APPENDIX B

DISCUSSION DOCUMENT ON

THE ASSESSMENT OF ADDITIONAL WORKS REQUIRED AT UPSTREAM MCWAP WATER SUPPLY DAMS IN THE CROCODILE RIVER (WEST)

MOKOLO AND CROCODILE (WEST) WATER AUGMENTATION PROJECT (MCWAP) FEASIBILITY STUDY

REPORT 10: REQUIREMENTS FOR THE SUSTAINABLE DELIVERY OF WATER

Project No. WP9528

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1. BACKGROUND

The Mokolo and Crocodile (West) Water Augmentation Project (MCWAP) will supply the planned coal mines, coal fired power stations and coal to petroleum plants, as well as associated users with raw water. The proposed developments will take place along a roughly east-west corridor between Lephalale and Steenbokpan and will utilise the underlying coal field. In order to support this development water will be supplied directly from the Mokolo Dam on the Mokolo River (Phase 1) and from the Klipvoor, Roodekopjes and Vaalkop Dams along the Crocodile River (West) to the Vlieëpoort Abstraction Works (Phase 2). The water will then be pumped from Mokolo Dam and from the Abstraction Works at Vlieëpoort to Terminal Reservoirs located at of each of the main industrial bulk users.

The existing users along the Crocodile River (West) downstream of the Vaalkop, Roodekopjes and Klipvoor Dams are supplied from the river. These users rely on releases from the above dams and accruals from the catchments downstream of the dams. MCWAP water requirements will also be released from these dams in accordance with a release schedule determined by the MCWAP Management Authority (Refer to **Annexure E**).

The planned releases should take account of MCWAP bulk user requirements, irrigation requirements, abstractions by other users (mines, local municipalities), predicted river losses, accruals and ecological Reserve releases (the term IFR used in the tables) downstream of Vlieëpoort.

2. SUPPLY DAM RELEASE CAPACITY AND REQUIREMENTS

The water requirements for Phase 2 of the MCWAP Transfer Scheme will be supplied by releases from dams in the Crocodile River (West) upstream of the Abstraction Works at Vlieëpoort. The dams identified as potential primary water sources were Hartebeespoort and Roodekopjes Dams on the Crocodile River (West), Roodeplaat and Klipvoor Dams on the Pienaars River and Vaalkop Dam on the Elands River.

2.1 Pertinent Data of Main Supply Dams

The supply dams, their full storage capacity, outlet works discharge capacity and the relevant sub-catchments in which they are located in are detailed in Table 2-1. Figure 2-1 shows a schematic layout of the sub-catchments, rivers and dams.

Key data pertaining to the outlet works of Hartebeespoort, Roodekopjes, Roodeplaat, Klipvoor and Vaalkop Dams are given in Table 2-2.

Table 2-1: Main Supply Dams in the Crocodile River (West) Catchment

Dam Name	River	FSC (Net) (Million m^3)	Discharge Capacity of Dam Outlet Works	
			Discharge [2] (m^3/s)	Annualised [3] (Million m^3)
Upper Crocodile Sub-Catchment:				
Rietvlei Dam	Hennops River	12.3	N/A	N/A
Hartebeespoort Dam	**Crocodile River**	**186.4**	**7.2**	**225.9**
Buffelspoort Dam	Sterkstroom River	10.3	N/A	N/A
Roodekopjes Dam	**Crocodile River**	**102.3**	**7.2**	**226.6**
Pienaars River Sub-Catchment:				
Roodeplaat Dam	**Pienaars River**	**41.2**	**8.3**	**261.7**
Klipvoor Dam	**Pienaars River**	**42.1**	**7.0**	**219.1**
Elands River Sub-Catchment:				
Kosterrivier Dam	Koster River	12.8	N/A	N/A
Lindleyspoort Dam	Elands River	14.3	N/A	N/A
Olifantsnek Dam	Hex River	13.7	N/A	N/A
Bospoort Dam	Hex River	15.8	N/A	N/A
Vaalkop Dam	**Elands River**	**56**	**6.3**	**198.7**
TOTALS		**428.0**		

Notes:

1. The dams indicated in **bold** would be used to supply the MCWAP. The other dams listed are the remaining dams of some significant size in the sub-catchments.
2. Discharge calculated with dam operating at annual average of 80% of full capacity head at the outlet works, or approximately 66% of FSC.
3. Assuming inflows into dam will balance outflows (i.e. no draw down).

