the preferred scheme*". The review is included in the Geotechnical Report.

The feasibility investigations provided a general level of information on ground and construction conditions along the pipeline route and for the weir site for the BBTS. This information has been used in the overall evaluation of the most suitable options, to arrive at the infrastructure now proposed.

6.4.1 Weir site

The proposed Michell's Pass diversion weir would be a concrete structure, located close to the existing DWA weir (H1H006), just upstream of the bridge on the R43 over the Breede River. Trial pit MP1 (shown in **Figure 48**) did not expose bedrock, and the actual depth to bed rock and its quality are unknown. Core drilling in the area would be necessary to determine this, which would be a significantly more intensive and costly investigation. This was not recommended for this feasibility level investigation and the weir design itself has been based on an alluvial foundation, resulting in a structure in which leakage downstream will be acceptable, as this would simply contribute to the summer base flow, a desirable outcome in itself. Complications at this site include the existing intake facilities on the left bank, which could interfere with the construction and positioning of the proposed new weir.

The typical alluvial deposit conditions close to the weir site can be seen in **Figure 49**.

Figure 49: Trial Pit Excavation Showing Alluvial Conditions at the Weir Site

6.4.2 Pipeline route

The location of the pipeline route is shown in **Figure 48**. The most important geotechnical factors to consider when assessing construction conditions and costs for the pipeline include:

- Excavation conditions,
- Stability of the sidewalls of the pipe trenches, particularly in the alluvium,
- Groundwater conditions,
- Use of excavated material for pipe bedding and backfill, and
- Engineering properties of the backfill.

The pipeline route was sub-divided into nine regions or sections of similar soil profile, and therefore similar geotechnical conditions. The anticipated soil profile for each section, together with the interpreted construction conditions and material conditions are summarised in the detailed geotechnical report (**Appendix 8**).

Groundwater is expected at depth over nearly half of the pipeline route. The quantity of groundwater inflow could be significant particularly in those sections occurring within the Breede River alluvium, which has high permeability. Groundwater would adversely affect excavation conditions, stability of the excavated slopes in the trenches, and pumping and possibly local de-watering would be required.

Machine excavation is generally expected to be possible along the pipeline route. Approximately three quarters of the pipeline route would be excavated in coarse or fine alluvium, which would require flat temporary slopes because of the lack of stability of the material, and over-excavation is likely. Some hard rock is expected in places along the route.

There is potential for the use of excavated materials for selected granular material, selected fill and main fill on the pipeline route. However, it is essential that selective excavation is undertaken and the different materials are kept separate. If all the material were to be mixed, the resulting mixture would only be suitable for main fill. There is likely to be a lack of both selected granular material, selected fill and main fill, so sieving of the coarse alluvium through a grizzly gird is recommended to produce material which is suitable for all three fill/bedding types.

The pipeline route traverses numerous farms; consequently numerous subsurface services, drainage ditches, roads and orchards would be affected.

6.4.3 Geotechnical Recommendations

The geotechnical investigations undertaken to date support the feasibility studies and the preliminary designs. If this BBTS progresses to detailed design, then consideration should be given to further investigating the following aspects at a greater level of detail:

i. The nature of the alluvium and particularly the depth to and the condition of the bedrock at the pipeline river crossings;
ii. More detailed trial pitting along the pipeline routes;
iii. Specific laboratory testing to confirm the suitability of the sandy soils for use as selected granular material.
iv. Detailed geotechnical investigations at the potential Boontjies Dam site would be required, should that option be further considered. This is important both from a foundation design perspective but also to verify the extent and suitability of material available for construction purposes as well as the design considerations from a seismic perspective.

The main deliverable for the geotechnical investigation is the geotechnical report (**Appendix 8**). It contains the necessary descriptions and locations of the trial pits excavated, as well as the soil profiles and the results of the tests undertaken at each.

7. INFRASTRUCTURE PRELIMINARY DESIGN

This Section provides a summary of the key design considerations and should be read in conjunction with the preliminary design reports and layout drawings provided in the:

- *Conveyance Infrastructure Preliminary Design Report for the Berg River Voëlvlei Augmentation Scheme and the Breede-Berg (Michell's Pass) Water Transfer Scheme* (Worley Parsons, December 2012), enclosed in **Appendix 10**.
- *Diversion Weirs Design for the Berg River Voëlvlei Augmentation Scheme and the Breede-Berg (Michell's Pass) Water Transfer Scheme* (ASP Technology, September 2012), enclosed in **Appendix 11**.
- *Preliminary Design of Papenkuils Pump Station Upgrade and Pre-feasibility Design of Boontjies Dam, for Breede-Berg (Michell's Pass) Water Transfer Scheme,* enclosed as **Appendix 6** to this report.

7.1 INFRASTRUCTURE REQUIREMENTS

The BBTS would comprise the following additional infrastructure:

- The diversion weir on the Upper Breede River at the existing DWA stream flow gauging station (H1H006), in close proximity to the Witbrug, at the foot of Michell's Pass. The weir has been planned so as to minimize the entrainment of sand and boulders into the gravity pipeline.
- During the winter months the diversion weir would divert water across the catchment divide into the tributary catchment of the Klein Berg River, from whence the water would flow into the Voëlvlei Dam via the existing Klein Berg Diversion canal. The gravity main would be between 7600 m (Alternative A) and 9645 m long (Alternative B), depending on which of two alternative options are considered, and the pipeline diameter would be 2000 mm being required at an average depth of 3,0 m and a flow velocity of 1,592 m/s.
- For Alternative B, an additional 1115 m of 1100 mm dia. pipeline would be required (acting only as a rising main) to connect from the pump station at the toe of the Boontjies Dam to the 2000 mm dia. pipeline from the Michell's Pass Diversion site.
- The scheme would be operated in accordance with the developed operating rules, defined to ensure compliance with the ecological flows in both the source and receiving river systems.
- In the event of the Boontjies Dam being considered as an alternative option for providing water for the environment (EWRs), the dam would be about 34 m high including 2 m of freeboard and would have a capacity of approximately 8 million m^3. It would be equipped with the necessary spillway and outlet features as well as a rising main pipeline connected to the gravity pipeline. In so doing reversal of flow and pumping of water in an "upstream" direction in summer would be possible, to enable water to be delivered to back to the headwaters of the scheme, so as to enable the provision of irrigation water in summer to existing users.
- The pump station at Papenkuils would be upgraded to maintain the yield of Brandvlei Dam. If the EWR is to be met in the Breede River downstream of the Papenkuils Pump Station, then after the BBTS scheme has been constructed a capacity of 26 m^3/s would be required at the pump station to maintain the existing yield of Brandvlei Dam, an increase in capacity of 19 m^3/s over the present of 7 m^3/s capacity of the pump station. The cost estimate was determined for this possibly conservative 26 m^3/s option, although it might be possible to maintain the yield and to provide the EWR by upgrading the total pumping capacity to 15 m^3/s with a stepped pumping rule.

The CCT's existing Voëlvlei Water Treatment Works, Pump station and Pipeline would supply the City's Plattekloof, proposed Spes Bona and Glen Gary Reservoirs. As discussed in **Section 4.2** the proposed Spes Bona Reservoir and the linking pipeline to the Glen Gary Reservoir would be constructed by the City to facilitate the operation of their supply system and would not form part of the BBTS, although this infrastructure would be essential for its operation.

There would also be no need to change to the WCDM's infrastructure however the following modifications to the infrastructure at Withoogte have previously been recommended to improve the operation of this supply system:

- The existing intake arrangements should be improved or a second intake pipeline should be constructed from Misverstand Dam to the Withoogte raw water pump station to enable Misverstand Dam to be drawn down to greater extent so as to facilitate and improve the management of summer flows in the Lower Berg River.
- The second partially constructed clear water reservoir at Withoogte should be completed to provide additional clear water storage for bridging periods when high salinities occur as a result of runoff in the local Maatjies and Sout River tributaries of the Berg River.

In optimising the diversion from the Breede River, balanced against the provision of ecological flows, a diversion capacity of $5m^3/s$ appears optimal and this has formed the basis for the design of the BBTS.

7.2 DIVERSION SCHEME INFRASTRUCTURE

The existing Artois canal alignment formed the basis for the conceptual design of the BBTS. The location of the proposed diversion weir is ideally situated at the same location as the current Artois canal inlet as this offers a position which:

- Enables the scheme to be operated under gravity, and
- Does not have an upstream inundation impact on the pristine and ecologically important Witels River.

The founding conditions at the proposed low level concrete weir would be on alluvial material which would leak. This leakage would not be measured as is the situation at the existing weir, however the leakage would contribute to the EWR if it is determined that releases for this purpose would be feasible as discussed in **Section 2.3.2**. As such leakage might make a significant contribution to the EWR it may be necessary to provide measures to seal the foundations which are likely to be expensive.

7.2.1 Gravity Main Pipeline and Discharge Arrangements

For Alternative A (provision of ecological flows from Koekedouw Dam), the proposed gravity pipeline would transfer the abstracted winter flood water from the Breede River to a closed discharge chute, which would discharge water into the Blousloot River, a tributary of the Boontjies River, which in turn is a tributary of the Klein Berg River. A balancing tank would be provided to ensure control at the chute inlet, while an appropriate outlet structure is proposed at the discharge point into the Blousloot River, to safeguard the river morphology from excessive velocities and resultant erosion problems. The required chute size was determined for a discharge of 5 m^3/s and average surface slope of 0.0415 m/m using inlet control and Manning head loss principles. Initially it was proposed that the chute should discharge flow directly into the Boontjies River (in close proximity to Wolseley). However, design refinements were necessary to address landowner concerns and mitigate potential impacts on farming activities. In so doing a shorter pipeline route was identified for the pipeline to discharge into the Blousloot River as shown in **Figure 50**, providing a further advantage to this proposed alignment.

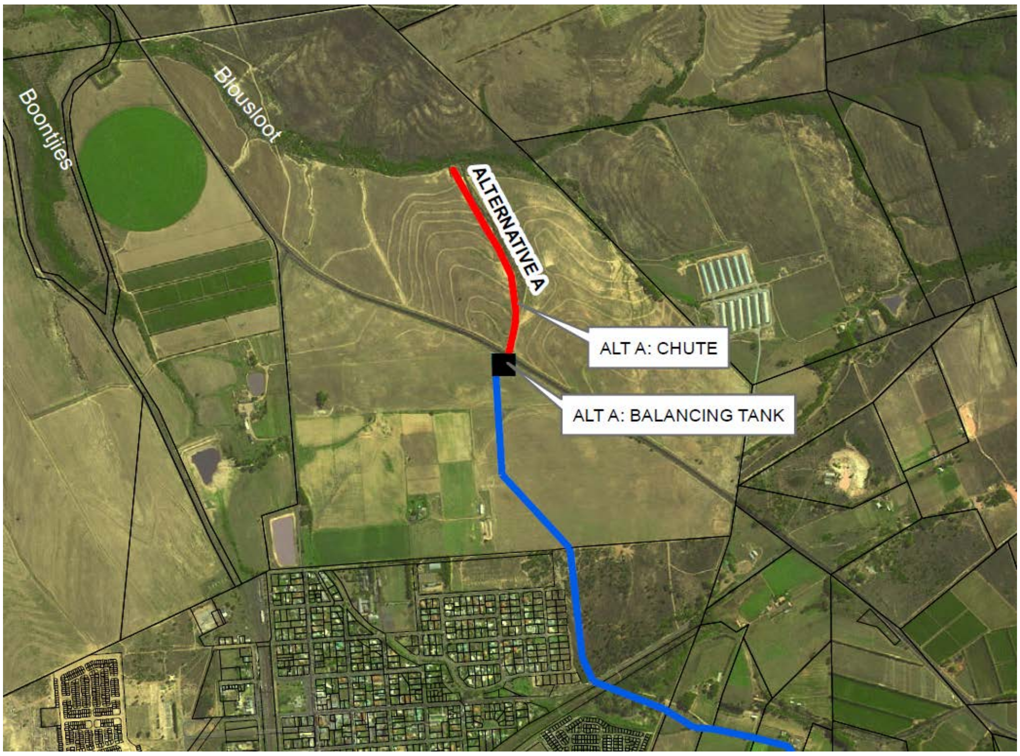


Figure 50: Potential Alignments and Discharge Locations for the BBTS (Alternative A)

For Alternative B (provision of ecological flows via proposed Boontjies Dam)

The alternative to providing summer EWR releases from Koekedouw Dam would involve the provision for additional storage of surplus winter water in the proposed dam on the Boontjies River, a tributary of the Klein Berg River as shown in **Figure 51**. The water diverted from the Michell's Pass Diversion weir would be conveyed under gravity via the pipeline to the Boontjies Dam where it would be discharged under controlled means into the proposed dam. In winter the dam would fill and water spilled and/or released from it, would then flow into the Klein Berg River, to be diverted into the Voëlvlei Dam. The water stored in the Boontjies Dam would be available in summer for pumping to the Artois irrigators who would be supplied from this dam instead of by their current summer abstractions from the Breede River. The summer flows in the Breede River at Michell's Pass that are currently diverted would continue to flow down the river to be available towards meeting the summer EWR requirements downstream of the proposed diversion weir. Any shortfalls in providing for the summer EWRs could also be addressed through pumping water from the Boontjies Dam back to the Breede River to meet that need, and provision for this has been made in the preliminary design of the pump station. The capacity of the dam would be about 8 million m^3.

