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

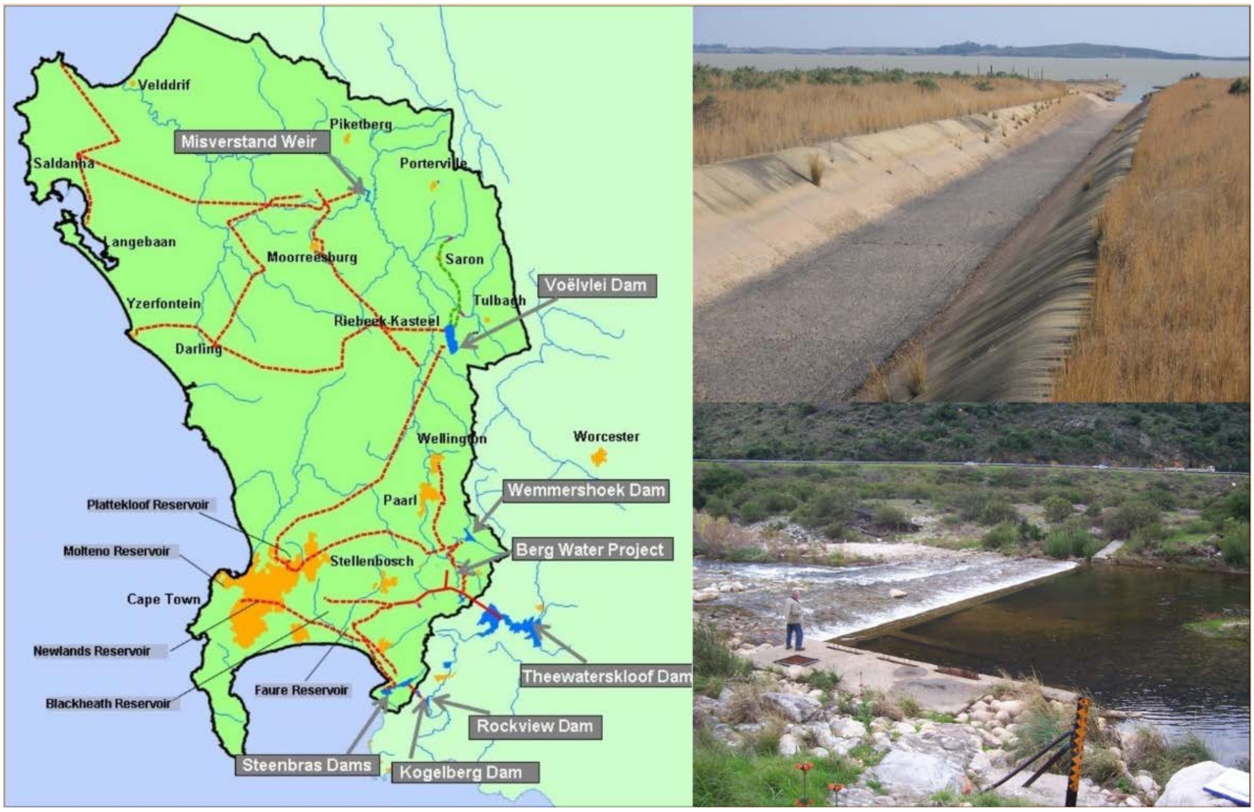
Department of Water Affairs
Directorate: Options Analysis

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

REPORT No.3 – VOLUME 2
Breede-Berg (Michell's Pass) Water Transfer Scheme

APPENDIX No.6

Preliminary Design of Papenkuils Pump Station Upgrade and Pre-Feasibility Design of the Boontjies Dam, for the Breede-Berg (Michell's Pass) Water Transfer Scheme



December 2012

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1. Papenkuils Pumping Scheme Upgrade

1.1 Introduction

The Papenkuils Pump Station would need to be upgraded from its current capacity of between 5 and 7 m^3/s to 26 m^3/s in order to maintain the existing yield of the Brandvlei Dam.

