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

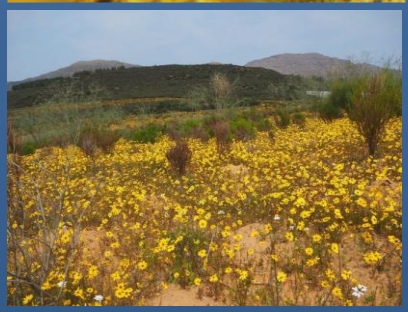
ECOLOGICAL RESERVE IMPLEMENTATION PLAN

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

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4.0	RDM/WMA09/00/CON/0124	Surface Water Delineation Report
5.0	RDM/WMA09/00/CON/0125	EcoClassification Report
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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 have 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 recommendations for the implementation of the ecological Reserve determination for surface and groundwater in the G30 and F60 Tertiary Catchments (Figure 1) of the Olifants-Doorn Water Management Area. Included in this report are key recommendations for the protection of ecological hotspots, flow and non-flow-related mitigation measures, recommendations relating to the use of ground and surface water and the associated monitoring requirements to inform the implementation of the ecological Reserve.

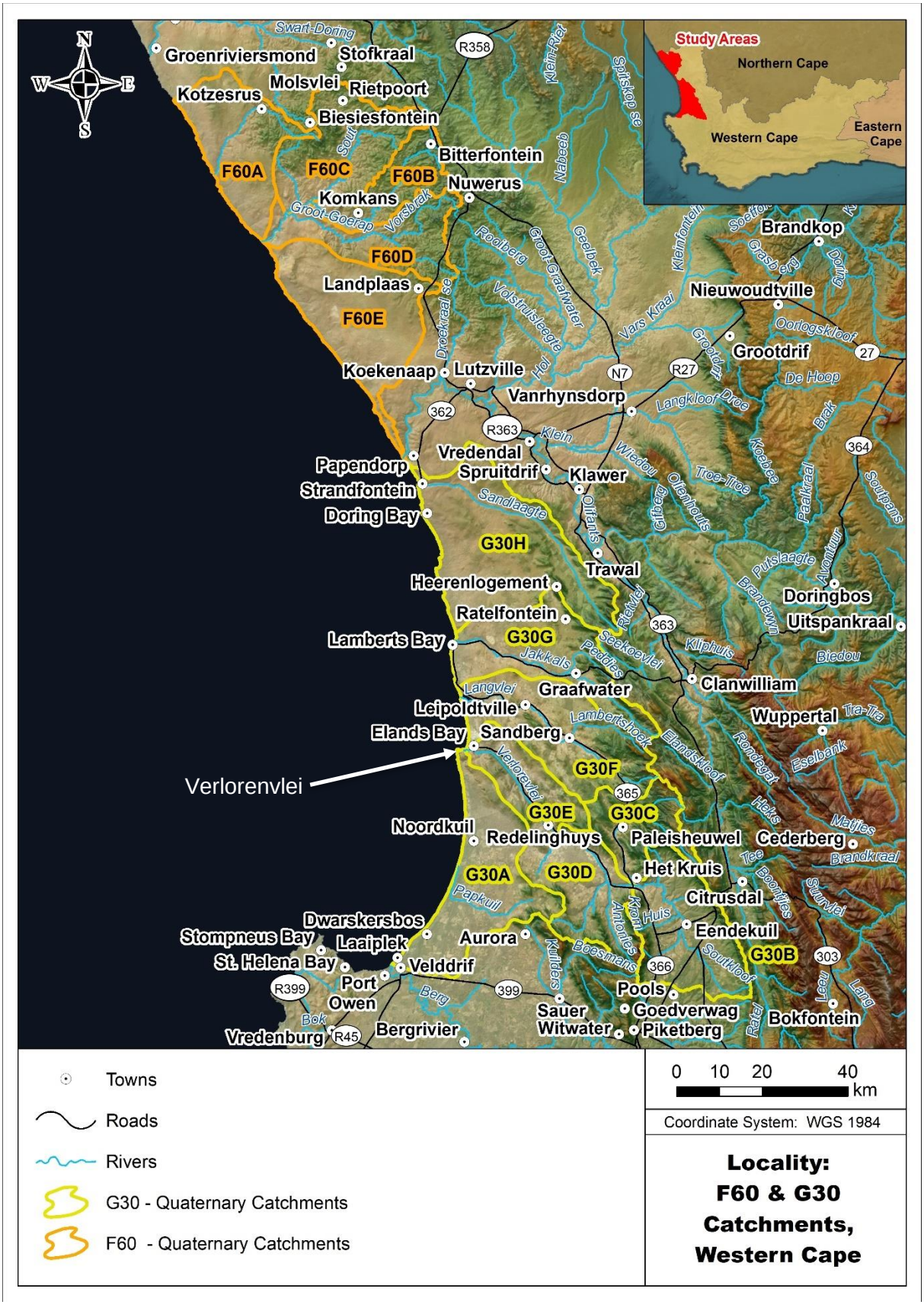

Figure 1: Map of the study area with the location of the G30 and F60 Catchments and main aquatic features shown

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 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.

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.

2. Description of Water Resource Units

This implementation plan is for the rivers, wetlands, estuaries and groundwater within the F60 and G30 Catchments, which form part of Berg-Olifants WMA.

2.1. Rivers and Wetlands

The specific locations of the river and wetland EWR sites are provided in Table 1 and shown in Figure 2.

Table 1: Location of River and Wetland EWR sites

Water Resource	Quaternary	EWR Site / Node 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

Water Resource	Quaternary	EWR Site / Node No.	Description of location	Geographic coordinates	
				Latitude	Longitude
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