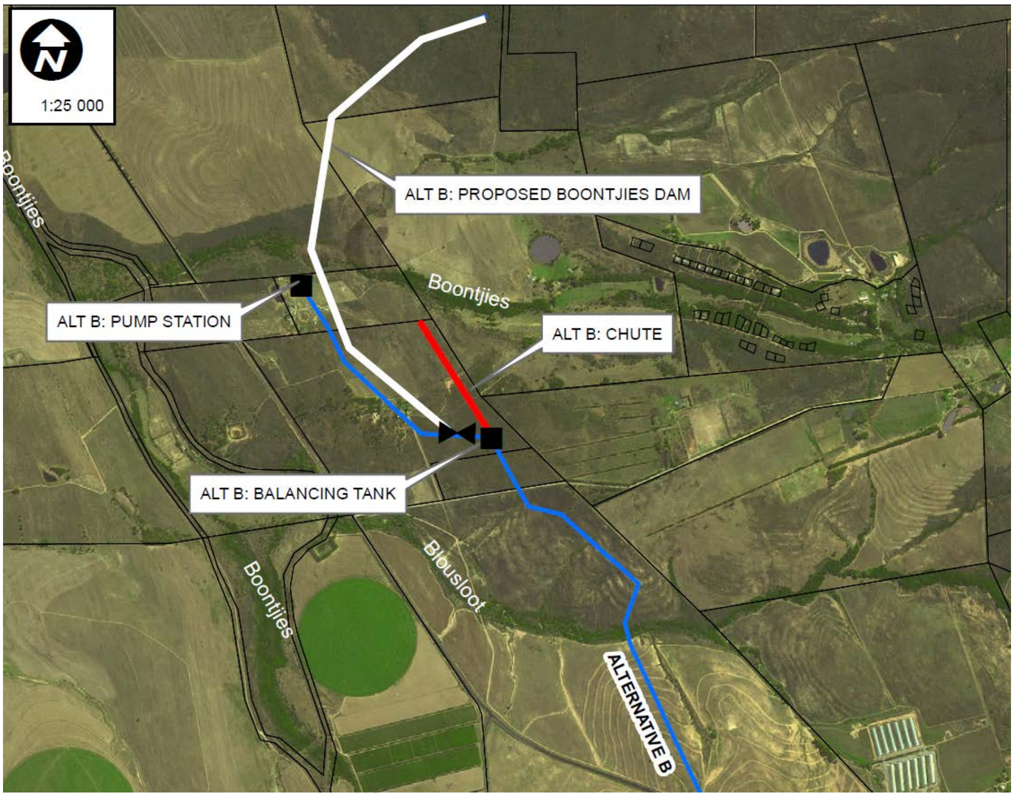


Figure 51: Potential Alignments and Discharge Locations for the Boontjies Dam Option (Alternative B)

Table 19 shows the design parameters adopted for the gravity main for both Alternatives A and B.

Table 19: Gravity Main Design Parameters

Design Parameter	Design Flow 5m^3/s	
	Alternative A (without Boontjies Dam)	Alternative B (with Boontjies Dam)
Head Loss calculation	Colebrook White & Darcy-Weisbach	
Gravity Main Length	7600 m	9645 m
Gravity Main Properties	2000mm dia GRP	2000mm dia GRP
Maximum Flow Velocity	1,592 m/s	1,592 m/s

Air-valves have been allowed for at high points and scour valves at low points to facilitate scouring and drainage of the pipeline.

7.2.2 Selection of Pipe Material

Buried piping must resist internal pressure, external loads, differential settlement and the corrosive action of soils. The profile, flow velocity, size and stiffness of the pipe all affect the design. Various pipe materials are available on the market and those considered for this large diameter pressure application included mild steel, ductile iron and GRP. A comparison undertaken between these pipeline materials identified that, for the purpose of this preliminary design, GRP pipes are considered the preferred pipeline material. Their advantages include flexibility, light weight and corrosion resistant properties. A cautionary approach is required when considering the selection of bedding and backfill material as this pipe type is more susceptible to backfill properties than mild steel (MS) or ductile iron (DI).

It is understood that in the event of implementation, DWA may prefer that ductile iron or mild steel pipes be used in the detailed design rather than GRP. Based on the pipeline length involved for Alternative A for example (7600 m), this would result in a marginal capital cost increase of about 20% for ductile iron and 4% for mild steel. However, the latter will require more extensive maintenance costs in the longer-term.

7.2.3 Pump Station Design for the Boontjies Dam Option

A pump station would be required to facilitate the supply of irrigation water during summer from the proposed Boontjies Dam and to provide for any potential shortfalls in meeting the summer EWRs downstream of the diversion site on the Breede River. The pump station which would be located at the proposed dam would have the design parameters shown in **Table 20** below.

Table 20: Design Parameters for the Boontjies Dam Pump Station

Design Parameter	Design Flow
	1 m^3/s
Friction losses	3 m
Rising main diameter	1100 mm (bypass) & 2000 mm, GRP
Lengths	1115 m of 1100 mm dia & 9645 m of 2000 mm dia
Maximum flow velocity (1100 mm pipe)	1,052 m/s
Pump Duty (dam full)	39 m @ 1 m^3/s
Pump duty (dam empty)	60 m @ 1 m^3/s

7.3 PAPENKUILS PUMP STATION UPGRADE

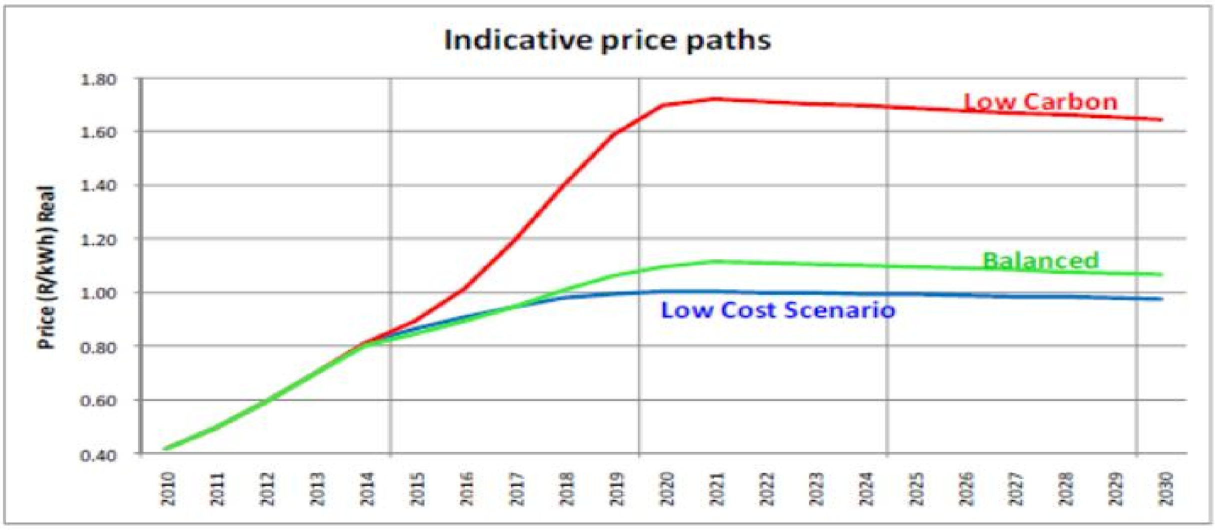
It has been assumed that the capacity of the Papenkuils Pump Station would need to be increased by 19 m^3/s from the current capacity of between 5 and 7 m^3/s to 26 m^3/s to maintain the yield of Brandvlei Dam if the Michell's Pass scheme is implemented although the existing yield of the Dam and the downstream EWR could perhaps be met by a smaller 15 m^3/s pump station. The existing pumps have a nominal capacity of 5 m^3/s but are currently being operated to pump flows of up to 7 m^3/s, depending on the dam level. The existing Papenkuils Pump Station comprises civil infrastructure that was built to enable upgrading to a capacity of approximately 20 m^3/s by including space for two more pump stations of the same size as the existing pump station and a tunnel through the hill to the dam with a capacity of up to 40 m^3/s. The design parameters for the upgrade to the Papenkuils Pump Station are given in **Table 21**.

Table 21: Design Parameters for the Upgrade to the Papenkuils Pump Station

Design Parameter	Design Flow
	26 m^3/s
Friction losses	3 m
Tunnel rising main diameter (existing)	3.5 m diameter tunnel
Tunnel length (existing)	350 m
Maximum flow velocity in tunnel	2,7 m/s
Pump Station Duty (dam full)	21 m @ 26 m^3/s

7.4 ELECTRICITY COST CONSIDERATIONS

The Executive Summary of the Draft Integrated Electricity Resource Plan for South Africa - 2010 to 2030 IRP 2010 dated 22 October 2010 compiled by the Department of Energy describes nine future electricity generation scenarios that were investigated and evaluated in accordance with a multi-criteria decision making framework (MCDF). The criteria used for evaluating the scenarios were CO_2 emissions, price path peak, average water consumption, uncertainty factor, localisation potential and regional development. This MCDF process led to the selection of the Balanced Scenario which would achieve a price path similar to that of the Low Cost Scenario shown in **Figure 52** as well as the Low Carbon Scenario, all based on 2010 costs. Both graphs assume an average tariff of R0.42/kWh in 2010.



Ref: Executive Summary of the Draft Integrated Resource Plan for South Africa – 2010-2030 IRP 2010; Department of Energy

Figure 52: Electricity Prices for Balanced, Low Cost and Low Carbon Scenarios in 2010

Some of the conclusions contained in the Draft Integrated Resource Plan are as follows:

- The Revised Balanced Scenario provides a significant reduction in carbon emissions while allowing only a marginal increase in the price to the electrical consumer.
- Importantly, the Revised Balanced Scenario provides for localisation of renewable technologies.
- The increase in renewable capacity does not come at the expense of security of supply.
- Regional development (e.g. the increased reliance on the Zambezi River) does pose a minor risk to security of supply.

Since the Draft Integrated Resource Plan was published in 2010, NERSA has granted Eskom average tariff increases of 24.8% for 2010-2011, 25.8% for 2011-2012 and 16% for 2012-2013. In November 2012 Eskom requested NERSA to approve further tariff increases of 16% per annum for the next 5 years however an increase of only 8% per annum was approved by NERSA. Never the less it has been assumed that future electricity price increases will be necessary to provide Eskom with a tariff at least equal to the Low Cost Scenario price of R1.00/kWh for 2010 shown in **Figure 52.** This corresponds to an average price of about R1.19/kWh in 2013 values based on an assumed inflation rate of 6% per annum from 2010 to 2013.

The future electricity tariffs for year round pumping and for pumping during the winter months from May to October have been based on the average annual price or R1.19/kWh as described above and on Eskom's Megafllex Tariffs for 2012/2013 as shown in **Table 22**. These tariffs were increased pro rata to correspond to the projected future average year round price of R1.19/kWh.

Pumping from the potential Boontjies Dam

Table 22 shows that if the pumping of raw water from the Boontjies Dam would take place year round then the rate would be 119 cents/kWh. This may be a conservative approach as most of the pumping to supply the irrigators would take place during the summer months for which the future Low Demand Season September to May tariff is 97 cents/kWh. Therefore for the URV determination it was assumed that the cost of pumping from the Boontjies Dam would be 110 cents/kWh.

Pumping at Papenkuils Pump Station

Pumping at the upgraded Papenkuils Pump Station would take place mainly during the winter months when the BBTS is operating. If pumping would only take place in the winter months when water is available after the EWR requirement has been met, and thus would occur mainly during high flow events and not at predictable times the electricity cost based on the escalated River Pumping Tariff for May to October would be 141 cents/kWh.

Pumping from Voëlvlei to Cape Town

The pumping of treated water from Voëlvlei to Cape Town would take place throughout the year for which the electricity tariff would be about 119 cents/kWh, however these costs were not included in the URV calculations.