The current Papenkuils Pump Station includes civil infrastructure that was built to enable an upgrade to a capacity of approximately 20 m^3/s. The following data were extracted from the White Paper for the scheme published in 1981: W.P.–M '81: Supplementary Report on the Proposed Greater Brandvlei Government Water Scheme, which was an update on the earlier white paper of 1972: W.P-J '72: Report on the Greater Brandvlei Dam Government Water Scheme.

The proposed scheme of 1981-82 included the current pump station which was constructed, shown as Pumping Station 1 in **Figure 1** (from W.P-M'81), and a weir across the Breede River located downstream of the current pump station which was never built. The weir would have had a storage capacity of about 7.8 million m^3. At present a temporary rubble weir is constructed each year just downstream of the pump station to provide the minimum head on the river side required for pumping to take place.

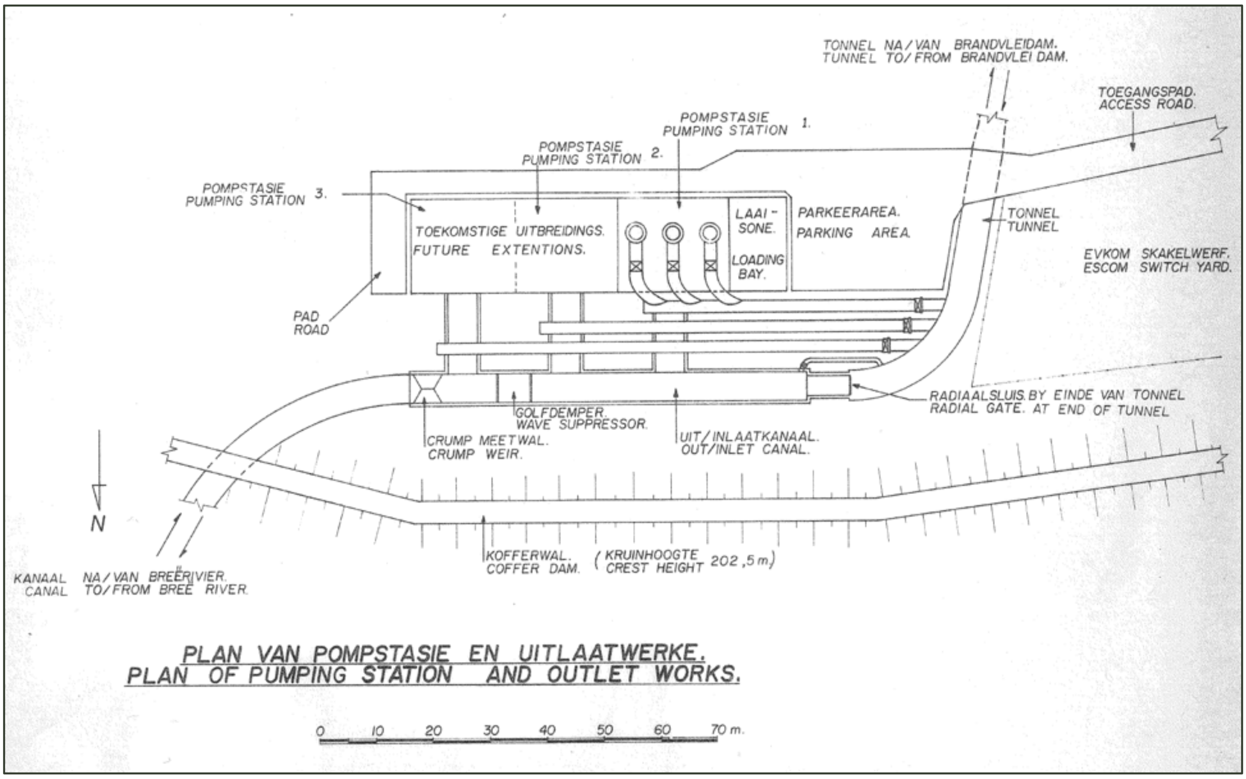

Figure 1: The proposed Papenkuils Pump Station given in the White Paper W.P.–M '81

The civil works for pumping stations 2 and 3 have been partially constructed, with the main pipe work in place, but the building super structures and pipe connections to the tunnel still requiring construction. **Figure 2** shows the blanked off pipes from pumping stations 2 and 3 that can be connected into the tunnel when these two additional pumping stations are developed. **Figure 3** shows the current pump station and canal looking towards the tunnel from adjacent to the wave suppressor as shown in **Figure 1**.