Referring to Table 2-3, it seems clear that the main sources of supply would be the Hartebeespoort – Roodekopjes Dams (upper Crocodile) and Roodeplaat – Klipvoor Dams (Pienaars River) nodes. The possible contribution of Vaalkop Dam appears small, but Vaalkop Dam could be used to provide for some of the irrigation requirements if shortfalls develop. It is also clear from Table 2-3 that very little growth in the return flows (water availability) in the Elands river sub-catchment is expected, thereby confirming the upper Crocodile and Pienaars River sub-catchments as primary sources of water. This information is continually received by DWA – in the updates of the Crocodile River (West) Reconciliation Strategy. These figures should be considered as indicative.

It is also interesting to note that Klipvoor Dam presently appears to be the preferred source of irrigation water judging from the release data shown in Table 2-4. Vaalkop Dam appears to be rarely used for irrigation purposes as it only supply to the limited irrigation on the Elands River up to the confluence with the Crocodile River.

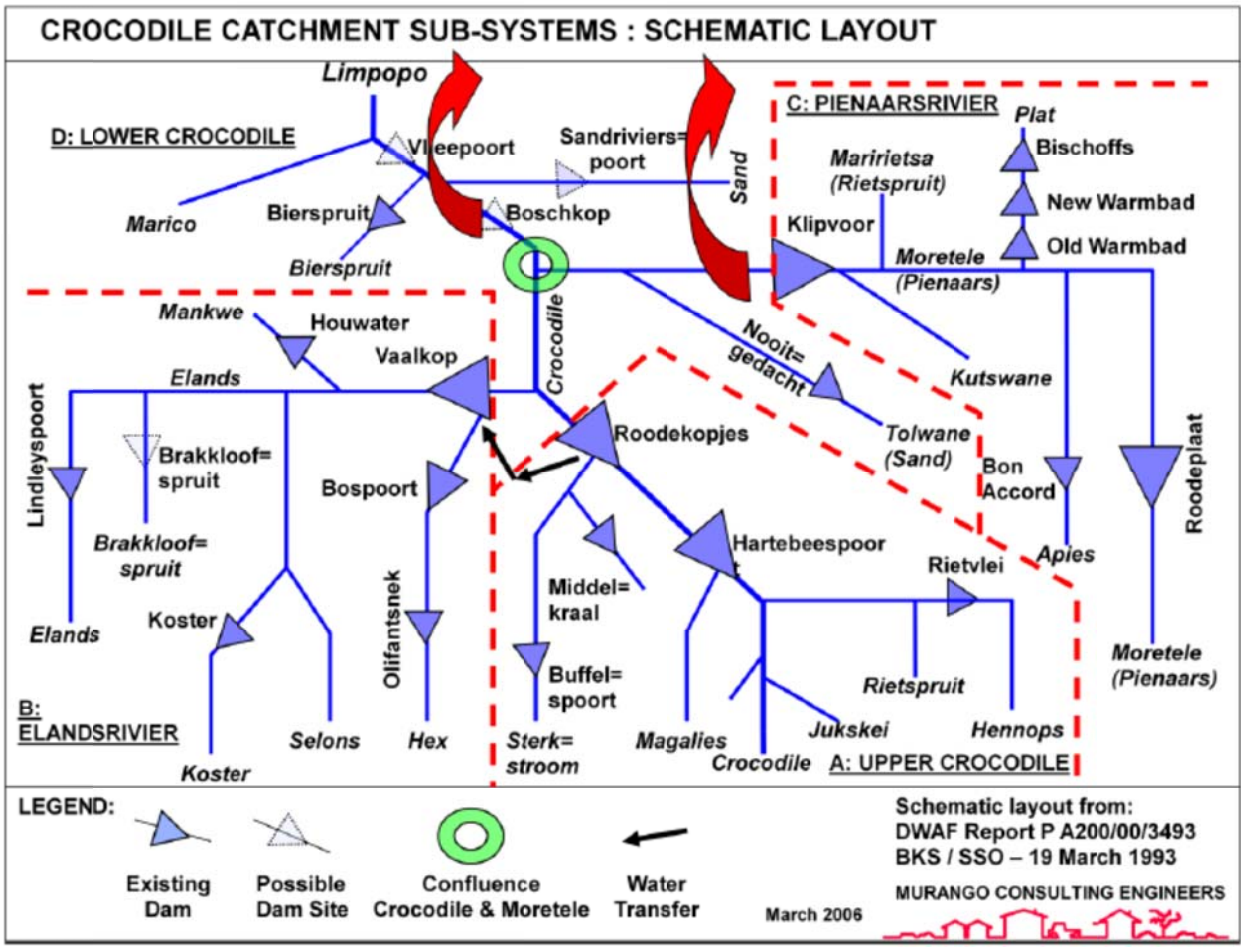

Figure 2-1: Schematic of Upstream Supply Dams (Courtesy BKS/SSO)

