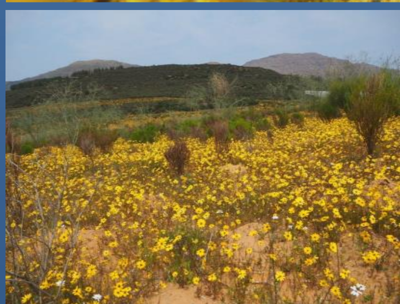
RESERVE DETERMINATION STUDY FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE F60 AND G30 CATCHMENTS WITHIN THE BERG-OLIFANTS WMA

MAIN INTEGRATED REPORT

June 2023



Department of Water and Sanitation

Chief Directorate: Water Ecosystem Management

DEPARTMENT: WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEM MANAGEMENT

RESERVE DETERMINATION STUDY FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE F60 AND G30 CATCHMENTS WITHIN THE BERG-OLIFANTS WMA

WP11340

MAIN INTEGRATED REPORT AND IMPLEMENTATION PLAN

REPORT NUMBER: RDM/WMA09/00/CON/0131

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EXECUTIVE SUMMARY

BACKGROUND

The Chief Directorate: Water Ecosystems Management of the Department of Water and Sanitation (DWS) initiated a preliminary Reserve determination study for the G30 and F60 Tertiary Catchments of the Berg Olifants Water Management Area (WMA). The Verlorevlei within the study area is of particular importance as a designated Wetland of International Importance under the Ramsar Convention on Wetlands of International Importance, Especially as Waterfowl Habitat. In addition, peat wetlands have been identified to occur in the area that is associated with the Verlorevlei that provide important ecological services but are under severe threat and require urgent protection. The purpose of this report is to provide an integrated summary of the findings and recommendations of the Reserve determination for surface (rivers, wetlands and estuaries) and groundwater in the G30 and F60 catchments

STUDY AREA

The study area comprises the F60 (Knersvlakte) and the G30 (Sandveld) Tertiary Catchments in the Western Cape Province, with the most northerly section of the catchment falling within the Northern Cape Province.

Groundwater in the G30 (Sandveld) catchment plays a significant role in sustaining surface water ecosystems, enables extensive agricultural activity and is the sole source of freshwater for most of the towns and settlements. The catchments contain both fractured and intergranular areas with average yields ranging from very low (0.5 l/s) to high yielding (> 5 l/s). Groundwater quality is described as being good across the G30 catchments, however, where Malmesbury Group formations occur, the main aquifer can be identified as yielding groundwater of poor quality. The main recharge areas have been identified as the mountainous areas towards the east of the study area that form part of the Cederberg and Piketberg Mountain ranges.

Perennial and seasonal river, wetland and estuarine systems within the G30 Tertiary Catchment include:

- *Verlorenvlei River System with its main tributaries, the Kruismans, Bergvlei, Krom Antonies and Hol Rivers, as well as the Verlorenvlei Estuary;*
- *Langvlei River with the Wadrif wetland and pan;*
- *Jakkals River and Jakkalsvlei Estuary;*
- *Sandlaagte River*
- *Rosherpan and Papkuil River; and*
- *Several smaller wetland areas along watercourses, coastline and on hillslopes.*

Groundwater availability in the F60 catchments is much lower than in the G30 catchments. The geological setting of the area is also more complex, containing both intergranular and fractured aquifers. The regional expected yields are very low (0.1 - 0.5 l/s) with higher-yielding boreholes (up to 2 l/s) at the most southern point of the F60 catchments. Groundwater quality across the catchment is generally categorised as poor, with EC values of over 1000 mS/m.

The F60 Tertiary Catchment comprises ephemeral rivers, wetlands and estuaries, including:

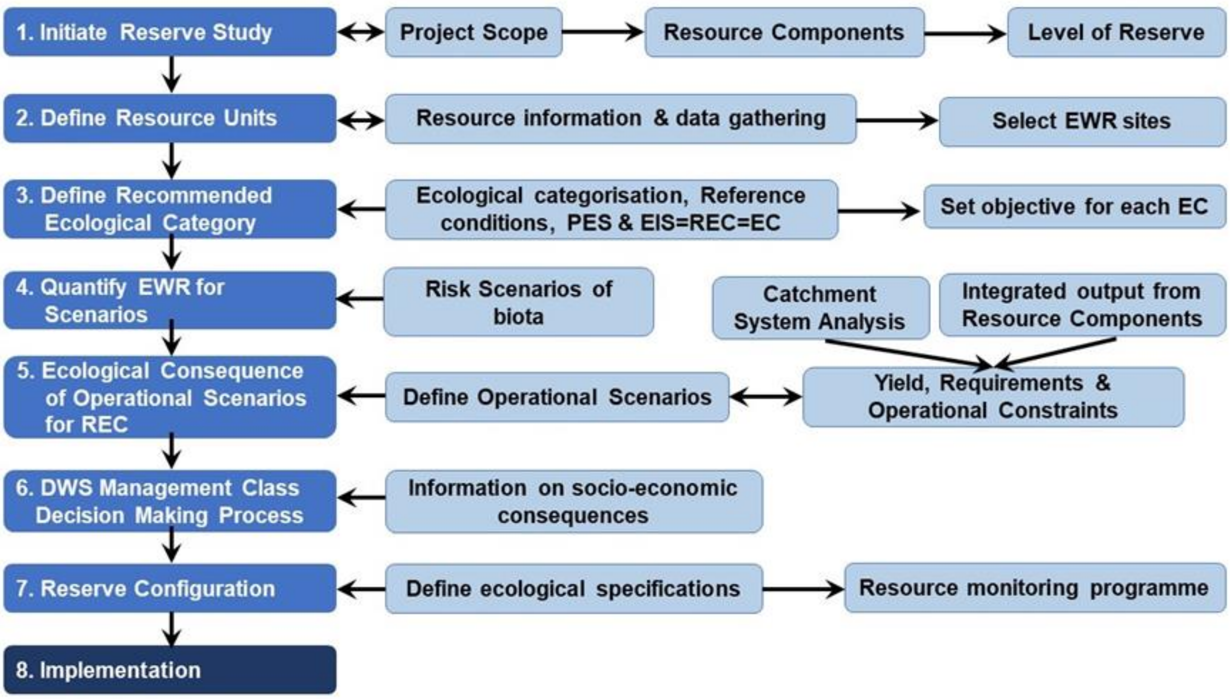
- *Sout River System with its main tributaries, the Groot and Klein Goerap Rivers and the South Estuary;*
- *Brak River and Estuary; and*
- *Several mostly isolated depression wetlands.*

STUDY METHODOLOGY AND APPROACH

The river, wetland, estuarine and groundwater components of the Reserve determinations used the latest Resource Directed Measures (RDM) recommended methodologies, but needed a slightly adapted approach to address the following:

- *Most of the surface water features within the study area are non-perennial with a hydrological regime and water quality that has high variability.*
- *Surface water ecosystems in these systems are often dominated by wetland habitats or confined to isolated pools during the dry summer season.*
- *The estuaries within the area comprise mostly coastal lakes or estuarine salt pans, with a low diversity of hardy species. These systems are mostly nearly permanently closed and also have very little freshwater inflow from their associated river systems.*
- *Very close integration occurs between the surface water ecosystems (rivers, wetlands and estuarine habitats) as well as with the groundwater. Integration of these two specialist fields and the recommended ecological Reserve (quantity and quality) thus needs to take place.*

The revised generic procedure is provided below, which shows the process for the determination of the Ecological Water Requirement (EWR) in the context of the larger RDM process, with possible links to issues such as the stakeholder process, classification, implementation and operation, indicated as suggested ways to integrate the Reserve determination process.



The Reserve Determination Process (adapted from DWAF, 2008)

DELINEATION OF WATER RESOURCES AND EWR SITES

<u>Groundwater Resource Units (GRUs)</u>

G30 Catchments: Within the G30 catchments, the GRUs closely align with the quaternary catchments as they tend to each incorporate a single valley that relates well with perceived groundwater flow and surface water contribution.

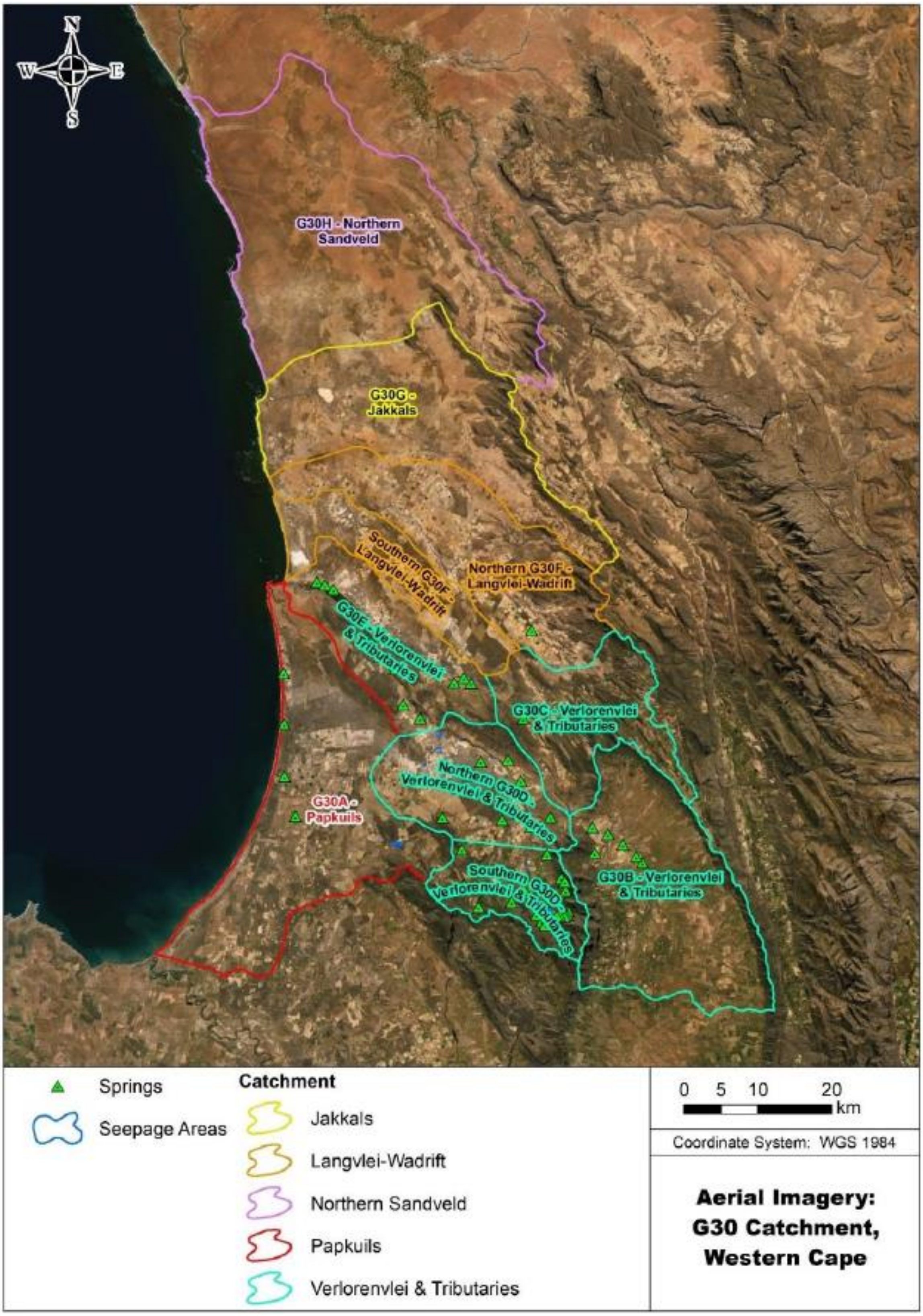
- *Papkuils (G30A GRU): Comprises the G30A catchment, including the Papkuils River and Rosherpan*
- *Verlorenvlei & Tributaries (Southern G30D GRU): Comprises the upper reaches of the Krom Antonies and Hol River catchments.*
- *Verlorenvlei & Tributaries (Northern G30D GRU): Comprises the lower reaches of the Hol, Krom Antonies and Kruismans Rivers to their confluence with the Verlorenvlei River.*
- *Verlorenvlei & Tributaries (G30B GRU): Comprises the upper Kruismans River between the Citrusdal and Piketberg Mountain ranges.*
- *Verlorenvlei & Tributaries (G30C GRU): Comprises the Bergvallei Valley.*
- *Verlorenvlei & Tributaries (G30E GRU): Comprises the Verlorenvlei area and includes the Kruisfontein Springs.*
- *Langvlei-Wadrift (Northern G30F GRU): Langvlei has two "paleochannel type structures" running through the valley, a northern and a southern valley. This GRU comprises the northern one.*
- *Langvlei-Wadrift (Southern G30F GRU): This GRU lies south of the Northern G30F GRU and includes the Wadrif aquifer.*
- *Jakkals (G30G GRU): Comprises the Jakkals River catchment.*
- *Northern Sandveld (G30H GRU): Comprises the Sandlaagte catchment and is referred to as the Northern Sandveld.*

F60 Catchments: As for the G30 catchment, in F60 the GRUs also closely align with the quaternary catchments.

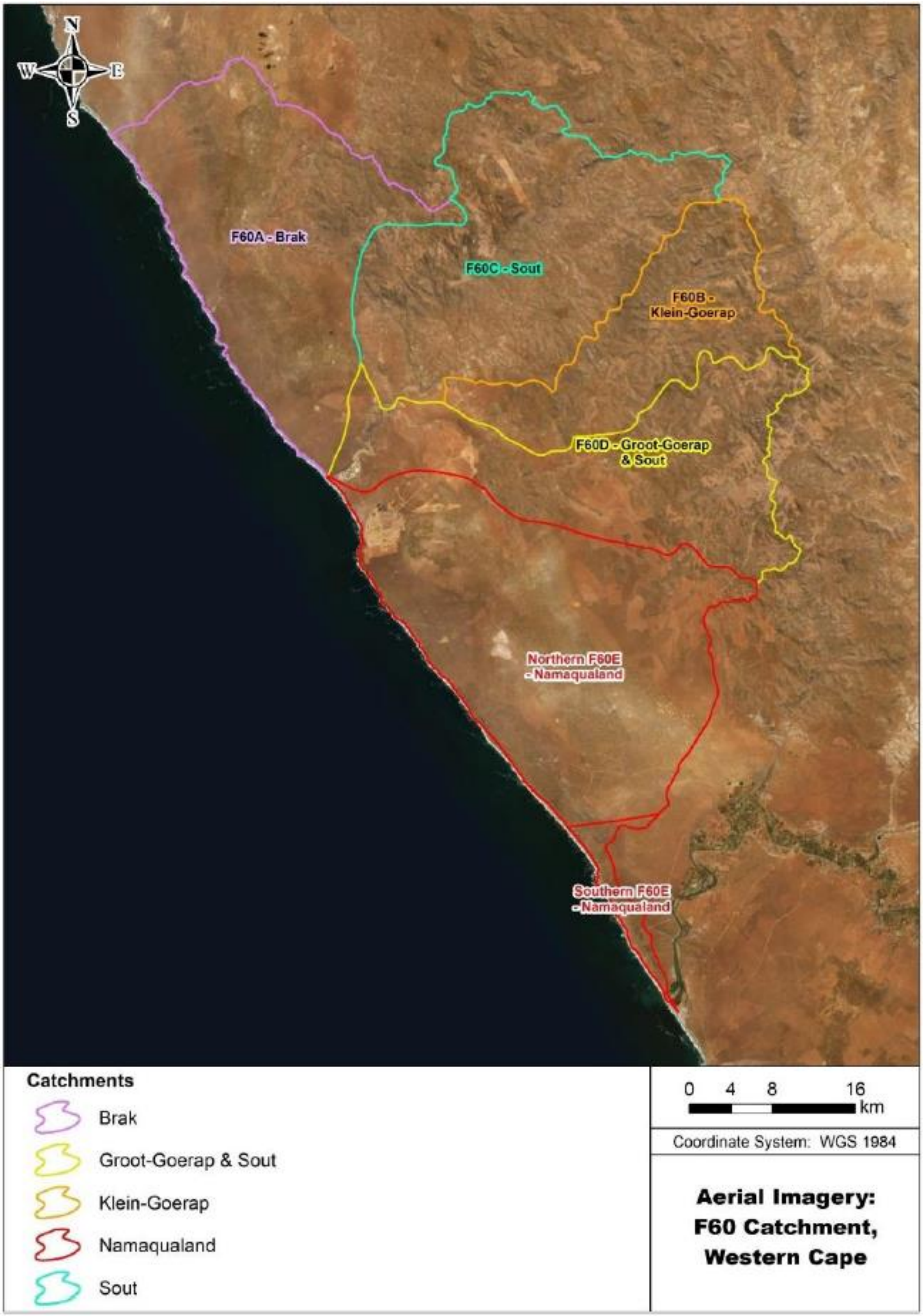
- *Namaqualand (Southern F60E GRU): The GRU is situated on the coast in the area north of the Olifants River Estuary. There are no watercourses within this unit, only depression wetlands.*
- *Namaqualand (Northern F60E GRU): Comprises the northern portion of the F60E catchment. As for the Southern Namaqualand GRU, there are no watercourses within this unit, only depression wetlands.*
- *Groot-Goerap & Sout (F60D GRU): The groundwater unit falls within the F60D catchment and includes the Groot-Goerap and lower Sout Rivers.*
- *Klein-Goerap (F60B GRU): The groundwater unit falls within the F60B quaternary catchment boundaries and includes the Klein Goerap River. F60 and G30 Ecological Reserve: Draft Scenario Report, 2023 13*
- *Sout (F60C GRU): The groundwater unit falls within the F60C quaternary catchment boundaries and includes the Sout River (before it joins with the Groot-Goerap).*
- *Brak (F60A GRU): The groundwater unit falls within the F60A quaternary catchment boundaries and includes the Brak River Catchment.*

Rivers and Wetlands

The study area comprises seven main topographical catchments (the Papkuils, Verlorenvlei, Langvlei/Wadrift, Jakkals and Sandlaagte catchments in the G30 Tertiary Catchment area, and the Sout and Brak catchments in the F60 Tertiary Catchment area). The only catchment within the study area that makes sense to subdivide further is the Verlorenvlei and split this into the upper catchment, upstream of the Krom Antonies Tributary, and the lower catchment that includes the Verlorenvlei and Krom Antonies Catchments. The selection of Wetland Resource Units for EWR determination in the study area was not a semi-automated desktop-based exercise but rather involved the application of expert judgement, including that obtained through discussions between team members during the reconnaissance field trip. Many of the sites listed below have both river and wetland characteristics.



Combined map of delineated GRUs for the G30 catchments



Combined map of delineated GRUs for the F60 catchments

Location of River and Wetland EWR sites:

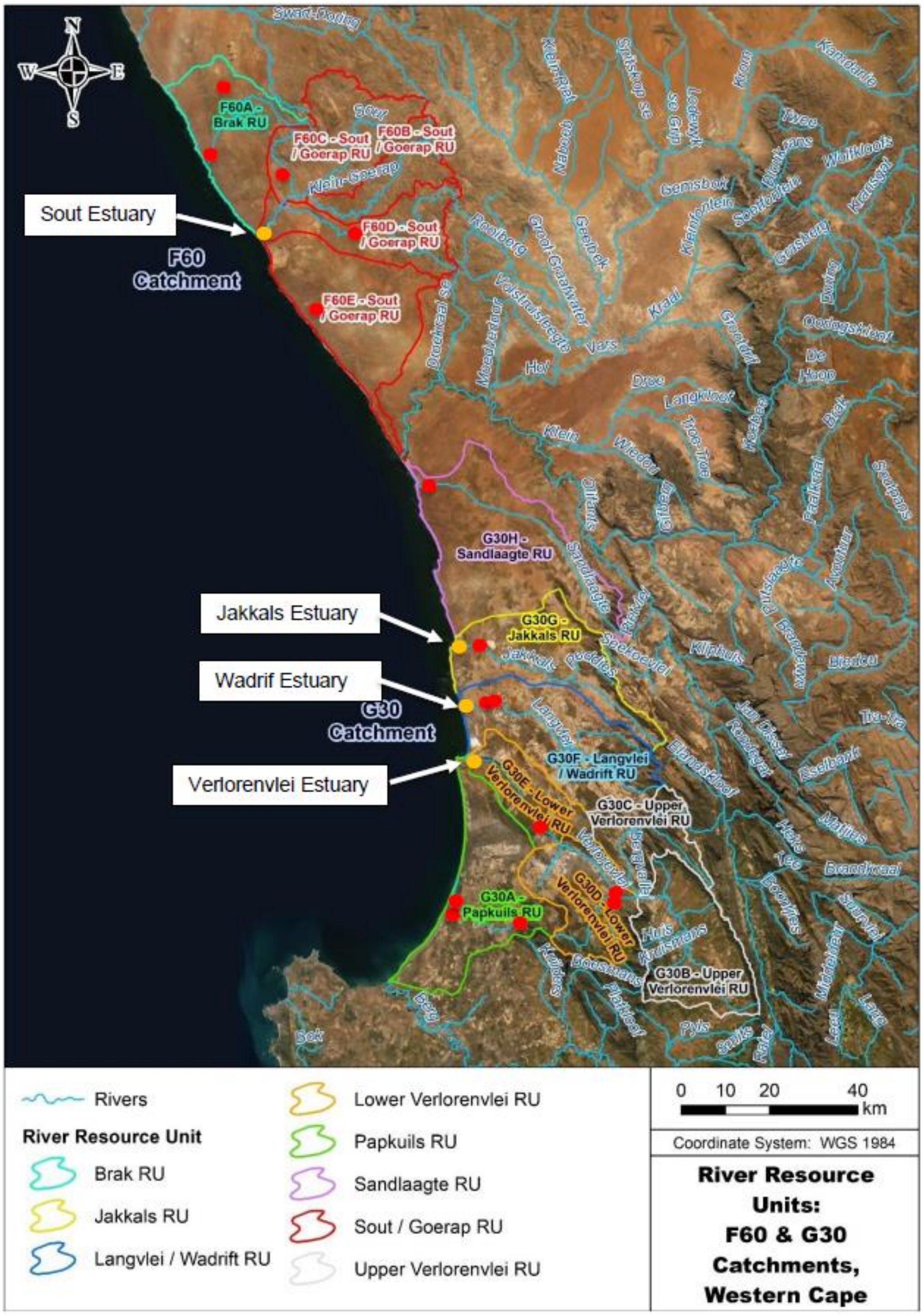
River/Wetland	Quat	EWR Site No.	Description of location	Geographic coordinates	
				Latitude	Longitude
Lower Brak River	F60A	EWR1	Lower Brak River above the Estuarine Functional Zone on Farm RE/559 Strandfontein	31° 5'21.84"S	17°44'18.66"E
North West Fynbos depression Wetland	F60A	EWR 2	Depression wetland in the NW Fynbos Bioregion within F60	30°57'15.89"S	17°46'43.61"E
Klein Goerap River	F60B	Node 1	Klein Goerap River at the confluence with the Sout River in Quaternary Catchment F60B	31° 9'36.31"S	17°58'1.77"E
Sout River	F60C	Node 2	Sout River at the confluence with the Groot Goerap River in Quaternary Catchment F60C	31°10'56.75"S	17°54'15.40"E
Lower Groot Goerap River	F60D	EWR3	Lower Goerap River on Ptn 4 of Komkans 141	31°14'17.91"S	18° 5'4.26"E
Knersvlakte depression Wetland	F60C	EWR 4	Depression in the Knersvlakte-Hardeveld Bioregion group in F60	31° 7'12.48"S	17°54'33.50"E
Sandveld depression Wetland	F60E	EWR5	Depression wetland in the Sandveld Bioregion of Catchment F60	31°24'10.86"S	17°59'24.11"E
Lower Sandlaagte River	G30H	EWR6	Lower Sandlaagte River on Re of Ptn 13, Hollebakstrandfontein 270	31°45'35.93"S	18°13'53.10"E
Lower Jakkals River	G30G	EWR7	Lower Jakkals River above Estuarine Funcional Zone on Ptn 3 of Farm 88 Kookfontein	32° 4'59.30"S	18°22'20.10"E
Lower Langvlei River	G30F	EWR8	Lower Langvlei River above Wadrift Pan and Wetland on Ptn 23 of Farm 226 Brandwacht	32°12'5.82"S	18°23'54.02"E
Wadrift Wetland	G30F	EWR9	Wadrift Wetland on the lower Langvlei River, upstream of Wadrift Pan on the farm Wagendrift 230 Re	32°12'52.21"S	18°22'31.50"E
Bergvallei River	G30B	Node 3	Bergvallei River at the confluence with the Kruismans River in Quaternary Catchment G30B	32°36'4.08"S	18°44'59.39"E
Upper Kruismans	G30C	Node 4	Upper Kruismans River at the confluence with the Bergvallei River in Quaternary Catchment G30C	32°36'5.87"S	18°45'1.94"E
Lower Kruismans River	G30D	EWR10	Lower Kruismans above R366 bridge on Ptn 1 of Farm 42 Eenheid	32°36'0.58"S	18°41'34.83"E
Lower Krom Antonies River	G30D	EWR11	Lower Krom Antonies upstream of the Kruismans River confluence. on Farm RE/40 Goergap	32°36'4.02"S	18°41'28.52"E
Lower Verlorenvlei River	G30E	EWR12	Lower Verlorenvlei River at the upper edge of the Estuarine Functional Zone on Ptn 4 of Farm 4 Wittedrift	32°27'29.91"S	18°31'2.19"E
Isolated depression/ duneslack wetland	G30A	EWR13	Small isolated depression wetland above the tar road on Ptn 27 of Farm 277	32°22'39.14"S	18°19'48.28"E
Rocherpan	G30A	EWR14	Rocherpan within Rocherpan Nature Reserve on Farm 272	32°36'49.34"S	18°17'55.89"E
Lower Papkuils River	G30A	EWR15	Lower Papkuils river/wetland above railway line on Ptn 1 of Farm 30 Bokram	32°37'53.62"S	18°18'46.32"E
Papkuilsvlei	G30A	EWR16	Lower Papkuilsvlei on Ptn 3 of Farm 18 Rietfontein	32°38'1.26"S	18°29'56.29"E

Estuaries

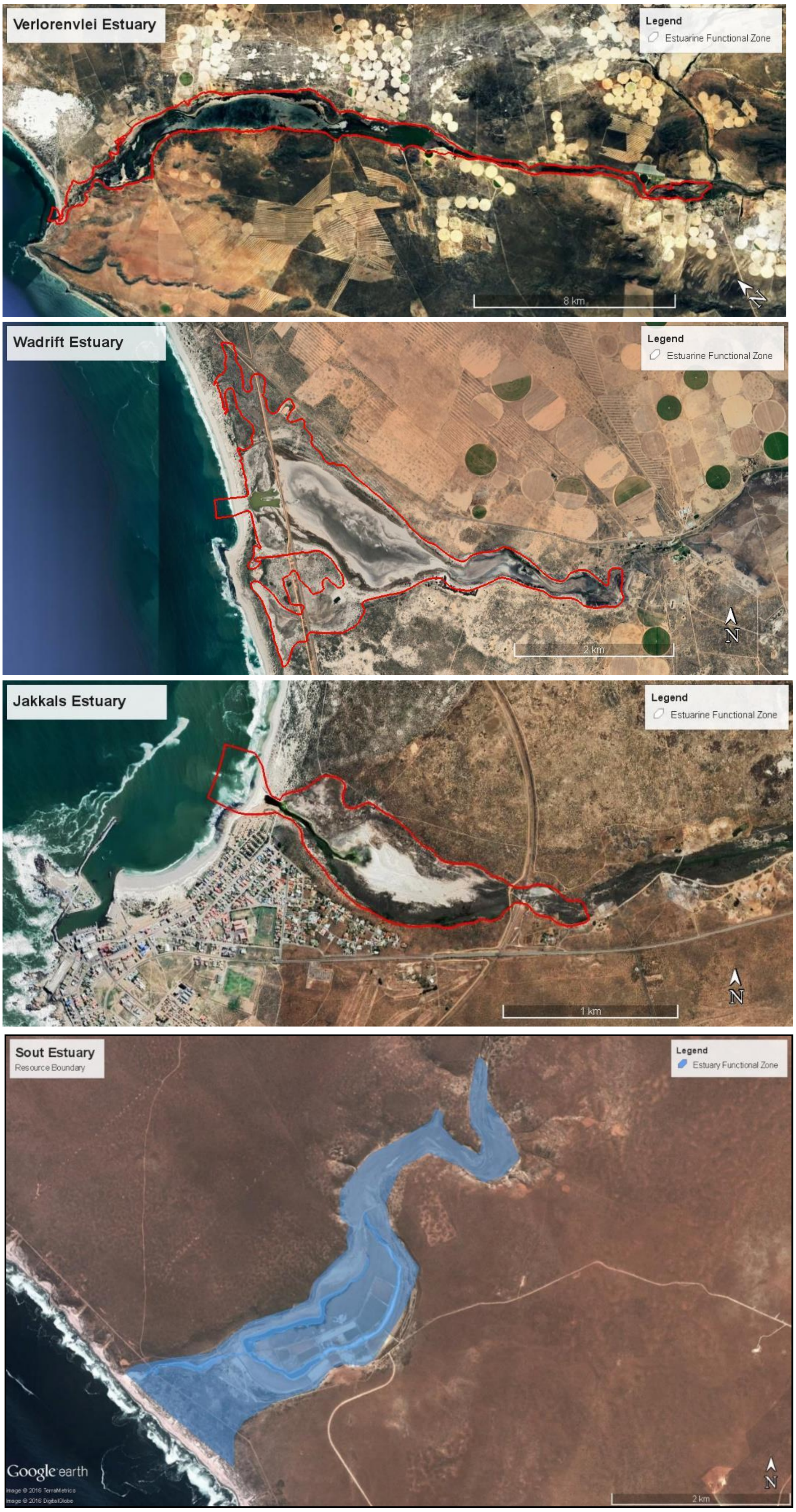
The estuarine functional zone for each estuary was delineated based on consideration of historical extent, the limit of tidal influence and a default lateral boundary that comprises the +5m mean sea level topographical contour.

Location of Estuaries

Estuary	*Quat*	*Location of Estuary Head*	*Location of Estuary Mouth*
Verlorenvlei	*G30E*	*32°25'55.82"S; 18°29'57.78"E*	*32°18'58.34"S; 18°20'5.96"E*
Wadrift	*G30F*	*32°12'49.87"S; 18°22'37.15"E*	*32°12'15.54"S; 18°19'32.43"E*
Jakkals	*G30G*	*32°5'26.89"S; 18°20'1.32"E*	*32°5'5.39"S; 18°18'48.25"E*
Sout	*F60D*	*30°28'17.92"S 17°22'32.83"E*	*30°28'20.54"S 17°21'34.07"E*



Map of the river and wetland resource units and the proposed EWR sites (red placemarks) for rivers and wetlands, as well as the location of the Estuary Resource Units (orange placemarks) in the F60 and G30 Catchments



Geographical boundaries of the Verlorenvlei , Wadrift, Jakkals and Sout (Noord) Estuaries

ECOCLASSIFICATION OF EWR SITES

The findings of the Present Ecological Status (PES) and Ecological Importance and Sensitivity (EIS) assessments, as well as the Recommended Ecological Category (REC), are provided below for the rivers and wetland EWR sites.

Summary of PES, EIS and REC for the Rivers and Wetlands EWR sites/nodes:

Quaternary	Node/ EWR site	Water Resource	PES	EIS	REC
F60A	EWR1	Lower Brak River	B	Moderate	B
F60B	Node 1	Klein Goerap River	B	Moderate	B
F60C	Node 2	Sout River	C	Moderate	C
F60D	EWR3	Lower Groot Goerap River	B	Moderate	C
G30A	EWR15	Lower Papkuils River	C/D	High	C
G30B	Node 3	Bergvallei River	D/E	High	C
G30C	Node 4	Upper Kruismans	D	High	C
G30D	EWR10	Lower Kruismans River	D	High	C
G30D	EWR11	Lower Krom Antonies River	C/D	High	C
G30E	EWR12	Lower Verlorenvlei River	D	High	C
G30F	EWR8	Lower Langvlei River	E	High	D
G30G	EWR7	Lower Jakkals River	C/D	Moderate	D
G30H	EWR6	Lower Sandlaagte River	C/D	Low	C

Summary of data for wetlands where no EWR was determined:

Quaternary	EWR site	Wetland	PES	EIS	REC
F60A	EWR 2	North West Fynbos depression Wetland	A/B	High	A/B
F60C	EWR 4	Knersvlakte depression Wetland	B	Moderate	B
F60E	EWR 5	Sandveld depression Wetland	C	Moderate	C
G30F	EWR9	Wadrift Wetland	F	High	D
G30A	EWR13	Isolated depression/ duneslack wetland	C	High	C
G30A	EWR14	Rocherpan	D	High	C
G30A	EWR16	Papkuilsvlei / Rietvlei	D	Very High	C

Summary of Reserve data for the estuaries in G30 and F60:

Quaternary	Estuary	PES	EIS	REC
G30E	Verlorenvlei	D1	Important	C2
G30F	Wadrift	D	Important	C
G30G	Jakkals	D	Low to Average	D
F60D	Sout3	E	Average	D

1The observed Present (2022) was estimated to be E Category due to the extended drought, which together with the abstraction of water, caused persistent long-term exposure of the lake margins and bed (very low water levels). Assuming that recovery is possible after lake levels increase again, an evaluation of the 101-year Present simulation scenario indicated a PES = Category D.

2 The Verlorenvlei Estuary was categorised as an "important estuary". It is a Ramsar site and a desired protected area in the Biodiversity Plan for the National Biodiversity Assessment. Therefore, according to the guidelines for assigning a REC, the condition of the estuary should be elevated to the Best Attainable State (BAS). The Best Attainable State for the estuary is B.

3 The Sout Estuary assessment was undertaken at a desktop with hydrology that was of very low confidence. It is recommended that the system should be restored from an E to a D. As most of the impacts are non-flow related the present day flows should be maintained as the recommended flow.

EWR RECOMMENDATIONS

Groundwater

The G30 catchments receive an estimated total groundwater recharge of 103.92 Mm^3/a of which 6.59 Mm^3/a represents the groundwater baseflow component needed for the surface water systems, 4.824 Mm^3/a represents the spring flow component needed and 0.406 Mm^3/a, the Basic Human Needs component of the Reserve. The Reserve for the catchment is 11.82 Mm^3/a which is 11.37% of the recharge. Currently, 1.798 Mm^3/a of groundwater is estimated to be abstracted for town supply and 53.13 Mm^3/a of groundwater is estimated to be abstracted for irrigation. This leaves the current total water balance at 38.73 Mm^3/a.

The F60 catchments receive an estimated total groundwater recharge of 7.826 Mm^3/a of which 0.0142 Mm^3/a represents the Basic Human Needs component of the Reserve. The Reserve for the catchment is 0.0142 Mm^3/a which is 0.002% of the recharge. Currently, 0.183 Mm^3/a of groundwater is estimated to be abstracted for town supply. This leaves the current total water balance at 7.628 Mm^3/a.