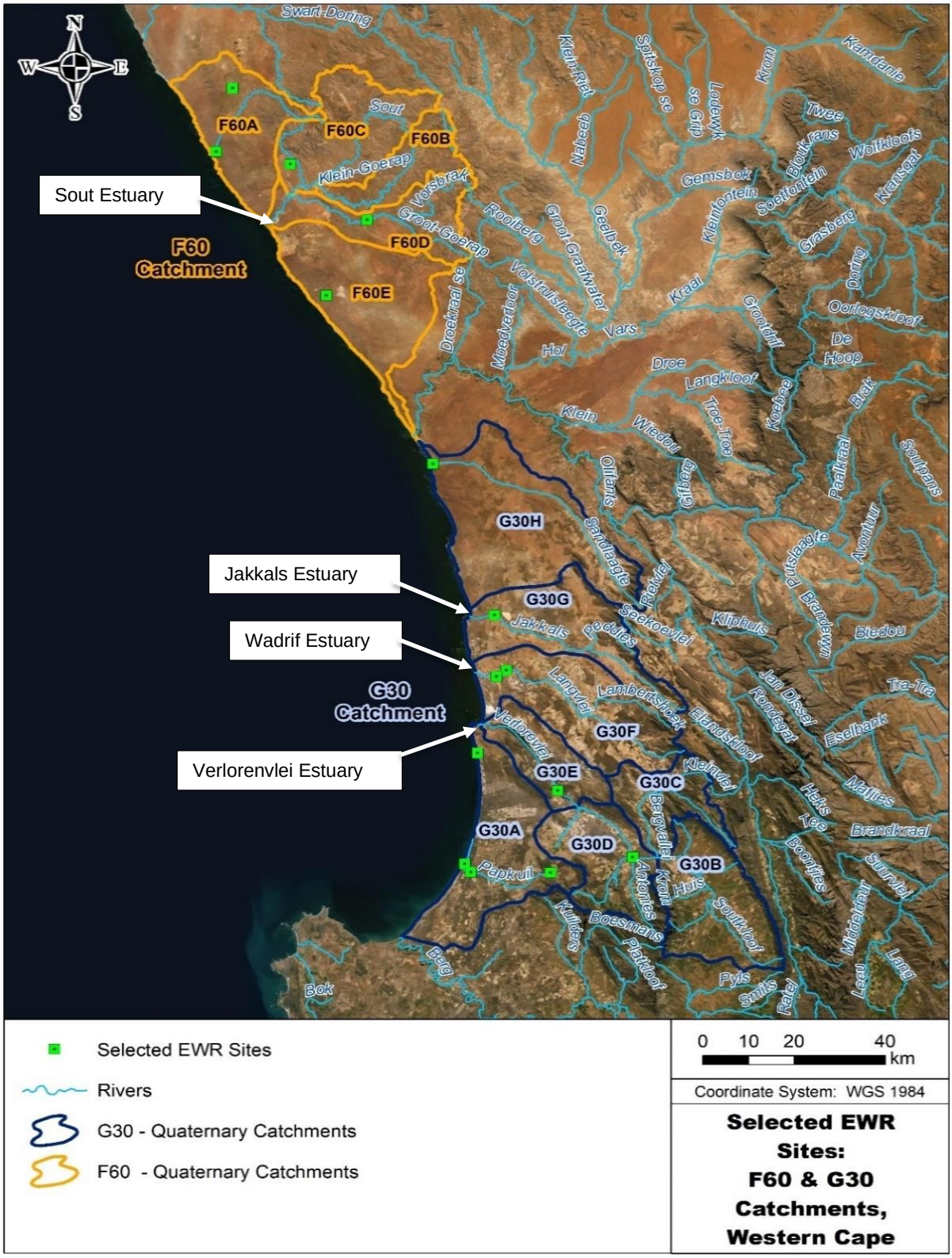

Figure 2. Map of the EWR sites for rivers, wetlands and Estuary Resource Units in the F60 and G30 Catchments

2.2. Estuaries

The location and extent of the estuary EWR sites are provided in Table 2 below and are shown in Figure 3 to Figure 6.

Table 2: Location of Estuaries

Estuary	Quaternary	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

Figure 3. Geographical boundaries of the Verlorenvlei Estuary

Figure 4. Geographical boundaries of the Wadrift Estuary

Figure 5. Geographical boundaries of the Jakkals Estuary

Figure 6. Geographical boundaries of the Sout (Noord) Estuary

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 for the rivers and wetland EWR sites in Table 3 and

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

Table 4 and the estuaries in Table 5.

Table 3: 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

Table 4: 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

Table 5: Summary of Reserve data for the estuaries in G30 and F60.

Quaternary	Estuary	PES	EIS	REC
G30E	Verlorenvlei	D[1]	Important	C[2]
G30F	Wadrift	D	Important	C
G30G	Jakkals	D	Low to Average	D
F60D	Sout[3]	E	Average	D

[1]*The 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 a 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.*

2.3. Groundwater Resource Units

G30 Catchments (Figure 7): Within the G30 catchments, the Groundwater Resource Units (GRUs) closely align with the quaternary catchments within the study area 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 (Figure 8): 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.

