CLASSIFICATION OF SIGNIFICANT WATER RESOURCES IN THE CROCODILE (WEST), MARICO, MOKOLO AND MATLABAS CATCHMENTS: WP 10506

INTEGRATED UNITS OF ANALYSIS (IUA) DELINEATION REPORT

FINAL

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EXECUTIVE SUMMARY

Background

The Chief Director Water Ecosystems in the Chief Directorate Resource Directed Measures, Directorate Water Resources Classification has initiated the Classification of Significant Water Resources Study for the Mokolo and Matlabas catchments: Limpopo Water Management Area (WMA) and the Crocodile (West) Marico WMA. The purpose of this study is to coordinate the implementation of the 7 step process of the Water Resource Classification System (WRCS) in the Crocodile (West), Marico, Mokolo and Matlabas catchments in order to determine a suitable management class (MC) for all significant water resources and in so doing deliver the Integrated Water Resources Management (IWRM) template with recommendations for presentation to the delegated authority.

The determination of the MC is necessary to facilitate a balance between protection and use of water resources in the Crocodile (West), Marico, Mokolo and Matlabas catchments. In determining the class, it is important to recognise that different water resources will require different levels of protection. In addition to achieving ecological sustainability of the significant water resources through classification, the process will allow due consideration of the social and economic needs of competing interests by all who rely on the water resources. The WRCS will be applied taking account of the local conditions, socio-economic imperatives and system dynamics within the context of the South African situation. The process will also require a wide range of complex trade-offs to be assessed and evaluated at a number of levels.

As part of the classification process the first step is to delineate the units of analysis: the spatial units that will be defined as significant water resources. Each integrated unit of analysis (IUA) represents a homogenous area which requires its own specification of the MC. This report details the process of delineating and determining the IUAs for the water resources in the Crocodile (West), Marico, Mokolo and Matlabas catchments.

Integrated Units of Analysis (IUA) delineation approach

The process followed in terms of IUA delineation is that described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWA, February 2007).

Delineation of units of analysis is required as it would not be appropriate to set the same MC for all water resources in such an extensive area. The delineation of a WMA/catchment into IUAs for the purpose of determining the MC for significant rivers is done primarily according to a number of socio-economic criteria and drainage region (catchment area) boundaries. IUAs are therefore a combination of socio-economic zones and watershed boundaries (DWA, 2007). Ecological information also plays a role in the delineation.

The following was considered for delineation of IUAs within the Crocodile (West), Marico, Mokolo and Matlabas catchments:

- Socio-economic zones (SEZs);
- Catchment area boundaries (drainage regions and water resource systems);
- Similar land use characteristics/land based activities;

- Eco-regions and geomorphology;
- Ecological information;
- Present status of water resources; and
- Stakeholder input.

IUA Delineation Results

Twenty IUA's were identified and are tabled below and illustrated in the map to follow.

IUA ID No.	Quaternary catchment	EWR sites			Rationale for the IUA
		EWR Site ID	EWR Site Name	River System	
1	A21A A21B A21C A21D A21E A21H A23A A23B A23D A23E	EWR 1 (A21H)	Crocodile: Upstream of the Hartbeespoort Dam	Crocodile West	Water resources presently in a D category due to urbanization, return flows (increased flows) and poor water quality. However *Barbus Mattozi* is still present in the system. Rietvlei Dam is situated in the upper reaches of the Hennops River. Rivers: Bloubankspruit, Hennops, Crocodile. In respect of the Bloubankspruit it should be noted that: • The inter-Ministerial Committee on AMD has approved neutralisation of AMD from the Western Basin as the preferred method of treatment; • It is expected that an estimated 60ML/d of sulphate contaminated water will be discharged via the Tweelopiesspruit to the Bloubankspruit for the immediate and short term (up to 7 years); • DWA have again relaxed the sulphate discharge quality to 3 000mg/l; it ios expected that both surface and groundwater quality (the Zwartkrans Dolomitic Compartment that feeds the Bloubankspruit through a series of dolomitic springs) may be compromised. Evidence gained by Mogale City Local Municipality through monitoring suggests that this may affect the IUA category in the near future.
		EWR 2 (A21C)	Jukskei: Heron Bridge School	Crocodile West	Water resources presently in an E category due to urbanization, industrialization, return flows (increased flows) and poor water quality Rivers: Modderfontein, Sandspruit, Jukskei
		EWR 4 (A23B)	Pienaars: Downstream of Roodeplaat Dam	Crocodile West	The upper parts of the catchment are impacted by urbanization, irrigation in some areas; water treatment works releases and increased flows. Roodeplaat Dam on the Pienaars and Bon Accord Dam on the Apies contribute to changes in the flow regime. The present state of the Pienaars River downstream of Roodeplaat Dam is in a C category and the EIS is high. This reach of the river provides for the colonization of several fish species no longer found in other tributaries and the system is important for fish movement, especially with Roodeplaat Dam upstream and Klipvoor Dam downstream. No EWR site is situated on the Apies River.

IUA ID No.	Quaternary catchment	EWR sites			Rationale for the IUA
		EWR Site ID	EWR Site Name	River System	
					Rivers: Apies, Pienaars, Moreletta, Bloubankspruit
2	A21F A21G	Rapid EWR 9	Magalies: Downstream of Malony's Eye	Crocodile West	The present state of the Magalies River is in a B category, especially with Maloney's Eye situated in the upper reaches. The EIS is very high due to the presence of the rare *Barbus motebensis* in the system. The Magalies River is an important provincial conservation area and has been identified as a sensitive catchment in the Gauteng conservation plan. The lower reaches of the Magalies and Skeerpoort Rivers are impacted by water abstraction for irrigation. Rivers: Magalies, Skeerpoort The following has been noted by Mogale City Local Municipality: • Over abstraction and illegal abstraction of groundwater from the Steenkoppies Dolomitic Compartment which feeds Maloney's Eye raise serious concerns; • The Gauteng Department of Agriculture and Rural Development's Conservation Plan Version 3.3 has indicated that major areas associated with Maloney's Eye are defined as Irreplacable Sites; and • This area is defined in terms of Mogale City Local Municipality Spatial Development Plan (SDF) for tourism. Any forms of mining activities in the Upper reaches of Maloney's Eye are considered incompatible with the SDF and would potentially threaten the Class B status of the river.
3	A21J	EWR 3	Crocodile: Downstream of Hartbeespoort Dam in Mount Amanzi	Crocodile West	The water resources are in a degraded state (C/D to E category) due to changes in the flow regime as a result of Hartbeespoort Dam just upstream of this IUA and the poor water quality from IUA1. Roodekopjes Dam is situated at the outlet of this IUA. Rivers: Crocodile and smaller tributaries (Rosespruit, Kareespruit)
4	A21K A22G A22H A22J	EWR 6	Hex: Upstream of Vaalkop Dam	Crocodile West	The water resources of the Hex River have been degraded due to the Olifantsnek, Bospoort and Vaalkop Dams situated on the river. Rustenburg and extensive mining in the middle reaches of the catchment further impacts on the water resources, both quantity and quality. The Waterkloofspruit (mostly wetland) is still in a very good condition and forms part of a conservation area. Klipvoor Dam is situated at the outlet of this IUA. Rivers: Hex, Waterkloofspruit
		Rapid EWR 11	Sterkstroom: Upstream Buffelspoort Dam	Crocodile West	The present state of the water resources is in a C category. Some irrigation is present in the upper reaches of the system. Buffelskloof Dam and part of Roodekopjes Dam is situated in the catchment. The EIS is high due to the presence of the

IUA ID No.	**Quaternary catchment**	**EWR sites**			**Rationale for the IUA**
		EWR Site ID	**EWR Site Name**	**River System**	
					vulnerable *Barbus motebensis and the h*igh abundance of the unique *Amphilius uranoscopus* and *Barbus motebensis* upstream in catchment. Rivers: Sterkstroom
5	A22A A22B A22C A22D A22E A22F	Rapid EWR 10	Elands: Upstream Swartruggens Dam	Crocodile West	The water resources in the upper catchment of the Elands River are in a C category. This deteriorates further downstream with the presence of Swartruggens and Lindley'spoort Dams, mining, irrigation and return flows from water treatment works. The presence of the vulnerable *Barbus motebensis* contributes to a high EIS for the upper reaches. This reach also serves a refugia as the downstream catchment and river has been degraded. The unique Pilanesberg area is situated in the middle reaches of the IUA. Klipvoor Dam is situated at the outlet of this IUA. Rivers: Koster, Selons, Elands and some smaller tributaries in the lower reaches of the IUA
6b	A31B	EWR 2	Groot Marico: Upstream confluence with Sterkstroom	Groot Marico	The water resources are in a B category with some impacts due to irrigation and degraded riparian zone and alien invasive plants. The EIS is very high mainly due to the unique Blepharoceridae, locality of aquatic lampyridae as well as a large number of inverts and fish sensitive to water quality changes. The Marico Bosveld Dam is situated at the outlet of this IUA. Rivers: Polkadraaispruit, Groot Marico
6a	A31D A31E	EWR 5	Klein Marico Downstream Klein Maricopoort Dam	Groot Marico	The water resources are in a C category due to the impacts of Zeerust and the Klein Maricopoort Dam (irrigation) in the upper reaches of the catchment. Kromellenboog Dam, mainly being used for irrigation is situated in the lower Klein Marico River just before the confluence with the Groot Marico. Rivers: Rhenosterfontein, Malmaniesloop, Klein Marico, Karee
7	A31A	EWR 1	Kaaloog-se-Loop: Below gorge	Groot Marico	The water resource is in a B category and is situated close to the source of the Marico River. The EIS is very high with the presence of the rare and endangered *B motebensis and B waterburg* and the very high taxon richness of inverts (>45). The area has been identified a a national priority area for protection/conservation due to the dolomitic eyes and associated fauna and flora. Rivers: Kaaloog-se-Loop, Vanstraatenvlei
8	A31C	None		Malmanies -loop	Mainly groundwater – Malmanie's Eye
9	D41A	EFR M8	Molopo: Wetland	Molopo	Mainly groundwater – Molopo Eye. Water from the eye is diverted for use and only a small volume is released into the Molopo River.
10	A10A	None	-		Mainly groundwater – Dinokana Eye. The water from the eye flows to the Ngotwane Dam at the border of Botswana and is mainly used for domestic purposes.
11a	A31F A31G A31H	EWR 3	Groot Marico: Downstream Marico Bosveld	Groot Marico	The presence of Kromellemboog Dam (Klein Marico) and specifically the Marico Bosveld Dam just upstream of this IUA has severely

IUA ID No.	Quaternary catchment	EWR sites			Rationale for the IUA
		EWR Site ID	EWR Site Name	River System	
	A31J A32A A32B A32C A10B		Dam		impacted on the flow of the Marico River. Only small volumes of seepage from the dams are available instream. This resulted in a degraded system with a PES of a C/D. The EIS is high due to the species/taxon richness of the system and the presence of a number of inverts sensitive to water quality changes. Rivers: Groot Marico and a number of seasonal streams
11b	A10C A32D A32E	EWR 4	Groot Marico: Downstream Tswasa Weir	Groot Marico	The present state is a C category mainly due to the impact of the Molatedi Dam upstream and the release pattern from the Tswasa Weir for irrigation purposes just upstream of the site. The EIS is high as this reach forms a natural refugia with a number of perennial pools and is adjacent to the Madikwe Provincial Nature Reserve. Water is currently transferred from Molatedi Dam to Botswana. Rivers: Groot Marico and a number of seasonal tributaries.
12	A24D A24E A24F	None	-	Bierspruit	The water resources are degraded due to mining activities, town development and irrigation in the catchment. The Bierspruit Dam is situated in the upper reaches of the Bierspruit. No EWR site is present in this IUA. Rivers: Wilgespruit, Bierspruit and some seasonal tributaries
13	A21L A24A A24B A24C A24G A24H A24J	EWR 7	Crocodile: Upstream of the confluence with the Bierspruit	Crocodile West	The water resources of the Crocodile River in this reach have been degraded due to increased flows (irrigation return flows, releases from upstream dams for irrigation) and water quality impacts. The PES is a D category. Rivers: Crocodile and a number of seasonal tributaries
		EWR 8	Crocodile: Downstream of the confluence with the Bierspruit in Ben Alberts Nature Reserve	Crocodile West	The water resources of the Crocodile River in this reach have been degraded due to increased flows (irrigation return flows, releases from upstream dams for irrigation) and water quality impacts (mining and towns). The PES is a C category as the site is situated in the Ben Alberts Nature Reserve with improved riparian vegetation. Rivers: Crocodile
14	A23C A23F A23G A23H A23J A23K A23L	EWR 5	Pienaars/ Moretele: Downstream of the Klipvoor Dam in Borakalalo National Park	Crocodile West	The lower reach of the Pienaars/Moretele River flows through the extensive Moretele Floodplain and the Borakalalo National Park. Klipvoor Dam is situated in this reach. The present state is in a D category mainly due to the changes in flow as a result of the releases from the dams and water quality impacts from upsteam urbanization. The EIS is high due to the presence of the unique *Barbus Mattozi* and a number of fish species (*Chiloglanis pretoriae, Labeobarbus marequensis, Labeo cylindricus, Labeo molybdinus*) and inverts intolerant to water quality and flow changes. The downstream reach is important for fish movement, especially with Roodeplaat and Klipvoor Dams upstream of the site. Rivers: Pienaar/Moretele, Plat, Riet, Tolwane,

IUA ID No.	Quaternary catchment	EWR sites			Rationale for the IUA
		EWR Site ID	EWR Site Name	River System	
					Kutswane, Tshwane
15	A42A A42B A42C A42D A42E A42F	1A	Mokolo: Vaalwater	Mokolo	The PES is a C/D category mainly due to the abstractions for irrigation purposes and general farming activities. The EIS is high due to the presence of rare and endangered mammals, reptiles and unique fish species. Rivers: Mokolo, Sand, Klein Sand, Grootspruit and a number of smaller tributaries
		1B	Mokolo: Tobacco	Mokolo	The present state is in a B/C category with farming activities the main impact on the water resources. The EIS is high due to the presence of rare and endangered mammals, reptiles and unique fish species and the taxon and species richness of the system. Rivers: Frikkie-se-Loop, Sterkstroom, Dwars, Mokolo
		2	Mokolo: Ka'ingo	Mokolo	The present state is in a B/C category with farming activities and abstraction weirs the main impacts on the water resources. The EIS is very high due to the presence of rare and endangered mammals, reptiles and unique fish and invert species and the taxon and species richness of the system. Rivers: Taaibosspruit, Mokolo
16	A42G A42H A42J	3	Mokolo: Gorge	Mokolo	The present state is in a B/C category with farming activities and the Mokolo Dam the main impacts on the water resources. The EIS is very high due to the presence of rare and endangered biota and fish species intolerant to water quality changes. Rivers: Mokolo, Malmanies, Bulspruit
		4	Mokolo: Malalatau	Mokolo	The present state is in a C category with farming activities and the Mokolo Dam the main impacts on the water resources. The EIS is very high due to the presence of rare and endangered biota and fish species intolerant to water quality changes. Rivers: Mokolo, Rietpruit
		5	Mokolo: Tambotie Floodplain	Mokolo	This reach of the river was assessed as a floodplain. The IHI for the floodplain was determined as a D category due to decreased flows, farming activities and sand mining that changed the groundwater characteristics of the system. Rivers: Mokolo, Tambotie, Sandloop
17a	A41A A41B	-	-	Matlabas	The Matlabas River flows through the Marakele Nature Reserve. There are no EWR sites in the catchment. The groundwater Reserve has been undertaken for the catchment. Rivers: Mamba and Motlhabatsi
17b	A41C A41D	-	-	Matlabas	Grazing and abstraction from small farm dams are the main activities impacting on the water resources. River: Matlabas

Biophysical and Managements Nodes

Biophysical nodes are established to serve as points that account for interactions between ecosystems and management nodes (allocation). Nodes are established to serve as modelling points for the classification process in a catchment. The establishment of biophysical and management nodes are guided by a number of considerations. The key considerations are:

- Significant water resources;
- Biophysical and eco-regional characteristics;
- Location of Ecological Water Requirement (EWR) sites and ecological information;
- Ecological Importance and Sensitivity (EIS) categories of water resources;
- Present Ecological State (PES);
- Broad-scale hydrological and geomorphological characters;
- Water infrastructure; and
- Water management, planning and allocation information.

Based on the above considerations, proposed biophysical and allocation nodes have been established in each of the IUAs delineated for the Crocodile (West), Marico, Mokolo and Matlabas catchments. The nodes proposed will be confirmed and finalised at the conclusion of Step 3 of the Classification Process.

The proposed biophysical and management nodes and quaternary catchments within each IUA are tabulated and illustrated in the map below. EWR sites are also indicated.

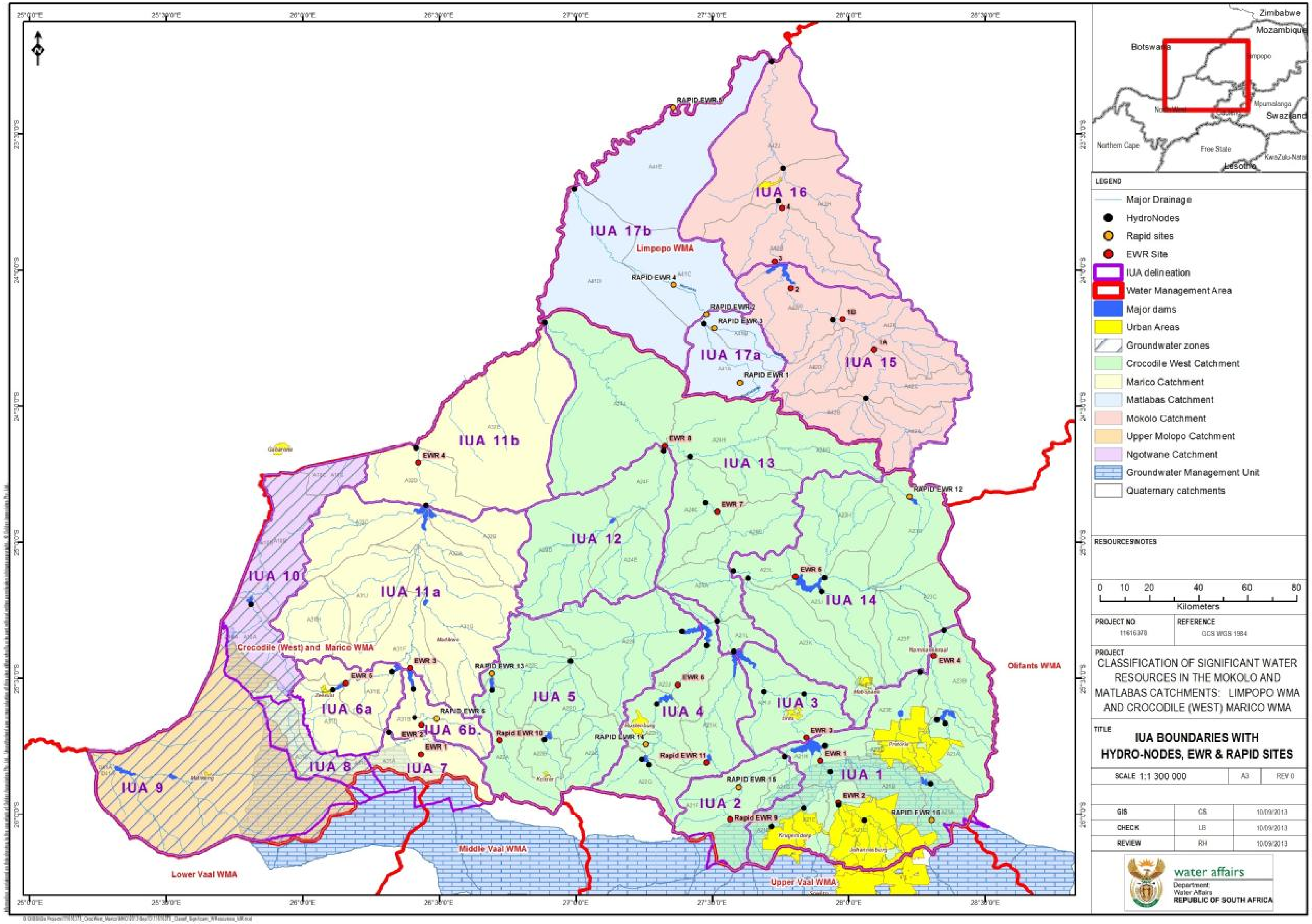
Current proposed biophysical and management nodes per IUA

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
1	HN1	A21A	Rietspruit (source) to Rietvlei Dam (CROC_EWR16)	Low	Low	C	Management, urban impacts, Rietvlei Dam	Quantity/quality, dolomitic
	HN2	A21B	Sesmylspruit with its' tributaries to confluence with Hennops	Moderate	Moderate	E	Biophysical, urban impacts	Quality
	HN3	A21C	Modderfonteinspruit to confluence with Jukskei	Moderate	Moderate	E	Biophysical, urban, industrial;	Quality
	HN4	A21C	Klein Jukskei at confluence with Jukske	Moderate	Moderate	E	Biophysical. semi urban	Quality
	HN5	A21C	Jukskei River at CROC_ EWR2	Moderate	Moderate	E	Biophysical, WWTW	Quantity/quality
	HN6	A21D	Bloubankspruit and tributaries (outlet of quaternary/confluence with Crocodile)	Moderate	Moderate	D	Biophysical, acid mine drainage, dolomitic, Botanical gardens, Cradle of Humankind	Quality/quantity
	HN7	A21A, B, H	Hennops (source) to confluence with Crocodile	Moderate	Moderate	D	Biophysical, urban, industrial	Quantity/quality
	HN8	A21H	Swartspruit to Hartbeespoort Dam	Moderate	Moderate	D	Semi urban	Quality
	HN9	A21E, H	Crocodile (source) to CROC_EWR1	Moderate	Moderate	D	Biophysical, urban	Quantity/quality
	HN10	A21H, J	Crocodile at Hartbeespoort Dam, outlet of IUA1	High	High	C/D	Hartbeespoort Dam, Management	Quantity/quality
	HN11	A23A	Pienaars(source) and including Moreletaspruit and Edendalespruit to outlet of Roodeplaat Dam	Low	Low	E	Management, urban, industrial; WWTW, canalised, Roodeplaat Dam	Quantity/quality
	HN12	A23B	Pienaars from Roodeplaat Dam to outlet of quaternary catchment (outlet of IUA1) (CROC_EWR4)	High	High	C	Management, sand mining	Quantity/quality
	HN13	A23B	Boekenhoutspruit to confluence with Pienaars	High	High	C	Biophysical	Quantity/quality
	HN14	A23D	Skinnerspruit (source) to confluence with Apies	Low	Low	E	Biophysical, urban, canalised urban river	Quantity/quality
	HN15	A23D, E	Apies (source) to Bon Accord Dam, below the dam at outlet of IUA1	Low	Low	F	Management, dolomitic at source	Quantity/quality,
2	HN16	A21F	Magalies below Maloney's Eye at CROC_EWR9	Very high	Very high	B	Biophysical, dolomitic at source	Quantity
	HN17	A21G, F	Magalies (CROC_EWR15)	Low	Low	C/D	Management	Quantity/quality
	HN18	A21G, F	Skeerpoort at outlet of IUA2	Low	Low	C/D	Management	Quantity/quality

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
3	HN19	A21J	Rosespruit at confluence with Crocodile	High	High	C/D	Biophysical	Ecological
	HN20	A21J	Crocodile from Hartbeespoort Dam to upstream Roodekopjes Dam, outlet of IUA3	Moderate	Moderate	D	Biophysical	Ecological
4	HN21	A21K	Sterkstroom (source) to Buffelspoort Dam (CROC_EWR11)	High	High	C	Biophysical	Quantity/quality
	HN22	A21K	Sterkstroom from Buffelskloof Dam to Roodekopjes Dam, outlet of IUA4	High	High	C	Management	Quantity/quality
	HN23	A22G	Hex (source) to Olifantsnek Dam	Moderate	High	C	Management, Olifantsnek Dam	Quantity/quality
	HN24	A22H	Waterkloofspruit (CROC_EWR14) to confluence with Hex	Low	Low	B/C	Biophysical, wetland, nature reserve	Wetland driven
	HN25	A22H	Hex from Olifantsnek Dam to Bospoort Dam	Moderate	Moderate	D	Management, urban, mining, Bospoort Dam	Quantity
	HN26	A22J	Hex from Bospoort Dam to Vaalkop Dam (CROC_EWR6)	Moderate	Moderate	D	Biophysical, Bospoort Dam	Quantity/quality
	HN27	A22J	Elands from Vaalkop Dam to confluence with Crocodile, outlet of IUA4	Moderate	Moderate	D	Management, Vaalkop Dam	Quantity/quality
5	HN28	A22A	Elands (source) to Swartruggens Dam (CROC_EWR10)	High	High	C	Management	Quantity
	HN29	A22A	Elands from Swartruggens Dam to Lindleypoort Dam	Moderate	High	C	Management, Swartruggens Dam, WWTWs	Quantity/quality, management
	HN30	A22B	Koster (source) to Koster Dam	Moderate	High	C	Biophysical, wetland	Wetland driven
	HN31	A22C, A22D	Selons to confluence with Elands	Moderate	High	C	Biophysical	Quantity/quality
	HN32	A22E, A22F	Elands from Lindleypoort Dam (CROC_EWR13) to Vaalkop Dam, outlet of IUA5	Low	Low	C	Management, Lindleyspoort Dam	Quantity/quality, management
6b	HN33	A31B	Polkadraaispruit to confluence with Marico (MAR_EWR6)	Moderate	Moderate	B/C	Biophysical	Quantity/quality
	HN34	A31B	Marico from MAR_EWR2 to N4 road at town	Very High	Very High	B	Biophysical	Quantity/quality
	HN63	A31B	Marico from N4 road to Marico-Bosveld Dam, outlet of IUA6b	Very High	Very High	B	Biophysical	Quantity/quality
6a	HN64	A31D	Malmaniesloop to confluence with Klein Marico Klein Marico and tributaries upstream of Zeerust	High	High	C	Biophysical, groundwater, WWTW, urban	Groundwater node
	HN35	A31D	Klein Marico from Zeerust to Klein Maricopoort Dam	High	High	C	Biophysical	Quantity/quality

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
	HN65	A31E	Klein Mario from Klein Maricopoort Dam to	High	High	C	Management, Klein Maricopoort Dam	Quantity/quality
	HN36	A31E	Kromellemboog Dam (MAR_EWR5), outlet of IUA6a	Moderate	Moderate	C	Management, Kromellemboog Dam	Quantity/quality
7	HN37	A31A	Kaaloog-se-Loop (MAR_EWR1) to concluence with Groot Marico	Very High	Very High	B	Biophysical, dolomitic	Quantity
	HN38	A31A	Vanstraatenvlei and tributaries at confluence with Kaaloog-se-Loop, outlet of IUA7	High	High	B	Biophysical, dolomitic	Quantity
8	-	A31C	Groundwater	-	-	-	Management, groundwater	Groundwater node
9	HN66	D41A	Molopo at outlet of wetland	-	-	-	Management, groundwater	Groundwater node
	HN67	D41A	Molopo at Modimola	Low	Low	E	Biophysical	Quality
	HN39	D41A	Molopo at outlet of IUA9	Low	Low	E	Management	Quality
10	HN68 -	A10A A10A, B, C	Ngotwane from Dinokana to Ngotwane Dam Ngotwane from Dinokana to outlet of IUA10	- -	- -	- -	Management, groundwater, Ngotwane Dam Management	Groundwater node
11a	HN40	A31F, G, A32A	Marico from Marico Bosveld and Kromelmboog Dam to Molatedi Dam (MAR_EWR3), outlet of IUA11a	High	High	C/D	Management, Madikwe Nature Reserve, Marico-Bosveld Dam	Quantity
11b	HN41	A32D, E	Marico from Molatedi Dam to confluence with Crocodile (MAR_EWR4), outlet of IUA11b	High	High	C	Management, Molatedi Dam, Twasa weir, international, Madikwe Nature Reserve	Quantity/quality
12	HN42	A24D, E, F	Bierspruit to confluence with Crocodile River, outlet of IUA12	Moderate	Moderate	D	Mining	Seasonal rivers, quantity
13	HN43	A24G, A24H	Sand to confluence with Crocodile	Moderate	Moderate	C	Biophysical	Quantity/quality
	HN44	A21L, A24A-C, A24H	Crocodile from Roodekopjes Dam (CROC_EWR7) to proposed Mokolo transfer (CROC_EWR8)	Moderate	Moderate	D	Management, irrigation, mining, transfer	Quantity/quality,
	HN45	A24J	Crocodile from CROC_EWR8 to confluence with Limpopo, outlet of IUA13	Moderate	Moderate	C	Management for international, groundwater	Quantity/quality
14	HN46	A23G	Platspruit (source, CROC_EWR12) to confluence with Pienaars	Moderate	Moderate	B/C	Biophysical	Quantity

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
	-	A23C, A23F	Wetland at Pienaars & Apies confluence and inflow to Klipvoor Dam	Moderate	Moderate	C	Biophysical; floodplain	Quantity/wetland
	HN47	A23H	Karee/Rietspruit to confluence with Pienaars	Moderate	Moderate	C	Biophysical	Quantity
	HN48	A23J A23J, A23L	Moretele (Pienaars) to confluence with Crocodile (CROC_EWR5), outlet of IUA14	High	High	D	Management, Klipvoor Dam, Borakalalo Nature Reserve	Quantity/quality
	HN49	A23K	Tolwane to confluence with Moretele	High	High	D	Biophysical	Quantity/quality
15	HN50	A42A	Sand (source) to confluence with Grootspruit	Moderate	Moderate	C	Biophysical	Quantity/quality
	HN51	A42B	Grootspruit (source) to confluence with Sand	Moderate	Moderate	C	Biophysical	Quantity/quality
	HN52	A42C	Mokolo to confluence with Dwars (MOK_EWR1a)	High	High	C/D	Biophysical	Quantity/quality
	HN53	A42D, A42E	Mokolo to confluence with Sterkstroom (MOK_EWR1b)	High	High	B/C	Biophysical	Quantity/quality
	HN54	A42D	Sterkstroom (source) to confluence with Mokolo, including Dwars	High	High	B/C	Biophysical, Ecological	Quantity,
	HN55	A42F	Mokolo from Sterkstroom to Mokolo Dam (MOK_EWR2), outlet of IUA15	Very high	Very high	B/C	Biophysical	Quantity/quality
16	HN56	A42G	Rietspruit (source) to Mokolo confluence	Moderate	Moderate	B/C	Biophysical	Quantity/quality
	HN57	A42G	Mokolo below dam (MOK_EWR3) to Rietspruit confluence (MOK_EWR4)	Very High	Very High	B/C	Management, Mokolo Dam	Quantity/quality
	HN58	A42H, A42J	Mokolo from MOK_EWR4 to confluence with Limpopo, outlet of IUA16.	Very High	Very High	C	Biophysical, floodplain	Use wetlands requirements for river
17a	HN59	A41A	Mothlabatsi to confluence with Mamba	Very High	Very High	B	Biophysical, Marekele National Park	Quantity,
	HN60	A41B	Mamba to confluence with Mothlabatsi, outlet of IUA17a	Moderate	Moderate	B/C	Biophysical	Quantity
17b	HN61	A41C	Matlabas from Mamba confluence to MAT_EWR2	High	High	B/C	Biophysical	Quantity/quality
	HN62	A41C, D	Matlabas from MAT_EWR2 to confluence with Limpopo, outlet of IUA17b	Moderate	Moderate	B	Management, international	Quantity/quality



IUAs within Crocodile (West), Marico, Mokolo and Matlabas catchments indicating location of proposed nodes and EWR sites

The report includes the economic rationale for delineation of Integrated Unit of Analysis (IUAs), and thereafter summarises available economic data describing the communities and economies of the Crocodile (West), Marico, Mokolo and Matlabas catchments, by IUA.

The report further analyses the state of aquatic ecosystem services in the study area, and determines a preliminary baseline value for determining the relationships between economic value, social well-being and ecosystem characteristics.

The main objective of this document is a proposed decision-analysis framework for the analyses of scenarios in the latter steps of this project, and thus links the socio-economic and ecological value and condition of the relevant water resources.

The water resources of the study area are natural assets that produce raw water and other aquatic ecosystem services. The raw water is used as an input in economic production, whilst households often directly use the other aquatic ecosystem services. Various economic sectors produce a variety of goods and services, many of them consumed as intermediate goods and services, but ultimately consumed by households. Households provide labour to the economic production process. Finally, the economic production process also produces a variety of effluents, which end up back in the aquatic environment as pollutants.

Total economic production of goods and services, measured as Value Added (VAD)[1], was approximately R550 billion in 2011. In contrast, the value of aquatic ecosystem services in that year was estimated at only R1, 983 million, thus contributing less than 1% of the value added to the economy of the study area. However, this aquatic ecosystems valuation excludes a number of important transactions relating to water resources. Firstly, two key ecosystem services were inadequately captured in the analyses: water regulating services and health services. Secondly, the damaging effects of emissions in the form of water pollutants and sedimentation emitted into aquatic ecosystems (i.e. water resources) are key environmental externalities and have thus far not been addressed. Another externality not dealt with is the conservation cost of aquatic ecosystem stewardship function. It is also important to note that these figures are estimations at present and will be updated in subsequent phases of the project.