Results of the preliminary Reserve for the G30 and F60 Catchments:

Sub-catchment	*River System*	*Calculated recharge in MCM (%total annual flow)*	*Total abstracted for Town supply (MCM)*	*Reserve (BHN + Springflow + Baseflow Contributions)*	*Total abstracted for irrigation (MCM)*	*Groundwater Balance (MCM)*
G30A1	*Papkuils*	*1.34 (3.5%)*				
G30A2	*Papkuils Lower*	*0.10 (3.5%)*				
G30A_Groundwater		*5.50 (3.5%)*				
G30A_Total		*6.94*	*0*	*0.253*	*6.800*	*-0.110*
G30B1	*Upper Kruismans*	*2.75 (23%)*				
G30B1	*Upper Kruismans*	*1.39 (5%)*				
G30B2	*Soutkloof*	*1.69 (23%)*				
G30B2	*Soutkloof*	*2.92 (5%)*				
G30B3	*Huis tributary*	*6.25 (23%)*				
G30B3	*Huis tributary*	*4.33 (5%)*				
G30B_Total		*19.32*	*0.054*	*3.506*	*2.154*	*13.610*
G30C1	*Kleinvlei*	*5.98 (23%)*				
G30C2	*Jansekraal*	*5.81 (23%)*				
G30C3	*Bergvallei*	*2.92 (3.5%)*				
G30C_Total		*14.72*	*0.074*	*1.542*	*6.331*	*6.769*
G30D1	*KA upper*	*7.71 (23%)*				
G30D1	*KA lower*	*1.01 (5%)*				
G30D2	*Hol upper*	*6.15 (23%)*				
G30D2	*Hol lower*	*1.88 (5%)*				
G30D3	*Matroosfontein*	*1.56 (3.5%)*				
G30D4	*Verlorenvlei*	*1.84 (3.5%)*				
G30D_Total		*20.14*	*0.0380*	*3.286*	*10.538*	*6.278*

Sub-catchment	River System	Calculated recharge in MCM (%total annual flow)	Total abstracted for Town supply (MCM)	Reserve (BHN + Springflow + Baseflow Contributions)	Total abstracted for irrigation (MCM)	Groundwater Balance (MCM)
G30E1	Kruisfontein	0.91 (3.5%)				
G30E2	Verlorenvlei	0.45 (3.5%)				
G30E3	Verlorenvlei	0.35 (3.5%)				
G30E4	Verlorenvlei	2.72 (5%)				
G30E_Total		4.43	0.443	0.792	2.943	0.254
G30F1	Langvlei	2.39 (3.5%)				
G30F2	Lambertshoek	8.01 (23%)				
G30F3		3.29 (3.5%)				
G30F4		0.22 (3.5%)				
G30F_Groundwater _North		0.12 (3.5%)				
G30F_Groundwater _South		0.44 (3.5%)				
G30F_Total		14.47	0.986	1.713	18.433	-5.103
G30G1	Jakkals	11.15				
G30G2	Peddies	3.05 (23%)				
G30G3		2.31 (3.5%)				
G30G4		0.10 (3.5%)				
G30G_Groundwater _West		0.43 (3.5%)				
G30G_Groundwater _East		0.32 (3.5%)				
G30G_Total		17.37	0.203	0.670	3.617	12.876
G30H1		4.15 (3.5%)				
G30H_Groundwater		2.39 (3.5%)				
G30H_Total		6.53	0	0.059	2.314	4.160
F60A	Brak	1.39 (3.5%)	0	0.001		1.390
F60B	Klein-Goerap	1.44 (3.5%)	0.183146	0.009		1.253
F60C	Sout	2.48 (3.5%)	0	0.004		2.478
F60D	Groot-Goerap	2.02 (3.5%)	0	0		2.020
F60E		0.49 (3.5%)	0	0.0006		0.486
G10K_Groundwater _North		23.40 (23%)	0		unknown Z	23.32-XYZ

Where: nMAR = Natural mean annual runoff, MCM = million cubic meters and BHN = Basic Human Needs

Groundwater Quality

To be added once groundwater report and template has been updated

Surface Water Quantity

Summary of the Reserve flow recommendations for River and Wetland EWR sites/nodes:

Quaternary	Node/ EWR site	Water Resource	REC	nMAR (MCM)	EWR (MCM)	BHN* Reserve (MCM)[1]	Total Reserve (% NMAR)
F60A	EWR1	Lower Brak River	B	0.07	0.019	0.001	28.57
F60B	Node 1	Klein Goerap River	B	0.07	0.019	0.009	40
F60C	Node 2	Sout River	C	0.255	0.046	0.004	19.6
F60D	EWR3	Lower Groot Goerap River	C	0.11	0.020	0.008	25.45
G30A	EWR15	Lower Papkuils River	C	1.378	0.407	0.129	38.9
G30B	Node 3	Bergvallei River	C	16.353	7.039	0.038	43.28
G30C	Node 4	Upper Kruismans	C	11.457	4.51	0.004	39.4
G30D	EWR10	Lower Kruismans River	C	27.813	11.279	0.004	40.57
G30D	EWR11	Lower Krom Antonies River	C	7.318	2.730	0.001	37.32
G30E	EWR12	Lower Verlorenvlei River	C	47.502	17.617	0.021	37.13
G30F	EWR8	Lower Langvlei River	D	8.955	1.718	0.025	19.46
G30G	EWR7	Lower Jakkals River	D	2.315	0.685	0.131	35.25
G30H	EWR6	Lower Sandlaagte River	C	2.80	0.330	0.059	13.89

Where: nMAR = Natural mean annual runoff, MCM = million cubic meters and BHN = Basic Human Needs

NOTE: The total Reserve amount accounts for both ecological and basic human needs., where the total population of quaternary catchments was based on Census 2011 data, updated where available.

For the wetlands not linked to any river EWRs, only Rocherpan had sufficient data to provide any EWR recommendation. Based on a rudimentary analysis of past water level recordings and rainfall data, it is recommended that a maximum water level (depth) of 1 m or more should be attained in the main pan at Rocherpan for the five months of July to November each year. This would presumably require the regional water table to be at a higher level than it has been in recent years, through a reduction in groundwater abstraction in the catchment, so that rainfall can more readily result in the inundation of the pan.

Summary of the Reserve recommendations for the estuaries in G30 and F60:

Quaternary	Estuary	REC	Natural MAR (MCM)	Present MAR (MCM)	Ecological Reserve* (MCM)	Ecological Reserve (% NMAR)
G30E	Verlorenvlei	C*	33.3	17.93	27.505	82.6
G30F	Wadrift	C	4.75	3.2	3.658	77
G30G	Jakkals	D	1.41	0.96	0.804	57
F60D	Sout	D	0.46	0.46	-#	-#

** The Verlorenvlei Estuary was categorised as an "important estuary". It is a Ramsar site and a desired protected area in the Biodiversity Plan for the National Biodiversity Assessment. Therefore, according to the guidelines for assigning a REC, the condition of the estuary should be elevated to the Best Attainable State (BAS). The Best Attainable State for the estuary is B.*

#. The Sout Estuary assessment was undertaken at a desktop with hydrology that was of a very low confidence. It is recommended that the system should be restored from a E to a D. As most of the impacts are non-flow related the present day flows should be maintained as the recommended flow.

Surface Water Quality

Due to limited data at the river and wetland EWR sites, the water quality guidelines were used as additional information. The tables below provide the physical water quality Reserve requirements for each of the EWR sites as these vary from site to site, as well as the chemical water quality Reserve requirements which are the same for all the EWR sites.

Physical Water quality Reserve Requirements for the rivers and wetlands:

Quality Constituent	Parameter	Ecological Reserve	Basic Human Needs	Reserve Requirement: water quality
Papkuils River (REC = C)				
Physical water quality	pH (pH units)	7.6	6 - 9	5^{th} percentile 5.6 – 5.9 95^{th} percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	129	<70	≤129[5]
	Total Dissolve Solid (mg/l)	868	<450	≤868[5]
	Turbidity (NTU)	3.8	1 - 5	1 – 5
	Dissolve Oxygen (mg/l)	12.4		6 – 7
Kruismans River (REC = C)				
Physical water quality	pH (pH units)	7.19 – 7.35	6 - 9	5th percentile 5.6 – 5.9 95th percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	650 - 990	<70	≤650 (wet season) ≤990 (dry season)[5]
	Total Dissolve Solid (mg/l)	4400 - 6800	<450	≤4400 (wet season) ≤6800 (dry season)5
	Turbidity (NTU)	1.8 – 19.2	1 - 5	1 – 5
	Dissolve Oxygen (mg/l)	13		6 – 7
Krom Antonies River (REC = C)				
Physical water quality	pH (pH units)	7.65 – 7.78	6 - 9	5^{th} percentile 5.6 – 5.9 95^{th} percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	29 - 157	<70	≤29 (wet season) ≤157 (dry season)[5]
	Total Dissolve Solid (mg/l)	202 - 1044	<450	≤202 (wet season) ≤1044 (dry season)[5]
	Turbidity (NTU)	1.4 – 18.2	1 - 5	1 – 5
	Dissolve Oxygen (mg/l)	10.8		6 – 7
Verlorenvlei River (REC = B/C)				
Physical water quality	pH (pH units)	7.62	6 - 9	5^{th} percentile 5.6 – 5.9 95^{th} percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	194	<70	<194[5]
	Total Dissolve Solid (mg/l)	1300	<450	<1300[5]
	Turbidity (NTU)	4.4	1 - 5	1 - 5
	Dissolve Oxygen (mg/l)	8.9		6 - 7
Langvlei River (REC = D)				
Physical water quality	pH (pH units)	6.9	6 - 9	5^{th} percentile 5.0 – 5.6 95^{th} percentile 9.2 – 10.0
	Electrical conductivity (mS/m)	1214	<70	≤1214[5]
	Total Dissolve Solid (mg/l)	7998	<450	≤7998[5]
	Turbidity (NTU)	37	1 - 5	1 – 5
	Dissolve Oxygen (mg/l)	14		6 – 7
Jakkals River (REC = C)				
Physical water quality	pH (pH units)	7.12 – 7.39	6 - 9	5^{th} percentile 5.6 – 5.9 95^{th} percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	2200 - 10100	<70	≤2200 (wet season) ≤10100 (dry season)[5]
	Total Dissolve Solid (mg/l)	14606 - 61200	<450	≤14606 (wet season) ≤61200 (dry season)[5]
	Turbidity (NTU)	0.88 - 14	1 - 5	1 - 5
	Dissolve Oxygen (mg/l)	N/A		6 - 7

Chemical Water quality Reserve Requirements for the rivers and wetlands

Quality Constituent	Parameter	Ecological Reserve	Basic Human Needs	Reserve Requirement: water quality
General chemistry – Major Ions[1,2,3]	Sodium (mg/l)	N/A	<200	<200[4]
	Magnesium (mg/l)	N/A	<70	<70[4]
	Chloride (mg/l)	N/A	<200	<200[4]
	Calcium (mg/l)	N/A	<80	<80[4]
	Sulphate (mg/l)	N/A	<200	<200[4]

Quality Constituent	Parameter	Ecological Reserve	Basic Human Needs	Reserve Requirement: water quality
	Chloride (mg/l)	N/A	N/A	<0.35[4]
	Fluoride (mg/l)	N/A	< 1.5	<1.5[4]
	Manganese (µg/l)	N/A	<0.15	<0.15[4]
	Potassium (mg/l)	N/A	<50	<50[4]
Nutrients [1,2,3]	Phosphate (PO_4)(mg/l)	<0.2	N/A	<0.015 - 0.025
	Total Inorganic Nitrogen (mg/l)[3]	<0.5	<0.9	<0.7 – 1
Physical water quality	pH (pH units)	7.6	6 - 9	5th percentile 5.6 – 5.9 95th percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	129	<70	≤129[5]
	Total Dissolve Solid (mg/l)	868	<450	≤868[5]
	Turbidity (NTU)	3.8	1 - 5	1 – 5
	Dissolve Oxygen (mg/l)	12.4		6 – 7
Toxics and complex mixtures[1]	Toxics (as listed in DWAF, 1996)	≤ TWQR	≤ TWQR	≤ TWQR
Microbiological Water Quality[3]	Faecal Coliforms (count per 100ml)	-	-	-
	Total Coliforms (count per 100ml)	-	<10	<10[4]

NOTE: Where a difference in the water quality values for the Ecological Reserve and Basic Human Needs Reserve was found, the stricter or more protective value was selected for the water quality component of the Reserve.

1 ref: South African Water Quality Guidelines, Volume 1: Domestic Water Use, 2nd Ed. 1996. Department of Water Affairs and Forestry. Pretoria, South Africa.

2 ref: South African Water Quality Guidelines, Volume 7: Aquatic Ecosystems, 2nd Ed. 1996. Department of Water Affairs and Forestry. Pretoria, South Africa.

3 ref: South African National Standard 241:2011 Water Quality Standards

4 note: Based on Basic Human Needs requirements. Water for domestic use should be treated to SANS 241: 2011 Water Quality Standards.

5 note: The Reserve Requirement does not meet the Basic Human Needs requirements as it is a naturally high salinity system and would never meet the BHN requirements. Water for domestic use should be treated to SANS 241: 2011 Water Quality Standards

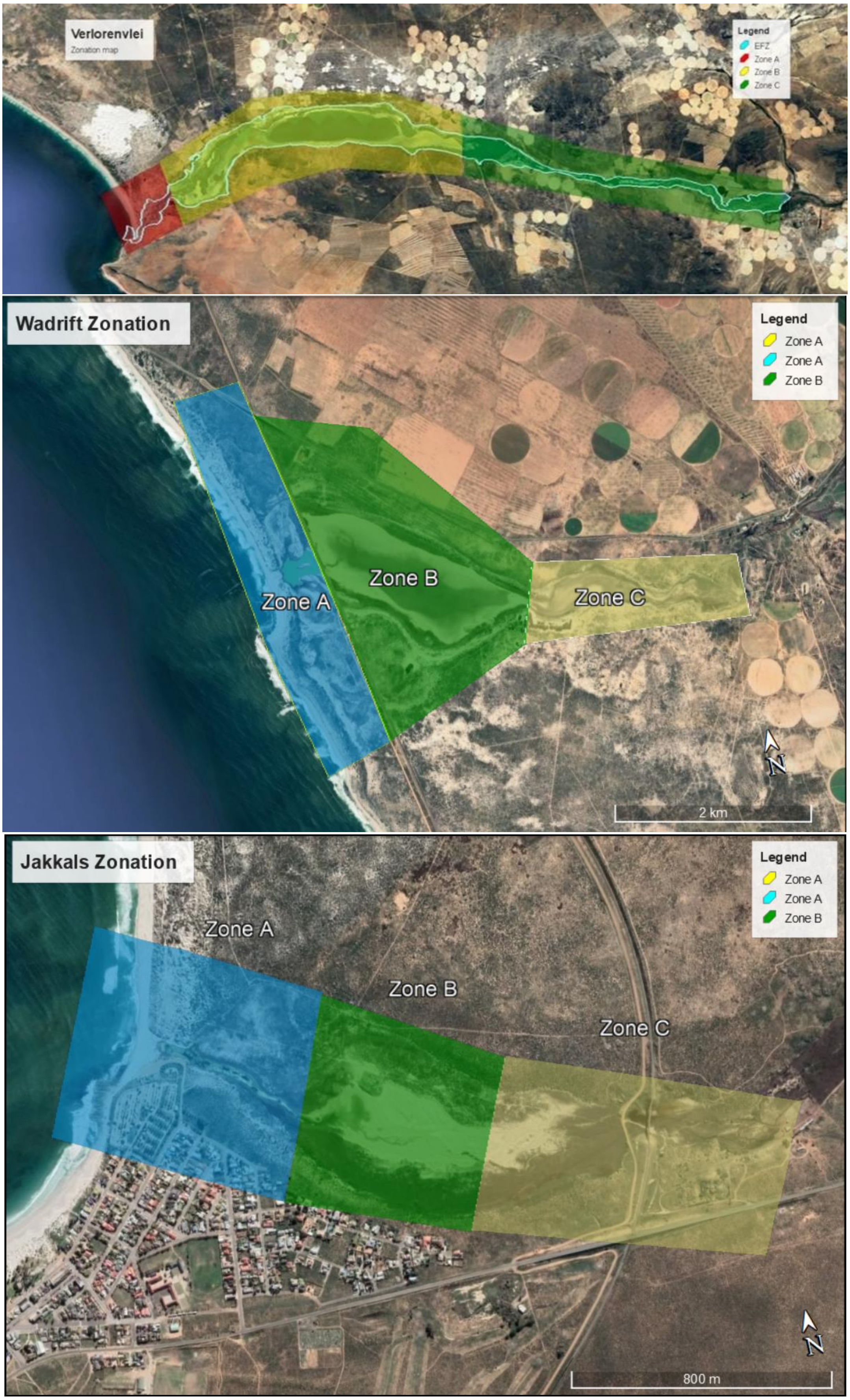
The water quality requirements for the estuaries are included in the Ecological Specifications and thresholds of potential concern (TPC) given for each of the estuaries are summarised below.

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
Verlorenvlei Estuary		
Water quality	Salinity structure and the occurrence of different abiotic states should correspond as closely as possible with the Reference condition; State 5 (Closed, Low water level hypersaline) should not occur at all.	Salinity in Zone A > 45 (for 3 years) Salinity in Zone B > 3 Salinity in Zone C > 1.5 (See Verlorenvlei zonation map below)
	Water quality in river inflow does not detrimentally affect water quality conditions in estuary, specifically relating to inorganic nutrient enrichment and toxic substances	River inflow: pH of river inflow exceeds 8.5 or is less than 5.5 Dissolved oxygen (DO) less than 4 mg/ℓ Turbidity persistently exceeds 10 NTU Dissolved Inorganic Nitrogen (DIN) persistently greater than 200 µg/ℓ Dissolved Inorganic Nitrogen (DIN) persistently greater than 50 µg/ℓ Toxic substance concentrations (e.g. heavy metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine)
	Water quality in estuary does not detrimentally impact biotic health, specifically relating to nutrient	Estuary: pH drop below 6, or persistently above 9 DO less than 4 mg/ℓ

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
	enrichment and diurnal fluctuation in pH and (e.g. decreasing at night and increasing during day time), or acidification and potential hypoxia developing during algal decay.	*Turbidity persistently exceeds 20 NTU (e.g. as a result of persistent algal blooms)* *Resultant DIN exceeds 100 µg/ℓ (in a closed system this would suggest excessive enrichment through remineralisation)* *Resultant DIP exceeds 20 µg/ℓ) (in a closed system this would suggest excessive enrichment through remineralisation)* *Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality guidelines (freshwater and coastal marine)*
Wadrift Estuary		
Water quality	*Salinity structure and the occurrence of different abiotic states should correspond as closely as possible with the Reference condition; State 5 (Closed, Low water level hypersaline) should not occur at all.*	*Salinity in any part of the estuary exceeds 65* *(See Wadrift Estuary zonation map below)*
	Water quality in river inflow does not detrimentally affects water quality conditions in estuary, specifically relating to inorganic nutrient enrichment and toxic substances	*River inflow:* *pH of river inflow exceeds 8.5 or decreases below 5.5* *Dissolved oxygen (DO) less than 4 mg/ℓ* *Turbidity persistently exceeds 10 NTU* *Dissolved Inorganic Nitrogen (DIN) persistently greater than 200 µg/ℓ* *Dissolved Inorganic Nitrogen (DIN) persistently greater than 50 µg/ℓ* *Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine). A comprehensive baseline sampling will have to be conducted to determine the substances to be incorporated into a long term monitoring programme.*
	Water quality in estuary does not detrimentally impact biotic health, specifically relating to nutrient enrichment and diurnal fluctuation in pH and (e.g. decreasing at night and increasing during day time), or acidification and potential hypoxia developing during algal decay.	*Estuary:* *pH drop below 6, or persistently above 9* *DO less than 4 mg/ℓ* *Turbidity persistently exceeds 20 NTU (e.g. as a result of persistent algal blooms)* *Resultant DIN exceeds 100 µg/ℓ (in a closed system this would suggest excessive enrichment through remineralisation)* *Resultant DIP exceeds 20 µg/ℓ) (in a closed system this would suggest excessive enrichment through remineralisation)* *Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality guidelines (freshwater and coastal marine)*
Jakkals Estuary		
Water quality	*Salinity structure and the occurrence of different abiotic states should correspond as closely as possible with the Present State;* *State 1 (Closed, Low water level hypersaline) should not occur more than at present*	*Salinity in any part of the estuary exceeds 35* *(See Jakkals River Estuary zonation map below)*
	Water quality in river inflow does not detrimentally affects water quality conditions in estuary, specifically relating to inorganic nutrient enrichment and toxic substances	*River inflow:* *pH of river inflow exceeds 8.5* *Dissolved oxygen (DO) less than 4 mg/ℓ* *Turbidity persistently exceeds 10 NTU* *Dissolved Inorganic Phosphate (DIP) persistently greater than 200 µg/ℓ* *Dissolved Inorganic Nitrogen (DIN) persistently greater than 50 µg/ℓ* *Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality*

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
		Guidelines (freshwater and coastal marine). Comprehensive baseline sampling will have to be conducted to determine the substances to be incorporated in a long term monitoring programme.
	Water quality in estuary does not detrimentally impact biotic health, specifically relating to nutrient enrichment and diurnal fluctuation in pH and (e.g. decreasing at night and increasing during day time), or acidification and potential hypoxia developing during algal decay.	*Estuary:* *pH drop below 6, or persistently above 9* *DO less than 4 mg/ℓ* *Turbidity persistently exceeds 20 NTU (e.g. as a result of persistent algal blooms)* *Resultant DIN exceeds 100 µg/ℓ (in a closed system this would suggest excessive enrichment through remineralisation)* *Resultant DIP exceeds 20 µg/ℓ) (in a closed system this would suggest excessive enrichment through remineralisation)* *Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine). Comprehensive baseline sampling will have to be conducted to determine the substances to be incorporated into a long term monitoring programme.*
Sout Estuary		
Water quality	*Extreme hypersalinity should be prevented*	*Upper reaches: >120 psu (hyper salinity)* *Middle Reaches: > 80 psu (hyper salinity)* *Lower reaches: > 60 psu (hyper salinity)*
	Water quality in estuary does not detrimentally impact biotic health, specifically relating to nutrient enrichment and potential hypoxia developing during algal decay.	*DIN: Entire estuary, average >0.1 mg/ℓ* *DIP: Entire estuary, average >0.01 mg/ℓ* *DO: Entire estuary, average >6 mg/ℓ* *Turbidity: Entire estuary, average >10 NTU except during floods* *Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine) Comprehensive baseline sampling will have to be conducted to determine the substances to be incorporated in a long term monitoring programme.*

Where: DIN = Diisolved Inorganic Nitrogen, DIP = Dissolved Inorganic Phosphorus, DO = Dissolved Oxygen, NTU = nephelometric turbidity units, psu = Practical Salinity Units



Zonation of the Verlorenvlei, Wadrift and Jakkals Estuaries

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ACRONYMS AND ABBREVIATIONS

BHN	Basic Human Needs
CD:RDM	Directorate: Resource Directed Measures
CMB	Chloride Mass Balance
CSIR	Council for Scientific and Industrial Research
DEADP	Department of Environmental Affairs and Development Planning
DFFE	Department of Forestry, Fisheries and the Environment
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphorus
DO	Dissolved Oxygen
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EcoStatus	Ecological Status
EIS	Ecological Importance and Sensitivity
EISC	Ecological Importance and Sensitivity Category
EWR	Ecological Water Requirements
GIS	Geographic Information System
GRAII	Groundwater Resource Assessment II
GRU	Groundwater Resource Unit
IFR	Instream Flow Requirement
l/s	Litre per second
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mbgl	meters below ground level
MCM (Mm^3)	Million Cubic Metres
nMAR	Natural Mean Annual Runoff

MIRAI	Macro Invertebrate Rapid Assessment Index
NCMP	National Chemical Monitoring Programme
NWA	National Water Act
PAI	Physico-chemical Driver Assessment Index
NTU	Nephelometric Turbidity Units,
PES	Present Ecological State
PESC	Present Ecological Status Class
psu	Practical Salinity Units
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQO	Resource Quality Objective
RU	Resource Units
RWQO	Resource Water Quality Objective
SANBI	South African National Biodiversity Institute
SAWS	South African Weather Service
TEC	Target Ecological Category
TMG	Table Mountain Group
TPC	Thresholds of Potential Concern
VEGRAI	Vegetation Rapid Assessment Index
WMA	Water Management Area
WMS	Water Management System
WR2012	Water Resources 2012
WRC	Water Research Commission
WRSM	Water Resources Simulation Model

GLOSSARY

ANTHROPOGENIC	Caused by human activity
AQUATIC	Relating to water
AQUIFER	Underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt)
BASEFLOW	That part of stream flow contributed by groundwater and discharged gradually into the channel.
BIOTA	The living organisms occupying a place together, e.g. plants, animals, bacteria, etc in the aquatic biota, or terrestrial biota.
CATCHMENT	The area from which any rainfall will drain into the watercourse or watercourses, through surface or subsurface flow.
ECOCLASSIFICATION	The term used for Ecological Classification refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various biophysical attributes of rivers compared to the natural or close to natural reference condition. The purpose of EcoClassification is to gain insights into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river. The EcoClassification process also supports a scenario-based approach where a range of ecological endpoints has to be considered.
ECOLOGICAL HEALTH	A descriptive non-specific term for the combination of all factors, biotic and abiotic, that make up a particular environment and its organisms
ECOREGIONS	Areas of similar ecological characteristics.
ECOSYSTEM	A community of animals, plants and bacteria with its physical and chemical environment.
EPHEMERAL	An ephemeral stream has flowing water only during, and for a short duration after, precipitation events in a typical year
ENVIRONMENT	All of the external factors, conditions, and influences that affect the growth, development, and survival of organisms or a community. This includes climate, physical, chemical, and biological factors, nutrients, and social and cultural conditions.

ESTUARY	A partially or fully enclosed body of water that is open to the sea permanently or periodically, and within which the sea water can be diluted, to a measurable extent, with fresh water drained from land.
FLOW REGIME	Recorded or historical sequence of flows used to create a hydrological profile of the water resource.
HABITAT	The environment or place where a plant or animal is most likely to occur naturally.
HYDRAULICS	Of, involving, moved by, or operated by a fluid, especially water, under pressure.
HYDROLOGY	The scientific study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.
IMPACTS	The measurable effect of one thing on another.
INDIGENOUS	Living or growing naturally in a particular area, but not naturally confined only to that area or any resource consisting of (a) any living or dead animal, plant or other organisms of an indigenous species, (b) any derivative of such animal, plant or other organisms; or (c) any genetic material of such animal, plant or other organisms.
LEGISLATION	A law or a series of laws
MANDATE	The authority to do something, given to an organisation or government, by the people who support it.
MODIFIED	Changed, altered.
POLICY	A plan of action, statement of ideals, etc. proposed by an organization, government, etc.
PRISTINE	Remaining in a pure or natural state.
PREDATION	A predator is an animal that kills and eats other animals. Predation is the capturing of prey as a means of maintaining life.
PRESENT ECOLOGICAL STATE	The current state or condition of a resource in terms of its various components, i.e. drivers (physico-chemical, geomorphology, and hydrology) and biological response (fish, riparian vegetation and aquatic invertebrates). The prequel to recommended ecological category
QUATERNARY CATCHMENT	A fourth-order catchment in a hierarchical system in which the primary catchment is the major unit.

RIPARIAN	Of, on, or relating to the banks of a water course, including the physical structure and associated vegetation. The area of land adjacent to a stream or river that is influenced by stream-induced or related processes.
SPECIES	A kind of animal, plant or other organisms that does not normally interbreed with individuals of another kind, and includes any sub-species, cultivar, variety, geographic race, strain, hybrid or geographically separate population
TERTIARY CATCHMENT	A third-order catchment in a hierarchal classification system in which a primary catchment is a major unit.
SURFACE WATER	All water that is exposed to the atmosphere, e.g., rivers, reservoirs, ponds, the sea, etc.
VARIABILITY	The tendency to vary i.e. to change.
WATERCOURSE	"A natural channel or depression in which water flows regularly or intermittently" (definition in the NWA)
WATER QUALITY	The value or usefulness of water, determined by the combined effects of its physical attributes and its chemical constituents and varying from user to user
WETLANDS	"Land which is transitional between terrestrial and aquatic systems where the water table is usually at, or near the surface or the land is periodically covered with shallow water and which land in normal circumstances supports, or would support vegetation typically adapted to life in saturated soil" (definition in the NWA)

1. INTRODUCTION

1.1 Background

The Chief Directorate: Water Ecosystems Management of the Department of Water and Sanitation (DWS) has embarked on a preliminary Reserve determination study for the G30 and F60 catchments (Figure 1). These are the two remaining Tertiary Catchments of the Berg Olifants Water Management Area (WMA) that still require a higher level of confidence Reserve determination. The Verlorevlei within the study area was designated as a Wetland of International Importance (Ramsar Site) on 28 June 1991 under the Ramsar Convention on Wetlands of International Importance, Especially as Waterfowl Habitat. In addition, peat wetlands have been identified to occur in the area that is associated with the Verlorevlei that provide important ecological services but are under severe threat and require urgent protection. It is therefore crucial that the Reserve calculations are revisited and the water resources with the Sandveld catchments addressed holistically, with a clear understanding of the surface and groundwater interactions and interdependencies being well researched and documented.

1.2 Objectives

This study aims to identify gaps in previous Reserve Determination Studies and to determine the Reserve at a high level of confidence to yield results that could be gazetted and provide legal protection specifications. The following objectives are listed:

1. Determination of the water quantity and quality for the protection of rivers at various Ecological Water Requirement (EWR) sites;
2. Determination of the water quantity and quality for the protection of priority wetlands, pans and lakes;
3. Determination of the water quantity and quality of estuarine freshwater requirements for the protection of various identified estuaries;
4. Determination of the groundwater quantity and quality requirements for the protection of groundwater resources; and
5. Determination of the quantity and quality of water required for the provision of Basic Human Needs.

1.3 Purpose of this Report

The purpose of this report is to provide an integrated summary of the findings and recommendations of the Reserve determination for surface and groundwater in the G30 and F60 catchments (Figure 1) of the Olifants-Doorn Water Management Area.

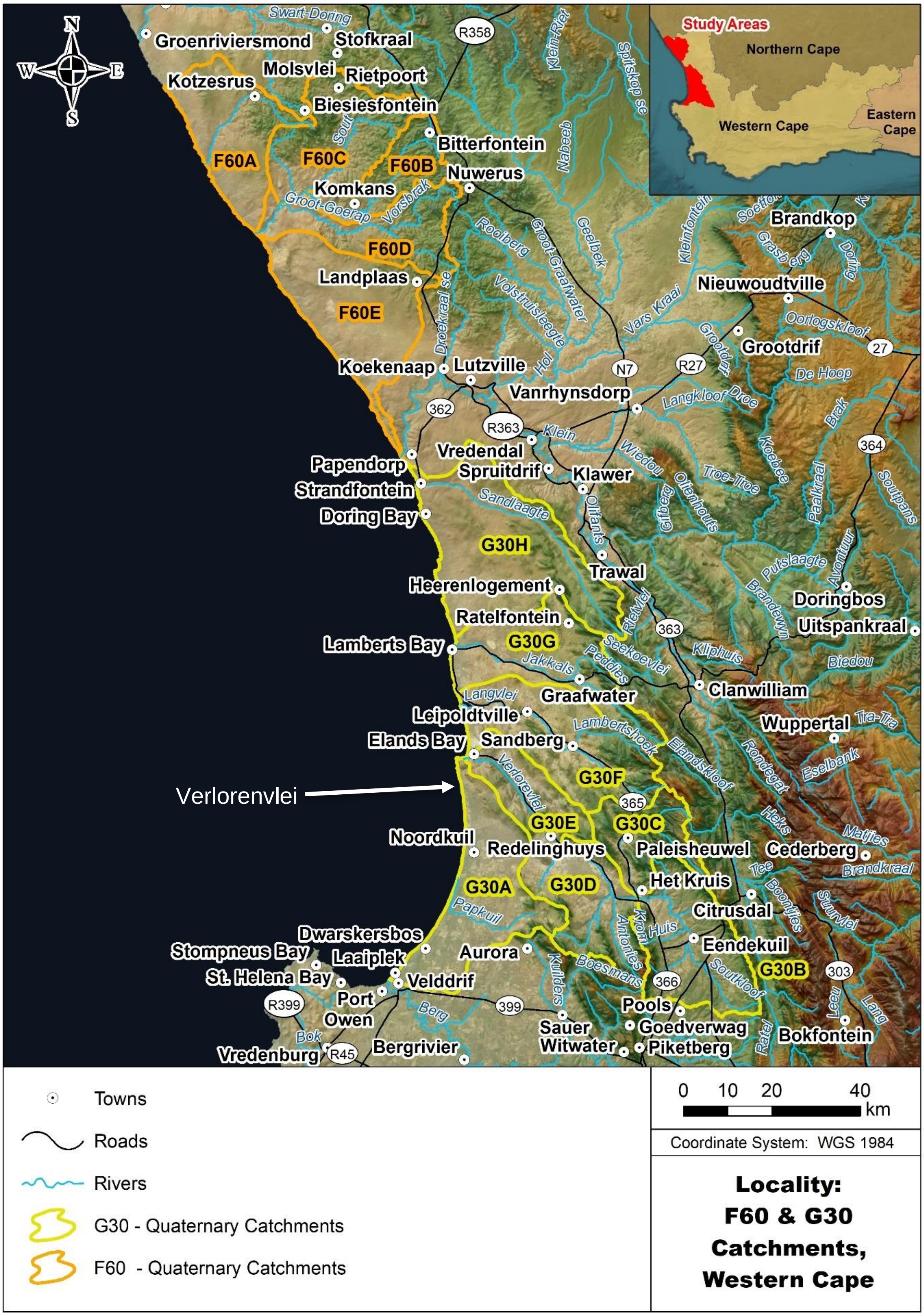

Figure 1: Map of the study area with the location of the G30 and F60 Catchments and main aquatic features shown

1.4. The Study Area

The study area comprises two Tertiary Catchments, the F60 (Knersvlakte) and the G30 (Sandveld) Catchments. The majority of the F60/G30 Catchment Area falls within the Western Cape Province, with a small section of the most northerly section of the catchment falling within the Northern Cape Province.

The Sandveld consists of the coastal plain along the west coast of South Africa, bordered by the Olifants River catchment in the north and east, the Berg River catchment in the south and the Atlantic Ocean coastline in the west. The area contains the following seasonal river and wetland systems:

- Verlorenvlei River System with its main tributaries, the Kruismans, Bergvlei, Krom Antonies and Hol Rivers, as well as the Verlorenvlei Estuary;
- Langvlei River with the Wadrift wetland and pan;
- Jakkals River and Jakkalsvlei Estuary;
- Sandlaagte River
- Rosherpan and Papkuil River; and
- Several smaller wetland areas along watercourses, coastline and on hillslopes.

As the study area is a water-scarce region with largely non-perennial and ephemeral river systems, it has a depauperate native freshwater fish ichthyofauna, comprising three recognised fish species Endangered Verlorenvlei redfin *Pseudobarbus verlorenvlei*, Data Deficient Cape Galaxias *Galaxias zebratus* and the Data Deficient Cape kurper *Sandelia capensis*. Similarly, the macroinvertebrate communities mainly comprise low diversities of hardy species and air-breathing taxa. A low amphibian species richness also occurs with eleven frog species known from or expected to occur in this area, with eight being reliant on the annual inundation of wetland habitats. Verlorenvlei and the adjacent Wadrift Pan, however, provide important habitat for birdlife.

The Ramsar-designated Verlorenvlei estuarine and wetland system is the best-known of the systems and has a clear responsibility of actively conserving the unique wetland and the biological diversity that it supports.

The Groot Goerap/Sout and Brak River Catchments to the north of the Sandveld are in the even more arid Knersvlakte region. The area comprises ephemeral rivers and wetlands, including:

- Sout River System with its main tributaries, the Groot and Klein Goerap Rivers and the South Estuary;
- Brak River and Estuary; and
- Several mostly isolated depression wetlands.

Groundwater in the G30 (Sandveld) catchment enables extensive agricultural activity and is the sole source of freshwater for most of the towns and settlements within the catchments. Groundwater also plays a significant role in sustaining surface water ecosystems. The catchments contain both fractured and intergranular areas. Average yields range from very low (0.5 l/s) to high yielding (> 5 l/s), with identified paleochannels producing boreholes of a yield higher than 25 l/s. Groundwater quality is described as being good across the G30 catchments, however, where Malmesbury Group formations occur, the main aquifer can be identified as yielding groundwater of poor quality. The main recharge areas have been identified as the mountainous areas towards the east of the study area that form part of the Cederberg and Piketberg Mountain ranges.

Groundwater availability in the F60 catchments is much lower than in the G30 catchments. The geological setting of the area is also more complex. The area has been classified as containing both intergranular and fractured aquifers (DWAF 2005). The regional expected yields are very low (0.1 - 0.5 l/s) with higher-yielding boreholes (up to 2 l/s) at the most southern point of the F60 catchments. Groundwater quality across the catchment is generally categorised as poor, with EC values of over 1000 mS/m.

