Report – Rev 3

Costs and Technicalities

Associated with Upgrading

50 Community Dams

South Eastern Limpopo Province

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Summary

This report forms part of an initiative by Ukwakhisana to increase the storage capacity of 50 community dams in Mpumalanga. The increased supply of water will be gravity fed to vegetable gardens downstream of the dam, and will also ensure that livestock have a year round supply of drinking water. Accordingly this report considers different ways of increasing the capacities of the dams and the associated costs.

Approach

Two methods of increasing the capacity of the dams have been considered. The first involves increasing the depth of the reservoir by removing sedimentation and earth from the basin (or floor) of the dams. The second method involves raising the height of the earth embankment. In each of these cases it is possible to (a) use bulldozers to move the material, or (b) use an excavator combined with ADT haulers to transport the earth, and a dozer to level off after the haulers have tipped.

There are thus four possible combinations or options to be considered, and these are summarised in table 1 below:

Table 1 - Summary of Dam Enhancement Options in Mpumalanga

Item	Option	Earthmoving Machines	Bank m3	hours	days	R/dam excl VAT	R for 50 dams excl VAT (millions)
1	Basin-Excavator	1 x 330L ME excavator 2 x 725 ADT haulers 1 x D6H II dozer	25000	186.0	20.7	428114	21.4
2	Basin-Dozer	3 x D6H II dozer	25000	147.8	16.4	257614	12.9
3	Embankment-Excavator	1 x 330L ME excavator 2 x 725 ADT haulers 1 x D6H II dozer 1 x 533D compacter	16000	127.4	14.2	340524	17.0
4	Embankment-Dozer	3 x D6H II dozer 1 x CP533D compacter	16000	63.0	7.0	162535	8.1

Note that in the construction of the embankment a compactor is also required to ensure that the structure has adequate shear strength and is relatively impermeable.

In determining the hours for the earthmoving equipment it has been assumed that the material to build the embankment will come from the inside of the reservoir. This means that the dozer pushes forwards from the basin to the embankment (see diagram attached to appendix 8), or in the case where the basin is to be deepened the dozer will push and spread the material to the sides of the dam (see diagram in appendix 7). Similarly, by positioning the excavator inside the basin, the distances that the ADT haulers have to travel are minimised.

Representative Dam

In order to determine the volumes of earth to be excavated, transported/pushed, levelled and compacted (depending on the option) it is necessary to establish what may be referred to as a 'representative dam'. As it was not possible to visit all 50 dams to take measurements, the approach adopted is to average out the critical measurements (see figure 1) of the four dams that were inspected on 30-07-03 by Paul de Bruyn (Ukwakhisana), Dave du Toit (Barlows Equipment), Ian Johnstone (Consultant to Barlows), and Nicholas Papenfus (Dams for Africa). Next the length of the average embankment is increased by 50%, from 100m to 150m, effectively increasing the dam's capacity by 50%. This measure was prompted by Paul's knowledge of the other dams, which he considers to be slightly larger on average than the four measured dams. In other words the 'representative dam' has an increased storage of 50% relative to the average of the four that were measured. The representative dam is defined by the following dimensions which are illustrated in figure 1; L = 100m x 1,5 = 150m, Z = 136m, M = 34m, E = 2.64, h = 3,37. The options of deepening the basin or raising the height of the embankment are now applied to the 'representative dam', resulting in two 'design' dams as follows:

Deeper Basin:	L = 150m	Z = 136m	M = 34m	E = 4.64m	h = 3,37m
Higher Embk:	L = 254m	Z = 230m	M = 34m	E = h - 0,9m	h = 5,37m

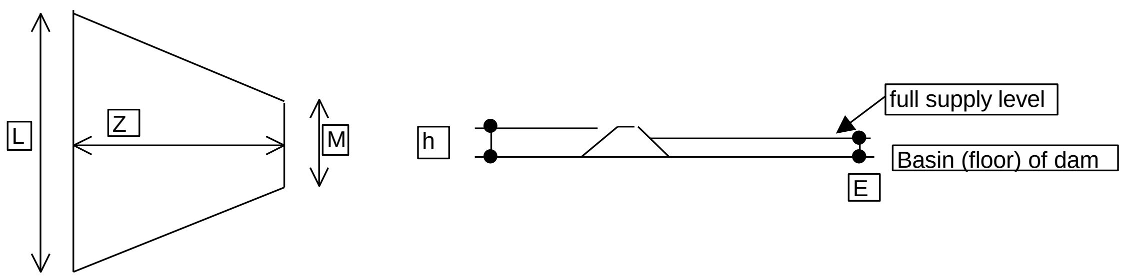


Figure 1 – Critical measurements used in determining the capacity of dams

These measurements are used to calculate the excavated volumes which are recorded in table 1. They also form the basis for other calculations resulting in the average slope and distance that the dozer has to push; the gradient and distances for the ADT haulers, etc.