Table 22: Eskom 2012-2013 Tariffs and Estimated Future Escalation

SEASON	Eskom 2012-2013 Megaflex Tariffs (cents/kWh)							Future Increases %	Increased Future Tariff (cents/kWh)
	Electrification and Rural Subsidy	Reactive Energy Charge	Environmental Levy	Peak (25 hrs per week)	Peak (47 hrs per week)	Peak (96 hrs per week)	Average Tariff		
Low Demand Season: Sep to May (273 days)	.0456	0.00	0.03	60.35	36.92	25.84	34.15	285%	96.8
High Demand Season: June to Aug (92 days)	.0456	0.09	0.03	216.33	56.18	29.98	65.20	285%	184.8
River Pumping Tariff May to Oct							49.68	285%	140.8
Pipeline Pumping Tariff Jan to Dec							41.98	285%	119.0

8. ENVIRONMENTAL CONSIDERATIONS

8.1 ACTIVITIES FOR AUTHORISATION

The environmental process for the proposed BBTS will need to fulfil the requirements of all relevant legislation, including but not limited to:

a) National Environmental Management Act, 1998 (Act No. 107 of 1998)

b) National Water Act, 1998 (Act No. 36 of 1998)

c) National Heritage Resources Act, 1999 (Act No. 25 of 1999)

8.1.1 National Environmental Management Act, No. 107 of 1998

NEMA, as amended, establishes, *inter alia*, the principles for decision-making on matters affecting the environment. Section 2 sets out the National Environmental Management Principles which apply to the actions, including decision-making, of organs of state that may significantly affect the environment. Furthermore, Section 28(1) states that "Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped, to minimise and rectify such pollution or degradation of the environment.".

In terms of the EIA regulations, promulgated in terms of Section 24 of NEMA, certain activities are identified, which require authorisation from the competent environmental authority, in this case the Department of Environmental Affairs and Development Planning (DEA&DP), before commencing. Listed activities in Government Notice (GN) No. 545 require Scoping and EIA whilst those in GN No. 544 and 546 require Basic Assessment (unless they are being assessed under an EIA process). Due to the nature and extend of the proposed BRVA Scheme, a full EIA process will be required.

8.1.2 National Water Act, No. 36 of 1998

The National Water Act (NWA) (Act No 36 of 1998) provides for the sustainable and equitable use and protection of water resources. It is founded on the principle that the National Government has overall responsibility for and authority over water resource management, including the equitable allocation and beneficial use of water in the public interest, and that a person can only be entitled to use water if the use is permissible under the NWA. The Act also distinguishes between various types of water use[1] in Section 21 which may require a Water Use Licence or a General Authorisation.

The proposed augmentation scheme will require an Integrated Water Use Licence that allows for the following[2]:

- Diversion of surplus winter water from the Breede River to the Klein Berg River;
- Diversion of surplus winter water from the Klein Berg River to the Voëlvlei Dam;
- Increase of the Voëlvlei Dam's storage capacity (if the dam was to be raised); and
- Replacement of the existing permit issued to the Voëlvlei Dam under the previous Water Act of 1956 (Act No 54 of 1956), to allow for the additional water to be taken from the dam (i.e. by the CCT and any other user).

[1] Taking water from a water resource, storing water, impeding or diverting the flow of water in a watercourse and altering the bed, banks, course or characteristics of a watercourse.
[2] The Integrated Water Use Licence would also include the existing lawful water use at Voëlvlei Dam.

8.1.3 National Heritage Resources Act, No. 25 of 1999

In terms of the National Heritage Resources Act (No. 25 of 1999) (NHRA), any person who intends to undertake "*any development … which will change the character of a site exceeding 5 000 m^2 in extent*", *"the construction of a road…powerline, pipeline…exceeding 300 m in length"* or *"the rezoning of site larger than 10 000 m^2 in extent…"* must at the very earliest stages of initiating the development notify the responsible heritage resources authority, namely the South African Heritage Resources Agency (SAHRA) or the relevant provincial heritage agency, i.e. Heritage Western Cape (HWC). These agencies would in turn indicate whether or not a full Heritage Impact Assessment (HIA) would need to be undertaken.

Section 38(8) of the NHRA specifically excludes the need for a separate HIA where the evaluation of the impact of a development on heritage resources is required in terms of an Environmental Impact Assessment (EIA) process. Accordingly, since the impact on heritage resources would be considered as part of the EIA process, no separate HIA would be required. SAHRA or HWC would review the EIA reports and provide comments to DEA&DP, who would include these in their final environmental decision. However, should a permit be required for the damaging or removal of specific heritage resources, a separate application would have to be submitted to SAHRA or HWC for the approval of such an activity.

8.2 THE ENVIRONMENTAL IMPACT ASSESSMENT (EIA) PROCESS

NEMA requires that the EIA process be undertaken by a suitably qualified and experienced independent Environmental Assessment Practitioner[3] (EAP). Due to Aurecon's involvement with the technical aspects of the project, Aurecon's in-house environmental specialists are not considered to be independent and hence an external independent EAP will need to be appointed[4].

A very important component of the EIA process is the requisite specialist studies and the following studies were identified during the pre-feasibility studies as being necessary: Agriculture, Aquatic, Botanical, Heritage and Social. Specialists that were involved during the pre-feasibility studies should preferably also be involved in the EIA process due to their existing understanding of the project.

In terms of timeframes, it is anticipated that the EIA process will take approximately 11 months until the submission of the Final EIA Report. However, activities and timeframes involving the authorities, such as approval of the Scoping Report, cannot be guaranteed. It is anticipated that DEA&DP will take 3 to 7 months to make a decision on the Environmental Authorisation, followed by the statutory appeal period. Experience shows that there are many variables within an EIA process, which have the potential to delay progress towards specified milestones, most notably the requisite input of technical information from the applicant, the stakeholder (including public) participation process, specialist input and authority review.

8.3 PUBLIC PARTICIPATION

8.3.1 Introduction

Effective and equitable engagement with stakeholders contributes to the identification of key issues of concern and possible solutions, as well as accessing relevant local or traditional knowledge. Through engaging stakeholders proactively, proponents and decision-makers are able to understand and clarify the degree to which other stakeholders will be willing to accept any trade-offs which may be required. This ensures more informed decision-making and ultimately sustainable development.

[3] Section 17 of GN No. R543
[4] Five EAPs were contacted for proposals to undertake the necessary work. Of these only three companies responded. Unfortunately DWA was unable to sub-contract the EIA investigation to WCWS's current contract and the normal procurement process will need to be undertaken.

8.3.2 Preliminary Public Notification Of The Study

The public participation process was undertaken in both Afrikaans and English to accommodate the language preferences of the local communities. Newspaper advertisements to notify the public that the study had commenced were placed in a number of local and regional newspapers as indicated in **Table 23**. The public database developed during the WCWSS Reconciliation Strategy Study was also used to notify the broader public that the study had commenced. This database was updated and maintained throughout the study.

Table 23: Summary of Advertisements Placed to Notify the Broader Public of the Commencement of the Study

NEWSPAPER	DATE
Die Burger	14 February 2009
Paarl Post	19 February 2009
Witzenberg Herald	19 February 2009
Overstrand Herald	20 February 2009
Weekend Argus	14 & 15 February 2009
Worcester Standard	19 February 2010
Caledon Kontreinuus	20 February 2009

Letters of notification were sent to relevant authorities including the:

- Department of Agriculture (Western Cape);
- Department of Environmental Affairs and Tourism;
- Western Cape Department of Environmental Affairs and Development Planning;
- Department of Transport and Public Works;
- Heritage Western Cape;
- Department of Local Government and Housing;
- Eskom;
- CapeNature; and
- Potentially affected municipalities.

Notifications were also specifically addressed to the Berg and Breede CMA Reference Groups and the Water User Associations in the Berg and Breede WMAs.

8.3.3 Meetings

A number of public and stakeholder meetings were held during the course of the project. The first two public meetings were held at the beginning of Phase 1 at two different geographic centres, namely Worcester and Grabouw, as these locations are in reasonably close proximity to the potential schemes. At the end of Phase 1 (December 2010) a second round of public meetings was held in Worcester and Grabouw to present the findings and recommendations to the public. These meetings were advertised in the Worcester Standard and the Overstrand Herald in November 2010.

Two Stakeholder Committee Meetings were also held pre and post an Options Prioritisation Workshop that was held in March 2010. The Stakeholder Committee comprises national, provincial and local authorities, WUAs, conservation authorities, emerging farmers and other statutory bodies that have direct connections with the water sector.

A separate meeting was held with potentially affected landowners to identify issues and concerns regarding the proposed layouts of the BRVAS and the BBTS.

A summary of the public and stakeholder engagement process (public and stakeholder meetings and workshops) is provided in **Table 24** below.

Table 24: Summary of Public and Stakeholder Meetings during the Course of the Study

MEETING TYPE	TARGET GROUP	LOCATION	DATE
Public Meeting	Interested & Affected Parties (I&APs)	Elgin-Grabouw Country Club, Grabouw	5 March 2009
Including landowners, authorities and Water Users Associations (WUAs).			
Public Meeting	I&APs	Protea Cumberland Hotel, Worcester	7 March 2009
Committee Meeting	Water sector stakeholders	Department of Agriculture, Elsenberg	31 March 2009
Including national, provincial and local authorities, WUAs, conservation, emerging farmers and statutory bodies.			
Options Prioritisation Workshop	Water sector representatives & project specialists	Nelson's Creek Wine Estate, Paarl	25 March 2010
Including Municipalities, Catchment Management Agency, CapeNature, CSIR, Department of Agriculture and DWA (National and Regional).			
Committee Meeting	Water sector stakeholders	Department of Agriculture, Elsenberg	15 April 2010
Public Meeting	I&APs	Tri Active (Green Mountain Lodge), Elgin Valley	4 December 2010
Public Meeting	I&APs	Protea Cumberland Hotel, Worcester	4 December 2010
Stakeholder Meeting	Potentially affected landowners	Dutch Reformed Church, Wolseley	2 March 2011
Focussed specifically on Breede Berg (Mitchell's Pass) Water Transfer Scheme and the Berg River Voëlvlei Augmentation Scheme			

8.3.4 Newsletters

Newsletters were sent to all registered Interested and Affected Parties and members of the Stakeholder Committee in November 2011 and March 2013 in order to keep them informed about the status of the project until the required EIA process commences.

8.3.5 Conclusions

Experience gained from interactions with Stakeholders and Interested and Affected Parties (I&APs) on this project, has shown that the proposed scheme is very sensitive in terms of public opinion. It is therefore of great importance to Stakeholders and I&APs that continuity between the Preliminary Phase and the EIA process is ensured. The existing Stakeholder and I&AP databases will therefore be provided to the appointed independent EAP to ensure that all registered parties are informed about the EIA process.

8.4 ALTERNATIVE ALIGNMENTS CONSIDERED

The NEMA Regulations[5] require that "*alternatives to the proposed activity that are feasible and reasonable*" be identified and considered during the EIA process. Alternatives can include activity alternatives, site alternatives, design or layout alternatives, technology or operational alternatives, as well as the "no-go" option.

8.5 WAY FORWARD FOR EIA

The proposed BBTS will need to comply with the requirements of all relevant legislation, including (but not limited to) NEMA, NWA and NHRA. Specialist input and assessments will be required to provide the decision-making authorities with sufficient information to make an informed decision. Some of the requisite studies may need to be completed during a specific season to ensure a comprehensive assessment of potential impacts on the environment, e.g. botanical assessment. These studies should be carefully planned to prevent any unnecessary delays to the project programme. It is also important to ensure that project information provided to specialists and the EAP does not change significantly during the EIA process as it could potentially necessitate the revision of assessments. It is therefore recommended that a design freeze should be applied to the project to prevent unnecessary costs and programme delays during the EIA process.

Furthermore, it is important for DWA to take into consideration the EIA process timeframes when undertaking forward planning to meet future water requirements, as it can take up to 18 months (or in some cases even longer) to receive environmental authorisation. However, activities and timeframes involving the authorities cannot be guaranteed and should be considered as variable in the programme.

An independent EAP will need to be appointed to ensure compliance with the requirements of Section 17 of the EIA Regulations. Once the EAP has been appointed, a public meeting should be held to allow the Western Cape Water Consultants to present the technical findings in order to update Stakeholders and I&APs on the current project status and way forward. The meeting should also familiarise Stakeholders and I&APs with the EAP and EIA process that will be undertaken.

[5] Section 27 (e) (iii) of R543

9. DETERMINATION OF UNIT REFERENCE VALUES (URVS) AND FINANCING OPTIONS

9.1 CAPITAL COSTS

Appendix 6 and **Appendix 12** provide the detailed cost estimates and costing schedules for the various components of the scheme. These costs have been based on detailed Bills of Quantities and rates, drawing on unit rates from similar recent projects. The key capital costs of the main components of the possible 5 m^3/s diversion scheme options for the BBTS are shown in **Table 25** below.