In order to internalise the environmental costs and benefits into the production economy (and thus link the socio-economic and ecological value and condition of the relevant water resources), the relevant transactions can be modelled using four economic modelling techniques schematically shown in Figure 2. These techniques, together, form the decision-analysis framework:

- Social Accounting Matrixes (SAMs), obtained from the Development Bank of Southern Africa (DBSA), model the transactions between economic production sectors and household consumption.
- Environmental Economic Accounts for Water (Water EEAs) model the transactions between economic production and water resources (and expands the Water sector component of the SAM).
- Environmental and Resource Economics (ERE) modelling, based on the Millennium Ecosystem Assessment framework, models the production of aquatic ecosystem services.
- The effects of water pollutants on water resources and households can be modelled in various ways, however in this case; we will simulate the economic effects of implementing a Waste Discharge Charge System (WDCS).

This decision-analysis framework lends itself to a cost-benefit analysis (CBA) for evaluating scenarios.

[1] Akin to Gross Domestic Product (GDP), and is formally defined as the sum of labour, company profits, taxes paid and interest earned.

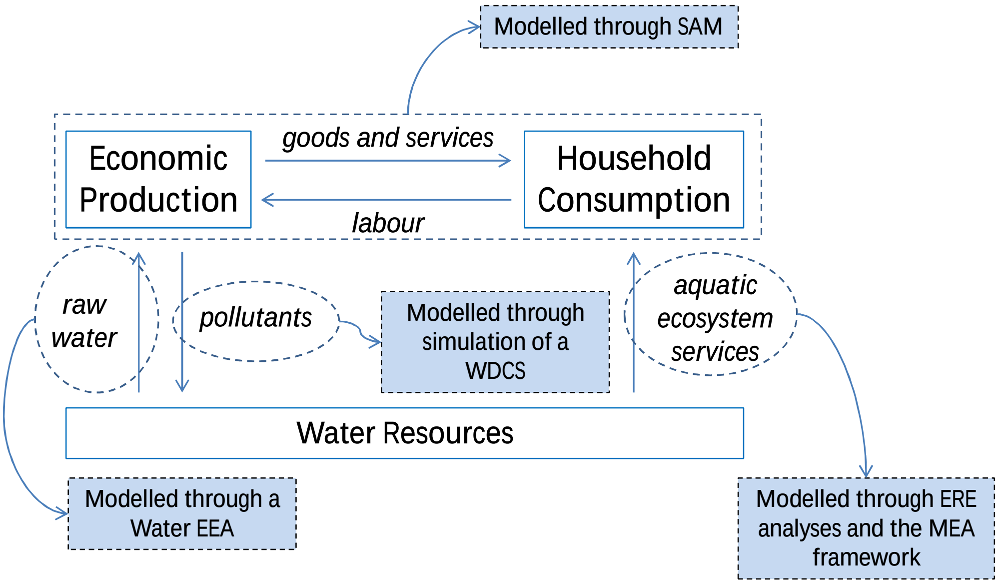


Figure 2: Schematic representation of the economic modelling techniques required to address the transactions of the Crocodile (West), Marico, Mokolo and Matlabas catchments' water economy

DOCUMENT INDEX

Reports as part of this study:

Bold type indicates this report.

Report Index	Report number	Report title
1	RDM/WMA1,3/00/CON/CLA/0111	Inception Report
2a	RDM/WMA1,3/00/CON/CLA/0112A	Information Analysis Report : Crocodile (West) Marico WMA
2b	RDM/WMA1,3/00/CON/CLA/0112B	Information Analysis Report : Mokolo and Matlabas catchments
3	**RDM/WMA1,3/00/CON/CLA/0212**	**Integrated Units of Analysis Delineation Report**

LIST OF ABBREVIATIONS AND ACRONYMS

CD: RDM	Chief Directorate: Resource Directed Measures
CSIR	Council for Scientific and Industrial Research
DWA	Department of Water Affairs
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
GDP	Gross Domestic Product
IUA	Integrated Unit of Analysis
IWRM	Integrated Water Resource Management
MC	Management Class
MU	Management Unit
NFEPA	National Freshwater Ecosystem Priority Areas
NWA	National Water Act
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQOs	Resource Quality Objectives
SDF	Spatial Development Framework
SEZ	Socio-Economic Zones
WMA	Water Management Area
WRC	Water Resource Classification
WRCS	Water Resource Classification System
WRYM	Water Resources Yield Model
WRPM	Water Resources Planning Model

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1 INTRODUCTION

1.1 Background

The National Water Act (Act No. 36 of 1998) (NWA) is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public without seriously affecting the functioning of the water resource systems. In order to achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the implementation of resource directed measures (RDM). As part of the RDM, a management class (MC) has to be determined for a significant water resource, as the means to ensure a desired level of protection. The purpose of the MC is to establish clear goals relating to the quantity and quality of the relevant water resource.

The classification system, the Reserve and Resource Quality Objectives (RQOs) together are intended to ensure comprehensive protection of all water resources. An important consideration in the determination of RDM is that they should be technically sound, scientifically credible, practical and affordable.

The Chief Directorate: Resource Directed Measures (CD:RDM), Directorate Water Resources Classification (D: WRC) of the Department of Water Affairs (DWA) is tasked with the responsibility of ensuring that the water resources are classified in terms of the Water Resource Classification System (WRCS). This is to ensure that a balance is sought between the need to protect and sustain water resources on one hand and the need to develop and use them on the other. The CD: WE has identified the need to undertake the classification of significant water resources (rivers, wetlands, groundwater and lakes) in the Crocodile (West), Marico, Mokolo and Matlabas catchments, in accordance with the WRCS.

The MC and associated RQOs will assist the DWA in making more informed decisions regarding the authorisation of future water uses, operation and management of the system and the evaluation of the magnitude of the impacts of the present and proposed developments.

The data sources for the socio-economic component of the Crocodile (West), Marico, Mokolo and Matlabas catchments' study were both numerous and varied. The aim of this section is to give some insight on the data sources used and the assumptions that were made.

The demographic data that is available for the study area is based on the 2011 Census.

For the agricultural component of the study several data sources were utilised. Land use and broad agricultural categories were determined by using land cover estimates derived from high-resolution satellite imagery published by the South African National Land Cover Project (CSIR, 2002).

The Department of Agriculture, Forestry and Fisheries (DAFF) provided two distinct databases:

1. **Crop Type Data:** The data set provides detailed information on the major crop types grown in Gauteng and North West Province, but unfortunately does not yet includes Limpopo Province. However, there are plans to include the province in the near future.
2. **Crop Boundary Data:** The data set provides detailed information on the major agricultural types i.e. irrigation area, commercial area, subsistence area at a national level.

Agricultural data was also gathered from the Census of Commercial Agriculture 2007, which was published by StatsSA (2011). The data gives detailed national information on agricultural area and major crop types grown at the time of the census in 2007.

For the mining component of the study several data sources were utilised. Annual production figures of minerals by Province were received from the Department of Mineral Resources (DMR). Information for individual mines was collected from 2011 annual reports where available.

1.2 Study Area

The spatial extent for the classification study includes tertiary drainage regions tertiary drainage regions A10, A21 to A24, A31, A32 and quaternary drainage region D41A.

The study area is the Crocodile (West), Marico, Mokolo and Matlabas catchments (Figure 1). The sub-catchments for the study area are set out in Table 1.

Table 1: The sub-catchment areas within the study area

Sub-catchment	Catchment Area (km^2)	Quaternary catchments
Upper Crocodile (A21)	6 336	A21 A – L
Elands (A22)	6 221	A22 A – J
Apies/Pienaars (A23)	7 588	A23 A – L
Lower Crocodile (A24)	9 204	A24 A – J;
Marico (A31 and A 32)	12 030	A32 A – E; A31 A – J
Ngotwane (A10)	1 842	A10 A – C
Upper Molopo (D41))	4 300	D41 A
Matlabas (A41)	6 014	A41A – E
Mokolo (A42))	8 387	A42 A – J

The Mokolo and Matlabas catchments

The Mokolo catchment stretches from the Waterberg Mountains through the upper reaches of the Sand River, and includes the Mokolo Dam and a number of small tributaries that join the main Mokolo River up to its confluence with the Limpopo River, including the Tambotie, Poer-se- Loop, and Rietspruit rivers. The catchment covers an area of 8 387 km^2.

The Matlabas catchment is situated in a predominantly flat area. Matlabas River originates in the Waterberg mountain range and the altitude varies from 1 400 m to approximately 840 m at the confluence with the Limpopo River. The catchment is largely undeveloped with limited water resources and limited water use. The area covers approximately 6 014 km^2.

The climate in the Lephalale area is mild winters (4-20 °C) and moderate summers (17-28°C). Rainfall in the Matlabas and Mokolo catchment areas ranges from 600 mm in the east to 400 mm in the west towards the Botswana border.

Exxaro's Grootegeluk Colliery the largest open cast coal mine of its kind in the world, with a current annual production of 15.3 Mt/a, is currently the only commercial coal mining operation in the Waterberg Basin and is being expanded to supply the new Medupi Power Station with coal. However, the Lephalale area has been selected by Sasol to access the vast coal reserves in the Waterberg coal fields for its Maphuta coal to liquid fuel projects (Mafutha). This project is currently on the backburner. Additional to Matimba and Medupi three new Eskom power stations CF3, CF4 and CF5 are envisaged for the future.

The Steenbokpan area, quaternary catchment A41E in the Matlabas catchment, is part of the Lephalale coalfield and numerous mining developments are foreseen for this region. Current and future developments around the available coal reserves in the Steenbokpan area will require adequate planning for future water needs.

Crocodile (West) and Marico WMA

The Crocodile (West) Marico WMA (WMA 3) borders on Botswana in the north-west and includes the two major river systems: Crocodile West and Marico, which give rise to the Limpopo River at their confluence.

The two major rivers in the Crocodile (West) Marico WMA are the Crocodile (West) River and the Groot Marico River, which form the south-western part of the Limpopo River basin (Drainage Region A), eventually draining into the Indian Ocean in Mozambique. The WMA also includes the headwaters of the Molopo River, a tributary of the Orange River which drains westwards to the Atlantic Ocean.

The WMA covers a total catchment area of 47 565 km^2. The Pienaars, Apies, Moretele, Hennops, Jukskei, Magalies and Elands rivers are the major tributaries of the Crocodile River which together make up the A20 tertiary drainage catchment, with 39 quaternary catchments. The Crocodile River contributes to the flow of the Limpopo River, which has an international river basin shared with Botswana, Zimbabwe and Mozambique.

The high altitude of Johannesburg and the Highveld ensures favourable weather throughout the year. Summer days are moderate (maximum temperatures average 28°C and the minimum average is 17°C). Brief thundershowers are characteristic of this time of year. Winter days are warm, up to 25°C and evenings are cold with frequent frosts. Pretoria is a few degrees hotter, lying at a lower altitude. Maximum temperatures in midwinter average 19°C and the minimum average is 5 °C. Further west in the monthly distribution of average daily maximum temperatures for Rustenburg range from 19.3°C in July to 29.4°C in January.

Average rainfall in the area ranges from 600 – 800 mm with most rainfall occurring mainly during summer. Further west the area around Rustenburg receives about 513mm of rain per year, decreasing to less than 500 mm in the Mafikeng and Groot Marico areas.

As indicated in Figure 1, the Crocodile (West) Marico WMA stretches across three provinces: Gauteng, Northwest and Limpopo. Economic activity across the WMA is diverse with the Upper Crocodile sub-catchment (A21) and the urban areas of the Pienaars sub-catchment (A23) comprising a well-developed manufacturing and general commercial urban economy. Rustenburg in the Elands River sub-catchment (A22) is well known for its extensive platinum mining activities. The rural parts of the Pienaars River sub-catchment (A23); the Lower Crocodile River (A24); and the Groot Marico (A3) economies are dominated by agriculture and eco-tourism activities.

Mining operations in the Crocodile (West) Marico WMA is dominated by platinum and the platinum group metals, gold, chrome, manganese, iron ore, diamonds, dimension stone and mineral sands, as well as smaller quantities of vanadium, limestone and andalusite (an aluminium nesosilicate mineral). The entire western section of the mineral-rich Bushveld Igneous Complex is situated here, resulting in intense mining activity in the region

Irrigation occurs mostly in the Crocodile catchment, immediately downstream of the Hartbeespoort Dam and also further downstream towards the south of Thabazimbi. Irrigation is done at Mmbatho with water sourced from the Grootfontein dolomitic compartments. Dry land crops, mostly maize, are grown in the higher rainfall south and south-eastern parts of the WMA. Stock and game farming dominate land-use in the drier northern and western regions.

Several heavy industries occur in the WMA including Pelindaba and Valindaba (direct abstractions from the Crocodile River upstream of Hartbeespoort Dam), and the Dwaalboom cement factory at Thabazimbi (supplied by Magalies Water from the Vaalkop Dam). Three relatively small power stations: Rooiwal, Pretoria West and Kelvin, are present in the WMA.

Although the Crocodile (West) Marico WMA is not as renowned for its tourism activities as other provinces (e.g. Mpumalanga, KwaZulu-Natal, Eastern Cape and Western Cape), tourism nevertheless plays an important role in stimulating accommodation, transport and retail sectors. Of special interest is the Hartbeespoort Dam, a significant hub for various forms of recreation and tourism.

The Regional Gross Domestic Product (GDPR) of the Crocodile (West) Marico WMA was estimated to be R130,1 billion in 1997 with the following contributions from various municipal areas:

Tshwane = 34,1%;

Johannesburg = 32,0%;

Ekurhuleni = 10,0%; and

Other 22,9%.

The key economic sectors contributing to GDPR were:

- Manufacturing = 22,7%;
- Government sector 18,7%;
- Finance 17,7%;
- Transport 15,7%; and
- Other 25,2%.

The University of Pretoria estimated a GDPR of R137.6 billion for the Crocodile (West) Marico WMA for 2002 (Hassan *et al.* 2008).

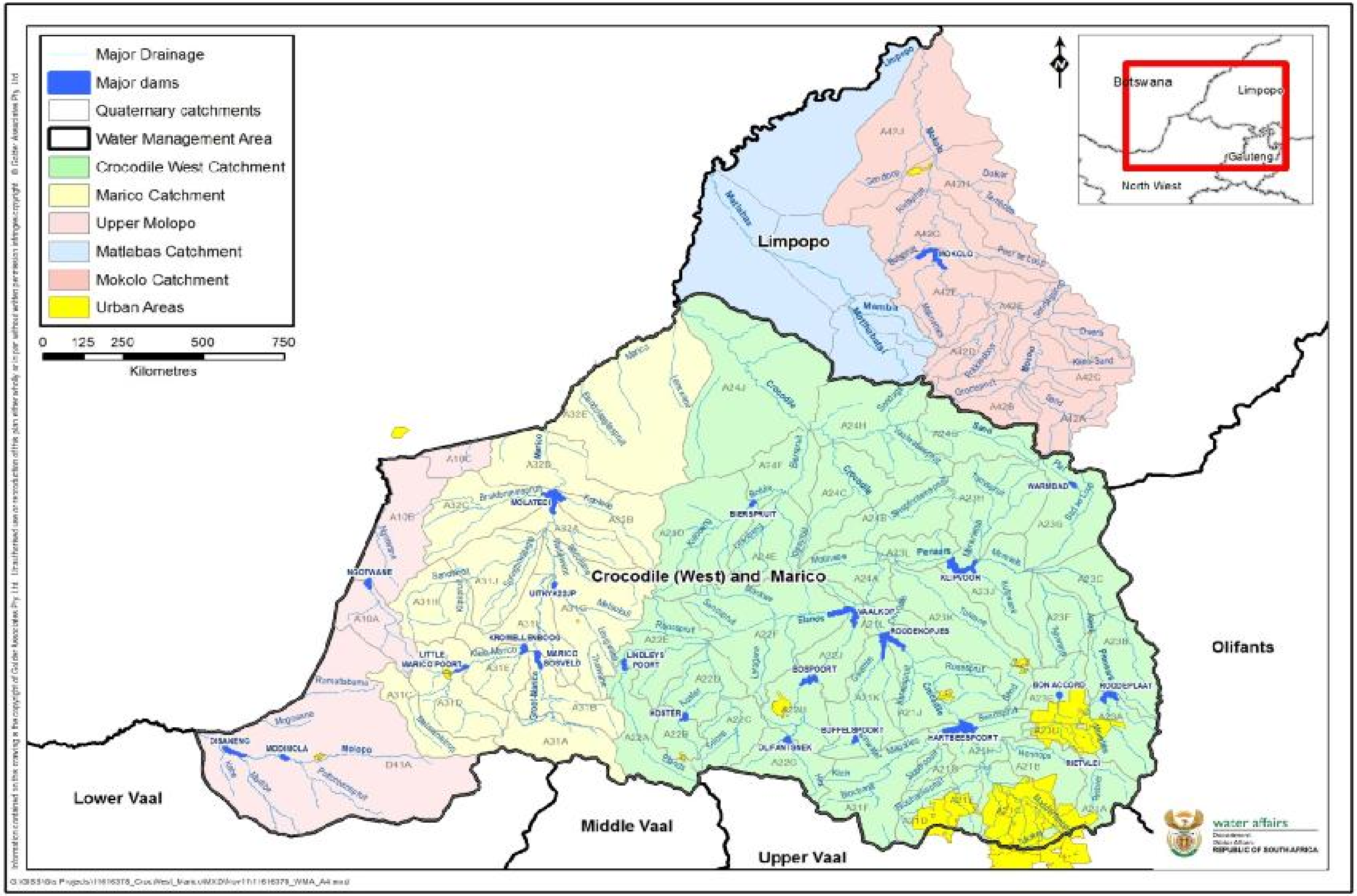

Figure 1: The study area: Crocodile (West), Marico, Mokolo and Matlabas catchments indicating sub-catchment areas

1.3 Purpose of the Study: Classification of Significant Water Resources in the Crocodile (West), Marico, Mokolo and Matlabas catchments

The purpose of this study is to coordinate the implementation of the 7 step process of the WRCS illustrated in Figure 2 in the Crocodile (West), Marico, Mokolo and Matlabas catchments in order to determine a suitable MC for the significant water resources and in so doing deliver the Integrated Water Resource Management (IWRM) template with recommendations for presentation to the delegated authority of DWA.

The determination of the MC is necessary to facilitate a balance between protection and use of water resources. In determining the class, it is important to recognise that different water resources will require different levels of protection. In addition to achieving ecological sustainability of the significant water resources through classification, the process allows for due consideration of the social and economic needs of competing interests by all in the study area who rely on the water resources.

The WRCS will be applied taking account of local conditions, socio-economic imperatives and system dynamics within the context of the South African situation. The process will also require a wide range of complex trade-offs to be assessed and evaluated at a various levels.

The Crocodile (West)/Marico WMA is a highly utilised and regulated catchment and like many other WMAs in South Africa its water resources are becoming more stressed due to an accelerated rate of development resulting in the scarcity of water resources. The Matlabas and Mokolo are less utilised and regulated, however are located in a water scare catchment in which rapid development is expected to take place. There is therefore an urgency to ensure that water resources in the Crocodile (West), Marico, Mokolo and Matlabas catchments area are able to sustain their level of uses and be maintained at their desired states.

The MC of the significant water resources in the Crocodile (West), Marico, Mokolo and Matlabas catchments will ensure that the desired condition of the water resources is maintained, and on the other hand, the degree to which they can be utilised, adequately managed within the economic, social and ecological goals of the water users. The MC of the water resource will set the boundaries for the volume, distribution and quality of the Reserve and Resource Quality Objectives (RQOs), and consequently the potential allocable portion of a water resource for use.

Figure 2: Steps for determination of the Management Class

1.4 Purpose of the report

As part of the classification process the first step is to delineate the units of analysis: the spatial units that will be defined as significant water resources. Each integrated unit of analysis (IUA) represents a homogenous socio-economic area which requires its own specification of the MC. This report therefore details the process of delineating the IUAs for the water resources in the Crocodile (West), Marico, Mokolo and Matlabas catchments.

The purpose of this report is therefore:

- To provide the information used to delineate the IUAs;
- To detail the defined set of delineated IUAs within the Crocodile (West), Marico, Mokolo and Matlabas catchments, and
- To list the biophysical nodes within the IUAs and management nodes at each IUA outlet.

2 INTEGRATED UNITS OF ANALYSIS DELINEATION

2.1 Approach

IUAs are the spatial units that are defined as significant water resources. The objective of defining IUAs is to establish broad scale units for assessing the socio-economic implications of different catchment configuration scenarios and to report on the ecological conditions at a sub-catchment scale (DWA, 2007a).

Delineation of units of analysis is required as it would not be appropriate to set the same MC for all water resources in a catchment. The delineation of a WMA/catchment into IUAs for the purpose of determining the MC for significant rivers is done primarily according to a number of socio-economic criteria and drainage region (catchment area) boundaries. IUAs are thus a combination of socio-economic zones and watershed boundaries (DWA, 2007b). Ecological information also plays a role in the delineation.

The process followed in terms of IUA delineation is that described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWA, 2007b).

In the IUA delineation process overlaying all of the above data does not necessarily result in a logical and clear delineation and expert judgement, a consultative process and local knowledge may be required for the final delineation of the IUAs. The practicalities of dealing with numerous significant water resources and associated tributaries within one study must also be considered to determine a logical and practical set of IUAs.

Biophysical nodes are established within an IUA to serve as modelling points for the Classification process in a catchment. The nodes are used to assess the response of upstream water resources to changes in water quality, quantity and timing (DWA, 2007b). Biophysical nodes should be located at the end points of eco-system reaches to allow for meaningful trade-offs. The establishment of biophysical nodes is guided by a number of considerations.

2.2 IUA Delineation

The following was considered for delineation of IUAs within the Crocodile (West), Marico, Mokolo and Matlabas catchments:

- Socio-economic zones (SEZs);
- Catchment area boundaries (drainage regions and water resource systems);
- Similar land use characteristics/land based activities;
- Eco-regions and geomorphology;
- Ecological information;
- Present Ecological State (PES); and
- Stakeholder input.

2.2.1 Socio-economic Zones

Socio-economic zones (SEZs) determined for the Crocodile (West), Marico, Mokolo and Matlabas catchments were based on broad socio-economic parameters. Table 2 describes the broad socio-economic zones. Once the SEZs had been determined, seventeen IUAs for the Crocodile (West), Marico, Mokolo and Matlabas catchments were delineated, taking into account the above-mentioned guidelines.

Table 2: Description of the socio-economic zones (SEZ) for the Crocodile (West), Marico, Mokolo and Matlabas catchments

Name	Description	Location (Quaternary catchment)
Urban SEZ	The Urban SEZ includes the major metropolitan municipalities of Johannesburg, Tshwane and the other municipalities in-between. The SEZ includes a large portion of Gauteng conurbation, which includes: Johannesburg, Ekurhuleni (East Rand), and Tshwane (greater Pretoria). The conurbation comprises a population of approximately 14.6 million people.	A21A-E and A21G and H; A23A,B,D and E.
Conservation SEZ	The areas of particular importance to conservation efforts include the Cradle of Humankind and the Magaliesburg Protected Area as well as the upper catchment of the Marico River. The dolomitic headwaters of the Marico River contain unique biodiversity and it has been recognised as an important fish sanctuary. Other possible areas include the Madikwe Protected Area located in the lower Marico Catchment.	Magaliesburg PA: A21F, A21G, Upper Marico headwaters: A31A,B,C,D,E Madikwe: Lower portion of A32E Upper Matlabas headwaters: A41A, A41B
Mining SEZ	The Mining SEZ comprises of the platinum mining area surrounding the town of Rustenburg. The CWM WMA contains a large portion of the Bushveld Igneous Complex, the largest platinum group metals (PGM) deposit worldwide.The Steenbokpan area in the Matlabas catchment, is part of the Lephalale coalfield.	A21J, A21K, A21L, A23K, A23L A41E
Agricultural SEZ	A large proportion of the CWM WMA falls within this category. The Upper Crocodile River area below the Hartbeespoort Dam is largely of a commercial agricultural nature. The area encompassing the Moretele River is largely temporary commercial dryland agriculture in nature and includes the agricultural district of Bela Bela. The lower Crocodile River Catchment down to the Limpopo River is characterised by some commercial agricultural activities, some subsistence farming and cattle/game farming. Upper Molopo Catchment consists mainly of dryland and some subsistence agriculture. The Marico Catchment below the Marico Bosveld Dam comprises commercial and small-scale agriculture. The Mokolo Catchment comprises some commercial and small-scale agriculture. The Matlabas	Essentially the rest of the WMA.

Name	Description	Location (Quaternary catchment)
	catchment comprises mostly natural veld which is used for stock or game farming.	

2.2.2 Socio-Economic Status

Crocodile (West) River Catchment

Economic activity across the study area is diverse. The Upper Crocodile sub-catchment (A21) and the urban areas of the Pienaars sub-catchment (A23) comprise a well-developed manufacturing and general commercial urban economy. Rustenburg in the Elands River sub-catchment (A22) is well known for its extensive platinum mining activities. The rural parts of the Pienaars River sub-catchment (A23); the Lower Crocodile River (A24); and the Groot Marico (A3) economies are dominated by agriculture and eco-tourism activities.

Mining operations in the Crocodile (West) Marico WMA is dominated by platinum and the platinum group metals, gold, chrome, manganese, iron ore, diamonds, dimension stone and mineral sands, as well as smaller quantities of vanadium, limestone and andalusite. The entire western section of the mineral-rich Bushveld Igneous Complex is situated here, resulting in intense mining activity in that region. Coal mining occurs in the Mokolo catchment.

Irrigation occurs mostly in the Crocodile catchment, immediately downstream of the Hartbeespoort Dam and also further downstream towards the south of Thabazimbi. Irrigation is done at Mmabatho with water sourced from the Grootfontein dolomitic compartments. Dry land crops, mostly maize, are grown in the higher rainfall south and southeastern parts of the WMA. Stock and game farming dominate land-use in the drier northern and western regions.

There are several heavy industry firms in the study area. These include Pelindaba and Valindaba (direct abstractions from the Crocodile River upstream of Hartbeespoort Dam), and the Dwaalboom cement factory at Thabazimbi (supplied by Magalies Water from the Vaalkop Dam). Three relatively small power stations, Rooiwal, Pretoria West and Kelvin, are present in the Crocodile (West) Marico WMA.

Although the study area is not as renowned for its tourism activities as other provinces (e.g. Mpumalanga, KZN, Eastern Cape and Western Cape), tourism nevertheless plays an important role in stimulating accommodation, transport and retail sectors. Of special interest is the Hartbeespoort Dam, a significant hub for various forms of recreation and tourism.

The Regional Gross Domestic Product (GDPR) of the Crocodile (West) Marico WMA was estimated by DWA to be R130,1 billion in 1997 with the following contributions from various municipal areas:

- Tshwane = 34,1%
- Johannesburg = 32,0%
- Ekurhuleni = 10,0%
- Other 22,9%

The key economic sectors contributing to GDPR were:

- Manufacturing 22,7%
- Government sector 18,7%
- Finance 17,7%
- Transport 15,7%
- Other 25,2%

Marico Catchment

The Marico, as well as the Upper Molopo and Ngotwane catchments are considered the poorest of all catchments within the Croc (West) and Marico WMA. The economy is characterised by the primary sectors of agriculture on the dolomites of the Upper Molopo and the Marico catchment as well as mining around Zeerust, with some secondary industries such as cement manufacturing at the Slurry. The tourism sector is growing particularly in the lower Marico in the game reserves of Madikwe.

Matlabas and Mokolo Catchments

The economy of both the Matlabas and the Mokolo is characterised by the agricultural sector. Power generation is an important sector in the Mokolo catchment with the Matimba and Medupi (under construction) power stations found here. Three new Eskom power stations CF3, CF4 and CF5 are envisaged for the future. Coal mining in support of power generation activities is also an important sector, and both catchments have been earmarked for future coal mining developments.

2.2.3 Population

Previous Population Estimates

The Crocodile West and Marico WMA is the second most populous WMA in the country, which closely relates to the large proportionate contribution to the national economy (this area generates almost a third of the country's GDP). According to DWAF the total population of this catchment has been estimated to be about 4.9 million people (based on 1995 data). Most of these people reside in the urban metropolitan area of Johannesburg and Tshwane.

Population estimates for the Marico, Upper Molopo & Upper Ngotwane area in 1995 was estimated to be 539 100 with 199 600 located in Marico and Upper Ngotwane catchments (DWAF 2004b). Approximately 62% of the population or 340 000 are located in the Upper Molopo catchment.

Population figures for the Matlabas and Mokolo catchments were estimated at 10 045 and 56 362 respectively (DWAF 2004c).

Current Population Estimates

Data from Census 2001 showed a population of 5 492 746 (StatsSA 2002). For the purposes of this study, the population for the entire study area was calculated at 7 792 397 people using the Census 2011 Ward data (StatsSA 2013), which is a 42% increase in 10 years.

2.2.4 Catchment Area Boundaries

The Crocodile (West), Marico, Mokolo and Matlabas catchments are sub-catchments of the Limpopo River Basin.

Crocodile (West) and Marico catchments

The Crocodile River and its tributaries run a long course from the Highveld across varying terrain and geology to meet with the Limpopo River in Botswana and the Groot Marico River and its tributaries runs from the upper reaches of the Marico catchment to the Botswana border.

The Crocodile (West) Marico WMA lies within the A primary drainage region as well as including tertiary drainage region D4A. The catchment area includes the secondary drainage regions A1 to A3, 20 tertiary drainage areas and 55 quaternary catchments.

The WMA covers a total catchment area of 47 565 km^2 (Table 3). The Pienaars, Apies, Moretele, Hennops, Jukskei, Magalies and Elands rivers are the major tributaries of the Crocodile River which together make up the A20 tertiary drainage catchment, with 39 quaternary catchments. The Crocodile River contributes to the flow of the Limpopo River, which has an international river basin shared with Botswana, Zimbabwe and Mozambique.

Table 3: The sub-catchment areas within the study area

Sub-catchment	Catchment Area (km^2)	Quaternary catchments
Upper Crocodile (A21)	6 336	A21 A – L
Elands (A22)	6 221	A22 A – J
Apies/Pienaars (A23)	7 588	A23 A – L
Lower Crocodile (A24)	9 204	A24 A – J;
Marico (A31 and A 32)	12 030	A32 A – E; A31 A – J
Ngotwane (A10)	1 842	A10 A – C
Upper Molopo (D41))	4 300	D41 A
Matlabas (A41)	6 014	A41A – E
Mokolo (A42))	8 387	A42 A – J

IUAs were delineated based on the socio-economic criteria and drainage region (catchment area) boundaries described above.

2.2.5 Land use/land based activities

Land use in the study area is extremely varied. The urban areas of northern Johannesburg, Midrand and the areas under the City of Tshwane Metropolitan Council dominate land use in the southeastern portion of the catchment. The area between Rustenburg and Brits on the northern side of the Magaliesberg range is known for its citrus farming activities, whereas irrigated cash crop farming takes place below the Hartebeespoort Dam and Brits. Irrigation also occurs down the mainstream of the Crocodile River, the most significant areas being just south and north of the town of Thabazimbi. Extensive platinum mining occurs in the area around Rustenburg, while gold mining occurs in the upper Crocodile catchment (DWAF 2004a).

Land use characteristics in the Marico catchment comprises of rural economic activities consisting of subsistence dryland agriculture and cattle grazing with some commercial irrigation in the upper catchment and along the Marico River downstream of the Marico Bosveld Dam and Molatedi Dam.

Land use In the Upper Molopo catchment consists mainly of grazing and dryland subsistence agriculture, with Mafikeng the major urban and industrial town in the catchment (DWAF 2004b).

Most of the Limpopo WMA (including the Matlabas and Mokolo catchments) is too dry for dryland agriculture and there are limited surface water resources to support irrigation. Land use is therefore dominated by stock farming (mostly cattle) while there is an increasing tendency to replace this with game farming (DWAF 2004c).

2.2.6 National Land Cover Database

Land use estimates were calculated using the National Land Cover (CSIR 2002) (Table 4). Although 10 years old, the database is the only national land cover database available and provides useful information on land use activities at a national scale.

According to the NLC, the natural land use category forms the largest part of the study area followed by the degraded land use category.

Table 4: Land use categories for the Crocodile (West), Marico, Mokolo and Matlabas catchments (Source: NLC: CSIR 2002)

Land Use Category	Area (ha)
Cultivation	889 825
Degraded	234 685
Mines	20 329
Natural	4 711 112
Plantations	3 520
Urban Built-up	277 765
Water bodies	38 129
Grand Total	**6 175 364**

2.2.6.1 Agriculture

Agricultural activities are extremely varied in the study area and range from commercial irrigated agriculture in the areas below Hartebeespoort Dam and the Upper Marico catchment to small scale and subsistence farming scattered throughout. The Matlabas and Mokolo catchments are characterized by dryland agriculture and cattle or game farming. These areas have limited surface water availability for further irrigation expansion.