Figure 2: Blanked off pipes that can link pumping stations 2 and 3 with the tunnel

Figure 3: View of the pump station from the wave suppressor towards the tunnel

1.2 Design details

Table 1 from W.P.-M'81 gives the design levels for the pump station which would affect the static pumping head.

Table 1: Levels for the Papenkuils Pumping Scheme (from W.P.–M '81)

Description	Level (m)
Brandvlei Dam FSL	210.5
Bed level of river at proposed weir site (minimum)	190.0
Lowest level at proposed concrete spillway structure	192.5
Estimated minimum pumping level	192.5
Maximum static pumping head used for the upgrade estimate	18.0

The pump station also includes a tunnel to Brandvlei Dam, 3.5 m in diameter and approximately 350 m long, which according to W.P.-M'81 has a capacity of 40 m^3/s when releasing water back to the Breede River from the dam under gravity, that corresponds to a velocity in the tunnel of 4.2 m/s. The DWA gauge H1H028 which measures the flow in the canal at the pump station has a maximum flow on the discharge table of 28.51 m^3/s at 2 m, although an inspection of the recorded releases from the dam reveal that the releases seldom exceed 13 m^3/s. If the pump station was upgraded to 26 m^3/s capacity, then when pumping was taking place at full capacity the velocity in the tunnel would be 2.7 m/s.

According to W.P.-M'81, the initial pump station would have a design capacity of 5 m^3/s with 3 pumps with total installed capacity of 1800 kW. Data on the pumps obtained from DWA revealed that the 3 pumps each have a pump shaft power of 470 kW and can pump 1.7 m^3/s each, at a head of 20 m. The total power of the pump station is 1250 kVA. According to DWA the pump station has in recent years, since the drought in the early 2000's, been operated at higher pump speeds which has allowed up to 7 m^3/s to be pumped by the 3 pumps depending on the water level in the dam. This is at the cost of efficiency and may result in a reduction in the life of the pumps. For this study the current pumping rate has been used as a base, despite this not being ideal for the pumps themselves because it represents their current day use.

To upgrade the pump station to 26 m^3/s would require an increase in capacity of 19 m^3/s, the basic technical details for this are given in **Table 2**.

Table 2: Technical details for upgrading Papenkuils Pump Station to 26 m^3/s

Description	Value
Total pumping rate required including current 5 m^3/s (m^3/s)	26
Friction + static head @ FSL @ 26 m^3/s (m)	18.94
Losses @ pumps, estimate (m)	2.00
Total pumping head @ FSL @ 26 m^3/s , estimate (m)	20.94
Increase in pumping capacity required (m^3/s)	19
Power required for upgrade portion: duty pumps for 19 m^3/s (kW)	5400
Power required including standby pumps (25%) for 19 m^3/s (kW)	6800

If the same type of pumps (470 kW) were used for the upgrade as are currently installed at the pump station, then 12 duty pumps would be required (5640 kW) and if 25% standby capacity were provided then 15 pumps would be required (7050 kW). At present the pump station is operated with all pumps running, i.e. no pumps are left idle serving as standby pumps.

It may be preferable to install new pumps in the upgraded portion of the pump station that would be able to pump at least 2.3 m^3/s, thus reducing the number of pumps required. The fact that 7 m^3/s is pumped on occasion at present from pump station 1, shows that it is possible to pump this flow rate through the existing pipework into the tunnel.

1.3 Capital cost estimate

The mechanical and electrical portion of the upgrade was costed based on unit rates for pump stations that have Vertical Shaft Mixed Flow Pumps, the pump type that is currently installed at Papenkuils (**Figure 4**). A unit rate of R10 000 / kW was used.