Table 25: Summary of Capital Cost Estimate for the BBTS Alternatives

Cost Item	5m^3/s Scheme Option: costs in R(millions)	
	Alternative A without Boontjies Dam	Alternative B with Boontjies Dam
Weir at Michell's Pass	50.06	50.06
Gravity main	173.13	230.14
Balancing tank	4.69	4.69
Closed discharge chute	16.28	16.28
Boontjies Dam	not applicable	97.80
Boontjies Dam pump station (Mech/Elec)	not applicable	13.65
Boontjies Dam pump station (Civil)	not applicable	4.38
Rising main: Boontjies Dam to main pipeline	not applicable	14.38
River protection	52.50	42.00
Papenkuils pump station upgrade (Mech/Elec)	78.20	78.20
Papenkuils pump station upgrade (Civil)	11.88	11.88
Contingencies (10% of above, dam = 15%)	38.67	61.23
SUB-TOTAL CONSTRUCTION COST	**425.39**	**624.67**
Professional fees	32.57	45.57
Servitude & property	6.08	19.53
TOTAL CAPITAL COST EXCL. VAT	**464.06**	**689.77**
VAT @ 14%	**64.97**	**96.57**
TOTAL CAPITAL COST INCL. VAT	**529.01**	**786.34**

Note: The VAT EXCLUSIVE amounts are used for the Unit Reference Value Calculations shown in **Section 9.3**.

Ductile Iron Pipes as an Alternative to GRP:
Should ductile iron pipes be selected by DWA as the preferred pipe material for the BBTS gravity main, then the capital cost increase of the two alternatives is estimated as follows:

- Alternative A: ~ 20% increase from R529 to R633 million
- Alternative B: ~ 18% increase from R786 to R925 million

Mild Steel Pipes as an Alternative to GRP:
Should mild steel pipes be selected by DWA as the preferred pipe material for the BBTS gravity main, then the capital cost increase is estimated as follows:

- Alternative A: ~ 3.8% increase from R529 to R549 million
- Alternative B: ~ 3.5% increase from R786 to R814 million

9.2 OPERATION AND MAINTENANCE COSTS

Operation and Maintenance (O&M) costs were included in the URV calculations as a constant annual cost, based on the following widely used general estimates for costing of these items:

- Civil O&M cost at 0.5% of the civil capital cost
- Mechanical and electrical O&M cost at 4% of the mechanical and electrical capital costs.

The O&M costs were calculated using the percentages above applied to capital costs that include preliminary and general items and contingencies, but exclude the costs of professional fees (for design, recoverable expenditures, construction supervision and site occupational health and safety supervision), servitude and property, and VAT.

Additionally, allowance was made for refurbishment of the pump station mechanical and electrical equipment every 15 years, assuming an estimated refurbishment cost of 60% of the initial capital cost for this equipment. The capital costs on which these costs were based included preliminary and general items and contingencies, but excluded the costs of professional fees, property and servitude and VAT.

Table 26: Summary of Operating and Maintenance Costs for the BBTS Alternatives

Operating and Maintenance Cost Items	5m^3/s Scheme Option: Annual Costs in R(million)/a	
	Alternative A without Boontjies Dam	Alternative B with Boontjies Dam
Maintenance Costs		
Civil	1.70	2.06
Dams		0.28
Mechanical and Electrical	3.44	4.04
Electricity Costs		
Boontjies Dam Pump Station (0.86 MW)		
Papenkuils Pump Station (4.1 MW)	2.05	2.55
TOTAL Operating and Maintenance Costs	**7.19**	**8.93**

9.3 UNIT REFERENCE VALUES

The unit reference values for the two diversion options were assessed using a spreadsheet-based economic evaluation model. The economic evaluation for each option was carried out on the following basis:

- Costing base date – 2012
- Life-time evaluation period – 30 years, starting 2013
- Discount rates – 6%, 8% and 10%
- Costs discounted to date of first expenditure
- The yield estimates determined in this study

The model calculates the following output indices for each scheme:

- NPV - Net Worth of Costs
- URV - Unit Reference Value

The Unit Reference Values are calculated as follows:

$$URV = \frac{\textit{Present Worth of costs}}{\textit{“Present Volume” of water delivered}}$$

- Electricity was costed at 130 c/kWh

The URV assessment is inclusive of the following:

- Preliminary and General Costs.
- Construction Costs.
- Professional Fees (including site supervision).
- Expropriation / compensation.
- Contingencies.
- Operation and Maintenance (including electricity costs).

The URV assessment was exclusive of VAT.

The yields and URVs for the different discount rates are summarised in **Table 27. Table 28** to **Table 33** provide the output of the URV assessment showing the calculations based on the capital and operating costs described above, and on the yield for each of the two diversion capacities.

Table 27: Summary of Operating and Maintenance Costs for the BBTS Alternatives

Scheme option	Yield (Million m^3/a)	Discount rate (per annum)		
		6%	8%	10%
Alternative A: without Boontjies Dam	36	R 1.37	R 1.62	R 1.90
Alternative B: with Boontjies Dam	36	R 1.98	R 2.37	R 2.78

Table 28: Unit Reference Value Output Calculation for 5m³/s Scheme (Alternative A: without Boontjies Dam) at 6% Discount Rate

MICHELL'S PASS OPTION A - BULK WATER COSTS

Scheme : Gravity diversion from Breede River to Klein Berg River, no storage for supply of Artois Farmers summer demand

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	36	mcm/a	After Riverine Reserve at Michell's Pass
Demand Growth	2%	p/a	
Years to Full Supply	3.5	Years	

CAPITAL COST COMPONENTS

	CIVIL	DAM	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Michell's Pass	47.68			2.38	50.06	60.07
Gravity main: weir to balancing tank	138.50			34.63	173.13	207.74
Balancing tank	3.75			0.94	4.69	5.62
Blousloot closed chute	15.50			0.78	16.28	19.53
Blousloot and Boontjies River protection	50.00			2.50	52.50	63.00
Papenkuils pump station upgrade (Mech/Elec)			68.00	10.20	78.20	93.84
Papenkuils pump station upgrade (Civil)	9.50			2.38	11.88	14.25
Contingencies (10%)	26.49	0.00	6.80	5.38	38.67	
SUB-TOTAL CONSTRUCTION COST	291.42	0.00	74.80	59.18	425.39	
Professional fees					32.57	
Servitude & property					6.08	
TOTAL CAPITAL COST EXCL. VAT	370.21	0.00	93.84		464.05	464.05
VAT @ 14%	51.83	0.00	13.14		64.97	
TOTAL CAPITAL COST INCL. VAT	422.04	0.00	106.97		529.01	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	1.697	
	(0.25% Dams) =	0.000	
	(4% Mech & Elec) =	3.441	
	Annual total =	5.138	
		Papenkuils	
ELECTRICITY:	Power Required :	4100	KW @ weighted average dam level
	# Days Pumping :	16	days
		@ 19 m3/s	equivalent pump rate
	Unit Rate :	130.00	c/kWh
	Electricity Consumption Costs :	2.0	Rmill/yr
	Total Energy Cost :	2.0	Rmill/yr

WATER REQUIREMENTS / **COSTS**

Calend year	Year	Supply (10^6m^3)	NPV of supply	Weir	Gravity main	Balancing tank	Boontjies chute	Blousloot & Boontjies River protection	Papenkuils pump station (Mech/Elec)	Papenkuils pump station (Civil)			Maint	Energy
2013	**1**													
2014	2													
2015	3			30.03	103.87	2.81	9.76	31.50	46.92	7.12				
2016	4			30.03	103.87	2.81	9.76	31.50	46.92	7.12				
2017	5	18.00	14.258										2.57	1.02
2018	6	36.00	26.901										5.14	2.05
2019	7	36.00	25.379										5.14	2.05
2020	8	36.00	23.942										5.14	2.05
2021	9	36.00	22.587										5.14	2.05
2022	10	36.00	21.308										5.14	2.05
2023	11	36.00	20.102										5.14	2.05
2024	12	36.00	18.964										5.14	2.05
2025	13	36.00	17.891										5.14	2.05
2026	14	36.00	16.878										5.14	2.05
2027	15	36.00	15.923										5.14	2.05
2028	16	36.00	15.022										5.14	2.05
2029	17	36.00	14.171										5.14	2.05
2030	18	36.00	13.369										5.14	2.05
2031	19	36.00	12.612						51.61				5.14	2.05
2032	20	36.00	11.898										5.14	2.05
2033	21	36.00	11.225										5.14	2.05
2034	22	36.00	10.590										5.14	2.05
2035	23	36.00	9.990										5.14	2.05
2036	24	36.00	9.425										5.14	2.05
2037	25	36.00	8.891										5.14	2.05
2038	26	36.00	8.388										5.14	2.05
2039	27	36.00	7.913										5.14	2.05
2040	28	36.00	7.465										5.14	2.05
2041	29	36.00	7.043										5.14	2.05
2042	30	36.00	6.644										5.14	2.05
DISCOUNT RATE @		6.00%	378.78	51.95	179.66	4.86	16.89	54.48	122.03	12.32	0.00	0.00	54.06	21.53

UNIT REFERENCE VALUE = 1.37 R/m³

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period	(422.04)	56.502	
b) Dams - 20 year period	(0.00)	0.000	
c) Mech./Elec equipment - 15 year period	(106.97)	15.706	72.208
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		1.697	
ii. Dams (0.25%)		0.000	
iii. Mech./Elec. (4%)		3.441	
b) Energy costs		2.05	7.184
TOTAL ANNUAL COST:			79.393

UNIT COST OF WATER = 2.21 R/m³

Table 29: Unit Reference Value Output Calculation for 5m3/s Scheme (Alternative A: without Boontjies Dam) at 8% Discount Rate

MICHELL'S PASS OPTION A - BULK WATER COSTS

Scheme : Gravity diversion from Breede River to Klein Berg River, no storage for supply of Artois Farmers summer demand

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	36	mcm/a	After Riverine Reserve at Michell's Pass
Demand Growth	2%	p/a	
Years to Full Supply	3.5	Years	

CAPITAL COST COMPONENTS

	CIVIL	DAM	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Michell's Pass	47.68			2.38	50.06	60.07
Gravity main: weir to balancing tank	138.50			34.63	173.13	207.74
Balancing tank	3.75			0.94	4.69	5.62
Blousloot closed chute	15.50			0.78	16.28	19.53
Blousloot and Boontjies River protection	50.00			2.50	52.50	63.00
Papenkuils pump station upgrade (Mech/Elec)			68.00	10.20	78.20	93.84
Papenkuils pump station upgrade (Civil)	9.50			2.38	11.88	14.25
Contingencies (10%)	26.49	0.00	6.80	5.38	38.67	
SUB-TOTAL CONSTRUCTION COST	291.42	0.00	74.80	59.18	425.39	
Professional fees					32.57	
Servitude & property					6.08	
TOTAL CAPITAL COST EXCL. VAT	370.21	0.00	93.84		464.05	464.05
VAT @ 14%	51.83	0.00	13.14		64.97	
TOTAL CAPITAL COST INCL. VAT	422.04	0.00	106.97		529.01	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	1.697	
	(0.25% Dams) =	0.000	
	(4% Mech & Elec) =	3.441	
	Annual total =	5.138	
		Papenkuils	
ELECTRICITY:	Power Required :	4100	KW @ weighted average dam level
	# Days Pumping :	16	days
		@ 19 m3/s	equivalent pump rate
	Unit Rate :	130.00	c/kWh
	Electricity Consumption Costs :	2.0	Rmill/yr
	Total Energy Cost :	2.0	Rmill/yr