Although relatively small in terms of total Rand production when compared with other WMAs, agriculture in the study area is considered an important sector in terms of job creation and contribution to regional gross domestic product (GDP-R) of the WMA (Table 5).

Table 5: Summary of all crops production for RSA for 2002, by Water Management Area

All crops WMA	Dryland area ha	Dryland production tons	Irrigated area ha	Irrigated production tons	Dryland production R	Irrigated production R	Total production R
Limpopo	12,355	25,594	21,825	234,096	42,313,007	312,372,093	354,685,100
Luvuvhu to Letaba	6,170	42,399	8,958	127,193	68,267,789	187,637,711	255,905,500
Crocodile-West Marico	5,741	36,967	21,191	191,728	38,087,383	317,181,617	355,269,000
Olifants	205,771	605,471	111,463	1,320,967	762,668,223	2,266,217,677	3,028,885,900
Inkomati	3,624	61,172	35,753	1,701,865	44,259,691	863,058,609	907,318,300
Usutu to Mhlatuze	132,128	1,998,945	41,973	1,226,611	565,368,646	405,458,954	970,827,600
Thukela	58,145	1,528,357	17,809	547,976	302,493,741	165,653,359	468,147,100
Upper Vaal	877,440	3,070,614	63,223	572,056	2,598,460,018	743,854,582	3,342,314,600
Middle Vaal	742,823	1,865,067	26,697	167,462	2,089,475,765	212,788,435	2,302,264,200
Lower Vaal	145,850	345,336	56,852	627,739	380,401,641	943,197,659	1,323,599,300
Mvoti to Umzimkulu	111,657	4,084,300	16,740	578,889	779,637,009	206,017,391	985,654,400
Mzimvubu to Keiskamma	25,859	309,825	9,383	210,843	132,139,027	116,379,973	248,519,000
Upper Orange	383,351	1,008,587	83,476	646,421	862,896,792	664,487,408	1,527,384,200
Lower Orange	11,053	29,696	26,808	190,574	37,508,307	270,795,093	308,303,400
Fish to Tsitsikamma	21,282	131,395	28,210	373,400	96,999,368	390,969,532	487,968,900
Gouritz	77,158	182,192	43,699	395,296	156,463,104	539,785,096	696,248,200
Olifants/Doorn	178,015	403,706	79,991	1,964,655	475,973,523	2,141,770,577	2,617,744,100
Breede	120,105	323,295	51,631	822,708	444,040,456	1,717,973,744	2,162,014,200
Berg	150,719	343,471	16,999	174,857	496,257,869	279,203,731	775,461,600
Total	3,269,246	16,396,387	762,679	12,075,336	10,373,711,358	12,744,803,242	23,118,514,600

Agricultural Area Estimates

The area under agriculture is generally difficult to estimate. The difficulty in obtaining data is often compounded by seasonality of crop rotation and the economic climate in which farmers operate. Farmers will not plant in times of economic uncertainty so therefore snapshots of area under agriculture can often be misleading.

Estimations of area under cultivation (Table 6) were sourced from the Department of Agriculture, Forestry and Fisheries (DAFF) and gave the total area as 620 806 ha for the study area (DAFF 2010). Of particular interest is the pivot irrigation total of 53 065 ha, which is less than the value given by the Reconciliation Strategy developed for the Crocodile (West) River catchment of 55 974 ha (DWA 2008). However, the DAFF (2010) estimate only takes into consideration pivot irrigation and not other irrigation methods, which may account for the discrepancy.

Table 6: Agricultural area (ha) by Agricultural categories in the Crocodile (West) Marico WMA and Matlabas and Mokolo catchments (Source: DAFF 2010)

Agriculture Category	Area (ha)
High Cultivation	103 421
Low Cultivation	201 428
Medium Cultivation	131 619
Old Fields	18 148
Pivot Irrigation	53 065
Small Scale Farming	113 124
Grand Total	620 806

Crop Types

A variety of crop types are grown in the study area. Data from the Census of Commercial Agriculture (StatsSA 2007) was used in order to determine the amount and type of crops grown under dryland and irrigated conditions. The Commercial Census data looks only at major crop types grown, so does not represent the complete picture of agriculture in the study area.

Table 7: Crop types grown under dryland or irrigation in Crocodile (West) Marico WMA and Matlabas and Mokolo catchments (Source: Census of Commercial Agriculture (StatsSA 2007))

Crop Type	Area (ha)	
	Dryland	**Irrigation**
Maize	73 259	20 282
Wheat	6 313	10 036
Sunflower	29 121	2 717
Soyabean	1 739	2 529
Groundnut	587	786
Dry beans	22	-
Potatoes	719	-
Tomatoes	543	-
Onions	618	-
Pumpkins	216	-
Oranges	1 882	-
Beetroot	115	-
Carrots	1 359	-
Cabbage	523	-
Greenbeans	35	-
Total	**117 049**	**36 350**

2.2.6.2 Mining

Platinum Mining

Mining activities in the study area are dominated by the platinum mining industry, which is centred on the Rustenburg in the Elands catchment. The catchment contains the western section of the mineral-rich Bushveld Igneous Complex (BIC) (Figure 3), which is the world's largest and most valuable layered intrusion. Within the complex, three horizons, the Merensky Reef, UG2 Chromitite and the Platreef are mined for Platinum Group Metals (PGM). Platinum and palladium production from the BIC represents 72% and 34% of annual global production respectively. The BIC holds over half the world's platinum, chromium, vanadium and refractory minerals and has ore reserves that could last for hundreds of years. These also include significant reserves of tin, fluorite and copper.

Figure 3: General map of the Bushveld Igneous Complex. The western limb is shown to the left of the map (Source: Johnson Matthey 2003)

The largest producer of PGMs in the study area is Anglo American Platinum (Amplats) with an estimated production of 3,5 million *oz,* followed by Impala Platinum (Implats) with 1,8 million *oz* in 2011. The total PGM production of the study area was estimated at 7,2 million *oz* in 2011 (Table 8), which is approximately 78% of South Africa's annual PGM production (Chamber of Mines 2011).

Table 8: Platinum Group Metals (PGM) mining operations in the Crocodile (West), Marico, Mokolo Matlabas catchments (Source: 2011 Annual Reports)

Company	Mine	PGM
Aquarius	Kroondal	207 473
	Marikana	52 962
	CTRP	2 438
	Platinum Mile	11 417
	Sub Total	**274 290**
AmPlats	Bathopele Mine	243 200
	Khomanani Mine	179 700
	Thembelani Mine	205 900
	Khuseleka Mine	245 500
	Siphumelele Mine	163 900

Company	Mine	PGM
	Tumela Mine	543 000
	Dishaba Mine	291 100
	Union Mine	515 400
	Union North Mine	184 800
	Union South Mine	330 700
	Western Limb Tailings Retreatment	65 500
	Kroondal	445 900
	Marikana	92 100
	Sub Total	**3 506 700**
Implats	Impala	1 854 200
	Sub Total	**1 854 200**
Lonmin	Marikana	1 303 597
	Pandora	48 199
	Sub Total	**1 351 796**
Northam	Zondereinde	244 957
	Sub Total	**244 957**
	Grand Total	**7 231 943**

Chrome Mining

South Africa is the world's largest producer of ferrochrome. The country holds about 70% of the world's total chrome reserves, mostly located in the BIC ores, and produces 75% of the world's ferrochrome. Chromite is mined primarily from the UG2, and LG and MG chromitite seams of which UG2 also contains significant amounts of PGE's. Thus several platinum mines produce chromite as a by-product. There are several primary chrome mines, specifically maintained to provide chromite feed to the developing ferrochrome industry. Most of South Africa's chrome mines are developed along the Eastern BIC, in the Steelpoort Valley.

Major ferrochrome producers in the study area include Samancor, Xstrata Alloys and Ruukki (Table 9).

Table 9: Major chrome mines and operations in the Crocodile (West), Marico, Mokolo and Matlabas catchments (Source: Annual Reports 2011)

Company	Operation		Product	Amount (2011)(kt)
	Mine	Smelter/Plant		
Xstrata	Boshoek		Chrome	
	Chrome Eden		Chrome	
	Horizon		Chrome	

Company	Operation		Product	Amount (2011)(kt)
	Mine	Smelter/Plant		
	Waterval		Chrome	210
	Kroondal		Chrome	792
	Rhovan		Ferrovanadium	
		Rustenburg	Ferrochrome	183
		Wonderkop	Chromite pellets	368
		Boshoek	Chrome	141
		Tswelopele Pelletiser	Chromite pellets	
Smancor	Western Chromite Mines		Chrome	1500
Ruukki	Stellite Mine			

Other Mining

Kumba Iron Ore operates an iron ore mine in the mountains around Thabazimbi. Production at Thabazimbi was estimated at 0,9Mt for 2011 (Kumba Iron Ore AR 2011).

Granite mining is prevalent in the study area particular along the Magaliesberg Mountains and a strip of rocky hills between Rustenburg in the West and Pretoria in the East.

2.2.6.3 Power Generation

Three relatively small power stations, Rooiwal, Pretoria West and Kelvin, are present in the Crocodile (West) Marico WMA. Matimba and Medupi (under construction) power stations can be found in the Mokolo catchment. Three new Eskom power stations CF3, CF4 and CF5 are envisaged for the future.

2.2.6.4 Manufacturing

The manufacturing sector is an important sector in the study area and remains a critical component of the domestic economy. In Gauteng alone it employs 600,000 people in over 9,000 enterprises. It is therefore one of the biggest employers in the province (Gauteng 2010).

Major manufacturing sectors in the Gauteng portion of the study area includes: manufacture of textiles and clothing; manufacture of petroleum products, chemicals, rubber and plastics; manufacture of metallic products, manufacture of non-metallic products and manufacture of transport equipment (Gauteng 2010).

2.2.6.5 Tourism Economy

While not as developed as other WMAs, the tourism economy of the study area is an important contributor to regional GDP (GDP-R). Of particular importance to the study area are the Cradle of Humankind World Heritage Site, The Marakele National Park, the area containing the dolomitic eyes in the upper Marico catchment and the Hartebeespoort Dam and surrounds. Hunting is also an important sector, with large portions of land in the Mokolo catchment and the lower Crocodile River Catchment associated with hunting activities.

2.2.7 Eco-regions and Geomorphology

Eco-regions

Eco-regional classification allows for the grouping of rivers according to similarities. The available information has been used to delineate eco-region boundaries at a very broad scale (*i.e.* Level I) for South Africa. Attributes such as physiography, climate, rainfall, geology and potential natural vegetation were evaluated in this process and thirty one Level I Eco-regions were identified for South Africa (Kleynhans et al., 2005). The next level, Level II, which uses the same attributes but includes more detail, was defined in 2007 (Kleynhans *et al*., 2007).

While eco-regions descriptions tend to be based on physical and vegetation attributes, the assumption is that the biota within an eco-region is likely to be similar.

The Eco-Region Level II information was used to delineate the Crocodile (West) River catchment (DWA, 2009). The available Level II information was obtained from the DWAF, Directorate Resource Quality Services (D: RQS). Eco-regions integrate important physical variables, such as topography, landscape, geology, soils and vegetation cover, and as such, provided a basic template for identifying Resource Unit Boundaries. The eco-regions of the Crocodile (West), Marico, Mokolo and Matlabas catchments are described in **Table 10** and illustrated in Figures 4, 5 and 6.

Table 10: Eco-regions descriptions as used in Figures 4, 5, 6 and 7

Level 1	***Level 2***	***Description***
Limpopo Plain	1.02, 1.03 and 1.04	This dry to arid ecoregion (mean annual temperature high to very high) located in the northern part of the study area is characterized by plains and lowlands with a low to moderate relief. The vegetation types consist mostly of Bushveld types and Mopane veld. Mean annual precipitation is low to arid (200-600 mm) and rainfall is received during the early to mid-summer months, with a coefficient of annual variation of 20 to 40%. The altitude ranges between 300 and 1 100 m. Mean annual air temperatures are between 18 and >22°C. The Marico River, a perennial river, traverses this region. The Mokolo River enters the Limpopo Plain at the junction between the Mokolo River and the Rietspruit and continues down the Limpopo valley.
Waterberg	6.01 and 6.02	The Waterberg eco-region is predominantly a tableland with moderate to high relief and consisting of sandstones that are important escarpment shapers. The Bushveld types such as Waterberg Moist Mountain Bushveld dominate the vegetation. The rainfall is seasonal, being received during the early to mid-summer months, and the mean annual precipitation is generally moderate (300-600 mm) with a coefficient of annual variation of <20 to 35%. The altitude ranges between 700 and 900 m. Rainfall is concentrated in early to mid-summer. Mean annual air temperatures are between 14 and 22°C. The Mokolo River enters this region through a relatively steep gorge upstream of Vaalwater and flows out of the area at the junction between the Mokolo River and the Rietspruit.

Level 1	*Level 2*	*Description*
Western Bankenveld	7.01. 7.02, and 7.03, 7.04, 7.05 and 7.06	The Western Bankenveld eco-region is located in the south-western and south-eastern part of the study area. This eco-region is characterized by a complex topography that varies from lowlands, hills and mountains to closed hills and mountains with the relief varying from moderate to high. The altitude ranges between 900 and 1 700 m. Mixed Bushveld is the most definitive vegetation type of the region. Mean annual precipitation is low to moderate (400-700 mm), and rainfall occurs during the early to late summer months with a coefficient of annual variation of <20 to 35%. The Crocodile (West), the Elands (West) and the Pienaars Rivers flow through this region, as well as the Sand River in the upper part of the Mokolo River.
Bushveld Basin	8.01 and 8.05	This eco-region is extensive in the area (over 50%). This region consists predominantly of plains with a low relief, with Mixed Bushveld being the dominant vegetation type. Plains with a moderate relief and lowlands with a moderate relief occur in the eastern portion of this eco-region. The altitude ranges between 700 and 1 700 m. Mean annual precipitation is 400-600 mm while rainfall is received during the early to mid-summer months with a coefficient of annual variation of 25 to 35%. Mean annual air temperatures are between 14 and 22°C. Perennial rivers traverse the region including the Marico, Elands (West), Crocodile (West) and Pienaars rivers.
Eastern Bankenveld	9.03	Closed hills and mountains with moderate and high relief together with North-eastern Mountain Grassland and Mixed Bushveld are definitive of this region. It occupies less than 5 % of the study area and is located in the eastern part of the Crocodile (West) and Marico catchment. The altitude ranges between 500 and 2 300 m. Mean annual precipitation is moderate to moderately high (300 to 1000 mm), and rainfall is received during the early to mid-summer months, with a coefficient of annual variation of <20 to 34%. Mean annual air temperatures are between 10 and 22°C. The Pienaars River and its tributaries flow through this region.
Highveld	11.01, 11.03 and 11.09	The Highveld eco-region is defined by plains with a moderate to low relief, as well as various grassland vegetation types (with moist types present towards the east and drier types towards the west and south). The altitude ranges between 1 100 and 2 100 m. Mean annual precipitation varies from low to moderately high, increasing from west to east, and rainfall occurs during the early to late summer months, with a coefficient of annual variation of <20 to 35%. Mean annual air temperatures are between 12 and 20°C. The Hex and Elands rivers flow through the area.

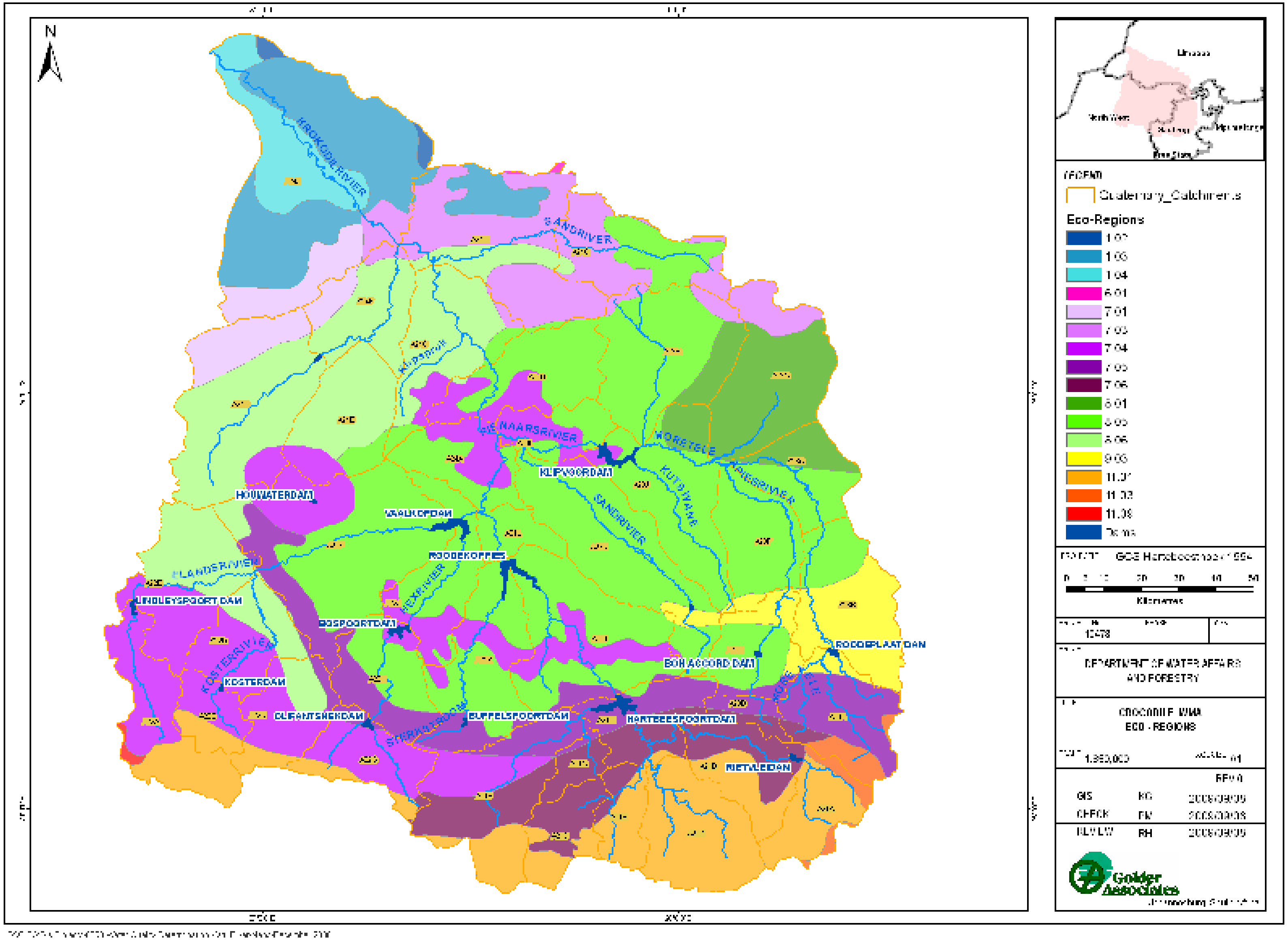

Figure 4: Eco-regions that occur in the Crocodile (West) catchment (Source: DWA, 2009)

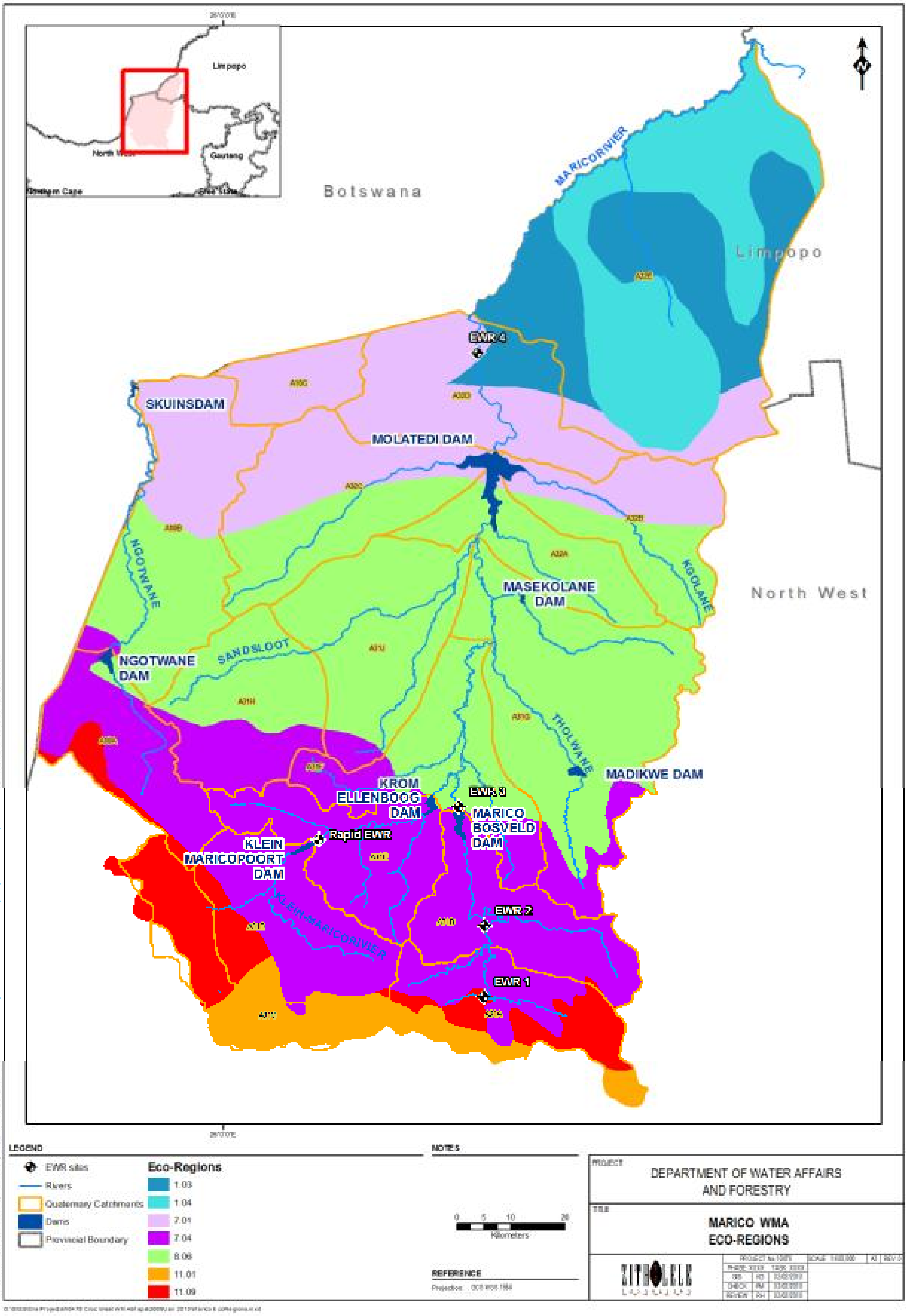

Figure 5: Eco-regions that occur in the Marico catchment (Source: DWA, 2009)

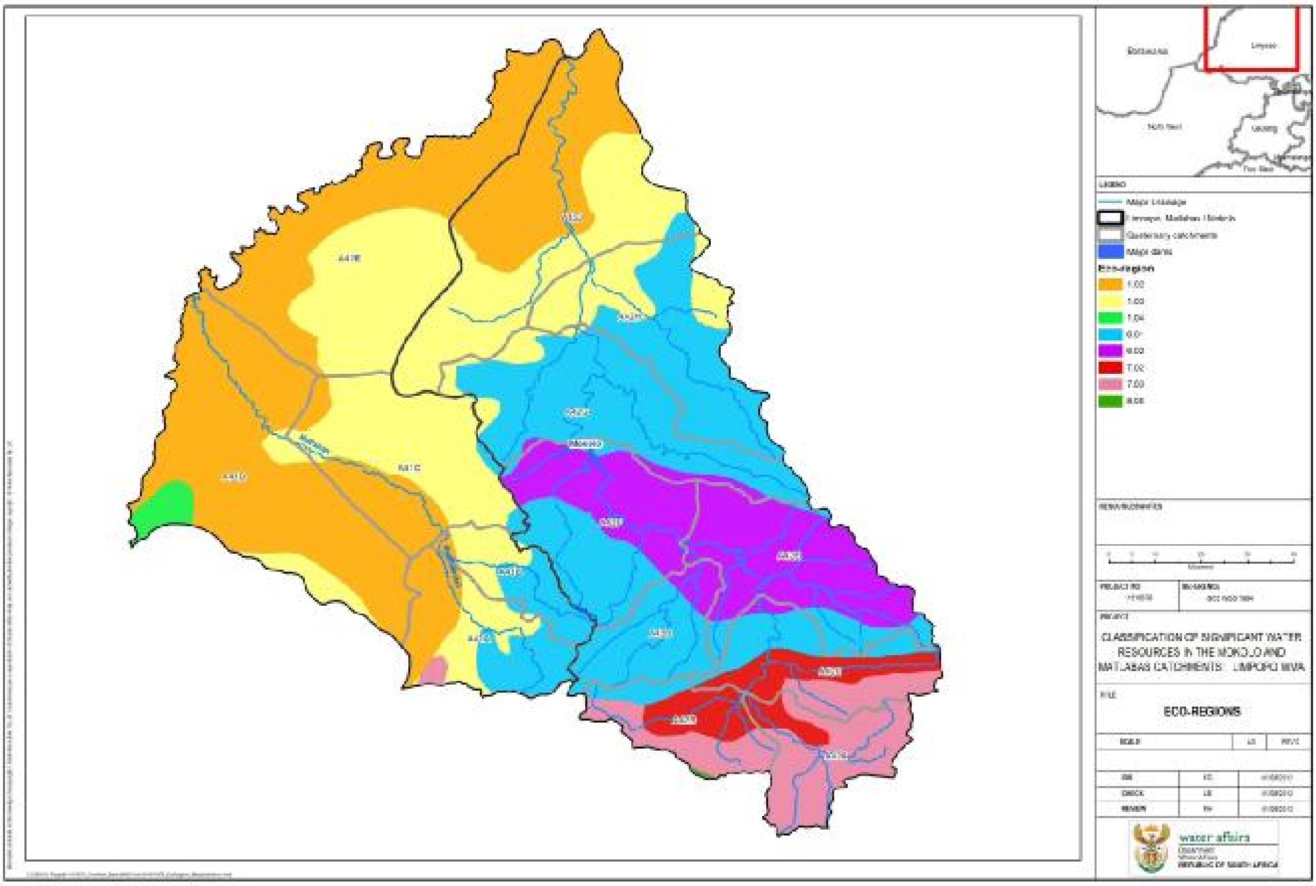

Figure 6: Eco-regions that occur in the Mokolo and Matlabas catchments (Source: DWA, 2010)

Geomorphology

Geomorphology provides a basis of classification for the purpose of describing the physical habitat of riparian and aquatic ecosystems, as it encompasses the physical processes which have shaped the river channel. Rivers and streams change naturally along their lengths with respect to temperature, depth, current speed, substratum, turbidity and chemical composition. The longitudinal physical and chemical changes can be used to classify the reaches of rivers. Rowntree et al., (2000) developed a zonal classification system for Southern African rivers modified from Noble and Hemens (1978). On the basis of channel features ten geomorphological zone classes have been defined and are described in Table 11.

Table 11: Geomorphological zonation of South African river channels (Adapted from Rowntree et al., 2000)

Zone class	Zone	Gradient class
S	Source zone	Not specified
A	Mountain headwater stream	>0.1
Ar	Rejuvenated bedrock fall/cascades	>0.02
B	Mountain stream	0.04 – 0.099
C	Transitional	0.02 – 0.039
D	Upper foothills	0.005 – 0.019

Zone class	Zone	Gradient class
Dr	Rejuvenated upper foothills	0.001 – 0.019
E	Lower foothills	0.001 – 0.005
F	Lowland river	0.0001 – 0.0009
Er	Rejuvenated lower foothills	0.001 – 0.019

The geomorphological zones that occur in the Crocodile (West), Marico, Mokolo and Matlabas catchments include:

- Lower Foothills;
- Lowland River;
- Upper Foothills;
- Transitional;
- Mountain stream; and
- Mountain Headwater stream.

2.2.8 Ecological information

2.2.8.1 Crocodile (West) Marico WMA

Dolomite forms the main watershed of the Molopo, Marico and Malmani Rivers to the southwest of the study area, as well the upper reaches of the Apies, Pienaars and tributaries of the Crocodile River to the southeast of the study area. The actual source of the Molopo Ngotwane, Marico and Malmani rivers are known as dolomitic eyes, which are wetlands fed by groundwater originating from fractures in the underlying dolomite. The water from these dolomitic eyes is typically alkaline (pH range from 7.5 to 9.3) having picked up magnesium and calcium carbonates through solution from the parent dolomite. Associated with this is the active tufa waterfall in Bokkraal se loop (fed by dolomitic eye, on tributary of Marico River) and the associated active- seasonal tufa cascade on Kuilfontein; a tributary of Marico River. Being perennial, all the wetland systems associated with, and downstream of, the eyes form peat wetlands or peatlands. Peatlands are defined as peat-accumulating fresh water wetlands which develop in areas where there is a net surplus of water with an accreting substrate comprising a high percentage of undecomposed organic plant material (usually with more than 20 - 35% organic matter on a dry weight basis - Mitsch and Gosselink, 1986).

Three Peat Wetland Eco-regions are represented in the study area, being the Highveld, Central Highlands and Bushveld Basin (Marneweck, Grundling and Muller, 2001). The peat wetlands within the former two regions in particular have developed over long periods ranging between 7000 to 15000 years (depending on peat depth) with peat accumulation rates of between 0.3 to 0.6mm/year (Grundling and Marneweck, 1999; Marneweck *et. al.*, 2001). Peatlands in general, and more specifically those associated with the dolomitic eyes, are rare in South Africa and southern Africa in general. Those associated with the dolomites in the Molopo, Malmani and Marico Rivers in particular comprise unique ecosystems characterised by a high degree of endemicity (species which are found only there). The results from both the morphological and genetic studies of the fish species showed that the indigenous cichlid populations inhabiting these dolomitic wetlands are unique, with a number of populations having differentiated to the extent where they may be considered as separate species (DEA&T, 1995). One cyprinid species in particular, *Barbus cf. brevipinnis* (a type of ghieliemientjie) is endemic to the Molopo and is currently under high risk of extinction due to loss of habitat as a result of reduced flows to the wetland area. Also *Barbus motabensis* type locality and NFEPA Fish species.

Studies on the aquatic invertebrates of these dolomitic wetlands have also produced several new distribution records for South Africa and also 21 new species to science (DEA&T, 1995). Similarly, the ostracod diversity from the Molopo system showed that of all the species found in the area at the time of the survey, 30% were new to southern Africa and one species was new to science (DEA&T, 1995). For this reason, dolomitic eyes and their associated peatlands are regarded as sensitive systems. Most of these systems are also important water supply sources and thus the associated ecosystems have been impacted by water abstraction. They are also threatened by groundwater contamination from agriculture, industry and mining, habitat transformation and invasions by alien species (particularly exotic plants e.g. poplars and fish species e.g. black bass) and some have been mined for peat. Working for Wetlands (WfWetlands) started doing rehabilitation work in the Molopo catchment in 2001 including in the headwaters. It has long been recognized that an integrated management strategy is required for conserving or maintaining these unique wetland systems.

The wetlands within the Borakalalo National Park are also considered of high conservation value, despite being heavily degraded. They have also been the focus of WfWetlands work over the past few years. Borakalalo forms the western end of the Moretele floodplain. This is the second largest floodplain in the Bushveld Ecoregion and represents the southern-most natural distribution of Wild Rice (*Oryza longistaminata*) in Africa. The floodplain is used extensively by the surrounding communities for fishing and grazing and is also regarded as an important birding area, with the floodplain and surrounding area supporting 362 of the 461 species recorded in the North West Province. The wetland also includes traditionally sacred sites which have high cultural significance.

The Mareetsane wetland near Mafeking also provides important ecosystem services for people, livestock and wildlife, including water supply and livelihoods support. It is on the Mareetsane River, which flows into the Molopo River. Working for Wetlands (WfW) has been undertaking wetland rehabilitation work on this system. Other rehabilitation projects within the study area targeted by WfW include a wetland system within the Rustenburg Nature Reserve and on the Hex River. These projects were undertaken in partnership with the Local Municipality and Tribal Authority.

A wetland type not well represented in the study area is pans. Pan complexes (groups of pans) occur in three main areas in the study area, namely: south and northwest of Koster (a complex of approximately 24 pans); northeast of Derby (7 pans); and in Johannesburg (approximately 24 pans between Midrand and Kempton Park). Despite impacts from agriculture, an extensive complex of hillslope seepage and valley-bottom wetlands remains associated with the pans near Koster and Derby. Pans are recognized as being important for biodiversity support and more recently their links to other wetland systems in relation to landscape hydrology have also been highlighted. Pans are also unique in terms of their individual biogeochemical attributes. This combination of an extensive network of pans, hillslope seepages and valley-bottom systems, and also that they are unaffected by urbanization and not found elsewhere in the catchments under consideration, renders this an important water resource in the study area. The pans in the Midrand and Kempton Park area are also considered important, but mainly from a biodiversity perspective as they support related bird and amphibian populations. Those that still have some of their catchments intact or that still have associated hillslope seepage wetlands also support some of the last remaining populations of the endangered Giant bullfrog (*Pyxicephalus adspersus*) on the Highveld. The remaining pans and wetlands are thus regarded as critical habitat for these populations. The wetlands including the pans in this area are all threatened by impacts from urbanization. Wetland habitat loss continues as urbanization expands and the hydrology of the related systems and catchments change due largely to storm water management or lack thereof. It is likely that populations of the Giant bullfrog may occur or be found in the pans in the Koster and Derby areas.

