WESTERN CAPE WATER SUPPLIES

PRE-FEASIBILITY STUDY

PRELIMINARY EVALUATION OF STEENBRAS, CAMPANULA AND RIVERLANDS (DOOLHOF UPPER) DAMS

1 INTRODUCTION

Following the introductory site visit to potential dam sites in the Western Cape in March 2009, the optimum reservoir storage and corresponding full supply level for each of the selected dams was estimated. This information was presented by Aurecon in an e-mail dated 23 November 2009 giving the possible range in system yield for different full supply levels at the selected sites.

1.1 Location of dam sites

The dam sites were located using enlargements of the 1 in 10000 aerial photos. The scale of the enlargements varied from 1 in 3500 to 1 in 4500. The contours were interpolated at intervals from 20m to 5m and some were lost.

For the purpose of the initial study only dams estimated to contribute >10million m^3/a were included. The particulars of the dams identified are as follows:

DAM SITE	Full Supply Level	Dam Crest Elevation	Estimated Increased Yield (million m^3/a)
Steenbras Lower	367 masl	370 masl	23
	360 masl	363 masl	15
Steenbras Upper	397 masl	400 masl	22
	387 masl	390 masl	14
Campanula	140 masl	143 masl	10
Riverlands (Doolhof Upper)	318 masl	320 masl	14

1.2 Costing Rates

The preliminary unit rates are based on current prices used in Gauteng and KwaZulu-Natal and may not be applicable to the Western Cape and the absolute estimate of construction cost will depend upon more accurate costing data.

2 STEENBRAS LOWER DAM

It was determined that the existing dam, first built in 1919, could not be raised by more than a few metres. Increased capacity at Steenbras Lower site would necessarily have to be achieved by constructing a new dam downstream. Two types were considered viz. a rockfill embankment dam with clay core and a concrete gravity dam. Two possible heights of dam were studied with crests at 370masl and 363masl respectively.

2.1 Embankment Dam Crest at 370masl

The axis of this 70m high dam is 520m long located on a curve about 100m downstream of the middle point of the existing Steenbras Dam. A saddle dam 15m high and 300m long is required on the right flank where a concrete overflow spillway and discharge chute could be located leading to the Steenbras River gorge 400m downstream of the dam. A new intake structure for the Water Treatment Plant will be required and rockfill protection for the downstream face of the Upper Steenbras dam.

2.2 Embankment Dam Crest at 363masl

The axis of this 63m high dam is 490m in length and would follow a similar line to the higher dam. A low saddle embankment and concrete spillway could be located on the right flank with a concrete lined discharge chute as for the higher dam.

2.3 Preliminary Design Assumptions

Materials for construction will consist of excavated quartzitic sandstone of the TMG for the shell zones and Bokkeveld shale borrowed from the upstream reservoir basin area for the core.

Embankment slopes:	U/S 2.5:1; D/S 1.75:1
Max width of core 50m:	Core trench 30m x 3m deep.
Concrete overflow 30m wide:	Chute 30m wide x 200m long

2.4 Estimates of quantity and cost

The principal quantities and ball-park cost estimates are as follows:

Crest at 370 masl:

	Volume	Rate@2009	R million
Rockfill	1.1Mm^3	200	R220
Core	0.5Mm^3	150	R75
Saddle Embankment	0.09Mm^3	200	R18
Concrete Overflow	4000m^3	1500	R6
RC Chute	6000m^3	2500	R15
Excavation	60000m^3	80	R5
Slope protection	40000m^3	100	R4
New WTW Intake	Sum	1	R20
Sub-total			R363
P & G + misc		75%	R272
TOTAL			**R635**

Crest at 363 masl:

	Volume	Rate@2009	R million
Rockfill	0.8Mm^3	200	R160
Core	0.4Mm^3	150	R60
Concrete Overflow	2000m^3	1500	R3
RC Chute	6000m^3	2500	R15
Excavation	50000m^3	80	R4
Slope protection	20000m^3	100	R2
New WTW Intake	Sum	1	R20
Sub-total			R264
P & G + misc		75%	R198
TOTAL			**R462**

2.5 Concrete Gravity Dam with crest at 370masl

The axis of a concrete dam would be 400m long and located further downstream than that of the embankment dam. Conventional concrete or RCC could be considered. The spillway overflow could be incorporated into the main structure, but an embankment saddle dam would be required on the right flank. As for the embankment dam option, a new intake structure for the Water Treatment Plant will be required and rockfill protection for the downstream face of the Upper Steenbras dam.

2.6 Concrete Gravity Dam with crest at 363masl

The axis of the lower dam would be 390m long without the need for a saddle embankment on the right flank.