Civil costs were estimated based on a unit rate for the size of building that would be required, the unit rate that was used was R10 000 / m^2, which is slightly lower than the unit rate used for the other pump stations for the Michell's Pass and Berg River Schemes. This is because it is not certain at this stage how much civil work would be required to upgrade the pump station. Based on the current pump station capacity of 5 m^3/s, which is often operated at up to 7 m^3/s, and which occupies one of the three pump station spaces that have been allowed for at the site in the original layout (**Figure 1**), it should theoretically be possible to upgrade the pump station to at least 21 m^3/s without major civil works. This is because a lot of the major civil infrastructure has already been constructed and pumping station 1 is being operated at up to 7 m^3/s at present. However it is not clear what the cost implications of the last 5 m^3/s would be and whether it would be possible to include the full required capacity of 26 m^3/s in the existing layout.

It has been estimated that the building would need to have a floor area of 950 m^2, based on the installation of pumps that could pump 2.3 m^3/s each.

A cost estimate for the upgrade to 26 m^3/s capacity is given in **Table 3**.

Table 3 Cost estimate for the upgrade to Papenkuils Pump Station

Description	19 m3/s
Mechanical and electrical	
Mechanical and Electrical	R 68,000,000
Preliminary and general	R 10,200,000
Subtotal A	R 78,200,000
Civil	
Civil	R 9,500,000
Preliminary and general	R 2,375,000
Subtotal B	R 11,875,000
Subtotal 1	R 90,075,000
Contingencies	R 9,007,500
Subtotal 2	R 99,082,500
Fees	R 7,926,600
Total project cost (excl VAT)	**R 98,001,600**
VAT	R 13,720,224
Total project cost (incl VAT)	**R 111,721,824**

Sensitivity of the URVs to changes in the capital costs of the Papenkuils Pump Station was tested and the URVs were found to not be very sensitive to changes in the capital costs of the Papenkuils Pump Station.

Figure 4: The interior of Papenkuils Pump Station showing the currently installed vertical turbine pumps

1.4 Energy requirement

Since the Papenkuils tunnel serves the purpose of both being able to deliver water to Brandvlei Dam as a rising main, and to release water from the dam back to the Breede River under gravity, the head against which the pump station has to pump is constantly varying according to the level of Brandvlei Dam. This affects the energy required and thus the cost of pumping. Although the pump station will be designed with the capacity to pump 26 m^3/s to the FSL, this will in practise only occur occasionally.

To calculate the energy required for pumping at the upgraded pump station, the monthly time series of Brandvlei Dam levels was extracted from the Water Resource Yield Model (WRYM) for a scenario that modelled the current pump flow of 7 m^3/s, and also for a scenario that modelled the upgraded pump station. On average over the 768 months or 64 years of current day monthly time series that was modelled, it would be required to pump at full capacity for 32 days per year for the upgraded pump station and 79 days per year with the current flow of 7 m^3/s. Due to the complex operation of the entire Breede River Basin and the various inflows and demands off Brandvlei Dam, the different sized pump stations would result in different time-series of dam levels. The additional portion of the upgraded pump station capacity would be needed to pump for 16 days per year on average. The maximum number of days pumping that would have been required for the upgrade portion of the pump station (the portion in excess of 7 m^3/s) was 33 in 1973, and the minimum was 0 days in 1980.

The weighted average dam level over the historic period that was modelled (1927-1990) was calculated to determine the head against which the pumps would pump on average, weighted according to volume that was pumped in each month. This calculation estimated that the weighted average dam level to which the pump station would pump would be 205.31 m amsl, which is equivalent to a total head of 13.75 m including static and friction head. This would require on average, a power of 4100 kW for the 19 m^3/s of additional capacity. The energy required to maintain the yield of Brandvlei Dam was thus based on a power of 4100 kW operating over 16 days per annum. For comparison, the capital cost was based on the total installed capacity required to pump water to the FSL, of 6800 kW.

2. Boontjies Dam

2.1 Introduction

The potential Boontjies Dam would store water for summer use by the farmers around Wolseley who currently rely on summer diversions from Michell's Pass via the Artois Canal. This would in turn allow the restoration of perennial flows in the summer months and allow the environmental water requirement to be met immediately downstream of the proposed diversion weir on the Breede River at this location.