Cost and Time

With Ian's assistance specialised software developed by Caterpillar was used to determine the number of hours and days it would take for the various earth moving machines to excavate/push/haul/spread/compact, and this duration is also reflected in table 1. These days apply to *each* machine, as the machines all work at the same time.

This time was used in the detailed costing for the four options, shown in appendices 1, 2, 3, and 4. These hours (based on a 9 hour day) were also applied to diesel and ground engagement costs. Also shown in the appendices is a further time allowance made for cutting new spillways in the case of the embankment options, with a smaller time allowance for repairing the existing spillways in the case of the basin options.

Next the cost of the low-bed is factored in, and an allowance made for site establishment. An allowance is also made for installing a simple siphon, for irrigation purposes. Finally the cost for the designer/contractor is included so that the total cost brought into Table 1 is all inclusive, with two notable exclusions. The first is VAT, and the second is the costs associated with Ukwakhisana project management, to be agreed between financiers and Ukwakhisana.

Finally table 1 summarises all the various components in the appendices to reflect the cost of upgrading the 'representative' dam for each option, and the projected cost for upgrading 50 dams.

Conclusion

The costs and some of the technicalities associated with upgrading 50 community earth embankment dams have been considered. Option 4, which considers raising the height of the embankment by 2m by utilizing dozers is clearly the most cost effective (see table 1). However, if too much land will be inundated by raising the embankment, or houses will be flooded etc., it may be necessary to resort to option 2, where increased capacity is achieved by increasing the depth of the reservoir basin by an average of 2m, also using dozers.

Appendices

Appendix 1 : Basin – Excavator
Appendix 2 : Basin – Dozer
Appendix 3 : Embankment – Excavator
Appendix 4 : Embankment – Dozer
Appendix 5 : Ripping production for average basin - Dozer
Appendix 6 : Ripping production for average basin - Embankment
Appendix 7 : Dozing distance and grade – Basin
Appendix 8 : Dozing distance and grade – Embankment
Appendix 9 : Compaction costs with CP 533 D

Appendix 1: Basin - Excavator

(Cost Structure for Excavating Basin of 'representative' dam using 1 Excavator and 2 Haulers)

Item	**Earthmoving machine Costs (Barloworld Equipment)**						
	Earthmoving machines		330L ME Excavator	725 ADT hauler	725 ADT hauler	D6H II dozer for levelling	Total
a	Hourly rate	R/hr	330	270	270	260	
b	Diesel consumption	Litres/hr	36	26	26	28	
c	Diesel rate	R/litre	3.47	3.47	3.47	3.47	
d	Diesel cost (28 litres /hr) = b x c	R/hr	124.92	90.22	90.22	97.16	
e	Ground engaging tools	R/hr	12.80			3.64	
f	Total hourly rate = a+d+e	R/hr	467.72	360.22	360.22	360.80	
g	Production hours based on 1 excavator (EMF calc)	hrs	182.05	182.05	182.05	182.05	
j	Add spilway repair time	hrs	4	4	4	4	
k	Total Production time =g + j	hrs	186.0	186.0	186.0	186.0	
l	Total Production costs = k x f	R/dam	87018	67018	67018	67126	288179
	Contingency for hard ground					10%	28818
	Lowbed cost based 800km/trip @ R16/km	R/dam				12800	
	Establishment of camp: fence, diesel tanks etc.	R/dam				14000	
	Provission for siphon	R/dam				7000	33800
	Design and Build Fee (Dams for Africa)						
	Drawings, site establishment, setting out, level control, compaction control, material selection, soil testing, scheduling and supervision of machines and equipment, engineering input, cost control, general management.	R			15%	52620	
	Travelling expenses	R				16991	
	Accomodation	R				7706	77316
	Project Management (Ukwakhisana)						
	To be agreed between financiers and Ukwakhisana	R					
	Total	R					**428114**