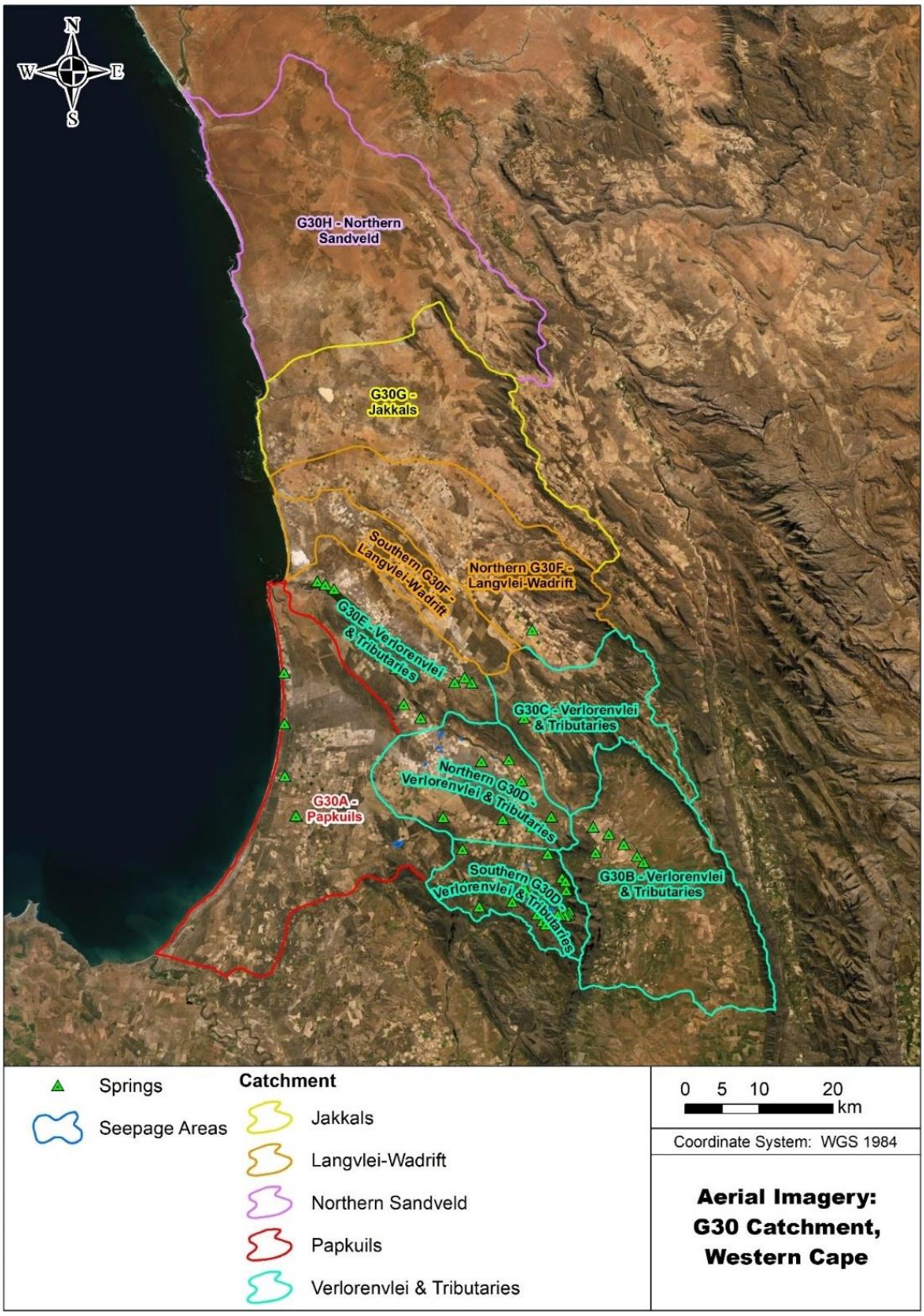

Figure 7: Combined map of delineated GRUs for the G30 catchments

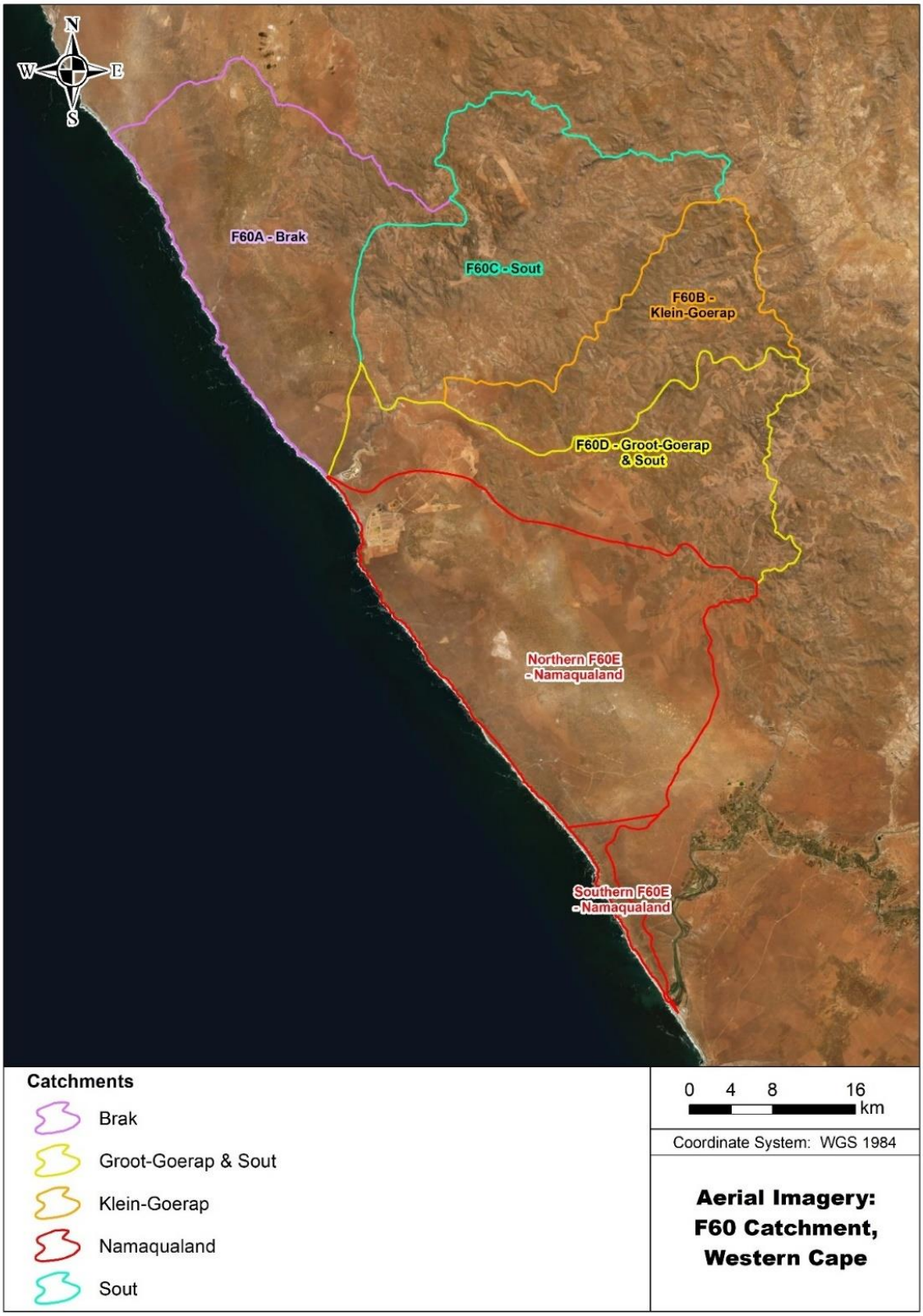

Figure 8: Combined map of delineated GRUs for the F60 catchments

3. RECOMMENDED EWR

3.1. Surface Water Quantity and Quality

3.1.1. Surface Water Quantity

Below is a summary of the EWR recommendations. The detailed average monthly flow and depths for the EWR sites and their alternative ecological categories is attached in the appendices.

Table 6: Summary of the Reserve recommendations for River and Wetland EWR sites/nodes.

Quat	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 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.

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

Table 7: Summary of the Reserve recommendations for the estuaries in G30 and F60.

Quat	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.*

3.1.2. 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 8 and

Table 9 should be taken into consideration when drafting the WULAs. Table 8 provides the physical water quality Reserve requirements for each of the EWR sites as these vary from site to site.

Table 9 is a generic table of the chemical water quality Reserve requirements which are the same for all the EWR sites.

Table 8: 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 9: 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]
	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 in Section 4.

3.2. 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 10 as shown below:

Table 10: Results of the preliminary Reserve for the G30 and F60 Catchments

Sub-catchments used to calculate recharge	River System	Area (km²)	MAP (mm)	Estimated Recharge (% of total annual flow)	Calculated recharge (MCM)	Total abstracted for Town supply (MCM)	Reserve (BHN + Springflow + Baseflow Contributions)	Total abstracted for irrigation (MCM)	Groundwater Balance (MCM)
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				

Sub-catchments used to calculate recharge	River System	Area (km²)	MAP (mm)	Estimated Recharge (% of total annual flow)	Calculated recharge (MCM)	Total abstracted for Town supply (MCM)	Reserve (BHN + Springflow + Baseflow Contributions)	Total abstracted for irrigation (MCM)	Groundwater Balance (MCM)
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				
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**

4. ECO-SPECIFICATIONS, RESOURCE QUALITY OBJECTIVES AND MONITORING RECOMMENDATIONS

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. Defined Eco-Specifications or EcoSpecs and Thresholds of Potential Concern (TPCs) are intended to inform the monitoring and assessment of 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.

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.

4.1 Surface Water Monitoring: Rivers and Wetlands

4.1.1. 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.

4.1.2. Water Quality Monitoring

Water quality 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 sites, 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 (rivers and wetlands) 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 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 rivers and wetlands 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.

4.1.3. 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 11.

Table 11. 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 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 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 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	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>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 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 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

Indicator	Ecological Specification	Threshold of Potential Concern	Recommended Monitoring
Aquatic Invertebrates	SASS5 Score>60 ASPT>4.8 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 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 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.
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	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 of 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.
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	A change, particularly an Increase of species from adjacent drier lateral riparian zones into a lower, normally wetter, zone.	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

Indicator	Ecological Specification	Threshold of Potential Concern	Recommended Monitoring
	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.	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.	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 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.
Papkuilsvlei (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.
Rocherpan Wetland (REC = C)			

Indicator	Ecological Specification	Threshold of Potential Concern	Recommended Monitoring
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.