2.7 Preliminary Design Assumptions

Aggregate for concrete will be obtained from crushed quartzitic sandstone of the TMG.

Dam slopes slopes:	U/S 1:1; D/S 0.6:1
Depth of foundation excavation in the footprint:	5m
Concrete overflow:	30m wide with stilling basin.

2.8 Estimates of quantity and cost

The principal quantities and ball-park cost estimates are as follows:

Crest at 370 masl

	Volume	Rate@2009	R million
Mass Concrete	260000m^3	1500	R390
Excavation	50000m^3	80	R4
Saddle Embankment	0.09Mm^3	200	R18
Slope protection	60000m^3	100	R6
New WTW Intake	Sum	1	R20
Sub-total			R438
P & G + misc		75%	R328
TOTAL			**R766**

Crest at 363 masl

	Volume	Rate@2009	R million
Mass Concrete	230000m^3	1500	R345
Excavation	40000m^3	80	R3
Slope protection	100000m^3	100	R10
New WTW Intake	Sum	1	R20
Sub-total			R378
P & G + misc		75%	R283
TOTAL			**R661**

3 STEENBRAS UPPER DAM

When designed in 1974 the Steenbras Upper Dam was restricted to a height of 370masl to avoid encroaching on the N2 bridge over the Steenbras River. In order to raise the dam by 20 to 30m it will be necessary to construct a thicker core zone. This cannot be done without taking the dam out of service and cutting into the embankment. The present proposal envisages constructing a new embankment downstream and using the existing dam as an upstream toe. A concrete dam was not considered in view of the difficulty of excavating the foundations within the reservoir of the lower dam.

Two possible heights were studied for the new embankment dam with crests at 400masl and 393masl respectively.

3.1 Rockfill Embankment Crest at 400masl

The axis of the dam would be 1600m long effectively straight across the Steenbras River valley about 75m downstream of the existing crest. The downstream toe would extend up to 70m into the reservoir of the lower Steenbras Dam. Quartzitic sandstone material for rockfill could be quarried from outcrops to the South, but may not fall completely within the proposed new reservoir basin. It has been assumed that there would be ample resources of clay derived from weathered Bokkeveld Shale. The raised reservoir level will require reconstruction of the hydroelectric pumped storageintake on the right flank of the reservoir upstream. Provision will be needed for rerouting the N2 road alignment and bridge over the SteenbrasRiver.

3.2 Embankment with Crest at 390masl

The location of this dam with a crest length of 1560m would follow very closely that of the higher dam. There would remain the requirement to reconstruct the pumped storage scheme intake and to realign the N2 road and bridge.

3.3 Estimates of Quantities and Costs

The principal quantities and ball-park cost estimates are as follows:

<u>Crest at 400 masl</u>

	Volume	Rate@2009	R million
Rockfill	$3.3Mm^3$	200	R660
Core	$1.5Mm^3$	100	R15
Excavation	$0.5Mm^3$	60	R30
New PSS Intake	Sum	1	R50
Realign N2	Sum	1	R20
Sub-total			R775
P & G + misc		75%	R581
TOTAL			**R1 356**

<u>Crest at 390 masl</u>

	Volume	Rate@2009	R million
Rockfill	$1.6Mm^3$	200	R320
Core	$1.0Mm^3$	100	R10
Excavation	$0.4Mm^3$	60	R24
New PSS Intake	Sum	1	R50
Realign N2	Sum	1	R20
Sub-total			R424
P & G + misc		75%	R318
TOTAL			**R742**

4 CAMPANULA DAM

This dam site is located on the Palmiet River on the northern boundary of the Kogelberg Nature Reserve. The geology consists of the felspathic sandstones of the Upper TMG forming an east west ridge with the overlying Bokkeveld Shale outcropping in the reservoir basin. Both a rockfill embankment and a concrete dam were considered, but with only one crest elevation.

4.1 Embankment Dam with crest at 143masl

This dam would have a straight crest about 500m long. A concrete overflow spillway and chute will be required on the right flank discharging to the Palmiet River downstream. The effect of long term sedimentation and the provision for the release of compensation will have to be taken into account in determining the assured yield of the reservoir. The intake/outlet works should be designed accordingly.

4.2 Estimates of Quantities and Costs

The principal quantities and ball-park cost estimates are as follows:

<u>Crest at 143 masl</u>

	Volume	Rate@2009	R million
Rockfill	$0.5Mm^3$	200	R100
Core	$0.2Mm^3$	150	R30
Concrete Overflow	$500m^3$	1500	R1
RC Chute	$1000m^3$	2500	R3
Excavation	$20000m^3$	80	R2
Intake/outlet Works	Sum	1	R20
Sub-total			R156
P & G + misc		75%	R117
TOTAL			**R273**

4.3 Concrete Gravity Dam Crest at 143masl

This dam would have a straight crest about 500m long. It would be provided with an ogee overflow crest with stilling basin.