2.2 Design details

Various dam sites were investigated of which two promising sites were identified, namely Sites 1 and 9 as shown in **Figure 5**. Site 9 was selected for this study. The dam wall would have a curve shape in plan to maximise storage volume.

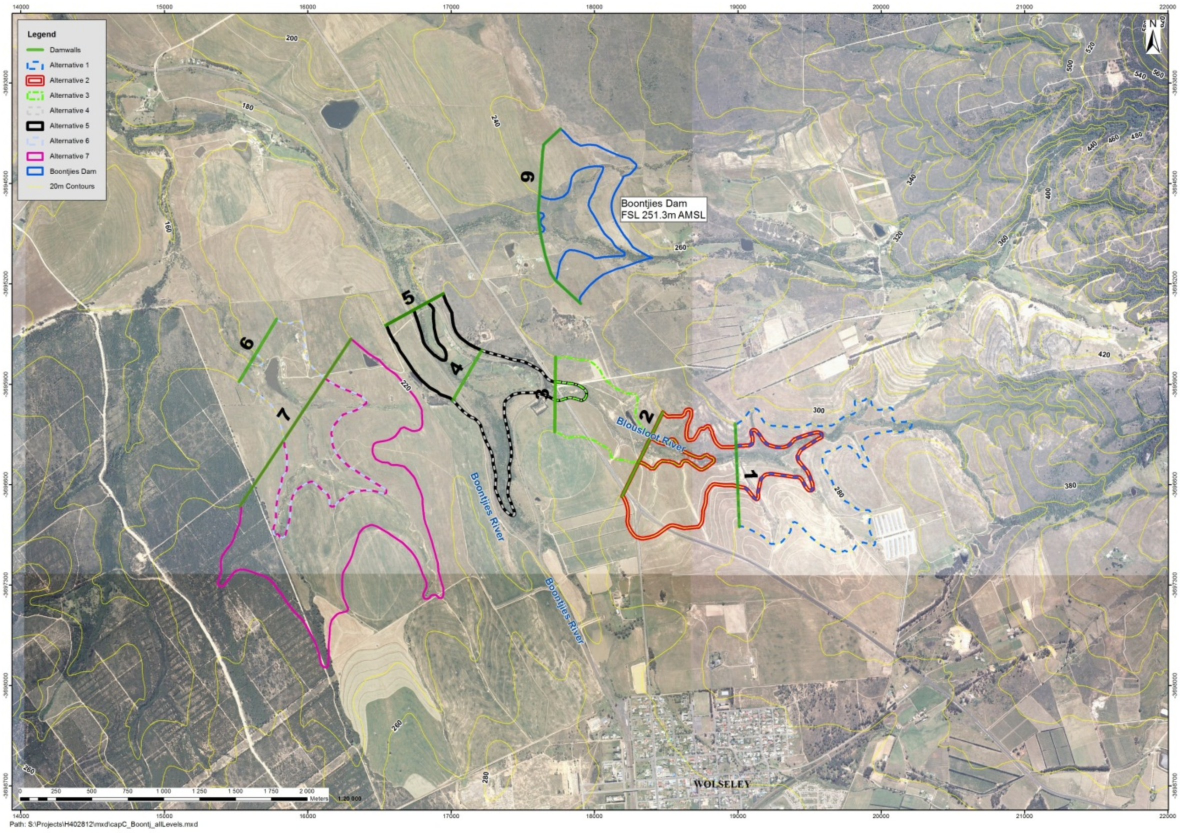

Figure 5: **The various dam sites investigated for the potential Boontjies Dam**

Figure 6 gives a plan of the dam basin, dam wall and associated infrastructure. **Figure 7** provides a long section along the centreline of the dam wall crest and **Figure 8** shows a cross-section through the dam wall along the line of the outlet structure.