Appendix 2 : Basin - Dozer

(Cost Structure for Excavating Basin of 'representative' Dam using 3 Dozers)

Item	Earthmoving machine Costs (Barloworld Equipment)					
Item	Earthmoving machines		D6H II dozer for pushing	D6H II dozer for pushing	D6H II dozer for pushing	Total
a	Hourly rate	R/hr	260	260	260	
b	Diesel consumption	Litres/hr	28	28	28	
c	Diesel rate	R/litre	3.47	3.47	3.47	
d	Diesel cost (28 litres /hr) = b x c	R/hr	97.16	97.16	97.16	
e	Ground engaging tools	R/hr	3.64	3.64	3.64	
f	Total hourly rate = a+d+e	R/hr	360.80	360.80	360.80	
g	Production hours based on 1 dozer (EMF calc)	hrs	396.3	396.3	396.3	
h	Ripping hours based on 1 dozer (apdx 5 calc)	hrs	35.1	35.1	35.1	
I	Production hours with 3 dozers working = (g+h)/3	hrs	143.8	143.8	143.8	
j	Add spilway repair time	hrs	4	4	4	
k	Total Production time = I + j	hrs	147.8	147.8	147.8	
l	Total Production costs = k x f	R/dam	53326	53326	53326	159979
	Contingency for hard ground				10%	15998
	Lowbed cost based 600km/trip @ R16/km	R/dam			9600	
	Establishment of camp: fence, diesel tanks etc.	R/dam			14000	
	Provission for siphon	R/dam			7000	30600
	Design and Build Fee (Dams for Africa)					
	Design and build: Drawings, site establishment, setting out, level control, compaction control, material selection, soil testing, scheduling and supervision of machines and equipment, engineering input, cost control, general management.	R		15%	30986	
	Travelling expenses	R			13795	
	Accomodation	R			6256	51037
	Project Management (Ukwakhisana)					
	To be agreed between financiers and Ukwakhisana	R				
	Total	R				**257614**

Appendix 3 : Embankment - Excavator

(Cost Structure for raising Embankment of 'representative' dam using 1 Excavator and 2 Haulers)

Item	**Earthmoving Machine Costs (Barloworld Equipment)**							
	Earthmoving machines		330L ME Excavator	725 ADT hauler	725 ADT hauler	D6H II dozer for levelling	CP 533D compactor	Total
a	Hourly rate	R/hr	330	270	270	260	130	
b	Diesel consumption	Litres/hr	36	26	26	28	14	
c	Diesel rate	R/litre	3.47	3.47	3.47	3.47	3.47	
d	Diesel cost (28 litres /hr) = b x c	R/hr	124.92	90.22	90.22	97.16	48.58	
e	Ground engaging tools	R/hr	12.80			3.64		
f	Total hourly rate = a+d+e	R/hr	467.72	360.22	360.22	360.80	178.58	
g	Production hours based on 1 excavator (EMF calc)	hrs	118.41	118.41	118.41	118.41	118.41	
j	Add spilway construction time	hrs	9	9	9	9	9	
k	Total Production time =g + j	hrs	127.4	127.4	127.4	127.4	127.4	
l	Total Production costs = k x f	R/dam	59590	45894	45894	45968	22752	220099
	Contingency for hard ground						10%	22010
	Lowbed cost based 1000km/trip @ R16/km	R/dam					16000	
	Establishment of camp: fence, diesel tanks etc.	R/dam					14000	
	Provission for siphon	R/dam					7000	37000
	Design and Build Fee (Dams for Africa)							
	Drawings, site establishment, setting out, level control, compaction control, material selection, soil testing, scheduling and supervision of machines and equipment, engineering input, cost control, general management.	R				15%	41866	
	Travelling expenses	R					14156	
	Accomodation	R					5393	61415
	Project Management (Ukwakhisana)							
	To be agreed between financiers and Ukwakhisana	R						
	Total	R						**340524**

Appendix 4 : Embankment - Dozer

(Cost Structure for raising Embankment of 'representative' dam using 3 Dozers)