Land use in the area consists largely of livestock farming (sheep and goats), with small areas being used for dryland farming. Intensive irrigation of citrus and potatoes is undertaken in the south. Urban and rural areas are small, with the main towns being Redelinghuys, Elands Bay, Eendekuil, Leipoldtville, Graafwater, Lamberts Bay, Strandfontein and Bitterfontein. Water abstraction from surface and groundwater in the southern portion of the study area has significantly modified the flow of the aquatic ecosystems, particularly in summer. Modified flows have reduced habitat integrity and, consequently, the goods and services provided by these ecosystems.

1.5. Study Methodology and Approach

The river, wetland, estuarine and groundwater components of the Reserve determinations are based on the latest RDM recommended methodologies. While the standard methodologies for the determination of the Basic Human Needs and ecological Reserve will be followed in the study, recognition of the need for a slightly adapted approach for the Sandveld and Knersvlakte Rivers needs to be undertaken. This adapted approach is deemed to be necessary to address the following:

- Most of the surface water features within the study area are non-perennial with a hydrological regime that has high variability in flow both spatially and temporally with a highly unpredictable surface water flow.
- Surface water ecosystems in these systems are often confined to isolated pools that eventually dry up. The aquatic biota associated with these habitats comprises hardy species with low diversity, although both the habitat and biota may be of high ecological importance;
- The estuaries within the area comprise mostly coastal lakes or estuarine salt pans, with a low diversity of hardy species. These systems are mostly nearly permanently closed and also have very little freshwater inflow from their associated river systems. As a result, they tend to be hypersaline;
- Very close integration occurs between the surface water ecosystems (rivers, wetlands and estuarine habitats) as well as with the groundwater. Integration of these two specialist fields and the recommended ecological Reserve (quantity and quality) thus needs to take place; and
- The sequencing and interaction between the tasks and disciplines on this project are critical. The products from the groundwater specialists will provide an improved understanding of the surface water ecosystems and the delineation of the river reaches

and wetland regions. Enough time must be set aside to allow for integration. The wetlands component will especially need to provide inputs to and rely on inputs from the Rivers and Groundwater specialists. Once the priority wetlands have been determined, a key step will be to interact with the specialists to obtain assistance in determining EWRs. The River specialists would also need to have input into the wetland priorities chosen.

The revised generic procedure is provided in Figure 2 (DWAF, 2008), which shows the process for the determination of the Ecological Water Requirement in the context of the larger Resource Directed Measures process, with possible links to issues such as the stakeholder process, classification, implementation and operation, indicated as suggested ways to integrate the Reserve determination process.

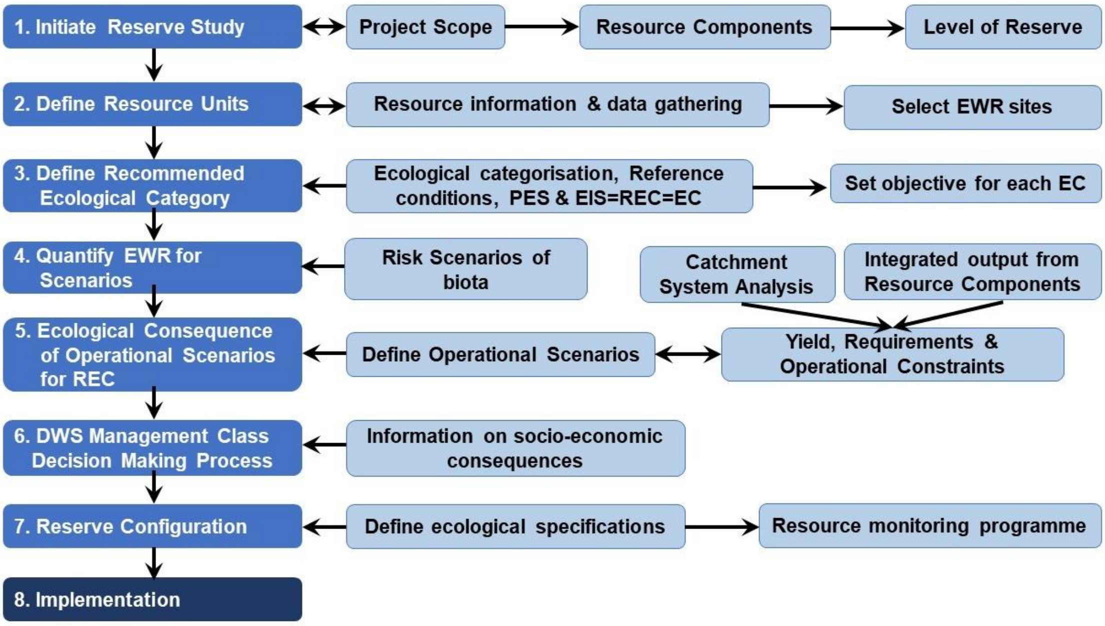

Figure 2: The Reserve Determination Process (adapted from DWAF, 2008)

This report documents the outcome of all the above steps of the Reserve determination process.

1.6. Data Gaps and Assumptions

Lack of data across the F60 and G30 sub-catchments impacts the level of confidence in the Reserve determinations. Active sampling of surface and groundwater did not form part of the scope of this project and thus the Reserve determination is reliant on existing data where available. For the sub-catchments, the lack of flow and water quality data and the widespread undocumented abstraction and storage of water provides additional uncertainty. For both catchment clusters, there is also a significant lack of information on reference pre-development and water use conditions.

1.6.1. Groundwater levels and quality data

Data for the Groundwater Reserve determination was obtained through various sources, with the DWS long-term monitoring data forming the base of the assessment with regard to water levels and trends in the catchments. The main data sources included:

- The National Groundwater Archive (NGA)
- The Department of Water and Sanitation`s monitoring database for the Berg, Sandveld, Cederberg and Bitterfontein Monitoring Networks
- The internal GEOSS database for work done within the F60 and G30 catchments for current and archived projects
- The Stellenbosch University work that has been done in the G30 catchments
- The Potato South Africa monitoring project, although only limited access was granted to this database
- Namaqua Sands Mine

Most of the water level data was obtained from single event measurements taken, where a preference was given to static water levels where available. The only available long-term monitoring data is in the central Sandveld region, with the DWS monitoring data mostly being used and supplemented with the other above-mentioned available datasets.

In terms of water quality, electrical conductivity (EC) and pH are the only data readily available that provide an indication of the groundwater quality for much of the study area. Detailed water quality data from laboratory testing analysis results are not freely available and difficult to obtain. The more comprehensive groundwater analysis results are grouped within the central G30 catchments, with no comprehensive groundwater analysis available within the F60 catchments.

1.6.2. Groundwater abstraction and borehole yield data

Groundwater abstraction data was obtained to determine the level of stress in each Groundwater Resource Unit. Borehole yield data from the NGA and GEOSS databases were then used to provide an indication of the exploitation potential of groundwater for a certain area.

Currently, there is no dataset of the actual monitored water abstraction. The data for registered springs and boreholes were sourced through WARMS data and provided a spatially well-distributed data set for the G30 catchments but had no data for the F60 catchments. For the G30 catchments, the main groundwater uses are for water abstracted for irrigation and municipal supply. For the F60 catchments, registered groundwater use was much lower.

Most water users within the catchments use both ground and surface water interchangeably, abstracting when surface water is available and then changing to groundwater when surface water flow ceases. The Verification and Validation (V&V) data was used to calculate the ratio between groundwater and surface water use, for each catchment. An average irrigation factor of 7000 m^3/ha/a was used to calculate the volumes being abstracted for irrigation use, whereas the 2017/2018 Crop Census data obtained from the Department of Agriculture (Western Cape Department of Agriculture, 2018) was used to determine the extent of crop types irrigated. This factor is considered an average value used in the G30 catchment by DWS.

Municipal abstraction data was obtained from recent Water Use License applications submitted for towns in the G30 catchments. Groundwater use for towns in the F60 catchments was estimated based on groundwater use monitoring data for Bitterfontein (Matzikama Municipality, 2022), which treats and pipes the water to other settlements within the F60 catchment. Lepelsfontein has its own groundwater supply, however, there is no abstraction data from which volumes could be calculated.

1.6.3. Hydrologic Parameter Data

1.6.3.1. Groundwater recharge

For the central G30 catchments, isotope dating has linked the groundwater found in the low-lying coastal regions with rainwater sampled in the higher-lying mountainous regions of the Piketberg and Citrusdal mountains (GEOSS, 2019), although most of the studies have been focused on the Piketberg Mountains and the Verlorenvlei Catchment. Groundwater recharge in the Verlorenvlei catchments has been determined using rainfall/runoff modelling (Watson et al., 2018), a natural tracer technique using Chloride Mass Balance (CMB) (Watson et al., 2020 and GEOSS, 2019) and a GIS−based modelling approach (Conrad et al., 2004).

Recharge dominantly occurs in areas of high elevation, such as the Piketberg Mountains, and therefore into the Table Mountain Group (TMG) aquifer. Thus, it can be noted that aquifer-specific recharge values are available for the G30 catchments that make up the Krom-Antonies and Verlorenvlei system (G30D and G30E), but not for other G30 catchments and not for the F60 catchments.

The Groundwater Resource Assessment II (GRAII, 2012), calculated groundwater recharge values for each of the G30 and F60 catchments. These values were calculated per catchment and are not aquifer specific, but if no other recharge values are available, these could be used.

For the other G30 catchments, it was thus decided to use aquifer-specific recharge, assigning representative recharge values per aquifer. These representative values were obtained from the latest studies done by Stellenbosch University: TMG: 23%, Malmesbury Shales: 5% and Sand Aquifer: 3.5% of Mean Annual Precipitation (MAP). These estimated recharge values are more representative of some of the other G30 catchments than the GRAII values.

Recharge was calculated on a small scale (surface water catchment delineations were used) where possible and then added up to represent the complete groundwater resource units. A recharge calculation was also done of the portion of the Piketberg Mountain range that falls outside the G30 catchment (in G10K), to provide an indication of what volumes can be expected to recharge the G30A, G30D and G30E catchments through lateral recharge from outside of the G30 catchment system.

1.6.3.2. Groundwater Baseflow

For the G30 river systems, fault zones have been mapped parallel or near the river/wetland systems. The current hypothesis is that these fault systems act as preferred pathways for groundwater flow and that at discontinuous sections along these structural faults, there is an upwelling of groundwater into the unconsolidated sands. These areas are where seepage zones and springs are present and also where groundwater exploration is targeted. It could be assumed that these areas would contribute to the baseflow of these systems, at certain points along the system.

The baseflow calculations for the F60 and G30 catchments are based on data from the GRAII (2012) and a recent study completed by Watson (2019) where the groundwater component within the J2000 rainfall-run-off modeller was distributed to calculate baseflow and streamflow estimates. Baseflow and streamflow estimates were calculated for the four main tributaries; 1) Bergvallei, 2) Kruismans, 3) Hol and 4) Krom Antonies. These tributaries make up 81% of the streamflow into the Verlorenvlei. It was also found that of the water entering the Verlorenvlei, ~56% of the total flow is surface run-off, with groundwater baseflow and interflow contributing ~40% and ~4%, respectively (Watson et al., 2019). For those not linked to the Verlorenvlei system (G30H and the F60 systems), the GRAII (2012) values were used. Baseflow estimations obtained from the GRAII model as well as the estimated baseflow percentage of total flow calculated by Watson (2019).

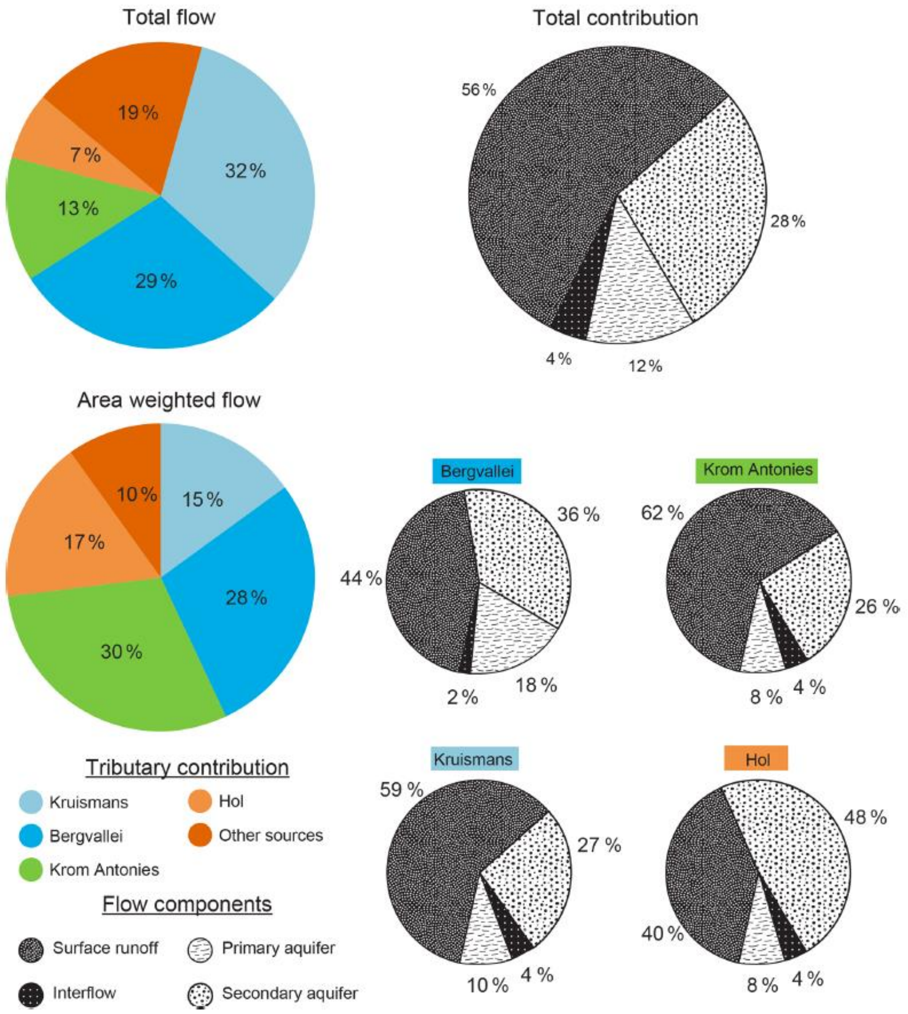

Figure 3: The Verlorenvlei flow contributions (total flow and area-weighted flow) of Kruismans, Bergvallei, Krom Antonies and Hol as well as flow component separation into surface runoff, interflow, primary aquifer flow and secondary aquifer flow (Watson, 2019)

1.6.4. River and Wetlands

1.6.4.1. Hydrology

There are no operational streamflow gauges in the study area. Historical observed daily flows are available on the Kruismans River at Tweekuilen/Eendekuil (DWS flow gauge G3H001) for the period 1971 to 2005. The observed flows from this gauge were used during this study to validate the modelled flows for the Verlorenvlei Catchment. The DWS flow gauge at E3H001 on the Troe-troe River was used as a reference gauge for the validation of shale-derived flows in the G30F, G30G and G30H catchments.

No long-term water level measurements were available for any of the wetland sites, especially for recent years. The only site for which some water level data were obtained, together with site-specific rainfall data, was the main pan in the Rocherpan wetland (part of "Die Vlei"). Routine water level measurements for this wetland, as collected by CapeNature Reserve staff, were only available for the period June 1982 to December 1996.

Fourteen rainfall stations in the catchment have been used in WR2012 hydrological modelling for the quaternary catchments. Eight stations of these stations had data available up to 2020. Additional rainfall data for nine stations were sourced from DWS, private users and the South African Weather Station. The additional rainfall data enabled the WR2012 hydrology to be extended to the 2020 hydrological year.

The approach to the hydrological modelling in the study catchment had to take into consideration the pronounced surface water and groundwater interactions. Since the WRSM Pitman model is a rainfall-runoff model, it simulates surface water runoff and has limited groundwater modelling capabilities. Baseflow and spring flow contributions were modelled explicitly by using a defined time series of inflows calculated outside of the model and with inputs and guidance from the groundwater specialists. Given the lack of observed flow data in the catchment, validation of simulated flows could only be undertaken by means of flow records at two streamflow gauges, namely G3H001 and inferred from E3H001, as well as with inputs from the specialists on the team (estuarine and riverine specialists). Bed-losses were included on the channel modules in the model at appropriate locations in the catchment, notably in the Papkuils and Jakkals Rivers.

The WRSM2000 Pitman model was updated with the latest land-use information available (Western Cape Department of Agriculture Crop Census 2017/18 and Department of Environmental Affairs Land Cover dataset) to produce the best possible estimates of present-day flow. Land-use components included: Irrigation and return flows, Afforestation, Alien invasive plants and Urban/rural water requirements.

The large dams and smaller farm dams were also included in the WRSM2000 Pitman model setup. The smaller dams were incorporated to include the effect of irrigation from farm dams, as well as the effect of multiple small dams' regulation in streamflow and loss of water by evaporation from the dam surfaces. The subsequent result is a reduction in water yield from water resource developments downstream of these dams. The present-day flows were then generated using the configured model with all the catchment development information incorporated at the required resolution.

1.6.4.2. Water Quality

The major information gap for the water quality Reserve determination is the lack of historical and present-day water quality data which impacts the confidence of the Reserve results. The lack of water quality data also makes it challenging to determine reference conditions. Even more challenging is the fact that both G30 and F60 quaternary catchments have non-perennial rivers linked to wetlands with definite wet and dry rainfall seasons, with and without interaction with the groundwater and springs in the study areas. Reference conditions were determined by following the non-perennial river methodology as described in Seaman *et al,* 2010, in which the catchment and not only the EWR site are included in the evaluation of the reference condition.

Water quality monitoring data is available on the DWS Water Management System (WMS) and is part of the National Chemical Monitoring Programme (NCMP). The Western Cape Regional Office has been monitoring the water quality since 2019 in some rivers in the G30 catchment. From an examination of the spatial distribution of water quality sampling points in the study area, it appears as if there is a good distribution of monitoring points that could be used to describe the spatial changes in water quality. However, these points are mostly associated with once-off, longitudinal river water quality surveys. The only monitoring points in the G30 tertiary catchment where there is a longer data record are at the Kruismans River at Tweekuilen/Eendekuil, and the Hol River at Wittewater/Papkuilsvlei gauging sites, referred to as G3H001 and G3H005 respectively.

At the G3H001 sampling site (Kruismans River at Tweekuilen/Eendekuil), some 374 samples were collected from 1970 to 2017, while 102 samples were collected at G3H005 (Hol River at Wittewater Papkuilsvlei) between 1978 and 2017. Sampling frequency started at monthly intervals but was later reduced to *ad hoc* sample collection. The historical data record at both sampling stations was examined for seasonal changes to determine if there are differences in water quality between the wet and dry seasons.

There is no long-term water quality monitoring data available in the F60 tertiary catchment.

The fact that the rivers and wetlands are fed from different water resources (groundwater, surface water runoff and springs) does not enable one to confidently extrapolate water quality characteristics from one EWR site to the next. Close cooperation between the specialists from the wetlands, groundwater and rivers was required to understand the flow interaction between the different water resources, as each of the resources can have a different chemical footprint depending on its origin (Seaman *et al*., 2010).

It was proposed that the Physico-chemical Driver Assessment Index (PAI) model (DWAF, 2008, DWS, 2016) be used where applicable in line with the use of the other assessment indices (HAI, GAI, FRAI, MIRAI and VEGRAI). However, there are not enough data available to populate the PAI and it was therefore not used in this study.

2. DELINEATION OF WATER RESOURCES

Below are lists of the groundwater resource units (GRUs) and surface water EWR sites in the G30 and F60 catchments. The resource units largely coincide with the quaternary catchments within the study area, with the EWR sites being located at the existing point of the associated watercourse in the quaternary catchment. The delineated resource units and EWR sites are shown in Figure 4 to Figure 6.

2.1. Groundwater Resource Units

G30 Catchments (Figure 4): Within the G30 catchments, the GRUs closely align with the quaternary catchments as they tend to each incorporate a single valley that relates well with perceived groundwater flow and surface water contribution.

- **Papkuils (G30A GRU)**: Comprises the G30A catchment, including the Papkuils River and Rosherpan
- **Verlorenvlei & Tributaries (Southern G30D GRU)**: Comprises the upper reaches of the Krom Antonies and Hol River catchments.
- **Verlorenvlei & Tributaries (Northern G30D GRU)**: Comprises the lower reaches of the Hol, Krom Antonies and Kruismans Rivers to their confluence with the Verlorenvlei River.
- **Verlorenvlei & Tributaries (G30B GRU)**: Comprises the upper Kruismans River between the Citrusdal and Piketberg Mountain ranges.
- **Verlorenvlei & Tributaries (G30C GRU)**: Comprises the Bergvallei Valley.
- **Verlorenvlei & Tributaries (G30E GRU)**: Comprises the Verlorenvlei area and includes the Kruisfontein Springs.
- **Langvlei-Wadrift (Northern G30F GRU)**: Langvlei has two "paleochannel type structures" running through the valley, a northern and a southern valley. This GRU comprises the northern one.
- **Langvlei-Wadrift (Southern G30F GRU)**: This GRU lies south of the Northern G30F GRU and includes the Wadrift aquifer.
- **Jakkals (G30G GRU)**: Comprises the Jakkals River catchment.
- **Northern Sandveld (G30H GRU)**: Comprises the Sandlaagte catchment and is referred to as the Northern Sandveld.

F60 Catchments (Figure 5): As for the G30 catchment, in F60 the GRUs also closely align with the quaternary catchments.

- **Namaqualand (Southern F60E GRU)**: The GRU is situated on the coast in the area north of the Olifants River Estuary. There are no watercourses within this unit, only depression wetlands.
- **Namaqualand (Northern F60E GRU)**: Comprises the northern portion of the F60E catchment. As for the Southern Namaqualand GRU, there are no watercourses within this unit, only depression wetlands.
- **Groot-Goerap & Sout (F60D GRU)**: The groundwater unit falls within the F60D catchment and includes the Groot Goerap and lower Sout Rivers.
- **Klein-Goerap (F60B GRU)**: The groundwater unit falls within the F60B quaternary catchment boundaries and includes the Klein Goerap River.

- **Sout (F60C GRU)**: The groundwater unit falls within the F60C quaternary catchment boundaries and includes the Sout River (before it joins with the Groot-Goerap).
- **Brak (F60A GRU)**: The groundwater unit falls within the F60A quaternary catchment boundaries and includes the Brak River Catchment.

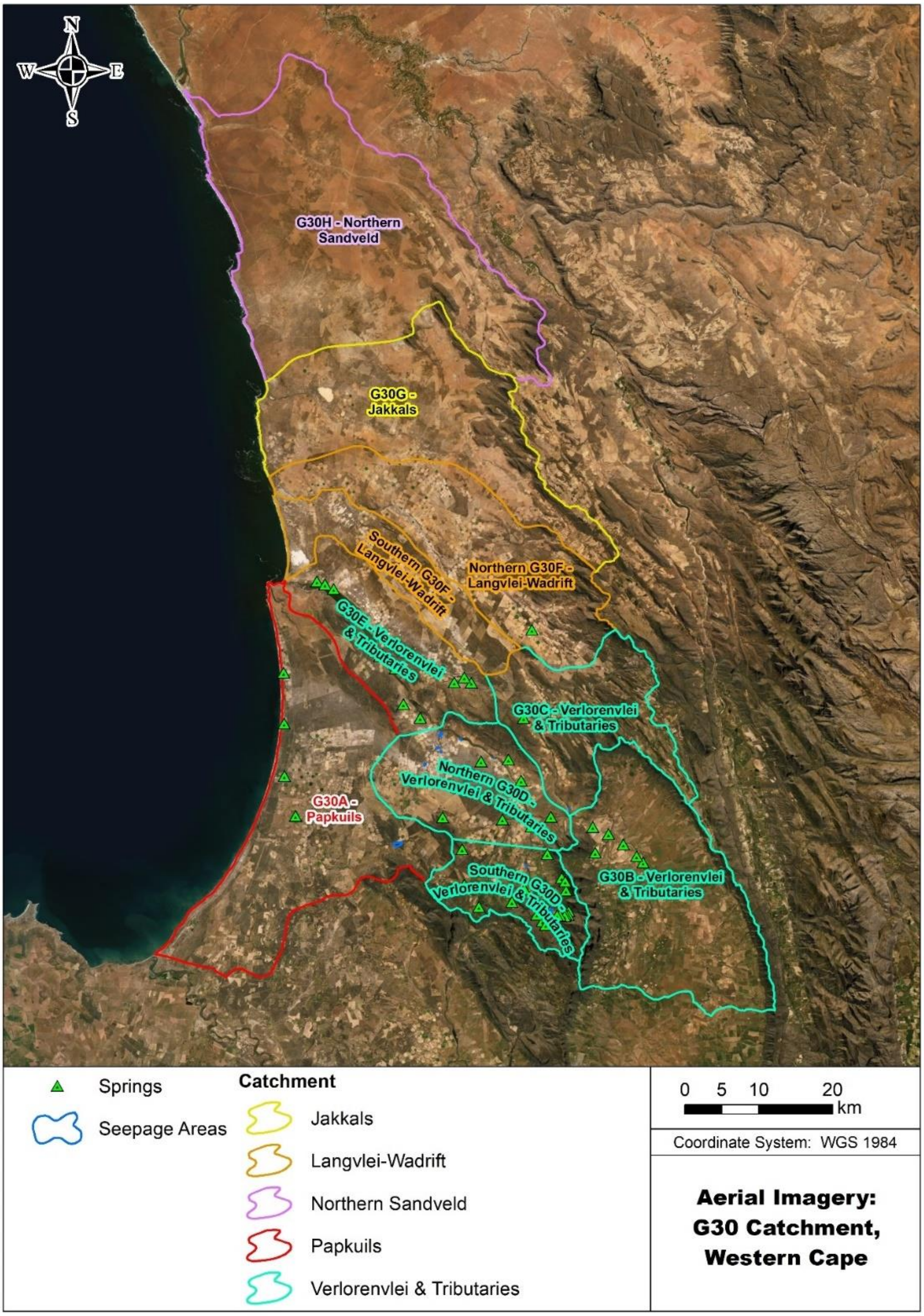

Figure 4: Combined map of delineated GRUs for the G30 catchments

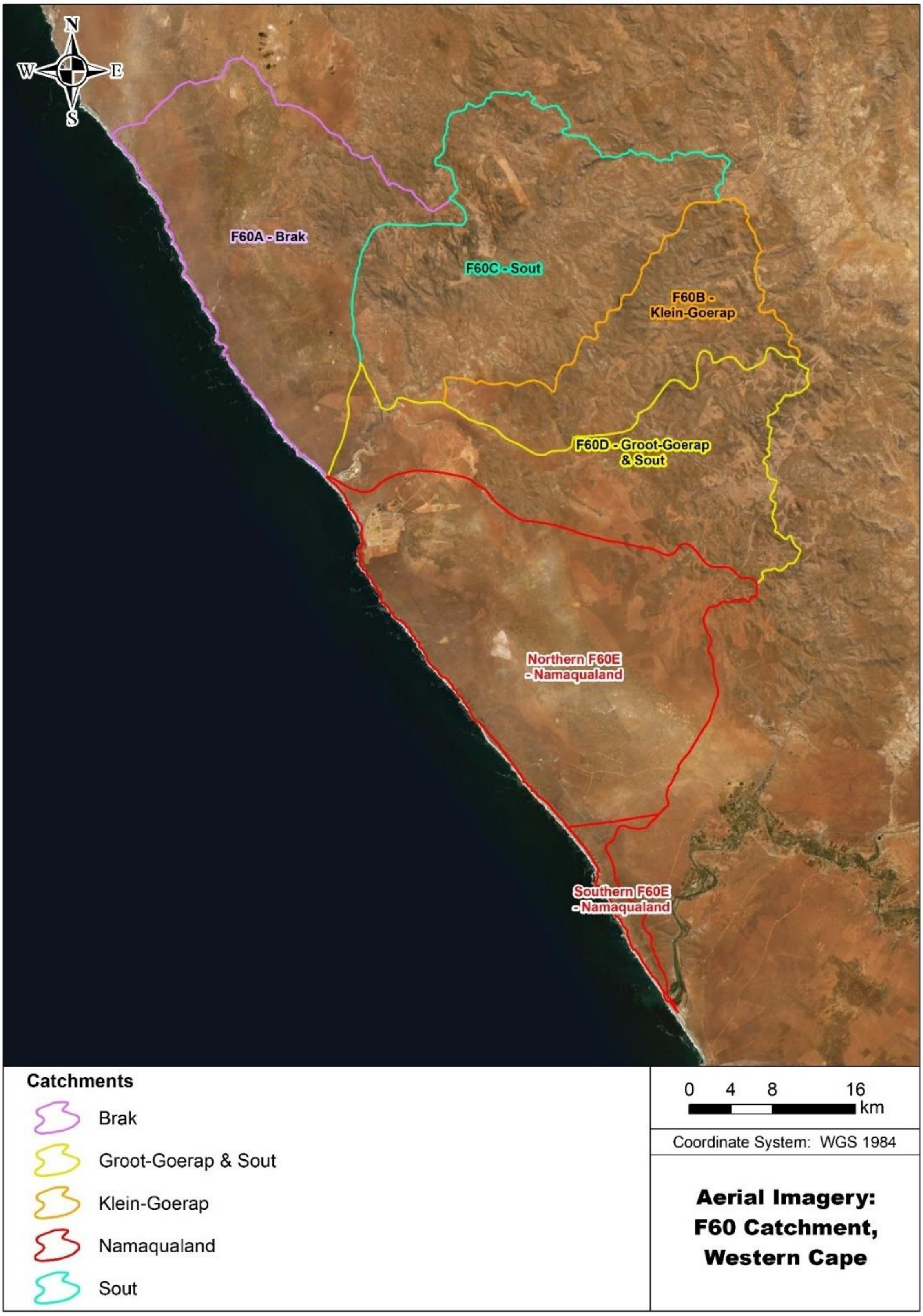

Figure 5: Combined map of delineated GRUs for the F60 catchments

2.2. River and Wetland EWR sites

From the perspective of the rivers and wetlands, the most logical resource unit is the topographical catchments. The study area comprises seven main topographical catchments (the Papkuils, Verlorenvlei, Langvlei/Wadrift, Jakkals and Sandlaagte catchments in the G30 Tertiary Catchment area, and the Sout and Brak catchments in the F60 Tertiary Catchment area). The only catchment within the study area that makes sense to subdivide further is the Verlorenvlei and split this into the upper catchment, upstream of the Krom Antonies Tributary, and the lower catchment that includes the Verlorenvlei and Krom Antonies Catchments. The selection of Wetland Resource Units for EWR determination in the study area was not a semi-automated desktop-based exercise but rather involved the application of expert judgement, including that obtained through discussions between team members during the reconnaissance field trip. Many of the sites listed below have both river and wetland characteristics.

- **EWR1 RW-F60A BRAK STRAN** Brak River and Valley Bottom Wetland
- **EWR2 W-F60A DEPR NUWEB** North West Fynbos Depression Wetland
- **EWR3 RW-F60B GRGO KOMKA** Sout/Groot-Goerap River
- **EWR4 W-F60C DEPR ADOON** Knersvlakte Depression Wetland
- **EWR5 W-F60E DEPR ELSIE** Sandveld Depression Wetland
- **EWR6 RW-G30H SAND HOLLE** Sandlaagte River
- **EWR7 RW-G30G JAKK KOOKF** Jakkals River and Valley Bottom Wetland
- **EWR8 RW-G30F LANG BRAND** Langvlei River and Valley Bottom Wetland
- **EWR9 W-G30F WADR WAGEN** Wadrift Valley Bottom Wetland
- **EWR10 RW-G30D VERL EENHE** Upper Verlorenvlei River and Valley Bottom Wetland
- **EWR11 RW-G30D KROM GOERG** Krom Antonies River and Floodplain Wetland
- **EWR12 RW-G30E VERL WITTE** Lower Verlorenvlei River and Floodplain Wetland
- **EWR13 W-G30A DUNE FA277** West Strandveld Duneslack Wetland
- **EWR14 W-G30A ROSH FA272** Rosherpan Wetland
- **EWR15 RW-G30A PAPK BOOKR** Papkuils River and Valley Bottom Wetland
- **EWR16 W-G30A PAPK RIETF** Upper Papkuils Seep Wetland

2.3. Estuary Resource Units

The estuarine functional zone for each estuary was delineated based on consideration of historical extent, the limit of tidal influence and a default lateral boundary that comprises the +5m mean sea level topographical contour.

- Verlorenvlei Estuarine Lake (G30E)
- Wadrift Arid, Predominantly Closed Estuary (G30F)
- Jakkals Temporary Closed Estuary (G30G)
- Sout Arid, Predominantly Closed Estuary (F60D)

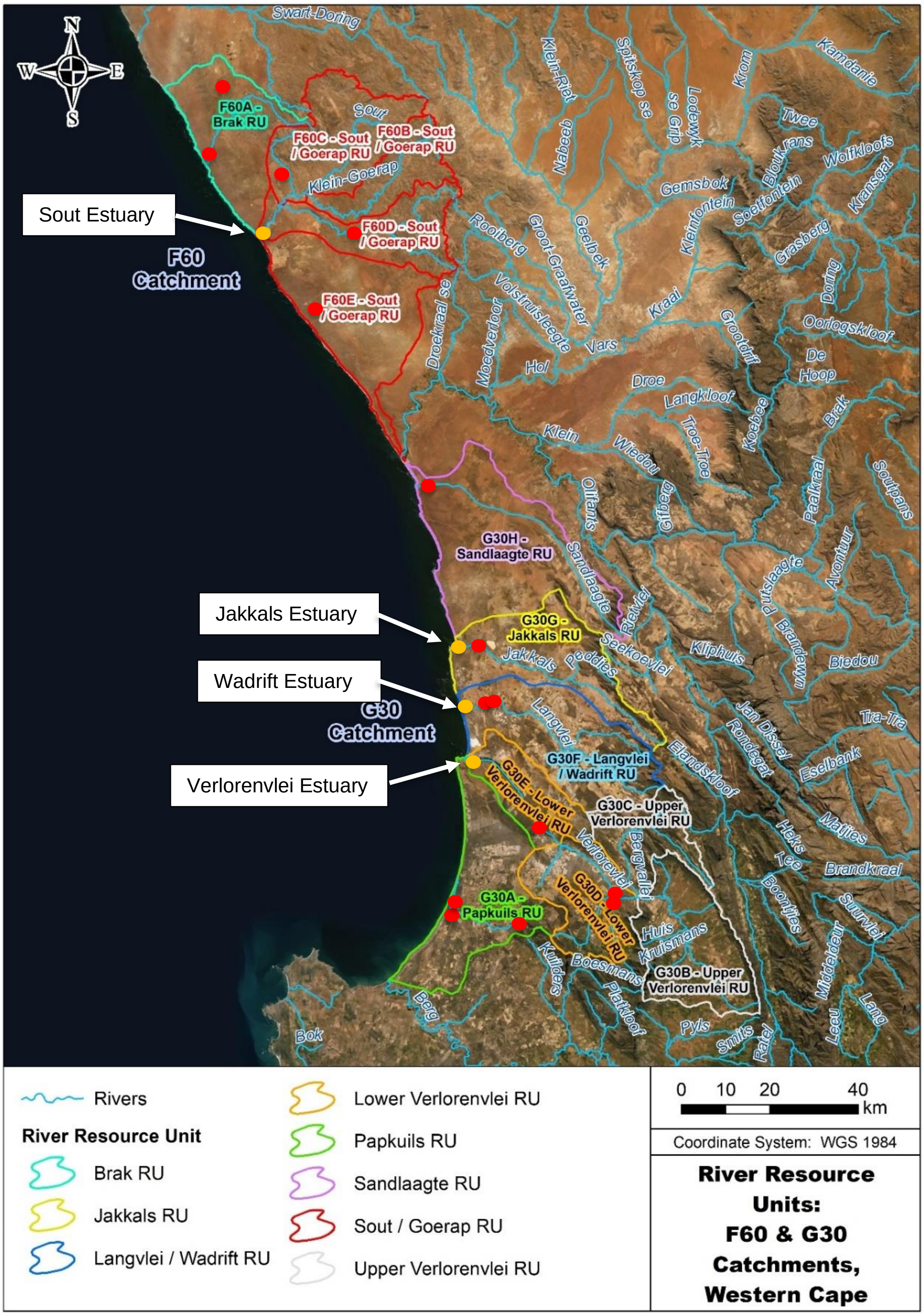

Figure 6. Map of the river and wetland resource units and the proposed EWR sites (red placemarks) for rivers and wetlands, as well as the location of the Estuary Resource Units (orange placemarks) in the F60 and G30 Catchments

3. STATUS QUO FOR GROUNDWATER AND SURFACE WATER ECOSYSTEMS

3.1. Groundwater

3.1.1 Papkuils-G30A GRU

The majority of the GRU in G30A is low-lying coastal flats. Thick sand is underlain by TMG formations and Malmesbury shales, although boundaries between formations are undefined due to thick sand cover. Boreholes are drilled into the alluvial sand. Papkuils seepage area at the upstream end of the Papkuils River forms the only significant observed groundwater/surface water interaction site in this unit, and this spring site is a significant one. Water quality is good around the Papkuils seep and along the eastern area of the GRU, where a "paleochannel type structure" has been observed.