Figure 6: Plan of the proposed Boontjies Dam wall, associated infrastructure and basin

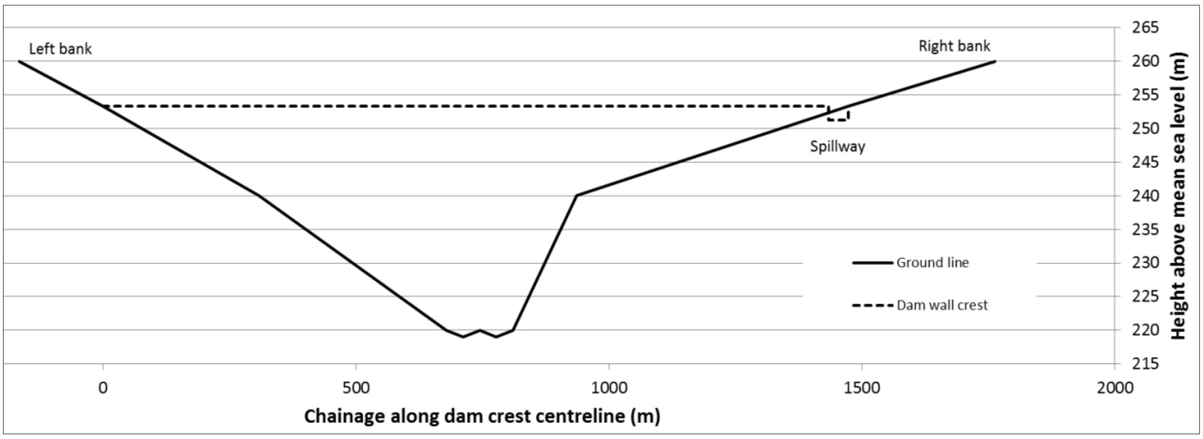

Figure 7: Long section along the proposed Boontjies Dam wall

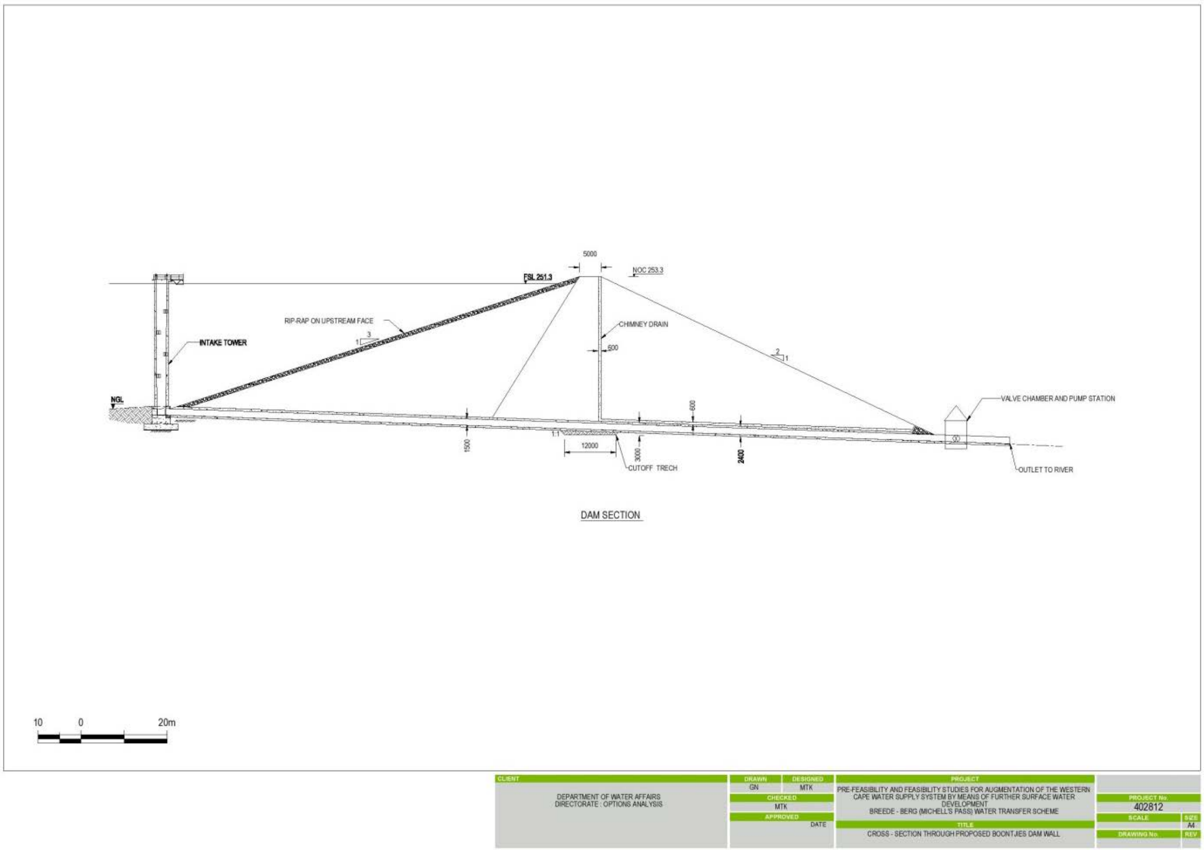

Figure 8: Cross section through the proposed Boontjies Dam wall along the line of the outlet structure

The dam's required live storage volume was determined to be 7.46 million m^3. With this volume, the existing irrigators would be supplied at a very high level of assurance during the summer months. If this project were to reach detail design stage it is recommended that a more rigorous determination of the storage volume that would be required is made, which would include a pre-determined assurance of supply. This could potentially save costs on the Boontjies Dam as the dam size determined in this study has been done so at a pre-feasibility level and could potentially be further optimised.

A dead storage allowance of 5% (0.37 million m^3) was included which brings the dam's total storage volume to 7.83 million m^3. It has been assumed that the dam would be constructed out of earthfill, sourced within the dam basin. The dam would require a full supply level 32.3 m above the valley floor, or at a level of 251.3 m amsl. With an allowance of 2 m of freeboard, the dam wall would be 34.3 m high at 253.3 m amsl and the spillway would be located at level 251.3 m amsl (32.3 m above the valley floor).

Table 4 provides the characteristics of the dam basin.

Table 4: Characteristics of the proposed Boontjies River Dam basin

Description	Level (m amsl)	Level (m above bed)	Volume (10^6 m^3)
Dam bed	219.0	0.0	0.00
Top of dead storage	229.3	10.3	0.37