EWR sites in the Crocodile (West) Marico

Intermediate Reserve determination studies were undertaken for all of the major catchments during 2008 to 2011. These results are available for Crocodile West and its main tributaries (Pienaars, Elands, Jukskei) and the Groot Marico and Klein Marico. These results were enhanced by additional Rapid III studies and extrapolations undertaken to those areas that were not covered by an intermediate assessment.

The Molopo catchment was assessed as part of the ORASECOM study in 2010, but due to the almost episodic nature of the river, only the Molopo wetland in quaternary catchment D41A was assessed. This catchment is mainly groundwater driven and should be assessed from a groundwater perspective during the WRCS.

Table 12 sets out the details of the EWR sites for the Crocodile (West)/Marico WMA that were undertaken as part of the Intermediate Reserve determination and Table 13 sets out additional EWR sites that were as identified as gaps during the delineation study and for which Rapid III Reserve determinations were undertaken.

Table 12: Details of EWR sites from intermediate Reserve studies

EWR site	River: Site name	Quaternary catchment	PES	Coordinates	Level of determination
Crocodile (West) River system					
EWR 1	Crocodile: Upstream of the Hartbeespoort Dam	A21H	D	E 27.896 S 25.8004	Intermediate
EWR 2	Jukskei: Heron Bridge School	A21C	E	E 27.9621 S 25.9539	Intermediate
EWR 3	Crocodile: Downstream of Hartbeespoort Dam in Mount Amanzi	A21J	C/D	E 27.8431 S 25.7168	Intermediate
EWR 4	Pienaars: Downstream of Roodeplaat Dam	A23B	C	E 28.312 S 25.4155	Intermediate
EWR 5	Pienaars/Moretele: Downstream of the Klipvoor Dam in Borakalalo National	A23J	D	E 27.80457 S 25.12657	Intermediate

EWR site	River: Site name	Quaternary catchment	PES	Coordinates	Level of determination
	Park				
EWR 6	Hex: Upstream of Vaalkop Dam	A22J	D	E 27.3749 S 25.5214	Intermediate
EWR 7	Crocodile: Upstream of the confluence with the Bierspruit	A24C	D	E 27.51743 S 24.88661	Intermediate
EWR 8	Crocodile: Downstream of the confluence with the Bierspruit in Ben Alberts Nature Reserve	A24H	C	E 27.32569 S 24.64476	Intermediate
Rapid EWR 9	Magalies: Downstream of Malony's Eye	A21F	B	E 27.56581 S 26.01689	Rapid III
Rapid EWR 10	Elands: Upstream Swartruggens Dam	A22A	C	E 26.72044 S 25.72655	Rapid III
Rapid EWR 11	Sterkstroom: Upstream Buffelspoort Dam	A21K	C	E 27.47848 S 25.80739	Rapid III
Groot Marico River system					
EWR 1	Kaaloog-se-Loop: Below gorge	A31A	B	E 26.433 S 25.777	Intermediate
EWR 2	Groot Marico: Upstream confluence with Sterkstroom	A31B	B	E 26.435 S 25.669	Intermediate
EWR 3	Groot Marico: Downstream Marico Bosveld Dam	A31F	C/D	E 26.392 S 25.461	Intermediate
EWR 4	Groot Marico: Downstream Tswasa Weir	A32D	C	E 26.424 S 24.706	Intermediate
EWR 5	Klein MaricoDownstream Klein Maricopoort Dam	A31E	C	E 26.159 S 25.516	Rapid III
Molopo River system					
EFR M8	Molopo: Wetland	D41A	C	-25.8812	

Table 13: Details of additional sites for which Rapid IIIs were undertaken

EWR site name	Latitude	Longitude	River Name	Quaternary	Comment
Crocodile (West) River system					
EWR 12	-24.8304	28.2224	Buffelspruit	A23G	Rapid III
EWR 13	-25.48108	26.69039	Elands	A22E	Rapid III
EWR 14	-25.7414	27.2568	Waterkloofspruit	A22H	Rapid III
EWR 15	-25.89690	27.59820	Magalies	A21H	Rapid III
CROC 16	-26.01885	28.30442	Rietvlei	A21A	Rapid III
Marico River system					

EWR site name	Latitude	Longitude	River Name	Quaternary	Comment
EWR 6	-25.64697	26.48928	Polkadraaispruit	A31B	Rapid III

The following sites were also assessed but found to be unsuitable for a Rapid III determination.

Table 14: Details of sites assessed for potential Rapid III determination but found to be unsuitable

River Name	Latitude	Longitude	Quaternary	Comment
Bierspruit	-24.83830	27.28370	A24F	Dry, Habitat Integrity
Hex	-25.88189	27.31008	A22G	Dry, Habitat Integrity
Hennops	-25.82556	27.98944	A21H	Flows to high, habitat integrity
Bloubankspruit	-25.96778	27.80111	A21D	Flows too high, habitat integrity, discharge

2.2.8.2 Mokolo catchment

Between Bela-Bela and Lephalale in the north eastern section of the study area, is the Waterberg. This comprises the watershed and upper catchment of the Mokolo catchment area. This area is characterized by steep mountain slopes with sandy nutrient poor soils, rocky plateaus and mixed broad leaved savanna bushveld. The wetland systems typically found in the Waterberg include hillslope seeps, sheetrock wetlands and channeled and unchanneled valley-bottom systems. Water quality is typically good, and the streams are flanked by narrow riparian zones with the larger dominant tree typically being the Waterberry (*Syzygium cordatum*) and water pear (*Syzygium guineense)*. Valley-bottom wetlands typically comprise a mixture of tall emergent plants such as the common reed *Phragmites australis* and the grass *Miscanthus junceus* and shorter grass-sedge meadows dominated by *Leersia hexandra* and Red vlei grass (*Ischaemum fasciculatum*). The main ecosystem services supplied by these systems include flood attenuation, water quality enhancement, streamflow augmentation and biodiversity maintenance.

Extensive wetland systems occur in the Sand River catchment (southernmost watershed of the Mokolo River). They form important habitat for Blue cranes and are thus of high importance from a conservation and biodiversity perspective. Land use in the area is mostly agricultural and as a result many of the wetland systems have been degraded. WfWetlands targeted the area for wetland rehabilitation and to date a number of projects have been implemented. In addition to these wetlands, the riparian and instream habitats of the Sterkstroom, Taaibosspruit and Rietspruit are also considered important ecologically. These are also some of the remaining rivers in the catchment that still support flow dependent fish species (River Health Programme, 2006).

Downstream of the Mokolo Dam the Mokolo River enters the Limpopo plain. Here colluvial processes dominate and the river and associated riparian and wetland habitats are controlled by the deposition, transport and erosion of sediment. Here the alluvial (river process driven) aquifer supports an extensive riparian forest fringe and instream biota. The riparian zone in particular, which includes large specimens of the Nyala berry (*Xanthocercis zambesiaca*), Waterberry (*Syzygium cordatum*) and the Tamboti (*Spirostachys africana*), is dependent on this shallow alluvial aquifer system. The lower reaches also support Leadwood trees (*Combretum imberbe*). In the vicinity of Lephalale, the river is extensively used for sand mining. This together with the regulated flows from the Mokolo Dam upstream has affected the structure of the river along this reach with resulting alterations to the flow regime and pattern. There is also evidence suggesting that the resulting changes have not only affected the distribution and abundance of reedbeds in the system, but also the alluvial aquifer which in turn is impacting on the instream and riparian ecosystem.

The Tambotie River which flows through D'Nyala Nature Reserve and joins the Mokolo River near to Lephalale, is also regarded as an important system. The floodplain of the Tambotie River supports an extensive population of Tamboti (*Spirostachys Africana*) and Leadwood trees (*Combretum imberbe*). Water abstraction and the droughts experienced in the 1980's and early 1990's impacted on the system and with the drying out of the alluvial aquifer during this time, many of the Leadwood trees died. This floodplain system is nevertheless considered to have high ecological importance and sensitivity and is a key wetland in the region.

EWR sites in the Mokolo catchment

Table 15 sets out the details for EWR sites undertaken during the intermediate Reserve determination project. No additional sites were identified in the Mokolo River system.

Table 15: Details of EWR sites in the Mokolo River system

EWR site	River: Site name	Quaternary catchment	PES	Coordinates	Level of determination
Mokolo River system					
1a	Mokolo: Vaalwater	A42C	C/D	S24 17.362 E28 05.544	Intermediate
1b	Mokolo: Tobacco	A42E	B/C	S24 10.697 E27 58.661	Intermediate
2	Mokolo: Ka'ingo	A42F	B/C	S24 03.897 E27 47.230	Intermediate
3	Mokolo: Gorge	A42G	B/C	S23 58.080 E27 43.614	Intermediate
4	Mokolo: Malalatau	A42G	C	S23 46.272 E27 45.315	Intermediate
5	Mokolo: Tambotie floodplain	A42G	D	N/A	-

2.2.8.3 Matlabas catchment

The Matlabas River flows through the Marakele Nature Reserve. The park is characterized by the Waterberg Moist Bushveld vegetation type (veld type 12), mixed Bushveld (veld type 18) and the Sweet Bushveld (veld type 17). The Sweet Bushveld is mostly found along the banks of the Matlabas River and forms an important winter refuge area for game particularly during limiting periods at the end of the dry season. The planned western expansion of the park will include more of this vegetation type, which is crucial to sustain adequate numbers of prey species for large predators such as lion and spotted hyena. One of the rare and threatened plant species of Marakele is the Waterberg cycad (Waterbergbroodboom) *Encephalartos eugene-maraisii*. This cycad is endemic to the Waterberg region and grows to 5 m tall among low shrubs at an altitude of 1 450 m.

Channeled valley bottom wetlands and meandering floodplains occur in the Matlabas catchment. The species that occur in those wetlands include marginal zone riparian obligates, permanent or seasonal wetland obligates, or aquatic species, which are more sensitive to water availability than other riparian species.

EWR sites in the Matlabas catchment

There was no high confidence surface water Reserve determination study undertaken in the Matlabas catchment; hence no EWR sites. Rapid EWR determination studies were undertaken in May 2012 and the results of these studies will be reflected in the subsequent EWR report.

2.2.9 Water Infrastructure

2.2.9.1 Crocodile (West) Marico

Major bulk water supply systems

A complex water infrastructure network exists, with most of the water requirements supplied by two major water boards (Rand Water and Magalies Water) which source water from the Upper Vaal WMA and the Crocodile (West) River catchment. Most of the urban water requirements are supplied from surface water. Tshwane Metropolitan Municipality, Bela Bela and Thabazimbi Local Municipalities use groundwater in addition to surface water.

Dams

The following major dams exist in the Crocodile (West) River catchment:

- Hartbeespoort, Roodekopjes, Buffelspoort, Rietvlei, Roodeplaat, Klipvoor, Bon Accord, Leeukraal, Bischoffs, New Warmbaths, Old Warmbaths, Nooitgedacht, Meintjes, Vaalkop, Bospoort, Olifantsnek, Lindleyspoort, Kosterrivier, Mankwe (Houwater), Sun City, Rockwell, Swartruggens and Bierspruit.

The Crocodile River system is regulated by 9 major dams:

- Rietvlei, Hartbeespoort and Roodekopjes in the Upper Crocodile catchment;
- Roodeplaat and Klipvoor dams in the Apies/Pienaar catchment, and
- Olifantshoek, Bospoort, Lindleyspoort and Vaalkop in the Elands River catchment.

No major dams occur in the Lower Crocodile catchment area.

There are some 3 800 minor impoundments in the Crocodile (West) River catchment. (irrigation/municipal/recreation dams):

- 1 150 with a total storage capacity of ±19 million m^3 are in the Upper Crocodile sub-catchment,

- 688 with a total storage capacity of ±14 million m^3 are in the Elands sub-catchment,
- 856 with a total storage capacity of ±11 million m^3 are in the Apies-Pienaars sub-catchment; and
- 460 with a total storage capacity of ±12 million m^3 are in the Lower Crocodile sub-catchment.

Wastewater treatment works

There are currently 32 wastewater treatment works (WWTW) operational in the Crocodile (West) River catchment. The largest WWTW in South Africa, Johannesburg Northern Works, is located in the Crocodile catchment discharging an average 400Ml/d to the Jukskei River.

Main irrigation related infrastructure

The Hartbeespoort, Buffelspoort and Middelkraal Government Water Schemes (GWS) as well as the Magalies, Zeekoeihoek, Kromdraai, Sterkwater and Buffelshoek Irrigation Boards (IB) are in the Upper Crocodile sub-catchment. The Lindleyspoort Ground Water Schemes (GWS) as well as Koster River, Olifantsnek, Modderfontein and Glyklip IBs are in the Elands sub-catchment. The Pienaars GWS as well as the Bon Accord and Warmbad IBs are in the Apies-Pienaars sub-catchment and the Crocodile West River IB is in the Lower Crocodile sub-catchment.

Rand Water imports water from the Upper Vaal WMA to the Crocodile (West) River catchment for urban, industrial and mining use. Water is also imported to Cullinan from the Olifants River catchment for urban use and for use on the Premier Diamond mine. Magalies Water exports water to supply the requirements of Modimolle (previously known as Nylstroom).

There are several inter-quaternary transfers within the Crocodile (West) River catchment. Most of these transfers form part of the Magalies Water supply system, supplying water to urban areas, mines and industries. A number of effluent transfers within the Crocodile (West) River catchment are also present.

2.2.9.2 Marico catchment

The natural mean annual runoff (MAR) of the Marico River catchment is approximately 126 million m^3/a. The available surface water resource is mainly from the Marico Bosveld and the Molatedi dams. The Marico Bosveld Dam in the upper catchment and the Molatedi Dam further downstream are the two major storage dams that regulate flow in the Marico River. There are other dams in the catchment such as the Klein Maricopoort and Sehujwane Dams, from which water is mainly used for irrigation along the Marico River. The main surface water impoundments of the Marico catchment are indicated in Table 16. There are no other economical sites available for the construction of dams in this sub-area (DWAF, 2004).

Table 16: Major dams in the Marico catchment

Catchment	River	Dam	Purpose
A31B	Groot Marico	Marico Bosveld	Irrigation
A31D	Klein Marico	Klein Maricopoort	Irrigation
A31E	Klein Marico	Kromellenboog	Irrigation

Catchment	River	Dam	Purpose
A31G	Tholwane	Madikwe	Domestic
A31H	Sandsloot	Sehujwane	Domestic
A32A,B,C	Groot Marico	Molatedi dam	Irrigation/Domestic
A31G	Tholwane	Pella	Domestic

The Marico Bosveld Dam situated in the upper catchment of the Groot Marico River (A31B) supplies irrigators downstream in A31.

There are a number of important rural settlements and irrigation developments in the Marico catchment, with Zeerust, Groot Marico and Madikwe being the main areas. The Marico River catchment borders on Botswana in the north and water is transferred from the Molatedi Dam to Gaborone. There is commercial agriculture downstream of the Marico Bosveld Dam and downstream of the Molatedi Dam.

The TSWASA scheme, which consists of the Molatedi Dam and associated infrastructure, was constructed to supply water to the former homeland of Bophuthatswana, South Africa and the Government of Botswana. An agreement known as the TSWASA agreement was signed in 1988. Its purpose was to supply water to the parties as follows (DWAF, 2004):

- 7.1 million m^3 /a to Gaborone for primary purposes;
- 5.0 million m^3 /a for irrigation purposes in the former Homeland of Bophuthatswana; and
- 10.6 million m^3 /a for irrigation purposes in the then Republic of South Africa.

The above volumes are slightly higher than the firm yield of Molatedi Dam of 21 million m^3/a. However, the dam is operated at a higher risk, which is acceptable for irrigation purposes and hence there is potential for the Molatedi Dam to not be able to supply the demands with a 100% assurance (DWAF, 2004).

Zeerust the main urban centre in the Marico River catchment obtains most of its water supply from groundwater although the Klein Maricopoort River supplements its water supply. The rural towns of Madikwe and surrounding villages obtain their water requirements from the Madikwe Dam on the Thulane River. Some of the rural villages further downstream obtain their water from the Pella Dam. These water resources are fully utilised. There is potential for groundwater development to meet additional rural water supplies. The rural villages in the western portion of the catchment obtain their water from the Sehujwane Dam (DWAF, 2004).

Apart from water required for irrigation, other requirements include water mainly for domestic use and stockwatering. The urban water requirements are for the main towns of Zeerust, Groot Marico and Madikwe. Return flow is not being directly utilised but it contributes to the yields of the dams in the catchment. The Marico River catchment has no commercial afforestation and there is no water used for strategic uses.

Return flows from wastewater treatment works in Zeerust and return flows from the mines around Zeerust as well as irrigation in the Marico catchments is estimated at approximately 6 million m^3/a. Irrigation is the major contributor to the return flows in the Marico River catchment.

In terms of the Internal Strategic Perspective (ISP) for the catchment there are potential risks of supply failure from the Sehujwane, Marico Bosveld, Madikwe and Molatedi dams because the demands on the dams are much higher than the available yield. The Kromellenboog Dam is also being operated in combination with Marico Bosveld Dam and is also over utilised. The current operating rules for all the dams in the catchment which supply the irrigation scheme in the downstream catchment A31F, need to be reviewed (DWAF, 2004).

2.2.9.3 Mokolo catchment

The Mokolo River rises on the northern escarpment of the Wolkberg Mountains and flows almost due north to the Limpopo River. The surface water resources of the Mokolo catchment are substantial while groundwater is also used. The catchment is mostly rural in nature with only two significant towns, Vaalwater in the south and Lephalale in the north. The numerous small farm dams in the catchment, the run-of river and Mokolo Dam contribute to a large surface water resource estimated at 77 million m^3/a after allowing for the Ecological Reserve. The Mokolo Dam was constructed to provide water to the power station and coal mines located near Lephalale. The dam has a full supply capacity of approximately 146 million m^3. The natural MAR at the dam site is estimated at 240 million m^3/a.

The small capacity of the dam, when considered against the growth potential of Lephalale, means that there is limited capacity to manage water releases for environmental purposes. The downstream river is therefore dependant on flood flows that overspill the dam, and irregular water releases supplied to downstream irrigation agriculture.

However, in recent years, the downstream river has become heavily infested with reeds (*Phragmites mauritianus*), and irrigation releases have been increasingly hard to manage. The reeds not only consume large volumes of water, but also restrict flow through narrow encroached channels, delaying the delivery of released water to the lower reaches of the river.

The inability to deliver water effectively to the lower river is thought to impact adversely on water temperatures and ecological cues that could disrupt breeding cycles of aquatic fauna due to the unseasonal nature of the releases. The Mokolo Irrigation Board has, through consultation with DWAF and Limpopo Environmental Affairs, embarked on a regular aerial spraying program of the reeds using a herbicide. While the spraying appears to have a significant impact on the reeds, the effects of decaying weeds on water quality and the cumulative impacts of the herbicide on aquatic fauna, and other flora, have yet to be determined.

The current groundwater resource is estimated at 11 million m^3/a and this is used to supply irrigation and domestic rural use.

The town of Lephalale has three small domestic wastewater treatment works of < 5ML/d capacity and Vaalwater has one. ESKOM also runs a wastewater treatment works in Lephalale and the mines in the catchment all have a small wastewater treatment works.

2.2.9.4 Matlabas catchment

The Matlabas catchment is a largely undeveloped catchment with limited water resources and water use. There are no significant dams in this catchment and a significant portion of the water use is from groundwater due to the low assurance of the run-of-river yields. Due to the highly erratic surface water flow, the yield from surface water resources is negligible, while there are ample groundwater resources which are underutilised.

The largest water use in the Matlabas catchment is irrigation, but even this is very limited and estimated at only 4 million m^3/a, half of which is sourced from groundwater. There are limited rural requirements, estimated as 2 million m^3/a, which are supplied from groundwater.

2.2.10 Present Status of water resources

Crocodile (West) and Marico WMA

The Crocodile (West) Marico WMA (WMA 3) borders on Botswana (north-west) and includes two major river systems the Crocodile West and Marico, which give rise to the Limpopo River at their confluence.

The two major rivers in the Crocodile (West) Marico WMA are the Crocodile (West) River and the Groot Marico River, which form the south-western part of the Limpopo River basin (Drainage Region A), eventually draining into the Indian Ocean in Mozambique. The WMA also includes the headwaters of the Molopo River, a tributary of the Orange River which drains westwards to the Atlantic Ocean.

The WMA covers a total catchment area of 47 565 km^2. The Pienaars, Apies, Moretele, Hennops, Jukskei, Magalies and Elands rivers are the major tributaries of the Crocodile River which together make up the A20 tertiary drainage catchment, with 39 quaternary catchments. The Crocodile River contributes to the flow of the Limpopo River, which has an international river basin shared with Botswana, Zimbabwe and Mozambique.

The water resources of the WMA are already fully utilised and the importance of the transfers and return flows in the water balance cannot be overemphasised especially in light of the continued strong growth expectations in the Tshwane-Johannesburg and the Platinum Belt regions. These factors will impact on flows and water quality along the Crocodile River and also on South Africa's international obligations. An estimated 549 million m^3/a of the natural mean annual runoff of 855 m^3/a that originates in the WMA, flows out, 96% of this, to the Limpopo River.

Water quality assessments of the different sub catchments in the Crocodile (West)/Marico WMA have been done previously. The biggest impacts on water quality in the area are from the large scale water and land users. The urban areas in the south-east of the catchment, with their undersized water systems and large waste problems impact substantially on the Hartbeespoort and Roodeplaat dams. Other contributors to the poor water quality include industries and abandoned and operational mines. The return flows from domestic wastewater treatment works are also a major contributing factor and local authorities struggle to comply with discharge standards. Fertilizers and pesticides from agricultural activities are likely to have a negative impact however have not yet been quantified.

Groundwater quality is generally good, apart from specific rural areas where the groundwater is polluted by poor sanitation facilities.

In addition treated wastewater return flows from the Upper Vaal WMA play an important role downstream where the water is used in the Crocodile (West)/ Marico catchment area making up approximately 27% of available water, in excess of 356 million m^3/a. The quantities are increasing and while serving as a potential source of water for future development, the cumulative impact on the water quality needs to be determined.

Mokolo and Matlabas catchments

The Mokolo catchment stretches from the Waterberg Mountains through the upper reaches of the Sand River, and includes the Mokolo Dam and a number of small tributaries that join the main Mokolo River up to its confluence with the Limpopo covering an area of approximately 8 387 km^2.

The Matlabas catchment is situated in a predominantly flat area of the Limpopo WMA. Matlabas River originates in the Waterberg mountain range and the altitude varies from 1 400 m to approximately 840 m at the confluence with the Limpopo River. The catchment is largely undeveloped with limited water resources and limited water use covering an area of approximately 6 014 km^2.

Groundwater quality in much of the Mokolo catchment is poor due to extensive coal and gas fields. This poor quality groundwater could still be used for industrial purposes or irrigation, however, is unsuitable for domestic use. Coal mining activities also impact on the surface water quality of the Mokolo catchment. Expected water quality concerns are acid mine drainage and high total dissolved solids. However, the extent of diffuse pollution from the mines and other industries in the area is unknown and must be investigated and quantified.

The rapid and uncontrolled growth of informal settlements around Vaalwater and Alma (south of Vaalwater) is a source of concern with regard to the surface and groundwater quality.

There are no reported water quality problems in the Matlabas catchment, either surface or groundwater. Due to the low levels of development in this catchment, no water quality problems are anticipated.

2.2.11 Stakeholder input

As part of the WRC process the stakeholders in the Crocodile (West), Marico, Mokolo and Matlabas catchments were engaged through stakeholder processes to obtain proposals and motivations on the IUA delineation for the WMA.

3 DELINEATION OF IUAS

Based on the SEZs determined and the assessment of the information and considerations outlined in Section 2.2, twenty IUAs were delineated for the Crocodile (West), Marico, Mokolo and Matlabas catchments (Table 17). The availability of representative EWR sites within each IUA and catchment boundaries and catchment modelling schematics were also considered. The WRCS Guideline, Volume 2, Ecological, hydrological and water quality guidelines for the 7-step classification procedure (February 2007) was also followed in terms of IUA delineation.

The twenty IUAs delineated are listed in Table 17 and illustrated in Figure 7. The identified IUAs have been discussed with the Department and accepted by stakeholders within the Crocodile (West), Marico, Mokolo and Matlabas catchments.

Table 17: IUAs delineated in the Crocodile (West), Marico, Mokolo and Matlabas catchments

IUA ID No.	Main river system/proposed IUA name
1	Upper Crocodile/Hennops/Hartebeespoort
2	Magalies
3	Crocodile/Roodekopjes
4	Hex/Waterkloofspruit/Vaalkop
5	Elands/Vaalkop
6a	Klein Marico/Kromellemboog
6b	Groot Marico
7	Kaaloog-se-Loop
8	Malmaniesloop
9	Molopo
10	Dinokana Eye/Ngotwane Dam
11a	Groot Marico/Molatedi Dam
11b	Groot Marico/seasonal tributaries
12	Bierspruit
13	Lower Crocodile
14	Tolwane/Kulwane/Moretele/Klipvoor
15	Upper Mokolo
16	Lower Mokolo
17a	Mothlabatsi/Mamba
17b	Matlabas

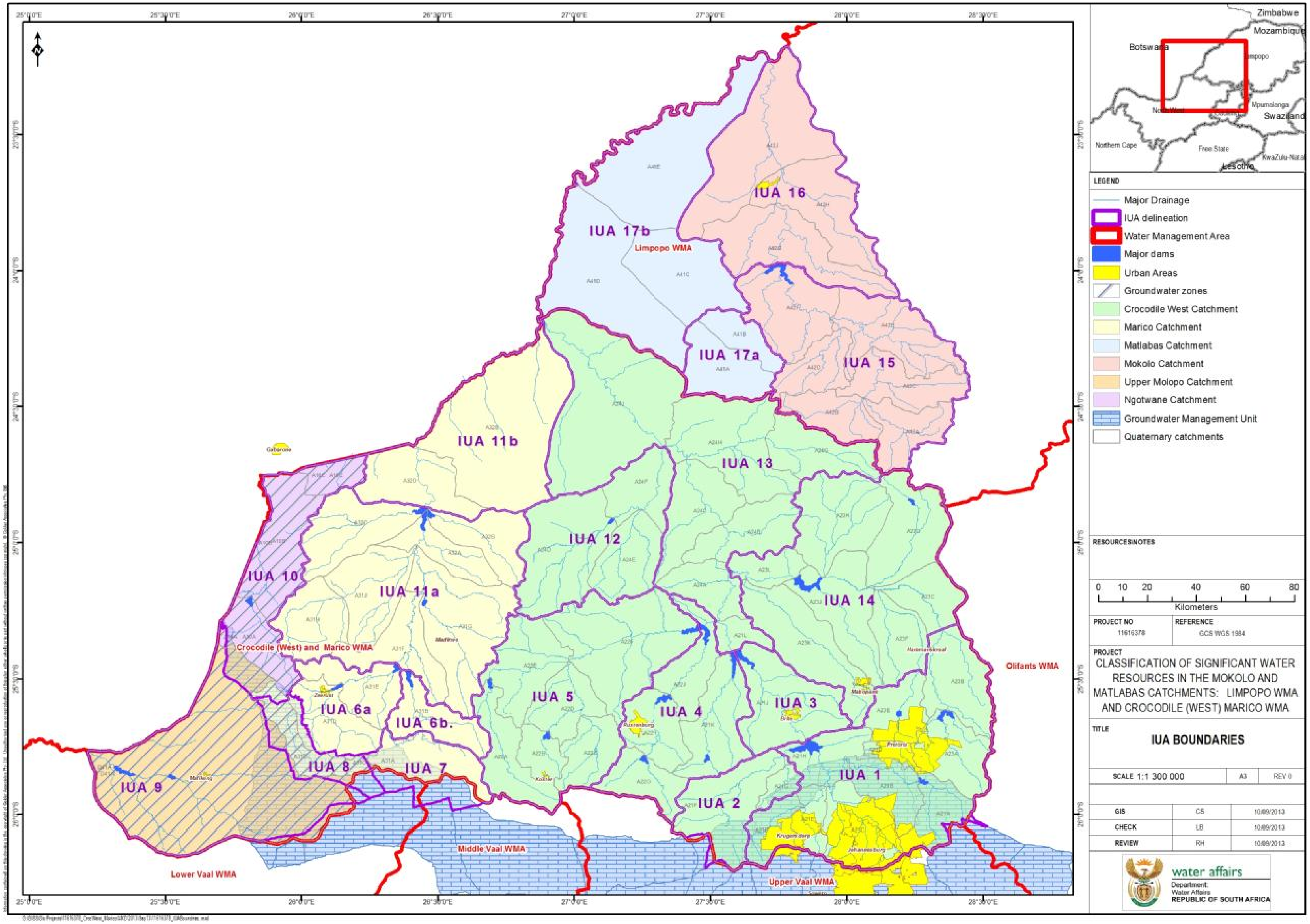

Figure 7: IUAs (20) delineated for the Crocodile (West), Marico, Mokolo and Matlabas catchments

3.1 Socio Economic Description

The 20 IUAs differ markedly in size, population and economic activity. A brief overview of the important characteristics of the IUAs is given below. A more detailed analysis is given in Table 18.

IUA 1 is by far the most populous of all IUAs as it includes the Metropolitan Municipalities of Tshwane (full), Johannesburg (part) and Ekurhuleni (part) and the town of Krugersdorp. The IUA is also a major hub for commercial, financial and industrial sectors for South Africa as well as Africa. In terms of population, IUA 14 is the second most populous IUA in the study area and contains the areas of Mabopane, Hammanskraal and Soshanguve. These areas are a mix of rural and urban settlements and are characterised by high unemployment rates. IUA 11a and IUA 11b are characterised by a large rural population with high unemployment rates.

Mining in the study area is largely centred on IUA 4, which contains the town of Rustenburg and is dominated by PGM mining. Other major mining activities can be found in IUA 12, where there are significant deposits of iron ore and andalusite. Granite mining is found throughout IUAs 4, 5, 12 and 13.

The dominant land use in IUA 13 (which comprises of the lower reaches of the Crocodile River) is largely natural, but irrigation along the Crocodile River main stem is an important contributor to local GDP. Agriculture is also an important sector in IUAs 9, 14 and 5.

IUAs 15 and 16 are found within the Mokolo Catchment and are largely rural in nature with large tracts of land set aside for game farming and hunting. IUA 16 contains the Matimba coal fired power station and the Medupi power station (under construction). IUA 17 is found within the Matlabas catchment, is comprised of conservation and game farming. Both IUAs 16 and 17 have been earmarked for future coal mining developments.