It has been hypothesized that these saturated sand zones could be caused by discontinuous groundwater upwelling from fault zones. It has been observed that where sand is underlain by TMG sandstone, water quality in the sand is generally better than where the sand is underlain by Malmesbury shales.

Borehole yields are below 2 L/s and groundwater abstraction is moderate, with areas of higher abstraction being focused on areas with better quality and higher yields, like around the seepage area (yield of > 25L/s and EC < 60mS/m). Rainfall is between 330 and 230 mm/a.

3.1.2 Verlorenvlei & Tributaries-Southern G30D GRU

This unit comprises the upper reaches of the Krom-Antonies and Hol River catchments in G30D. Contact springs are still found up against mountainsides where TMG meets Malmesbury Group shales, Graafwater and other TMG group formations. The Graafwater formation is more 'aquitard' in nature than the TMG formations found in the area (e.g., Peninsula, Piekenierskloof).

Seepage areas exist along fault lines in the upper reaches of the Krom Antonies/Mountonshoek Valley. Rainfall ranges between 340 and 560 mm/a, including TMG mountain areas of higher recharge and water levels are generally shallow (<17mbgl), except in large-scale production boreholes, where water levels have been lowered (50 - 70mbgl).

Boreholes are drilled into hard rock mostly, although a few high-yielding boreholes have been recorded to have been drilled into the sand in the southwestern portion of the valley. This sandy area also contains seepage areas that could provide baseflow to the Krom Antonies catchment.

Groundwater abstraction in the area is extensive. The quality of the groundwater is very good in the most southern parts of the valley, closest to the mountains. The quality then deteriorates towards the north and especially the northeast. The area has also been highlighted as an area where preliminary existing lawful use (ELU) volumes exceed the final ELU volumes determined. Some farms have continued to drill and build dams to get to their "preliminary ELU".

3.1.3. Verlorenvlei & Tributaries-Northern G30D GRU

The GRU comprises the lower reaches of the Hol, Krom Antonies and Kruismans Rivers, as well as where the rivers meet to form the Verlorenvlei River in quaternary catchment G30D. Malmesbury shales and TMG are overlain by quaternary sands.

The Matroosfontein spring/seepage area near Redelinhuys, in the northern portion of this unit is the only major spring observed, although seepage areas within the Verlorenvlei River have also been reported in the northern portion of this unit. It has been hypothesized that discontinuous groundwater upwelling along inferred and mapped fault lines could be introducing older water from the fractured rock aquifer into the sand deposits overlying it.

Rainfall is below 300 mm/a for most of the unit. Faulted contact between the Piketberg and Peninsula Formations mapped along the western bank of the Verlorenvlei Valley. Groundwater abstraction in the area is extensive towards the northern portion of this GRU.

A decrease in flow at the Matroosfontein spring has been reported and is being linked to an increase in upstream dams and additional boreholes being drilled into the Matroosfontein section of the GRU. Springs and seepage areas in this GRU are largely being used up completely or are being channelled into dams.

3.1.4. Verlorenvlei & Tributaries-G30B GRU

The groundwater unit falls within the quaternary G30B catchment boundaries. The GRU lies between the Citrusdal and Piketberg Mountain ranges. The area is dominated by the Porterville Formation, which forms part of the Malmesbury Group.

Water quality is generally poor and yields low (around 1-5 L/s) for much of the valley. Boreholes are drilled into the hard rock, although a few sand boreholes with higher yields (>5L/s) and good quality have been recorded and are located in the pockets of deeper quaternary sands found in the valley, overlying the Porterville Formation.

A few high yielding (16 – 18 L/s) boreholes have been reported towards the southwestern corner against the Piketberg mountains. Contact and fault springs have been reported along the Piketberg Mountains, as well as some on the Citrusdal side, where TMG formations meet the Porterville formation. The yields of these springs vary, but the quality is usually good. Most of these springs are used for domestic or irrigation supply and no longer contribute to surface water flow in the Kruismans River. Some springs have also been reported along the bank of the Kruismans River.

Groundwater abstraction is moderate, with mostly dryland crops in the basin area of the unit and large-scale groundwater and springwater use in the southwestern portion of the GRU, along Piketberg Mountain. In this portion, it is reported that the farms use spring water as well as high-yielding boreholes drilled near fault zones. Rainfall varies between 300 - 500 mm/a.

3.1.5. Verlorenvlei & Tributaries-G30C GRU

The groundwater unit falls within the quaternary G30C catchment boundaries and is made up of the area known as the Bergvallei Valley. The entire valley is underlain by the TMG formations. Borehole yields in the area are high (> 20 L/s in some cases), and quality is good.

Rainfall varies from 460 mm/a in mountainous areas to as low as 300 mm/a around Het Kruis downstream of the Kruismans and Bergvallei Rivers confluence. Groundwater use is extensive in the area, and a drop in water levels has been observed in this unit. The upper reaches of the valley have boreholes drilled into the river valley into the shallow hard rock aquifer. In the lower catchment, boreholes target the sand deposits overlaying the fractured aquifer.

There are large-scale northwest-southeast trending faults in the area. Farmers lower down in the catchment have reported that their water levels are dropping due to increased abstraction in the upper reaches of the valley. The upper reaches of the Bergvallei Valley have completely been transformed, and little of the old river channel remains visible. The Het Kruis wetland area has subsequently dried up progressively in the last 15 years with the increased abstraction in the upper reaches of the GRU.

3.1.6 Verlorenvlei & Tributaries-G30E GRU

The unit falls within the quaternary G30E catchment boundaries of the Verlorenvlei River and Estuary. The geology is characterised by TMG formations, and the Klipheuwel Formation (Malmesbury Group) being overlain by thick quaternary sediments. The Klipheuwel Formation is seen as the basement rock for the area and outcrops to the western side of the Verlorenvlei wetland.

The groundwater found on this side of the wetland is usually of poor quality with low yields. Boreholes drilled on the eastern side of the wetland in some areas produce very high-yielding boreholes (>20L/s) with very good quality (EC<60mS/m). These boreholes are located in close proximity to the inferred large northwest-southeast trending inferred fault that lies towards the east of the wetland and runs along it.

It has been hypothesized that these saturated sand zones could be caused by discontinuous groundwater upwelling from fault zones. Borehole yields drop significantly when going past the Vensterklip farm and the road that leads to Leipoldtville. The old Graauwe Duynen wellfield is situated to the north of Elands Bay but is only minimally being used for town supply due to poor quality and low yields. Rainfall decreases from around 300mm/a at the top of the catchment to as low as 230mm/a near Elands Bay.

The Kruisfontein Springs north of Redelinghuys is most likely completely groundwater-fed and likely fault related. Some smaller springs occur along the wetland area, but these are used for domestic or irrigation uses and do not contribute a significant amount to the wetland at this stage. Boreholes are also drilled along the wetland and spring areas.

3.1.7 Langvlei-Wadrift - Northern G30F GRU

The unit falls within the quaternary G30F catchment boundaries and makes use of geological and hydrological boundaries to separate this GRU from the Southern G30F GRU. Whereas other quaternary catchments within the Sandveld generally incorporate one valley area that usually has a "paleochannel type structure" running through the valley, G30F has two, a northern and a southern valley.

In this GRU, groundwater abstraction is extensive. The highest yields and best quality water is found from boreholes in the upper reaches of the GRU, between Sandfontein and Sandberg in the upper to middle portion of the unit. Passing Sandberg, groundwater quality deteriorates and becomes more saline. Boreholes are drilled into the primary sand and, in some cases, into bedrock. The sand layer becomes thicker towards the coast and is underlain by TMG formations that outcrop towards the upper reaches of the GRU.

Rainfall varies from a maximum of around 400 mm/a in the upper reaches of the GRU to as low as 180 mm/a on the coast. It was reported that historically, the area had more springs. Currently, the only significant one that has been observed is Sandfontein in the upper catchment. Depth to groundwater is around 20 mbgl and shallower in the upper reaches of GRU (< 5 mbgl).

3.1.8 Langvlei-Wadrift - Southern G30F GRU

The groundwater unit falls within the quaternary G30F catchment boundaries and makes use of geological and hydrological boundaries to separate this GRU from the Northern G30F GRU. Whereas other quaternary catchments within the Sandveld generally incorporate one valley area that usually has a "paleochannel type structure" running through the valley, G30F has two, a northern and a southern valley. Rainfall decreases from around 280 mm/a at the top of the catchment to as low as 200 mm/a near the coast.

In this GRU, groundwater abstraction is extensive. The highest yields and best quality water is located towards the sea, in what is known as the upper-Wadrift area. The lower Wadrift aquifer was historically also a good aquifer. This wellfield holds a large number of boreholes that were abandoned when the aquifer was damaged during over-abstraction. The over-abstraction of groundwater also resulted in the drying up of the Wadrift wetland. Subsequent salt accumulation resulted in the groundwater becoming too saline to use.

This GRU falls within the Wadrift Subterranean Government Water Control Area (SGWCA). Current groundwater abstraction is focused in the upper Wadrift aquifer, and boreholes are drilled into the thick sand cover overlaying the TMG formations. Groundwater quality in the upper-Wadrift is very good (< 40 mS/m), and high yields (> 12 L/s) can be obtained in certain areas where saturated sand is identified. Dry boreholes are also drilled, and this is important in highlighting that the aquifer is confined to certain areas to form a typical paleo-channel. No large faults have been linked to this high-yielding saturated sand aquifer, unlike some of the other paleochannel structures in the Sandveld.

Lamberts Bay uses this wellfield for town supply, and a large volume is also being abstracted for agricultural uses. Municipal monitoring data has displayed a decline in water level for the past ten years. Vegetation die-off has also been observed in the old river bed.

3.1.9 Jakkals- G30G GRU

The groundwater unit falls within the quaternary G30G catchment boundaries, referred to as the Jakkals River Catchment. Rainfall decreases from around 340 mm/a at the top of the catchment to as low as 190 mm/a near Lamberts Bay. This GRU falls within the Graafwater Subterranean Government Water Control Area.

A "paleo channel type structure" exists and has been well documented (Jolly, 1992). The best groundwater yields (12 - 20 L/s) and quality (90 - 130 mS/m) are found in the lower portion of the GRU, north of the Jakkals River and about 7- 12 km east of Lamberts Bay, in the area known as Kookfontein and Varsfontein.

Boreholes drilled around the Jakkals River or to the south of the river provide poor yields (<2L/s) and poor-quality water with elevated levels of chloride and iron. Towards the upper reaches of the GRU and around Graafwater, high yields can be obtained, but the quality is generally much lower than in other areas of the Sandveld. This is most likely due to the Graafwater Formation. This formation is a shale unit within the TMG and, unlike the Piekenierskloof and Peninsula, is linked to poor quality, iron and chloride-rich water. The formation is usually a relatively thin formation, but it dominates the geology around Graafwater and where it underlies the sand deposits into which boreholes are drilled, yields moderate-poor quality water, although yields can still be good (10 – 12 L/s).

For the town of Graafwater, new boreholes drilled cased-off portions of the sand deposits, which were the most clay-rich and through this found a useable supply of water, although it is still chloride rich.

None of the springs in the lower Jakkals River GRU is reportedly still flowing. Water levels generally range between 3 – 23 mbgl, but 60 – 70 mbgl have been recorded at some production boreholes. Groundwater use is extensive in areas that are groundwater rich. Much less water is being abstracted in areas north of Graafwater and to the south of Lamberts Bay. In such areas, dryland crops are mostly cultivated as well as livestock farming.

3.1.10 Northern Sandveld - G30H GRU

The groundwater unit falls within the quaternary G30H catchment boundaries, referred to as the Northern Sandveld. As with the rest of the Sandveld, coastal sand deposits are underlain by TMG and Klipheuwel, although sand deposits are shallower in some areas than for the rest of the Sandveld. Resting water levels are much deeper than what is found in the rest of the Sandveld, with water levels getting deeper going from the southeast portion (30 mbgl) to the northern portion (50 mbgl) of the GRU. Some winter seepage areas have been reported towards the upper reaches of the catchment.

Groundwater usage in this area is much lower than for the rest of the Sandveld. Groundwater quality is generally poor with EC values higher than 1 000 mS/m being normal for large areas. Borehole yields are very varied (0.2 - 5 L/s), although some high-yielding boreholes have been drilled towards the upper portions of the GRU (8 - 15 L/s). These boreholes are most likely linked to the large northwest-southeast trending fault that runs along the Sandlaagte River. This site also had relatively good quality for the area (360 mS/m) but still had elevated levels of Sodium

(500 mg/L) and Chloride (1 000 mg/L). Agriculture is focused on dryland crops and animal farming.

Rainfall ranges from 270 mm/a towards the southwest portion of the GRU to 170 mm/a in the north-western portion around Strandfontein and Doringbaai. Reportedly, these towns are the only ones in the Sandveld that do not use groundwater as their only water supply due to poor water quality. Recently, multiple requests for exploration for heavy minerals along the coast have been submitted. Concerns have been raised about how mining could impact the limited groundwater supply.

3.1.11 Namaqualand- Southern F60E GRU

The groundwater unit falls within the southern portion of the quaternary F60E catchment boundaries. It has been subdivided from the larger F60E catchment due to the fact that this area hosts karst and fractured aquifers rather than intergranular and fractured aquifers. A karst aquifer exists in limestone and dolomite areas which possess a topography peculiar to and dependent upon the underground solution as well as the diversion of surface waters to underground routes. Usually, in the Western Cape, intergranular (water moving through sand grains) and fractured (water moving through faults and fracture plains in hard rock) are more common.

The geology underlying the GRU has been mapped as calcareous and gypsiferous soil, silcrete and other alluvial deposits overlying the metamorphosized units of the Gariep Supergroup in certain areas GRU and the sandstone Peninsula Formation (TMG) in other areas. This sedimentary formation is the only TMG formation that falls within the F60 catchment area and accounts for the fractured aquifer being mapped just below the karst aquifer in this GRU. This area displays the transition from sedimentary deposits found in the G30 catchments to the intrusive and metamorphic rock units that dominate the geology of the F60 catchments. This fractured aquifer could potentially yield good-quality water, but due to the proximity of the coast within the F60E boundaries, boreholes have not been drilled to verify this hypothesis.

The GRU is situated on the coast in the area north of the Olifants River Estuary. Rainfall is around 130 mm/a and depth to groundwater is between 10 and 50 mbgl. Extremely little groundwater is abstracted. The only known groundwater user that has been identified is Tormin mine. They use borehole water for dust suppression. The volume is yet to be confirmed by the mine. Drinking water is trucked in. The groundwater quality for the region is classified as “poor” in the northern section of the GRU (300 – 1 000 mS/m) and “marginal” in the southern section (70 – 300 mS/m). Yields of 0.5 - 2 L/s are expected, although it has been reported that one higher-yielding borehole does exist, this will need to be confirmed by the mine.

3.1.12 Namaqualand- Northern F60E GRU

The groundwater unit falls within the northern portion of the quaternary F60E catchment boundaries. It has been subdivided from the larger F60E catchment due to the fact that this area does not host karst aquifers, and yield are also lower than in the southern section. Expected yields are between 0 and 0.5 L/s.

The geology in the GRU is characterised as gneiss and granite formations from the Little Namaqualand Suite being overlain by quaternary sand deposits. Very few hard rock formations are exposed in this area and geological boundaries between rock formations and faults are not defined. Depth to groundwater is around 40 mbgl and is perceived to be shallower to the coastline (although very little data is available currently). Rainfall is between 140- 120 mm/a, with the lowest rainfall occurring along the coast. Recharge to the area is very low, and groundwater recharge is likely to be fault driven. Contact zones between geological units and faults would be targeted for groundwater exploration, although even where water can be found, the quality could likely be too poor for use.

Groundwater abstraction is thus very low. Namaqua sands mine is located in the northern section of the GRU, and a farm was also identified through the V & V process that noted that they use about 2 200 m^3/a for animal feedlots. No irrigation has been identified, and water is likely mostly only used for animal drinking water and for domestic use where the quality is good enough. The water quality has been identified as being very poor (300 – 1 000 mS/m) for most of the GRU of the north-eastern section, having been classified as having EC values that exceed 1 000 mS/m. No towns are located in this GRU.

The Namaqua Sand Mine is situated to the north of the GRU, where heavy minerals are being mined, such as zircon, garnet, ilmenite, rutile and magnetite. These naturally occurring deposits are some of the richest placer deposits in the world. Because of this, there is interest in commissioning more mines in the area. This could potentially impact the very limited groundwater resource.

3.1.13 Groot-Goerap & Sout - F60D GRU

The groundwater unit falls within the quaternary F60D catchment boundaries and includes the areas surrounding the Groot Goerap and lower Sout River. The underlying geology is very complex and characterised by Quaternary age material consisting of sand and calcareous and gypsiferous soil, underlain by igneous and metamorphic formations. The area is mostly underlain by different age granite and gneiss variants of the Little Namaqualand Suite and Kamiesberg Group. The sandstone Flaminkberg Formation also overlays the older igneous rock units towards the north-eastern corner of the GRU. There are also northwest-southeast trending fault structures cross-cutting the igneous formations towards the eastern portion of the GRU.

A large dyke structure has been mapped and can be observed from an aerial view. It is known that many unmapped dykes can also be located in the area. These dykes are targeted during groundwater exploration, as well as low-lying areas around drainage channels. It has been noted groundwater intersected in drainage channels sometimes yields extremely salty water. Groundwater quality varies between 800 – 3 000 mS/m, although the south-eastern corner of the GRU has been reported to yield better quality water (200 – 500 mS/m). Yields generally vary between 0.1 and 1 L/s.

There is very little perceived groundwater abstraction. Mostly dryland and livestock farming and some mining activity (Namaqua Sands) towards the coast. NGA database does note multiple very low yielding boreholes with poor quality. These boreholes are likely used for animal drinking water and, where possible, domestic uses. Rainfall is highest in the upper catchment (150 mm/a) and drops to around 100 mm/a at the coast. Groundwater levels are between 30 and 18 mbgl.

3.1.14 Klein-Goerap - F60B GRU

The groundwater unit falls within the quaternary F60B catchment boundaries and includes the areas surrounding the Klein Goerap River. Like with other GRUs, geology is dominated by igneous and metamorphic rock units. In this GRU, less of the catchment is covered by quaternary deposits and thus, geological units, boundaries and structures are easier to distinguish. Granites and gneisses from the Little Namaqua Suite and Kamiesberg Group are overlain by quaternary deposits. These igneous formations have experienced multiple phases of deformation and the units have been folded syncline and anticline structures are evident. Northwest-southeast trending fault structures also cross-cut the igneous formations.

There is very little perceived groundwater abstraction. Mostly dryland and livestock farming. Rainfall is around 140 mm/a across the GRU. Groundwater levels are between 17 and 40 mbgl (although NGA noted water levels as shallow as 3 mbgl and as deep as 72 mbgl). Yields are generally very low (< 0.3 L/s), although some higher-yielding boreholes (3 – 5 L/s) have been documented in the northeast section of the GRU, around Bitterfontein.

Water quality is very poor (> 1 000 mS/m), especially in the northern portion of the GRU. Good quality for the area is around 200 - 500 mS/m and is found in the upper reaches of the GRU. The fractured hard rock aquifer is targeted as the main aquifer in this GRU.

Bitterfontein has a desalination plant that treats groundwater to drinking water standards. The treated water from Bitterfontein boreholes is then piped to the Nuwerus, Rietpoort, Stofkraal, Molsvlei and Put-se-kloof, as well as being used in Bitterfontein itself. Most of the Bitterfontein boreholes are situated in the neighbouring quaternary catchment, E33D. Kliprand uses its own boreholes for town supply. It has been reported that some of the production boreholes at Bitterfontein have been over-abstracted.

3.1.15 Sout - F60C GRU

The groundwater unit falls within the quaternary F60C catchment boundaries and includes the areas surrounding the Sout River (before it joins with the Groot-Goerap). The regional geology comprises Quaternary age material consisting of sand and calcareous and gypsiferous soil, underlain by igneous and metamorphic formations. The area is mostly underlain by different age granite and gneiss variants of the Koegel Fontein Complex, Spektakel Granite Suite, Little Namaqualand Suite and Kamiesberg Group. There are several younger dike intrusions mapped within the GRU, such as the Zout River Basalt plug that can clearly be seen from above as a large dark shape towards the southern border of the GRU. There are also northwest-southeast trending fault structures that cross-cut the igneous formations towards the southwest of the GRU.

There is very little perceived groundwater abstraction. Some dryland farming is evident, although most of the GRU does not display any signs of cultivation and livestock farming is assumed to be the predominant activity in the area. Villages situated in this area receive water (piped) from the treatment plant at Bitterfontein.

These fault structures are targeted during groundwater exploration. Rainfall is around 120 - 130 mm/a across the GRU. Groundwater levels are between 12 and 40 mbgl. Yields are generally very low (< 0.3 L/s), although some higher-yielding boreholes (2 – 3 L/s) have been documented in the north section of the GRU, around Rietpoort. Water quality is poor (around 1 000 mS/m) at the bottom portion of the GRU but improves towards the north of the catchment. Relatively good quality (around 200 mS/m) can be found in this area and NGA records that many of the boreholes found in F60C are in this section of the GRU. These boreholes are mostly drilled into the Louisrus Formation (Kammiesberg Group). This formation is the oldest in the area and is characterised by fine to medium-grained quartz-rich gneisses.

3.1.16 Brak - F60A GRU

The groundwater unit falls within the quaternary F60A catchment boundaries and includes the areas surrounding the Brak River. Most of the GRU is covered by quaternary aeolian sand deposits, with hard rocks only outcropping towards the north-eastern corner and along the coastal terraces. In these areas, the geology is dominated by the granites and gneisses of the Spektakel Suite, as well as the younger Koegel Fontein Complex (mostly the Rietpoort Granite) that intruded the Spektakel units. Faults have been mapped along the coast, cross-cutting the geology perpendicular to the coastal terraces.

Very little to non-existent groundwater abstraction is evident. Mostly dryland and livestock farming and some possible mining activity towards the north. Rainfall is very low (100 - 120 mm/a), and very little recharge is evident. NGA has recorded a few boreholes in the catchment. Matzikama Municipality has not confirmed the water supply for Kotzesrus and Lepelsfontein, but it is suspected to be groundwater. This will be investigated.

Groundwater levels are deep (> 35 mbgl), with some shallower water levels having been documented around Lepelsfontein. Documented yields are very low (< 0.2 L/s) for most of the catchment, although NGA reported a few higher-yielding boreholes on the southern coastline of the GRU. Water quality data for these boreholes are not available, therefore, it is unclear if water from these boreholes can be used without intensive treatment. Boreholes target saturated sand areas, although it is hypothesized that faults mapped along the coast would be the most likely source of recharge to the sands due to low rainfall.

3.2. Rivers and Wetlands

3.2.1. River and Wetland Resource Units

The study area comprises the Papkuils, Verlorenvlei, Langvlei/Wadrift, Jakkals and Sandlaagte catchments in the G30 Tertiary Catchment and the Sout and Brak catchments in the F60 Tertiary Catchment. The lower reaches of the Verlorenvlei, Langvlei and Jakkals Rivers comprise extensive longitudinal wetlands with localised and weak riverine components. Short sections of morphologically distinct river channels exist in the upper catchments (Upper Kruismans, Bergvallei, Krom Antonies catchments and the headwaters of the Langvlei Alexandershoek and Lambertshoek tributaries). An important secondary characteristic is the presence of multiple freshwater springs, or 'eyes', occurring along the length of all three systems. Lateral intrusions of brackish to saline water also occur, resulting in distinct variations in water quality and plant species throughout each of the three systems. In essence, portions of these systems exist as a series of wetlands, connected by surface channels in places but mostly by flow through the hyporheos.

All the systems, particularly within their lower wetland sections, are largely groundwater driven or are groundwater-dependent ecosystems. Thus, although the discussions below describe these systems as rivers, they comprise rather a mix of river and wetland and are fed from both ground and surface water. In their lowest reaches, the habitat changes quickly from riverine to wetland and then to estuarine.

3.2.1.1. Papkuils catchment

The most southern catchment, Quaternary Catchment G30A, is situated between Piketberg and the coast. It is largely a flat catchment, with a number of small water bodies, the most important being Rocherpan and the Papkuilsvlei (Rietvlei) that feeds the Papkuils River. The river itself comprises largely a longitudinal valley-bottom wetland that has been significantly modified by the surrounding agricultural activities both in terms of habitat loss as well as reduced groundwater contribution to wetland habitats.

3.2.1.2. Verlorenvlei Catchment

Quaternary catchments G30B (Kruismans River) and G30C (Bergvallei River) form the upper catchment of Verlorenvlei. The catchment of the Kruismans River (G30B) is basin-shaped and surrounded by high mountains, with the Piketberg Mountains to the west and the Olifantsrivierberg to the east. The Kruismans River flows to the north and west, where it cuts through the Piketberg Mountains and is joined by the Bergvallei, Krom Antonies, and Hol Rivers to form the Verlorenvlei River.

The Bergvallei River (G30C) drains the Swartberg Mountains (which reach an elevation of 1153 m above mean sea level (mamsl)) to the east and flows in a southerly direction into the Kruismans River. There are no major towns in this catchment and it is mainly an agricultural area with extensive use of groundwater and recent construction of many smaller storage dams. The catchment is an important recharge area for the Sandveld aquifers.

The Kruismans River drains into quaternary catchment G30D on the northwestern side of the Piketberg Mountains. The Piketberg Mountains are steeply-sided, dropping off over a short distance into a catchment that is rather flat and featureless. It is a catchment of extensive agriculture, due to its relatively flat relief. It is also within this catchment that alien plant infestation is at its greatest along the course of the Verlorenvlei River. Many smaller storage dams have also been constructed in the upper reaches of this river and catchment.

The Krom-Antonies and Hol tributaries contribute to surface water flow from the southern part of the G30D catchment. The Verlorenvlei River comprises mostly an extensive floodplain wetland system that flows from catchment G30D into G30E, through a well-defined catchment that is rectangular in shape with a northwest / southeast trend. It is a hilly and scenic catchment with a significant amount of agricultural activity and contains the Verlorenvlei wetland. The large Matroosfontein and Kruisfontein springs are essential in contributing to the flow of the lower river during the dry season.

3.2.1.3. Langvlei Catchment

To the north of the Verlorenvlei catchment (G30E) is the Langvlei catchment (G30F), which extends from the Swartberg (1153 mamsl) in the east to the coast. The Alexandershoek and Lambertshoek Rivers drain these mountains and join to form the Langvlei River, which is for much of its length a valley-bottom wetland system predominantly fed by groundwater. This catchment is quite rugged, yet agricultural activity is the greatest here in the entire study area. To the south of the Langvlei River is a mountain ridge formed by the Bobbejaansfonteinberge, Olifantsberg and Grootberg, which does not form the catchment boundary, as to the south of this ridge is another wide and almost secluded valley that contains the Wadrift aquifer and associated wetland.

The town of Leipoldtville is situated near the Bobbejaansfonteinberge and Langvleiberge. In the Brandwag area, extensive wetland areas occur up until the Wadrift area and the Lambert's Bay wellfield. The Wadrift Wetland, however, is now desiccated and permanently damaged due to the underground peat fire that burnt there for approximately two years. Downstream from the Wadrift peatland wetland is the Wadrift saltpan which extends down to the coastal dune system.

3.2.1.4. Jakkals catchment

To the north of the Langvlei/Wadrift catchment is the Jakkals catchment (G30G), containing the Jakkals River that also flows mostly as a valley-bottom wetland system presumed to be fed predominantly by groundwater. It is bounded to the east by the rugged Langeberg and Uitkomsberge mountains that drop off quite rapidly to the west. The town of Graafwater is at the base of these mountains. From Graafwater to the coast, the topography is relatively flat and featureless. At the coast, the Jakkals River terminates with the Jakkalsvlei. Agricultural activity occurs only to a limited extent within this catchment.

3.2.1.5. Sandlaagte catchment

The most northern catchment of the G30 Tertiary Catchment area (G30H) consists of the coastal plain south of the Olifants River mouth. There are no significant surface water bodies within this rather arid catchment and land use development is limited.

3.2.1.6. Sout catchment

To the north of the Olifants River Estuary is the Sout River Catchment that comprises the Groot Goerap (F60D), Klein Goerap (F60B) and the Sout River (F60C). The rivers drain westwards from the high-lying hills along the N7, draining down to the deep sands on the coast. The towns of Rietpoort, Nuwerus and Bitterfontein lie within the upper reaches of this catchment. Due to the arid nature of this area, the surface water features are largely ephemeral and land use activities are limited. Wetlands in the catchment are mostly highly ephemeral isolated depressions.

3.2.1.7. Brak catchment

The Brak River Catchment is a small catchment (F60A) in the northern portion of F60. The smaller settlements of Kotzerus and Lepelfontein are located within this catchment. Like the Sout River to the south, the Brak River drains the higher-lying Ribbokberg, draining westwards through the deep sands on the coast. The surface water features are ephemeral, with limited land use that comprises largely livestock. As in the Sout River catchment, wetlands in this catchment also consist mostly of highly ephemeral isolated depressions, although the Lower Brak River consists of a rather extensive valley-bottom wetland.

3.2.2. Rainfall and Hydrology

The G30 tertiary catchments have low rainfall along the coast with a MAP of approximately 200 mm, increasing from the west to south-east of the study area. The MAP increases up to 500 mm in the Banghoek mountains. Overall, the Sandveld MAP is approximately 290 mm/a. The catchment is characterised by endorheic areas in the Papkuils (G30A) and the Langvlei (G30F) catchments, and most runoff is generated in the Kruismans (G30B), the Bergvallei (G30C) and the Krom Antonies and the Hol Rivers in G30D.

The F60 tertiary catchments have a relatively uniform rainfall distribution with mean annual precipitation (MAP) of 115 mm/a. The runoff characteristics are uniform, with an estimated mean annual runoff of less than 2.5 mm. More than half the catchment area is considered endorheic and does not contribute to surface water runoff.

The land use in the catchments is predominantly dryland (rain-fed) commercial crop cultivation with an estimated total area of 1,500 km^2. The extent of irrigated crop cultivation is estimated to cover an area of about 380 km^2. The main crop types are potatoes, citrus, maize, pasture, wine grapes and wheat. Irrigated agriculture is supplied by both surface water and groundwater sources.

There are no major dams in the G30 catchments, but there are many smaller farm dams with a total combined full supply capacity estimated at 8.50 million m^3. These are primarily located in the upper parts of the Kruismans (G30B), Bergvallei (G30C) and Krom Antonies and Hol (G30D) catchments. There are 36 registered dams (dams with a capacity exceeding 50 000 m^3) in the November 2019 Dam Safety Register with a combined full supply capacity of 7.18 million m^3.

It was assumed that baseflows are reduced by 50% from natural conditions under the current day scenarios. It was further assumed that there were no spring flows except for Papkuils (G30A), Kruisfontein (G30E), Matroosfontein (G30D) and these were reduced by more than 50% from natural conditions. Most of the water supplied to Redelinghuys and Lamberts Bay is from groundwater sources however the water is abstracted from springs feeding surface water ecosystems (Lamberts Bay has a total demand of 0.915 million m^3/a and Redelinghuys a registered abstraction is 46 500 m^3/a).

3.2.3. Water Quality

Only two water quality monitoring points in the G30 tertiary catchment have a longer data record, the gauging sites on the Kruismans River at Tweekuilen/Eendekuil (G3H001) and the Hol River at Wittewater Papkuilsvlei (G3H005), that could be examined for long-term trends and for seasonal changes.

For the Kruismans River (1970 to 2017):

- The EC varied from less than 200 to more than 800 mS/m, with a definitive seasonal trend (highest EC concentrations at the end of the dry season and the start of the wet season (first seasonal flushing), decreasing during the rest of the wet season, and then again increasing as the dry season progresses.
- The pH varied from about 6.5 to about 8.5, with a slight seasonal trend (highest pH values recorded during the dry season).
- The orthophosphate (PO_4-P) concentrations varied from 0.003 to 0.147 mg/l, with a slight seasonal trend (highest PO_4-P concentrations were recorded during the wet season).
- The Total Inorganic Nitrogen (TIN) varied from very low to more than 2 mg/l, with a strong seasonal pattern with the highest TIN values recorded during the wet season when the leaching of fertilizers from agricultural lands occurs.
- No distinct long-term trends could be observed with the exception of increases in concentrations and variability during the drought period.

For the Hol River (1978 and 1990):

- The EC varied from less than 100 to more than 500 mS/m, with a definitive seasonal trend (highest EC concentrations at the end of the dry season and the start of the wet season (first seasonal flushing).

Western Cape Regional Office has been monitoring water quality at 12 sites primarily in the Verlorenvlei Catchment since 2013. The sampling frequency varies from monthly to quarterly. Below is a summary of the water quality results:

- There is a large decrease in EC values (median of 700 mg/l decrease to 200 mg/l) downstream of the confluence of the Krom Antonies River with the Verlorenvlei River which illustrates the importance of the less saline flow contribution of the tributary on the larger river.
- The median pH values for the Kruismans and Verlorenvlei Rivers vary within a narrow range of 7.4 to 7.6. This excludes the estuary values which tended to be higher.
- The PO_4-P concentrations were in general low (median of <0.5 mg/l) with the highest in the upper and lower Kruismans River. The inflow from the Krom Antonies River does not seem to have an impact on the PO_4-P concentrations.
- The NO_3+NO_2-N concentrations increased in a downstream direction with the highest concentrations recorded in the lower Kruismans River. Downstream of the Hol and Krom Antonies confluences the nitrogen concentrations were low, probably the result of uptake by the extensive reedbeds that cover this reach of the Verlorenvlei River.

The water quality information collected during the two site surveys at the EWR sites was evaluated based on the limited water quality sampling results, the trends from the G3H001 water quality gauging station, and the current land use activities.