WATER REQUIREMENTS / **COSTS**

	Calend year	Year	Supply (10^6m^3)	NPV of supply	Weir	Gravity main	Balancing tank	Boontjies chute	Blousloot & Boontjies River protection	Papenkuils pump station (Mech/Elec)	Papenkuils pump station (Civil)			Maint	Energy
	2013	**1**													
	2014	2													
	2015	3			30.03	103.87	2.81	9.76	31.50	46.92	7.12				
	2016	4			30.03	103.87	2.81	9.76	31.50	46.92	7.12				
	2017	5	18.00	14.258										2.57	1.02
	2018	6	36.00	26.901										5.14	2.05
	2019	7	36.00	25.379										5.14	2.05
	2020	8	36.00	23.942										5.14	2.05
	2021	9	36.00	22.587										5.14	2.05
	2022	10	36.00	21.308										5.14	2.05
	2023	11	36.00	20.102										5.14	2.05
	2024	12	36.00	18.964										5.14	2.05
	2025	13	36.00	17.891										5.14	2.05
	2026	14	36.00	16.878										5.14	2.05
	2027	15	36.00	15.923										5.14	2.05
	2028	16	36.00	15.022										5.14	2.05
	2029	17	36.00	14.171										5.14	2.05
	2030	18	36.00	13.369										5.14	2.05
	2031	19	36.00	12.612						51.61				5.14	2.05
	2032	20	36.00	11.898										5.14	2.05
	2033	21	36.00	11.225										5.14	2.05
	2034	22	36.00	10.590										5.14	2.05
	2035	23	36.00	9.990										5.14	2.05
	2036	24	36.00	9.425										5.14	2.05
	2037	25	36.00	8.891										5.14	2.05
	2038	26	36.00	8.388										5.14	2.05
	2039	27	36.00	7.913										5.14	2.05
	2040	28	36.00	7.465										5.14	2.05
	2041	29	36.00	7.043										5.14	2.05
	2042	30	36.00	6.644										5.14	2.05
DISCOUNT RATE @			8.00%	295.70	49.59	171.51	4.64	16.12	52.01	115.41	11.76	0.00	0.00	42.20	16.81
								UNIT REFERENCE VALUE =						1.62	R/m³

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period	(422.04)	56.502	
b) Dams - 20 year period	(0.00)	0.000	
c) Mech./Elec equipment - 15 year period	(106.97)	15.706	72.208
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		1.697	
ii. Dams (0.25%)		0.000	
iii. Mech./Elec. (4%)		3.441	
b) Energy costs		2.05	7.184
TOTAL ANNUAL COST:			**79.393**

UNIT COST OF WATER = 2.21 R/m³

Table 30: Unit Reference Value Output Calculation for $5 m^3/s$ Scheme (Alternative A: without Boontjies Dam) at 10% Discount Rate

MICHELL'S PASS OPTION A - BULK WATER COSTS

Scheme : Gravity diversion from Breede River to Klein Berg River, no storage for supply of Artois Farmers summer demand

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	36	mcm/a	After Riverine Reserve at Michell's Pass
Demand Growth	2%	p/a	
Years to Full Supply	3.5	Years	

CAPITAL COST COMPONENTS

	CIVIL	DAM	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Michell's Pass	47.68			2.38	50.06	60.07
Gravity main: weir to balancing tank	138.50			34.63	173.13	207.74
Balancing tank	3.75			0.94	4.69	5.62
Blousloot closed chute	15.50			0.78	16.28	19.53
Blousloot and Boontjies River protection	50.00			2.50	52.50	63.00
Papenkuils pump station upgrade (Mech/Elec)			68.00	10.20	78.20	93.84
Papenkuils pump station upgrade (Civil)	9.50			2.38	11.88	14.25
Contingencies (10%)	26.49	0.00	6.80	5.38	38.67	
SUB-TOTAL CONSTRUCTION COST	291.42	0.00	74.80	59.18	425.39	
Professional fees					32.57	
Servitude & property					6.08	
TOTAL CAPITAL COST EXCL. VAT	370.21	0.00	93.84		464.05	464.05
VAT @ 14%	51.83	0.00	13.14		64.97	
TOTAL CAPITAL COST INCL. VAT	422.04	0.00	106.97		529.01	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	1.697		
	(0.25% Dams) =	0.000		
	(4% Mech & Elec) =	3.441		
	Annual total =	5.138		
		Papenkuils		
ELECTRICITY:	Power Required :	4100	KW	@ weighted average dam level
	# Days Pumping :	16	days	
		@ 19 m3/s	equivalent pump rate	
	Unit Rate :	130.00	c/kWh	
	Electricity Consumption Costs :	2.0	Rmill/yr	
	Total Energy Cost :	2.0	Rmill/yr	

WATER REQUIREMENTS / **COSTS**

	Calend year	Year	Supply ($10^6 m^3$)	NPV of supply	Weir	Gravity main	Balancing tank	Boontjies chute	Blousloot & Boontjies River protection	Papenkuils pump station (Mech/Elec)	Papenkuils pump station (Civil)			Maint	Energy
	2013	**1**													
	2014	2													
	2015	3			30.03	103.87	2.81	9.76	31.50	46.92	7.12				
	2016	4			30.03	103.87	2.81	9.76	31.50	46.92	7.12				
	2017	5	18.00	14.258										2.57	1.02
	2018	6	36.00	26.901										5.14	2.05
	2019	7	36.00	25.379										5.14	2.05
	2020	8	36.00	23.942										5.14	2.05
	2021	9	36.00	22.587										5.14	2.05
	2022	10	36.00	21.308										5.14	2.05
	2023	11	36.00	20.102										5.14	2.05
	2024	12	36.00	18.964										5.14	2.05
	2025	13	36.00	17.891										5.14	2.05
	2026	14	36.00	16.878										5.14	2.05
	2027	15	36.00	15.923										5.14	2.05
	2028	16	36.00	15.022										5.14	2.05
	2029	17	36.00	14.171										5.14	2.05
	2030	18	36.00	13.369										5.14	2.05
	2031	19	36.00	12.612						51.61				5.14	2.05
	2032	20	36.00	11.898										5.14	2.05
	2033	21	36.00	11.225										5.14	2.05
	2034	22	36.00	10.590										5.14	2.05
	2035	23	36.00	9.990										5.14	2.05
	2036	24	36.00	9.425										5.14	2.05
	2037	25	36.00	8.891										5.14	2.05
	2038	26	36.00	8.388										5.14	2.05
	2039	27	36.00	7.913										5.14	2.05
	2040	28	36.00	7.465										5.14	2.05
	2041	29	36.00	7.043										5.14	2.05
	2042	30	36.00	6.644										5.14	2.05
DISCOUNT RATE @			10.00%	235.48	47.39	163.88	4.44	15.41	49.70	109.28	11.24	0.00	0.00	33.61	13.39

UNIT REFERENCE VALUE = 1.90 R/m³

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period	(422.04)	56.502	
b) Dams - 20 year period	(0.00)	0.000	
c) Mech./Elec equipment - 15 year period	(106.97)	15.706	72.208
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		1.697	
ii. Dams (0.25%)		0.000	
iii. Mech./Elec. (4%)		3.441	
b) Energy costs		2.05	7.184
TOTAL ANNUAL COST:			**79.393**

UNIT COST OF WATER = 2.21 R/m³

Table 31: Unit Reference Value Output Calculation for 5m³/s Scheme (Alternative B: with Boontjies Dam) at 6% Discount Rate

MICHELL'S PASS OPTION B - BULK WATER COSTS

Scheme : Gravity diversion from Breede River to Klein Berg River, Boontjies Dam storage for supply of Artois Farmers summer demand

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	36	mcm/a	After Riverine Reserve at Michell's Pass
Demand Growth	2%	p/a	
Years to Full Supply	3.5	Years	

CAPITAL COST COMPONENTS

	CIVIL	DAM	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Michell's Pass	47.68			2.38	50.06	62.60
Gravity main: weir to Boontjies Dam	184.12			46.03	230.14	287.81
Balancing tank	3.75			0.94	4.69	5.86
Boontjies Dam closed chute	15.50			0.78	16.28	20.35
Boontjies Dam		81.50		16.30	97.80	122.31
Boontjies Dam pump station: Mech/Elec			13.00	0.65	13.65	17.07
Boontjies Dam pump station: Civil	3.50			0.88	4.38	5.47
Rising main: Boontjies Dam to main	11.50			2.88	14.38	17.98
Boontjies River protection	40.00			2.00	42.00	52.52
Papenkuils pump station upgrade (Mech/Elec)			68.00	10.20	78.20	97.80
Papenkuils pump station upgrade (Civil)	9.50			2.38	11.88	14.85
Contingencies (10%, dam = 15%)	31.55	12.23	8.10	8.54	61.23	
SUB-TOTAL CONSTRUCTION COST	347.09	93.73	89.10	93.94	624.67	
Professional fees					45.57	
Servitude & property					19.53	
TOTAL CAPITAL COST EXCL. VAT	454.02	124.19	111.56		689.77	704.62
VAT @ 14%	63.56	17.39	15.62		96.57	
TOTAL CAPITAL COST INCL. VAT	517.58	141.58	127.18		786.34	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	2.056		
	(0.25% Dams) =	0.281		
	(4% Mech & Elec) =	4.041		
	Annual total =	6.378		
		Papenkuils	Boontjies	
ELECTRICITY:	Power Required :	4100	864	KW Brandvlei @ weighted average dam level
	# Days Pumping :	16	22	days
		@ 19 m3/s	@ 1 m3/s	equivalent pump rate
	Unit Rate :	130	110	c/kWh
	Electricity Consumption Costs :	2.0	0.5	Rmill/yr
	Total Energy Cost :	2.5	Rmill/yr	

WATER REQUIREMENTS / **COSTS**

Calend year	Year	Supply (10^6m^3)	NPV of supply	Weir	Gravity main	Balancing tank	Boontjies chute	Boontjies Dam	Boontjies Dam pump station: Mech/Elec	Boontjies Dam pump station: Civil	Rising main	Boontjies River protection	Papenkuils pump station: Mech/Elec	Papenkuils pump station: Civil	Maint	Energy
2013	**1**															
2014	2															
2015	3			31.30	143.91	2.93	10.18	61.15	8.54	2.74	8.99	26.26	48.90	7.43		
2016	4			31.30	143.91	2.93	10.18	61.15	8.54	2.74	8.99	26.26	48.90	7.43		
2017	5	18.00	14.258												3.19	1.27
2018	6	36.00	26.901												6.38	2.55
2019	7	36.00	25.379												6.38	2.55
2020	8	36.00	23.942												6.38	2.55
2021	9	36.00	22.587												6.38	2.55
2022	10	36.00	21.308												6.38	2.55
2023	11	36.00	20.102												6.38	2.55
2024	12	36.00	18.964												6.38	2.55
2025	13	36.00	17.891												6.38	2.55
2026	14	36.00	16.878												6.38	2.55
2027	15	36.00	15.923												6.38	2.55
2028	16	36.00	15.022												6.38	2.55
2029	17	36.00	14.171												6.38	2.55
2030	18	36.00	13.369												6.38	2.55
2031	19	36.00	12.612						9.01				51.61		6.38	2.55
2032	20	36.00	11.898												6.38	2.55
2033	21	36.00	11.225												6.38	2.55
2034	22	36.00	10.590												6.38	2.55
2035	23	36.00	9.990												6.38	2.55
2036	24	36.00	9.425												6.38	2.55
2037	25	36.00	8.891												6.38	2.55
2038	26	36.00	8.388												6.38	2.55
2039	27	36.00	7.913												6.38	2.55
2040	28	36.00	7.465												6.38	2.55
2041	29	36.00	7.043												6.38	2.55
2042	30	36.00	6.644												6.38	2.55
DISCOUNT RATE @		6.00%	378.78	54.14	248.90	5.07	17.60	105.77	21.90	4.73	15.55	45.42	125.46	12.84	67.11	26.81

UNIT REFERENCE VALUE = 1.98 R/m³

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period	(517.58)	69.293	
b) Dams - 20 year period	(141.58)	18.954	
c) Mech./Elec equipment - 15 year period	(127.18)	18.674	106.921
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		2.056	
ii. Dams (0.25%)		0.281	
iii. Mech./Elec. (4%)		4.041	
b) Energy costs		2.55	8.927
TOTAL ANNUAL COST:			**115.848**

UNIT COST OF WATER = 3.22 R/m³

Table 32: Unit Reference Value Output Calculation for 5m³/s Scheme (Alternative B: with Boontjies Dam) at 8% Discount Rate

MICHELL'S PASS OPTION B - BULK WATER COSTS

Scheme : Gravity diversion from Breede River to Klein Berg River, Boontjies Dam storage for supply of Artois Farmers summer demand

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	36	mcm/a	After Riverine Reserve at Michell's Pass
Demand Growth	2%	p/a	
Years to Full Supply	3.5	Years	