4.1.4. Additional River and Wetland Biotic Monitoring Recommendations

4.1.4.1. 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 12. Recommended monitoring sites for freshwater fish for the Reserve study area

River	Monitoring site	Sampling time, Gear
Kruismans	Road bridge pool	Summer, overnight fyke

	32º 44' 45" S; 18º 49' 05" E	
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.

4.1.4.2. 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 of 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 site. 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.

4.1.4.3. Riparian and Wetland Vegetation

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.

4.1.4.4. 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.

4.2 Surface Water Monitoring: Estuaries

4.2.1. Verlorenvlei

The TPCs associated with each of the ecological specifications for the Verlorenvlei Estuary are provided in Table 13. Ecological Specifications and TPCs for the estuary were defined for **Category B.**

Table 13: 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 9 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)

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
	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.
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%)	• 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.

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
	and indigenous freshwater species (<1%). All numerically dominant indigenous species are represented by 0+ juveniles 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 9. Zonation of Verlorenvlei Estuary

4.2.2. Wadrift Estuary

Since the Wadrift 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 14. Ecological Specifications and TPC were defined for **Category C.**

Table 14: 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 10 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

Abiotic/biotic Component	Ecological Specification	Threshold of Potential Concern
		• 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 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 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	• Numbers of waterfowl drop below 600, waders below 100 in summer, and terns below 250

Abiotic/biotic Component	Ecological Specification	Threshold of Potential Concern
	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.	• Overall numbers of bird species drop below 1000 for 3 consecutive counts.

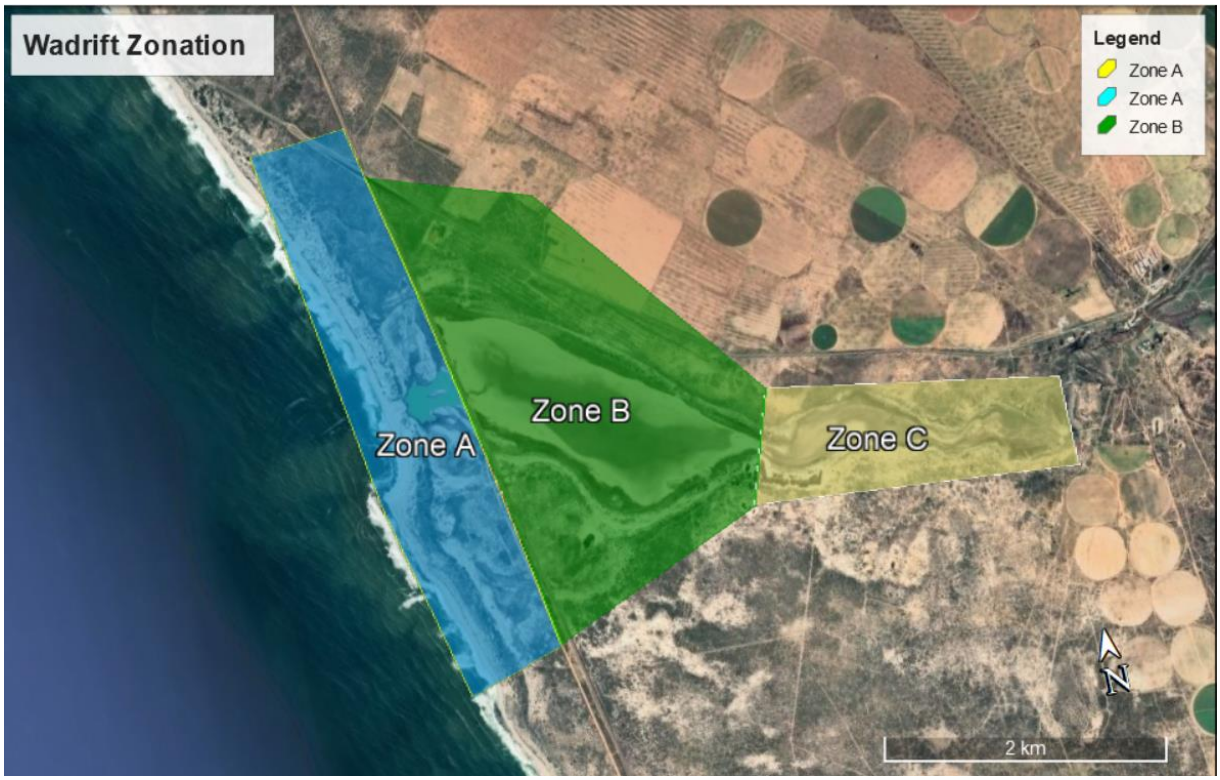

Figure 10. Zonation of the Wadrift Estuary

4.2.3. 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 15. Ecological Specifications and TPCs were defined for **Category D.**

Table 15: 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 11 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

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
		• 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 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}. • 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	Retain the present invertebrate assemblages	Baseline to be determined

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
Zooplankton		
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

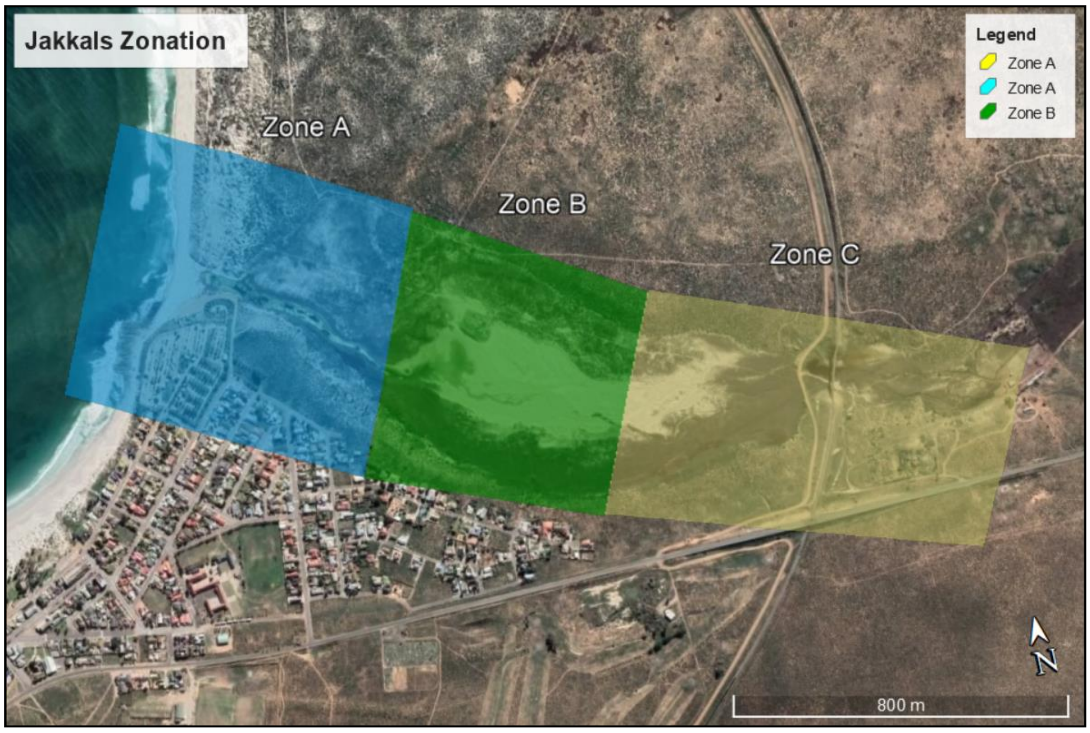

Figure 11. Zonation of the Jakkals Estuary

4.2.4. 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 16. Ecological Specifications and thresholds of potential concern (TPC) were defined for **Category D.**