- **Jakkals (EWR 7)** The electrical conductivity is lower during the wet season, but still very high. The water can still be used for irrigation of selected crops (> 540 mS/m) provided sound irrigation management is practised and yield decreases are acceptable. However, the management and soil requirements become increasingly restrictive, and the likelihood of sustainable irrigation decreases rapidly. The water cannot be used for livestock watering (both wet and dry season) on a long-term basis (DWAF, 1996). The water quality ecological class of the Jakkals River is probably a C/D, at a low confidence level.
- **Langvlei (EWR 8)** The electrical conductivity is lower during the wet season, but still very high. The water can still be used for irrigation of selected crops (> 540 mS/m) provided sound irrigation management is practised and yield decreases are acceptable. However, the management and soil requirements become increasingly restrictive, and the likelihood of sustainable irrigation decreases rapidly. The water cannot be used for livestock watering (both wet and dry season) on a long-term basis (DWAF, 1996). The water quality ecological class of the Langvlei is probably a D to a D/E, at a low confidence level.
- **Kruismans (EWR 10)** The electrical conductivity is lower during the wet season, but still high. The water can still be used for irrigation of selected crops provided sound irrigation management is practised, and yield decreases are acceptable, as well as for livestock watering (both wet and dry season) although there may be an initial reluctance to drink, there are no adverse effects (DWAF, 1996). The water quality ecological class of the lower Kruismans River is probably no better than a D, at a low confidence level.
- **Krom Antonies (EWR 11)** The electrical conductivity is much lower during the wet season, but both the wet and dry season values indicate a good water quality suitable for irrigation and livestock watering (DWAF, 1996). The water quality ecological class of the lower Krom Antonies River is probably no better than a C, at a low confidence level.
- **Verlorenvlei (EWR 12)** The electrical conductivity is relatively low. The water can be used for moderately salt-tolerant crops using a low-frequency application system. Wetting of the foliage of salt-sensitive crops should be avoided. The water quality is acceptable for livestock watering (DWAF, 1996). The water quality ecological class of the lower Verlorenvlei River is probably a D, at a low confidence level.
- **Papkuils (EWR 16)** Water quality is good around the Papkuils seep and electrical conductivity in the surface water is relatively low. the water is fit for use for most crops, except for low salt-tolerant crops. The water quality is acceptable for livestock watering (DWAF, 1996). The water quality ecological class of the Papkuils River is probably no better than a C, at a low confidence level.

3.2.4. River and Wetland Ecological Assessments

As the inland surface water ecosystems of the G30 study area, in particular, depend on both surface and groundwater supply, they contain elements of both river and wetland habitats. The assessment of the PES for these rivers/wetlands has thus been combined. Below are the summary tables for the more detailed PES assessments undertaken at the EWR sites in the G30 Catchment where the ecological categories and colour code shown below have been used.

Table 1. Ecological Categories used for River and Wetland PES assessments.

Ecological Categories	Score (%)
Natural (A)	90-100
Largely Natural (B)	80-89
Moderately modified (C)	60-79
Largely modified (D)	40-59
Seriously modified (E)	20-39
Critically modified (F)	0-19

3.2.4.1. Verlorenvlei Catchment

The combined ecostatus for the Kruismans and downstream Verlorenvlei integrated river-wetland Resource Units (RU) is a D Category (largely modified) while the integrity of the Krom Antonies RU is slightly better and is a C/D Category (moderately to largely modified). The confidence in the results is medium to low due to a general shortage of data. All the RUs in this catchment show a decreasing trend.

Table 2. EcoStatus results for Lower Kruismans, Lower Krom-Antonies and Lower Verlorenvlei RUs

EWR 10: Lower Kruismans

EIS: High due to downstream Ramsar site; refugia for endemic and endangered fishes

PES: D Impacts due to abstraction of groundwater, agricultural activities. Impacts are largely flow related.

REC: B/C The EIS is high; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution to baseflow as well as surface water runoff

AEC = C Better monitoring and management of water use (particularly unauthorised abstraction and storage use is required)

Site: Kruismans	
ECOSTATUS COMPONENT	METRIC GROUP: CALCULATED RATING (%)
Hydrology	39.0
Water Quality	50.0
Geomorph	63.0
Driver score	**48.5**
Vegetation	37.0
Macroinvertebrates	49.0
Fish	70.0
Biotic Responses Score	**49.3**
Combined Ecostatus for Separate Component Assessments	**48.8**
River Habitat Integrity	**54.5**
Wetland Integrity	**59.0**
Overall Ecostatus Score	**54.1**
Overall Ecostatus Category	**D**
Trajectory of change	**Negative**
Confidence	**Medium/Low**

EWR 11: Lower Krom Antonies

EIS: High due to downstream Ramsar site; refugia for endemic and endangered fishes

PES: C/D Impacts due to abstraction of groundwater, agricultural and peri-urban activities. Impacts are largely flow related.

REC: B/C The EIS is high; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution to baseflow

AEC = C Better monitoring and management of water use (particularly unauthorised abstraction and storage use is required)

Site: Krom Antonies	
ECOSTATUS COMPONENT	METRIC GROUP: CALCULATED RATING
Hydrology	55.0
Water Quality	60.0
Geomorph	56.8
Driver score	**56.7**
Vegetation	44.0
Macroinvertebrates	58.0
Fish	70.0
Biotic Responses Score	**54.8**
Combined Ecostatus for Separate Component Assessments	**55.9**
River Habitat Integrity	**58.1**
Wetland Integrity	**59.0**
Overall Ecostatus Score	**57.7**
Overall Ecostatus Category	**C/D**
Trajectory of change	**Negative**
Confidence	**Medium/Low**

EWR 12: Lower Verlorenvlei

EIS: High due to downstream Ramsar site; refugia for endemic and endangered fishes

PES: D Impacts due to abstraction of groundwater, and agricultural activities. Impacts are largely flow related.

REC: B/C The EIS is high; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution to baseflow as well as surface water runoff

AEC = C Better monitoring and management of water use (particularly unauthorised abstraction and storage use is required)

Site: Verlorenvlei	
ECOSTATUS COMPONENT	METRIC GROUP: CALCULATED RATING
Hydrology	43.5
Water Quality	50.0
Geomorph	61.5
Driver score	**50.2**
Vegetation	57.8
Macroinvertebrates	44.0
Fish	70.0
Biotic Responses Score	**58.0**
Combined Ecostatus for Separate Component Assessments	**60.1**
River Habitat Integrity	**55.0**
Overall Ecostatus Score	**57.6**
Overall Ecostatus Category	**D**
Trajectory of change	**Negative**
Confidence	**Medium/Low**

3.2.4.2. Langvlei Catchment

The combined ecostatus for the Langvlei RU is a D/E Category (largely to seriously modified). The confidence in the results is medium to low due to a general shortage of data. The river-wetland RU shows a decreasing trend.

Table 3. EcoStatus results for Lower Langvlei RU

EWR 8: Lower Langvlei

EIS: Moderate

PES: E Impacts due to the abstraction of groundwater, and agricultural activities. Impacts are largely flow related.

REC: D The EIS is moderate; therefore, the REC is a slight improvement of the PES. Should be returned to a sustainable ecosystem functioning level. Need to restore the groundwater contribution to baseflow

AEC = REC Better monitoring and management of groundwater use (particularly unauthorised use is required)

Site:Langvlei	
ECOSTATUS COMPONENT	METRIC GROUP: CALCULATED RATING
Hydrology	36.0
Water Quality	45.0
Geomorph	42.0
Driver score	**39.8**
Vegetation	37.7
Macroinvertebrates	28.0
Fish	10.0
Biotic Responses Score	**27.5**
Combined Ecostatus for Separate Component Assessments	**34.9**
River Habitat Integrity	**41.5**
Wetland Integrity	**28.0**
Overall Ecostatus Score	**34.8**
Overall Ecostatus Category	**E**
Trajectory of change	**Negative**
Confidence	**Medium/Low**

<u>Wadrift Wetland</u>

No formal PES assessment was completed for the Wadrift Wetland, which is located within the Langvlei catchment downstream of the Langvlei RU. Site visits to this wetland were, however, undertaken and it was confirmed that the PES of the wetland is critically modified (Ecological Category F). Impacts include a severely lowered water table (observed to be 0.5 to 1 m below ground level during the September site surveys), dried-out peat sediments and denuded vegetation. Despite its very poor PES, this wetland is still considered to have a High EIS rating, due in part to the presence of peat, its rather large extent and its location upstream of the estuary. The REC for Wadrift Wetland is Ecological Category D, which will require rehabilitation intervention. Restoration or rehabilitation of this wetland will be impossible to achieve without ensuring that less groundwater is taken from the catchment so that the water table can be raised back to near the surface, facilitating the re-establishment of the permanently saturated conditions required for the maintenance of peatlands.

3.2.4.3. Jakkals Catchment

The combined ecostatus for the Jakkals RU is a C Category (moderately modified). The confidence in the results is medium to low due to a general shortage of data. The river-wetland RU shows a decreasing trend.

Table 4. EcoStatus results for Lower Jakkals RU

<table>
<tr><td colspan="2">EWR 7: Lower Jakkals</td></tr>
<tr><td>EIS: Moderate

PES: C/D Impacts due to abstraction of groundwater, agricultural and peri-urban activities. Impacts are largely flow related.

REC: B/C The EIS is moderate; therefore, the REC is an improvement of the PES. Need to restore some groundwater contribution to baseflow

AEC = C Better monitoring and management of groundwater use (particularly unauthorised use is required)</td>
<td>
<table>
<tr><td>Site: Jakkals</td><td></td></tr>
<tr><td>ECOSTATUS COMPONENT</td><td>METRIC GROUP: CALCULATED RATING</td></tr>
<tr><td>Hydrology</td><td>68.0</td></tr>
<tr><td>Water Quality</td><td>60.0</td></tr>
<tr><td>Geomorph</td><td>56.0</td></tr>
<tr><td>Driver score</td><td>62.7</td></tr>
<tr><td>Vegetation</td><td>55.0</td></tr>
<tr><td>Macroinvertebrates</td><td>37.0</td></tr>
<tr><td>Biotic Responses Score</td><td>45.5</td></tr>
<tr><td>Combined Ecostatus for Separate Component Assessments</td><td>55.8</td></tr>
<tr><td>River Habitat Integrity</td><td>56.3</td></tr>
<tr><td>Wetland Integrity</td><td>62.0</td></tr>
<tr><td>Overall Ecostatus Score</td><td>58.0</td></tr>
<tr><td>Overall Ecostatus Category</td><td>C/D</td></tr>
<tr><td>Trajectory of change</td><td>Negative</td></tr>
<tr><td>Confidence</td><td>Medium/Low</td></tr>
</table>
</td></tr>
</table>

3.2.4.4. Papkuils Catchment

The combined ecostatus for the Lower Papkuils RU is a C/D Category (moderately to largely modified). The confidence in the results is medium to low due to a general shortage of data. This river-wetland RU shows a decreasing trend.

Table 5. EcoStatus results for Lower Papkuils RU

<table>
<tr><td colspan="3">EWR 15: Lower Papkuils</td></tr>
<tr><td rowspan="16">EIS: Moderate

PES: D Impacts due to abstraction of groundwater, agricultural activities. Impacts are largely flow related.

REC: C The EIS is moderate; therefore, the REC is a slight improvement of the PES. Need to restore some groundwater contribution to baseflow

AEC = REC Better monitoring and management of groundwater use (particularly unauthorised use is required)</td><td>Site: Papkuils</td><td></td></tr>
<tr><td>ECOSTATUS COMPONENT</td><td>METRIC GROUP: CALCULATED RATING</td></tr>
<tr><td>Hydrology</td><td>57.0</td></tr>
<tr><td>Water Quality</td><td>70.0</td></tr>
<tr><td>Geomorph</td><td>37.0</td></tr>
<tr><td>Driver score</td><td>54.4</td></tr>
<tr><td>Vegetation</td><td>45.9</td></tr>
<tr><td>Fish</td><td>50.0</td></tr>
<tr><td>Biotic Responses Score</td><td>43.0</td></tr>
<tr><td>Combined Ecostatus for Separate Component Assessments</td><td>49.8</td></tr>
<tr><td>River Habitat Integrity</td><td>56.4</td></tr>
<tr><td>Wetland Integrity</td><td>38.0</td></tr>
<tr><td>Overall Ecostatus Score</td><td>48.1</td></tr>
<tr><td>Overall Ecostatus Category</td><td>D</td></tr>
<tr><td>Trajectory of change</td><td>Negative</td></tr>
<tr><td>Confidence</td><td>Medium/Low</td></tr>
</table>

Papkuilsvlei

The valley-bottom wetland just below the headwaters of the Papkuils River system (Papkuilsvlei / Rietvlei) was rated to have an overall PES of Ecological Category D (largely modified), with the hydrology in Ecological Category E (seriously modified). The confidence in the results is medium due to a general shortage of quantitative or long-term data, but site visits to the wetland were undertaken during both the dry and wet seasons. The anticipated trajectory of change is downward for all components of wetland condition, except water quality which is anticipated to remain largely the same. The REC for this wetland is Ecological Category C, which will require rehabilitation intervention and the clearing of alien invasive vegetation from the wetland and surrounding areas. The wetland is considered to be of Very High EIS.

Table 6. WET-Health (Level 2) PES results for Rietvlei (Papkuilsvlei) Wetland RU

<table>
<tr><td></td><td colspan="4">Wetland PES Summary</td></tr>
<tr><td>Wetland name</td><td colspan="4">Papkuils Upper</td></tr>
<tr><td>Assessment Unit</td><td colspan="4">Rietvlei</td></tr>
<tr><td>HGM type</td><td colspan="4">Unchannelled VB wetland</td></tr>
<tr><td>Areal extent (Ha)</td><td colspan="4">94.5 Ha</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5">Final (adjusted) Wetland PES Scores</td></tr>
<tr><td>PES Assessment</td><td>Hydrology</td><td>Geomorphology</td><td>Water Quality</td><td>Vegetation</td></tr>
<tr><td>Impact Score</td><td>7.0</td><td>2.6</td><td>3.4</td><td>4.3</td></tr>
<tr><td>PES Score (%)</td><td>30%</td><td>74%</td><td>66%</td><td>57%</td></tr>
<tr><td>Ecological Category</td><td>E</td><td>C</td><td>C</td><td>D</td></tr>
<tr><td>Trajectory of change</td><td>↓</td><td>↓</td><td>→</td><td>↓</td></tr>
<tr><td>Confidence (revised results)</td><td>Medium</td><td>Medium</td><td>Medium</td><td>Medium</td></tr>
<tr><td>Combined Impact Score</td><td colspan="4">5.2</td></tr>
<tr><td>Combined PES Score (%)</td><td colspan="4">48%</td></tr>
<tr><td>Combined Ecological Category</td><td colspan="4">D</td></tr>
<tr><td>Hectare Equivalents</td><td colspan="4">45.0 Ha</td></tr>
</table>

Rocherpan wetland (Die Vlei)

The main pan (depression wetland) within Rocherpan Nature Reserve forms part of a much larger elongated dune slack wetland depression named "Die Vlei". The hydrology of the broader wetland (Die Vlei) has been severely negatively affected by a reduction in inputs from the east and north via small drainage lines and seepage and by a presumed lowering of the regional water table due to extensive groundwater abstraction in the local catchment. This has resulted in a Hydrology PES that is seriously to critically modified (Ecological Category E/F) and an overall Wetland PES of Ecological Category D (largely modified). The confidence in the results is medium due to a general shortage of quantitative data, especially over the last 20 years, but site visits to the wetland were undertaken during both the dry and wet seasons. The anticipated trajectory of change is downward for all components of wetland condition. The REC for this wetland is Ecological Category C, which will require the reinstatement of water inputs from the local catchment (mainly groundwater). The wetland is considered to be of Very High EIS.

Table 7. WET-Health (Level 2) PES results for Rocherpan (Die Vlei) Wetland RU

	Wetland PES Summary			
Wetland name	Die Vlei (Rocherpan wetland)			
Assessment Unit	Die Vlei			
HGM type	Depression without flushing			
Areal extent (Ha)	170.0 Ha			
Final (adjusted) Wetland PES Scores				
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	8.0	1.7	1.1	4.5
PES Score (%)	20%	83%	89%	55%
Ecological Category	E/F	B	B	D
Trajectory of change	↓↓	↓	↓	↓
Confidence (revised results)	Medium	Medium	Medium	Medium
Combined Impact Score	4.3			
Combined PES Score (%)	57%			
Combined Ecological Category	D			
Hectare Equivalents	96.9 Ha			

G30A dune-slack depression

The relatively small dune-slack wetland in Catchment G30A that was identified as one of the Wetland RUs for this study was assessed to be in a largely modified PES overall (Ecological Category D), with seriously modified hydrology (Ecology Category E) due to presumed lowering of the water table through extensive groundwater abstraction in the local catchment. The confidence in the results is medium due to a general shortage of quantitative or long-term data, but site visits to the wetland were undertaken during the current study. The anticipated trajectory of change is downward for all components of wetland condition. The REC for this wetland is Ecological Category C, which will require the reinstatement of water inputs from the local catchment (mainly groundwater). The wetland is considered to be of High EIS.

Table 8. WET-Health (Level 2) PES results for G30A Dune Slack Wetland RU

	Wetland PES Summary			
Wetland name	G30A dune slack wetland			
Assessment Unit	G30A depression			
HGM type	Depression without flushing			
Areal extent (Ha)	0.7 Ha			
Final (adjusted) Wetland PES Scores				
PES Assessment	Hydrology	Geomorphology	Water Quality	Vegetation
Impact Score	7.4	1.2	3.8	4.5
PES Score (%)	26%	88%	62%	55%
Ecological Category	E	B	C/D	D
Trajectory of change	↓↓	↓	↓	↓↓
Confidence (revised results)	Medium	Medium	Medium	Medium
Combined Impact Score	5.3			
Combined PES Score (%)	47%			
Combined Ecological Category	D			
Hectare Equivalents	0.3 Ha			

3.2.4.5. Sandlaagte, Sout and Brak Catchments

The rivers in the F60 Catchment are in a largely natural to moderately modified ecological condition, with mostly just localised impacts. There is, however, significant agricultural activity and groundwater use in the upper Sandlaagte River in G30H that has modified the river, particularly in its upper reaches.

Table 9. EcoStatus results for Sandlaagte River in G30H and River RUs in F60

River	Instream Integrity Score	Riparian Integrity Score	Ecostatus	Ecological Category
Brak	82	82	82	B
Klein Goerap	77	75	76	C
Groot Goerap	74	73	74	C
Sout	71	69	70	C
Sandlaagte	61	54	58	C/D

MEDIUM to LOW levels of confidence in the EcoClassification results in the catchments was attributed to the lack of monitored flow and water quality data primarily. Due to the arid nature of the rivers in the area, there is also a high degree of variability, and the amount of biological data is also limited.

The Wetland RUs in Tertiary Catchment F60 are mostly in a largely natural ecological condition (Ecological Category A/B or A), with mostly just localised impacts except for the Sandveld Depression Wetland (EWR 5) in Quaternary Catchment F60E which is affected by more extensive agricultural and other disturbances within and around the wetland. For all of these wetlands, the existing PES should be maintained as the REC. The two wetlands in F60A are considered to be of High EIS, while the other depression Wetland RUs in F60 are estimated to be of Moderate EIS. All of these assessments were completed with a low level of confidence, as they were mostly desktop-based with limited field verification at some of the sites.

Table 10. EcoStatus results for Wetland RUs in F60

Quat	EWR site	Wetland RU	PES	EIS	REC
F60A	EWR1	Lower Brak River Valley-bottom Wetland	B	High	B
	EWR2	North West Fynbos depression Wetland	A/B	High	A/B
F60C	EWR4	Knersvlakte depression Wetland	B	Moderate	B
F60E	EWR5	Sandveld depression Wetland	C	Moderate	C

3.3. Estuaries

3.3.1. Verlorenvlei

The Verlorenvlei is classified as an Estuarine Lake (Van Niekerk *et al*., 2020) located in the Cool temperate region of the Western Cape near the town of Elands Bay. The geographical boundaries of the estuary are defined as follows:

Downstream boundary (mouth):	32°18'59.14"S; 18°19'58.18"E
Upstream boundary:	32°28'21.27"S; 18°32'25.17"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

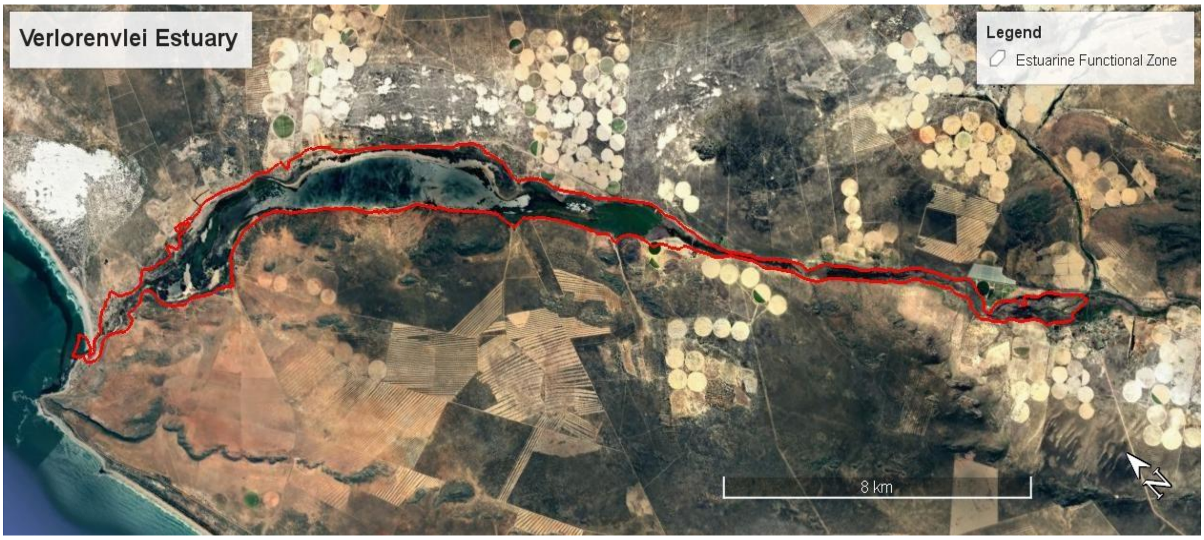

Figure 7: Geographical Boundary of Verlorenvlei Estuary

Historically the system breached to sea at an annual timescale (every 2 - 5 years), with mouth opening coinciding with periods of high rainfall. Over the last decades, the utilisation of freshwater resources has decreased opportunities for marine connectivity. Salinity varies from hypersaline to fresh in the system. The EHI score for the estuary in the observed Present (2022) was estimated to be 23 (PES = E Category) due to the extended drought, which together with the abstraction of water, caused persistent long-term exposure of the lake margins and bed (very low water levels). Assuming that recovery is possible after lake levels increase again, an evaluation of the 101-year Present simulation scenario indicated an EHI score of 50 (PES = Category D).

Table 11. Estuarine Health Score (EHI) for the Verlorenvlei Estuary

Variable	Present (2022-23)	Present (101-year simulated period)	% attributed to non-flow related impacts	Confidence
Hydrology	42	67	0%	Very Low: Relationship between surface and ground water poorly understood and modelled resulting in very low confidence in low flows
Hydrodynamics and mouth condition	0	53	20%	Medium: no long term record of open and close mouth state. Some observations. Water Level recorder.
Water quality	22	43	0%	Low: Only two data sets for nutrients, pH and oxygen. Some historical observations of salinity. About 20 years annual pH observations (main vlei)
Physical habitat alteration	30	65	20%	Medium: No long-term bathymetry (indicate infilling of lake)
Habitat health score	24	57		
Microalgae	23	43	0%	Low: No microalgae data (this study the first detail record)
Macrophytes	45	55	13%	Medium: Aerial photographs (>1930s) and satellite imagery available.
Invertebrates	10	50	5%	Low: No detail surveys, limited historical records
Fish	5	30	20%	Medium: Several historical sampling trips
Birds	30	40	40%	High: CWAC counts (long term record)
Biotic health score	23	44	49	
Estuary Health Score	23	50	55	Low
Present Ecological Status	E	D	D	Low

The functional importance of the estuary was deemed to be high (80%), because of the system's importance as a roosting and foraging area for marine and coastal birds. The EIS for Verlorenvlei Estuary, based on its present state, was therefore estimated to be 74, i.e., the estuary is rated as “Important”. It is a Ramsar site and a desired protected area in the Biodiversity Plan for the National Biodiversity Assessment

Table 12. Importance scores (EIS) for the Verlorenvlei Estuary

Criterion	Weight	Score
Estuary Size	15	70
Zonal Rarity Type	10	60
Habitat Diversity	25	70
Biodiversity Importance	25	82
Functional Importance	25	80
Weighted Estuary Importance Score		74

The Recommended Ecological Category for the estuary is its “Best Attainable State” i.e. a B Category. The existing Verlorenvlei Estuary Management Plan recommends at a minimum a B/C Category.

3.3.2. Wadrift

The Wadrift Estuary is classified as an Arid, Predominantly Closed estuary (Van Niekerk et al., 2020) located in the Cool temperate region of the Western Cape near the town of Lamberts. The geographical boundaries of the estuary are defined as follows:

Downstream boundary (mouth)	32°12' 15.54"S; 18°19' 32.43"E
Upstream boundary	32°12' 49.87"S; 18°22' 37.15"E
Lateral boundaries	5 m contour above Mean Sea Level (MSL) along each bank

Figure 8: Geographical Boundary of Wadrift Estuary

There is no record of the Wadrift Estuary being open to the sea in recent times. However, regular overwash from the sea results in a marine to hypersaline salinity regime in the section of Wadrift facing the sea. The landward side of Wadrift is generally fresher. This system is deemed to be severely/ critically modified due to the Sishen-Saldanha railway track bisecting it and the severe over-abstraction of surface and groundwater flowing into it. The EHI score for the estuary is estimated to be 46 (PES = D category) due to significant changes in the hydrology, mouth status, water quality, microalgae and bird fauna.

Table 13. Estuarine Health Score (EHI) for the Wadrift Estuary

Variable	Health score/100	% attributed to non-flow related impacts	Confidence
Hydrology	50	0%	Very Low: Relationship between surface and ground water poorly understood and modelled resulting in very low confidence in low flows
Hydrodynamics and mouth condition	62	50%	Low: Water Level recorder on the side of pan, do not reflect when inundated.
Water quality	44	0%	Low: No data on most variables
Physical habitat alteration	50	80%	Low: No long-term bathymetry (indicate infilling of pan)
Habitat health score	52		Low
Microalgae	56	10%	Low: No microalgae data (this study the first detail record)
Macrophytes	40	40%	Medium: Aerial photographs (>1930s) and satellite imagery available.
Invertebrates	40	30%	Low: No data
Fish	25	30%	Low: No data
Birds	45	45%	High: CWAC counts (long term record)
Biotic health score	41		Low
Estuary Health Score	46	61	
Present Ecological Status	D	C/D	Low

The system's functional importance was deemed to be 70, because of its importance as a roosting foraging and/or nesting area for marine and coastal birds. The EIS for the estuary, based on its present state, was therefore estimated to be 61, i.e., the estuary is rated as "Important".

Table 14. Importance scores (EIS) for the Wadrift Estuary

Criterion	Weight	Score
Estuary Size	15	70
Zonal Rarity Type	10	30
Habitat Diversity	25	60
Biodiversity Importance	25	60
Functional Importance	25	70
Weighted Estuary Importance Score		61

The REC for the estuary is a "C" Category or "Best attainable State" (BAS). The estuary does not have any statutory protection and is not included in the subset of estuaries identified as requiring protection to conserve South Africa's estuarine biodiversity estate. However, the NBA 2018 Ecosystem Threat Status Assessment lists the system's ecosystem type as "Endangered' (Van Niekerk et al., 2019).

3.3.3. Jakkals

The Jakkals Estuary or Jakkalsvlei is classified as a Large, Temporarily Closed estuary (Van Niekerk *et al*., 2020) located in the Cool temperate region of the Western Cape near the town of Lambertsbaai (Figure 9). The geographical boundaries of the estuary are defined as follows:

Downstream boundary (mouth):	32° 5' 5.39"S; 18°18' 48.25"E
Upstream boundary:	32° 5' 26.89"S; 18°20' 1.32"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

Figure 9: Geographical Boundary of Jakkals Estuary

The estuary seasonally opens to the sea during periods of higher rainfall. The salinity regime in the system varies from fresh to marine, depending on the runoff from the catchment. The EHI score for the estuary in its present state was estimated to be 53 (PES = D category) due to significant changes in the hydrology, mouth status, water quality, microalgae and bird fauna.

Table 15. Estuarine Health Score (EHI) for the Jakkals Estuary.

Variable	Health score/100	% attributed to non-flow related impacts	Confidence
Hydrology	44	0%	Very Low: Relationship between surface and ground water poorly understood and modelled resulting in very low confidence in low flows
Hydrodynamics and mouth condition	49	10%	Low: No long term mouth state information
Water quality	56	60%	Low: No data on most variables
Physical habitat alteration	60	30%	Low: No long-term bathymetry (indicate infilling of pan)
Habitat health score	52		
Microalgae	49	0%	Low: No microalgae data (this study the first detail record)
Macrophytes	60	10%	Medium: Aerial photographs (>1930s) and satellite imagery available.
Invertebrates	50	5%	Low: No data
Fish	50	20%	Low: No data
Birds	55	20%	Medium: Some bird counts
Biotic health score	53		
Estuary Health Score	53	58	
Present Ecological Status	D	C/D	Low

The functional importance was deemed to be relatively high (40%), because of the estuary's relative importance as roosting, foraging and/or nesting area for marine and coastal birds. The EIS for the Jakkals Estuary, based on its present state, was therefore estimated to be 29, i.e., the estuary is rated as of "Low to Average Importance".

Table 16. Importance scores (EIS) for the Jakkals Estuary

Criterion	Weight	Score
Estuary Size	15	20
Zonal Rarity Type	10	10
Habitat Diversity	25	30
Biodiversity Importance	25	30
Functional Importance	25	40
Weighted Estuary Importance Score		29

The Recommended Ecological Category for the Jakkals Estuary is thus a Category D (Largely modified) based on its importance. However, some efforts need to be made to prevent further trajectory downward and ensure the protection of ecosystem services, such as fish nursery function.

3.3.4. *Sout (Noord)*

The Sout (Noord) is classified as an Arid, Predominantly Closed estuary (Van Niekerk *et al*., 2020) located in the Cool temperate region of the Western Cape near the town of Lamberts Bay. The geographical boundaries of the estuary are defined as follows:

Downstream boundary (estuary mouth):	31°14' 38.40"S; 17°50' 57.36"E
Upstream boundary:	31°12' 36.28"S; 17°53' 28.41"E
Lateral boundaries:	5 m contour above Mean Sea Level (MSL) along each bank

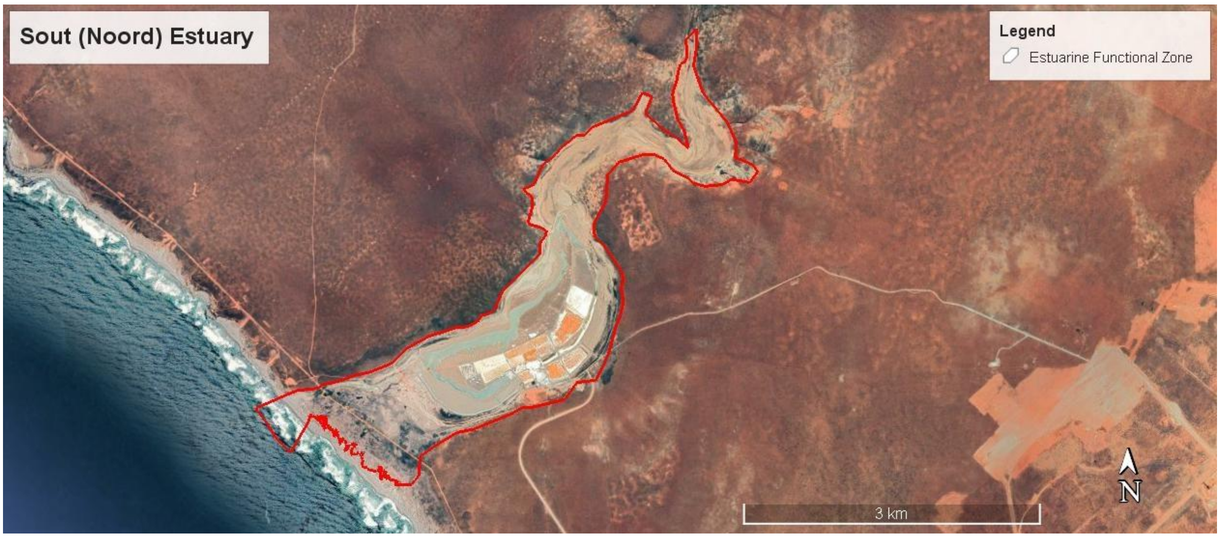

Figure 10: Geographical Boundary of Sout (Noord) Estuary

This estuary is largely transformed as it is used to produce salt, with saltworks infrastructure (roads, channels and berms) resulting in several disconnected sections, with a PES = E.

Table 17. Estuarine categories for the Sout Estuary.

Variable	Health score/100	% attributed to non-flow related impacts	Confidence
Hydrology	40	0%	Very Low: The relationship between surface and groundwater poorly understood and modelled resulting in very low confidence in low flows
Hydrodynamics and mouth condition	20	90%	Low: No water level data
Water quality	56	90%	Low: No data on most variables
Physical habitat alteration	36	90%	Low: No long-term bathymetry (indicate infilling of the pan)
Habitat health score	38		
Microalgae	25	90%	Low: No microalgae data.
Macrophytes	20	90%	Medium: Aerial photographs (>1930s) and satellite imagery available.
Invertebrates	30	90%	Low: No data
Fish	20	90%	Low: No data
Birds	30	90%	Medium: Some bird counts
Biotic health score	25		
Estuary Health Score	**32**	**50**	**LOW**
Present Ecological Status	**E**	**D**	

The EHI score for the Sout River Estuary, based on its Present State, is **32**, translating into a **Present Ecological Status** of a **E** category (Seriously modified). due to significant habitat modification for salt works, numerous artificial channels and diversion of the water course, several access roads bisecting the estuary, some loss of freshwater input from groundwater abstraction; and mining activities. There is no record of the Sout (Noord) estuary being open to the sea in recent times. However, saltwater is pumped into various parts of the system artificially, resulting in a marine to hypersaline salinity regime.

The Estuarine Importance score determined for the Sout River Estuary, based on its Present State is 43, signifying that the estuary is of average to low importance. The Sout Estuary does not have any statutory protection and is not an estuary identified as requiring protection in order to conserve South Africa's estuarine biodiversity estate (Turpie *et al.* 2004, Turpie & Clark 2007, Turpie *et al.* 2012).

Table 18. Importance scores (EIS) for the Sout Estuary

Criterion	Weight	Score
Estuary Size	15	100
Zonal Rarity Type	10	30
Habitat Diversity	25	30
Biodiversity Importance	25	10
Functional Importance	25	60
Estuary Importance Score (Average)		43

The Recommended Ecological Category for the Sout Estuary is thus a Category D (Largely modified) based on its importance.

4. GROUNDWATER - SURFACE WATER INTERACTION AND PRIORITY WATER RESOURCE MANAGEMENT AREAS

4.1. Groundwater - Surface Water Interaction

4.1.1. F60 Catchments

For the F60 catchments, all the rivers are episodic with little evidence of groundwater/surface water interaction. Due to a general lack of springs and seepage areas, it is very difficult to delineate areas of clear ground and surface water interaction. Springs that were observed during the study are completely groundwater dependent with a low flow of poor-quality water. Some springs are however still used by wildlife and livestock watering and thus need to be protected.

4.1.2. G30 Catchments

Significant lengths of the Verlorenvlei River are thought to be the gaining sections where there is groundwater contribution to surface water flow. The longest section is downstream of the confluence of the Hol, Krom Antonies and Kruismans Rivers, with important sections occurring at Redelinghuys and at the headwaters of Verlorenvlei, (GEOSS, 2019). Watson *et al* (2019) calculated that and on average, groundwater makes up 40% of the total annual flow of the four main tributaries (Bergvallei, Kruismans, Hol and Krom Antonies) of the Verlorenvlei River System.

The recharge in the Verlorenvlei System is mainly generated in the TMG aquifer, which is a secondary porosity aquifer system and water is held in the fracture network. The recharge rates into the TMG aquifer have been estimated to be 37.6 to 50 mm/year using the Chloride Mass Balance (CMB) (Watson et al., 2020a) and agree with bulk rainfall/runoff modelling estimates (Watson et al., 2018). The fractured TMG aquifers receive the highest amount of direct recharge (~22-25% of MAP) (Umvoto, 2021).

For the G30F Langvlei and Wadrift systems, the assumed impact of possible over-abstraction of the lower-Wadrift aquifer and the subsequent drying up of the wetland could indicate that historically, this aquifer discharged into the Langvlei River in this area. The Langvlei EWR site has been chosen adjacent to where the upper Wadrift aquifer meets the river channel because the site is where one of the few remaining wetland areas. In the upper Langvlei system, shallow water levels in boreholes drilled near the river channel and reports of some boreholes becoming artesian could also be linked to groundwater and surface water interaction along the system.