Table 2-2: Supply Dam Outlet Works Key Data

Dam	Outlet Works Key Data: Valve Diameter	FSL (masl) (1)	Maximum Available Head (m)	Discharge Co-efficient (C_d) (1)	Maximum Discharge Capacity (2) (m^3/s)
Hartebeespoort Dam	2 x 600mm	1 162,5	20,0	0,72	8,0
Roodekopjes Dam	1 x 900mm	1 107,0	21,0	0,70	8,0
Roodeplaat Dam	2 x 450mm	1 214,0	28,0	0,70	9,3
Kilpvoor Dam	2 x 600mm	989,3	15,8	0,78	7,8
Vaalkop Dam	1 x 380mm 1 x 800 mm	981,0	13,0	0,78	7,0

Notes:

1. Derived from data obtained from BKS.

2. $Q = C_d \times A_{outlet} \times (2 \times g \times H)^{0,5}$
3. Recent improvements at Roodeplaat Dam not considered. The capacity constraint along this node lies with Klipvoor Dam.

Table 2-3: Water Availability in Supply Dam Catchments

Dam	Available Water in 2000 (million m^3/a)	Water balance in 2000 (million m^3)	Available Water in 2025 (million m^3/a)	Water balance in 2025 (million m^3)
Hartebeespoort Dam Roodekopjes Dam	615	42	781	95
Roodeplaat Dam Kilpvoor Dam	368	1	531	40
Vaalkop Dam	157	20	161	13

Notes:

1. Extracted from data contained in DWA Report No. P WMA 03/000/00/0203, Overview of Water Resources Availability and Utilisation, BKS, 09/2003.

Table 2-4: Irrigation Release Patterns and MCWAP Water Requirements

Water Sources	Volume Required (Million m^3 per annum)
Klipvoor Dam	56
Roodekopjes Dam	33
Vaalkop Dam	3
Boreholes in the Alluviums	28
TOTAL	**120**
MCWAP Water Requirements	**Volume Required (Million m^3 per annum)**
Phase 1 (Mokolo Dam)	28,7
Phase 2 Stage 1 (Crocodile River (West)) Scenario 9	169,3
Phase 2 Stage 2 (Crocodile River (West)) Scenario 9	422,0

2.2 Water Release Requirements

The MCWAP water requirements are given in Table 2-4 and the resulting water requirements that will be imposed on the supply dams for release are shown in Table 2-5.

The total release required is the sum of the water requirements of the Phase 2 Transfer Scheme, irrigation requirements of the Crocodile Irrigation Board, total estimated losses along the river and the estimated IFR at Vlieëpoort. In the absence of the final determination of the Reserve an estimate was used for this analysis. The ecological Reserve at Vlieëpoort was

estimated to be in the order of 25 Million m^3/a in DWA Report No. P WMA 03/000/00/0203, analysis of the gauging weir data at A2H116 confirmed the figure of 25 Million m^3, but the flow simulations that was done to assess river losses (described in Supporting Report 12) resulted in a somewhat higher figure of 28,9 Million m^3/a. The higher figure was used for the assessments done in this report.