CAPITAL COST COMPONENTS

	CIVIL	DAM	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Michell's Pass	47.68			2.38	50.06	62.60
Gravity main: weir to Boontjies Dam	184.12			46.03	230.14	287.81
Balancing tank	3.75			0.94	4.69	5.86
Boontjies Dam closed chute	15.50			0.78	16.28	20.35
Boontjies Dam		81.50		16.30	97.80	122.31
Boontjies Dam pump station: Mech/Elec			13.00	0.65	13.65	17.07
Boontjies Dam pump station: Civil	3.50			0.88	4.38	5.47
Rising main: Boontjies Dam to main	11.50			2.88	14.38	17.98
Boontjies River protection	40.00			2.00	42.00	52.52
Papenkuils pump station upgrade (Mech/Elec)			68.00	10.20	78.20	97.80
Papenkuils pump station upgrade (Civil)	9.50			2.38	11.88	14.85
Contingencies (10%, dam = 15%)	31.55	12.23	8.10	8.54	61.23	
SUB-TOTAL CONSTRUCTION COST	347.09	93.73	89.10	93.94	624.67	
Professional fees					45.57	
Servitude & property					19.53	
TOTAL CAPITAL COST EXCL. VAT	454.02	124.19	111.56		689.77	704.62
VAT @ 14%	63.56	17.39	15.62		96.57	
TOTAL CAPITAL COST INCL. VAT	517.58	141.58	127.18		786.34	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	2.056		
	(0.25% Dams) =	0.281		
	(4% Mech & Elec) =	4.041		
	Annual total =	6.378		
		Papenkuils	Boontjies	
ELECTRICITY:	Power Required :	4100	864	KW Brandvlei @ weighted average dam level
	# Days Pumping :	16	22	days
		@ 19 m3/s	@ 1 m3/s	equivalent pump rate
	Unit Rate :	130	110	c/kWh
	Electricity Consumption Costs :	2.0	0.5	Rmill/yr
	Total Energy Cost :	2.5	Rmill/yr	

WATER REQUIREMENTS / **COSTS**

Calend year	Year	Supply (10^6m^3)	NPV of supply	Weir	Gravity main	Balancing tank	Boontjies chute	Boontjies Dam	Boontjies Dam pump station: Mech/Elec	Boontjies Dam pump station: Civil	Rising main	Boontjies River protection	Papenkuils pump station: Mech/Elec	Papenkuils pump station: Civil	Maint	Energy
2013	**1**															
2014	2															
2015	3			31.30	143.91	2.93	10.18	61.15	8.54	2.74	8.99	26.26	48.90	7.43		
2016	4			31.30	143.91	2.93	10.18	61.15	8.54	2.74	8.99	26.26	48.90	7.43		
2017	5	18.00	14.258												3.19	1.27
2018	6	36.00	26.901												6.38	2.55
2019	7	36.00	25.379												6.38	2.55
2020	8	36.00	23.942												6.38	2.55
2021	9	36.00	22.587												6.38	2.55
2022	10	36.00	21.308												6.38	2.55
2023	11	36.00	20.102												6.38	2.55
2024	12	36.00	18.964												6.38	2.55
2025	13	36.00	17.891												6.38	2.55
2026	14	36.00	16.878												6.38	2.55
2027	15	36.00	15.923												6.38	2.55
2028	16	36.00	15.022												6.38	2.55
2029	17	36.00	14.171												6.38	2.55
2030	18	36.00	13.369												6.38	2.55
2031	19	36.00	12.612						9.01				51.61		6.38	2.55
2032	20	36.00	11.898												6.38	2.55
2033	21	36.00	11.225												6.38	2.55
2034	22	36.00	10.590												6.38	2.55
2035	23	36.00	9.990												6.38	2.55
2036	24	36.00	9.425												6.38	2.55
2037	25	36.00	8.891												6.38	2.55
2038	26	36.00	8.388												6.38	2.55
2039	27	36.00	7.913												6.38	2.55
2040	28	36.00	7.465												6.38	2.55
2041	29	36.00	7.043												6.38	2.55
2042	30	36.00	6.644												6.38	2.55
DISCOUNT RATE @		8.00%	295.70	51.68	237.61	4.84	16.80	100.97	20.71	4.52	14.84	43.36	118.67	12.26	52.39	20.93

UNIT REFERENCE VALUE = 2.37 R/m³

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period	(517.58)	69.293	
b) Dams - 20 year period	(141.58)	18.954	
c) Mech./Elec equipment - 15 year period	(127.18)	18.674	106.921
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		2.056	
ii. Dams (0.25%)		0.281	
iii. Mech./Elec. (4%)		4.041	
b) Energy costs		2.55	8.927
TOTAL ANNUAL COST:			**115.848**

UNIT COST OF WATER = 3.22 R/m³

Table 33: Unit Reference Value Output Calculation for 5m³/s Scheme (Alternative B: with Boontjies Dam) at 10% Discount Rate

MICHELL'S PASS OPTION B - BULK WATER COSTS

Scheme : Gravity diversion from Breede River to Klein Berg River, Boontjies Dam storage for supply of Artois Farmers summer demand

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	36	mcm/a	After Riverine Reserve at Michell's Pass
Demand Growth	2%	p/a	
Years to Full Supply	3.5	Years	

CAPITAL COST COMPONENTS

	CIVIL	DAM	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Michell's Pass	47.68			2.38	50.06	62.60
Gravity main: weir to Boontjies Dam	184.12			46.03	230.14	287.81
Balancing tank	3.75			0.94	4.69	5.86
Boontjies Dam closed chute	15.50			0.78	16.28	20.35
Boontjies Dam		81.50		16.30	97.80	122.31
Boontjies Dam pump station: Mech/Elec			13.00	0.65	13.65	17.07
Boontjies Dam pump station: Civil	3.50			0.88	4.38	5.47
Rising main: Boontjies Dam to main	11.50			2.88	14.38	17.98
Boontjies River protection	40.00			2.00	42.00	52.52
Papenkuils pump station upgrade (Mech/Elec)			68.00	10.20	78.20	97.80
Papenkuils pump station upgrade (Civil)	9.50			2.38	11.88	14.85
Contingencies (10%, dam = 15%)	31.55	12.23	8.10	8.54	61.23	
SUB-TOTAL CONSTRUCTION COST	347.09	93.73	89.10	93.94	624.67	
Professional fees					45.57	
Servitude & property					19.53	
TOTAL CAPITAL COST EXCL. VAT	454.02	124.19	111.56		689.77	704.62
VAT @ 14%	63.56	17.39	15.62		96.57	
TOTAL CAPITAL COST INCL. VAT	517.58	141.58	127.18		786.34	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	2.056			
	(0.25% Dams) =	0.281			
	(4% Mech & Elec) =	4.041			
	Annual total =	6.378			
		Papenkuils	Boontjies		
ELECTRICITY:	Power Required :	4100	864	KW	Brandvlei @ weighted average dam level
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		@ 19 m3/s	@ 1 m3/s	equivalent pump rate	
	Unit Rate :	130	110	c/kWh	
	Electricity Consumption Costs :	2.0	0.5	Rmill/yr	
	Total Energy Cost :	2.5	Rmill/yr		

WATER REQUIREMENTS / **COSTS**

Calend year	Year	Supply ($10^6 m^3$)	NPV of supply	Weir	Gravity main	Balancing tank	Boontjies chute	Boontjies Dam	Boontjies Dam pump station: Mech/Elec	Boontjies Dam pump station: Civil	Rising main	Boontjies River protection	Papenkuils pump station: Mech/Elec	Papenkuils pump station: Civil	Maint	Energy
2013	**1**															
2014	2															
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2016	4			31.30	143.91	2.93	10.18	61.15	8.54	2.74	8.99	26.26	48.90	7.43		
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2041	29	36.00	7.043												6.38	2.55
2042	30	36.00	6.644												6.38	2.55
DISCOUNT RATE @		10.00%	235.48	49.39	227.05	4.62	16.06	96.49	19.62	4.32	14.18	41.44	112.40	11.72	41.72	16.67
							UNIT REFERENCE VALUE =								2.78	R/m³

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period	(517.58)	69.293	
b) Dams - 20 year period	(141.58)	18.954	
c) Mech./Elec equipment - 15 year period	(127.18)	18.674	106.921
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		2.056	
ii. Dams (0.25%)		0.281	
iii. Mech./Elec. (4%)		4.041	
b) Energy costs		2.55	8.927
TOTAL ANNUAL COST:			**115.848**

UNIT COST OF WATER = 3.22 R/m³

9.4 COMPARISON OF URVS FOR SCHEMES

The proposed BBTS is one of the few remaining surface water schemes that could be developed to supply the growing water requirements of the WCWSS. This scheme would make extensive use of existing infrastructure namely the existing Klein Berg Diversion Canals, the Voëlvlei Dam and the existing water treatment works and pipeline to Cape Town as well as the existing infrastructure of the WCDM. The Unit Reference Values (URVs) for the two alternatives are R1.62/m^3 (Alternative A) and R2.37m^3 (Alternative B) respectively (for a discount rate of 8% per annum) as determined above. These are relatively low compared with the URVs of other schemes.

Whilst the financial and yield assessments in this Feasibility Study are favourable for the possible implementation of the scheme, other factors (such as environmental and hydrological uncertainty) will ultimately influence the decision on the suitability of this possible diversion scheme.

In comparison, the URVs (at 8% discount rates) for the two alternatives for the Berg River-Voëlvlei Augmentation (BRVA) scheme which would also deliver water to the Voëlvlei Dam are estimated as follows.

- A 4m^3/s pumped diversion with a stepped pumping rule would have a URV of R1.52/m^3 and would yield about 23 million m^3/a.
- A 6m^3/s pumped diversion with a variable abstraction rate would have a URV of R1.94/m^3 and would yield about 20 million m^3/a.

During Phase 1 (pre-feasibility) of this study, the URV of the Steenbras Augmentation Scheme was determined to be R4.33/m^3 (at 8% discount rate) and the scheme would yield about 23 million m^3/a.

The URV's of other potential schemes that have been investigated in other studies, and generally in less detail, are provided below:

- The CCT has recently commissioned the feasibility study of a desalination scheme. Estimates based on previous studies indicate that the URV would be of the order R7-R8/m^3 for a scheme that would supply about 83 million m^3/a (for a discount rate of 6%).
- The CCT also plans to commission a feasibility study of the potable use of waste water. Previous estimates indicate that this scheme would have a URV of about R5-6/m^3 for a scheme that would also yield about 83 million m^3/a (for a discount rate of 6%).
- The feasibility study of the Table Mountain Aquifer has entered the pilot wellfield phase and is expected to yield about 5 million m^3/a and have a URV of R1,90/m^3 (for a discount rate of 6%).

In summary, for a discount rate of 8% pa the URVs of the BBTS Alternative A and Alternative B schemes are R1.62/m^3 and R2.37/m^3 respectively whereas those for the BRVA scheme for the 4 m^3/s and the 6 m^3/s schemes were determined to be R1.52/m^3 and 1.94/m^3 respectively. .

9.5 A CAUTIONARY APPROACH TO IMPLEMENTATION

Apart from having favourable URVs as described in **Section 9.4** above, this BBTS has a number of associated challenges involved with its feasibility, which include:

- Uncertainty in the hydrology of the Breede River and the need for a Breede WAAS;
- Uncertainty in the ability to meet the EWRs without the need for an "EWR" dam;
- Development of further water supply schemes in the Breede WMA is not in alignment with the objectives of the BOCMA's Catchment Management Strategy;
- Significant social objection has been raised to increased inter-basin transfers out of the Breede WMA.
- The implementation timeframe for the BBTS would mean it could only come on line by 2023. As discussed in **Section 9.6**. The BRVA scheme on the other hand could come on line by 2019.

9.6 POSSIBLE TIME FRAME FOR IMPLEMENTATION

The earliest possible timeframe for implementation of the BBTS (should it go ahead) is likely to be as indicated in **Figure 53**. This suggests that water could first be supplied in about 2023. However there are a number of critical factors (including strategic decisions) affecting the timing of the potential implementation of the BBTS. These are:

- Timing and undertaking of the Breede WAAS;
- Updating of this Feasibility Study to account for the outcomes of the Breede WAAS,
- Undertaking a Comprehensive Reserve determination for the Breede River and its estuary based on the updated hydrology;
- Reconciliation Strategy decisions around implementation of the BRVA scheme, notably the CCT pipeline capacity and the possible need to raise Voëlvlei if the BBTS scheme is considered as a further augmentation to the BRVA scheme.