For the G30G (Jakkals) system, no perceived contribution from groundwater to surface water flow has been documented and this stream has historically been classified as a losing system (recharging groundwater) (GEOSS, 2005). Historically, springs did occur (Kookfontein) towards the coast along the Jakkals River, but no springs that currently still flow could be identified. However, because this lower section of the Jakkalsvlei River, where the EWR site is located, is one of the only remaining wet areas, it is postulated that some groundwater could still be entering the system at this point. The clay banks along the northern side of this small wetland have been found to be wet during the summer, and it is hypothesized that groundwater in the primary aquifer may still be discharging where it meets the clay bank. Sampling of the vegetation and water quality at the EWR site also supports this hypothesis.

4.2. Important Groundwater Aquifers

Nine important aquifers have been delineated for the G30 catchments (Figure 11) that should be protected against over-abstraction as these are the most vulnerable due to their good quality and high groundwater availability. Currently, these are the areas that host the highest-yielding boreholes as well as the highest reported groundwater abstraction volumes.

Some of these areas, like the G30D_Moutonshoek area, have been linked to the baseflow of the local rivers (Eilers *et al*., 2017 and Eilers, 2018). While others, like the G30D_Matroozefontein and G30A_Papkuil, are linked to extensive seepage areas that form an important contribution to surface water systems.

Two of the delineated areas, G30C_Bobergvlei and Jansekraal and G30B_Steenebrug, are within the Bergvallei Tributary which is regarded as the largest groundwater flow contributor. In these areas, there are reports of declining water levels and very high abstraction amounts.

Four important aquifers (G30E_Verlorenvlei, G30F_Wadrift, G30F_Langvlei and G30G_Graafwater) are linked to coastal catchments and the hypothesis of an unconscious upwelling of groundwater along fault zones that create paleochannel type of environments.

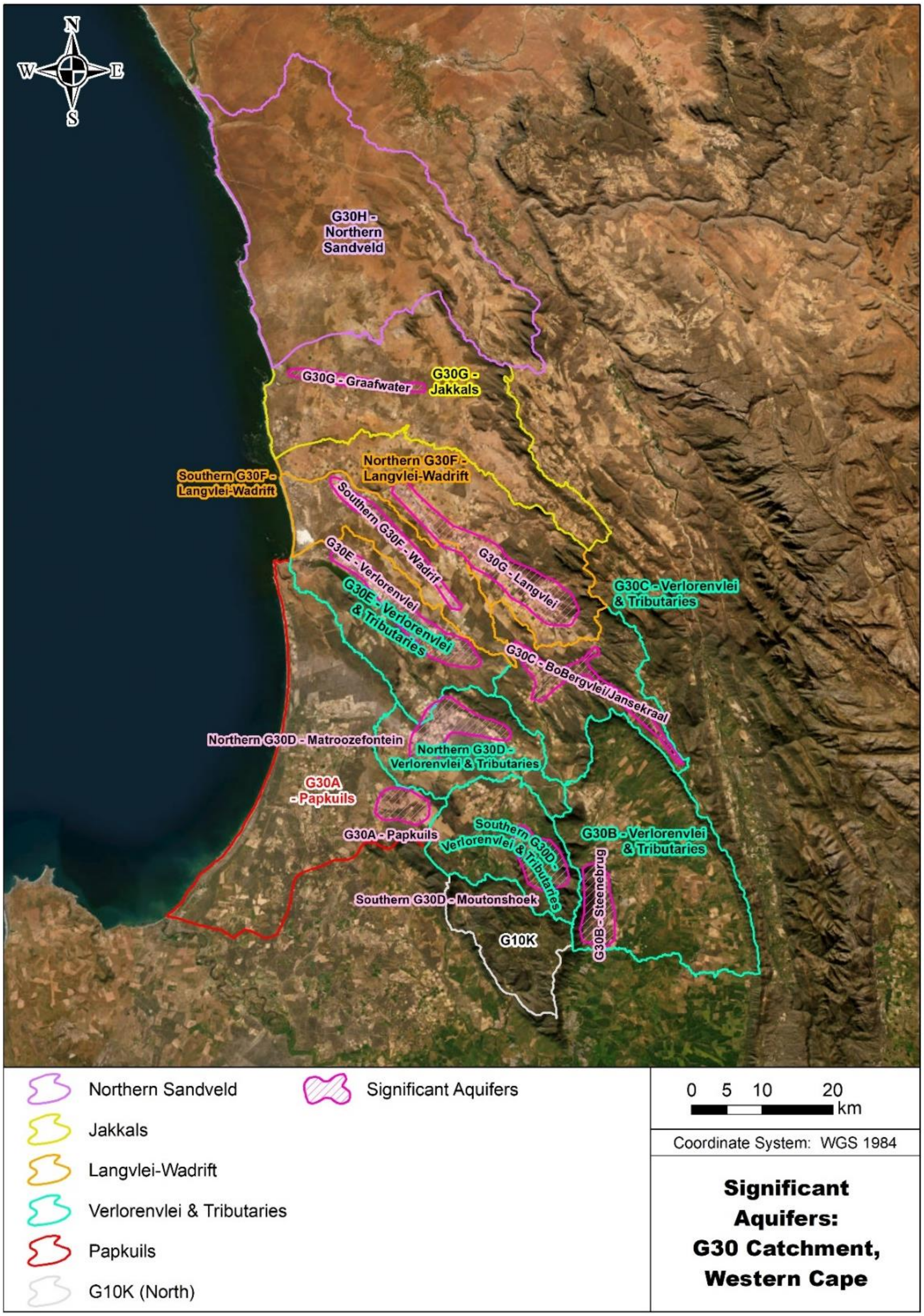

Figure 11: Delineation of important aquifers in the G30 catchments on satellite imagery

4.3. Aquatic Biodiversity Hotspots and Protection Areas

The most important sites for fish conservation in the Verlorenvlei River System would appear to be large deep permanent pools in the mainstem which are maintained by groundwater (e.g. springs) in the dry season, for example, the stretch of river from the Krom Antonies confluence to Wittedrift. Because of the extensive reed beds which make precise pool identification in the dry season difficult, it is recommended that this entire stretch be regarded as a fish hotspot. *This stretch of the river contains all three native fish species, including the two endangered endemics*. The deep pools just below Redelinghuys are particularly important. In addition, the upper tributary areas of the Krom Antonies and Wabooms / Upper Kruismans rivers are fish conservation hotspots as they provide excellent habitat for the native indigenous fish species because they are perennial or mostly perennial, and have riparian zones in a fair to good ecological condition. The Krom Antonies River in the Moutonshoek Nature Reserve is especially important for fish conservation, with its healthy large populations of Verlorenvlei redfin and Cape kurper. *Conserving the native fishes in this nationally important river system hence requires a system-level approach focusing on upper catchments but also the mainstem of the Verlorenvlei River.*

The large wetland at the source of the Papkuils River is another fish hotspot as it provides habitat for Cape Galaxias and potentially Cape kurper too.

5. EWR RECOMMENDATIONS

5.1. River and Wetland EWRs

The EWR results are provided for the rivers in the tables on the following pages. The EWR is expressed as both m^3/s (median value) and the depth at the EWR site due to the high level of uncertainty in the hydrology and the groundwater contribution to surface water flow, particularly during the low flow months (December to April).

Table 19. EWR 7 Lower Jakkals: EWR results for PES and REC

Month	PES (C/D)		REC (C)		AEC (D)	
	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)
October	0.000	0.000	0.017	0.350	0.009	0.350
November	0.000	0.000	0.026	0.360	0.015	0.350
December	0.000	0.000	0.021	0.360	0.012	0.350
January	0.000	0.000	0.015	0.350	0.008	0.350
February	0.000	0.000	0.015	0.350	0.008	0.350
March	0.000	0.000	0.015	0.350	0.008	0.350
April	0.000	0.000	0.034	0.360	0.021	0.360
May	0.000	0.000	0.067	0.370	0.034	0.360
June	0.031	0.360	0.104	0.380	0.065	0.370
July	0.019	0.350	0.399	0.420	0.271	0.400
August	0.000	0.000	0.181	0.390	0.12	0.380
September	0.000	0.000	0.067	0.370	0.043	0.360

Table 20. EWR 8 Lower Langvlei: EWR results for PES and REC

Month	PES (E)		REC & AEC (D)	
	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)
October	0.000	0.000	0.025	0.130
November	0.000	0.000	0.032	0.130
December	0.000	0.000	0.02	0.120
January	0.000	0.000	0.016	0.110
February	0.000	0.000	0.014	0.110
March	0.000	0.000	0.014	0.110
April	0.000	0.000	0.041	0.140
May	0.000	0.000	0.101	0.170
June	0.104	0.180	0.145	0.190
July	0.105	0.180	0.591	0.270
August	0.060	0.150	0.439	0.250
September	0.008	0.090	0.18	0.200

Table 21. EWR 10 Lower Kruismans: EWR results for PES and REC

Month	PES (D)		REC (B/C)		AEC (C)	
	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)
October	0.638	0.810	1.708	1.030	1.229	0.940
November	0.309	0.690	0.987	0.900	0.608	0.800
December	0.123	0.580	0.46	0.750	0.234	0.650
January	0.063	0.520	0.334	0.700	0.17	0.620
February	0.037	0.490	0.225	0.650	0.114	0.570
March	0.019	0.450	0.215	0.640	0.11	0.570
April	0.019	0.450	0.249	0.660	0.127	0.590
May	0.071	0.530	0.919	0.880	0.650	0.810
June	0.471	0.750	2.479	1.130	1.994	1.070
July	0.680	0.820	1.756	1.030	1.254	0.950
August	1.038	0.910	3.932	1.280	3.198	1.220
September	1.003	0.900	1.831	1.050	1.292	0.960

Table 22. EWR 11 Lower Krom Antonies: EWR results for PES and REC

Month	PES (C/D)		REC (B/C)		AEC (C)	
	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)
October	0.161	0.640	0.389	0.810	0.238	0.700
November	0.066	0.560	0.222	0.690	0.113	0.600
December	0.019	0.510	0.091	0.580	0.037	0.520
January	0.011	0.500	0.075	0.570	0.031	0.520
February	0.012	0.500	0.045	0.520	0.018	0.510
March	0.007	0.500	0.044	0.520	0.018	0.510
April	0.004	0.490	0.051	0.520	0.021	0.510
May	0.007	0.500	0.207	0.680	0.116	0.600
June	0.046	0.520	0.664	1.000	0.482	0.880
July	0.217	0.680	0.506	0.890	0.319	0.760
August	0.317	0.760	1.247	1.330	0.917	1.160
September	0.266	0.720	0.509	0.890	0.32	0.760

Table 23. EWR 12 Lower Verlorenvlei: EWR results for PES and REC

Month	PES (D)		REC (B/C)		AEC (C)	
	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)
October	1.094	1.060	2.915	1.280	1.905	1.180
November	0.637	0.950	1.353	1.100	0.819	1.000
December	0.183	0.750	0.474	0.900	0.242	0.790
January	0.078	0.640	0.352	0.850	0.175	0.740
February	0.037	0.550	0.24	0.790	0.115	0.690
March	0.022	0.500	0.23	0.780	0.109	0.680
April	0.039	0.560	0.263	0.800	0.127	0.700
May	0.175	0.740	2.424	1.240	0.794	1.140
June	1.061	1.050	5.187	1.430	3.528	1.330
July	1.684	1.150	3.141	1.300	2.053	1.200
August	2.184	1.210	8.538	1.580	5.839	1.470
September	1.987	1.190	3.193	1.300	2.081	1.200

Table 24. EWR 15 Lower Papkuils: EWR results for PES and REC

Month	PES (D)		REC (C)		AEC (D)	
	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)	Discharge (m^3/s)	Depth (m)
October	0.000	0.350	0.033	0.500	0.021	0.510
November	0.000	0.350	0.031	0.510	0.021	0.510
December	0.000	0.350	0.030	0.510	0.020	0.500
January	0.000	0.350	0.025	0.480	0.016	0.480
February	0.000	0.350	0.025	0.480	0.016	0.480
March	0.000	0.350	0.025	0.480	0.016	0.480
April	0.000	0.350	0.065	0.560	0.051	0.540
May	0.007	0.520	0.073	0.660	0.071	0.620
June	0.035	0.640	0.562	0.800	0.489	0.730
July	0.037	0.650	0.211	0.680	0.165	0.650
August	0.019	0.580	0.332	0.760	0.279	0.710
September	0.008	0.520	0.139	0.650	0.112	0.610

EWR tables and rule files were then generated for each of the EWR river sites and are summarised in the table below.

Table 25. Summary of the EWRs at the EWR sites for the REC and AEC

Site	Natural	Present day		EWR						
	nMAR	MAR	PES	REC/ AEC	Low Flow EWR		High Flow EWR		Total EWR Flow	
	10^6 m^3	10 m^3			10^6 m^3	% MAR	10^6 m^3	% MAR	10^6 m^3	% MAR
EWR 7	2.315	1.24	C/D	C	0.269	11.63	0.780	33.68	1.049	45.32
				D	0.140	6.04	0.545	23.54	0.685	29.58
EWR 8	8.955	7.08	E	D	0.420	4.69	1.298	14.49	1.718	19.18
EWR 10	27.813	18.97	D	B/C	7.143	25.68	8.253	29.67	15.396	55.35
				C	3.638	13.08	7.641	27.47	11.279	40.55
EWR 11	7.318	5.14	C/D	B/C	1.749	23.90	2.400	32.80	4.149	56.70
				C	0.710	9.70	2.020	27.60	2.730	37.30
EWR 12	49.702	33.36	D	B/C	7.318	14.72	20.991	42.23	28.309	56.96
				C	3.789	7.62	14.828	29.83	18.617	37.46
EWR 15	1.378	1.19	D	C	0.196	14.2	0.289	20.97	0.485	35.18
				C/D	0.123	8.95	0.272	19.77	0.395	28.72

5.2. Estuary EWRs

5.2.1. Verlorenvlei Estuary

The Best Attainable State for the Verlorenvlei Estuary without significant restoration interventions is a C Category. While this represents a significant improvement on the observed PES (2022), attaining the REC would require restoring flow to the system (82.6% to remain in the system) and improving the water quality, as well as addressing some of the existing non-flow-related issues affecting the estuary.

Table 26. Summary of the monthly flow (distribution in Mm^3) for Verlorenvlei Estuary for REC=C Category

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Max	10.52	5.70	2.19	0.66	0.47	0.62	7.55	26.54	63.09	75.00	44.29	25.86
95%	7.02	4.22	1.26	0.42	0.22	0.26	0.97	11.76	27.65	25.96	29.00	15.22
90%	6.07	3.67	1.02	0.37	0.17	0.15	0.47	7.92	19.63	17.19	23.22	12.42
80%	4.83	2.37	0.72	0.29	0.13	0.11	0.24	1.67	6.84	10.54	11.21	7.48
70%	4.09	2.12	0.61	0.25	0.11	0.08	0.18	1.03	5.36	6.79	8.79	6.56
60%	3.86	1.79	0.55	0.23	0.11	0.08	0.13	0.55	3.98	5.19	6.78	5.73
50%	3.41	1.65	0.49	0.21	0.09	0.06	0.10	0.47	2.75	4.51	5.85	5.15
40%	3.27	1.47	0.46	0.20	0.09	0.06	0.09	0.37	1.66	4.10	5.16	4.54
30%	2.79	1.27	0.40	0.18	0.08	0.05	0.07	0.23	1.29	3.22	4.54	4.20
20%	2.50	1.06	0.35	0.16	0.08	0.05	0.06	0.17	0.87	2.28	3.56	3.40
10%	1.93	0.82	0.27	0.13	0.06	0.04	0.05	0.13	0.61	1.72	2.93	2.80
5%	1.69	0.65	0.22	0.11	0.06	0.03	0.03	0.07	0.31	1.29	2.57	2.72
Min	0.85	0.37	0.13	0.09	0.05	0.03	0.02	0.04	0.17	0.44	1.02	1.27

5.3.2. Wadrift Estuary

The REC for the Wadrift Estuary is a C Category, representing a significant improvement on the PES. Attaining this state would require restoring a certain amount of flow to the system (77% to remain in the system) as well as addressing some of the existing non-flow related issues affecting the estuary.

Table 27. Summary of the monthly flow (distribution in Mm^3) for Wadrift Estuary for REC=C Category

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Max	0.65	1.84	0.56	0.05	0.00	0.04	1.52	7.82	16.25	23.38	9.13	2.06
95%	0.20	0.01	0.00	0.00	0.00	0.00	0.13	2.56	5.41	4.40	2.63	0.87
90%	0.06	0.00	0.00	0.00	0.00	0.00	0.04	0.86	2.58	2.24	1.46	0.52
80%	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.28	1.66	1.17	0.75	0.23
70%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.76	0.71	0.46	0.14
60%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.56	0.55	0.28	0.09
50%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.33	0.21	0.05
40%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.24	0.14	0.02
30%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.13	0.08	0.00
20%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00
10%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.00
5%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.00
Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00

5.3.3. Jakkals Estuary

The REC for the Jakkals Estuary is a D Category, which requires the maintenance of its present state, i.e. PES D Category. Thus, it was agreed that the flow requirements for the estuary are the same as those described for the Present (57% to remain in the system).

Table 28. Summary of the monthly flow (distribution in Mm^3) for Jakkals Estuary for REC=D Category

%ile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Max	0.12	0.85	0.22	0	0	0	0.38	3.12	7.36	9.8	5.49	0.75
95%	0	0	0	0	0	0	0.08	0.85	2.01	1.59	0.99	0.42
90%	0	0	0	0	0	0	0	0.36	0.97	0.81	0.56	0.18
80%	0	0	0	0	0	0	0	0.05	0.57	0.45	0.17	0.02
70%	0	0	0	0	0	0	0	0	0.22	0.21	0.1	0
60%	0	0	0	0	0	0	0	0	0.13	0.12	0.03	0
50%	0	0	0	0	0	0	0	0	0.08	0.05	0	0
40%	0	0	0	0	0	0	0	0	0	0	0	0
30%	0	0	0	0	0	0	0	0	0	0	0	0
20%	0	0	0	0	0	0	0	0	0	0	0	0
10%	0	0	0	0	0	0	0	0	0	0	0	0
5%	0	0	0	0	0	0	0	0	0	0	0	0
Min	0	0	0	0	0	0	0	0	0	0	0	0

6. SCENARIOS

6.1. Scenario Descriptions

Scenarios identified during the project, consideration of the present-day hydrology and discussions with various stakeholder groups are as follows:

- **Reference scenario –** this represents the study catchment in the natural condition. It is assumed that baseflows contribute to surface flow in catchments where the Table Mountain Group aquifer is dominant, with about 30% of annual surface flow being a baseflow contribution.
- **Current-day scenario** represents the current-day development in the study catchment, which is primarily agriculture. Irrigated agriculture is supplied by both surface water and groundwater sources. It was assumed that baseflows are reduced by 50% from natural under the current day scenarios. It was further assumed that there was no spring flow contribution to baseflow except for Papkuils (G30A), Kruisfontein (G30E), Matroosfontein (G30D) and these were reduced by 50% from natural.
- **Sustainability scenario** (Scenario 1)– this is the least amount of water that should remain in the water resources within the study area to ensure the long-term sustainability of the associated aquatic ecosystems. This scenario was developed to represent an improvement from the current day as a quasi-sustainable case in which surface water abstraction (irrigation and farm dam storage) was reduced by 50% from the current day, baseflows were reduced by 25% from natural and all spring flows reduced by 50% from natural.
  - **Climate change scenario** (Scenario 2) - The anticipated impact of global climate change for the area is that more extreme precipitation events will occur, and temperatures will increase, with a resulting increase in a change in the water availability in areas where water is exploited. The climate change scenario was based on the results of the National Assessment of Potential Climate Change Impacts on the Hydrological Yield of Different Hydro-Climatic Zones of South Africa (Schutte *et al*, 2022; Schulze and Davis, 2021).

  Change in mean annual precipitation shows that in a dry year, most of the WMA will have reductions in MAP of 10 to 20%, while in average years, projected reductions are somewhat lower at 10-15% while in wet years, the east of the WMA is even projected to getting more rainfall than at present. The associated mean annual streamflow during a low flow year shows reductions of 20 to 60%, while in a year of average flows, reductions of 20-40% are foreseen, but with some flow increases possible in the extreme east of the WMA, with these eastern increases expanding in a 1:10 high flow year with the positive being that the east is the source of several important rivers in the Berg-Olifants WMA. The assessment of climate change impacts in the F60 and G30 catchments was made by extracting the results of mean annual rainfall and mean annual A-Pan equivalent evapotranspiration for the quaternary catchments in the study area.

6.2. Scenario Hydrology

Below is a summary of the modelled natural mean annual runoff, the present-day flows for each of the quaternary catchments in the study area (Table 29) and for the EWR sites (Table 30).

Table 29. Summary of simulated MARs for the quaternary catchments for the scenarios considered.

Quaternary	Natural MAR	Current MAR	Sustainability Scenario MAR	Climate Change Scenario MAR
	million m^3/a			
F60A	0.07	0.07	0.07	0.04
F60B	0.07	0.07	0.07	0.06
F60C	0.25	0.25	0.25	0.21
F60D	0.46	0.46	0.46	0.40
F60E	0.05	0.05	0.05	0.00
G30A	1.24	1.19	1.19	0.65
G30B	15.82	10.71	12.45	7.00
G30C	10.94	8.26	9.64	6.09
G30D	46.45	34.67	39.63	23.82
G30E	33.3	17.93	23.74	9.11
G30F	4.75	3.2	3.64	1.99
G30G	1.41	0.96	0.99	0.53
G30H	1.36	1.36	1.36	0.82

Table 30. Summary of the simulated MARs at the EWR sites for the scenarios considered. The percentage of natural flow for each scenario is provided in brackets.

EWR Site	Description	Natural	Current	Sustainability Scenario MAR	Climate Change Scenario MAR
		Million m^3/a			
EWR1	Lower Brak River	0.07	0.07 (100%)	0.07 (100%)	0.04 (57%)
EWR2,4,5	Isolated depression wetlands	-	-	-	-
EWR3	Lower Groot Goerap River	0.11	0.11 (100%)	0.11 (100%)	0.06 (55%)
EWR6	Lower Sandlaagte River	1.36	1.36 (100%)	1.36 (100%)	0.82 (60%)
EWR7	Lower Jakkals River	2.18	1.26 (58%)	1.32 (61%)	0.77 (35%)
EWR8	Lower Langvlei River	4.69	3.44 (73%)	3.83 (82%)	2.18 (46%)
EWR9	Wadrift Wetland	4.75	3.2 (67%)	3.64 (77)	1.99 (42%)
EWR10	Lower Kruismans River	26.76	18.96 (71%)	22.1 (83%)	13.09 (49%)
EWR11	Lower Krom Antonies River	6.99	5.13 (73%)	6.03 (86%)	3.43 (49%)
EWR12	Lower Verlorenvlei River	47.57	33.35 (70%)	39.31 (83%)	23.21 (49%)
EWR13	Isolated depression/duneslack wetland	-	-	-	-
EWR14	Rocherpan	-	-	-	-
EWR15	Lower Papkuils River	1.24	1.19 (96%)	1.19 (96%)	0.65 (52%)
EWR16	Papkuilsvlei	-	-	-	-

7. CONSEQUENCES

7.1. Water Quality Consequences

Based on the water quality data from the G3H001 - Kruismans River at Tweekuilen/Eendekuil, (the only long-term water quality monitoring site in the G30 catchment) the water quality is very variable from year to year although there seems to be a slight seasonal trend. The lack of water quality data makes it challenging to determine reference and present-day conditions and even more challenging is the fact that both G30 and F60 tertiary catchment have non-perennial rivers linked to wetlands with definite wet and dry rainfall seasons with and without interaction with the groundwater and springs in the study areas. The fact that the rivers are fed from different water resources (groundwater, surface water runoff and springs) does not enable one to confidently extrapolate water quality characteristics from one site to the next. The two possible future scenarios were investigated, and certain predictions were made, but with low confidence.

7.1.1. Sustainability Scenario - 50% reduction in surface water abstraction

Scenario 1 was developed to represent an improvement from the present day as a sustainable option. Based on the limited water quality data, one cannot quantify expected outcomes if the Sustainability Scenario was implemented. However, as most of the rivers are non-perennial rivers linked to wetlands with definite wet and dry rainfall seasons with and without interaction with the groundwater and springs in the study areas, high variability in quality is expected to continue. Some rivers, such as the Jakkals River, seem to have naturally high salinities and as it is also one of the least impacted parts of the G30 catchment, the Sustainability Scenario will probably not make a big difference in the water quality.

The water quality in the Kruismans and Krom Antonies Rivers, however, can be expected to improve for the Sustainability Scenario

and would be of benefit to the downstream users. Even though the rivers in G30 are currently in a degraded condition, it is expected that the systems are still sensitive to increases and decreases in freshwater inflows and abstractions, and more freshwater input (less abstraction) will benefit and improve the water quality in the rivers.

7.1.2. Climate Change Scenario - Impacts of climate change

An increase in **air temperature** will lead to an increase in water temperature. Water temperature can be estimated from the air temperature using relationships developed for South African perennial rivers by Dallas & Rivers-Moore (2019). Increased water temperatures could affect, inter alia, the quality of water for irrigation, dissolved oxygen content of water, and the rates of chemical and biological reactions in water, as well as have wide-ranging repercussions in the health sector through the creation of favourable conditions for the incubation and transmission of waterborne diseases. Heat waves can lead to severe short-term water quality impacts and increased fish mortality due to low oxygen concentrations brought about by a rapid increase in decomposition processes and temperature stress on fish and other aquatic biota.

Water temperature affects evaporation, which in turn affects the concentration of the salts in the water. Wide fluctuations in salinity are already a characteristic of the non-perennial rivers in the study area. An increase in water temperature would aggravate this, resulting in an increase in the occurrence of high salt concentrations in rivers and pools.

Elevated water temperatures can affect the rate at which compounds dissociate from suspended sediment particles. Enhanced dissociation of sediment-bound agrochemicals, metals, and nutrients can have an impact on aquatic biota.

Water temperature, in the presence of sufficient nutrients, often triggers algal blooms in rivers and pools. The dependence of the algal growth rate on water temperature is controlled with the parameter Θ, the temperature adjustment coefficient, which typically has a value between 1.01 and 1.2. A value of 1.072 corresponds to a doubling of the growth rate for every 10°C increase in water temperature (Bowie et al., 1985). An increase in surface water temperature could extend the growing season of free-floating and filamentous algae (blooms could occur earlier in the season and extend later into autumn).

An increase in water temperature creates more favourable conditions for bacterial growth. Studies have shown a strong correlation between the outbreak of waterborne diseases and above-normal water temperatures. Although wastewater effluents are not a major concern in the study area, local impacts of seepage from pit latrines and septic tanks, and degraded sewerage infrastructure, will be aggravated by high water temperatures. However, an increase in water temperature could also lead to a more rapid die-off of bacteria in water. This could restrict the duration and spatial extent of waterborne disease outbreaks.

The solubility of oxygen in water is indirectly related to water temperature. The saturation decreases as temperature increases. In freshwater, the dissolved oxygen concentrations range from 14.6 mg/L at 0°C to 7.6 mg/L at 30°C. An increase in water temperature would therefore result in lower DO in the water to the detriment of dissolved oxygen-sensitive organisms. The decomposition of organic matter consumes dissolved oxygen. The rate of decomposition is temperature dependent and an increase in water temperature would increase the incidence of oxygen depletion in the study and the negative impacts on aquatic biota.

Enhanced evaporation is the additional evaporation, over and above that under present climatic conditions, from open water bodies such as dams and wetlands as well as from the soil and plant systems. Evaporation has the effect of concentrating salts and other constituents in an open water body when the water volume is reduced. It can also concentrate salts and other constituents in the soil when the soil moisture is reduced as a result of evaporation at the surface and water losses by evapotranspiration from plants.

Enhanced evaporation leads to the concentration of nutrients in a smaller volume of water. Free-floating algae, attached algae, and rooted water plants will respond to the increased nutrient concentrations.

Enhanced evaporation would also have the effect of concentrating organic matter into a smaller volume of water. This could increase the impacts of processes that affect dissolved oxygen in water. Aquatic organisms may therefore experience wider diurnal fluctuations in dissolved oxygen as photosynthetic processes dominate during daytime and respiration/decomposition processes dominate during night-time.

Enhanced evaporation would concentrate agrochemicals and other toxic substances into a smaller volume of water, thereby increasing the concentration that aquatic organisms are exposed to.

Mean annual streamflow during a low flow year shows reductions of 20 to 60%, while in a year of average flow reductions of 20-40% are foreseen. A reduction in streamflow will have serious impacts on water quality because it would decrease the introduction of good-quality runoff. This reduces the dilution of poor-quality water in rivers and pools in the study area. There is an inverse relationship between salinity and the suspended sediment concentrations in turbid rivers. An increase in salinity promotes the coagulation of sediment particles, causing them to settle out. This clearing of the water promotes deeper light penetration of the water column, thereby increasing the heating up of the water.

7.2. Ecological Consequences

7.2.1. Rivers and Wetlands

The revised PES data and EI-ES data from the PES/EIS results, as well as the Classification and RQO projects, were used to derive the Recommended Ecological Category (REC) for the river and wetland systems within the study area. These are summarised in Table 31. An analysis of the outcome of the scenario assessments and the resulting ecological category for each scenario for the key EWR sites is included in Table 32.

Table 31.Summary of the Recommended Ecological Categories for the rivers and wetlands in the study area

Quaternary	Node/ EWR site	Water Resource	PES	EIS	REC
F60A	EWR1	Lower Brak River	B	Moderate	B
F60A	EWR 2	North West Fynbos depression Wetland	A/B	High	A/B
F60B	Node 1	Klein Goerap River	B	Moderate	B
F60C	Node 2	Sout River	C	Moderate	C
F60C	EWR 4	Knersvlakte depression Wetland	B	Moderate	B
F60D	EWR3	Lower Groot Goerap River	B	Moderate	C
F60E	EWR 5	Sandveld depression Wetland	C	Moderate	C
G30A	EWR15	Lower Papkuils River	C/D	High	C
G30A	EWR13	Isolated depression/ duneslack wetland	C	High	C
G30A	EWR14	Rocherpan	D	High	C
G30A	EWR16	Papkuilsvlei / Rietvlei	D	Very High	C
G30B	Node 3	Bergvallei River	D/E	High	C
G30C	Node 4	Upper Kruismans	D	High	C
G30D	EWR10	Lower Kruismans River	D	High	C
G30D	EWR11	Lower Krom Antonies River	C/D	High	C
G30E	EWR12	Lower Verlorenvlei River	D	High	C
G30F	EWR8	Lower Langvlei River	E	High	D
G30F	EWR9	Wadrift Wetland	F	High	D
G30G	EWR7	Lower Jakkals River	C/D	Moderate	D
G30H	EWR6	Lower Sandlaagte River	C/D	Low	C

Table 32. Summary of the Ecological Category for the different runoff scenarios at each of the key river and wetland EWR sites.

EWR site No.	Description	Scenario PES			REC
		Current	Sustainability	Climate Change	
EWR7	Lower Jakkals River	C/D	C	D	D
EWR8	Lower Langvlei River	E	D	E/F	D
EWR10	Lower Kruismans River	D	C	E	C
EWR11	Lower Krom Antonies River	C/D	C	D	C
EWR12	Lower Verlorenvlei River	D	C	E	C
EWR15	Lower Papkuils River	C/D	C/D	E	C

Many of the impacts on the rivers and wetlands are non-flow related; thus, improving flow will not necessarily result in an improvement of the ecological condition of the rivers and wetlands. It can, however, be expected that the Sustainability Scenario will result in some improvement in ecological conditions while the Climate Change Scenario, results in a substantial reduction in flow and can be expected to result in a noticeable decline in the ecological integrity of the aquatic ecosystems.

7.2.2. Estuary Consequences

The scenarios have been considered for the three estuaries within the study area. Table 33 is a summary of the estuarine assessment of the estuary health index and corresponding ecological category.

Table 33. Summary of the Estuary Health Index score and corresponding Ecological Category for the different runoff scenarios

Estuary	Scenario		
	Current	Sustainability	Climate Change
VERLORENVLEI			
Estuary Health Score	50	60	39
Ecological Status	D	C/D	D/E
WADRIFT			
Estuary Health Score	46	53	33
Ecological Status	D	D	E
JAKKALSVLEI			
Estuary Health Score	53	56	37
Ecological Status	D	D	E

The Best Attainable State determined for the Verlorenvlei Estuary is a C Category without significant restoration interventions. Attaining the REC would require restoring flow to the system and improving the water quality, as well as addressing some of the existing non-flow-related issues affecting the estuary. The flow requirements for the estuary are the same as those described for the Sustainability Scenario.

The REC for the Wadrift Estuary is a C representing a significant improvement on the PES. Attaining this state would require restoring a certain amount of flow to the system as well as addressing some of the existing non-flow-related issues affecting the estuary. The flow requirements for the estuary are the same as those described for Sustainability Scenario.

The REC for the Jakkals Estuary is a D Category which requires the maintenance of its present state, i.e. PES D Category. Thus, the flow requirements for the estuary are the same as those described for the Present or Current-day Scenario.

7.3. Socio-Economic Consequences

Water resources provide important benefits to society, both as being essential for the production of economic goods and for ecological goods and services such as waste assimilation, recreation and tourism. Due to the increasing scarcity of water for use and ecological benefits and scarcity of resources to develop water infrastructure, it is necessary to make decisions about conservation and demand management and reallocation of the resource among competing uses while considering government social objectives of achieving equity, economic efficiency and sustainability. Economic valuation plays an increasingly important role in decision-making between socioeconomic development and the protection of the resource for long-term sustainability. Therefore, the development and management of water resources cannot be interpreted without some idea of the value of water to the socioeconomic activities taking place in a catchment, and the value of ecological goods and services provided by the catchment, either through direct or indirect use of water.

8. RECOMMENDED EWR

8.1. Groundwater

The G30 catchments receive an estimated total groundwater recharge of 103.92 Mm^3/a of which 6.59 Mm^3/a represents the groundwater baseflow component needed for the surface water systems, 4.824 Mm^3/a represents the spring flow component needed and 0.406 Mm^3/a, the Basic Human Needs component of the Reserve. The Reserve for the catchment is 11.82 Mm^3/a which is 11.37% of the recharge. Currently, 1.798 Mm^3/a of groundwater is estimated to be abstracted for town supply and 53.13 Mm^3/a of groundwater is estimated to be abstracted for irrigation. This leaves the current total water balance at 38.73 Mm^3/a.

The F60 catchments receive an estimated total groundwater recharge of 7.826 Mm^3/a of which 0.0142 Mm^3/a represents the Basic Human Needs component of the Reserve. The Reserve for the catchment is 0.0142 Mm^3/a which is 0.002% of the recharge. Currently, 0.183 Mm^3/a of groundwater is estimated to be abstracted for town supply. This leaves the current total water balance at 7.628 Mm^3/a.