Table 2-5: Estimated Water Release Requirements – Base Design Case

Year	Total Net MCWAP Water Requirement (1) (m^3/a)	Phase 1 Mokolo Supply (2) (m^3/a)	Phase 2 Crocodile Water Requirements (3) (m^3/a)	Irrigation Requirements (m^3/a)	Total River Losses (4) (m^3/a)	IFR at Vlieëpoort (m^3/a)	TOTAL Release Required (m^3/a)	TOTAL Peak Release Required (m^3/a)
2009	12.3	13.5	-	120.0	48.2	28.9	197.1	197.1
2010	12.3	13.5	-	120.0	48.2	28.9	197.1	197.1
2011	13.9	13.5	-	120.0	48.2	28.9	197.1	197.1
2012	17.4	28.7	-	120.0	48.2	28.9	197.1	197.1
2013	31.2	28.7	3.2	120.0	48.3	28.9	200.4	200.8
2014	41.0	28.7	13.7	120.0	48.6	28.9	211.2	213.1
2015	56.0	28.7	29.8	120.0	49.0	28.9	227.7	231.8
2016	63.8	28.7	38.1	120.0	49.3	28.9	236.3	241.6
2017	103.5	28.7	80.6	120.0	50.3	28.9	279.8	291.1
2018	141.7	28.7	121.5	120.0	51.1	28.9	321.5	338.4
2019	148.7	28.7	129.0	120.0	51.3	28.9	329.2	347.2
2020	157.1	28.7	138.0	120.0	51.4	28.9	338.3	357.5
2021	165.4	28.7	146.8	120.0	51.6	28.9	347.3	367.8
2022	175.5	28.7	157.6	120.0	51.8	28.9	358.3	380.3
2023	181.8	28.7	164.4	120.0	51.9	28.9	365.2	388.2
2024	187.5	28.7	170.5	120.0	52.0	28.9	371.4	395.2
2025	190.6	28.7	173.8	120.0	52.1	28.9	374.8	399.1
2050	422.0	28.7	421.4	120.0	54.0	28.9	624.3	683.3

Notes:

1. Water requirements based on the Scenario 10 requirements schedule.
2. Ignores the option of short-term over-utilisation of Mokolo Dam.
3. Water requirement plus 2% system losses for both Phase 1 and Phase 2 of MCWAP. Also see Table 2-6 for other allowances that would be applicable.
4. Includes for evaporation, evapo-transpiration, accruals, diffuse in- and outflows, seepage into alluvial aquifer and unauthorised use. Refer to Supporting Report 12 for a detailed assessment of river losses.

Although the Scenario 9 water requirements schedule was used for the preparation of the Pre-feasibility and Feasibility Study Reports, the Scenario 10 water requirements schedule was used in this report to prevent an unnecessarily conservative assessment of the adequacy of the capacity of the outlet works of the main supply dams. Scenario 10 differs from Scenario 9 in that some of the projects were delayed in Scenario 10 in order to reduce the pressure on the timing of the delivery of MCWAP Phase 2 and to reduce the water requirements during the early stages of Phase 1 of the MCWAP.

The net MCWAP water requirements were increased by the estimated total system losses of 2% and the peak demand allowance of 9%. The Phase 1 system losses were added to the Phase 2 requirements. However, it is important to note that the 20% allowance for the 5% down time recovery period of 90 days also needs to be considered as a short term release requirement. The impact of the 20% allowance is shown in Figure 2-2. The allowances and factors used to arrive at the required release are shown in Table 2-6.

Table 2-6: Allowances and Factors used in determining Release Requirements

Item No.	Allowance and Factors Applied	Basic Design Case	Peak Design Case
1.	Allowance for water requirement peaks (average annual allowance) (1), (4).	9%	0%
2.	System Losses. Phase 1A (Mokolo Dam supply) added to Phase 2 Crocodile River (West) transfer system losses.	2%	2%
3.	Allowance for 90 day Recovery Period after maximum 18 day system outage (3).	0%	20%
4.	95% Reliability factor (4).	5%	0%
5.	Allowance for variations in river flow (5).	0%	0%
6.	Failure of Phase 1A Mokolo Dam supply (due to over-usage, etc.) (6).	Nil	28,7 million m^3/a

Notes:

1. Refer to Supporting Report 12 for details.
2. The % allowances factor was applied in the form: Flow x (1 + %).
3. The allowance for the 90 day Recovery Period was used independent of the other factors (apart from for the system loss factor) to avoid compounding of related allowances.
4. The greater of the peak flow factor and reliability flow factor was used.
5. It was assumed that all the water requirements would be available in the river at the Abstraction Works. The issues related to river flows are addressed in sections of Supporting Report 10. Flow variations of up to 2,5 m^3/s are provided for in the Abstraction Works designs, but this was not considered as relevant for this assessment, hence the 0% allowance.
6. Only used if greater than 20% allowance for Recovery Period. Based on Scenario 10 this is the case before 2022.

2.3 Capacity of Supply Dam Outlet Works

For the purposes of calculating outlet discharge capacities at the various dams a minimum long-term dam water level of 66% of FSC was used. Depending on the shape of the storage

capacity curve for a particular dam, this was assumed to be on average equivalent to 80% of the maximum available head at the outlet works.

A proper systems analysis of the system as a whole should be undertaken to confirm the following assumptions:

- The required releases would be balanced by inflows (and additional transfers) into the Pienaars River and Upper Crocodile River (West) sub-catchments.
- The average long-term operating level of the dams, assumed to be 66%.