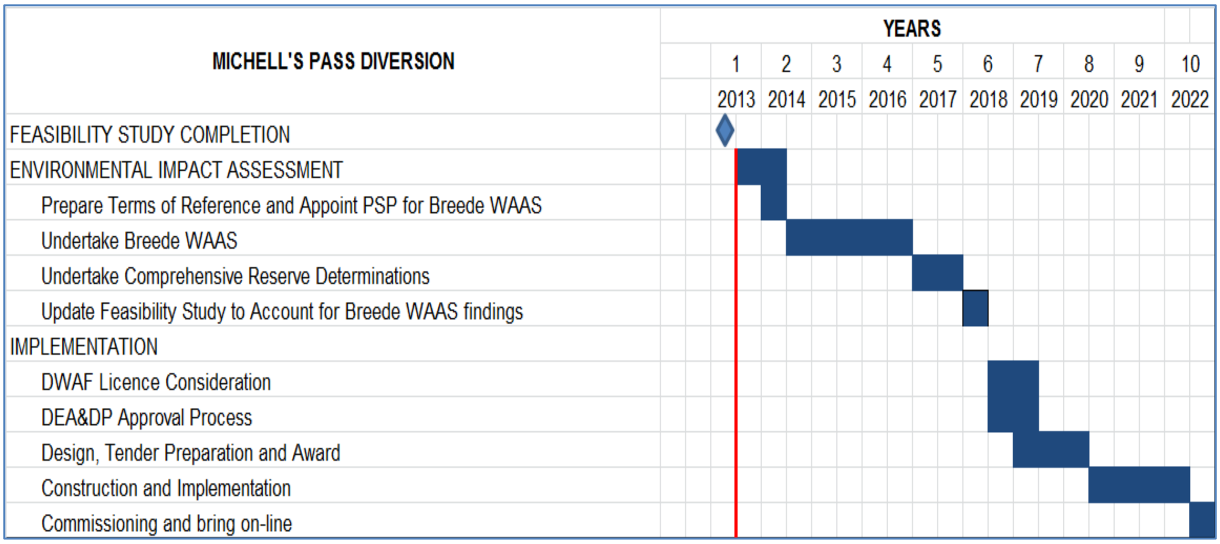

Figure 53: Potential Implementation Timeframe for the BBTS

9.7 FINANCING OPTIONS FOR THE SCHEME

9.7.1 Introduction

A key factor in the financing of future water resource infrastructure is the issue of ownership. If the asset is owned by the DWA then the finance charges for the creation of the asset would fall under the Pricing Strategy for Raw Water Use Charges. If the asset is owned by the Municipality (CCT) the governing legislation would be the Municipal Financial Management Act (MFMA). In the case of this scheme it is unlikely that the assets will be owned by the Municipality as the scheme would be integral components of DWA's existing assets.

9.7.2 Assets Owned by DWA

There are a number of options set out in the Pricing Strategy for the financing of Water Resource Infrastructure.

9.7.2.1 Return on Assets (ROA)

This charge reflects payment towards the development and betterment capital value of waterworks on government water schemes. It is determined by fixing a charge to earn a specific rate of return on the current depreciated replacement value of the infrastructure.

ROA is based on the social opportunity cost of capital to government and this should approach the level necessary to fund the annual capital expenditure budget requirement for the development of new waterworks and betterment of existing infrastructure from the fiscus.

In terms of the proposed revised Pricing Strategy, once a ring fenced provision account for ROA has been established, ROA revenue will be applied to the funding of water resource development, prioritised as follows:

(i) Planning and feasibility of future augmentation

(ii) Betterment

(iii) Social projects

The scheme would fall into the category of "Planning and feasibility of future augmentation schemes" and the costs would ultimately be fully recovered from the water uses.

9.7.2.2 Government schemes funded off-budget

Water management institutions such as the TCTA, which are directed by the Minister of Water Affairs to implement and fund government water schemes off-budget, are entitled, by the National Water Act (NWA), to raise loans to finance the development of new water resource infrastructure, and should therefore be able to service these loans through cost recovery. These institutions, in consultation with stakeholders, can on a project by project basis determine the extent of charges as determined by the proposed financial modelling. The primary charge will be the Capital Unit Charge (CUC). An example of this funding arrangement is the construction of the Berg Water Project to augment water to the CCT. The CCT has an Agreement with DWAF who in turn have an Agreement with TCTA. The loans are raised by TCTA on the strength of these Agreements and the end users (ie CCT's consumers) paying for the full cost of the Berg Water Project.

9.7.2.3 Schemes Owned by CMAs and WUAs

Catchment management agencies and water user associations can also levy charges for the development and use of waterworks. These charges, in terms of the Pricing Strategy, must take inter alia the following into account:

(a) Recovery of overheads/management, operations and maintenance costs;

(b) Recovery of capital costs and the servicing of loans (water management institutions are entitled by the Act to raise loans to finance new water supply infrastructure, and should therefore be able to service these loans through cost recovery);

(c) Reasonable provision for the depreciation of assets, which can be placed in a reserve fund for utilisation at the appropriate time for refurbishment.

Charges levied by water management institutions may be levied on a proportional or differential basis, depending on the relevant constitution, or if so directed by the Minister to give effect to the provisions regarding the rendering of financial assistance in terms of the NWA.

9.7.3 Municipal Asset

Should the asset be owned by the Municipality, it would have to form part of their long-term capital expenditure programme and would have to be specifically budgeted for. A municipal water asset would be recovered through the water tariffs. The governing legislation would be the Municipal Financial Management Act (MFMA).

10. ENVIRONMENTAL CONSIDERATIONS

10.1 ACTIVITIES FOR AUTHORISATION

The environmental process for the proposed BRVA Scheme will need to fulfil the requirements of all relevant legislation, including but not limited to:

a) National Environmental Management Act, 1998 (Act No. 107 of 1998);

b) National Water Act, 1998 (Act No. 36 of 1998); and

c) National Heritage Resources Act, 1999 (Act No. 25 of 1999).

10.1.1 National Environmental Management Act, No. 107 of 1998

NEMA, as amended, establishes, *inter alia*, the principles for decision-making on matters affecting the environment. Section 2 sets out the National Environmental Management Principles which apply to the actions, including decision-making, of organs of state that may significantly affect the environment. Furthermore, Section 28(1) states that "Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped, to minimise and rectify such pollution or degradation of the environment."

In terms of the EIA regulations, promulgated in terms of Section 24 of NEMA, certain activities are identified, which require authorisation from the competent environmental authority, in this case the Department of Environmental Affairs and Development Planning (DEA&DP), before commencing. Listed activities in Government Notice (GN) No. 545 require Scoping and EIA whilst those in GN No. 544 and 546 require Basic Assessment (unless they are being assessed under an EIA process). Due to the nature and extent of the proposed BRVA Scheme, a full EIA process will be required.

10.1.2 National Water Act, No. 36 of 1998

The National Water Act (NWA) (Act No 36 of 1998) provides for the sustainable and equitable use and protection of water resources. It is founded on the principle that the National Government has overall responsibility for and authority over water resource management, including the equitable allocation and beneficial use of water in the public interest, and that a person can only be entitled to use water if the use is permissible under the NWA. The Act also distinguishes between various types of water use[6] in Section 21 which may require a Water Use Licence or a General Authorisation.

The proposed augmentation scheme will require an Integrated Water Use Licence that allows for the following[7]:

- Diversion of surplus winter water from the Berg River to the Voëlvlei Dam;
- Increase of the Voëlvlei Dam's storage capacity (when the dam is raised); and
- Replacement of the existing permit issued to the Voëlvlei Dam under the previous Water Act of 1956 (Act No 54 of 1956), to allow for the additional water to be taken from the dam (i.e. the CCT and any other user).

10.1.3 National Heritage Resources Act, No. 25 of 1999

In terms of the National Heritage Resources Act (No. 25 of 1999) (NHRA), any person who intends to undertake "*any development … which will change the character of a site exceeding 5 000 m^2 in extent*",

[6] Taking water from a water resource, storing water, impeding or diverting the flow of water in a watercourse and altering the bed, banks, course or characteristics of a watercourse.

[7] The Integrated Water Use Licence would also include the existing lawful water use at Voëlvlei Dam.

"the construction of a road…powerline, pipeline…exceeding 300 m in length" or *"the rezoning of site larger than 10 000 m² in extent…"* must at the very earliest stages of initiating the development notify the responsible heritage resources authority, namely the South African Heritage Resources Agency (SAHRA) or the relevant provincial heritage agency, i.e. Heritage Western Cape (HWC). These agencies would in turn indicate whether or not a full Heritage Impact Assessment (HIA) would need to be undertaken.

Section 38(8) of the NHRA specifically excludes the need for a separate HIA where the evaluation of the impact of a development on heritage resources is required in terms of an Environmental Impact Assessment (EIA) process. Accordingly, since the impact on heritage resources would be considered as part of the EIA process, no separate HIA would be required. SAHRA or HWC would review the EIA reports and provide comments to DEA&DP, who would include these in their final environmental decision. However, should a permit be required for the damaging or removal of specific heritage resources, a separate application would have to be submitted to SAHRA or HWC for the approval of such an activity.

10.2 THE ENVIRONMENTAL IMPACT ASSESSMENT PROCESS

NEMA requires that the EIA process be undertaken by a suitably qualified and experienced independent Environmental Assessment Practitioner[8] (EAP). Due to Aurecon and WorleyParsons's involvement with the technical aspects of the project, neither party's in-house environmental specialists are considered to be independent. Therefore an external independent EAP will need to be appointed[9].

A very important component of the EIA process is the requisite specialist studies and the following studies were identified during the pre-feasibility studies as being necessary: Agriculture, Aquatic, Botanical, Heritage and Social. Specialists that were involved during the pre-feasibility studies should preferably also be involved in the EIA process due to their existing understanding of the project.

In terms of timeframes, it is anticipated that the EIA process will take approximately 11 months until the submission of the Final EIA Report. However, activities and timeframes involving the authorities, such as approval of the Scoping Report, cannot be guaranteed. It is anticipated that DEA&DP will take 3 to 7 months to make a decision on the Environmental Authorisation, followed by the statutory appeal period. Experience shows that there are many variables within an EIA process, which have the potential to delay progress towards specified milestones, most notably the requisite input of technical information from the applicant, the stakeholder (including public) participation process, specialist input and authority review.

10.3 PUBLIC PARTICIPATION

10.3.1 Introduction

Effective and equitable engagement with stakeholders contributes to the identification of key issues of concern and possible solutions, as well as accessing relevant local or traditional knowledge. Through engaging stakeholders proactively, proponents and decision-makers are able to understand and clarify the degree to which other stakeholders will be willing to accept any trade-offs which may be required. This ensures more informed decision-making and ultimately sustainable development.

10.3.2 Preliminary Public Notification of the Study

The public participation process was undertaken in both Afrikaans and English to accommodate the language preferences of the local communities. Newspaper advertisements to notify the public that the study had commenced were placed in a number of local and regional newspapers as indicated in **Table 34**. The public database developed during the WCWSS Reconciliation Strategy Study was also used to notify the broader public that the study had commenced. This database was updated and maintained throughout the study.

[8] Section 17 of GN No. R543

[9] Five EAPs were contacted for proposals to undertake the necessary work. Of these only three companies responded. Unfortunately DWA was unable to sub-contract the EIA investigation to Aurecon's current contract and the normal procurement process will need to be undertaken.

Table 34: Summary of Advertisements Placed to Notify the Broader Public of the Commencement of the Study

NEWSPAPER	DATE
Die Burger	14 February 2009
Paarl Post	19 February 2009
Witzenberg Herald	19 February 2009
Overstrand Herald	20 February 2009
Weekend Argus	14 & 15 February 2009
Worcester Standard	19 February 2010
Caledon Kontreinuus	20 February 2009

Letters of notification were sent to relevant authorities including the:

- Department of Agriculture (Western Cape);
- Department of Environmental Affairs and Tourism;
- Western Cape Department of Environmental Affairs and Development Planning;
- Department of Transport and Public Works;
- Heritage Western Cape;
- Department of Local Government and Housing;
- Eskom;
- CapeNature; and
- Potentially affected municipalities.

Notifications were also specifically addressed to the Berg and Breede CMA Reference Groups and the Water User Associations in the Berg and Breede WMAs.

10.3.3 Meetings

A number of public and stakeholder meetings were held during the course of the project. The first two public meetings were held at the beginning of Phase 1 at two different geographic centres, namely Worcester and Grabouw, as these locations are in reasonably close proximity to the potential schemes. At the end of Phase 1 (December 2010) a second round of public meetings was held in Worcester and Grabouw to present the findings and recommendations to the public. These meetings were advertised in the Worcester Standard and the Overstrand Herald in November 2010.

Two Stakeholder Committee Meetings were also held pre and post an Options Prioritisation Workshop that was held in March 2010. The Stakeholder Committee comprises national, provincial and local authorities, WUAs, conservation authorities, emerging farmers and other statutory bodies that have direct connections with the water sector.

A separate meeting was held with potentially affected landowners to identify issues and concerns regarding the proposed layouts of the BRVAS and the BBTS.

A summary of the public and stakeholder engagement process (public and stakeholder meetings and workshops) is provided in **Table 35** below.