Table 18: General socio-economic descriptions (including population) of the 19 IUAS found in the Crocodile (West) Marico WMA and Matlabas and Mokolo catchments (Source: Census 2001 & 2011)

IUA	Quaternary catchment	Socio-economic Description	Area (Km^2)	Population (Census 2001)	Population (Census 2011)	Number of Households (Census 2011)
1	A21A-E; A21H; A23A; A23B; A23D and A23E	IUA 1 contains the Metropolitan Municipalities of Tshwane (full), Johannesburg (part) and Ekurhuleni (part) and the town of Krugersdorp. The IUA constitutes a large portion of South Africa's commercial, financial, industrial and manufacturing sectors and is an important contributor to National GDP.	5 076	2 945 840	4 660 835	1 624 304
2	A21F and A21G	The IUA contains the Magaliesburg conservation area as well as the Cradle of Humankind World Heritage Site. Both important for tourism and conservation activities. There are also agricultural activities in the IUA.	1 161	9 899	44 565	15 586
3	A21J	The area downstream from Hartbeespoort Dam is an important agricultural area and considerable tourism activities exist on the Crocodile River.	1 150	171 775	244 330	81 971
4	A21K; A22G; A22H; A22J	Rustenburg is the main town found in this IUA. The western limb of the Bushveld Igneous Complex (BIC), the largest platinum group metals (PGM) deposit worldwide, is found in this IUA. There is also substantial granite mining in the area.	2 533	315 239	471 919	172 271

IUA	Quaternary catchment	Socio-economic Description	Area (Km^2)	Population (Census 2001)	Population (Census 2011)	Number of Households (Census 2011)
5	A22A -F	The IUA contains the towns of Koster and Swartruggens. Major socio-economic activities include agriculture, private owned conservation areas and some tourism activities.	4 546	175 045	222 033	75 372
6 (a and b)	A31B; A31D and A31E	The IUA contains the town of Zeerust and Groot Marico. Major socio-economic activities include agriculture, light manufacturing, conservation and tourism. There have been rumours of nickel mining prospecting rights granted in the area.	1 901	23 620	31 316	8 684
7	A31A	The IUA is largely rural in nature with game farms and commercial agriculture present. The area is an important tourism area due to the dolomitic eyes found there.	632	2 901	6 394	1 764
8	A31C	The IUA is largely rural in nature with game farms and commercial agriculture present. The area is an important tourism area due to the dolomitic eyes found there.	485	3 550	5 707	1 489
9	D41A	The IUA contains the town of Mafikeng, which is the capital of the North West Province and is an important regional hub. Socio-economic activities include commercial agriculture, dry-land and subsistence farming and limited tourism activities.	4 298	307 111	322 201	91 587
10	A10A	The IUA is largely rural in nature and contains dry land and subsistence agriculture.	558	50 605	49 716	12 985

IUA	Quaternary catchment	Socio-economic Description	Area (Km^2)	Population (Census 2001)	Population (Census 2011)	Number of Households (Census 2011)
11a	A31F-J; A32A-C and A10B	This large IUA is largely rural in nature and contains a portion of the former Bophuthatswana Homeland. Major socio-economic activities in the IUA include: commercial agriculture, dry-land agriculture and subsistence farming. Local communities in the area highly dependent on the ecosystem services delivered by the Groot Marico River.	6 682	137 272	109 412	30 731
11b	A10C; A32D; A32E	This IUA is largely rural in nature and contains a portion of the former Bophuthatswana Homeland. Major socio-economic activities in the IUA include: commercial agriculture, dry-land agriculture and subsistence farming. Local communities in the area highly dependent on the ecosystem services delivered by the Groot Marico River.	3 613	10 887	34 662	9 814
12	A24D-F	The IUA contains the town of Thabazimbi. Mining is an important sector in this IUA, with iron ore and andalusite significant examples. The IUA is also important as a hunting area and the Marakele National Park is found here.	2 605	87 275	111 987	34 077
13	A21L: A24A-C and A24G-J	This large IUA is primarily agricultural in nature and contains commercial agriculture, dry-land and subsistence agriculture. In addition, the area has large hunting and private conservation areas.	6 806	65 701	88 962	25 979
14	A23C; A23F-L	This IUA contains the peri-urban areas of Mabopane and a portion of Hammanskraal, which have large populations. The IUA contains commercial agriculture, dry-land and subsistence agriculture. The Moretele flood plain is important from an ecosystems services point of view as it supports grazing in the dry season.	5 455	1 122 195	1 304 137	354 703

IUA	Quaternary catchment	Socio-economic Description	Area (Km^2)	Population (Census 2001)	Population (Census 2011)	Number of Households (Census 2011)
		The floodplain is also an important birding area. The IUA also contains the Borakalalo Game Reserve.				
15	A42A-F	The IUA is largely comprised of a mix between conservation and game farming. The IUA contains some commercial agriculture. Tourism, in the form of hunting and game viewing, is an important sector in this IUA. At present, a pipeline is being built from the Mokolo Dam to supply the Grootgeluk Coal Mine in IUA 16.	4 319	27 240	27 238	6 327
16	A42G-J	The IUA contains the town of Lephalale. The area is an important future energy hub and contains the Matimba power station as well as the Medupi power station, which is under construction. The Grootgeluk Coal Mine is in the IUA and several new coalmines have been earmarked for the future. The IUA is also important from a game farming and conservation perspective and contains the D'Nyala Nature Reserve.	4 074	27 604	46 276	13 133
17a	A41A-B	The IUA is largely comprised of conservation and contains the Marakele Nature Reserve.	693	-	4 983	1 414
17b	A41C, D, E	The major economic activities in this IUA are stock or game farming and tourism in the form of hunting. The Steenbokpan area that has been earmarked for future coal mining is in this IUA.	3 949	**-**	5 723	1 237

3.1.1 Household Income Categories

A large number of households within the study area (51%) fall within the Very Poor to Poor household income categories (Table 19). The trend is repeated across all IUAs, with 83% households in IUA 11b falling within this category. IUA 11b falls within the middle Marico River Catchment and used to be part of the former Bophuthatswana homeland. The IUA is characterised by a mainly subsistence agricultural sector and limited employment opportunities. IUA 1, which incorporates the urban areas of Johannesburg, Tshwane and Ekurhuleni, has a relatively better outlook with 44% of households falling within the lower two categories.

Table 19: Household income categories for households found within the Crocodile (West), Marico Mokolo and Matlabas catchments (Source: Census 2011)

IUA	Very Poor (no income- R 9 600)	Poor (R9 601- R 38 400)	Tolerable (R 38 401- R 76 800)	Comfortable (R 76 801-R 153 600)	Wealthy (>R 153 601)	Total number of households
1	337 827	394 752	213 734	176 722	513 565	1 636 601
2	3 424	6 907	2 502	1 196	1 744	15 774
3	18 691	29 693	14 948	8 380	10 697	82 409
4	41 650	46 195	40 515	21 579	23 617	173 555
5	18 285	26 715	17 335	8 100	5 736	76 170
6	1 910	3 461	1 243	1 093	1 206	8 913
7	418	1 023	189	84	98	1 812
8	427	798	167	62	74	1 529
9	27 677	35 736	10 224	7 878	10 589	92 103
10	4 412	5 980	1 276	806	656	13 130
11a	10 582	15 285	2 955	1 429	1 142	31 392
11b	3 091	5 190	862	466	366	9 975
12	9 530	11 162	6 694	4 418	2 730	34 533
13	5 932	9 385	4 425	3 164	3 358	26 265
14	104 958	132 003	53 150	35 122	31 852	357 085
15	1 335	2 968	942	549	580	6 374
16	2 676	3 298	2 148	1 807	3 342	13 271
17a	215	760	200	101	153	1 430
17b	193	457	211	183	207	1 251
Total	593 233	731 767	373 719	273 139	611 714	2 583 572

Employment

The unemployment rate can be defined as the number of people actively looking for a job divided by the total labour force (Table 20). The latest national employment statistics from Stats SA (2012) estimate the unemployment rate for the first quarter of 2012 at 25%.

Overall unemployment for the whole study area stands at 16% or 898 316 people, which is based on the 2011 Census data. The percentage of people who are discouraged work seekers stands at 3%. The unemployment rate ranges from 7% in IUA 17 (a) and (b) to 23% in IUA 14.

Table 20: Employment categories for the 19 IUAs in the Crocodile (West), Marico Mokolo and Matlabas catchments (Source: Census 2011)

IUA	Employed	Unemployed	Discouraged work-seeker	Not economically active
1	2 051 311	491 589	72 656	843 692
2	18 241	4 378	679	8 436
3	84 762	30 489	4 935	50 801
4	175 166	62 835	9 072	98 714
5	66 850	25 180	5 584	57 081
6	8 885	2 166	1 446	8 155
7	1 994	371	233	1 522
8	1 369	512	380	1 287
9	63 992	36 482	14 930	90 957
10	5 352	4 744	3 078	15 794
11a	13 170	11 197	5 450	33 713
11b	4 575	2 633	2 156	10 714
12	27 524	13 454	3 229	32 341
13	30 120	8 400	1 361	23 283
14	313 589	196 641	47 749	310 971
15	8 192	2 796	527	6 039
16	19 918	3 864	559	13 297
17a	2 560	243	49	780
17b	2 189	342	47	2 261
Grand Total	2 899 757	898 316	174 120	1 609 839

3.1.2 Employment by Sector

The majority of people employed in the study area are employed in the formal sector (75%) while 10% of employed are employed in the informal sector.

Table 21. Employment in the formal and informal sectors in the Crocodile (West), Marico Mokolo and Matlabas catchments (Source: Census 2011)

IUA	In the formal sector	In the informal sector	Private household	Do not know
1	1 603 737	174 014	275 798	50 788
2	10 850	2 920	4 262	589
3	60 923	11 305	11 296	2 523
4	132 098	19 732	21 468	3 850
5	49 880	9 246	7 429	1 254

IUA	In the formal sector	In the informal sector	Private household	Do not know
6	6 031	1 373	1 526	157
7	893	623	486	40
8	791	311	267	35
9	44 456	10 698	8 778	901
10	4 072	712	589	73
11a	8 272	2 331	2 655	309
11b	2 692	936	898	161
12	21 507	3 455	2 459	423
13	21 688	3 977	4 046	840
14	226 488	39 437	44 892	7 241
15	5 550	1 318	1 272	211
16	15 819	1 653	2 309	337
17a	1 461	565	487	110
17b	1 661	234	299	28
Grand Total	2 218 866	284 841	391 213	69 871

Employment in the study area is varied and distributed across all of the employment categories. Overall, the community; social and personal services sector provides the most employment in the study area (Table 22). IUA 1 has by far the most employed people with the Financial and Community; social and personal services providing a large proportion of all employment in the IUA. IUA 14 and IUA 4 are other centres of employment in the study area mainly due to the Mining and Quarrying (IUA 4) and Community; social and personal sectors (IUA 14). It is important to note that this analysis is based on the Census 2001 as the employment by sector data from the 2011 Census, was not yet available.

Table 22: Employment by sector for the 19 IUAs in the Crocodile (West) Marico WMA and Matlabas and Mokolo catchments (Source: Census 2001)

IUA	Agri-culture; hunting, forestry and fishing	Mining and quar-rying	Manufac turing	Electr-icity, gas and water supply	Constr-uction	Wholesale and retail trade; repairs, hotels and restaurants	Transport, storage and communication	Financial intermediation; insurance; real estate and business services	Commun-ity; social and personal services	Private households	Extra-territorial org$^{n/}$s	Reps of foreign govts.	Undeter-mined
1	22 119	10 109	124 201	6 650	63 994	182 092	63 319	201 794	226 580	123 643	190	1 296	126 593
2	743	466	220	19	167	339	75	102	188	289	2	0	186
3	8 204	2 966	8 645	316	2 623	7 149	1 782	2 785	6 985	4 253	8	12	3 009
4	3 550	55 596	6 241	398	4 194	11 216	2 579	4 149	9 667	5 893	3	1	3 923
5	3 316	11 488	3 178	274	2 664	8 627	1 636	3 596	9 999	4 039	-	3	3 075
6	1 862	218	268	25	162	850	133	297	1 387	566	-	-	636
7	415	63	47	2	15	39	8	14	35	82	-	-	49
8	270	31	77	1	24	46	11	17	58	131	-	-	20
9	3 262	882	3 018	439	2 584	7 397	2 619	4 332	19 045	6 707	8	-	2 096
10	149	133	130	57	166	512	163	162	1 604	451	-	-	214
11a	2 955	1 610	630	120	658	1 335	493	376	3 215	1 234	-	-	679
11b	1 077	721	47	8	81	113	44	44	242	254	-	-	131
12	949	6 589	1 464	93	725	1 812	552	686	3 023	1 275	-	-	917

IUA	Agri-culture; hunting, forestry and fishing	Mining and quar-rying	Manufac turing	Electr-icity, gas and water supply	Constr-uction	Wholesale and retail trade; repairs, hotels and restaurants	Transport, storage and communication	Financial intermediation; insurance; real estate and business services	Commun-ity; social and personal services	Private households	Extra-territorial org$^{n/}$s	Reps of foreign govts.	Undeter-mined
13	4 766	7 619	727	80	679	1 100	311	419	1 606	2 321	-	-	938
14	6 278	1 323	39 305	1 579	15 655	44 292	14 750	15 620	56 040	24 362	18	124	13 432
15	2 767	188	630	52	591	697	98	163	1 124	1 210	-	-	366
16	3 900	723	558	449	435	984	316	305	1 339	2 858	-	-	871
17a	181	142	42	18	56	78	15	26	126	92	-	-	38
17b	380	275	51	127	71	119	29	70	218	147	-	-	120
Total	**67 259**	**101 366**	**189 519**	**10 770**	**95 589**	**268 907**	**88 963**	**235 001**	**342 651**	**179 950**	**229**	**1 435**	**157 357**

3.1.3 Access to Basic Services

Access to basic services is an important component of human well-being. In this section data from the Census 2011 database was used and two major basic service categories were analysed:

1. Access to Water: This category is comprised of the following sub-categories as measured by the Census 2011:
    a. Piped (tap) water to community stand: distance less than 200m from dwelling;
    b. Piped (tap) water inside yard; and
    c. Piped (tap) water inside dwelling.
2. Access to Sanitation: This category is comprised of the following sub-categories as measured by the Census 2011:
    a. Flush toilet connected to sewerage system;
    b. Flush toilet with septic tank; and
    c. Pit latrine with ventilation (VIP).

The results of the analysis (Table 23) show that 93% of all households in the study area have access to water and 78% have access to sanitation. IUA 1 scores highly in all categories while IUAs 7, 13 and 15 have large numbers of households with limited provision to basic services. IUAs 10 and 11b score particularly low in the access to sanitation category.

Table 23: Access to water, sanitation and electricity for the 19 IUAs in the Crocodile (West) Marico WMA and Matlabas and Mokolo catchments (Source: Census 2001)

IUA	Number of households	Access to Water		Access to Sanitation	
1	1 624 304	1 606 437	99%	1 467 102	90%
2	15 586	12 850	82%	8 330	53%
3	81 971	69 889	85%	41 291	50%
4	172 271	160 912	93%	114 143	66%
5	75 372	72 861	97%	33 942	45%
6	8 684	8 476	98%	6 415	74%
7	1 764	1 576	89%	706	40%
8	1 489	1 339	90%	547	37%
9	91 587	74 277	81%	44 744	49%
10	12 985	11 835	91%	3 570	27%
11a	30 731	28 995	94%	8 844	29%
11b	9 814	9 361	95%	2 045	21%

IUA	Number of households	Access to Water		Access to Sanitation	
12	34 077	32 041	94%	9 937	29%
13	25 979	24 052	93%	16 246	63%
14	354 703	332 445	94%	220 366	62%
15	6 327	5 910	93%	3 675	58%
16	13 133	12 922	98%	10 815	82%
17a	1 414	1 365	97%	764	54%
17b	1 237	1 198	97%	797	64%
Grand Total	**2 563 430**	**2 468 741**	**96%**	**1 994 279**	**78%**

3.2 Land Cover

Land use estimates were calculated using the National Land Cover (CSIR 2002). Although 10 years old, the database is the only national land cover database available and provides useful information on land use activities at a national scale. According to the NLC data, the Natural land cover category is the most numerous land cover type in the study area. Land cover categories and estimates are given for each IUA in Table 24.

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Table 24: Land cover categories (ha) for the 20 IUAs in the Crocodile (West), Marico, Mokolo and Matlabas catchments (Source: CSIR 2002)

IUA	Area (ha)							
	Cultivation	**Degraded**	**Mines**	**Natural**	**Plantations**	**Urban Built-up**	**Water Bodies**	**Grand Total**
1	89 947	4 610	3 458	300 255	2 255	96 243	10 477	507 246
2	34 955	889	190	77 321	611	1 310	671	115 948
3	36 517	8 341	765	59 316	3	8 840	1 218	114 999
4	37 186	5 237	2 413	188 990	134	16 240	3 085	253 285
5	60 632	16 471	1 911	360 326	291	12 305	2 673	454 609
6 (a and b)	20 690	2 347	371	162 923	171	1 652	1 903	190 058
7	14 583	127		48 221	31	28	195	63 183
8	3 342	1 050		43 224		454	436	48 506
9	157 425	22 834	749	218 216		26 082	3 656	428 962
10	4 207	2 655		41 436		6 943	428	55 668
11a	70 904	49 147		522 565		20 062	5 195	667 873
11b	44 177	11 468	361	301 913		808	165	358 892
12	43 455	1 514	2 156	197 405		15 305	518	260 353
13	56 424	20 483	2 676	595 641		4 799	525	680 549
14	101 625	49 451	1 856	323 572	24	63 995	4 787	545 310
15	78 574	24 823	34	325 551		949	1 735	431 665
16	16 108	5 031	3 388	377 496		1 645	194	403 862
17 (a and b)	19 077	8 207		566 742		104	268	594 397
Grand Total	**889 825**	**234 685**	**20 329**	**4 711 112**	**3 520**	**277 765**	**38 129**	**6 175 364**

3.3 Agriculture

3.3.1 Agricultural Categories

Agriculture is an important economic sector in the study area and contributes significantly to the regional GDP of the area (Table 25 and Figure 8). IUA 9 is a particularly important agricultural area, with large amounts of area under high, low and medium cultivation. IUA 9 also has large areas of under small-scale farming, which is typically characterised by dryland, subsistence farming. IUA 11b also has a large area under small-scale farming.

Pivot irrigation is prevalent throughout the study area and is particularly conspicuous in the lower reaches of the Crocodile River in IUA 13. IUA 15 in the Mokolo catchment is also an important pivot irrigation area. It is important to note that the dataset only includes pivot irrigation and does not include other irrigation categories.

Table 25: Agricultural categories (ha) of the 18 IUAs in the Crocodile (West), Marico, Mokolo and Matlabas catchments (Source: DAFF 2010)

IUA	Area (ha)						
	High Cultivation	Low Cultivation	Medium Cultivation	Old Fields	Pivot Irrigation	Small Scale Farming	Grand Total
1	6 656	23 156	8 217	616	3 620	482	42 748
2	7 640	12 366	6 110	344	3 829	0	30 290
3	17 910	3 657	0	29	4 254	253	26 103
4	985	21 358	4 111	195	639	649	27 937
5	11 127	23 062	10 744	1 106	677	1 949	48 664
6	2 480	9 188	180	1 329	301	0	13 478
7	0	5 947	4 961	1 035	109	0	12 051
8	7	1 190	0	7	369	0	1 573
9	36 685	20 656	19 678	546	4 612	20 810	102 986
10	0	654	0	0	0	1 573	2 227
11a	3 900	9 089	2 880	4 023	1 269	35 402	56 563
11b	2 550	13 083	9 351	2 248	1 504	1 402	30 137
12	0	3 571	4 850	0	21	17 293	25 736
13	3 052	9 033	13 843	2 731	13 477	3 153	45 289
14	8 989	13 032	16 007	1 792	5 111	29 670	74 600
15	1 441	15 045	29 992	708	11 113	13	58 311
16	0	7 502	529	202	1 086	41	9 360
17	0	9 841	166	1 236	1 075	434	12 751
Total	**103 421**	**201 428**	**131 619**	**18 148**	**53 065**	**113 124**	**620 806**

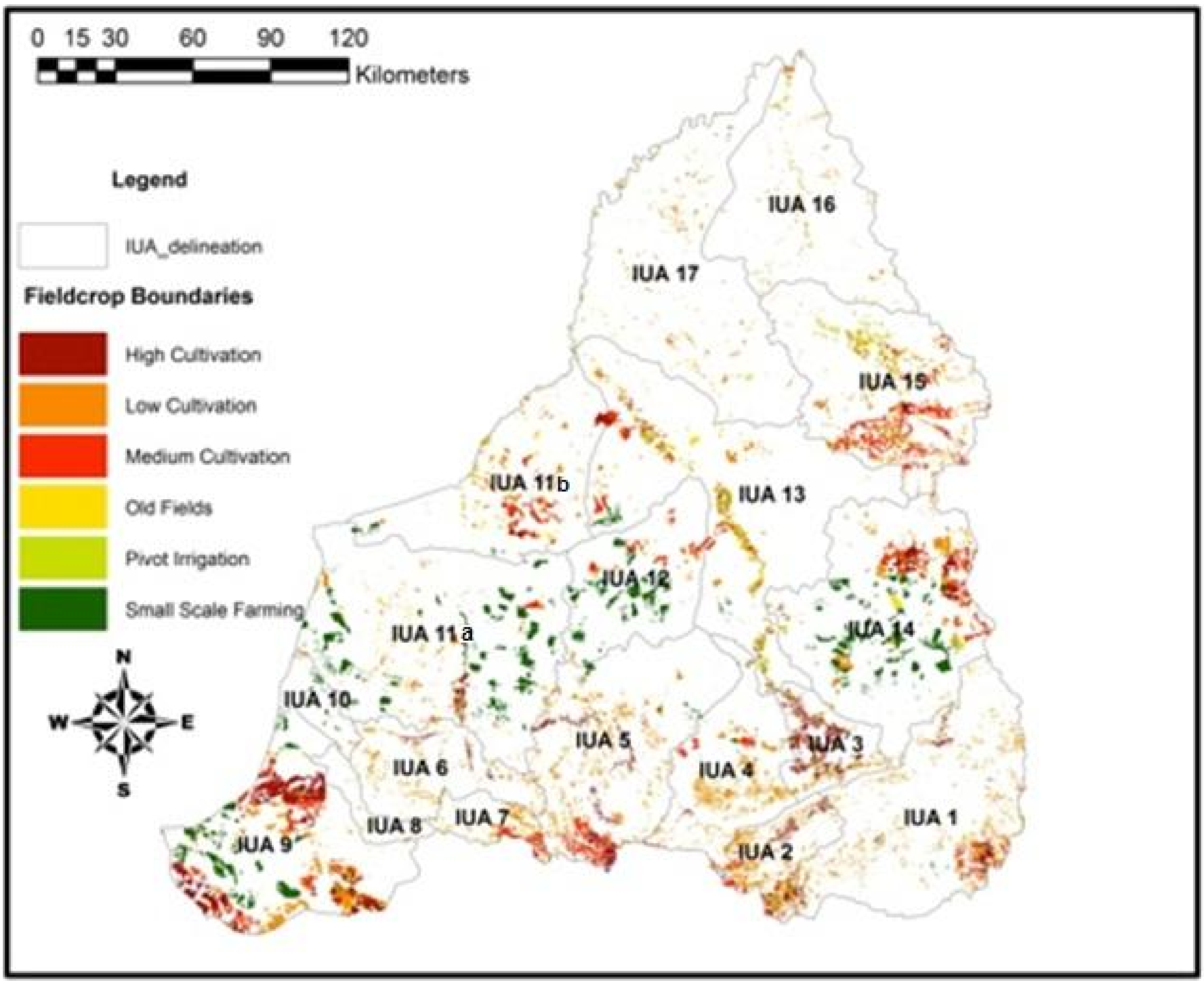

Figure 8: Agricultural categories of the 18 IUAs in the Crocodile (West), Marico, Mokolo and Matlabas catchments (Source: DAFF 2010)

3.3.2 Crop Types

Table 26 shows the variety and amount of crops grow throughout the study area. The information is based on the 2007 Agricultural Census (StatsSA 2011) and shows only the major crop types grown in 2007.

In terms of area, dryland maize is by far the most common crop grown in the study area followed by dryland sunflower and irrigated maize. IUA 13 has the most land set aside for agriculture and as a result of its close proximity to the Crocodile River a variety of crops are grown. A large portion of land is set aside for dryland maize production in IUA 9. IUA 4 shows a similar pattern.

Table 26: Major crop types grown (ha) in all 17 IUAs in the Crocodile (West), Marico, Mokolo and Matlabas catchments (Source: StatSA 2011)

IUA	Maize		Wheat		Sunflower		Soybean		Groundnut		Oranges	Carrot	Potato	Onion	Tomato	Cabbage	Grand Total
	Dryland	Irrigated	Dryland	Irrigated	Dryland	Irrigated	Dryland	Irrigated	Dryland	Irrigated							
1	5 827	1 121	219	525	399	54	1	0	8	12	77	384	101	30	36	174	**8 970**
2	2 675	667	79	377	369	41	-	-	6	9	64	518	91	23	27	74	**5 021**
3	7 541	2 620	363	1 771	765	179	-	-	28	43	271	157	5	106	128	85	**14 064**
4	10 871	2 616	355	1 624	1 439	203	-	-	25	39	335	154	11	97	117	83	**17 971**
5	9 626	870	106	289	1 669	111	-	-	4	6	227	24	11	16	22	21	**13 002**
6 (a and b)	1 178	80	8	51	227	7	-	-	-	-	15	-	1	-	3	3	**1 573**
7	680	42	4	13	128	6	-	-	-	-	12	-	1	-	1	1	**889**
8	158	13	1	15	32	-	-	-	-	-	0	-	-	-	1	1	**221**
9	15 629	961	115	250	3 136	65	-	-	227	18	1	-	14	-	2	3	**20 420**
10	178	14	2	17	36	-	-	-	-	-	0	-	-	-	1	1	**249**
11a	3 258	201	21	124	577	17	-	-	-	-	41	-	2	-	13	8	**4 262**
11b	849	489	564	903	1 400	5	347	653	-	47	120	-	-	17	2	1	**5 398**
12	421	147	176	276	424	2	109	205	-	15	37	-	-	5	7	-	**1 823**
13	6 839	3 328	2 084	2 583	7 162	625	727	1 080	44	111	426	100	86	147	97	54	**25 493**
14	2 491	1 581	1 486	258	6 785	765	242	13	37	11	127	22	114	92	37	12	**14 073**
15	2 222	2 146	94	114	2 826	475	12	13	101	73	12	-	197	51	41	-	**8 376**
16	1 199	1 562	79	43	257	76	-	-	56	192	6	-	42	9	4	-	**3 524**
17	1 616	1 823	556	803	1 491	87	300	565	51	208	109	-	43	24	5	-	**7 681**
Grand Total	**73 259**	**20 282**	**6 313**	**10 036**	**29 121**	**2 717**	**1 739**	**2 529**	**587**	**786**	**1 882**	**1 359**	**719**	**618**	**543**	**523**	**153 011**

4 DESCRIBE AND VALUE THE USE OF WATER

4.1 Objective

The objective of this sub-step is to describe the way in which water is currently used in the Crocodile (West), Marico, Mokolo and Matlabas catchments, and to estimate the value generated by that use.

4.2 Crocodile (West) River Catchment

The Crocodile (West) catchment is one of the most developed catchments in the country. The catchment is characterised by the sprawling urban and industrial areas of northern Johannesburg and Pretoria, extensive irrigation downstream of Hartbeespoort Dam and large mining developments north of the Magaliesberg.

Due to the extensive developments and high level of human activity in the catchment, water use in the catchment exceeds the water available from the local sources. Most of the water used in the catchment is therefore supplied from the Vaal River system via Rand Water, mainly to serve the metropolitan areas and some mining developments. This results in large quantities of effluent from urban and industrial users, most of which is discharged to the river system after treatment, for re-use downstream. In many of the streams and impoundments, water quality is severely compromised by the proportionate large return flows.

The water requirement values for the Crocodile West Catchment are taken from the Crocodile (West) River Reconciliation Strategy (DWA 2008) and are based on four growth scenarios (Table 28):

1. Scenario D High: medium water demand management efficiency, high population growth
2. Scenario D Base: medium water demand management efficiency, base population growth
3. Scenario D Low: medium water demand management efficiency, low population growth
4. Scenario C High: high water demand management efficiency, high population growth

Table 27: Summary of water requirements (units: million m^3)

Scenario	2005	2010	2015	2020	2025	2030
D: High	1 121	1 191	1 276	1 355	1 409	1 480
D: Base	1 112	1 170	1 237	1 299	1 344	1 404
D: Low	1 110	1 147	1 190	1 221	1 232	1 255
C: High	1 121	1 196	1 228	1 275	1 308	1 376

4.2.1 Urban Water Requirements

The Crocodile (West) catchment contains the largest urban centres in South Africa. Of particular importance are:

- The north, north east and north-west portions of the Johannesburg metropole in the upper Crocodile River Catchment;
- The Midrand area also in the upper Crocodile River Catchment;
- Tshwane Municipality including the city of Pretoria, mainly in the Pienaars River catchment; and
- The Rustenburg area in the Elands River Catchment.

The total urban water requirements (as per the four growth scenarios listed above) are given in Table 28.

Table 28: Urban water requirements (units: million m^3)

Scenario	2005	2010	2015	2020	2025	2030
D: High	579	604	673	736	790	850
D: Base	570	586	640	689	733	782
D: Low	568	565	597	615	626	638
C: High	579	609	626	657	688	746

4.2.2. Rural Water Requirements

Population projections were estimated (Table 29) for the rural areas of the Crocodile River catchment for high, base and low growth scenarios (DWA 2008).

Table 29: Rural population projections 2005-2015 (Source: DWA 2008)

Population Growth	2005	2010	2015
High	1 029 640	1 062 190	1 092 439
Base	1 021 543	1 043 424	1 039 056
Low	1 013 493	1 024 953	1 010 518

Taking these population projections into consideration, rural water requirements (Table 30) were calculated based on stepped per capita water requirements. The increase in per capita rural water requirements to 2010 is in line with commitment of DWA to increase the minimum level of water supplied to at least 50*l*/capita/day to clear the sanitation backlog and eradicate the bucket system (DWA 2008).

Table 30: Rural water requirements (units: million m^3)

Population Growth	2005	2010	2015
High	15	23	23
Base	15	23	22
Low	15	22	22

4.2.3 Irrigation Water Requirements

Irrigation is the single largest water user in the Crocodile River catchment using approximately 375,5 m^3/a (DWA 2008). According to DWA (2008) Irrigation areas and irrigation water requirements are expected to remain constant between 2005 and 2030. Distribution losses are a major concern in the study area and in some areas are estimated as high as 50%.

The irrigation water requirements, the estimated irrigation area, distribution losses and irrigation return flows are summarised per sub-area in Table 31.

Table 31: Irrigation water requirements (units: million m^3)

Sub catchment	Irrigation Area	Irrigation Requirement	Distribution losses	Total Irrigation Requirement		Irrigation Return Flows
				Volume	1:50 assurance	
Unit	ha	million m^3/a				million m^3/a
Upper Crocodile	20 260	115	57	172	147	11
Elands	1 514	8	2	10	8	1
Apies-Pienaar	6 164	32	3	36	30	3
Lower Crocodile	28 036	153	76	229	191	15
Total	55 974	308	138	447	376	30

4.2.4 Mining Water Requirements

The mining sector is an important contributor to GDP-R in the study area. Of particular importance is the large number of platinum deposits in the Elands sub-catchment, which are the largest PGM deposits in the world.

The total mining water requirements for the Crocodile River catchment are summarised in Table 32. The Reconciliation Strategy identified three scenarios: high, base and low (DWA 2008).

Table 32: Mining water requirements (units: million m^3)

Scenario	2005	2010	2015	2020	2025	2030
High	92	129	145	152	152	151
Base	92	126	139	144	145	145
Low	92	124	136	142	142	142

4.2.5 Power Generation Water Requirements

There are three power stations in the Crocodile River catchment: Kelvin in the Upper Crocodile sub-catchment and Pretoria-West and Rooiwal in the Apies-Pienaars sub-catchment. The water requirements of the Kelvin, Pretoria-West and Rooiwal power stations are 11 million m^3/a, 6 million m^3/a and 17 million m^3/a respectively.

4.2.6 Stock Watering

The water requirements for stock watering occur throughout the catchment and the total water requirements are 22 million m^3/a(DWA 2008).

4.3 Marico River Catchment (including the Upper Molopo and Ngotwane Catchments)

The Marico, Upper Molopo and Upper Ngotwane catchments are part of the Crocodile (West) and Marico WMA. The economy is mainly the primary sectors of agriculture on the dolomites of the Upper Molopo and the Marico catchment as well as mining around Zeerust, with some secondary industries such as cement manufacturing at the Slurry.

Water requirement data is sourced from the ISP for Marico, Upper Molopo and Upper Ngotwane Catchments (DWAF 2004a).

The main water user sectors in the three catchments are:

- Commercial irrigation farming in all three catchments;
- Urban water use in the main towns of Mafikeng, Zeerust, Groot Marico and Itsoseng; and
- Rural domestic water use.

The major water user in the Marico is irrigation (at 32 million m^3/a) along the Groot Marico River and the Klein Marico as well as downstream of Marico Bosveld and Klein Maricopoort. This is followed by rural water use of 12 million m^3/a.

In the Upper Molopo sub-area irrigation and urban water use are the major water users utilising 24 million m^3/a and 13 million m^3/a respectively. The sources of supply are the dolomitic aquifers of the Grootfontein compartment and Molopo springs.

Irrigated agriculture is the dominant water user in the Upper Ngotwane sub- area (5 million m^3/a) followed by rural water use of approximately 3 million m^3/a.

4.3.1 Total Water Requirements

The total water requirements for the Marico, Upper Molopo and Ngotwana catchments for different users are given in Table 33 (DWAF 2004b).

Table 33: Total water requirements for the Upper Molopo and Ngotwane catchments

Sub Area	Irrigation	Urban	Rural	Mining & Bulk Industry	Transfers Out	Total
Marico	32	9	12	5	7	65
Upper Molopo	24	13	6	5	0	48
Upper Ngotwane	5	2	3	0	0	10

4.4 Mokolo and Matlabas catchments

Both the Mokolo and Matlabas catchments are in a semi-arid region, with economic activity centred on livestock farming, irrigation and future mining developments.

The Matlabas catchment is a dry catchment with non-perennial flow and therefore limited sustainable yield form surface water. The limited water use in the catchment is from groundwater, which is under exploited (DWAF 2004c). According to the Limpopo ISP (DWA 2004c) there are no major water resources or water supply issues within the catchment.

In terms of a water resource point of view, the Mokolo catchment is one of the most developed catchments. The Mokolo Dam is situated in the catchment and provides water to a number of users including the Matimba Power Station and the Grootgeluk coal mine.

4.4.1 Water Requirements

Irrigation is the largest water user in the Matlabas catchment with an approximate requirement of 4 million m^3/a of which 2 million m^3/a is sourced from groundwater sources and 2 million m^3/a is sourced from surface water resources.