Earthmoving machine Costs (Barloworld Equipment)

Item	Earthmoving machines		D6H II dozer for pushing	D6H II dozer for pushing	D6H II dozer for pushing	CP 533D compactor	Total
a	Hourly rate	R/hr	260	260	260	130	
b	Diesel consumption	Litres/hr	28	28	28	14	
c	Diesel rate	R/litre	3.47	3.47	3.47	3.47	
d	Diesel cost (28 litres /hr) = b x c	R/hr	97.16	97.16	97.16	48.58	
e	Ground engaging tools	R/hr	3.64	3.64	3.64		
f	Total hourly rate = a+d+e	R/hr	360.80	360.80	360.80	178.58	
g	Production hours based on 1 dozer (EMF calc)	hrs	137.2	137.2	137.2	137.2	
h	Ripping hours based on 1 dozer (apdx 6)	hrs	24.8	24.8	24.8	24.8	
I	Production hours with 3 dozers working = (g+h)/3	hrs	54.0	54.0	54.0	54.0	
j	Add spilway construction time	hrs	9	9	9	9	
k	Total Production time = I + j	hrs	63.0	63.0	63.0	63.0	
l	Total Production costs = k x f	R/dam	22726	22726	22726	11248	79425
	Contingency for hard ground					10%	7942
	Lowbed cost based 800km/trip @ R16/km	R/dam				12800	
	Establishment of camp: fence, diesel tanks etc.	R/dam				14000	
	Provission for siphon	R/dam				7000	33800
	Design and Build Fee (Dams for Africa)						
	Drawings, site establishment, setting out, level control, compaction control, material selection, soil testing, scheduling and supervision of machines and equipment, engineering input, cost control, general management.	R				25195	
	Travelling expenses	R				13507	
	Accomodation	R				2666	41368
	Project Management (Ukwakhisana)						
	To be agreed between financiers and Ukwakhisana	R					
	Total	R					**162535**

Appendix 5 - Ripping Production for Average Basin

2003/09/26

Inputs			**Outputs**		
Machine = D6H Dozer with # 6 ripper with 3 shanks					
Ripping speed:	1.0	km/h			
Ripping distance	92	m	Time per rip pass	5.52	min
Turn & manoeuvre time	0.25	min	Time per rip pass incl turning time	5.77	min
Efficiency of operator	50	min/hr	No. of passes per hour after losses	8.7	pass/hr
Ripper shank spacing	1000	mm			
Number of shanks	3		Ripping width	3	m
Maximum ripper digging depth	500	mm			
Job controlled ripping depth	350	mm	Volume ripped per pass	97	Bm3
			Production per hr	837	Bm3/hr
Deration factor to suit practice	15	%	Derated production per hr	712	Bm3/hr
Bank volume to be ripped	25000	Bm3	Hours to complete ripping	**35.1**	hrs
Cost of dozer	260	R/hr	Ripping cost / Bm3	0.37	R/hr/Bm3