Table 16: 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, increased freshwater inflow will increase habitat diversity and reduce terrestrial species that have now replaced lost habitat.	• >20 % change in the area covered by different macrophyte habitats (accounts for natural changes due to the dynamic nature of estuaries). • 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	• Including flamingos, more than 10 species of waders and water birds that feed on brine shrimp

Abiotic/Biotic Component	Ecological Specification	Threshold of Potential Concern
	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.	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.

4.3. Groundwater: Quality Objectives and Associated Monitoring Recommendations

EcoSpecs as described in the previous section relate specifically to surface water resources with their associated aquatic ecosystems. It is thus RQOs that are specified for groundwater resources. Specifying RQOs for groundwater is however complex as the movement of groundwater is governed by aquifers and is not bound to surface drainage regions.

Because the groundwater Reserve and their associated RQOs for this study ultimately have to be linked to the surface water Reserve and EcoSpecs, it was decided to use quaternary catchments for the GRUs where possible. The quaternary catchments in the study area also tend to incorporate a single valley that relates well with perceived groundwater flow and surface water contribution.

RQOs exist for the quaternary catchments (The proposed classes and resource quality objectives are determined for all or part of every significant water resource within the catchments of the Olifants -Doorn Water Management Area, Government Gazette No 39943, dated 22 April 2016). In this study, the RQOs were revised and supporting monitoring recommendations were provided.

The groundwater resource quality objectives provided in Table 17 are proposed for each quaternary catchment, together with their monitoring recommendations.

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Table 17: Preliminary Resource Quality Objective Recommendations for F60 and G30 catchments (*to be updated with revised Groundwater data assessment results*)

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

4.4. Groundwater: Monitoring and Management Recommendations

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

- A groundwater monitoring programme must be established where there is no existence of groundwater quality and quantity monitoring.
- Firstly, 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 which 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 ECs, 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 (citizen science approach) 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 that can be used when compiling conditions related to borehole abstraction, when appropriate. These include:

- 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.
- 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.
- 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 18**.
- The monitoring data should be reviewed quarterly at first and can then be scaled down to bi-annually.
- Installation of a sampling tap at the production borehole (to monitor water quality) is essential.
- 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.
- 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.

- 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).
- The borehole and pump should be serviced annually.

A geohydrologist should review the above information at least annually to ensure optimal groundwater abstraction and management occurs.

Table 18: Proposed groundwater monitoring parameters.

Parameter	Frequency
Groundwater Level	Ideally every 15 minutes with a data logger, otherwise quarterly with a dipmeter
Chemical parameters	
pH (at 25 ºC)	Quarterly (Field Chemistry)
Electrical 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*
Cyanide (mg/L as CN-)	Quarterly*

Parameter	Frequency
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	

5. IMPLEMENTATION RECOMMENDATIONS

5.1. Water Use Related Recommendations

Below are implementation recommendations that relate to the various water use activities in terms of Section 21 of the NWA:

Section 21 (a): Considerations for the management of the abstraction of water

Hydrological variability within rivers and wetlands is one of the primary factors influencing the distribution of aquatic flora and fauna. The biological communities living in aquatic ecosystems are adapted to natural hydrological regimes. Unnatural low flows and altered hydrological regimes caused by water abstraction can have damaging impacts on the river and wetland systems and their associated biota, as well as any downstream estuarine systems.

It is not only the abstraction of surface water directly from the river and wetland systems that can detrimentally affect these ecosystems (and associated estuarine systems, where present), but also the abstraction of groundwater in areas where groundwater is an important contributor to surface water ecosystems. In relatively arid regions such as the F60 and G30 Catchments, the aquatic ecosystem impacts of the abstraction of groundwater for agricultural use and potable water supply is of particular concern.

It is critical that the following management practices are followed to ensure that aquatic ecosystems are protected from the potentially serious impacts that could result from the taking of water from surface water and groundwater resources:

- It should be ensured that over-abstraction does not occur. Thus, water balances should be used to quantify how much water is available in an aquatic system before allocating it to new users. The ecological water requirement (EWR) specified in the Reserve for each resource must also be included in the water balance as a user, before quantifying the allocatable portion.
- The environmental flow variability specified in the Reserve template for the determined REC of that resource is important as the integrity of a healthy aquatic ecosystem depends on the high and low flow variability. Aquatic ecosystems do not only require continuous supplies of low-flow water at a constant velocity or volume, high flow events are important as well in order to reset the ecosystems (i.e. to scour out accumulated sediment, release nutrients, etc). Thus, it should be ensured that a WULA for abstraction will not compromise the natural variability of the system before it is approved.

- An adaptive management approach should be taken for the implementation of the EWR in the G30 Catchment, where rainfall monitoring should be used to guide the amount of water that is allocated in a particular year or season. If there is a period of low rainfall, then less water should be allocated than during periods of normal or above-average rainfall.

- The identification of areas where declining groundwater levels are observed, and where groundwater-surface water interaction is significantly reduced should be prioritised according to the severity of the decline and trends. Once these areas have been identified, regulatory tools such as compulsory licencing and/or other interventions should be implemented to intervene as soon as possible. Focus areas should include, but not be limited to, the Bergvallei, Jansekraal and Langvlei/Wadrift Catchment areas, as well as the Papkuilsvlei and Rocherpan areas.

- No drilling of boreholes should be allowed within the flood zone or riparian zones of rivers, or within wetlands or a buffer area of at least 100 m around wetlands unless a formal application process is followed (with supporting specialist studies) to obtain approval for such activities where the impact on aquatic ecosystems can clearly be shown to be of low significance.

- Where existing groundwater abstraction activities need to be authorised or new abstraction activities are proposed, and there are wetland areas within 500 m of the abstraction point/s, then monitoring of the lateral inflow of subsurface water into the wetland/s and subsurface water levels within the wetland/s should be undertaken using piezometers to demonstrate that the potential impact of the abstraction on wetland vegetation will be of low significance before an authorisation is granted. Ongoing monitoring should also be undertaken once authorisation is granted, to show that there is no significant impact on water levels or wetland vegetation.