The systems analysis would also be required to determine the contribution that the Pienaars River node could make to the overall long-term supply requirements in order to reduce the additional requirements that would need to be supplied from the Upper Crocodile sub-catchment (by means of the proposed Kliprivier transfer scheme for example). This information would also be needed to refine the assessment that was done on the extent of additional outlet capacity to be provided at the relevant dams.

From Figure 2-2 it can be concluded that:

- The Hartebeespoort Dam - Roodekopjes Dam node would need support from the Pienaars River soon after commissioning of Phase 2 of MCWAP.
- If releases for MCWAP start with Hartebeespoort and Roodekopjes close to FSL the introduction of the Kilpvoor Dam – Roodeplaat Dam node could be postponed by a year to end of 2016.
- The latest date at which additional outlet capacity would need to be provided at Hartebeespoort and Roodekopjes Dams would be 2015, but that could be delayed to as late as 2025 depending on the degree of support that could be provided from Klipvoor and Roodeplaat Dams.

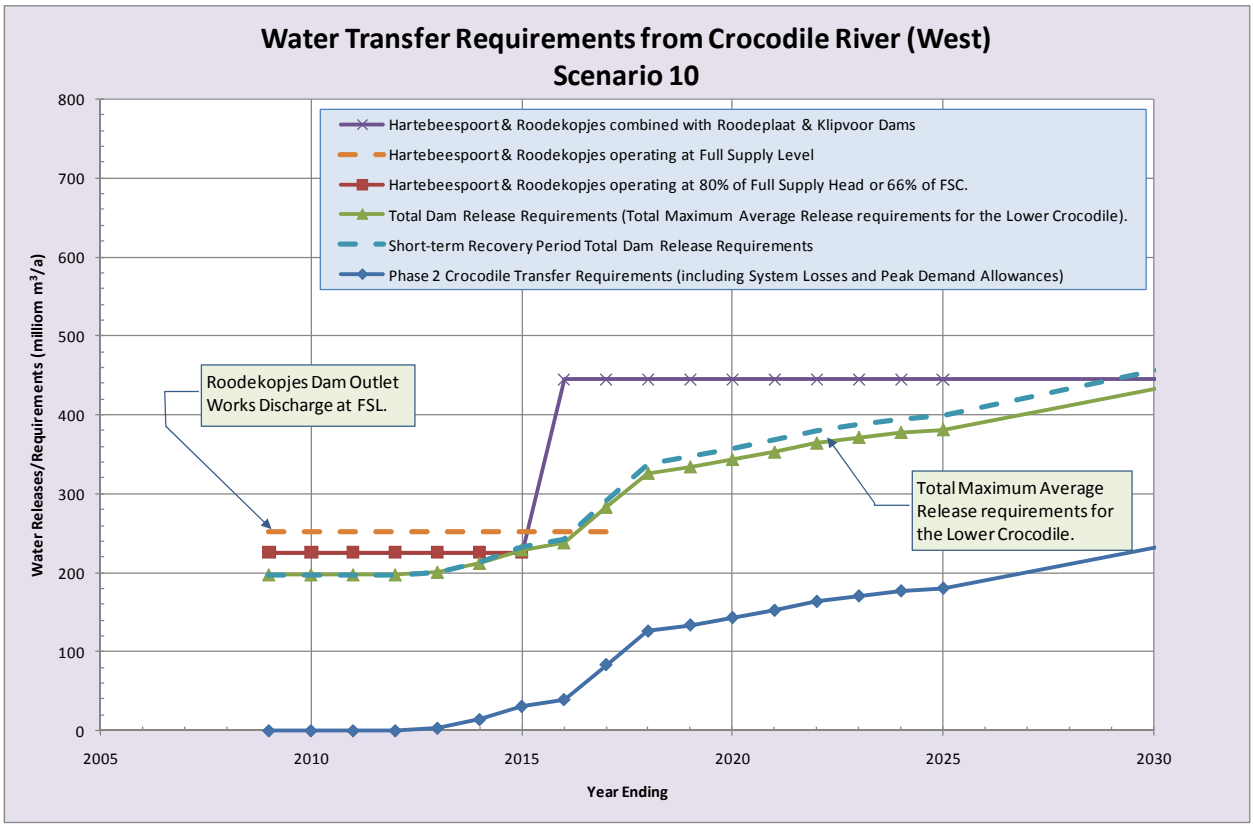

Figure 2-2: Water Transfer Requirements and Capacities of Supply Dam Outlet Works

2.4 Additional Outlet Capacity Requirements

Two release scenarios are possible:

- Scenario A where the full requirements will be supplied from Hartebeespoort/Roodekopjes Dams, and
- Scenario B where Klipvoor and Roodeplaat Dams are used to support Hartebeespoort and Roodekopjes Dams.