Irrigation, is the largest user in the Mokolo catchment, takes place mostly upstream of the Mokolo Dam, with water sourced from farm dams and run-of-river. There is an allocation of 10,4 million m^3/a (at 70% assurance) from the Mokolo Dam to irrigators downstream of the dam. Other allocations from the dam are 9,9 million m^3/a to the Grootgeluk mine and 7,3 million m^3/a to the Matimba power station. The towns of Lephalale and Vaalwater constitute the urban requirements in the catchment (DWAF 2004c).

The water requirements for the Matlabas and Mokolo catchments are given in Table 34 (DWAF 2004c).

Table 34: Water requirements in the Matlabas and Mokolo catchments (at 1:50 year assurance) in the year 2003 (units: million m^3)

Catchment	Irrigation	Urban	Rural	Mining	Power Generation	Transfers Out	Total
Matlabas	4	0	2	0	0	0	6
Mokolo	68	2	2	4	7	0	83

4.5 The Economic Value of Water Use in the Crocodile (West), Marico, Mokolo and Matlabas Catchments

Economic production activities use water as an input into their production processes. Production outputs are the gross income or turnover of each user activity. The Agriculture, Mining, Electricity and Water, and other sectors are all significant value adding sectors, with significant multiplier effects into the rest of the economy. The GDP (defined here as Value Added (VAD) of economic sectors directly dependent upon Water Use Licenses in the study area in 2011 was R549 billion (Table 35). This estimate is based on preliminary analysis conducted at this early stage of the project. A revised estimate will follow in a subsequent phase of the project.

Table 35: The GDP, expressed as Value Added (VAD) of the water sector in the in the Crocodile (West), Marico, Mokolo and Matlabas catchments

User Sector	Agriculture					Mining			
	Irrigation	Livestock Farming	Urban	Rural	Industrial	Platinum	Other	Power Generation	Total
Water Requirements	509	12	630	48	212	100	43	41	1 602
VAD/m3 (R/m3)	7,24	141,16	17,38	17,38	2 006,63	763,92	639,34	69,90	
VAD estimate (R'million)	2 688	1 694	10 952	834	425 406	76 392	27 491	2 866	549 323

5 DESCRIBE AND VALUE THE USE OF AQUATIC ECOSYSTEMS

The objective of this step is to determine the way in which aquatic ecosystems are currently being used in each socio-economic zone, and to estimate the value generated by that use.

5.1 What are Ecosystem Services and why are they Important?

Ecosystem services (ES), in their most basic form, can be defined as the benefits that people receive from ecosystems. The Millennium Ecosystem Assessment (MA 2005) provides a framework in which ecosystem services can be categorised (Figure 9 and Table 36).

The MA provides a sound and well-established framework for the assessment of ecosystem services and the benefits to human well-being. The MA established the concept of ecosystem services as an essential model for linking the functioning of ecosystems to human welfare benefits (Balmford et al. 2008) (See Figure below). The definition and categorisation of ecosystem services in the MA built upon previous work by leading authors such as Daily (1997), Costanza et al. (1997), and De Groot et al. (2002).

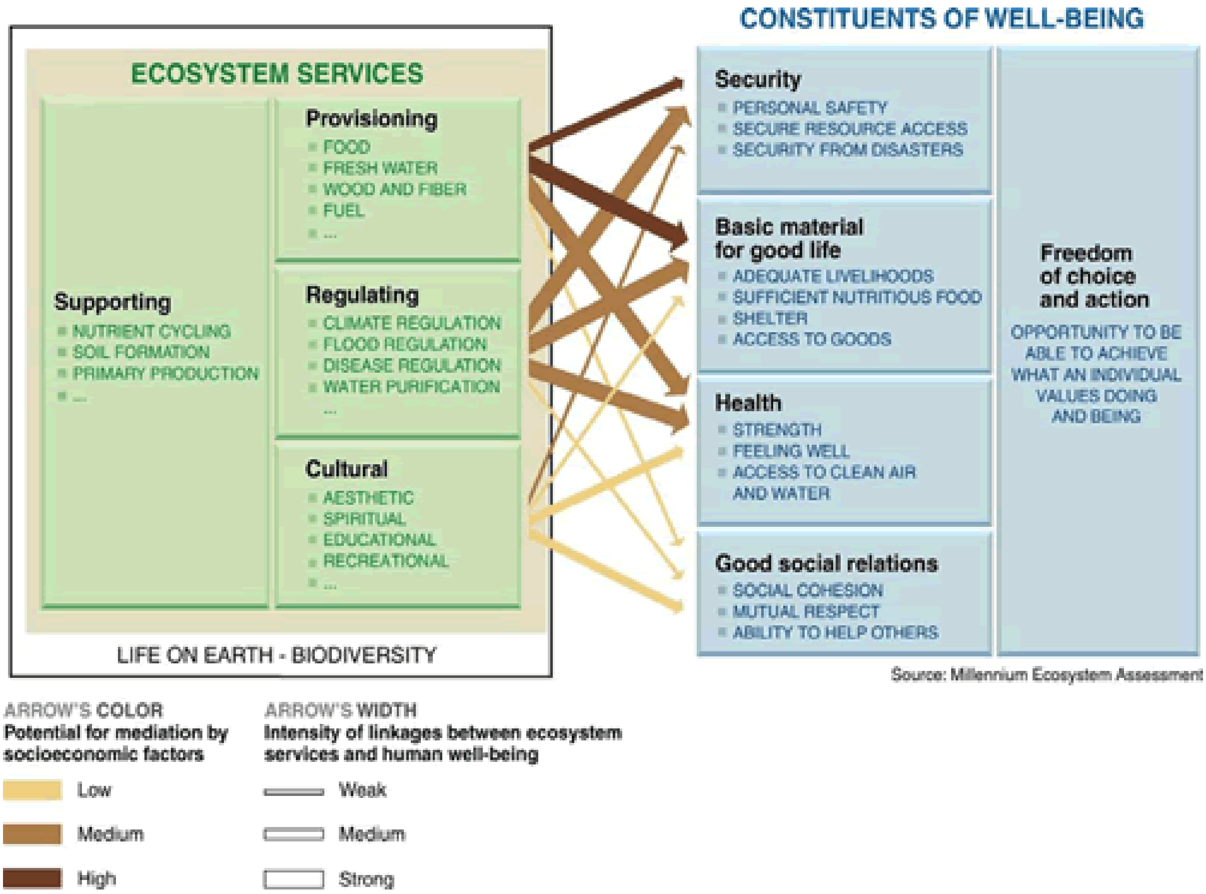

Figure 9: Diagrammatic representation of the link between ecosystem services and human well-being. Figure sourced from the Millennium Ecosystem Assessment (http://www.maweb.org)

Table 36: Categories of ecosystem services as proposed by the Millennium Ecosystem Assessment (2005)

What are ecosystem services? These are the benefits that people obtain from ecosystems. According to the MA (2005) they can be divided into four categories, supporting, regulating, provisioning and cultural services.		
Regulating services	**Provisioning services**	**Cultural services**
		
Regulating services are services, such as water purification, air quality regulation, climate regulation, disease regulation, or natural hazard regulation, that affect the impact of shocks and stresses to socio-ecological systems and are: public goods (globally in the case of disease or climate regulation) meaning that they “offer non-exclusive and non-rival benefits to particular communities” (Perrings 2006); and are thus frequently undervalued in economic markets; many of these are *indirectly used* being intermediate in the provision of cultural or provisioning services.	**Provisioning services** are the most familiar category of benefit, often referred to as ecosystem ‘goods’, such as foods, fuels, fibers, biochemicals, medicine, and genetic material, that are in many cases: *directly* consumed; subject to reasonably *well-defined property rights* (even in the case of genetic or biochemical material where patent rights protect novel products drawn from ecosystems); and are *priced in the market*.	**Cultural services** are the less familiar services such as religious, spiritual, inspirational and aesthetic well-being derived from ecosystems, recreation, and traditional and scientific knowledge that are: mainly passive or non-use values of ecological resources (*non-consumptive uses*); that have *poorly-developed markets* (with the exception of ecotourism); and *poorly-defined property rights* (most cultural services are regulated by traditional customs, rights and obligations); but are still *used directly* by people and are therefore open to valuation.
Supporting services are an additional set of ecosystem services referred to in the MA, such as nutrient and water cycling, soil formation and primary production, that capture the basic ecosystem functions and processes that underpin all other services and thus: are embedded in those other services (*indirectly used*); and are not evaluated separately.		

5.2 Preliminary Ecosystem Service Valuation

This section provides an overview of the value of ecosystem services produced by rivers and wetlands in Crocodile (West) Marico WMA and Matlabas and Mokolo catchments. The preliminary valuation is based on the ecosystem service valuation model developed for the Olifants WMA WRCS. As the project continues, a more in depth model for aquatic ecosystem services valuation will be developed.

According to the National Freshwater Ecosystem Priority Area database (NFEPA) the study area has approximately 7 391 km of river and 67 671 ha of wetalnd area. These values are important as they form the basis of the aquatic ecosystem valauation.

The following provisioning services were identified:

- river water for domestic use
- livestock watering and grazing
- sand and clay harvesting and use
- use of plant resources
- harvesting and use of wild food and medicinal products
- hunting resources
- fishing resources

The following regulating services were identified:

- value of flood attenuation
- value of base flow maintenance
- value of water purification
- carbon sequestration values

The following cultural services were identified:

- value of river based adventure tourism
- value of recreational angling
- ecotourism value
- property values
- scientific and educational value.

The combined ecosystem services produced by rivers were valued at R945 million per year in 2011 (Table 37). The combined ecosystem services produced by wetlands were valued at R1 038 million per year in 2011 (Table 38): a combined value of river and wetland ecosystem services of R1 983 million. These ecosystem services are of direct benefit to households and are therefore directly comparable to GDP and VAD. With the exception of the tourism and recreation services, these ecosystem services are external to the economy. The value of ecosystem services as externalities is thus estimated as approximately R1 538 million in 2011.

Table 37: Value (Rand million) of aquatic ecosystem services delivered by rivers in the Crocodile (West), Marico, Mokolo and Matlabas catchments

Rivers	Value (Rand million)
Domestic water use	359,22
Grazing	4,22
Livestock watering	56,69
Harvested products	63,61
Total	**483,74**
Water regulation	12,74
Carbon Sequestration	2,46
Total	**15,20**
Tourism	368,46
Recreation	50,71
Aesthetic value	27,29
Education	0,49
Total	**446,95**
Sub-Total	**945,90**

Table 38: Value (Rand million) of aquatic ecosystem services delivered by wetlands in the Crocodile (West), Marico, Mokolo and Matlabas catchments

Wetlands	Value (Rand million)
Livestock watering	565,81
Harvested products	308,30
Total	**874,11**
Flood attenuation	33,23
Groundwater recharge	27,32
Water purification	55,70
Carbon Sequestration	10,10
Total	**126,35**
Angling	10,94
Tourism	26,65
Total	**37,59**
Sub-Total	**1 038,05**

6 DEVELOP THE SOCIO-ECONOMIC FRAMEWORK AND THE DECISION-ANALYSIS FRAMEWORK

6.1 Objective

The WRCS Guidelines describes the objective of this sub-step to be the development of a suitable socio-economic valuation framework that links changes in yield and ecosystem characteristics to socio-economic values. The framework must enable forecasting of changes in socio-economic values due to changes in water yield and ecosystem characteristics for different water resource management scenarios. The WRCS Guidelines proposes the use of an integrated ecosystem services/economic modelling framework, but advises that the decision of which framework to adopt would depend on the specific characteristics of the catchment analysed, and the preference of DWA and the PSP team.

The WRCS Guidelines distinguish between three key variables (1) utilizable water yield, (2) water quality and (3) aquatic ecosystem health. All these variables affect the socio-economy and the WRCS Guidelines proposes that these effects be measured in terms of economic impact using a Social Accounting Matrix (SAM), or a related input-output analysis tool.

This section proposes a decision-analysis framework for supporting the required analyses.

6.2 The Water Economy in Context and a Critical Assessment of the Available Socio-economic Data

The water economy of the study area comprises several components: The water resources of the study area are natural assets that produce raw water and other aquatic ecosystem services. The raw water is used as an input in economic production, whilst the other aquatic ecosystem services are mostly directly used by households. Various economic sectors produce a variety of goods and services, many of them consumed as intermediate goods and services, but ultimately consumed by households. Households provide labour to the economic production process. Finally, the economic production process also produces a variety of effluents, which end up back in the aquatic environment as pollutants. Figure Figure 10 illustrates these transactions.

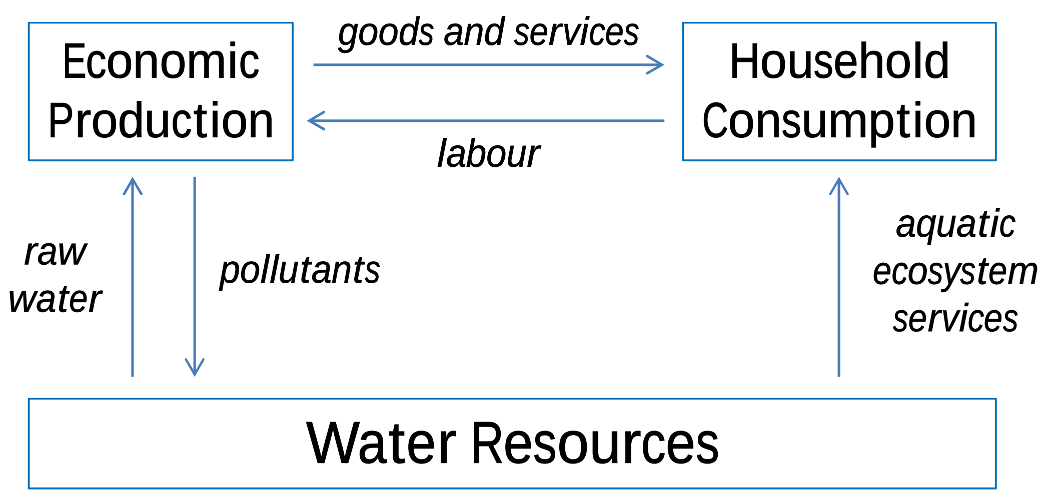

Figure 10: A schematic representation of the transactions between water resources, economic production and household consumption

The discussions in the preceding sections have extracted from available literature, some economic values related to the water economy of the Crocodile (West) Marico WMA and Matlabas and Mokolo catchments.

Total economic production for the Croc (West) Marico WMA, measured as Value Added (VAD), has been estimated at approximately R550 billion for 2011. It is important to note that these estimations do not take into account the GDPR of the Mokolo and Matlabas catchments. A more comprehensive estimation of GDPR for the whole study area will be included in subsequent drafts.

The value of aquatic ecosystem services (See Section 1(G)) external to the economy of the WMA was approximately R1,538 million in 2010. However, this aquatic ecosystems valuation excludes a number of important transactions relating to water resources, which will be included in subsequent drafts:

1. Firstly, the value of water regulation, which produces raw water for use in economic production, was not valued.
2. A second factor that needs to be valued is the value of human health associated with aquatic ecosystems. The World Health Organisation (WHO) postulates that environmental hazards are responsible for as much as a quarter of the total burden of disease worldwide, and more than one-third of the burden among children. Heading that list are diarrhoea, lower respiratory infections, various forms of unintentional injuries and malaria. The disease burden is much higher in the developing world, although in the case of certain non-communicable diseases, such as cardiovascular diseases and cancers, the per capita disease burden is larger in developed countries. Health impacts of environmental hazards run across more than 80 diseases and types of injury. The damaging effects of emissions in the form of water pollutants and sedimentation emitted into aquatic ecosystems (i.e. water resources) are an important environmental externality.
3. Another externality is the conservation cost of aquatic ecosystem stewardship function. These costs are defined as externalities because they are not borne by the formal economy, but instead result in degradation of the water resource asset.

These transactions can be modelled using various economic modelling techniques:

- Social Accounting Matrixes (SAMs) model the transactions between economic production sectors and household consumption.
- Environmental Economic Accounts for Water (Water EEAs) model the transactions between economic production and water resources (and expands the Water sector component of the SAM).
- Environmental and Resource Economics (ERE) modelling, based on the Millennium Ecosystem Assessment framework, models the production of aquatic ecosystem services.
- The effects of water pollutants on water resources and households can be modelled in various ways, however in this case; we will simulate the economic effects of implementing a Waste Discharge Charge System (WDCS).

The sections below provide background on each of these modelling techniques.

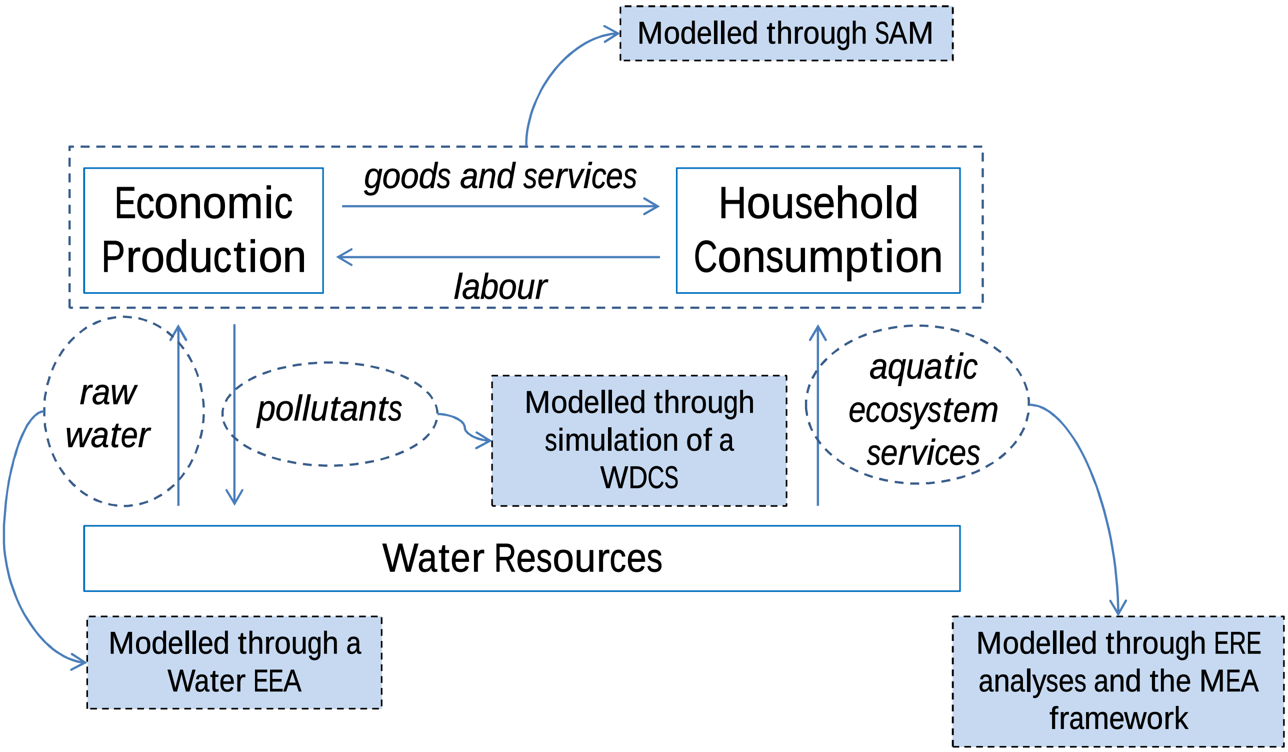

Figure 11: Schematic representation of the economic modelling techniques required to address the transactions of the Crocodile (West) Marico WMA and Matlabas and Mokolo catchments water economy.

6.3 Analyses of the Formal and Informal Economies Using Sectoral Analyses and SAMs

6.3.1 Macro-economic analyses[2]

Water resource management scenarios need to be evaluated in terms of their implications on the broader economy at a regional scale. The WRCS Guidelines proposes the use of a Social Accounting Matrix (SAM) (such as that developed by the Development Bank of Southern Africa (DBSA)) to model the macro-economic and social implications of different scenarios.

A SAM is a matrix that summarises the linkages that exist between the different role players in the economy i.e. business sectors, households and government. Thus, a SAM reflects all of the inter-sectoral transactions in an economy and the activities of households. A household is a very important economic definition, as it is the basic unit where significant decisions regarding important economic variables such as expenditure and saving are taken. A SAM combines households into meaningful groups, and thus enables analysis of different household groups, and its dependence on the rest of the economy. A SAM thus enables modelling of changes in economic activity on economic growth (i.e. the impact on GDP); job creation (i.e. the impact on labour requirements); impact on capital formation; and income distribution (i.e. the impact on low-income, poor households and the total income households).

A SAM enables the simulation of changes in sector turnover (please see the table below for a definition of sectors covered by a SAM) to estimate macro-economic impacts using economic

[2] DWA 2010a

multipliers. Economic models fundamentally incorporate a number of “multipliers” that form the nucleus of the modelling system. A multiplier specifies the nature and extent of the impact of a change in a specific economic quantity (e.g. agriculture) on another economic quantity or quantities (e.g. food manufacturing or employment). Multipliers consist of direct, indirect and induced multipliers. The direct multiplier measures an economic effect occurring in a specific sector, whilst the indirect multiplier measures those effects occurring in the different economic sectors that link backwards and forwards to this sector. The induced effect measures the additional economic activity generated by the spending of additional the salaries and profits generated. Sectoral multipliers are calculated using information contained in the Sectoral SAMs and data obtained from the Reserve Bank of South Africa and Stats SA.

The DBSA has published SAMs for each of the nine Provinces of South Africa (Table 39). The study area contains the Limpopo, Mpumalanga and Gauteng Provinces and therefore the SAMs for these three provinces will be used in the decision framework.

Table 39: Description of the economic sectors addressed by a SAM (Source: WRCS Guidelines (DWA 2010a))

Sector	Description
Agriculture, fishing and forestry (‘Agriculture’)	Includes agriculture, hunting and related services, comprising the following activities: • growing of crops; • market gardening; • horticulture; • mixed farming; • production of organic fertiliser; • forestry; • logging and related services; • fishing; and • operation of fish hatcheries and fish farms.
Mining and quarrying	Includes, *inter alia*: • mining and quarrying of metallic minerals (coal, lignite, gold, cranium ore, iron ore etc.); • extraction of crude petroleum and natural gas; • service activities incidental to oil and gas extraction; • stone quarrying; • clay and sand pits; and • mining of diamonds and other minerals.
Manufacturing	Includes, *inter alia*: • the manufacturing of food products, beverages and tobacco products; • production, processing and preserving of meat, fish, fruit, vegetables, oils, fats; • dairy products and grain mill products; • textile and clothing; • spinning and weaving; • tanning and dressing of leather; • footwear; • wood and wood products; • paper and paper products; • printing and publishing; • petroleum products;

Sector	Description
	• nuclear fuel; and • manufacture of chemical substances.
Electricity, water and gas	These are utilities. This sector includes: • supply of electricity, gas and hot water; • the production, collection and distribution of electricity; • the manufacture of gas and distribution of gaseous fuels through mains; • supply of steam and hot water; and • collection, purification and distribution of water.
Construction	This sector includes: • site preparation; • building of complete constructions or parts thereof; • civil engineering; • building installation; • building completion; and • renting of construction or demolition equipment.
Wholesale and retail trade, hotels and restaurants ('Trade')	This includes: • wholesale and commission trade; • retail trade; • repair of personal household goods; • sale, maintenance and repair of motor vehicles and motor cycles; and • hotels, restaurants, bars, canteens, camping sties and other short-stay accommodation.
Transport, storage and communication ('Transport')	Includes, *inter alia*: • land transport; • railway transport; • water transport; • transport via pipelines; • air transport; • activities of travel agencies; • post and telecommunications; • courier activities; and • storage.
Finance, real estate and business services	This includes: • financial intermediation; • insurance and pension funding; • real estate activities; • renting of transport equipment; • computer and related activities; • research and development; • legal, accounting, book-keeping and auditing activities; • architectural, engineering and other technical activities; and • business activities not classified elsewhere.
Government and social services ('Community services')	Includes, *inter alia*: • public administration and defence; • social and related community services (education, medical, welfare and religious organisations); • recreational and cultural services; and • personal and household services. Other Includes, *inter alia*: • private households; • extraterritorial organisations; and

Sector	Description
	• representatives of foreign governments and other activities not adequately defined.

6.3.2 Analyses of Sector Turnover

SAM analyses require inputs in the form of changes in sector turnover that may result from the scenarios to be modelled. SAM analyses are thus preceded by sector-specific analyses. Sector specific analyses are of a micro-economic nature.

Thus, every scenario to be modelled through a SAM has to be preceded by a sector-specific analysis.

6.4 Analyses of Aquatic Ecosystem Services Using ERE Analyses and the MA Framework

6.4.1 Background

The modelling and estimation of the value of aquatic ecosystem services is done through environmental and resource economics (ERE) modelling.

ERE studies seek to value the stream of future benefits delivered by the set of ecosystem services associated with an ecosystem. The evaluation thus usually begins with a systems analysis, which treats the ecosystem akin to an asset, which delivers benefits in the form of ecosystem services. The analysis begins with a systems analysis, such as that performed during water resource eco-classification and defines the ecosystem that is subject to enquiry. It assembles all relevant and valid scientific information about the system. It defines the boundaries of the entity to be analysed, and the meta-system within which it functions. It defines the biodiversity of the ecosystem.

The term ecosystem here means a natural unit consisting of all plants, animals and micro-organisms (biotic factors) in an area functioning together with all of the non-living physical (abiotic) factors of the environment. The concept of biodiversity, here following Noss (1990), is the living component of the ecosystem. Accordingly, the analysis interprets the ecosystem as a portfolio of abiotic and biotic assets that deliver a specific set of ecosystem services.

Ecosystem services are formally defined by the Millennium Ecosystems Assessment Framework and provide a scientific, logical and transparent definition of the value delivered by an ecosystem, to humans.

The evaluation proceeds to identify chains of causality that exist between ecosystem assets, drivers that impact upon them, and the ecosystem services benefits that are derived from these services. When these chains are defined and quantified through the selection and measurement of appropriate indicators, they form the bases for the development of production functions for each ecosystem service. Thereafter, the production functions are integrated into economic demand functions. A wide variety of ERE valuation techniques exist through which to estimate demand for ecosystem services. Data availability governs the selection of most appropriate valuation techniques, for each type of ecosystem service to be valued. The next step is to value the changes that would result from each development option, as the net present social values of the differences in future flows of ecosystem services.

Finally, an ERE analysis integrates the environmental economic valuation results into the SAM or directly into household benefits. The resultant model / analysis can then be run for each management scenario / project alternative, through a cost-benefit assessment (CBA).

Good ERE studies assist decision-makers to make informed and defendable decisions. The final output of a good ERE study is thus much more than some economic value: it is a transparent cause and effect analysis of management decisions, which communicates clearly.

6.4.2 The Millennium Ecosystems Assessment Framework of Ecosystem Services

The Millennium Ecosystems Assessment (MA) proposes a consistent and standardised classification of environmental goods and services, which it collectively refers to as ecosystem services.

In the MA system, ecosystems are aggregate assets that yield a flow of services, all of which benefit people, much like other capital stocks. These include provisioning services (including the production of fresh water, foods, fuels, fibres and biochemical and pharmaceutical products), cultural services (including non-consumptive uses of the ecosystem for recreation, amenity, spiritual renewal, aesthetic value and education) and regulating services (including the absorption of pollutants, storm buffering, erosion control and the like). The social opportunity cost of developments that change ecosystems accordingly includes the value of the resulting change in ecosystem services. This is makes it possible to evaluate environmental impacts alongside the other costs and benefits of the development options, and so to estimate the net present social value of distinct development options *inclusive of environmental effects*[3].

The MA classification system accommodates the framework of total economic values (TEV) of the environment (i.e. use, non-use and option and bequest values as used in many other studies to date), but supersedes TEV. It provides the analytic linkage between ecosystem function and human well-being.

It is important to recognize that the utilitarian values (the benefits consumed, used or enjoyed) of these services are not additive. Supporting and regulating services can be considered to be similar to intermediate consumption in the economic sense. Provisioning and cultural services are those that enter final consumption. In order to avoid double accounting, only the final consumption services should be valued. The supporting and regulating services in the MA system are the ecosystem functions and processes upon which the provisioning and cultural services depend. They are therefore embedded in those services, and are not evaluated separately, but through production functions.

6.5 Analyses of Water Quality Effects on the Economy Using a WDCS Simulation

6.5.1 Overview

Various aspects of economic development could have detrimental effects on the water quality of water resources, which in turn could affect economic activities such as irrigation productivity, operation and maintenance cost of water infrastructure, subsistence fishing, recreation, tourism and human health.

[3] More than 1,360 international experts have contributed to the MA. The key outputs of the MA have been published in five technical volumes and six synthesis reports. These contain a state-of-the-art scientific appraisal of the condition and trends in the world's ecosystems and the services they provide (such clean water, food, forest products, flood control, and natural resources) and the options to restore, conserve or enhance the sustainable use of ecosystems (MA, 2007).

Typical water pollution drivers include:

- Point-source pollution from wastewater treatment plants;
- Storm water pollution from a variety of sources (engine leaks, tyre and brake wear, fertilizers and pesticides from landscaping and pest management, sediment from erosion of non-landscaped areas and areas disturbed by construction, toxic chemicals from paints, solvents and cleaning compounds, and litter from plastics, paper and cold drink cans);
- Contamination of mine water affected by acid mine drainage and heavy metal concentrations (Huizenga 2004);
- Agricultural runoff (fertilizers, salts, nutrients and pesticides);
- Animal grazing and watering (microbiological, turbidity). (DWA 2010b)

6.5.2 Analytical approach[4]

The economic effects of poor water quality are difficult to measure. Firstly, water quality is an input variable (or intermediate consumption) to final-use goods and services and does therefore not have a direct monetary effect associated with it. Secondly, water quality is often measured by a complex set of indicators or variables, which may change (positively or negatively) along the length of a river and over time. In addition, there is often a disconnect between these water quality indicators and the fitness-for-use of water. The Department of Water Affairs has consequently (and recently) adopted a water quality abatement cost approach, as envisaged in the DWA's Waste Discharge Charge System (WDCS), to management of water quality. Although the details of implementation of the WDCS are still to be finalized, the WDCS approach provides a methodology for evaluating the economic effects of poor water quality.

The WDCS is premised upon the polluter-pays principle, which intends to assign the cost of preventing such damages to polluters, and thus internalizes the cost of pollution prevention into the economy. The WDCS would reduce pollution to a level where the Resource Quality Objectives (RQOs) of the particular catchment area are met (DWA 2007). Cognisance will be taken of the water quality parameters as prescribed by the South African Water Quality Guidelines (SAWQG) (DWAF 1996).

Water pollution abatement costs can be estimated if a marginal abatement cost curve is available. Such a curve is a multivariate mathematical-statistical function, which should ideally be developed, based on empirical data sourced from the particular catchment area within which the pollution problem is located. The marginal abatement cost curve relates a set of independent variables to the cost of water pollution abatement. The WDCS have identified five sets of water quality measures including salinity, pH, nutrient load, chemical oxygen demand (COD) and heavy metals, and these would thus form the independent variables of the abatement cost curve. In mathematical notation, the abatement cost curve is structured as follows:

$$Cj = f(Vj,Eij,Ms,Xj)$$

Where:

Cj: Total abatement cost for a water treatment plant

[4] DWA 2010b

Vj: Total annual wastewater treated

Eij: Vector of effluent/influent ratios for n pollutant measures

Ms: Vector of input prices at each water treatment plant

Xj: Vector of relevant water treatment plant characteristics

Figure 12 presents a simplified example of a marginal abatement cost curve.

The economic effect of reduced water quality is therefore quantified by estimating the cost of abatement required to improve the water quality category of the each IUA to its current state.

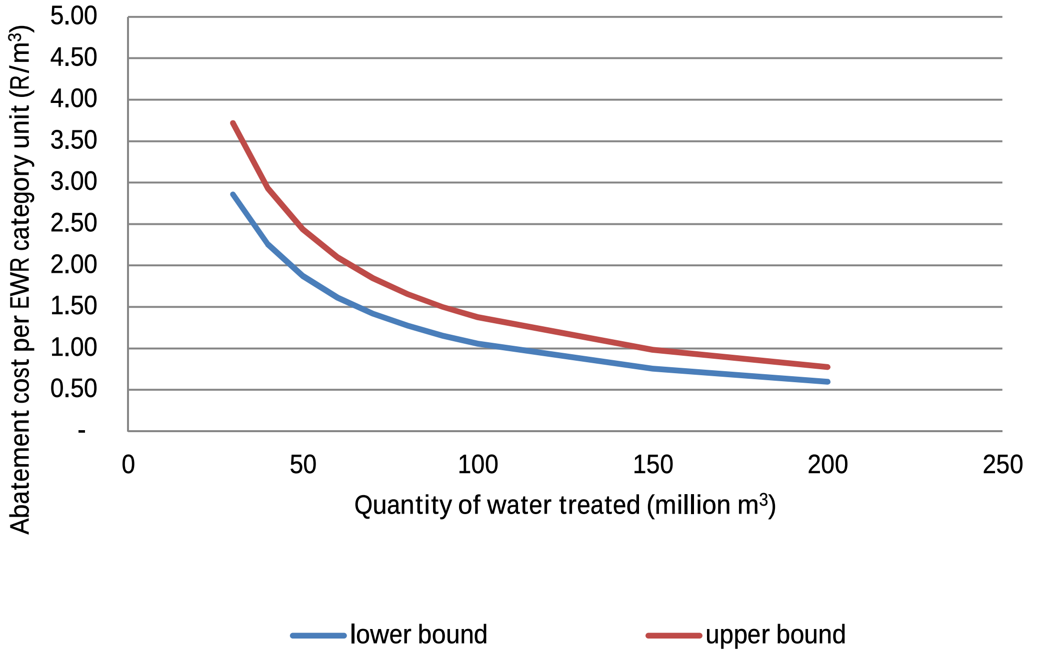

Figure 12: Schematic representation of the marginal abatement cost curve for water quality developed for this study.