- 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 lower reaches of the G30 river have been severely impacted (and in some cases totally lost) through surface and sub-surface water abstraction for agricultural activities in the region. Abstraction of water from the seepage and upper-catchment areas 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).

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Section 21 (b): Considerations and conditions for storage of water

Storage of water should not impact negatively the integrity of the water resource and the following are key considerations:

- the cumulative effect of dams on downstream users and on downstream aquatic ecosystems (including instream wetlands and estuaries);
- attenuation of small freshets and reduction in base flows by dams/weirs/obstruction;
- creating a barrier to the migration of aquatic biota; and

- management of environmental releases from dams should mimic the natural flow pattern, should require minimal intervention and should be monitored.

Section 21 (c) and (i): Considerations and conditions for any changes to the bed, banks, course or characteristic of a watercourse, or for impeding and diverting flow in the watercourse

The construction, operation and maintenance of buildings and infrastructure such as roads across water resources have the potential to cause serious environmental damage to the physical, biological and chemical components of the aquatic ecosystem. The construction, operation and maintenance of water supply infrastructure (dams, boreholes/wellfields, water pipelines, etc.) can also have a significant impact on river and wetland ecosystems. The methods employed for the construction and maintenance of these activities should therefore apply methods and management practices that minimise and avoid problems such as unnecessary habitat modification and riparian clearance, increased sedimentation and turbidity, erosion and severe bank instability and altered chemical composition.

The following recommendations should be considered in the evaluation of proposed Section 21 (c) and (i) water use authorisations:

a. Damage to riparian vegetation and instream habitat:

- The construction in or adjacent to the riparian zone should be managed and strictly controlled to minimize damage to the riparian zone.
- Operation & storage of equipment in the riparian zone to be prevented as far as possible.
- Where applicable, disturbed riparian zones (i.e. those areas that will not form part of the operational footprint but that were disturbed as part of the construction activities) should be re-vegetated using site-appropriate indigenous vegetation and/or seed mixes.
- Similarly, instream habitat conditions should be recreated as far as possible; this pertains to those areas where construction activities have disturbed the instream habitat beyond the operational footprint of the activity.
- Alien vegetation should not be allowed to colonize the disturbed riparian (and instream) areas.
- Rehabilitation of disturbed instream and riparian habitat should commence immediately after construction is completed. An aquatic ecologist should oversee this process.
- No construction camps should be allowed in the riparian zone.
- No stockpile areas should be located in the riparian zone.

b. Damage to wetland habitat:

Road crossings through wetlands can cause erosion and drainage of wetlands. Where diffuse flows are concentrated into one or two culverts, an incised channel develops downstream of the road and this lowers the local water table, drying out the wetland and enhancing further erosion by the continued concentration of flows. If the head cut from the erosion passes under the road crossing, the eroding channel can propagate upstream and further reduce wetland condition and integrity. Simple drop inlet structures as part of the bridge or road crossing design can prevent

upstream erosion, whilst flow dissipaters; numerous culverts and sensitive sitting of road crossings can reduce downstream erosion.

Wetlands which are eroded - where flows are concentrated into channels and floodplains desiccate - have reduced functioning and cannot attenuate floods or ameliorate water quality problems as well as intact wetlands. To minimise the impacts of road crossings, the following recommendations are provided:

- No road crossings through unchannelled valley bottom wetlands; since these are specifically sensitive to flow concentrations and erosion.
- Wherever possible, road crossings could coincide with the local key points across the wetland.
- Drop inlets should be built as part of the bridge design where culverts are proposed on small wetlands and streams;
- Numerous culverts and flow dissipators should be constructed where feasible and necessary to prevent the risk of erosion on downstream wetlands.

c. Bank erosion:

Slope/bank stabilization measures should be implemented where necessary, to prevent erosion during the operation phase (i.e. post-construction).

d. Sedimentation:

- Construction should take place during the low flow/winter months in order to minimize the risk of sediment and debris being washed into the streams and rivers. Natural instream hydrology is to be used to determine which months constitute the low flow months.

- Road construction and river diversions are a linear process, however, areas in and around the rivers should not be cleaned, graded and ditched/trenched more than a week before the construction. The aim is to prevent erosion and sedimentation and the collection of run-off trench water which has high sediment content.

- Stockpiling of soil and the construction camps must be stored clearly away (at least 100m where possible) from the riparian zone to prevent soil from being washed into the river. Soil stockpiles can also be covered to prevent wind and rain erosion.

- During the construction and operation phase erosion and siltation measures should be implemented (e.g. the use of temporary silt traps downstream of construction areas should be employed).

e. Bank compaction

The use of machinery within the instream & riparian zones may lead to the compaction of soils & vegetation. This will lead to decreases in the infiltration of rainwater, increases in run-off water and will limit re-vegetation from taking place. It is thus recommended that all compacted areas

that do not form part of the footprint activity be ploughed, landscaped to approximate the natural slope of the area and aerated followed by re-seeding.

f. Alteration of current flow regime and migration routes of aquatic biota by culverts and bridges

- Any instream structures used for construction purposes should not stop the natural flow in the water column for a prolonged period.

- The method of construction for the river crossings/river diversions should aim to maintain flows across the width of the natural river channel (or mimic it) without significantly increasing velocities. Energy dissipaters should be utilized on the downstream side of the culverts.

- In the case of bridges, bridge designs should aim towards the construction of as few as possible instream pillars, without compromising the safety of structures, where the pillars that do occur instream should have rounded edges to aid in the prevention of the build-up of debris.

- Culverts, and the new channel (in the case of river diversion), should be constructed in such a way as to allow for the movement of instream aquatic organisms (i.e. they should allow for low flow migration and not only high flow channelling of water).

g. Stormwater management

- Erosion down verges should be minimized by including frequent discharge points with energy dissipaters before discharging stormwater into the adjacent grasslands.
- Infiltration down the verges of the roads rather than surface runoff should be encouraged (this could for example include the use of grassed swales). Small detention ponds filled with *Phragmites* reeds would allow sediment and debris/litter to be trapped before entering the main drainage lines.
- Where stormwater enters the river systems, sediment and debris trapping, as well as energy dissipation control structures should be put in place.

h. Pollution of riparian zone & instream habitat

- The method used for river crossings must limit turbidity, sedimentation and chemical changes to the composition of the water.

- The possibility of spillages should be catered for in the design of the roads where for example, attenuation ponds prior to the discharge of stormwater could be employed or the stormwater systems themselves could be designed in such a way that it can be easily sealed off after the occurrence of a spill. If a spill occurs during the operational phase of the road, a suitably qualified team of experts will need to be consulted and a rehabilitation plan drawn up and implemented.

i. Monitoring and maintenance recommendations

When dead trees and other debris collect at the base of bridges and culverts they create hydraulic obstacles resulting in the scouring (erosion) of the downstream banks (this may also lead to an excessive soil deposition upstream of the bridge). It is therefore essential that a long-term monitoring and maintenance plan be implemented by the applicant whereby the applicant will be obligated to maintain bank stability (i.e. to control any erosion that has taken place as a result of the crossing infrastructure) as well as to clear any debris away from the base of the bridges (especially after high rainfall and flood events).