Table 35: Summary of Public and Stakeholder Meetings during the Course of the Study

MEETING TYPE	TARGET GROUP	LOCATION	DATE
Public Meeting	Interested & Affected Parties (I&APs)	Elgin-Grabouw Country Club, Grabouw	5 March 2009
Including landowners, authorities and Water Users Associations (WUAs).			
Public Meeting	I&APs	Protea Cumberland Hotel, Worcester	7 March 2009
Committee Meeting	Water sector stakeholders	Department of Agriculture, Elsenberg	31 March 2009
Including national, provincial and local authorities, WUAs, conservation, emerging farmers and statutory bodies.			
Options Prioritisation Workshop	Water sector representatives & project specialists	Nelson's Creek Wine Estate, Paarl	25 March 2010
Including Municipalities, Catchment Management Agency, CapeNature, CSIR, Department of Agriculture and DWA (National and Regional).			
Committee Meeting	Water sector stakeholders	Department of Agriculture, Elsenberg	15 April 2010
Public Meeting	I&APs	Tri Active (Green Mountain Lodge), Elgin Valley	4 December 2010
Public Meeting	I&APs	Protea Cumberland Hotel, Worcester	4 December 2010
Stakeholder Meeting	Potentially affected landowners	Dutch Reformed Church, Wolseley	2 March 2011
Focussed specifically on Breede Berg (Mitchell's Pass) Water Transfer Scheme and the Berg River Voëlvlei Augmentation Scheme			

10.3.4 Newsletters

Newsletters were sent to all registered Interested and Affected Parties and members of the Stakeholder Committee in November 2011 and March 2013 in order to keep them informed about the status of the project until the required EIA process commences.

10.3.5 Conclusions

Experience gained from interactions with Stakeholders and Interested and Affected Parties (I&APs) on this project, has shown that the proposed scheme is very sensitive in terms of public opinion. It is therefore of great importance to Stakeholders and I&APs that continuity between the Preliminary Phase and the EIA process is ensured. The existing Stakeholder and I&AP databases will therefore be provided to the appointed independent EAP to ensure that all registered parties are informed about the EIA process.

10.4 ALTERNATIVE ALIGNMENTS CONSIDERED

The NEMA Regulations[10] require that "*alternatives to the proposed activity that are feasible and reasonable*" be identified and considered during the EIA process. Alternatives can include activity alternatives, site alternatives, design or layout alternatives, technology or operational alternatives, as well as the "no-go" option.

10.5 WAY FORWARD FOR EIA

The proposed BRVA Scheme will need to comply with the requirements of all relevant legislation, including (but not limited to) NEMA, NWA and NHRA. Specialist input and assessments will be required to provide the decision-making authorities with sufficient information to make an informed decision. Some of the requisite studies may need to be completed during a specific season to ensure a comprehensive assessment of potential impacts on the environment, e.g. botanical assessment. These studies should thus be carefully planned to prevent any unnecessary delays to the project programme. It is also important to ensure that project information provided to specialists and the EAP does not change significantly during the EIA process as it could potentially necessitate the revision of assessments. It is therefore recommended that a design freeze should be applied to the project to prevent unnecessary costs and programme delays during the EIA process.

Furthermore, it is important for DWA to take into consideration the EIA process timeframes when undertaking forward planning to meet future water requirements, as it can take up to 18 months (or in some cases even longer) to receive environmental authorisation. However, activities and timeframes involving the authorities cannot be guaranteed and should be considered as variable in the programme.

An independent EAP will need to be appointed to ensure compliance with the requirements of Section 17 of EIA Regulations. Once the EAP has been appointed, a public meeting should be undertaken to allow the Western Cape Water Consultants to present the technical findings to update Stakeholders and I&APs on the current project status and way forward. The meeting will also familiarise Stakeholders and I&APs with the EAP and EIA process that will be undertaken.

[10] Section 27 (e) (iii) of R543

11. SUGGESTIONS OF THE PROJECT MANAGEMENT COMMITTEE

During the course of the Study, 24 Project Management Committee (PMC) Meetings were held (once every 2-3 months), and official meeting notes were recorded at each. The meetings were well represented by official study stakeholders including:

- The DWA Directorates of Options Analysis, National Water Resource Planning, Water Resource Planning Systems, National Water Resource Infrastructure (Southern Operations) and the DWA Western Cape Regional Office,
- The DWA Chief Directorates of Integrated Water Resource Planning and Resource Directed Measures,
- The Western Cape Provincial Department of Agriculture, and
- The City of Cape Town.

In addition to the project management function of the PMC meetings, a number of valuable suggestions were proposed during the course of these discussions. Those pertinent to the potential BBTS have been extracted from the relevant meeting minutes and are presented below in chronological order of the respective meeting dates:

1) Meeting the Reserve requirements immediately downstream of the BBTS diversion site is not the only concern. Of importance is the provision of a basin-wide contribution towards meeting the Reserve requirements, particularly in the lower Breede River and its estuary.

2) The absence of flow in the Breede River (and its upper tributaries) in summer should also be redressed, and should not be set-aside as a summer problem only.

3) Despite the fact that a component of the uncertainty in the middle Breede hydrology is related to poor stream flow gauging, a **Breede WAAS** is urgently required in order that the surface water development options in that system can be equitably compared (at equivalent levels of confidence) to those in the Berg WMA.

4) The modelling of the diversion schemes (notably Michell's Pass) in which only winter water would be diverted was a questionable approach as the proposed scheme makes no allowance for addressing the fact that the summer EWRs in the Upper Breede River are not being satisfied (due to over-allocation of water to irrigation). This should be remedied.

5) A significant problem in the Upper Breede is over-allocation. Compulsory Licensing is a tool that could be used to address this, as well as the option of buying out water from existing lawful users.

6) **Meeting the EWRs is a year-round obligation** and any new scheme should provide for the summer and winter EWRs, regardless of whether or not the summer EWR is currently being met. This approach has been adopted in the assessment of the proposed BBTS.

7) The concern was recognized that summer releases made into the Breede River could flow in the alluvium and not achieve the desired surface water low flow objectives. The feasibility of such releases needs to be considered through trial releases from Koekedouw Dam.

8) The EWR is not being met at present at numerous points in the Breede catchment including at the estuary. The economic value of the estuary is high because it supports the near-shore fishery. Monitoring also needs to be undertaken in order to refine the EWR. In particular the Middle Breede is in a very poor state. To rectify the situation the hydrology for the Breede River catchment needs

to be updated for the entire catchment and new developments within the basin need to be captured and modelled in the WRYM.

12. CONCLUSIONS AND RECOMMENDATIONS

12.1 CONCLUSIONS AND RECOMMENDATIONS OF THE STUDY

Based on the information presented in this report and its accompanying Appendices, the following conclusions are made in relation to the potential implementation of the BBTS:

1. The **Preliminary Reserve for the upper Breede River** immediately downstream of the proposed Michell's Pass abstraction site **is Category D** based on current available estimates and has been allowed for, as well as maintaining the present ecological status (PES) at some of the sites downstream of the Papenkuils Pump Station. Further investigations and trial releases would be necessary to determine whether such releases would be effective in providing the summer Preliminary Reserve flows in the Breede River downstream of the proposed abstraction site.

2. The proposed Michell's Pass **abstraction site would be located immediately downstream of the existing diversion weir** for the current inter-basin transfer via the Artois Canal scheme (for irrigation and supply to Wolseley). This is the most favourable location for the diversion structure in order to ensure a gravity diversion scheme without the need for supplementary pumping, and to ensure protection from inundation of the ecologically important Witels tributary.

3. Geologically this area is typical of Breede River alluvium which may result in a **weir structure** that leaks to some extent. This would serve towards providing for the summer base flows but may require **measures to seal the foundations as subsurface flows which would contribute to the Reserve** could not be measured.

4. The benefits of the **proposed pipeline** from Michell's Pass to the Boontjies River as a replacement of the Artois canal would be **more efficient control of water distribution to the irrigators and Wolseley** and reduced losses from those currently experienced out of the canal.

5. **The two potential alternatives investigated, with or without the Boontjies Dam, would both yield 36 million m^3/a.**

6. The **Alternative A scheme without the Boontjies Dam is considered to be more easily implemented and operated** and would also have a less disruptive effect on the current users of water from the Artois canal. This scheme would not provide the summer low flows of the Reserve unless these could be made available from the Koekedouw Dam, the feasibility of which would require further investigation and negotiation with the existing users and the funders of this Dam.

7. The **Alternative B scheme with the Boontjies Dam would require the gravity main to be operated in reverse as a rising main in summer** with pumping facilities provided to deliver water from this Dam to the Artois irrigators and if necessary, back into the Breede River towards meeting the summer Reserve flows.

8. Suitably **accurate survey information is available from this study for the purpose of undertaking detailed design of this scheme, with the exception of the Boontjies Dam** site which fell outside of the survey scope of this study.

9. **Geotechnical conditions at the proposed diversion site are typically alluvial** in nature but are acceptable for accommodating the weir design. Machine excavation is expected to be possible along the pipeline route. Although there is potential for the use of excavated materials for backfilling, the pipe type selection will influence the extent of selected fill material available insitu. Geotechnical investigations for the Boontjies Dam also fell outside the scope of this study.

10. From an integration perspective, the proposed Spes Bona Reservoir and the **linking pipeline to the Glen Gary Reservoir to be constructed by the CCT in the near future would enable most of the incremental yield of the scheme to be taken up by the CCT**. It is also likely that the **balance of the additional yield could be utilised by the WCDM** or alternatively the capacity of the Voëlvlei pipeline could perhaps be increased, however that investigation is beyond the scope of this study.

11. **For the gravity main between the weir and discharge point (9645 m long in the case of the Boontjies Dam and 7600 m long for the alternative without the Boontjies Dam) a 2000 mm dia GRP pipeline** is proposed for both alternatives. Should the DWA opt for ductile iron piping as a preferred pipe material, then it is estimated that the marginal cost increase of ductile iron over GRP pipes would increase the total cost of Alternative A by about 20% and of Alternative B by about 18%. In the case of mild steel pipes as an alternative to GRP, this would increase the capital costs of both alternatives by about 4%, but the maintenance costs in the longer-term would be more significant for mild steel pipes.

12. The **increase in the capacity of the Papenkuils Pump Station to reinstate the current yield of Brandvlei Dam while meeting the Preliminary Reserve flows downstream** would have to be confirmed, however preliminary estimates indicated that the pumping **capacity should be increased from 7 m^3/s to 26 m^3/s although an increase to 15 m^3/s with improved pumping rules may be adequate**. Further investigations would be required however the **cost estimate was based on upgrading the capacity of the pump station to 20 m^3/s for which provision was made when the existing pump station was constructed**.

13. The estimated **capital cost for the Boontjies Dam Alternative B including increasing the capacity of the Papenkuils Pump Station is R 786 million and that of the Alternative A without storage in a dam is R 529 million with annual operating and maintenance costs of R7.19 million and R8.93 million respectively.**. The corresponding **Unit Reference Values are R2.37/m^3 and R1.62/m^3 respectively** (for a discount rate of 8%).

14. All of the above considerations and recommendations are subject to first re-determining and updating the hydrology of the Breede River Basin via a Breede Water Availability Assessment Study (WAAS) so as to provide a reliable basis for making decisions around implementation and water allocation in general from the Breede River. This would have a significant impact on the potential timing of implementation and as a result, **water could only be expected to come on line from such a scheme by 2023**.

12.2 OVERALL RECOMMENDATIONS

On the basis of the financial assessment, and taking ease of operation into account, the option **without the Boontjies Dam is the preferred BBTS option**, subject to the feasibility of providing water for the Reserve of the upper Breede River being provided by releases from Koekedouw Dam being found to be feasible.

Although the same levels of concern have not been raised by water users in the Berg WMA in relation to the proposed BRVA scheme, the decision on which development option (Berg or Breede) to implement (if any) will need to be considered from a **strategic regional and national benefit** perspective.

Whilst the NWA requires new water resource development options to address existing environmental shortfalls, the question is who bears the financial cost for enabling such remedying to address over-allocation to / utilisation by irrigation. Demand side interventions such as **Compulsory Licencing** may need to be considered in such cases.

Regardless of how EWRs are provided for in the Breede River, the problem of that water being potentially unavailable for abstraction to the detriment of those upstream who had made sacrifices remains a significant challenge, possibly to be addressed through **compliance policing** in the short-term but ultimately through a **change of behaviour** in the longer-term.

The BBTS appears to be a favourable surface water intervention option from a yield and cost perspective, but would only be able to provide sufficient additional supply to augment the growth in the demands on the WCWSS system by about **3-4 years** and would not come on line before 2023. It is an option which must however be reconsidered after undertaking a Breede WAAS to provide updated reliable estimates of water availability and after consideration of its integration as a further augmentation of Voëlvlei Dam, **after the BRVA** scheme may have been implemented. However, it is not recommended as the next most suitable surface water intervention for augmenting the Western Cape Water Supply System.

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