Contour 240 m	240.0	21.0	2.25
Spillway	251.3	32.3	7.83
Dam crest	253.3	34.3	9.14

The spillway was sized based on the 1:100 year design flood calculated using the Regional Maximum Flood (RMF) method. At detail design stage the spillway and freeboard would need to be refined based on a more robust method of design flood determination. The RMF method was used at this pre-feasibility stage only to inform an estimate of spillway size. The design flood and spillway data are given in **Table 5**.

Table 5: Design flood estimation and spillway sizing

Item	Quantity
Catchment area (km^2)	11
Regional Maximum Flood (RMF) k region	5
Regional Maximum Flood (m^3/s)	332
100 year flood (m^3/s)	166
Estimated spillway capacity (m^3/s)	210
Spillway width (m)	40
Spillway length (m)	1140
Spillway depth (m)	2
Spillway volume (m^3)	91000

The spillway down the hillside would need to be very long, of the order of 1140 m so that spills could be released back into the Boontjies River below the dam wall. This is due to the site characteristics and the relatively long dam wall.

A multi-level outlet tower was allowed for with a height of 34.3 m. An outlet pipe with internal diameter of 1.5 m from the base of the multi-level outlet tower through the embankment, lined with steel and encased in concrete, to an outlet structure that can release 5 m^3/s to the Boontjies River under gravity was included. The pump station would be integrated into the outlet structure to pump up to 1 m^3/s into the rising main back to the farmers around Wolseley in the summer months. It was calculated that the dam would be able to release at least 5 m^3/s under gravity into the Boontjies River down to a head of 4 m.