Section 21 (d): Considerations and conditions for streamflow reduction activities

The following fundamental considerations must always be taken into account for Section 21(d) activities:

- Activities that may result in significant adverse effects on instream and riparian habitat should be avoided where less environmentally harmful alternatives are available. Less environmentally harmful alternatives must therefore be provided and should none of these alternatives deem feasible environmentally sound engineering and management practices should be employed for all actions, which may adversely affect the in-stream and riparian habitat.
- The proposed activity should not increase bank instability and the erosive potential of a stream. Steps should be taken to ensure that the channel is able to withstand the most probable maximum flood events without undue bank instability or erosion.
- All afforestation next to a watercourse (as defined in the Act) must be undertaken using the approach referred to in the document: “A practical field procedure for identification and delineation of wetlands and riparian areas.” According to the guideline, a minimum of 20m buffer should be implemented next to the delineated watercourse, between the outer boundary of the riparian zone and formal plantations or areas of cultivation. Should the distance differ from the requirements of other Government Departments, a greater buffer should apply.
- Alien vegetation must not be allowed to colonise the area, and all new alien vegetation recruitment must be controlled. The increase in invader plants (particularly of Australian *Acacia* spp.) in riparian zones and the upper catchments of the river systems is causing a loss of the sustained delivery of water to sensitive aquatic ecosystems. This process is particularly evident, for example, on the Papkuils River system where agricultural activities (including inter alia, tilling, abstraction, draining marshes, stock grazing, etc) are promoting a largely uncontrolled, invasion by particularly *Acacia saligna*, in the Upper Papkuils Wetland. Invasion by this invader plant results in the drying out of important wetland areas and a reduction in the delivery of water to the lower system, particularly during dry periods. Similar disruption in flows by the uncontrolled increase of invader plants was noted from the inspection of historic Google Earth images, in the feeder rivers in the Verlorenvlei River System, including the Krom Antonies and Kruismans Rivers. All riparian zones should thus be cleared of invasive plants, to maximise stream flow in the dry season. This is particularly important in the upper catchments of the Krom Antonies, upper Kruismans and Pampoenkraal Rivers.

- Measures to counteract soil erosion during harvesting must be taken, to avoid sedimentation of the nearest aquatic systems.

i. Section 21 (e), (f), and (g): Consideration and conditions for the use or disposal of water containing waste

The main land use activities which contribute to diffuse pollution are agricultural activities (irrigation, dry land cultivation and cattle grazing). The point source discharges are from wastewater treatment plants. The pollution from these sources can impact acidity, salinity, nutrients, toxicity and public health. It, thus, should be ensured that the RWQOs are considered when evaluating these types of activities to ensure the suitable management of the aquatic ecosystems.

Measures must always be provided to avoid disposal or spillage of any material (dredge material, sludge, waste, or other potentially harmful materials), that would destroy or degrade the instream and riparian habitat. Compensation measures for damage and/or mitigation measures must be recommended, if avoidance or minimization of the impacts of the proposed activity is not possible, or if mitigation measures fail to adequately protect the instream and riparian habitat.

In addition to the above considerations, the following fundamental conditions must always be taken into account for section 21(f) and (g) water use authorisation applications:

- Water containing waste or effluent must be treated to comply, as a minimum, with the water quality requirements specified in the general and special standards, as published in Government Notice 991 of 18 May 1984;
- Any sludge or slurry removed from a sewage treatment plant shall be disposed of according to the specifications of the guidelines published by the Department of Health in collaboration with other departments: Permissible utilisation and disposal of sewage sludge dated August 1999; and
- Measures should be implemented to reuse water containing waste or appropriate technological treatment options investigated and implemented.

When considering the approval of an application for irrigation with wastewater, the following conditions should be taken into consideration:

- Treated wastewater to be irrigated must be treated to comply with the water quality requirements specified in the general and special limits.
- The soil type of the land to be irrigated must be determined, purely because soils of the poorly drained classes are seldom suitable for waste application unless some form of artificial drainage is installed. If wastewater applications are limited by drainage conditions, then the water has to be applied in small amounts at very frequent intervals.
- Activities that lead to elevated levels of turbidity must be minimized. The use of a proper irrigation method could limit soil erosion and the subsequent sediment transport to surface water with excess runoff, i.e. drip and sprinkler irrigation instead of furrow irrigation.
- There should be a suitable buffer zone that minimises the risk of contamination of the nearby watercourse.

Section 21 (j): Consideration and conditions for removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people

When mining activities are undertaken, the mined area is typically dewatered and the water that is pumped out needs to be discharged somewhere. This occurs in association with most of the mining operations along the coast in the F60 and G30 Catchments. These activities can have detrimental consequences on nearby river and wetland ecosystems, and on estuaries if they are not undertaken carefully. The following conditions are recommended for the authorisation of dewatering activities, especially for mining operations:

- No dewatering discharge should be allowed to enter directly into any river, wetland or estuarine ecosystem. Instead, the water should be attenuated so as to allow for the settling out of sediments or contaminants before discharge to any watercourse;
- The sediments from dewatering operations, once settled out, should be returned to the area that was dewatered and not placed in or adjacent to rivers, wetlands or estuaries;
- Strict monitoring requirements should be put in place for all mine dewatering activities, to ensure that no aquatic ecosystems are negatively impacted by these activities.

5.2. River and Wetland Mitigation Recommendations

General degradation has taken place in the environment, particularly of the botanical component, along these ephemeral streams when comparing, for instance, the present day state to historical aerial images and to the vegetation described by Low & Pond (2003). This degradation is ascribed to the increased utilization of water and therefore reduction in surface flows and groundwater contribution, as much as to increased agricultural tilling, uncontrolled increase in invader plants and therefore destruction of the moderating contribution by the natural veld. Placing this arid environment vegetation, with relatively slower regrowth time compared to moister environments, under increased stress through increasing drier intervals causes slower and reduced response times to moisture when available, together with a lowered tolerance to stress from periodic natural droughts, which are a natural shaping occurrence. This results in the general riparian vegetation having a negative trend in its condition. Protection of the riparian zones as critical buffer zones to the rivers and wetlands is thus essential, the following interventions are recommended to reduce these impacts:

Livestock access to river corridors, wetlands and the adjacent riparian zones should be limited. Limited grazing of vegetation in these areas in late summer and autumn would be acceptable but late winter, spring and early summer when there is new plant growth should be avoided.

No drilling of boreholes should be allowed within the flood zone or riparian zones of rivers and in catchments which have been over-abstracted. The lateral inflow of groundwater to the river and wetland vegetation is critical for both the vegetation and biota in the wetlands and rivers and must be monitored to prevent long-term drying out of these areas. Piezometers should be installed within these areas to monitor and minimize the impact of adjacent groundwater abstraction.

There should be a legislated period for the abstraction of surface waters, for example when water is plentiful (June to September). Instream dams must release flows entering the dam outside of this period downstream of the dam, to sustain downstream ecosystems.