Appendix 6 - Ripping Production for Average Embankment

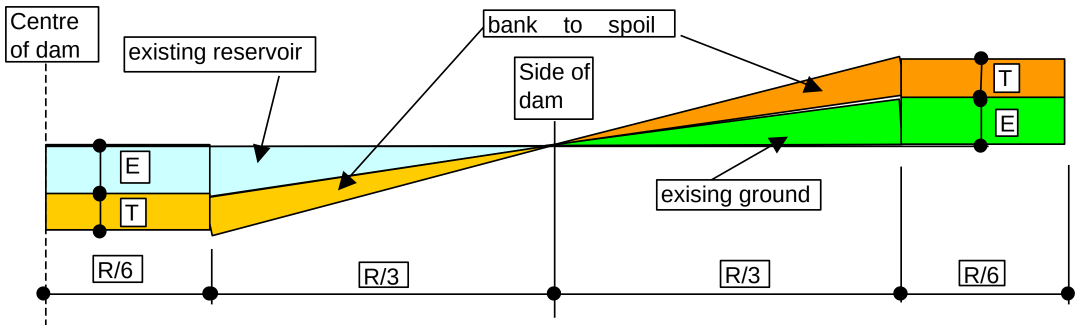
2003/09/26

Inputs			Outputs		
Machine = D6H Dozer with # 6 ripper with 3 shanks					
Ripping speed:	1.0	km/h			
Ripping distance	26.9	m	Time per rip pass	1.61	min
Turn & manoeuvre time	0.25	min	Time per rip pass incl turning time	1.86	min
Efficiency of operator	50	min/hr	No. of passes per hour after losses	26.8	pass/hr
Ripper shank spacing	1000	mm			
Number of shanks	3		Ripping width	3	m
Maximum ripper digging depth	500	mm			
Job controlled ripping depth	350	mm	Volume ripped per pass	28	Bm3
			Production per hr	758	Bm3/hr
Deration factor to suit practice	15	%	Derated production per hr	644	Bm3/hr
Bank volume to be ripped	16000	Bm3	Hours to complete ripping	**24.8**	hrs
Cost of dozer	260	R/hr	Ripping cost / Bm3	0.40	R/hr/Bm3

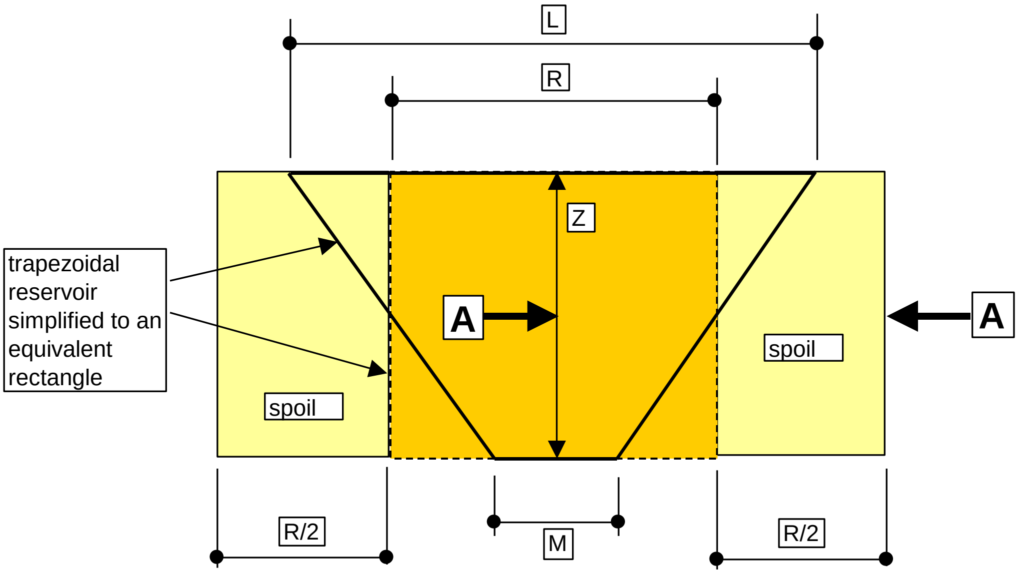
Appendix 7 - Dozing Distance and Grade - Basin

Inputs		
Length of embankment, L	150	m
Width at river mouth, M	34	m
Length of reservoir, Z	135.87	m
Desired avg increase in depth, F	2	m
Existing full supply depth, E	2.64	m

Outputs		
Average Ripping distance R = (L+M)/2	**92**	**m**
Bank Volume, V = R.Z.F	**25000**	**bm3**
Increase in depth at centre, T = 1,5.V/(R.Z)	3	m
Average vertical lift, V = 5/3.(E+T/2)	6.9	m
Average horizontal distance, X = 23/36.R	58.8	m
Average distance, S = sqrt(V.V+X.X)	**59.2**	**m**
Design % Grade, G = V/S %	**11.74**	**%**