Estimated quantities and other relevant physical data for the potential dam wall and its components are given in **Table 6.**

Table 6 Estimated quantities and physical data for the dam wall and its components

Item	Quantity
Embankment	
Crest width (m)	5.00
Downstream slope	1V:2H
Upstream slope	1V:3H
Freeboard (m)	2.00
Embankment volume (m^3)	1 319 000
Cutoff trench	
Cutoff trench depth (m)	3
Cutoff trench width (m)	12
Cutoff trench side slopes	1 : 1
Cutoff trench volume (m^3)	66 000
Spillway	
Spillway excavation volume (m^3)	91 000
Lined section of spillway: length (m)	50
Spillway slab depth (m)	0.3
Spillway concrete volume (m^3)	824
Outlet tower and pipe	
Outlet capacity (m^3/s)	5
Outlet tower: height (m)	34.3
Outlet tower: concrete volume (m^3)	155
Outlet pipe through dam wall: length (m)	200
Outlet pipe through dam wall: diameter (m)	1.5
Outlet pipe through dam wall: excavation volume (m^3)	6400
Outlet pipe through dam wall: concrete volume encasing steel pipe (m^3)	825

2.3 Capital cost estimate

The cost summary for the proposed Boontjies Dam is given in **Table 7.**

Table 7 Cost summary for the proposed Boontjies Dam

Boontjies Dam costing				
Item	**Unit**	**Quantity**	**Rate**	**Cost**
Embankment: cut-off trench excavation	m^3	66000	R 50	R 3,300,000
Embankment: fill	m^3	1319000	R 40	R 52,760,000
Outlet structure: soft material excavation (40%)	m^3	2560	R 60	R 153,600
Outlet structure: intermediate material excavation (20%)	m^3	1280	R 90	R 115,200
Outlet structure: hard rock material excavation (40%)	m^3	2560	R 350	R 896,000
Outlet structure: concrete volume	m^3	799	R 1,400	R 1,117,999
Outlet structure: vertical formwork rough outside	m^2	960	R 350	R 336,000
Outlet structure: steel pipe inside	m	200	R 6,200	R 1,240,000
Outlet structure: reinforcing steel (130 kg/m^3)	Tons	102	R 13,000	R 1,326,000
Outlet structure: house for valves, including valves	Sum	1	R 500,000	R 500,000
Tower: concrete volume	m^3	155	R 1,400	R 216,991
Tower: reinforcing steel (130 kg/m3)	Tons	20	R 13,000	R 261,939
Tower: vertical formwork smooth outside	m^2	378	R 400	R 151,091
Valves and gates	Sum	1	R 5,000,000	R 5,000,000
Spillway: soft material excavation (60%)	m^3	54600	R 100	R 5,460,000
Spillway: intermediate material excavation (30%)	m^3	27300	R 150	R 4,095,000
Spillway: hard rock material excavation (10%)	m^3	9100	R 300	R 2,730,000
Spillway: concrete section	m^3	824	R 1,400	R 1,153,050
Spillway: concrete section reinforcing steel (80 kg/m^3)	Tons	66	R 10,500	R 691,830
Sub-total A				**R 81,504,698**
Preliminary and general items			20%	R 16,300,940
Sub-total B				**R 97,805,638**
Contingencies			15%	R 14,670,846
Sub-total C				**R 112,476,484**
Professional fees			10%	R 11,247,648
Property and servitude cost	Ha	55	R 200,000	R 10,932,967

Sub-total D				**R 134,657,099**
VAT			14%	R 18,851,994
Total				**R 145,590,066**

The Boontjies Dam has been planned and costed at a pre-feasibility level only and the costs are based on best estimates from similar large dams that have been designed and built in the past few years, and also on experience with various farm dams that have been designed and built in the Wolseley area in the past few years. Sensitivity was tested and the URVs were found to not be very sensitive to changes in the capital costs of the dam.

3. Conclusions

Based on the pre-feasibility investigation, the potential dam would cost approximately R 145,590,066 (including VAT).

The Papenkuils Pump Station would need to be upgraded by 19 m^3/s to a capacity of 26 m^3/s, with a capital cost estimated at R 111,721,824 (including VAT). The annual energy requirement would be approximately 4100 kW for approximately 16 days per annum on average.