6.6 Analyses of Water Yield Effects on the Economy Using a Water SEEA

The economic transactions associated with water supply and use in the economy is officially captured in a format, which is referred to as Environmental Economic Accounts for Water. The United Nations sets out guidelines the System of Environmental Economic Accounting for Water (SEEAW). Statistics South Africa has developed various Water EEAs for South Africa. These accounts are compatible with SAMs.

Water EEAs provide an accounting framework that enables the integration of specialised physical resource sector data with other information on the economics of water supply and use in a structure that is consistent with the way data on economic activities are organised in the System of National Accounts (SNA). In addition to facilitating integration and sharing of a more comprehensive knowledge base, the Natural Resource Accounting (NRA) framework provides the basis for evaluating the consistency between the objectives and priorities of water resource management and broader goals of economic development planning and policy at national and local scales.

In Water EEAs, physical accounts present the physical flow of water resources (measured by volume), and monetary accounts convert the volumetric flow of water to economic values.

The physical accounts provide information on the volumetric supply and use of water. The monetary accounts provide a basket of measures that describe the economic and welfare impacts of water supply and use.

6.7 Modelling Scenarios

6.7.1 Overview

The overall analysis framework thus consists of four analytical components:

- Sectoral and SAM analyses;
- ERE analyses based on the MA Framework;
- Water quality analyses using a WDCS simulation; and
- Water yield analyses using a Water SEEA.

The analysis starts with the development of a set of plausible water resource management scenarios for all the IUAs. The risks to every economic sector, aquatic ecosystems and households are estimated, where after these risks are quantified through the Water SEEA, the WDCS simulation, the ERE analysis and finally the sectoral and SAM analyses.

Such analyses will enable cost-benefit assessment comparison of the different scenarios.

The analyses should enable modelling of the effects of various scenarios, such as those proposed by the DWA Reconciliation Strategy:

- Implementation of the ecological reserve;
- Population growth;
- Changes in key economic trends – such as growth in mining;
- Water conservation and demand management implementation;
- Water re-use and recycling;
- Groundwater development;
- Water transfers (from the East Rand of Vaal Dam); and
- Removal of Invasive Alien Plants.

7 BIOPHYSICAL AND ALLOCATION NODES

Biophysical nodes are established to account for interactions between ecosystems and management (allocation) nodes are established to account for specific catchment issues or impacts and to serve as modelling points for the Classification process in a catchment. The nodes are used to assess the response of upstream water resources to changes in water quality, quantity and timing (DWA, 2007). Biophysical nodes should be located at interactions between ecosystems and at the end points of eco-system reaches to account for interactions. Management or allocation nodes should be located at the downstream edge of a reach of interest, as required for modelling and to allow for meaningful trade-offs.

The establishment of biophysical and management (allocation) nodes is guided by a number of considerations. The key considerations are:

- Significant water resources
- Biophysical and eco-regional characteristics;
- Location of Ecological Water Requirement (EWR) sites and ecological information;
- Ecological Importance and Sensitivity categories of water resources;
- Present ecological state;
- Broad-scale hydrological and geomorphological characters;
- Water infrastructure; and
- Water management, planning and allocation information.

7.1 Identification of proposed nodes per IUA within the Crocodile (West), Marico, Mokolo and Matlabas catchments

7.1.1 Rivers

The proposed nodes for the IUAs of the Crocodile (West), Marico, Mokolo and Matlabas catchments catchment are summarised in Table 40. These are preliminary nodes based on existing information. The nodes identified are currently a combination of where (i) EWR sites are situated; (ii) management units (hydro nodes) have been identified for the yield model and (iii) at the outlet of quaternary catchments.

7.1.2 Wetlands

Nodes on the river downstream of important wetlands identified in the catchments of these tributaries and/or main stem rivers have been included.

7.1.3 Dams/lakes

For all major dams (water infrastructure) identified in the water resources reconciliation study, nodes have been included. Any other smaller dams recognised of having an important role in the regulation of the water resources have also been included.

7.1.4 Water quality

Water quality has also been considered for all the water resource components and where good quality or the need to improve water quality is a requirement additional nodes have been included.

7.1.5 Proposed Nodes

Based on the above considerations proposed biophysical and allocation nodes have been established in each of the IUAs delineated for the Crocodile (West), Marico, Mokolo and Matlabas catchments. The nodes proposed will be confirmed and finalised at the conclusion of Step 3 of the Classification Process, during the ‘quantification of the EWR and determination of the changes in non-water quality ecosystem goods, services and attributes’.

The nodes as tabled below (Table 40) and illustrated in Figure 13 have been updated with information from the 2012 PES/EIS study, NFEPA and information on important identified wetlands and groundwater areas. Those areas where water quality impacts exist and where management and planning information indicated an area of interest, nodes have been identified. Typically, areas or water resources with a high EIS or high conservation value has required the inclusion of a biophysical a node downstream of the area.

Table 40: Proposed biophysical and management (allocation) nodes per IUA within the Crocodile (West), Marico, Mokolo and Matlabas catchments

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
1	HN1	A21A	Rietspruit (source) to Rietvlei Dam (CROC_EWR16)	Low	Low	C	Management, urban impacts, Rietvlei Dam	Quantity/quality, dolomitic
	HN2	A21B	Sesmylspruit with its' tributaries to confluence with Hennops	Moderate	Moderate	E	Biophysical, urban impacts	Quality
	HN3	A21C	Modderfonteinspruit to confluence with Jukskei	Moderate	Moderate	E	Biophysical, urban, industrial;	Quality
	HN4	A21C	Klein Jukskei at confluence with Jukske	Moderate	Moderate	E	Biophysical. semi urban	Quality
	HN5	A21C	Jukskei River at CROC_ EWR2	Moderate	Moderate	E	Biophysical, WWTW	Quantity/quality
	HN6	A21D	Bloubankspruit and tributaries (outlet of quaternary/confluence with Crocodile)	Moderate	Moderate	D	Biophysical, acid mine drainage, dolomitic, Botanical gardens, Cradle of Humankind	Quality/quantity
	HN7	A21A, B, H	Hennops (source) to confluence with Crocodile	Moderate	Moderate	D	Biophysical, urban, industrial	Quantity/quality
	HN8	A21H	Swartspruit to Hartbeespoort Dam	Moderate	Moderate	D	Semi urban	Quality
	HN9	A21E, H	Crocodile (source) to CROC_EWR1	Moderate	Moderate	D	Biophysical, urban	Quantity/quality
	HN10	A21H, J	Crocodile at Hartbeespoort Dam, outlet of IUA1	High	High	C/D	Hartbeespoort Dam, Management	Quantity/quality
	HN11	A23A	Pienaars(source) and including Moreletaspruit and Edendalespruit to outlet of Roodeplaat Dam	Low	Low	E	Management, urban, industrial; WWTW, canalised, Roodeplaat Dam	Quantity/quality
	HN12	A23B	Pienaars from Roodeplaat Dam to outlet of quaternary catchment (outlet of IUA1) (CROC_EWR4)	High	High	C	Management, sand mining	Quantity/quality
	HN13	A23B	Boekenhoutspruit to confluence with Pienaars	High	High	C	Biophysical	Quantity/quality
	HN14	A23D	Skinnerspruit (source) to confluence with Apies	Low	Low	E	Biophysical, urban, canalised urban river	Quantity/quality
	HN15	A23D, E	Apies (source) to Bon Accord Dam, below the dam at outlet of IUA1	Low	Low	F	Management, dolomitic at source	Quantity/quality,
2	HN16	A21F	Magalies below Maloney's Eye at CROC_EWR9	Very high	Very high	B	Biophysical, dolomitic at source	Quantity
	HN17	A21G, F	Magalies (CROC_EWR15)	Low	Low	C/D	Management	Quantity/quality

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
	HN18	A21G, F	Skeerpoort at outlet of IUA2	Low	Low	C/D	Management	Quantity/quality
3	HN19	A21J	Rosespruit at confluence with Crocodile	High	High	C/D	Biophysical	Ecological
	HN20	A21J	Crocodile from Hartbeespoort Dam to upstream Roodekopjes Dam, outlet of IUA3	Moderate	Moderate	D	Biophysical	Ecological
4	HN21	A21K	Sterkstroom (source) to Buffelspoort Dam (CROC_EWR11)	High	High	C	Biophysical	Quantity/quality
	HN22	A21K	Sterkstroom from Buffelskloof Dam to Roodekopjes Dam, outlet of IUA4	High	High	C	Management	Quantity/quality
	HN23	A22G	Hex (source) to Olifantsnek Dam	Moderate	High	C	Management, Olifantsnek Dam	Quantity/quality
	HN24	A22H	Waterkloofspruit (CROC_EWR14) to confluence with Hex	Low	Low	B/C	Biophysical, wetland, nature reserve	Wetland driven
	HN25	A22H	Hex from Olifantsnek Dam to Bospoort Dam	Moderate	Moderate	D	Management, urban, mining, Bospoort Dam	Quantity
	HN26	A22J	Hex from Bospoort Dam to Vaalkop Dam (CROC_EWR6)	Moderate	Moderate	D	Biophysical, Bospoort Dam	Quantity/quality
	HN27	A22J	Elands from Vaalkop Dam to confluence with Crocodile, outlet of IUA4	Moderate	Moderate	D	Management, Vaalkop Dam	Quantity/quality
5	HN28	A22A	Elands (source) to Swartruggens Dam (CROC_EWR10)	High	High	C	Management	Quantity
	HN29	A22A	Elands from Swartruggens Dam to Lindleypoort Dam	Moderate	High	C	Management, Swartruggens Dam, WWTWs	Quantity/quality, management
	HN30	A22B	Koster (source) to Koster Dam	Moderate	High	C	Biophysical, wetland	Wetland driven
	HN31	A22C, A22D	Selons to confluence with Elands	Moderate	High	C	Biophysical	Quantity/quality
	HN32	A22E, A22F	Elands from Lindleypoort Dam (CROC_EWR13) to Vaalkop Dam, outlet of IUA5	Low	Low	C	Management, Lindleyspoort Dam	Quantity/quality, management
6b	HN33	A31B	Polkadraaispruit to confluence with Marico (MAR_EWR6)	Moderate	Moderate	B/C	Biophysical	Quantity/quality
	HN34	A31B	Marico from MAR_EWR2 to N4 road at town	Very High	Very High	B	Biophysical	Quantity/quality
	HN63	A31B	Marico from N4 road to Marico-Bosveld Dam, outlet of IUA6b	Very High	Very High	B	Biophysical	Quantity/quality
6a	HN64	A31D	Malmaniesloop to confluence with Klein Marico Klein Marico and tributaries upstream of	High	High	C	Biophysical, groundwater, WWTW, urban	Groundwater node

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
			Zeerust					
	HN35	A31D	Klein Marico from Zeerust to Klein Maricopoort Dam	High	High	C	Biophysical	Quantity/quality
	HN65	A31E	Klein Mario from Klein Maricopoort Dam to	High	High	C	Management, Klein Maricopoort Dam	Quantity/quality
	HN36	A31E	Kromellemboog Dam (MAR_EWR5), outlet of IUA6a	Moderate	Moderate	C	Management, Kromellemboog Dam	Quantity/quality
7	HN37	A31A	Kaaloog-se-Loop (MAR_EWR1) to concluence with Groot Marico	Very High	Very High	B	Biophysical, dolomitic	Quantity
	HN38	A31A	Vanstraatenvlei and tributaries at confluence with Kaaloog-se-Loop, outlet of IUA7	High	High	B	Biophysical, dolomitic	Quantity
8	-	A31C	Groundwater	-	-	-	Management, groundwater	Groundwater node
9	HN66	D41A	Molopo at outlet of wetland	-	-	-	Management, groundwater	Groundwater node
	HN67	D41A	Molopo at Modimola	Low	Low	E	Biophysical	Quality
	HN39	D41A	Molopo at outlet of IUA9	Low	Low	E	Management	Quality
10	HN68 -	A10A A10A, B, C	Ngotwane from Dinokana to Ngotwane Dam Ngotwane from Dinokana to outlet of IUA10	- -	- -	- -	Management, groundwater, Ngotwane Dam Management	Groundwater node
11a	HN40	A31F, G, A32A	Marico from Marico Bosveld and Kromelmboog Dam to Molatedi Dam (MAR_EWR3), outlet of IUA11a	High	High	C/D	Management, Madikwe Nature Reserve, Marico-Bosveld Dam	Quantity
11b	HN41	A32D, E	Marico from Molatedi Dam to confluence with Crocodile (MAR_EWR4), outlet of IUA11b	High	High	C	Management, Molatedi Dam, Twasa weir, international, Madikwe Nature Reserve	Quantity/quality
12	HN42	A24D, E, F	Bierspruit to confluence with Crocodile River, outlet of IUA12	Moderate	Moderate	D	Mining	Seasonal rivers, quantity
13	HN43	A24G, A24H	Sand to confluence with Crocodile	Moderate	Moderate	C	Biophysical	Quantity/quality

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
	HN44	A21L, A24A-C, A24H	Crocodile from Roodekopjes Dam (CROC_EWR7) to proposed Mokolo transfer (CROC_EWR8)	Moderate	Moderate	D	Management, irrigation, mining, transfer	Quantity/quality,
	HN45	A24J	Crocodile from CROC_EWR8 to confluence with Limpopo, outlet of IUA13	Moderate	Moderate	C	Management for international, groundwater	Quantity/quality
14	HN46	A23G	Platspruit (source, CROC_EWR12) to confluence with Pienaars	Moderate	Moderate	B/C	Biophysical	Quantity
	-	A23C, A23F	Wetland at Pienaars & Apies confluence and inflow to Klipvoor Dam	Moderate	Moderate	C	Biophysical; floodplain	Quantity/wetland
	HN47	A23H	Karee/Rietspruit to confluence with Pienaars	Moderate	Moderate	C	Biophysical	Quantity
	HN48	A23J A23J, A23L	Moretele (Pienaars) to confluence with Crocodile (CROC_EWR5), outlet of IUA14	High	High	D	Management, Klipvoor Dam, Borakalalo Nature Reserve	Quantity/quality
	HN49	A23K	Tolwane to confluence with Moretele	High	High	D	Biophysical	Quantity/quality
15	HN50	A42A	Sand (source) to confluence with Grootspruit	Moderate	Moderate	C	Biophysical	Quantity/quality
	HN51	A42B	Grootspruit (source) to confluence with Sand	Moderate	Moderate	C	Biophysical	Quantity/quality
	HN52	A42C	Mokolo to confluence with Dwars (MOK_EWR1a)	High	High	C/D	Biophysical	Quantity/quality
	HN53	A42D, A42E	Mokolo to confluence with Sterkstroom (MOK_EWR1b)	High	High	B/C	Biophysical	Quantity/quality
	HN54	A42D	Sterkstroom (source) to confluence with Mokolo, including Dwars	High	High	B/C	Biophysical, Ecological	Quantity,
	HN55	A42F	Mokolo from Sterkstroom to Mokolo Dam (MOK_EWR2), outlet of IUA15	Very high	Very high	B/C	Biophysical	Quantity/quality
16	HN56	A42G	Rietspruit (source) to Mokolo confluence	Moderate	Moderate	B/C	Biophysical	Quantity/quality
	HN57	A42G	Mokolo below dam (MOK_EWR3) to Rietspruit confluence (MOK_EWR4)	Very High	Very High	B/C	Management, Mokolo Dam	Quantity/quality
	HN58	A42H, A42J	Mokolo from MOK_EWR4 to confluence with Limpopo, outlet of IUA16.	Very High	Very High	C	Biophysical, floodplain	Use wetlands requirements for river
17a	HN59	A41A	Mothlabatsi to confluence with Mamba	Very High	Very High	B	Biophysical, Marekele National Park	Quantit,
	HN60	A41B	Mamba to confluence with Mothlabatsi, outlet of IUA17a	Moderate	Moderate	B/C	Biophysical	Quantity

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
17b	HN61	A41C	Matlabas from Mamba confluence to MAT_EWR2	High	High	B/C	Biophysical	Quantity/quality
	HN62	A41C, D	Matlabas from MAT_EWR2 to confluence with Limpopo, outlet of IUA17b	Moderate	Moderate	B	Management, international	Quantity/quality

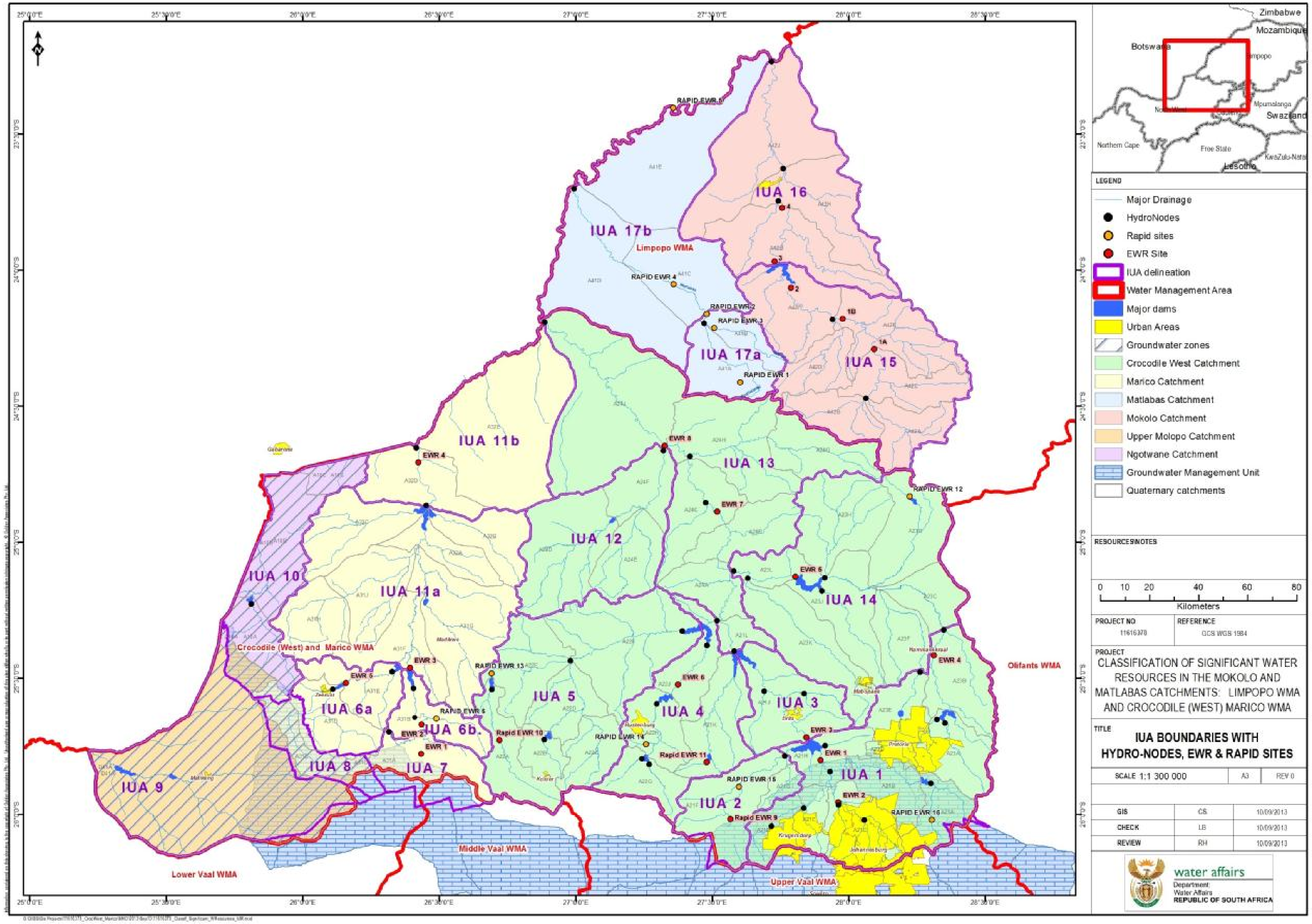

Figure 13: IUAs within the Crocodile (West), Marico, Mokolo and Matlabas catchments indicating location of proposed nodes and EWR sites

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APPENDIX A

RESULTS OF THE EVALUATION OF PES AND EIS PER SUB-QUENARY REACH IN THE CROCODILE (WEST), MARICO, MOKOLO AND MATLABAS CATCHMENTS (2012)

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A21A-01171	Hennops	D	D	C	D	Moderate	Moderate
A21A-01178	Rietvlei	D	D	C	D	Moderate	Moderate
A21B-01135	Hennops	E	E	D	E	Moderate	Moderate
A21C-01183	Jukskei	E	E	D	E	Low	Low
A21C-01232	Jukskei	E	E	E	E	Low	Low
A21C-01254	Braamfontein spruit	E	E	E	E	Low	Low
A21C-01167	Jukskei	E	E	D	E	Moderate	Moderate
A21C-01215	Jukskei	E	E	D	E	Low	Low
A21C-01262	Braamfontein spruit	E	E	E	E	Low	Low
A21C-01263	Sandspruit	E	E	E	E	Low	Low
A21C-01269	Jukskei	E	E	E	E	Low	Low
A21C-01195	0	E	E	E	E	Low	Low
A21C-01268	Modderfontein	E	E	E	E	Low	Low
A21C-01211	Klein-Jukskei	E	E	E	E	Low	Low
A21D-01185	Bloubankspruit	D	E	D	D	Moderate	Moderate
A21E-01162	Crocodile	E	E	E	E	Moderate	Moderate

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A21E-01224	Crocodile	E	E	E	E	Moderate	Moderate
A21F-01231	Bloubank	D	D	D	D	Moderate	Moderate
A21F-01116	Magalies	D	D	D	D	Moderate	Moderate
A21F-01156	Klein	D	D	D	D	Moderate	Moderate
A21F-01168	Magalies	C	C	D	C	Moderate	High
A21F-01208	Magalies	C	C	D	C	Moderate	Moderate
A21F-01307	Brandvlei	D	C	E	D	Moderate	Moderate
A21G-01126	Skeerpoort	C	C	C	C	Moderate	Moderate
A21H-01107	Crocodile	D	E	D	D	Moderate	High
A21H-01112	Crocodile					None	None
A21H-01097	Magalies	D	D	D	D	Low	Moderate
A21H-01108	Crocodile					None	None
A21H-01158	Crocodile	E	E	D	E	Moderate	High
A21H-01069	Swartspruit	D	D	C	D	Moderate	Moderate
A21H-01113		C	C	C	C	Low	None
A21J-01011	Crocodile	D	E	D	D	Moderate	Moderate

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A21J-0921	Crocodile	D	D	D	D	Moderate	High
A21J-0976	Crocodile	D	D	C	D	Moderate	Moderate
A21J-0999		B	C	B	B	Low	Low
A21J-01026		D	D	D	D	Low	Low
A21J-01053	Crocodile	E	E	E	E	Moderate	High
A21J-0949	Ramogatla	D	D	D	D	Low	Low
A21J-0972	Rosespruit	D	D	C	D	Moderate	Moderate
A21J-0989	Crocodile	C	C	C	C	Moderate	Moderate
A21J-0980	Rosespruit	C	C	C	C	Moderate	Moderate
A21J-0996	Kareespruit	D	C	D	D	Moderate	Moderate
A21K-0932	Sterkstroom					None	None
A21K-01023	Sterkstroom	D	D	D	D	High	High
A21K-0975	Tshukutswe	C	C	C	C	Moderate	High
A21K-0959	Gwathle	C	D	C	C	High	High
A21K-01124	Sterkstroom	C	C	C	C	Moderate	Moderate
A21K-01125	Kleinwater	B	B	B	B	High	High

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A21K-01028	Maretlwana	D	D	C	D	Moderate	Moderate
A21L-0853	Crocodile	D	E	D	D	Moderate	Moderate
A22A-01001	Elands	C	C	C	C	Moderate	High
A22A-0992		D	D	C	D	None	None
A22B-01014	Koster	C	D	C	C	Moderate	High
A22C-01021	Selons	C	C	C	C	Low	Low
A22C-01054	Selons	C	C	C	C	Low	Low
A22C-01101	Selons	C	C	C	C	Low	Low
A22C-01103		C	C	C	C	Moderate	Low
A22C-01058	Koedoespruit	B	A	B	B	Moderate	Moderate
A22D-0941	Selons	C	C	C	C	Moderate	Moderate
A22D-0966	Selons	C	C	C	C	Moderate	Moderate
A22D-0970	Dwarsspruit	C	C	C	C	Moderate	Moderate
A22E-0856	Roosspruit	C	C	C	C	Moderate	Moderate
A22E-0931	Elands	C	C	C	C	Moderate	Moderate
A22E-0830	Roosspruit	B	C	B	B	Moderate	Low

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A22E-0940	Elands	D	E	D	D	Moderate	High
A22E-0832		C	C	B	C	Moderate	Low
A22E-0955	Brakkloofspruit	C	C	C	C	Moderate	Moderate
A22F-0791	Elands	D	D	C	D	High	High
A22F-0845	Elands	C	C	C	C	Moderate	High
A22F-0869	Elands	D	D	D	D	High	Moderate
A22F-0895	Elands	C	C	C	C	Moderate	Moderate
A22F-0918	Elands	D	D	D	D	Moderate	Low
A22F-0939	Elands	C	D	C	C	Moderate	Moderate
A22F-0781	Madibamatsho	C	C	C	C	Low	Low
A22F-0822	Sandspruit	D	D	D	D	Low	Low
A22F-0891	Molapongwamonga na	C	D	C	C	Low	Low
A22F-0818	Elands	D	D	D	D	Low	Moderate
A22F-0790	Mankwe	C	C	C	C	High	Moderate
A22F-0901	Leragane	E	E	D	E	Moderate	Moderate
A22G-01131	Hex	C	C	C	C	Moderate	High

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A22G-01102	Rooikloofspruit	D	D	C	D	Moderate	Moderate
A22H-01076	Hex	D	D	C	D	Low	Moderate
A22H-01094	Hex	D	D	D	D	Moderate	Moderate
A22H-01070	Waterkloofspruit	B	B	B	B	Moderate	Moderate
A22H-01077	Sandspruit	D	D	D	D	Low	Low
A22J-0800	Matshikiti	C	C	C	C	Low	Low
A22J-0831	Elands	C	D	C	C	Moderate	Moderate
A22J-0865	Elands	D	E	D	D	Low	Moderate
A22J-0878	Hex	E	E	E	E	Moderate	Moderate
A23A-01041	Pienaars	E	E	F	E	None	None
A23A-01049	Hartbeesspruit	D	D	D	D	Moderate	Moderate
A23A-01072	Hartbeesspruit	E	E	E	E	Low	Low
A23A-01074	Moretele	E	E	E	E	Low	Low
A23A-01045	Edendalespruit	D	D	D	D	Low	None
A23A-01056	Pienaars	D	D	D	D	Moderate	Moderate
A23B-0896	Pienaars	C	D	C	C	Moderate	Moderate

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	**Ecological importance**: riparian-wetland-in-stream vertebrates (ex fish) **rating**	**Ecological sensitivity:** riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes **rating**
A23B-01012	Roodeplaatspruit	D	D	D	D	Moderate	Moderate
A23B-01034	Pienaars	D	E	D	D	Low	Low
A23B-0889	Boekenhoutspruit	C	D	C	C	Moderate	Moderate
A23C-0751	Pienaars	C	C	B	C	Moderate	High
A23D-01104	Skinnerspruit	E	E	E	E	Low	Low
A23D-01105	Apies	F	F	E	F	Low	Low
A23D-01110	Walkerspruit	F	F	E	F	None	None
A23D-01117	Apies	E	E	E	E	Low	None
A23E-01080	Wonderboom spruit	E	E	E	E	Low	None
A23E-01071	Apies	F	F	E	F	Low	Low
A23F-0801	Tshwane	D	D	C	D	Moderate	Moderate
A23F-0827	Apies	E	E	D	E	Moderate	Moderate
A23F-0828	Tshwane	D	E	D	D	Low	None
A23G-0630	Plat	C	D	C	C	Low	Low
A23G-0593	Bad se Loop	D	D	C	D	Low	Moderate
A23G-0573	Plat	D	D	C	D	Moderate	Moderate

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A23H-0619	Kareespruit	C	C	C	C	Low	None
A23H-0691	Marierietsa	C	C	C	C	Low	None
A23H-0607	Lepenya	B	C	B	B	Low	Low
A23H-0677	Marierietsa	C	C	C	C	Low	Low
A23H-0569	Tooyspruit	C	C	C	C	Moderate	Moderate
A23H-0572	Rietspruit	B	C	B	B	Low	None
A23H-0595	Droekloofspruit	C	C	C	C	Low	None
A23H-0622	Rietspruit	B	C	B	B	Moderate	Moderate
A23H-0588	Kareespruit	C	C	C	C	Low	None
A23J-0710	Moretele	C	C	C	C	Moderate	Moderate
A23J-0736	Moretele	C	C	B	C	Moderate	High
A23J-0793	Pienaars	C	C	B	C	Moderate	Moderate
A23J-0717	Pienaars	D	D	C	D	Low	Low
A23J-0782	Kutswane	D	D	D	D	Moderate	Low
A23K-0759	Tolwane	D	D	D	D	High	High
A23K-0984		D	D	D	D	Low	Low

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	**Ecological importance**: riparian-wetland-in-stream vertebrates (ex fish) **rating**	**Ecological sensitivity:** riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes **rating**
A23K-0988	Sand	D	E	D	D	Moderate	Low
A23L-0708	Pienaars	C	C	C	C	Moderate	High
A23L-0706	Pienaars	C	C	C	C	High	High
A23L-0697		C	C	C	C	Low	Low
A24A-0749	Crocodile	C	C	C	C	Moderate	Moderate
A24A-0760	Crocodile	D	D	D	D	Moderate	Moderate
A24A-0729	Motlhabe	C	C	C	C	Moderate	Low
A24B-0669	Crocodile	D	D	E	D	High	High
A24B-0600	Sleepfonteinspruit	B	C	B	B	Moderate	Low
A24C-0536	Crocodile	D	D	E	D	Moderate	Moderate
A24C-0596	Crocodile	D	D	E	D	Moderate	Moderate
A24C-0617	Klipspruit	C	C	B	C	Low	None
A24D-0603	Kolobeng	D	C	D	D	Moderate	Low
A24D-0611	Magoditshane	C	C	C	C	Low	None
A24D-0665	Bofule	C	C	C	C	Low	Low
A24D-0676	Kolobeng	C	C	C	C	Low	Low

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	**Ecological importance**: riparian-wetland-in-stream vertebrates (ex fish) **rating**	**Ecological sensitivity:** riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes **rating**
A24D-0690	Kolobeng	C	C	B	C	Moderate	Low
A24D-0604		C	C	B	C	Low	None
A24D-0723	Bofule	C	C	C	C	Low	None
A24D-0703	Kolobeng	C	C	C	C	Low	None
A24D-0722	Wilgespruit	C	C	C	C	Low	None
A24D-0716	Mothlabe	D	D	C	D	Low	None
A24E-0623	Brakspruit	C	C	C	C	Low	None
A24E-0642	Sefathlane	C	D	C	C	Moderate	Low
A24E-0652	Phufane	C	C	C	C	Low	None
A24E-0696	Sefatlhane	C	C	C	C	Low	None
A24E-0688	Lesobeng	B	B	B	B	Moderate	Low
A24F-0580	Bofule	C	D	C	C	Moderate	Low
A24F-0517	Bierspruit	D	D	D	D	Moderate	Moderate
A24G-0494	Sand	B	B	B	B	Low	None
A24G-0521	Sand	B	B	B	B	Low	None
A24G-0528		B	B	B	B	Low	None

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A24G-0543	Monyagole	B	B	B	B	Low	None
A24H-0500	Sand	B	B	B	B	Moderate	Moderate
A24H-0505	Sand	B	B	B	B	Moderate	Moderate
A24H-0507	Sand	B	B	B	B	Moderate	Moderate
A24H-0510	Crocodile	D	D	C	D	Moderate	Moderate
A24H-0516	Crocodile	D	D	C	D	Moderate	Moderate
A24H-0523	Vaalwaterspruit	C	C	B	C	Moderate	Moderate
A24H-0524		B	B	B	B	Low	None
A24H-0451		D	D	D	D	Low	None
A24H-0478	Sand	B	B	B	B	Moderate	Moderate
A24H-0538		B	B	B	B	Moderate	Moderate
A24H-0457	Sondags	B	B	B	B	Moderate	Moderate
A24H-0535	Vaalwaterspruit	B	C	B	B	Moderate	Moderate
A24J-0324	Crocodile	D	D	C	D	Moderate	Moderate
A24J-0413	Crocodile	D	D	C	D	Moderate	Moderate
A24J-0438	Crocodile	D	D	D	D	Moderate	Moderate