4.4 Estimates of Quantities and Costs

Crest at 143 masl

	Volume	Rate@2009	R million
Mass Concrete	170000m^3	1500	R255
Excavation	50000m^3	80	R4
Intake/Outlet	Sum	1	R10
Sub-total			R269
P & G + misc		75%	R202
TOTAL			**R471**

5 RIVERLANDS DAM (UPPER DOOLHOF)

This dam is located on a small stream at the head of the valley at the boundary of Riverlands with Doolhof Farm. The geology at the site consists of weathered Malmsbury Shale, but the extent over the reservoir basin has not been confirmed. The basin has a limited catchment area and the total freeboard has been reduced to 2m.

5.1 Embankment dam with crest at 320masl

The straight crest would be about 720m long with provision for a concrete spillway and discharge chute on the right flank.

5.2 Estimates of Quantities and Costs

Crest at 320 masl

	Volume	Rate@2009	R million
Rockfill	0.9Mm^3	200	R180
Core	0.4Mm^3	150	R60
Concrete Overflow	1000m^3	1500	R1
RC Chute	6000m^3	2500	R15
Excavation	40000m^3	50	R2
Intake/outlet Works	Sum	1	R10
Sub-total			R268
P & G + misc		75%	R201
TOTAL			**R469**

6 SUMMARY

Dam Site	**Type**	**Dam Crest Elevation**	**Estimated Yield Increase (million m^3/a)**	**Estimated Cost (R million)**	**Unit Cost R/m^3/a**
Steenbras Lower	Emb	370masl	23	635	28
	Emb	363mas	15	462	31
	Conc	370masl	23	766	33
	Conc	363mas	15	661	44
Steenbras Upper	Emb	400masl	22	1356	62
	Emb	390masl	14	742	53
Campanula	Emb	143masl	10	273	27
Riverlands	Emb	320masl	14	471	34

From a cost : yield benefit perspective, provisional ranking indicates that the most favourable option would be a choice between Campanula (crest at 143masl) and Steenbras Lower (crest at 370masl) and these two would merit further study to optimise their layouts. The estimates show that raising Steenbras Upper dam would be very costly. The sites at Campanula and Riverlands would accommodate lower dams at lower construction cost, but, on the basis of the given hydrology, the corresponding increase in yield to the system would be too small to be economic.

WESTERN CAPE WATER SUPPLIES

PRE-FEASIBILITY STUDY

PRELIMINARY OPTIONS FOR RAISING VOËLVLEI DAM

1 INTRODUCTION

As part of the study of options for development of the water resources of the Western Cape, the potential increase of the reservoir storage at Steenbras Lower Dam, Steenbras Upper Dam, Campanula Dam on the Palmiet River and the Riverlands Dam in Wellington was reviewed in my note of 11 February 2010. This assessment entails the potential raising of Voëlvlei Dam by 1m or 2m. The potential increase in yield to the Western Cape system by raising the FSL has been estimated by the Western Cape Water Consultants JV.

The raised dam would be filled by pumping from the Berg River and via the existing 24 Rivers and Klein Berg canals. The latter infrastructure offers little flexibility in raising the full storage level by more than about 2m. This study is therefore restricted to reviewing the options for raising the embankment by 1m or 2m which would increase the reservoir capacity by 15 and 31million m^3 respectively.

2 VOËLVLEI DAM

2.1 Effect of higher reservoir level

The raising of the reservoir FSL will require the dam to be extended laterally at the following locations:

a) By about 250m in the North East at the entrance of the 24 Rivers Canal
b) By about 50m in the North West
c) By about 200m in the South West at the saddle embankment

The enlarged reservoir will encroach on the Voëlvlei Water Treatment Works in the South West, but only the reservoir intake will be affected. The high flood level will affect the facilities of the Voëlvlei Yacht Club on the west shore. The raised high flood level will encroach on the Eastern shoreline by between 50 and 300m, but there is no evidence of any infrastructure in this area that would be affected.

2.2 Details of Dam

The embankment dam was constructed in (about) 1958 and substantially improved and extended around 1978. Details of the dam and improvements are scarce and the quality of the available plans is poor such that important dimensions are indecipherable. It has a maximum height of about 10m and the non-overflow crest elevation has been assumed as 82.4masl with FSL at 79.33masl. The crest is 12.36m wide and the total length is about 3.8km including the saddle embankment added at the northern rim of the reservoir basin. The available plans of the cross section show that the central impervious core extends up to an elevation of 79.93masl.