The results of the preliminary groundwater Reserve for all the quaternary catchments including the resource units are summarised in Table 34 as shown below:

Table 34: Results of the preliminary Reserve for the G30 and F60 Catchments

Sub-catchments used to calculate recharge	River System	Area (km^2)	MAP (mm)	Estimated Recharge (% of total annual flow)	Calculated recharge (Mm^3)	Total abstracted for Town supply (million m^3)	Reserve (BHN + Springflow + Baseflow Contributions)	Total abstracted for irrigation (million m^3)	Groundwater Balance (million m^3)
G30A1	Papkuils	131.1	292	3.5%	1.34				
G30A2	Papkuils Lower	10.0	292	3.5%	0.10				
G30A_Groundwater		604.3	260	3.5%	5.50				
G30A_Total					6.94	0	0.252981875	6.79956	-0.11070
G30B1	Upper Kruismans	23.7	505	23.0%	2.75				
G30B1	Upper Kruismans	92.4	300	5.0%	1.39				
G30B2	Soutkloof	17.8	415	23.0%	1.69				
G30B2	Soutkloof	194.5	300	5.0%	2.92				
G30B3	Huis tributary	53.8	505	23.0%	6.25				
G30B3	Huis tributary	288.5	300	5.0%	4.33				
G30B_Total					19.32	0.053676	3.5056685	2.1537	13.61017
G30C1	Kleinvlei	64.3	404	23.0%	5.98				
G30C2	Jansekraal	62.6	404	23.0%	5.81				
G30C3	Bergvallei	218.2	383	3.5%	2.92				
G30C_Total					14.72	0.074207	1.541531375	6.33080	6.76926
G30D1	KA upper	64.8	517	23.0%	7.71				
G30D1	KA lower	55.1	366	5.0%	1.01				
G30D2	Hol upper	51.7	517	23.0%	6.15				
G30D2	Hol lower	102.6	366	5.0%	1.88				
G30D3	Matroosfontein	128.2	347	3.5%	1.56				
G30D4	Verlorenvlei	151.8	347	3.5%	1.84				
G30D_Total					20.14	0.03798867	3.286462	10.53787	6.27765
G30E1	Kruisfontein	90.4	286	3.5%	0.91				
G30E2	Verlorenvlei	44.9	286	3.5%	0.45				
G30E3	Verlorenvlei	35.3	286	3.5%	0.35				
G30E4	Verlorenvlei	190.5	286	5.0%	2.72				
G30E_Total					4.43	0.443172	0.791505375	2.9434064	0.25440
G30F1	Langvlei	194.2	352	3.5%	2.39				
G30F2	Lambertshoek	98.9	352	23.0%	8.01				
G30F3		397.8	236	3.5%	3.29				
G30F4		30.2	212	3.5%	0.22				
G30F_Groundwater_North		20.2	175	3.5%	0.12				
G30F_Groundwater_South		59.1	212	3.5%	0.44				
G30F_Total					14.47	0.98592	1.713247375	18.43323	-5.10282
G30G1	Jakkals	134.4	268	xx	11.15				

Sub-catchments used to calculate recharge	River System	Area (km^2)	MAP (mm)	Estimated Recharge (% of total annual flow)	Calculated recharge (Mm^3)	Total abstracted for Town supply (million m^3)	Reserve (BHN + Springflow + Baseflow Contributions)	Total abstracted for irrigation (million m^3)	Groundwater Balance (million m^3)
G30G2	Peddies	49.4	268	23.0%	3.05				
G30G3		317.5	208	3.5%	2.31				
G30G4		21.7	138	3.5%	0.10				
G30G_Groundwater_West		89.8	138	3.5%	0.43				
G30G_Groundwater_East		44.2	208	3.5%	0.32				
G30G_Total					17.37	0.203213	0.670242125	3.616832	12.87576
G30H1		580.8	204	3.5%	4.15				
G30H_Groundwater		495.4	138	3.5%	2.39				
G30H_Total					6.53	0	0.059102625	2.31426	4.16041
F60A	Brak	386	103	3.5%	1.39	0	0.0010585		1.39047
F60B	Klein-Goerap	320	129	3.5%	1.44	0.183146	0.008513625		1.25314
F60C	Sout	622	114	3.5%	2.48	0	0.00406975		2.47771
F60D	Groot-Goerap	481	120	3.5%	2.02	0	0		2.02020
F60E		120	116	3.5%	0.49	0	0.000556625		0.48664
G10K_Groundwater_North		201.5	505	23.0%	23.40	0		unknown Z	23.32-XYZ

8.2. Surface Water Quantity

Below is a summary of the Reserve requirements for the rivers and wetlands EWR sites and nodes, which includes both the ecological Reserve as well as the Basic Human Needs Requirements. The basic human needs Reserve provides for the essential needs of individuals served by the water resource in question and includes water for drinking, food preparation and for personal hygiene. A life-line amount of 25 litres per person per day was used.

Table 35: Summary of the Reserve recommendations for River and Wetland EWR sites/nodes.

Quaternary	Node/ EWR site	Water Resource	REC	nMAR (MCM)	EWR (MCM)	BHN Reserve (MCM)[1]	Total Reserve (% NMAR)
F60A	EWR1	Lower Brak River	B	0.07	0.019	0.001	28.57
F60B	Node 1	Klein Goerap River	B	0.07	0.019	0.009	40
F60C	Node 2	Sout River	C	0.255	0.046	0.004	19.6
F60D	EWR3	Lower Groot Goerap River	C	0.11	0.020	0.008	25.45
G30A	EWR15	Lower Papkuils River	C	1.378	0.407	0.129	38.9
G30B	Node 3	Bergvallei River	C	16.353	7.039	0.038	43.28
G30C	Node 4	Upper Kruismans	C	11.457	4.51	0.004	39.4
G30D	EWR10	Lower Kruismans River	C	27.813	11.279	0.004	40.57
G30D	EWR11	Lower Krom Antonies River	C	7.318	2.730	0.001	37.32
G30E	EWR12	Lower Verlorenvlei River	C	47.502	17.617	0.021	37.13
G30F	EWR8	Lower Langvlei River	D	8.955	1.718	0.025	19.46
G30G	EWR7	Lower Jakkals River	D	2.315	0.685	0.131	35.25
G30H	EWR6	Lower Sandlaagte River	C	2.80	0.330	0.059	13.89

NOTE: *The total Reserve amount accounts for both ecological and basic human needs., where the total population of quaternary catchments was based on Census 2011 data, updated where available.*

For the wetlands not linked to any river EWRs, only Rocherpan had sufficient data to provide any EWR recommendation. Based on a rudimentary analysis of past water level recordings and rainfall data, <u>it is recommended that a maximum water level (depth) of 1 m or more should be attained in the main pan at Rocherpan for the five months of July to November each year</u>. This would presumably require the regional water table to be at a higher level than it has been in recent years, through a reduction in groundwater abstraction in the catchment, so that rainfall can more readily result in the inundation of the pan.

The ecological Reserve requirements for the estuaries in the study area is summarised below.

Table 36: Summary of Reserve data for the estuaries in G30 and F60.

Quaternary	Estuary	REC	Natural MAR (MCM)	Present MAR (MCM)	Ecological Reserve* (MCM)	Ecological Reserve (% NMAR)
G30E	Verlorenvlei	C*	33.3	17.93	27.505	82.6
G30F	Wadrift	C	4.75	3.2	3.658	77
G30G	Jakkals	D	1.41	0.96	0.804	57
F60D	Sout	D	0.46	0.46	-[3]	-[3]

1 *The observed Present (2022) was estimated to be E Category due to the extended drought, which together with the abstraction of water. Assuming recovery is possible, the Present simulation scenario indicated a PES = D*

[2]. *The Verlorenvlei Estuary was categorised as an "important estuary". According to the guidelines for assigning a REC, the condition of the estuary should be elevated to the Best Attainable State (BAS)of a B Category.*

[3.] *The Sout Estuary assessment was desktop with a hydrology of very low confidence. The estuary should be restored to a D. Most of the impacts are non-flow related and the present day flows should be maintained.*

8.3. Surface Water Quality

Due to limited data at the river and wetland EWR sites, the water quality guidelines were used as additional information. The Reserve requirements outlined in Table 37 and Table 38 should be taken into consideration when drafting the WULAs. Table 37 provides the physical water quality Reserve requirements for each of the EWR sites as these vary from site to site. Table 38 is a generic table of the chemical water quality Reserve requirements which are the same for all the EWR sites.

Table 37: Physical water quality Reserve Requirements for the rivers and wetlands

Quality Constituent	Parameter	Ecological Reserve	Basic Human Needs	Reserve Requirement: water quality
Papkuils River (REC = C)				
Physical water quality	pH (pH units)	7.6	6 - 9	5th percentile 5.6 – 5.9 95th percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	129	<70	≤129[5]
	Total Dissolve Solid (mg/l)	868	<450	≤868[5]
	Turbidity (NTU)	3.8	1 - 5	1 – 5
	Dissolve Oxygen (mg/l)	12.4		6 – 7
Kruismans River (REC = C)				
Physical water quality	pH (pH units)	7.19 – 7.35	6 - 9	5th percentile 5.6 – 5.9 95th percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	650 - 990	<70	≤650 (wet season) ≤990 (dry season)5
	Total Dissolve Solid (mg/l)	4400 - 6800	<450	≤4400 (wet season) ≤6800 (dry season)5
	Turbidity (NTU)	1.8 – 19.2	1 - 5	1 – 5
	Dissolve Oxygen (mg/l)	13		6 – 7
Krom Antonies River (REC = C)				
Physical water quality	pH (pH units)	7.65 – 7.78	6 - 9	5th percentile 5.6 – 5.9 95th percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	29 - 157	<70	≤29 (wet season) ≤157 (dry season)[5]
	Total Dissolve Solid (mg/l)	202 - 1044	<450	≤202 (wet season) ≤1044 (dry season)[5]
	Turbidity (NTU)	1.4 – 18.2	1 - 5	1 – 5
	Dissolve Oxygen (mg/l)	10.8		6 – 7
Verlorenvlei River (REC = B/C)				
Physical water quality	pH (pH units)	7.62	6 - 9	5th percentile 5.6 – 5.9 95th percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	194	<70	<194[5]
	Total Dissolve Solid (mg/l)	1300	<450	<1300[5]
	Turbidity (NTU)	4.4	1 - 5	1 - 5
	Dissolve Oxygen (mg/l)	8.9		6 - 7
Langvlei River (REC = D)				
Physical water quality	pH (pH units)	6.9	6 - 9	5th percentile 5.0 – 5.6 95th percentile 9.2 – 10.0
	Electrical conductivity (mS/m)	1214	<70	≤1214[5]
	Total Dissolve Solid (mg/l)	7998	<450	≤7998[5]
	Turbidity (NTU)	37	1 - 5	1 – 5
	Dissolve Oxygen (mg/l)	14		6 – 7
Jakkals River (REC = C)				
Physical water quality	pH (pH units)	7.12 – 7.39	6 - 9	5th percentile 5.6 – 5.9 95th percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	2200 - 10100	<70	≤2200 (wet season) ≤10100 (dry season)[5]
	Total Dissolve Solid (mg/l)	14606 - 61200	<450	≤14606 (wet season) ≤61200 (dry season)[5]
	Turbidity (NTU)	0.88 - 14	1 - 5	1 - 5
	Dissolve Oxygen (mg/l)	N/A		6 - 7

Table 38: Chemical Water quality Reserve Requirements for the rivers

Quality Constituent	Parameter	Ecological Reserve	Basic Human Needs	Reserve Requirement: water quality
General chemistry – Major Ions[1,2,3]	Sodium (mg/l)	N/A	<200	<200[4]
	Magnesium (mg/l)	N/A	<70	<70[4]
	Chloride (mg/l)	N/A	<200	<200[4]
	Calcium (mg/l)	N/A	<80	<80[4]
	Sulphate (mg/l)	N/A	<200	<200[4]
	Chloride (mg/l)	N/A	N/A	<0.35[4]
	Fluoride (mg/l)	N/A	< 1.5	<1.5[4]
	Manganese (µg/l)	N/A	<0.15	<0.15[4]
	Potassium (mg/l)	N/A	<50	<50[4]
Nutrients [1,2,3]	Phosphate (PO_4)(mg/l)	<0.2	N/A	<0.015 - 0.025
	Total Inorganic Nitrogen (mg/l)[3]	<0.5	<0.9	<0.7 – 1
Physical water quality	pH (pH units)	7.6	6 - 9	5th percentile 5.6 – 5.9 95th percentile 8.8 – 9.2
	Electrical conductivity (mS/m)	129	<70	≤129[5]
	Total Dissolve Solid (mg/l)	868	<450	≤868[5]
	Turbidity (NTU)	3.8	1 - 5	1 – 5
	Dissolve Oxygen (mg/l)	12.4		6 – 7
Toxics and complex mixtures[1]	Toxics (as listed in DWAF, 1996)	≤ TWQR	≤ TWQR	≤ TWQR
Microbiological Water Quality[3]	Faecal Coliforms (count per 100ml)	-	-	-
	Total Coliforms (count per 100ml)	-	<10	<10[4]

NOTE: *Where a difference in the water quality values for the Ecological Reserve and Basic Human Needs Reserve was found, the stricter or more protective value was selected for the water quality component of the Reserve.*

[1] *ref: South African Water Quality Guidelines, Volume 1: Domestic Water Use, 2nd Ed. 1996. Department of Water Affairs and Forestry. Pretoria, South Africa.*

[2] *ref: South African Water Quality Guidelines, Volume 7: Aquatic Ecosystems, 2nd Ed. 1996. Department of Water Affairs and Forestry. Pretoria, South Africa.*

[3] *ref: South African National Standard 241:2011 Water Quality Standards*

[4] *note: Based on Basic Human Needs requirements. Water for domestic use should be treated to SANS 241: 2011 Water Quality Standards.*

[5] *note: The Reserve Requirement does not meet the Basic Human Needs requirements as it is a naturally high salinity system and would never meet the BHN requirements. Water for domestic use should be treated to SANS 241: 2011 Water Quality Standards*

9. ECOSPECS/RESOURCE QUALITY OBJECTIVES AND MONITORING RECOMMENDATIONS

The final step in the study was to define EcoSpecs and Thresholds of Potential Concern (TPCs) to monitor the implementation of the Ecological Reserve. EcoSpecs are clear and measurable specifications of ecological attributes such as flow, water quality and biological integrity that define an Ecological Category. EcoSpecs refer explicitly to ecological information whereas Resource Quality Objectives (RQOs) include economic and social objectives.

TPCs are the upper and lower levels within a continuum of change for the selected environmental (abiotic or biotic) indicators. The TPCs provide specific targets or the limits of acceptable change in an ecosystem structure, function and composition. In essence, TPCs should provide early warning signals of potential non-compliance to ecological specification (i.e. not the point of ‘no return’). This implies that the indicators (or monitoring activities) selected as part of a long-term monitoring programme need to include biotic and abiotic components that are particularly sensitive to changes in flow. These limits may need to be modified as the knowledge and understanding of the ecosystem improves.

The overall aim of Reserve monitoring is to measure and determine how a resource changes over time and to ensure that the resource remains within the defined acceptable limits of change for the REC. Monitoring thus provides a critical link between the EcoSpecs and the required management interventions.

Essential requirements of a monitoring programme are:

- A clearly defined **baseline condition** against which future changes may be compared;
- Clearly defined objectives in terms of the REC and **EcoSpecs or RQOs**; and
- Clearly defined **TPC**s.

9.1 Groundwater Quality Objectives and Associated Monitoring Recommendations

The groundwater resource quality objectives provided in Table 39 are proposed for each quaternary catchment, together with their monitoring recommendations.

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Table 39: Preliminary Resource Quality Objective Recommendations for F60 and G30 catchments (to be updated)

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
G30A	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0.7 - 1.74	<11 mg/l	It recommended that this seepage area be installed with a spring flow infrastructure just before the stream goes under the road and that the water quality is also monitored every quarter. DWS monitoring needs to increase to include sites around spring.
		Salts	EC (mS/m)		28 - 14994	50 - 84.1	n/a	
		Pathogens	E-coli (counts/100 mL)		-	0	0 counts	
	Spring flow	-	Stream flow	Currently, the spring flow at Papkuils Seepage Area is not being monitored. This is a vital wetland and currently, the exact flow is unknown. The WARMS abstraction point linked to the spring is also seen as very conservative as the volume registered would not result in a wetland of this size.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	0.1 - 150	1 - 8.7	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified. It is recommended that monitoring sites be identified in the delineated important aquifer area.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 28	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
G30B	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that the Eendekuil municipal spring be installed with a spring flow infrastructure and that the water quality is also monitored every quarter.
		Salts	EC (mS/m)		10 - 860	-	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	Currently, the spring flow at Eendekuil is not being monitored and it is recommended that a flow meter be installed on the 63 mm pipe between the spring collection box and the dam.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	0.06 - 56.08	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified. It is recommended that monitoring sites be identified in the delineated important aquifer area.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0 - 21.47	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30C	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 4.5	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored every quarter.
		Salts	EC (mS/m)		2 - 180	5.2 - 59	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
	Spring flow	-	Stream flow	Although this area had many springs historically, none that are still flowing could be identified during this study. Some springs are reportedly still flowing, but these could not be identified.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	1.3 - 100	0.3 - 111.8	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently very little DWS monitoring in this catchment. Monitoring boreholes must be identified. It is recommended that monitoring sites be identified in the delineated important aquifer area and in the recharge area of the Citrusdal Mountains.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0 - 25.01	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30D	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 2.68	<11 mg/l	Matroozefontein spring is being monitored by Bergrivier Municipality. Data must be shared with DWS. It recommended that springs in the mountainous areas be identified and be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		42 - 640	24.1 - 330	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	The Matroozefontein spring acts as the sole water supply for the town of Redelinghuys and has been equipped with a flow monitoring system by the Bergrivier Municipality. Springs in the mountains are not being monitored.	-	n/a	Need to be determined from stream flow monitoring.	

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	0.64 - 60.13	0 - 78	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified. It is recommended that monitoring sites be identified in the delineated important aquifer area and the recharge area of the Piketberg Mountains.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.1 - 43.06	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30E	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 14	<11 mg/l	It is recommended that this Kruisfontein seepage area be installed with a spring flow infrastructure just before the stream goes under the road and that the water quality is also monitored every quarter. A sampling at current monitoring boreholes needs to increase the parameters being analysed borehole monitoring sites are sufficient, but boreholes around Kruisfontein spring would be beneficial. Elevated nitrate levels in some boreholes need to be investigated.
		Salts	EC (mS/m)		20 - 3498	20 - 3498	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	Kruisfontein seepage areas are located towards the northeast of Redelinghuys. The water from the various spring eyes flows into one channel that flows down and joins the Verlorenvlei River at Redelinghuys. Currently, this is not being monitored	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are	0 - 109.7	0.7 - 42	Should be maintained per borehole. In areas of groundwater-surface water interaction,	

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
				located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.			groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed. 1 mamsl (<10km from the coast)	
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 23	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30F	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 12	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored every quarter. Elevated nitrate levels in some boreholes need to be investigated.
		Salts	EC (mS/m)		31 - 2450	35 - 344	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	Although this area had many springs historically, none that are still flowing could be identified during this study. Some springs are reportedly still flowing, but these could not be identified.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream	0 - 121.9	1.3 - 112	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must	DWS borehole monitoring sites need to be increased in the delineated important aquifer and the Swartberg Mountains.

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
				location. Water levels should recover during the wet season.			decrease or stop if a continued negative trend is observed. 1 mamsl (<10km from the coast)	
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 31.5	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30G	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 0.63	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored every quarter.
		Salts	EC (mS/m)		12 - 2330	46 - 870	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Springflow	-	Stream flow	Although this area had many springs historically, none that are still flowing could be identified during this study.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	3.5 - 150	11.4 - 60	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed. 1 mamsl (<10km from the coast)	DWS borehole monitoring sites need to be increased to include boreholes in the upper reaches of the Jakkals river system.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered	0.01 - 23	n/a	n/a	The 2018 Government Gazette regarding the monitoring of

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
				when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.				groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
G30H	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	0 - 4.56	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		11 - 1361	364	n/a	
		Pathogens	E-coli (counts/100 mL)		-	0 - 5	0 counts	
	Spring flow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	0.01 - 230	32.23 - 48	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed. 1 mamsl (<10km from the coast)	DWS borehole monitoring sites need to be increased to include boreholes in the upper reaches of the Sandlaagte river system.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 13.33	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
F60A	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that springs when identified be installed with a

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
		Salts	EC (mS/m)		793 - 2450	-	n/a	spring flow infrastructure and that the water quality is also monitored every quarter.
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover during the wet season.	2.12 - 121.92	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed. 1 mamsl (<10km from the coast)	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified. This should include municipal boreholes at Lepelsfontein.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 7.5	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
F60A	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		793 - 2450	-	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Spring flow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover after rain.	2.12 - 121.92	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 7.5	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
F60B	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		108 - 1345	-	n/a	
		Pathogens	E-coli (counts/100 mL)		-	0	0 counts	
	Spring flow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream	0.35 - 76.2	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must	DWS does have monitoring sites around the Bitterfontein wellfield that is located across the quaternary boundary in E33D. It is recommended that a monitoring network needs to be installed around waste ponds at the desalination plant at Bitterfontein.

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
				location. Water levels should recover after rain.			decrease or stop if a continued negative trend is observed.	
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.02 - 5	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
F60C	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that some of the springs identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		200 - 3554	33.6 - 1184	n/a	
		Pathogens	E-coli (counts/100 mL)		-	0	0 counts	
	Spring flow	-	Stream flow	Springs have been identified and although they do not need larger surface water systems; these are extremely important for the local communities and ecosystems.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover after rain.	0 - 83	0 - 43	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when	0.01 - 6.5	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
				baseflow and streamflow are impacted.				of abstraction data must be developed per catchment
F60D	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not shall not deteriorate from natural background.	-	-	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		142 - 3433	-	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	
	Springflow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover after rain.	0 - 163	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 2.1	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment
F60E	Water Quality	Nutrients	NO3/NO2 (mg/L)	Water quality should not deteriorate from the natural background.	-	-	<11 mg/l	It recommended that springs when identified be installed with a spring flow infrastructure and that the water quality is also monitored on a quarterly basis.
		Salts	EC (mS/m)		15 - 3434	-	n/a	
		Pathogens	E-coli (counts/100 mL)		-	-	0 counts	

Quaternary catchment	Aquifer Characteristics	Sub-component	Indicator	RQO Description	Numerical Values			Monitoring Recommendations
					Range identified in NGA	Range identified in production boreholes	Recommended Limit	
	Springflow	-	Stream flow	Historically this area does not have many springs.	-	n/a	Need to be determined from stream flow monitoring.	
	Groundwater Levels	-	Groundwater level (mbgl)	Groundwater levels should be managed sustainably as to not allow water levels to drop below calculated critical water levels (obtained from yield test data). Where boreholes are located in areas that have been linked to baseflow, groundwater abstraction cannot take place if the radius of influence is > 0.5m at the stream location. Water levels should recover after rain.	0.23 - 127	-	Should be maintained per borehole. In areas of groundwater-surface water interaction, groundwater flux to surface water must be maintained. Abstraction must decrease or stop if a continued negative trend is observed.	Currently no DWS monitoring in this catchment. Monitoring boreholes must be identified.
	Groundwater Abstraction	-	Abstraction rate (L/s)	Approved abstraction must allow for drought restrictions and be lowered when water levels in the area display a continued declining trend and when baseflow and streamflow are impacted.	0.01 - 8.2	n/a	n/a	The 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment

9.2. Groundwater Monitoring

Over and above the monitoring recommendations specifically relating to the recommended groundwater RQOs, the following additional monitoring and assessment recommendations are provided:

To develop and or use groundwater sustainably in the area, the following needs to be taken cognizance of:

- A groundwater monitoring programme must be established where there is currently no existence of groundwater quality and quantity monitoring.
- The directive from the 2018 Government Gazette regarding the monitoring of groundwater abstraction volumes must be enforced and databases of abstraction data must be developed per catchment. This will vastly improve the accuracy of any reserve study for the area.
- For the G30 catchments not part of the Verlorenvlei system, it is recommended that isotope and inorganic sampling commences investigating the link between the E10 and the coastal G30 catchments of the northern Sandveld. It is hypothesized that the same system of lateral recharge from the mountainous areas towards the coastal areas occurs here as well as what has been found for the Piketberg mountains and the adjacent coastal catchments, but due to the lack of isotope and inorganic analysis data for this portion of the Sandveld, it could not be proven during this study. Thus, it is recommended that the sampling be done and analysed to investigate whether the northern Sandveld does obtain its recharge from the Cederberg and Swartberg Mountains as is assumed.
- For the G30 catchments, more monitoring sites need to be included in the Piket-Bo-Berg area, as well as the Swartberge and Citrusdal Mountains that's are the assumed peak recharge areas for these catchments. Monitoring sites are also vitally needed in the Bergvallei and Jansekraal valleys, as no monitoring data could be obtained for these areas. For the G30D (Moutonshoek) area, one company does monitor the water levels in their boreholes that have been installed with telemetry monitoring systems, and they have shown interest in sharing this dataset with DWS. Monitoring sites in the upper Krom-Antonies and Hol systems are still needed. Important aquifers have been delineated to assist in guiding monitoring site areas, as well as delineating areas where baseflow and spring flow could be affected by groundwater abstraction.
- It is understood that the Papkuils, Langvlei and Jakkals systems would each be unique, but due to a lack of baseflow separation and streamflow data, the relationship between the surface and groundwater for these systems could be proven during this study. For systems where some observations could be interpreted to link the surface and groundwater systems, like for the Langvlei, the average breakdown between groundwater and surface water for the Verlorenvlei system was used. It is however recommended that each of these systems should have similar baseflow estimations done as what has been done for the Verlorenvlei systems. It is understood that these are costly and time-consuming studies and thus it would be recommended that universities be contacted to assist with these proposed studies.
- G30A: Currently, the spring flow at Papkuils Seepage Area is not being monitored. This is a vital wetland and currently, the exact flow is unknown. The WARMS abstraction point linked to the spring is also seen as very conservative as the volume registered would not result in a wetland of this size. It recommended that this seepage area be installed with

a spring flow infrastructure just before the stream goes under the road and that the water quality is also monitored every quarter.

- G30B: Currently, the spring flow at Eendekuil is not being monitored and it is recommended that a flow meter be installed on the 63 mm pipe between the spring collection box and the dam.
- G30B: It is important to note that NO groundwater monitoring is being done in this GRU by DWS. It is recommended that monitoring sites be identified in the delineated important aquifer area, near the Steenebrug area.
- G30E: Kruisfontein Springs, located towards the northeast of Redelinghuys, NEEDS to be monitored. The water from the various springs flows into one channel that flows down and joins the Verlorenvlei River at Redelinghuys. It would be recommended that a flow measuring and monitoring system be installed just before the streams join and where the Kruisfontein stream flows underneath the road.
- G30E: During the drought of 2016-2018, it was reported that when this area of the upper Verlorenvlei wetland dried up completely, a small pool of water in the centre of the wetland area kept getting wet during the night and then dried during the day. This report could not be investigated as that portion of the wetland did not completely dry up during 2021 and 2022, but it would be recommended that if this occurs again, the pool is sampled. It would be difficult to sample (because of the mud layer), but could be done with a drone.
- G30E: For the monitoring boreholes adjacent to the Verlorenvlei wetland, more sampling and analysis are needed to link these changes with the specific activities and/or specific hydrogeological processes, thus increased water quality monitoring would be recommended for these boreholes.
- G30F: Some boreholes in this GRU highlighted the localised nature of the elevated nitrate levels that have been monitored and thus it would not be recommended to extrapolate the increase in nitrate that has been observed in certain boreholes across large areas until additional sampling be done. It would be recommended that in areas where high nitrates have been observed, surrounding boreholes be sampled to measure the extent of the higher nitrate area.
- G30G: For the upper reaches of the Jakkals river system, no boreholes are being monitored, but multiple NGA boreholes have been registered for this area. It is recommended that at least one of these boreholes be included in the monitoring system as it would be useful to monitor groundwater in this area.
- F60E: At Namaqua Sands Mine, the effect of mining activities has created a pollution plume. This is being closely monitored and modelled and the mine is working with DWS to minimise the impacts of the mining activities, but it does show that even in areas with a deep-water level and very high EC`s, the mining could still impact the groundwater quality and levels. It is thus vital that any mining activity in these areas must if approved, continually monitor and model the groundwater and their effects on it. It is recommended that any proposed mining activity, or any other proposed activity that could impact the groundwater in that, be closely evaluated, based on site-specific conditions, before any decision is made to approve such an activity.
- F60_Sampling of rivers and streams during flow events: At Namaqua Sands Mine, boreholes adjacent to the Groot Goerap do form part of their monitoring and sampling network and it would thus be recommended that the river must be sampled when it next flows to compare the surface water to that of boreholes drilled in the riparian zone of the

river. It was also observed that some of the production boreholes at Bitterfontein seem to be drilled near drainage channels, and although these boreholes are located across the quaternary boundary in the E33D quaternary catchment, it would be recommended that isotope and inorganic sampling and analyses be done during surface water flow periods to investigate the relationship between these boreholes and the surface water systems in these areas. It is also recommended that the local community leaders be asked to sample any of the other rivers in the F60 catchments when they flow. As these river systems are remote and far away from any DWS office, it would be recommended that the local people be incorporated into a river sampling network to gain information on these systems.

- F60B: The trends observed in the DWS monitoring boreholes could not be linked to the Bitterfontein production boreholes for the municipality. It is recommended that the monitoring data from the actual production boreholes be obtained and incorporated into the DWS monitoring system. Because these boreholes and the desalination plant supply all the settlements and small towns in the area with their only source of water, it is vital that the sustainability of the system be monitored. Some form of telemetry system is installed, but the current system does not seem to store groundwater water level data.
- F60B: A last recommendation for this municipal setup would be to monitor groundwater quality surrounding the Bitterfontein evaporation dams linked to the desalination plant. The municipality noted that this is currently not being done and it would be recommended that sampling in a 1km radius around these dams should be done to monitor the potential pollution risk these dams pose.
- For some of the quaternary catchments, there is no baseflow to meet the needs of the ecological component of the Reserve. For such catchments, the Reserve comprises the Basic Human Needs component and the Regional Office may need to take this into account when evaluating water use licences.

Borehole-specific recommendations for groundwater use licence conditions include:

a) An “observation pipe” needs to be installed (32 mm inner diameter, class 10) from the pump depth to the surface, closed at the bottom and slotted for the bottom 5 – 10 m, for the production borehole. This allows for a ‘window’ of access down the borehole which enables manual water level monitoring and can house an electronic water level logger.
b) Continuous monitoring of groundwater levels using a pressure transducer in the borehole is ideal. The water level in the borehole may not drop below the critical water level. These water levels should be calculated from yield test data done according to the National Standard (SANS 10299-4:2003, Part 4 – Test pumping of water boreholes). If the water level in the borehole drops below the critical water level, DWS must be contacted.
c) Water quality monitoring which includes sampling and analysis of the groundwater at an accredited laboratory is important. A sampling interval of quarterly is recommended for the first year of monitoring, thereafter, the water quality monitoring should be reviewed and can potentially be reduced to bi-annual or annually as seen in **Table 40**.
d) The monitoring data should be reviewed quarterly at first and can then be scaled down to bi-annually.
e) Installation of a sampling tap at the production borehole (to monitor water quality) is essential.
f) Installation of flow volume meters at the production boreholes (to monitor abstraction rates and volumes) is also important. External flow (e.g., mag-flow) meters are recommended.

g) Abstraction volumes must be monitored and recorded by a designated person on site. Depending on the frequency of use, daily, weekly or monthly abstraction should be recorded.
h) The appropriate borehole pumps must be installed, i.e. not an oversized pump that is choked with a gate valve. If the monitoring shows that more water can be abstracted, then the duration of pumping time can be increased (not the flow rate).
i) The borehole and pump should be serviced annually.
j) A geohydrologist should review the above information at least annually to ensure optimal groundwater abstraction and management occurs.

Table 40: Proposed groundwater monitoring parameters.

Parameter	Frequency
Groundwater Level	Ideally every 15 minutes with a data logger
Chemical parameters	
pH (at 25 ºC)	Quarterly (Field Chemistry)
Conductivity (mS/m) (at 25 ºC)	Quarterly (Field Chemistry)
Total Dissolved Solids (mg/L)	Quarterly (Field Chemistry)
Turbidity (NTU)	Quarterly*
Colour (mg/L as Pt)	Quarterly*
Sodium (mg/L as Na)	Quarterly*
Potassium (mg/L as K)	Quarterly*
Magnesium (mg/L as Mg)	Quarterly*
Calcium (mg/L as Ca)	Quarterly*
Chloride (mg/L as Cl)	Quarterly*
Sulphate (mg/L as SO_4)	Quarterly*
Nitrate & Nitrite Nitrogen (mg/L as N)	Quarterly*
Nitrate Nitrogen (mg/L as N)	Quarterly*
Nitrite Nitrogen (mg/L as N)	Quarterly*
Ammonia Nitrogen (mg/L as N)	Quarterly*
Total Alkalinity (mg/L as $CaCO_3$)	Quarterly*
Total Hardness (mg/L as $CaCO_3$)	Quarterly*
Fluoride (mg/L as F)	Quarterly*
Aluminium (mg/L as Al)	Quarterly*
Total Chromium (mg/L as Cr)	Quarterly*
Manganese (mg/L as Mn)	Quarterly*
Iron (mg/L as Fe)	Quarterly*
Nickel (mg/L as Ni)	Quarterly*
Copper (mg/L as Cu)	Quarterly*
Zinc (mg/L as Zn)	Quarterly*
Arsenic (mg/L as As)	Quarterly*
Selenium (mg/L as Se)	Quarterly*
Cadmium (mg/L as Cd)	Quarterly*
Antimony (mg/L as Sb)	Quarterly*
Mercury (mg/L as Hg)	Quarterly*
Lead (mg/L as Pb)	Quarterly*
Uranium (mg/L as U)	Quarterly*

Parameter	Frequency
Cyanide (mg/L as CN-)	Quarterly*
Total Organic Carbon (mg/L as C)	Quarterly*
E.coli (count per 100 ml)	Quarterly*
Total Coliform Bacteria (count per 100 ml)	Quarterly*
Heterotrophic Plate Count (count per ml)	Quarterly*
Total Petroleum Hydrocarbons (TPH)	Quarterly*
*Can be reduced to bi-annually or annually if reviewed and deemed appropriate	

9.3. Surface Water Monitoring

9.3.1. Flow Monitoring

- Hydrometeorological data is the primary input data for the WRSM2000 Pitman model. Of the fourteen rainfall gauges used in the WR2012 study, only eight had remained operational with data which could be included for extension of the rainfall input files. For this study, rainfall records for a further nine stations belonging to DWS or SAWS were sourced and one rainfall record from a private source was provided. The reduction in the number of operational rainfall gauges and their deteriorating spatial distribution over the study area are of serious concern. It is strongly recommended that DWS and SAWS undertake a coordinated campaign to re-instate all strategically-placed previously-closed rainfall stations.
- There are no operational flow gauging stations in the study catchments; therefore, no recent streamflow data were available for verification of the updated WRSM2000 Pitman model. It is strongly recommended that DWS undertakes reinstatement of closed gauging stations and installation of new gauging stations, and calibrated sections for flow measurements.
- Although the WRSM2000 Pitman model performed adequately, there are some limitations with the modelling of the integration of surface water and groundwater. Therefore, it is recommended that for future modelling in these catchments, alternative modelling software is considered which represents surface water–groundwater interactions more appropriately.
- The lack of hydrological monitoring data has been a major limitation in the current study, especially for the wetland EWR assessments. Flow gauging stations should be established and regularly monitored in all the main river systems (Jakkals, Langvlei, Papkuilsvlei, and the Verlorenvlei and its main tributaries, namely the Kruismans, Krom-Antonies and Hol Rivers). In addition to the flow gauging stations, surface and sub-surface water level monitoring (e.g. using piezometers and water level plates) should be carried out in the main wetland systems at the EWR sites established during the current study.
- • An adaptive management approach should be taken to the implementation of the EWR for Catchment G30, whereby rainfall monitoring should be used to guide the amount of water that is allocated in a particularly year or season. If there is a period of low rainfall, then less water should be allocated than there is following periods of normal or above-average rainfall.

9.3.2. Water Quality Monitoring

Resource Quality Objectives (RQOs) are specified during Water Resource Classification. with EcoSpecs defined during Reserve studies forming the ecological input to the RQOs. EcoSpecs are associated with the Ecological Reserve process and are provided at EWR sites, as the output of the Reserve Study. EcoSpecs are the detailed or numerical ecological input to RQOs as they are quantifiable, measurable, verifiable, and enforceable and, therefore ensure the protection of all components of the resource, which together define ecological integrity. As EcoSpecs are presented in a numerical quantitative format, they can be used for monitoring and compliance purposes. When setting EcoSpecs, the work is usually based on field surveys to establish a monitoring baseline and future monitoring is either to ensure that the present state is maintained, or that the REC is reached (DWS, 2015a; DWS, 2015b).