The total shortfall in outlet capacity for Scenario A is 21,7 – 7,2 = 14,5 m^3/s. The additional capacity can be provided with the installation of two additional 900mm diameter fixed cone sleeve valve (FCSV) controlled outlets at both Hartebeespoort and Roodekopjes Dams.

The total shortfall in outlet capacity for Scenario B is 21,7 – (7,2 + 7,0) = 7,5 m^3/s for the case where full use is made of the Roodeplaat – Klipvoor node. The additional capacity can be provided with the installation of two additional 700 mm diameter FCSV controlled outlets at both Hartebeespoort and Roodekopjes Dams. The incremental cost of installing 900mm diameter valves to have the flexibility of selecting either Scenario A or Scenario B mode operation would be relatively small. No additional outlet capacity would have to be provided at Roodeplaat or Klipvoor Dams.

In practice dam management rules would require that the surplus water from the Pienaars River sub-catchment would be released anyway. Referring to Table 2-3 the surplus could grow to

40 Million m^3/a (or 1,3 m^3/s) by 2025. The present irrigation releases from Klipvoor Dam could continue, thereby providing 56 million m^3/a (or 1,8 m^3/s) support to the Hartebeespoort – Roodekopjes node anyway.

The above calculations are based on the assumption that continuous releases would be made from the dams and that slug releases would not be considered. Slug releases could be an operating option at Roodeplaat and Hartebeespoort Dams to minimise unauthorised water use, but more extensive works would be required to provide these types of facilities at those dams.

A detail river hydraulic analysis would be required to size such releases in order to minimise downstream impacts on existing infrastructure.

2.5 Proposed Construction Methodology

The proposed construction methodology to facilitate installation of the additional outlet capacity would be to:

- Install a water tight compartment (concrete cubicle) on the upstream side of the dam wall.
- Excavate an opening for the pipework through the dam wall using a combination of drilling, hydro-demolition, expanding chemical explosives, diamond wire cutting and laser lancing.
- Install pipework, grout and seal.

This method of installation would obviously only be possible in the concrete sections of the dam wall.

This construction method was recently successfully used at Roodeplaat Dam and was reported on at the SANCOLD 2009 Conference in a paper “Retro-fitted Outlet Works for Roodeplaat Dam shows the way to supply the best quality water from an eutrophic impoundment”, by Pollard, IT and Kroon, J.

The cost of the Works at Roodeplaat Dam was reported to be in the order of R 13,5 Million (in ’n 2005 prices). For budget purposes an allowance of R 30 million per dam appears to be reasonable, bearing in mind that 800 mm diameter outlets were retro-fitted at Roodeplaat Dam and that the outlets located above the low level outlets.

3. CONCLUSIONS AND RECOMMENDATIONS

The total releases from the upstream supply dams to supply the users and MCWAP in the Lower Crocodile River (West) was estimated to be 7,3 m^3/s in 2015 when Phase 2 Crocodile River (West) Transfer of MCWAP is commissioned and rising to 12,7 m^3/s in 2025. Ultimately a release of 21,7 m^3/s would be required by 2050.

The assessments done showed that:

- The primary supply node, the Hartebeespoort Dam - Roodekopjes Dam node, would need support from the Pienaars River soon after commissioning of Phase 2 of MCWAP.

- If releases for MCWAP started with Hartebeespoort and Roodekopjes close to FSL the introduction of the Kilpvoor Dam – Roodeplaat Dam node could be postponed by a year to end of 2016.
- The latest date at which additional outlet capacity would need to be provided at Hartebeespoort and Roodekopjes Dams would be 2015, but that could be delayed to as late as 2025 depending on the degree of support that could be provided from Klipvoor and Roodeplaat Dams.

On the basis of the assessments done it was recommended that two 900mm diameter outlets be added each to the present outlet works at Hartebeespoort and Roodekopjes Dams at a first order estimated cost of R 60 million. No additional works were anticipated at Klipvoor and Roodeplaat Dams.

The assessments should be checked and confirmed once a systems analysis model (similar to the one used for the Vaal-Orange-Lesotho river system) is available for the Crocodile River (West).