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A24J-0363	Majadibodu	B	B	B	B	Low	None
A24J-0401		B	C	B	B	Low	None
A24J-0450		C	B	C	C	Low	None
A10A-0785		D	D	D	D	Low	Low
A10A-0838		D	D	D	D	Low	Moderate
A10A-0839		D	D	C	D	Low	Moderate
A10A-0914		C	C	C	C	Low	Moderate
A10A-0915		D	D	D	D	Low	Moderate
A10A-0971		C		C	C	None	None
A10A-0985		B		B	B	None	None
A10B-0	Ngotwane	D	D	D	D	Moderate	Moderate
A10B-0641	Ngotwane	D	D	D	D	Low	Low
A10B-0735		C	C	C	C	Low	Low
A10B-0764		C	D	C	C	Moderate	Moderate
A10B-0765		B	B	B	B	Low	Low
A31A-01059		B	C	B	B	high	high

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A31A-01063	Vanstraatensvlei	B	B	B	B	Moderate	High
A31A-01084	Vanstraatensvlei	B	C	B	B	Moderate	Moderate
A31A-01087	Vanstraatensvlei	A	A	A	A	Moderate	Moderate
A31B-01009	Polkadraaispruit	C	C	C	C	Moderate	Moderate
A31B-01039	Groot-Marico	C	C	C	C	High	High
A31B-0923	Groot-Marico	D	D	D	D	Moderate	High
A31C-0964	Malmanieloop	C	C	B	C	Low	Moderate
A31D-01006	Klein-Marico	C	C	C	C	Low	Low
A31D-01019	Klein-Marico	B	B	C	B	Low	Low
A31D-01022		C	C	C	C	Low	Low
A31D-01032		C	B	C	C	Low	None
A31D-01036		C	C	D	C	Moderate	Low
A31D-01040		D	C	D	D	Low	None
A31D-01064	Rhenosterfontein	C	C	C	C	Low	Low
A31D-0967	Kareespruit	C	C	D	C	Low	Low
A31D-0968	Kareespruit	D	D	D	D	Low	Low

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	**Ecological importance**: riparian-wetland-in-stream vertebrates (ex fish) **rating**	**Ecological sensitivity:** riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes **rating**
A31D-0983	Klein-Marico	C	C	C	C	Low	Low
A31D-0986		D	D	D	D	Low	Low
A31E-0926	Klein-Marico	D	D	C	D	Moderate	Moderate
A31E-0948	Klein-Marico	C	C	C	C	Moderate	Moderate
A31E-0951	Wilgeboomspruit	C	C	B	C	Moderate	High
A31E-0960		C	C	C	C	Moderate	Moderate
A31F-0768	Groot-Marico	D	E	D	D	Moderate	Moderate
A31F-0884	Klein-Marico	D	E	D	D	Moderate	Moderate
A31F-0906	Lethlakane	D	D	C	D	Moderate	1
A31F-0907	Groot-Marico	D	D	D	D	Moderate	Moderate
A31G-0687	Madikwene	C	C	B	C	1	Moderate
A31G-0720	Sedutlane	C	C	B	C	1	1
A31G-0742	Madikwene	B	C	B	B	1	1
A31G-0779	Tholwane	D	D	D	D	Low	Moderate
A31G-0850	Metsolodi	C	C	C	C	Low	Low
A31G-0868	Tholwane	C	D	C	C	Low	Low

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	**Ecological importance**: riparian-wetland-in-stream vertebrates (ex fish) **rating**	**Ecological sensitivity:** riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes **rating**
A31G-0933	Lesigwane	D	D	C	D	Low	Low
A31G-0935	Tholwane	C	C	C	C	Low	Low
A31H-0745	Sandsloot	C	C	C	C	Low	Low
A31H-0775	Sandsloot	D	D	C	D	Low	Moderate
A31H-0798	Klipspruit	C	C	C	C	Moderate	Low
A31H-0802		C	B	C	C	Moderate	Low
A31H-0879		B	B	B	B	Moderate	Low
A31H-0890	Sandsloot	C	C	C	C	Low	Low
A31J-0668	Sehubyane	C	C	B	C	Moderate	Moderate
A31J-0684	Kgabana la Thukhwi	D	D	D	D	Moderate	Moderate
A31J-0702	Sandsloot	C	C	C	C	Moderate	Moderate
A31J-0707	Sandsloot	C	C	C	C	Low	Low
A31J-0727	Springboklaagte	C	C	C	C	Low	Low
A31J-0740	0	B	C	B	B	Low	Low
A31J-0789	Sandsloot	B	B	B	B	Low	Low

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A31J-0797	Springboklaagte	C	B	C	C	Low	None
A31J-0810	0	C	C	D	C	Moderate	High
A31J-0813	Springboklaagte	C	C	C	C	Low	Low
A31J-0817	0	C	C	C	C	Moderate	Low
A32A-0621	Marico					None	None
A32A-0662	Marico					Low	Low
A32A-0666	Pitsedisulejang	C	C	C	C	Low	Moderate
A32A-0671	0	C	C	C	C	Low	None
A32A-0693	0	C	D	C	C	Low	None
A32B-0615	Kgolane	C	C	C	C	Moderate	Low
A32C-0582	Brakfonteinspruit	C	C	C	C	Low	Low
A32C-0586	0	B	B	B	B	Low	Low
A32C-0615	Marico					None	None
A32C-0625	Brakfonteinspruit	B	B	B	B	Low	Low
A32C-0635	Brakfonteinspruit	B	B	B	B	Low	Low
A32C-0645	0	C	C	C	C	Low	Low

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	**Ecological importance**: riparian-wetland-in-stream vertebrates (ex fish) **rating**	**Ecological sensitivity:** riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes **rating**
A32D-0514	Marico	C	D	C	C	Moderate	Moderate
A32D-0518	0	C	C	C	C	Low	None
A32D-0529	Maselaje	B	B	B	B	Low	Low
A32D-0539	Marico	C	C	C	C	Moderate	Moderate
A32E-00337_Lenkwane	Lenkwane	C	D	C	C	Low	None
A32E-00337_Marico1	Marico	C	C	C	C	Moderate	Low
A32E-00430_Lengope la	Lengope la Kgamanyane	C	C	C	C	Low	Low
A32E-00430_Marico	Marico	C	C	C	C	Moderate	Moderate
A32E-0456_Elandslaagte	Elandslaagte	C	C	C	C	Low	Low
A32E-00456_Marico	Marico	D	E	D	D	Moderate	Moderate
A31A-0600	A31A1	B	B	B	B	Moderate	High
A31A-0400	A31A1	B	B	B	B	Moderate	High
A31A_0800	A31A2	A	A	B	A	Moderate	High

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	**Ecological importance**: riparian-wetland-in-stream vertebrates (ex fish) **rating**	**Ecological sensitivity:** riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes **rating**
A31A_0500	A31A1	B	B	B	B	Moderate	High
A31A_0900	A31A2	C	C	C	C	Moderate	High
A41A-0340	Motlhabatsi	C	D	C	C	High	High
A41B-0334	Mamba	C	C	B	C	High	High
A41C-0279	Matlabas	D	D	D	D	Moderate	Moderate
A41C-0290	0	B	B	B	B	None	None
A41D-0205	Limpopo	D	D	D	D	High	Moderate
A41D-0206	Matlabas	C	C	C	C	High	Moderate
A41D-0217	Limpopo	D	D	D	D	Moderate	Moderate
A41E-0126	Limpopo	C	C	C	C	High	High
A42A-0462	Sand	C	C	C	C	Moderate	Moderate
A42A-0471	Sand	D	D	D	D	Moderate	Moderate
A42A-0481	Sand	C	C	C	C	Moderate	Moderate
A42A-0488	0	C	C	C	C	Moderate	Moderate
A42A-0499	0	C	C	C	C	Moderate	Moderate
A42A-0504	0	C	C	C	C	Moderate	Moderate

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A42A-0508	0	C	C	C	C	Moderate	Moderate
A42B-0446	Grootspruit	C	D	C	C	Moderate	Moderate
A42B-0455	Grootspruit	D	E	D	D	Moderate	Moderate
A42B-0470	Sandspruit	D	D	C	D	Moderate	Moderate
A42B-0472	Sandspruit	D	D	D	D	Moderate	Moderate
A42B-0473	0	E	E	D	E	Moderate	Low
A42C-0392	Mokolo	C	D	C	C	Moderate	Moderate
A42C-0432	Klein-Sand	D	E	C	D	Moderate	Moderate
A42C-0443	Klein-Sand	C	D	C	C	Moderate	Moderate
A42C-0445	Mokolo	C	D	C	C	Moderate	Moderate
A42C-0449	0	D	D	C	D	Moderate	Moderate
A42D-0346	Sterkstroom	D	D	D	D	Moderate	Moderate
A42D-0383	Sterkstroom	B	B	B	B	High	High
A42D-0385	Frikkiesloon	B	C	B	B	Moderate	High
A42D-0414	Grootfonteinspruit	B	C	B	B	High	High
A42D-0416	Sterkstroom	A	A	B	A	High	High

SQ reach	**SQ Name**	**PES category based on median of metrics**	**In stream PES**	**Riparian PES**	**OVERALL PES (calculated)**	**Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating**	**Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating**
A42E-0301	Mokolo	C	D	C	C	Moderate	Moderate
A42E-0312	Brakspruit	B	B	B	B	Low	Moderate
A42E-0316	Sondagsloop	C	C	C	C	Low	None
A42E-0330	0	D	D	D	D	Low	None
A42E-0336	Sondagsloop	C	C	B	C	Low	Moderate
A42E-0355	Mokolo	E	E	D	E	Moderate	Moderate
A42E-0362	Mokolo	D	E	C	D	Moderate	Moderate
A42E-0366	Dwars	C	C	C	C	Moderate	Moderate
A42E-0373	Klein-Vaalwaterspruit	C	D	C	C	Moderate	Moderate
A42E-0380	Dwars	C	C	C	C	Moderate	Moderate
A42E-0384	Dwars	C	C	C	C	Moderate	Moderate
A42E-0388	Heuningspruit	C	C	C	C	Moderate	Moderate
A42E-0398	Jim se Loop	C	C	C	C	Moderate	Moderate
A42E-0400	Dwars	B	B	B	B	Moderate	High
A42E-0402	Dwars	C	C	C	C	Moderate	High

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A42E-0421	0	C	B	C	C	Low	Moderate
A42F-0268	Mokolo					Not to be evaluated, whole section in the Mokolo Dam	Not to be evaluated, whole section in the Mokolo Dam
A42F-0275	Bulspruit	C	D	C	C	Low	Low
A42F-0283	Malmanies	C	C	C	C	Moderate	High
A42F-0285	Mokolo	C	C	C	C	Moderate	Moderate
A42F-0300	Mokolo	D	D	D	D	Moderate	Moderate
A42F-0331	Taaibosspruit	B	B	B	B	Moderate	Moderate
A42G-0225	Mokolo	C	C	C	C	High	High
A42G-0226	Rietspruit	C	C	B	C	Moderate	Moderate
A42G-0241	Mokolo	C	D	C	C	High	High
A42G-0243	Poer se Loop	B	B	B	B	Moderate	Moderate
A42H-0186	Tambotie	C	C	C	C	High	High
A42H-0194	Mokolo	D	D	C	D	High	High
A42H-0199	Duiker	B	B	B	B	Low	None

SQ reach	SQ Name	PES category based on median of metrics	In stream PES	Riparian PES	OVERALL PES (calculated)	Ecological importance: riparian-wetland-in-stream vertebrates (ex fish) rating	Ecological sensitivity: riparian-wetland-instream vertebrates (ex fish) intolerance water level/flow changes rating
A42H-0216	Tambotie	B	B	B	B	Moderate	Moderate
A42J-0132	Mokolo	D	D	C	D	High	High
A42J-0160	Mokolo	C	D	C	C	High	High
A42J-0182	Sandloop	C	C	C	C	Low	None

APPENDIX B

COMMENTS FROM STAKEHOLDERS

STAKEHOLDER NAME	COMMENTS
Mogale City Municipality: Executive manager, Integrated Environmental Management	In respect of the Bloubankspruit it should be noted that: • The inter-Ministerial Committee on AMD has approved neutralisation of AMD from the Western Basin as the preferred method of treatment; • It is expected that an estimated 60ML/d of sulphate contaminated water will be discharged via the Tweelopiesspruit to the Bloubankspruit for the immediate and short term (up to 7 years); • DWA again recently relaxed the sulphate discharge quality to 3 000mg/l; it ios expected that both surface and groundwater quality (the Zwartkrans dolomitic compartment that feeds the Bloubankspruit through a series of dolomitic springs) may be compromised. evidence gained by Mogale City Local Municipality through monitoring suggests that this may affect the IUA category in the near future.
	The following has been noted by Mogale City Local Municipality: • Over abstraction and illegal abstraction of groundwater from the Steenkoppies Dolomitic Compartment which feeds Maloney's Eye raise serious concerns; • The Gauteng Department of Agriculture and Rural Development's Conservation Plan Version 3.3 has indicated that major areas associated with Maloney's Eye are defined as Irreplacable Sites; and • This area is defined in terms of Mogale City Local Municipality Spatial Development Plan (SDF) for tourism. Any forms of mining activities in the Upper reaches of Maloney's Eye are considered incompatible with the SDF and would potentially threaten the Class B status of the said river.

APPENDIX C

REPORT ON STEP 2 OF THE WATER RESOURCES CLASSIFICATION SYSTEM: LINK THE VALUE AND CONDITION OF THE WATER RESOURCE

CLASSIFICATION OF SIGNIFICANT WATER RESOURCES IN THE CROCODILE (WEST), MARICO, MOKOLO AND MATLABAS CATCHMENTS: WP 10506

REPORT ON STEP 2 OF THE WATER RESOURCES CLASSIFICATION SYSTEM: LINK THE VALUE AND CONDITION OF THE WATER RESOURCE

Directorate: Water Resource Classification

JULY 2012

water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

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1 INTRODUCTION

The classification of South Africa's significant water resources is seen as a vital step in ensuring that a balance is sought between the need to protect and sustain water resources and the need to develop and use them. The Chief Directorate: Resource Directed Measures (CD:RDM), Directorate Water Resources Classification (D: WRC) of the Department of Water Affairs (DWA) is tasked with the responsibility of ensuring that the water resources are classified in terms of the seven step process of the Water Resource Classification System (WRCS).

This report is intended to provide a decision making framework as stipulated by Step 2 (Link the Value and Condition of the Water Resource) of the WRCS for the significant water resources in the Crocodile (West), Marico, Mokolo and Matlabas catchments.

The results from the Integrated Units of Analysis Delineation Report provide[1] the present day value of aquatic water use and the value of sectoral water use. These steps therefore provide a value baseline in which changes in value can be assessed for different scenarios of management classes. The primary objectives of Step 2 are to:

1. Define the quantitative relationships that will link change in the configuration of Management Class (MC) scenarios to a resulting change in economic value and social wellbeing.
2. Rationalise those values by selecting a subset on which efforts can be concentrated for evaluating catchment configuration scenarios in Steps 5 and 6.
3. Determine the scoring system that should be used to evaluate the catchment configuration scenarios in later steps

In order to achieve these objectives, the following sub-steps have been developed and are discussed in further detail in subsequent sections of this report:

1. **Step 2a**: Select the ecosystem values to be considered based on ecological and economic data;
2. **Step 2b:** Describe the relationships that determine how economic value and social wellbeing are influenced by ecosystem characteristics and the sectoral use of water; and
3. **Step 2c:** Define the scoring system for evaluating the scenarios.

[1] Report no.: *RDM/WMA1,3/00/CON/CLA/0212*

2 STEP 2(A): SELECT THE ECOSYSTEM SERVICES TO BE CONSIDERED BASED ON ECOLOGICAL AND ECONOMIC DATA

This section identifies the ecosystem services to be considered in the analyses to follow.

2.1 What are Ecosystem Services and why are they Important?

Ecosystem services (ES), in their most basic form, can be defined as the benefits that people receive from ecosystems. The Millennium Ecosystem Assessment (MA 2005) provides a framework in which ecosystem services can be categorised.

The MA provides a sound and well-established framework for the assessment of ecosystem services and the benefits to human well-being. The MA established the concept of ecosystem services as an essential model for linking the functioning of ecosystems to human welfare benefits (Balmford et al. 2008) The definition and categorisation of ecosystem services in the MA built upon previous work by leading authors such as Daily (1997), Costanza et al. (1997), and De Groot et al. (2002).

The Table below sets out the ecosystem services to be evaluated for the Crocodile (West)/Marico WMA and the Mokolo and Matlabas catchments. The set of ecosystem services are based on the outputs of Section 5 the IUA Delineation Report (*RDM/WMA1,3/00/CON/CLA/0212*) that was developed prior to this report. The MA (2003), recognises four types of ecosystem services discussed in Table 1 and Table 2:

- Supporting;
- Regulating;
- Provisioning; and
- Cultural.

Table 1: Rating of the applicability of ecosystem services affected by possible water management scenarios in the study area for regulating and provisioning categories

Category of ecosystem service	Types of services in the category	Description
Regulating	Water regulation (hydrological flows)	The timing and magnitude of runoff and flooding can be strongly influenced by changes in land cover, including in particular alterations that change the water storage potential of the system such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.
	Erosion regulation	Vegetative cover plays an important role in soil retention and the prevention of landslides.
	Water purification and waste treatment	Ecosystems can be a source of impurities in freshwater but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems

Category of ecosystem service	Types of services in the category	Description
	Disease regulation	Changes in ecosystems can directly change the abundance of human pathogens such as cholera and can alter the abundance of disease vectors such as mosquitoes.
	Pest regulation/ Biological control	Ecosystem changes affect the prevalence of crop and livestock pests and diseases.
	Detoxification	Biological processes are involved in the sequestration or detoxification of various chemical wastes introduced into the environment.
	Natural hazard regulation	Such as storm protection, the presence of coastal ecosystems such as mangroves and coral reefs can dramatically reduce the damage caused by hurricanes or large waves.
Provisioning	Food	Provision of food from crops, livestock, marine and freshwater capture fisheries, aquaculture or wild plant and animal food products
	Fresh water	Ecosystems provide storage and retention of water for domestic, industrial, and agricultural use
	Wood and fibre	Direct benefits from wood for timber and pulp, biomass energy (fuelwood and charcoal consumption) and from the production of agricultural fibres such as cotton, silk and hemp
	Biochemical and pharmaceutical products	Ecosystems provide natural products that have been used for biochemicals and pharmaceuticals and other natural products (such as cosmetics, personal care, bioremediation, biomonitoring and ecological restoration).
	Genetic resources	The potential in biodiversity for new products and industries, such as medicine, genes for plant pathogen resistance or ornamentals. Conserving genetic diversity maintains the potential to yield larger future benefits and ensures options for adapting to changing environments.

Table 2: Rating of the applicability of ecosystem services affected by possible water management scenarios in the study area for the cultural category

Category of ecosystem service	**Types of services in the category**	**Relevance and definition in the context of the entity**	**Examples**
Cultural	Aesthetic	The quality of the aggregate viewscape as seen by residents in and visitors to the entity	Perceived quality of viewscapes
	Spiritual	The degree to which the entity satisfies human needs for religious or other spiritual fulfilment	Use of opportunities for religious tourism (e.g. pilgrimages)
	Inspirational	The degree to which the entity inspires creativity among residents and visitors	Activity in art, literature and music dependent on the state of the entity
	Knowledge and education	The degree to scientific knowledge which arises from the study of the entity contributes to intellectual fulfilment among residents and visitors	Level of use of research and educational opportunities unique to the entity.
	Recreation and ecotourism	The degree to which the entity is enjoyed for leisure activity.	
	Sense of place	The degree to which people depend on the particular features of the entity for their cultural identity.	Potential culture loss in local communities (inverse measure)
	Cultural heritage values	The degree to which the cultural heritage within the entity is enjoyed by residents and visitors	Use and enjoyment of cultural heritage opportunities within the entity

3 STEP 2(B): DESCRIBE THE RELATIONSHIPS THAT DETERMINE HOW ECONOMIC VALUE AND SOCIAL WELLBEING ARE INFLUENCED BY THE ECOSYSTEM CHARACTERISTICS AND THE SECTORAL USE OF WATER[2]

The MA provides a sound and well-established framework for the assessment of ecosystem services and the benefits to human well-being. The MA's concept of ecosystem services is an essential model for linking the functioning of ecosystems to human welfare benefits.

Ecosystems are considered to be assets that yield a flow of services of benefit to people, much like other capital stocks. In the case of the Crocodile (West), Marico, Mokolo and Matlabas catchments, the water resources of the WMA deliver the set of ecosystem services identified in Table 1 and Table 2 above.

The influence of and feedbacks between human well-being, drivers of change and ecosystem services are demonstrated in the figure below. For instance, increased demand of water by upstream water users reduces water supplied downstream, resulting in changes in water quality, riparian zones, aquatic biodiversity and direct and indirect effects to a suite of ecosystem services to downstream beneficiaries. This problem can be exacerbated by the degradation of catchments affecting the capability of aquatic ecosystems to provide services and regulate natural and human-induced stressors and shocks to socio-ecological systems. The degradation of ecosystems in a bid to maximise the delivery of a small group of services, such as agricultural crops for food, water supply or grazing, jeopardises the delivery of other ecosystem services. It also often jeopardises the sustainable supply of the ecosystem services that are being maximised. Therefore, human well-being[3] is affected not only by the gap between the supply and demand of ecosystem services, but also by the diminished prospects for sustainable development thus increasing vulnerability of individuals and communities.

Humans, and their cultural diversity, are recognised as an integral part of socio-ecological systems and human well-being is the central focus for assessment. Inherent to this 'ecosystem approach' of the MA is the understanding that socio-ecological systems are complex and dynamic "with the changing human condition serving to both directly and indirectly drive change in ecosystems and with changes in ecosystems causing changes in human well-being. At the same time, many other factors independent of the environment change the human condition, and many natural forces influence ecosystems" (MA 2003).

Perturbations resulting from ecosystem change propagate through systems spatially, affecting local people as well as downstream users, and temporally, affecting current and future users. A multi-scale approach to assessment is required for proper evaluation of driving forces internal and external to the system in question and the differential effect of ecosystem changes on different areas and populations within a system i.e. upstream and downstream communities.

[2] WRC 2010

[3] "Human well-being is a human experience that includes the basic materials for a good life, freedom of choice and action, health, good social relationships, a sense of cultural identity, and a sense of security. The sense of well-being is strongly dependent on the specific cultural, geographical, and historical context in which different human societies develop, and is determined by cultural-socioeconomic processes as well as by the provision of ecosystem services. However, the well-being of the vast majority of human societies is based more or less directly on the sustained delivery of fundamental ecosystem services, such as the production of food, fuel, and shelter, the regulation of the quality and quantity of water supply, the control of natural hazards, etc." (Diaz et al. 2006).

Figure 1: Conceptual framework of the Millennium Ecosystem Assessment (MA 2003)

The MEA conceptual framework thus lays the thinking of a causal chain between drivers of change in ecosystems, the delivery and distribution of ecosystem services and the benefits to human well-being.

The definition of ecosystem services as ecological phenomena, which include ecosystem organisation, structure, process and/or function, provides some explanation for the variety of terms used in the literature to describe ecosystem services. It is important to note that there is a difference between the organisation (physical constitution) of an ecosystem, the process or functioning (operation) of an ecosystem, and the outcome or link to human well-being. The latter introduces an important concept, that some ecosystem services (ecological phenomena) are intermediate to the delivery of others.

The notion of intermediate versus final consumption ecosystem services is crucial in the context of valuation and avoiding double accounting. For instance nutrient cycling and water regulation and erosion regulation (intermediate services) interact to deliver water flow, nutrients and a certain range of sediment loads to a downstream estuary, which supports a large fishery and beautiful estuarine environment (food provision and recreation are the final services). In this example, the value of water regulation, nutrient cycling and erosion regulation would be captured in the benefits yielded by recreation and subsistence fishing service. The fish as well as the safe and healthy shoreline and water body are the benefits that are the endpoints that have a direct effect on human well-being.

One intermediate service may also input into multiple benefits (for instance water regulation is intermediate to flood protection and avoided damage or injury, water provision for multiple purposes, riparian subsistence agriculture, downstream aquatic ecosystems and recreation).

Although intermediate services are valued through final services and benefits, they are important to consider, especially with regards to their long-term sustainability and the effects of changes in these services on final services (in terms of resilience and thresholds). This has numerous important valuation and trade-off implications.

The MA framework sufficiently assists to address two key requirements for environmental resource economic valuation:

- it enables diligent and comprehensive analysis of all the benefits provided by aquatic ecosystems to humans; and
- it allows for the logical analysis of the causal chains producing these ecosystem services.

Figure 2: The distinction between intermediate services, final services and benefits (adapted from Fisher et al. 2008) illustrated by the stylised relationship between supporting, regulating, provisioning and cultural services as defined by the Millennium Ecosystem Assessment (MA) (Perrings 2007, Hassan 2007) and simplified example.

4 STEP 2(C): DEFINE THE SCORING SYSTEM FOR EVALUATING SCENARIOS

4.1 Overview

The decision-analysis framework to be used in this study, and defined in Step 1(i) (IUA Delineation Report 2012), lends itself to a cost-benefit analysis (CBA) for evaluating scenarios[4]. The decision-analysis framework developed above internalises the relevant water economy transactions and no additional absolute scoring system is required. Section 6 in particular demonstrates recent valuations for ecosystem services.

However, where required, comparative risk assessment (CRA) will be used as a method for estimating changes in delivery of ecosystem services, so that scenarios may be tested.

In the CRA method, experts formulate the chains of causality between a development activity or management scenario, the resulting change in ecosystem assets and effect on ecosystem services. In addition, the CRA serves to rate the consequences associated with the subsequent environmental effects and its uncertainty. The CRA process will help link the key economic drivers to the water resource.

Comparative risk assessment (CRA) is both an analytical process and a methodology for prioritizing complex problems. Comparative risk assessment is a multi-attribute evaluation procedure which allows for a theoretically sound and structured progression by way of manageable individual steps. For each step (such as structuring the problem, structuring and weighting the

[4] Current best practice methodologies (e.g. WRC 2007) will be used to carry out the CBA as well as to determine the appropriate discount rates.

attributes, sensitivity analysis) a range of practically tested techniques exist. The strength of the CRA is that it facilitates an explicit examination of assumptions and values and thus aids in a transparent comparative risk evaluation. This approach is therefore eminently suitable for those comparative risk assessment processes in which a variety of evaluators, both experts and other stakeholders take part.

This examination of the data is also a factual prerequisite for comparative analyses. Risk evaluation constitutes the link between the predominantly scientific/technical risk assessment and a socio-economic oriented valuation of risks.

A benefit of a CRA lies in the comparison of a new development fields (and by inference also complex systems), in the comparison of public risk perceptions for different cases, and in the comparison of cost and benefit effects.

4.2 CRA Methodology

Various management scenarios could pose a variety of hazards to the Crocodile (West), Marico, Mokolo and Matlabas catchments water resources and the ecosystem services it delivers. Any management scenario that results in a change from present ecological condition will result in changes to the delivery and distribution of ecosystem services.

With the assets and scenarios spatially and temporally bound, the effect of the scenario on each asset in terms of ecosystem service delivery is assessed. For each scenario-asset combination, the ecosystem services identified are assessed.

For each scenario-asset-service combination, the question asked is ‘What is the likelihood that this ecosystem service in this significant water resource will be affected under this scenario? What would be the consequences of this scenario in this significant water resource to the delivery of this ecosystem service?’

The likelihood is the probability of the scenario having an effect on the asset. Likelihood takes into account an element of uncertainty, in that the likelihood that an ecosystem service will be affected under the scenario in question over a specified time frame is rated. Uncertainty with regards to the knowledge upon which the statements or connections between scenario-asset-service linkages are made, is also stated explicitly for each CRA. This level of certainty (e.g. high, medium or low) is a statement based on the expert’s judgement of the certainty of and confidence in the risk assessment. For example, a low level of certainty indicates that evidence to bear out the assessment is weak or lacking.

Table 3: Qualitative and quantitative classes of likelihood of a scenario (environmental effect, or resultant change in the flow of an ecosystem service) eventuating from a management decision and of having an environmental consequence to a service from an environmental asset in the ecosystem adapted from the classification adopted by the IPCC (2007)

Likelihood rating	Assessed probability of occurrence	Description
Almost certain	> 90%	Extremely or very likely, or virtually certain. Is expected to occur.
Likely	> 66%	Will probably occur
Possible	> 50%	Might occur; more likely than not
Unlikely	< 50%	May occur
Very unlikely	< 10%	Could occur
Extremely unlikely	< 5%	May occur only in exceptional circumstances

The consequence is the change in the service from the environmental effect of the management scenario on the exposed asset. The assessment of consequences can follow, or adapt in an appropriate manner, the severity ratings (Table 4).

Table 4: Qualitative measures of consequence to environmental services in an ecosystem arising from the hazards linked to a management decision

Level of consequence		Environmental effect
1	Severe	Substantial permanent loss of environmental service, requiring mitigation or offset.
2	Major	Major effect on the on the asset or service, that will require several years to recover, and substantial mitigation.
3	Moderate	Serious effect on the on the asset or service, that will take a few years to recover, but with no or little mitigation.
4	Minor	Discernable effect on the asset or service, but with rapid recovery, not requiring mitigation.
5	Insignificant	A negligible effect on the asset or service.

During the CRA it is useful to identify all appropriate compensation measures (mitigation and offsets).

The level of risk is the product of likelihood and consequence in the event of an environmental effect on an asset. Figure 3 combines the likelihood and consequence rating to determine risk as:

- Low (L) risk requiring no to little response;
- Medium (M) risk requiring local level response;
- High (H) risk requiring regional level response; or
- Very High risk (VH) requiring national level response.

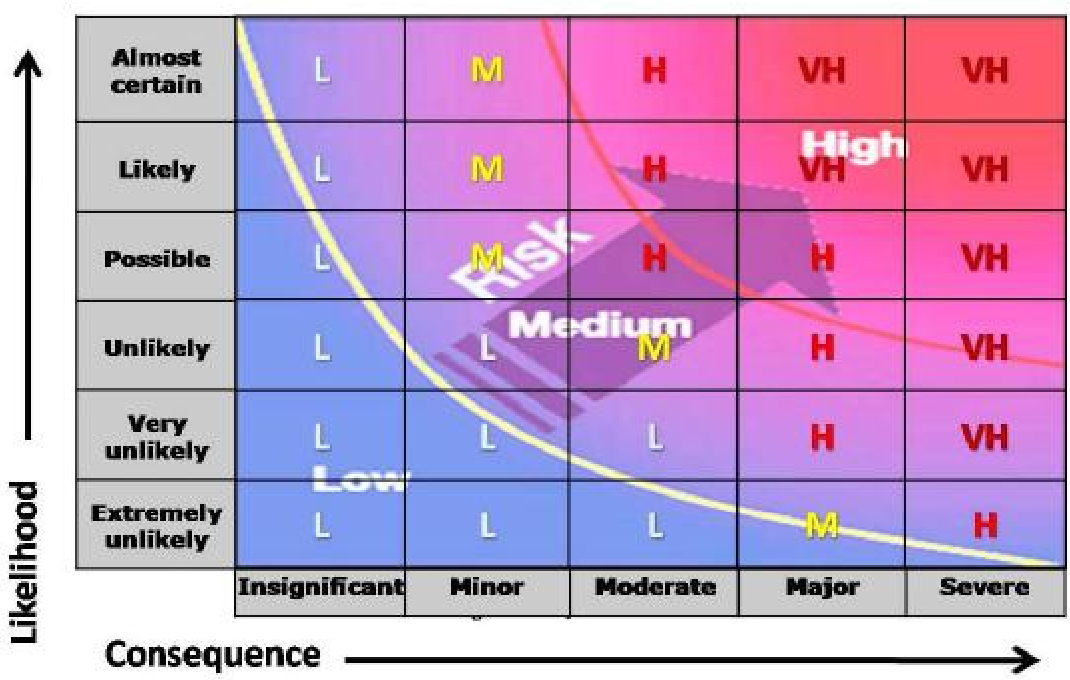

Figure 3: Levels of risk, assessed as the product of likelihood and consequence in the event of an environmental effect on an ecosystem asset (Adapted from Australian/New Zealand Standard on Risk Management (2004))

The outcome of the CRA should include:

- Description of the environmental effect statement, including hazard and effect statement, scope of consequence, outcome statement and likelihood of outcome.
- Table of ecosystem services with the likelihood and consequence of environmental effect, and the level of risk (see Figure 3).
- Statement of the level of certainty associated to the above risk assessment, based on the availability of existing evidence and certainty of expert knowledge.

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