EcoSpecs (water quality specifications or objectives for the PES and REC) are set for physico-chemical, quantifiable, and measurable, parameters, and are presented as percentiles. However, percentiles should be calculated within the framework of the current assessment method (DWAF, 2008), i.e. using the PES monitoring point at the EWR site, and the most recent three to five years of data, equivalent to a minimum of 60 data points (DWS, 2015a). However, there are not sufficient water quality data available for both G30 and F60 catchments to determine EcoSpecs in terms of percentages.

The EWR sites provide possible monitoring locations for monitoring the Ecospecs. These are only suggestions, and the locations may be adjusted according to the requirements of ongoing or forthcoming monitoring programmes. However, due to the high spatial variability of the water quality in the G30 catchment, ideally, the water quality monitoring should be at the EWR sites as a slight change of monitoring point, downstream or upstream of the EWR site, may give very different water quality results. There are ingoing monitoring activities in the G30 WMA (DWA: Western Cape Regional Office), and where possible, these should be taken into account in recommending future monitoring locations.

Ideally, surface water quality and groundwater quality should be measured at the same time and location, as the groundwater and surface water interaction is important in the G30 and F60 catchments. During the dry, summer months, some of the EWR sites are maintained only by groundwater or completely dry out, making monitoring of the EWR sites challenging. However, the above suggestion would imply an ideal situation and the practicality should be investigated.

The Ecospecs suggested are preliminary values since there are very limited data available to determine the Ecospecs. Long-term data sets are needed to ratify the Ecospecs to be able to test whether the Reserve requirements are being met.

It is recommended that the implementation of the additional baseline surveys and long-term monitoring programmes be undertaken in collaboration with various responsible departments in the DWS, as well as other national and provincial departments and institutions responsible for natural resource management such as, but not limited to, a catchment management agency, as well as relevant municipal authorities and even the local farming communities.

Water quality indicators to be monitored for Ecospecs, are proposed to be the following:

- Nutrients - Phosphate (PO_4-P), Total inorganic nitrogen calculated from NO_2+NO_3-N plus NH_4-N

- Salinity - Electrical conductivity and/or Total Dissolved salts
- System variables – pH, water temperature, dissolved oxygen (DO), and turbidity/suspended sediments

The Sandveld Monitoring Programme (DWS: Western Cape Regional Office) collects water quality samples on a monthly and quarterly intervals, provided there is surface water and flow at a sampling point. It is recommended that the EWR sites be linked to this programme. It is also recommended that monthly intervals be maintained for monitoring the water quality to be able to refine the Ecospecs at the EWR sites.

All water quality data collected should be stored in a central location where it is accessible to officials and the public. Ideally, this should be the Department's Water Management System (WMS) where the data for the various national monitoring programmes are stored.

Water quality data for the EWR sites should be abstracted and analysed every two years after a baseline study of at least five years or 60 data points. Compliance can only be assessed once the baseline is established. Summary statistics should be calculated (e.g. 50^{th} and 95^{th} percentiles) for the variables of concern and at least time series plots produced and examined for temporal trends. It is expected that there will be data gaps at the EWR sites that dry up during the summer months.

9.3.3. River and Wetland EcoSpecs and Monitoring Recommendations

A summary of the EcoSpecs and TPCs for the rivers and wetlands at the EWR sites is provided in Table 41.

Table 41. Ecological Specifications and TPC associated with the river and wetland EWR sites

Indicator	Ecological Specification	Threshold of Potential Concern	Recommended Monitoring
Papkuils River (REC = C)			
Fish	There should be at least two of the native species	One species captured during netting and juveniles or adults absent	Summer sampling with small seine and overnight fyke net
Aquatic Invertebrates	SASS5 Score>44 ASPT>4.2 MIRAI of 60 to 79	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or of invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as a basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transect would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches and associated wetlands are necessary to determine the sources of perturbations and of the

Indicator	Ecological Specification	Threshold of Potential Concern	Recommended Monitoring
	species in each lateral zone. Soil moisture data for the transect where vegetation was sampled.		effects of changes within each reach. It is essential that soil moisture data be collected together with any wetland vegetation sampling.
Kruismans River (REC = C)			
Fish			
Aquatic Invertebrates	SASS5 Score>60 ASPT>4.5 MIRAI of 60 to 79	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone. Soil moisture data for the transect where vegetation was sampled.	A change, particularly <u>an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone</u>. <u>An increase in exotic species/ agricultural weeds or of invasive species</u>. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as a basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transect would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches and associated wetlands are necessary to determine the sources of perturbations and of the effects of changes within each reach. It is essential that soil moisture data be collected together with any wetland vegetation sampling.
Krom Antonies River (REC = C)			
Fish	There should be at least two of the native species	One species captured during netting and juveniles or adults absent	Summer sampling with overnight fyke net and snorkel during the day
Aquatic Invertebrates			
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone. Soil moisture data for the transect where vegetation was sampled.	A change, particularly <u>an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone</u>. <u>An increase in exotic species/ agricultural weeds or of invasive species</u>. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as a basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transect would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches and associated wetlands are necessary to determine the sources of perturbations and of the effects of changes within each reach. It is essential that soil moisture data be collected together with any wetland vegetation sampling.

Indicator	Ecological Specification	Threshold of Potential Concern	Recommended Monitoring
Verlorenvlei River (REC = B/C)			
Fish	There should be at least two of the native species	One species captured during netting and juveniles or adults absent	Summer sampling with overnight fyke net
Aquatic Invertebrates	SASS5 Score>70 ASPT>4.8 MIRAI of 75 to 85	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation			
Langvlei River (REC = D)			
Fish	No fish present	No fish present	None
Aquatic Invertebrates	SASS5 Score>44 ASPT>4.2 MIRAI of 40 to 59	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone. Soil moisture data for the transect where vegetation was sampled.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as a basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transect would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches and associated wetlands are necessary to determine the sources of perturbations and of the effects of changes within each reach. It is essential that soil moisture data be collected together with any wetland vegetation sampling.
Jakkals River (REC = C)			
Fish	No fish present	No fish present	None
Invertebrates	SASS5 Score>44 ASPT>4.2 MIRAI of 60 to 79	Ensure no group consistently dominates (D abundance)	Annual SASS5 sampling at the end of winter/ early spring
Riparian/wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone. Soil moisture data for the transect	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as a basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transect would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches and associated wetlands are necessary to determine the sources of perturbations and of the effects of changes within each reach. It is essential that soil moisture data be collected

Indicator	Ecological Specification	Threshold of Potential Concern	Recommended Monitoring
	where vegetation was sampled.		together with any wetland vegetation sampling.
Papkuilsvlei (REC = C)			
Wetland vegetation			
Rocherpan Wetland (REC = C)			
Wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone. Soil moisture data for the transect where vegetation was sampled.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as a basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transect would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches and associated wetlands are necessary to determine the sources of perturbations and of the effects of changes within each reach. It is essential that soil moisture data be collected together with any wetland vegetation sampling.
G30A Dune-slack depression (REC = C)			
Wetland vegetation	A list of species, their individual cover % and height specification in each demarcated lateral zone. A vertical and horizontal photographic record of each plot in each zone and laterally along the length of each transect from each end. Notes about the condition of each species in each lateral zone. Soil moisture data for the transect where vegetation was sampled.	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone. An increase in exotic species/ agricultural weeds or invasive species. A change in the location of the boundaries between lateral zones. An absence of juvenile plants. An increase in the area of bare soil. An increase in soil salinity.	Early Spring sampling along the transects used in the current study to serve as a basis for long-term monitoring. Use fixed plots of 2m x 2m dimensions demarcated, permanently marked in each of the sampled units as mapped along these transects. Two additional parallel transects placed near each of the current transect would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches and associated wetlands are necessary to determine the sources of perturbations and of the effects of changes within each reach. It is essential that soil moisture data be collected together with any wetland vegetation sampling.

9.3.4. Additional River and Wetland Biotic Monitoring Recommendations

Fish

According to Kleynhans and Louw (2006), monitoring frequency should be dependent on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of the vulnerability of the assemblage. A monitoring frequency *of 1 X dry season is deemed appropriate for the Verlorenvlei and Papkuils river systems.* It is recommended that sampling be conducted annually at sites listed in the table below.

Table 42. Recommended monitoring sites for freshwater fish for the Reserve study area

River	Monitoring site	Sampling time, Gear
Kruismans	Roadbridge pool 32º 44' 45” S; 18º 49' 05” E	Summer, overnight fyke
Krom Antonies	Above causeway 32º 43' 15” S; 18º 42' 39”E	Summer, overnight fyke and snorkel during day
Verlorenvlei	Near Hol confluence 32º 35' 53” S; 18º 41' 22”E	Summer, overnight fyke
Verlorenvlei	Game farm 32º 35' 53”S; 18º 41' 22”E	Summer, overnight fyke
Verlorenvlei	Below Redelinghuys bridge 32º 28' 14”S; 18º 32' 07”E	Summer, overnight fyke
Papkuils	Wetland 32º 37' 55”S; 18º 30' 22”E	Summer, small seine and overnight fyke

According to Riemann *et al.* (2014), the RQOs for fish assemblages assume the application of a range of gear types including fyke nets in mainstem pools, seine nets on sandy beaches if they are present (5 X 2 m) and electrofishing in rocky riffles and runs. For most Verlorenvlei sites, overnight fykes are recommended and set as described by Rieman *et al.* (2014). Snorkel assessments can be undertaken at the Krom Antonies site because of the excellent water clarity there in summer.

Chakona et al. (2019) highlighted the need for long-term monitoring of the native fishes of the Verlorenvlei system, to focus on their temporal and spatial distribution and habitat use patterns, as well as understanding the breeding biology and other life history traits.

Aquatic Invertebrates

The macroinvertebrates occurring within the rivers in the study area with the exception of in the upper catchment of the Verlorenvlei River System comprise naturally hardy species such that macroinvertebrate sampling does not provide particularly meaningful results for monitoring compliance with the ecological Reserve. This is largely due to the fact that lower reaches comprise mostly wetland habitat. The EWR site are all in these lower reaches and are all near longer term National Aquatic Ecosystem Health Monitoring Programme sites. As such, it is recommended that this monitoring continue at these sites. It is however also important that additional monitoring points be established or maintained in the foothill zones of the main feeder streams of the Verlorenvlei River, given the importance of these rivers in providing good quality water to the lower river for most of the year. The following additional sites are proposed:

- Bergvallei River in the kloof below the confluence of the Jansekraal and Kleinvlei Rivers (there was a site established in the Jansekraal that has been severely impacted by instream dams upstream of the site),
- Kruismans River upstream of the R366 (there is one already established that should be maintained) and
- Krom Antonies River at the gravel road crossing just downstream of Moutonshoek.

The recommended timing of the monitoring is in spring, after the winter rainfall period and before many of the rivers cease to flow.

<u>Riparian and Wetland Vegetation</u>

There appears to be general degradation of the vegetation along the rivers and wetlands within the study area for various reasons, *inter alia* through:

- Changes in agricultural practices (perhaps causing salinification increase);
- Reduced stream flow and changes in groundwater recharge; and
- Changes to flows impacting flushing regimes.

The general changes deduced from the vegetation examined along the transects are:

- An increase in *Phragmites* beds where heavy grazing is absent (Stock browse young spears);
- Inundation periods, nutrient and sediment level changes and management practices are known to be causal to a change from *Phragmites* reeds to *Typha capensis* as is occurring on the Verlorenvlei River;
- Invasion of Salt Marsh vegetation into the wetted bank;
- Expansion and Salinification (with degradation) of the Salt Marsh vegetation;
- Loss of indigenous species diversity and vegetation cover in the Salt Marshes (weeds are numerous, invader shrubs are increasing); and
- Loss of grazable species from the Salt Marsh vegetation (grazing regimes, trampling effects).

A permanent monitoring programme of vegetation is required to conclusively support the differentiation between the effects of the different event sources. From comparisons to observations made by Low & Pond (2003) and the examination of historic aerial imagery, it appears that the vegetation is following a negative spiral through changed abstraction volumes and patterns, over-utilization of the riparian vegetation and uncontrolled increase of invader plants.

The following recommendations by Low & Pond (2003) for these Sandveld systems still hold, namely, the establishment of permanent reference monitoring transects to test the impacts of abstraction on aquatic health (and a possible rehabilitation programme), a monitoring programme is urgently required using permanent "plots" to record shifts in plant community content and boundaries, in response to abstraction and nutrient loading and other impacting factors. For instance, the current transects established in the current study need to be used as a basis for long-term monitoring with fixed plots of 2m x 2m dimensions demarcated and permanently marked in each of the sampled units along these transects. Two additional parallel transects placed near each of the current transects would give adequate repetition to quantify changes at each site. Similar sampling transects through different river reaches and their associated wetlands are necessary to determine the sources of perturbations and of the effects of changes within each reach. It is essential that soil moisture data be collected together with any wetland vegetation sampling.

These and more data are to be used to develop a rehabilitation model and methodology to monitor on-going vegetation changes for particular river reaches and the associated wetlands and tested by extrapolation through each system as a whole. The consequence of such a programme must give results that can be used to adjust abstraction patterns through each catchment in addition to providing a substantive rationale for the consideration of ongoing permit applications, for establishing rehabilitation objectives, including the monitoring of the reintroduction of desirable vegetation and species and the effects of the reshaping of rivers and wetland areas.

Wetlands

Without significant channel restoration to improve wetland functioning at some of the sites (e.g. Krom-Antonies, Kruismans) as well as alien vegetation removal and reduction in grazing in some cases, providing the recommended EWR will not improve wetland condition.

The seep wetlands and upper-catchment valley bottom wetlands that would, under natural conditions, have been a dominant source of water to the main longitudinal wetland systems in G30 have been severely impacted (and in some cases totally lost) through surface and mostly sub-surface water abstraction for agricultural activities in the region. The wetlands in the upper catchments that are still in reasonable ecological condition with good rehabilitation potential should be identified, rehabilitated and given appropriate protection status. Some of these potential areas have been identified in the current study, for example, the Upper Papkuilsvlei wetland system and the intact "eye" upstream of this. Abstraction of water from these seepage and upper-catchment areas also needs to be urgently curtailed to provide sufficient water to the main wetlands systems in G30, especially during the low-flow period (late spring / early summer to late summer / early autumn).

In addition to the flow gauging stations, surface and sub-surface water level monitoring (e.g., using piezometers and water level plates) should be carried out in the main wetland systems at the EWR sites established during the current study.

9.3.5. Estuary EcoSpecs

Verlorenvlei Estuary

The TPCs associated with each of the ecological specifications for the Verlorenvlei Estuary are provided in Table 43. Ecological Specifications and TPCs for the estuary were defined for **Category B.**

Table 43: Ecological Specifications and TPC associated with an Ecological Category B in the Verlorenvlei River Estuary

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
Water quality	Salinity structure and the occurrence of different abiotic states should correspond as closely as possible with the Reference condition; State 5 (Closed, Low water level hypersaline) should not occur at all.	• Salinity in Zone A > 45 (for 3 years) • Salinity in Zone B > 3 • Salinity in Zone C > 1.5 • (See Verlorenvlei zonation map in Figure 12 below)
	Water quality in **river inflow** does not detrimentally affect water quality conditions in estuary, specifically relating to inorganic nutrient enrichment and toxic substances	River inflow: • pH of river inflow exceeds 8.5 or is less than 5.5 • Dissolved oxygen (DO) less than 4 mg/ℓ • Turbidity persistently exceeds 10 NTU • Dissolved Inorganic Nitrogen (DIN) persistently greater than 200 µg/ℓ • Dissolved Inorganic Nitrogen (DIN) persistently greater than 50 µg/ℓ • Toxic substance concentrations (e.g. heavy metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine)
	Water quality **in estuary** does not detrimentally impact biotic health, specifically relating to nutrient enrichment and diurnal fluctuation in pH and (e.g. decreasing at night and increasing during day time), or acidification and potential hypoxia developing during algal decay.	Estuary: • pH drop below 6, or persistently above 9 • DO less than 4 mg/ℓ • Turbidity persistently exceeds 20 NTU (e.g. as a result of persistent algal blooms) • Resultant DIN exceeds 100 µg/ℓ (in a closed system this would suggest excessive enrichment through remineralisation) • Resultant DIP exceeds 20 µg/ℓ) (in a closed system this would suggest excessive enrichment through remineralisation) • Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality guidelines (freshwater and coastal marine)
Hydrodynamic	Estuary should be allowed to function as naturally as possible with minimal human intervention	• The mouth is breached artificially • No connectivity between Zone A, B and C
Sediment dynamics	Flood and breaching regimes to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota	• As for hydrodynamics above
Microalgae	Phytoplankton communities should reflect a diverse community, with moderate to low biomass (measured as chlorophyll-a concentration), and reduced occurrence of HABs. Benthic microalgal communities should reflect moderate biomass and medium- (closed phase) to high (open phase) benthic diatom diversity.	• Phytoplankton biomass greater than 20 µg Chl-*a* l^{-1}. • High-biomass HABs (> 60 µg Chl-*a* l^{-1} dominated by a single taxa, e.g., cyanophytes) in spring/summer. • Subtidal benthic microalgal biomass greater than 100 mg Chl-*a* m^{-2}. • Benthic diatom diversity (*H'*) less than 2.

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
Macrophytes	Monitor the distribution of plant community types i.e. reeds and sedges, submerged macrophytes, salt marsh during water level fluctuations. Maintain reeds and sedges and open water habitat which supports associated biota. Reeds and sedges are dependant on groundwater discharge (See methods described in Verlorenvlei EWR report). Increases in upper reaches are in response to sediment and nutrient input. Monitor acidic soils as long-term effects on the recovery of macrophytes are unknown. Important risk factors are pH and salinity, particularly in the groundwater and sediment. Water column turbidity is important for submerged macrophytes.	• Greater than 20% change in the area covered by different macrophyte habitats. • Open water area below 1.2 ha (Zone A), 405 ha (Zone B) and 14.3 ha (Zone C) results in exposure to acidic soils. • Groundwater salinity above 10 to 5 reduces the growth of reeds and sedges. • Sediment salinity > 75 results in no significant growth. Seed germination hampered below 15.
Invertebrates	The estuary should contain a diverse invertebrate community that includes representatives of all functional groups listed in this report, particularly the freshwater and brackish species including the macroinvertebrates.	• A decline in the abundance and diversity of crustacea and insect lavae in zooplankton (baseline to be determined).
Fish	Retain the following fish assemblages in the estuary (based on abundance): estuarine-resident species (20-30%), estuarine-associated marine species (60-70%) and indigenous freshwater species (<1%). All numerically dominant indigenous species are represented by 0+ juveniles within 12 months of the system being open.	• Level of estuary-associated marine species drops below 50% of total abundance. • Occurrence of alien freshwater species in the estuary. • Absence of 0+ juveniles of any of the dominant fish species within 12 months of the system being open.
Birds	The estuary should contain a diverse avifaunal community that includes representatives of all functional guilds listed in this report, particularly the migratory waders and waterfowl. The estuary should support thousands of birds in summer and hundreds in winter.	• Reduced abundance of piscivores (< 3 species; or <100 birds). • Numbers of waterfowl drop below 600 or waders below 100 in summer. • Overall numbers of waterbirds drop below 2000 for 3 consecutive counts in summer.

Figure 12. Zonation of Verlorenvlei Estuary

Wadrift Estuary

Since the Wadrift River Estuary has to be restored from a D to a C-category, the thresholds of potential concern (TPCs) should be seen as targets to be met within 5 to 10 years. Thereafter the estuary should be maintained such that these thresholds are not breached. The TPCs for the Wadrift Estuary are listed in Table 44. Ecological Specifications and TPC were defined for **Category C.**

Table 44: Ecological Specifications and TPC associated with an Ecological Category C in the Wadrift River Estuary

Abiotic/biotic Component	Ecological Specification	Threshold of Potential Concern
Water quality	Salinity structure and the occurrence of different abiotic states should correspond as closely as possible with the Reference condition; State 5 (Closed, Low water level hypersaline) should not occur at all.	• Salinity in any part of the estuary exceeds 65 (See Wadrift Estuary zonation map in Figure 13 below)
	Water quality in **river inflow** does not detrimentally affects water quality conditions in estuary, specifically relating to inorganic nutrient enrichment and toxic substances	River inflow: • pH of river inflow exceeds 8.5 or decreases below 5.5 • Dissolved oxygen (DO) less than 4 mg/ℓ • Turbidity persistently exceeds 10 NTU • Dissolved Inorganic Nitrogen (DIN) persistently greater than 200 µg/ℓ • Dissolved Inorganic Nitrogen (DIN) persistently greater than 50 µg/ℓ • Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine). A comprehensive baseline sampling will have to be conducted to determine the substances to be incorporated into long term monitoring programme.
	Water quality **in estuary** does not detrimentally impact biotic health, specifically relating to nutrient enrichment and diurnal fluctuation in pH and (e.g. decreasing at night and increasing during day time), or acidification and potential hypoxia developing during algal decay.	Estuary: • pH drop below 6, or persistently above 9 • DO less than 4 mg/ℓ • Turbidity persistently exceeds 20 NTU (e.g. as a result of persistent algal blooms) • Resultant DIN exceeds 100 µg/ℓ (in a closed system this would suggest excessive enrichment through remineralisation) • Resultant DIP exceeds 20 µg/ℓ) (in a closed system this would suggest excessive enrichment through remineralisation) • Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality guidelines (freshwater and coastal marine)
Hydrodynamics	Estuary should be allowed to function as naturally as possible with minimal human intervention	• No connectivity between Zone A and B (culvert levels in bridges raised above the floor ground)
Sediment dynamics	Flood and breaching regimes to maintain the sediment distribution patterns and	• As for hydrodynamics above

Abiotic/biotic Component	Ecological Specification	Threshold of Potential Concern
	aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota	
Microalgae	Phytoplankton communities should be maintained to reflect a diverse community, with moderate biomass (measured as chlorophyll-*a* concentration), and limited occurrence of HABs. Benthic microalgal communities should reflect moderate levels of biomass and diversity during the closed phase, and improve during periods of increased river inflow.	• Phytoplankton biomass greater than 20 µg Chl-*a* l^{-1}. • Frequent and monospecific (>90% relative abundance) high-biomass HABs (>60 µg Chl-*a* l^{-1}) • Subtidal benthic microalgal biomass greater than 100 mg Chl-*a* m^{-2}. • Benthic diatom diversity (*H'*) less than 2.
Macrophytes	Maintain the distribution, extent and diversity of plant community types, salt marsh and any remaining reed and sedges. Although peat swamps in the upper reaches will not return, increased freshwater inflow will increase habitat diversity and reduce terrestrial species that have now replaced lost habitat.	• Greater than 20% change in the area covered by different macrophyte habitats for baseline open and closed mouth conditions.
Benthic Inverts Zooplankton	Retain the present invertebrate assemblages	• Baseline to be determined
Fish	Retain the present fish assemblages.	• No fish present • Occurrence of alien freshwater species in the estuary.
Birds	The estuary should contain a rich avifaunal community that includes representatives of all the original groups, significant numbers of migratory waders and terns, as well as a healthy breeding population of resident waders. The estuary should support thousands of birds in summer and hundreds in winter.	• Numbers of waterfowl drop below 600, waders below 100 in summer, and terns below 250 • Overall numbers of bird species drop below 1000 for 3 consecutive counts.

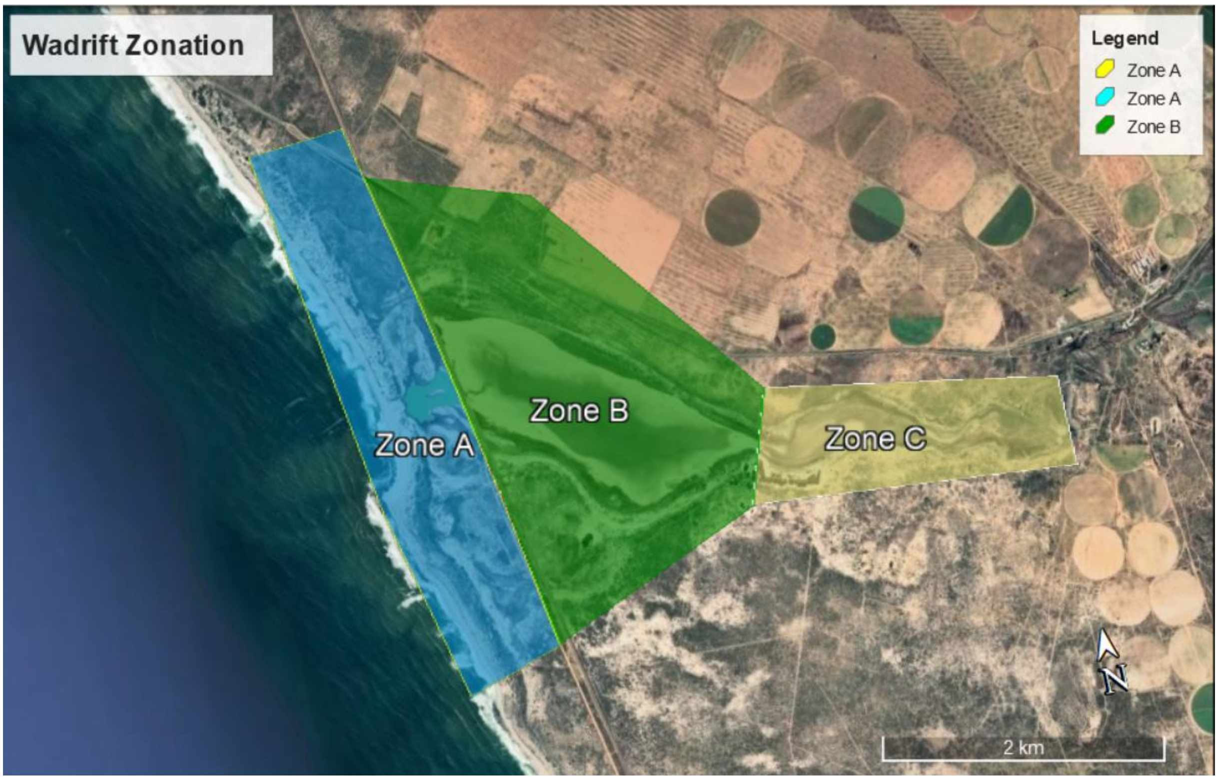

Figure 13. Zonation of the Wadrift Estuary

Jakkals River Estuary

The Jakkals River Estuary is to be maintained in a D-category. The TPCs for the Jakkals Estuary are listed in Table 45. Ecological Specifications and TPCs were defined for **Category D.**

Table 45: Ecological Specifications and TPC associated with an Ecological Category D in the Jakkals River Estuary

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
Water quality	Salinity structure and the occurrence of different abiotic states should correspond as closely as possible with the Present State; State 1 (Closed, Low water level hypersaline) should not occur more than at present	• Salinity in any part of the estuary exceeds 35 (See Jakkals River Estuary zonation map in Figure 14 below)
	Water quality in river inflow does not detrimentally affects water quality conditions in estuary, specifically relating to inorganic nutrient enrichment and toxic substances	River inflow: • pH of river inflow exceeds 8.5 • Dissolved oxygen (DO) less than 4 mg/ℓ • Turbidity persistently exceeds 10 NTU • Dissolved Inorganic Phosphate (DIP) persistently greater than 200 µg/ℓ • Dissolved Inorganic Nitrogen (DIN) persistently greater than 50 µg/ℓ • Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine). Comprehensive baseline sampling will have to be conducted to determine the substances to be incorporated in long term monitoring programme.
	Water quality in estuary does not detrimentally impact biotic health, specifically relating to nutrient enrichment and diurnal fluctuation in pH and (e.g. decreasing at night and increasing during day time), or acidification and potential hypoxia developing during algal decay.	Estuary: • pH drop below 6, or persistently above 9 • DO less than 4 mg/ℓ • Turbidity persistently exceeds 20 NTU (e.g. as a result of persistent algal blooms) • Resultant DIN exceeds 100 µg/ℓ (in a closed system this would suggest excessive enrichment through remineralisation) • Resultant DIP exceeds 20 µg/ℓ) (in a closed system this would suggest excessive enrichment through remineralisation) • Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine). Comprehensive baseline sampling will have to be conducted to determine the substances to be incorporated into a long term monitoring programme.
Hydrodynamics	Estuary should be allowed to function as naturally as possible	• >11% occurrence in State 1:Closed marine/hypersaline, indicated by extensive exposure of Zone B and C. • >72% occurrence in State 2:Closed marine • <5% occurrence of open mouth conditions • Overwash does not occur for 6 months
Sediment dynamics	Flood and breaching regimes to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota	• As for hydrodynamics above
Microalgae	Phytoplankton communities should be maintained to reflect a diverse	• Phytoplankton biomass greater than 20 µg Chl-*a* l^{-1}.

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
	community, with moderate biomass (measured as chlorophyll-*a* concentration), and limited occurrence of HABs. Benthic microalgal communities should reflect moderate levels of biomass and diversity during the closed phase, and improve during periods of increased river inflow.	• Monospecific (>90% relative abundance) high-biomass HABs (>60 µg Chl-*a* l^{-1}) • Subtidal benthic microalgal biomass greater than 100 mg Chl-*a* m^{-2}. • Benthic diatom diversity (*H'*) less than 2.
Macrophytes	Maintain the distribution, extent and diversity of plant community types, salt marsh and any remaining reed and sedges. Although peat swamps in the upper reaches will not return, increased freshwater inflow will increase habitat diversity and reduce terrestrial species that have now replaced lost habitat.	• Greater than 20% change in the area covered by different macrophyte habitats for baseline open and closed mouth conditions.
Benthic Invertebrates Zooplankton	Retain the present invertebrate assemblages	• Baseline to be determined
Fish	Retain the present fish assemblages.	• Less than 2 of the 5 expected species of fish observed • Occurrence of alien freshwater species in the estuary. • Absence of 0+ juveniles of any of the dominant fish species.
Birds	The estuary should contain a diverse although seasonally stochastic avifaunal community that includes representatives of functional guilds listed in this report, particularly the migratory waders and waterfowl. The estuary should support a few hundred waterbirds in summer in winter.	• Reduced abundance of piscivores (< 2 species; or <10 birds). • Numbers of waterfowl or waders drop below 50 in summer. • Overall numbers of waterbirds drop below 200 for 3 consecutive counts in summer, and less than 10 species are recorded in consecutive counts

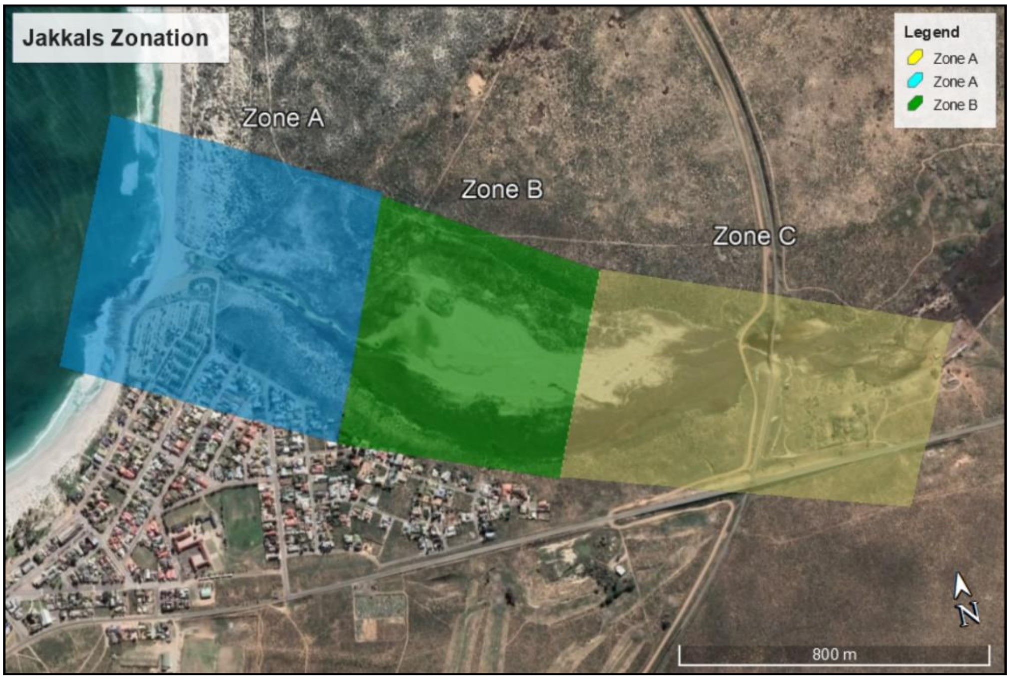

Figure 14. Zonation of the Jakkals Estuary

Sout River Estuary

The Sout River Estuary is to be restored to a D-category. The TPCs for the Sout Estuary are listed in Table 46. Ecological Specifications and thresholds of potential concern (TPC) were defined for **Category D.**

Table 46: Ecological Specifications and TPC associated with an Ecological Category D in the Sout River Estuary

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
Water quality	Extreme hypersalinity should be prevented	• Upper reaches: >120 psu (hyper salinity) • Middle Reaches: > 80 psu (hyper salinity) • Lower reaches: > 60 psu (hyper salinity)
	Water quality in estuary does not detrimentally impact biotic health, specifically relating to nutrient enrichment and potential hypoxia developing during algal decay.	• DIN: Entire estuary, average >0.1 mg/ℓ • DIP: Entire estuary, average >0.01 mg/ℓ • DO: Entire estuary, average >6 mg/ℓ • Turbidity: Entire estuary, average >10 NTU except during floods • Toxic substance concentrations (e.g. metals and agrochemicals) exceed South African Water Quality Guidelines (freshwater and coastal marine) Comprehensive baseline sampling will have to be conducted to determine the substances to be incorporated in a long term monitoring programme.
Hydrodynamics	Estuary should be allowed to function as naturally as possible	• Improved connectivity with the different water bodies and restored connectivity with the catchment through removal/modification of the weir at the head of the estuary.
Sediment dynamics	Flood and breaching regimes to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota	• The flood regime maintains the sediment distribution patterns and aquatic habitat (instream physical habitat). The suspended sediment concentration from river inflow does not deviate by more than 20% of the present sediment load-discharge relationship (to be determined). The sedimentation and erosion patterns in the estuary do not differ significantly from the present (± 0.5 m) (to be determined). • Changes in sediment grain size distribution patterns similar to the present. The median bed sediment diameter deviates by less than a factor of two from present levels (levels to be determined). The sand/mud distributions in the middle and upper reaches do not change by more than 20% from Present State over a five year average.
Microalgae	Phytoplankton communities should be maintained to reflect a diverse community, with moderate biomass (measured as chlorophyll-*a* concentration), and limited occurrence of HABs. Benthic microalgal communities should reflect moderate levels of biomass and diversity during the closed phase, and improve during periods of increased river inflow.	• Maintain the distribution of different phytoplankton groups and low biomass in the lower reaches (< 10 µg l^{-1} (Baseline to be detemined).
Macrophytes	Maintain the distribution, extent and diversity of plant community types, salt marsh and any remaining reed and sedges. Although peat swamps in the upper reaches will not return,	• >20 % change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries).

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
	increased freshwater inflow will increase habitat diversity and reduce terrestrial species that have now replaced lost habitat.	• Water column salinity not greater than 50 in the lower reaches to limit salt accumulation and dieback of salt marsh (*Sarcocornia pillansii*). • Prevent further disturbance and development in the salt marsh and floodplain habitat through salt works activities.
Benthic Invertebrates Zooplankton	Retain the present invertebrate assemblages	• Unincysted Brine shrimp should be present in the system for < 75% of the time. • Baseline to be determined
Fish	Not applicable. Hypersaline system.	• Not applicable. Hypersaline system.
Birds	The estuary should contain a diverse although seasonally stochastic avifaunal community that includes representatives of functional guilds listed in this report, particularly the migratory waders and waterfowl. The estuary should support a few hundred waterbirds in summer in winter.	• Including flamingos, more than 10 species of waders and water birds that feed on brine shrimp should be present < 75% of the time (During 40 – 150 and brine shrimp available). • The occurrence and cause of bird mortalities need to be verified.

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