The upstream face in the N is protected by a riprap layer 1.3m thick placed on a graded gravel base. Past dam safety inspections have reported that it has performed well under severe wave action. There is a substantial rock drain and filter in the downstream toe protecting the stability of the downstream slope.

2.3 Estimates of increased yield

The potential increase in yield from the enlarged reservoir capacity has been estimated as follows for different pumping rules from the Berg River.

DAM	Full Supply	Dam Crest Elevation	Estimated Increased Yield (million m^3/a)		
			Pump Rule 4-1	Pump Rule 4-3	Pump Rule 4-5
Voëlvlei	80.33 masl	83.4 masl	35	24	15
	81.33 masl	84.4 masl	40	28	18

2.4 Costing Rates

The preliminary unit rates are the same as those used for the Steenbras, Campanula and Riverlands estimates based on current prices used in Gauteng and KwaZulu-Natal and may not beapplicable to the Western Cape.The absolute estimate of construction cost will depend upon researching more accurate pricing data during the Feasibility Study Phase

3 OPTIONS FOR RAISING VOËLVLEI DAM

3.1 Overall Considerations

The generous width of the crest and the reported satisfactory performance of the embankment since construction, indicate that the construction of a parapet wall on the crest would be practicable and not prejudice the stability of the embankment slopes. Raising the FSL of the reservoir will exceed the height of the existing core zone and it will be necessary to increase the height of the impervious zone. Informal discussions with the Dam Safety Office, DWAF, revealed that it was unlikely that there would be any impediment to raising the embankment by the amounts now proposed.

3.2 Details of parapet walls

The construction of a parapet wall, either 1m or 2m high on the crest presents no difficulties. The total freeboard above the reservoir FSL will remain at 3.07m as a present, and the estimated reservoir rise under max flood conditions will not exceed 500mm. The wall could consist either of precast concrete units or of cast in situ reinforced concrete set on an alignment 3m from the u/s edge of the present crest. The design would need to take account of potential settlement along the embankment crest and make provision for flexible joints between sections of the wall.

In view of the low maximum height of the embankment and conservative slopes upstream and downstream, the increased load imposed by the raised FSL will not reduce the overall stability of the dam. Consideration could be given to providing the wall with a curved upstream face to deflect any exceptionally large wave runup. In the case of the 2m parapet wall, the elevation of the crest road could be raised by 1m+/- to enable the lake to be observed. The lateral extensions required to the dam in some areas (see 2.1 above) may be constructed as low earth berms, or the wall could be extended as appropriate.

3.3 Raising core zone

The core zone can be raised by excavating a trench 600mm wide about 2m deep from the existing crest to connect into the core and backfilling with selected clay or bentonite cement to ensure that the elevation of the impervious zone remains above the raised reservoir level at design flood. The large construction plant for this work will be readily accommodated on the wide crest. No work will need to be carried out on the downstream slope.

2.4 Estimates of quantity and cost

The principal quantities and ball-park cost estimates are as follows:

<u>1m parapet wall</u>

	Volume	Rate@2009	R million
Reinforced concrete	$22000m^3$	3000	R66
Cut off Trench & backfill	$5000m^3$	2000	R10
Lateral extensions to dam	Sum	1	R4
Sub-total			R80
P & G + misc		75%	R60
TOTAL			**R140**

<u>2m parapet wall</u>

	Volume	Rate@2009	R million
Reinforced concrete	$44000m^3$	3000	R132
Cut off Trench & backfill	$5000m^3$	2000	R10
General Fill behind wall	$15000m^3$	200	R3
Lateral extensions to dam	Sum	1	R7
Sub-total			R152
P & G + misc		75%	R114
TOTAL			**R266**

6 SUMMARY

The comparative unit costs of the yield are given in the following table:

Dam Site	**Type**	**Dam Crest Elevation**	**Estimated Yield Increase (million m^3/a)**	**Estimated Cost (R million)**	**Unit Cost R/m^3/a**
Voëlvlei Dam	Emb	1m raising	15	140	9
	Emb	2m raising	18	266	15

These provisional unit costs indicate that the raising of Voëlvlei Dam would constitute by far the most cost effective option of those studied in the Western Cape. The selection of this option would however, involve changes to the grades of the Klein Berg River canal supplying the reservoir. The estimates of the costs of this work have not been included. It is not expected that there will need to be any major works at the Voëlvlei WTW. The matter of any compensation to users of the reservoir shoreline such as the Voëlvlei Yacht club has not been investigated.