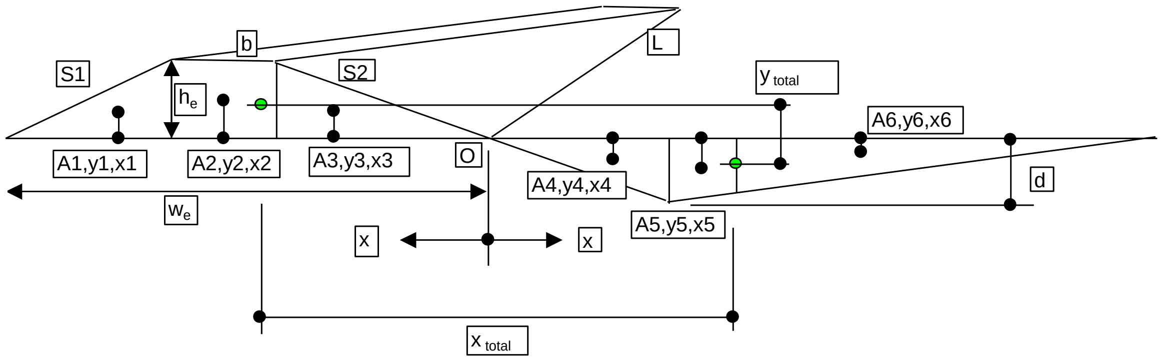
Section A A



Appendix 8 - Dozing Distance and Grade - Embankment

Inputs			**Outputs**		
Length of embankment (2)	254.1	m			
Downstream slope factor, s1	2				
Upstream slope factor, s2	3				
core width, b	3	m			
Determine equivalent height, h_e					
h_e - equiv h by trial and error	3.9288	m	$V_{embankment}$	12800	m3
			A1 = he.he.s1/2	15.44	m2
			A2 = he.b	11.79	m2
			A3 = he.he.s2/2	23.15	m2
			$A_{embankment}$	50.37	m2
			y1 = y3 = h_e/3	1.310	m
			y3 = h_e/2	1.964	m
			A1.y1	20.21	m3
			A2.y2	23.15	m3
			A3.y3	30.32	m3
			$y_{embankment}$	1.463	m
			x1 = s1he/3+b+s2.he	17.41	m
			x2 = b/2+s2.he	13.29	m
			x3 = s2.he.2/3	7.86	m
			A1.x1	268.7	m3
			A2.x2	156.6	m3
			A3.x3	181.9	m3
			$x_{embankment}$	12.05	m
Shrinkage factor, SF	0.8		A_{bank} = A $_{embankment}$/SF	62.97	m2
			d = sq rt[A_{bank}/(23/2)]	2.340	m
			A4 = s2.d.d./2	8.213	m2
			A6 = t.s3.t/2 = A_{bank}/2	31.48	m2
Bank slope factor = s3	20		t = sqrt [A_{bank}/s3]	1.774	m
			A5 = (d+t)/2.s3.(d-t)	23.27	m2
			y4 = d/3	0.780	m
			y5 = (d+t)/2	2.057	m
			y6 = t/3	0.591	m
			A4.y4	6.406	m3
			A5.y5	47.87	m3
			A6.y6	18.62	m3
			y_{bank} =	1.158	m
			x4 = s2.d.2/3	4.68	m
			x5 = s2.d+1/2(s3(d-t))	12.68	m
			x6 = s2.d+s3(d-t)+s3.t/3	30.16	m
			A4.x4	38.4	m3
			A5.x5	295.0	m3
			A6.x6	949.6	m3
			x_{bank}	20.38	m
			$y_{total} = y_{bank} + y_{embankment}$	2.621	m
			$x_{total} = x_{bank} + x_{embankment}$	32.4	m
			% Slope = y_{total} / x_{total}	**8.08**	**%**
			Distance	**32.5**	**m**
			Volume = A_{bank}*L	**16000**	**m3**
			Average ripping distance = [s3+s2].d/2	**26.9**	**m**

Appendix 8 - Dozing Distance and Grade - Embankment



Appendix 9 - Compaction Production for Average Embankment

2003/09/19

Inputs			Outputs		
Machine = CP533D Compactor					
Width of drum, W	2130	mm			
Working speed, S	*3.050*	km/hr			
Layer thickness, L	150	mm			
Passes for reqd compaction, P	4				
% Efficiency of operator	0.833	% min/min	Compaction rate = WxSxLx%eff / P	203	Cm3/hr
Compacted m3 to be placed	12800	Cm3	Total hours of compacting	***63.0***	hours
Total hours of dozing (from excel)	*63.0*	hrs	% Utilization of compactor	100.1	%
Hire Rate of Compactor (dry)	130	R	Cost of compactor (dry)	8196	R
Diesel consumption	14	litres/hr			
Price of Diesel	3.47	R/litre	Cost of diesel	6315.4	R
			Cost of compactor (wet)	14512	R