It is recommended that water use management interventions be put in place in the Krom Antonies and Wabooms / upper Kruismans River systems to ensure that critical dry season flows remain in these vital fish-supporting tributaries. Regulatory action should be taken against all landowners that build dams, weirs, install boreholes or bulldoze rivers without authorisation or without permission. The significant ecological deterioration of the Langvlei and Bergvallei Rivers are examples of the consequences of not taking such action.

The increase in invader plants (particularly of Australian *Acacia* spp.) in riparian catchments is causing a loss of their sustained delivery of water. This process is particularly evident, for example, on the Papkuils River system where agricultural activities (including *inter alia*, tilling, abstraction, draining marshes, stock grazing, etc) are promoting rampant, largely uncontrolled, invasion, by particularly *Acacia saligna*, in the Upper Papkuils Wetland. Invasion by this invader plant results in consequential canalisation and drying out of riparian wetlands and thus a reduction in their sustained delivery of water to the lower system. Similar disruption in flows by the uncontrolled increase of invader plants was noted from the inspection of historic Google Earth images, in the feeder rivers in the Verlorenvlei River system, including the Krom Antonies and Kruismans River Systems. All riparian zones should thus be cleared of invasive plants, to maximise stream flow in the dry season. This is particularly important in the upper catchments of the Krom Antonies, upper Kruismans and Pampoenkraal Rivers.

A dam in the upper Bergvallei Catchment has been stocked with the endangered Verlorenvlei redfin. A recent survey has shown that this has been a major success in terms of potentially restocking the system with indigenous fishes. It is thus recommended that all dams in the study area should be surveyed to determine their suitability for stocking native fishes under permit to create further refuges for them.

There is an urgent need for awareness and education of land-owners, especially riparian landowners, and scholars about river and freshwater ecology, threats to rivers and fish, and how to farm in an ecologically sustainable way. This should include LandCare, and the intervention funded by the Western Cape Department of Agriculture and Department of Water and Sanitation.

The Wadrift Wetland was not selected for intensive study because of the magnitude of disturbances here including considerable well-field water abstraction for Lamberts Bay and a fire that devastated the peat beds at the wetland. Some attempts to restore the riparian vegetation, particularly on the exposed burnt peat beds have not been successful. This appears to be due to, amongst other reasons, inadequate terrain and substrate preparation and little or inadequate post-treatment and after-care management. The recovery of a disruption of this magnitude in an arid environment requires a long-term management programme.

5.3. Estuary-Specific Recommendations

In respect of non-flow related impacts, priority interventions that need to be undertaken by the respective authorities, landowners and other stakeholders for the estuaries within the study area are provided below.

Table 19. Priority non-flow-related interventions that need to be implemented by the respective authorities, landowners and other stakeholders to improve the health status of the Verlorenvlei River Estuary to a B Category.

Measure	Responsibility
Reduce the levels of inorganic nutrients in inflowing water from the catchment and surroundings to halt the ongoing degradation (downward trajectory) and restore some resilience to Verlorenvlei during drier conditions.	
• Educate landowners/farmers on the impacts of excessive fertilizer use on the Verlorenvlei Estuary	Landowners, farmers, Department of Agriculture, DWS
• Develop and implement agricultural best practices specifically to reduce nutrient-enriched return flow and sediment erosion (e.g. through Biodiversity and Potatoes/Rooibos Initiatives)	DWS, CapeNature, Local municipality
• Address sanitation and sewage treatment facilities in Redelinghuys & Elandsbaai	Local municipality
Prevent illegal artificial breaching of the estuary to increase overall water levels and ensure resilience to droughts under a future hotter/drier climate through the implementation of the Verlorenvlei Mouth Management Plan.	DEADP, CapeNature, Local municipality,
Eradicate illegal gillnetting to ensure recovery and improve the resilience of fish in the system through improved compliance and enforcement of the Living Marine Resources Act.	Department of Agriculture Forestry, Fisheries & Environment (DFFE), CapeNature
Manage/eradicate alien and translocated fish in Verlorenvlei through the establishment of a controlled commercial fishery	Department of Agriculture Forestry, Fisheries & Environment (DFFE), CapeNature
Restore hydrological connectivity between the inlet and the main vlei through the removal of infilling and/or the upgrade of road crossings (Grootdrift and Redelinghuys causeways). Including the removal of the infill below the railway bridge.	Working for Wetlands programme, Municipality, DEADP
Protect and restore the reeds and sedges that occur in and around Verlorenvlei. The reed beds both acts as nutrient filters and refuge areas for invertebrates, fish and birds during low acidic events. This includes controlling the burning, cutting, grazing, and trampling of reeds. Cutting should only occur at designated areas around bridges. Reeds are sensitive to disturbance and already occur in a stressful environment, without their nutrient filtering capabilities the system will be in a much more eutrophic state.	Local/district municipality, DEADP
Manage and control salt marsh grazing in Verlorenvlei.	Department of Agriculture Forestry, Fisheries & Environment (DFFE), CapeNature
Control infrastructure development and land use change in the Verlorenvlei EFZ to reduce impacts associated with poor land use such as increased erosion and infilling and removal of riparian buffers (through IDP/SDF and EMP processes).	CapeNature, Local/district municipality,
Reinforce Ramsar status of Verlorenvlei through **promulgation as a formally protected area.**	CapeNature
Develop and implement a climate change adaptation plan for Verlorenvlei (in response to changes in freshwater flow, sea level rise, etc), including a formal agreement on the required freshwater requirements.	CapeNature, DEADP, DFFE

Table 20. Priority non-flow related interventions that need to be implemented by the respective authorities, landowners and other stakeholders to improve the health status of the Wadrift River Estuary to a C Category.

Measure	Responsibility
Urgently increase connectivity through bridges through the installation of more culverts and lower the floor level of exiting culverts to reduce salinity in Zone A. This may also increase opportunities for flushing and or breaching the system should a large flood occur. However, this would only be a secondary objective as this is not likely under the present flow regime and attenuation effect of the current extensive bridge configuration.	Transnet Freight Rail and DEADP and local/district municipality.

Create a novel/artificial wetland and buffer zones upstream where the peats use to occur in Langvlei (acting as a filter for nutrients and sediment). In turn, the artificial wetlands will act as a refuge for invertebrates, fish, and birds during the drier periods and droughts, restoring some of the species' diversity and abundance in the system.	DWS, CapeNature, local municipality, Working for Wetlands
Improve agricultural practices to reduce levels of inorganic nutrients (fertilizers) and agrochemicals in inflowing water from the catchment	Provincial Dept of Agriculture (Landcare unit|), DWS, CapeNature, local municipality, landowners, farmers
Control overgrazing and trampling of saltmarsh in and around Wadrift Estuary to protect these critical habitats. Restoring such habitats in such stressful environments is very costly, and much more effective to manage and control the activities impacting them.	Provincial Dept of Agriculture (Landcare unit|), DFFE, landowners, farmers; Cape Nature

Table 21. Priority non-flow related interventions that need to be implemented by the respective authorities, landowners and other stakeholders to improve the health status of the Jakkals River Estuary to a D Category.

Measure	Responsibility
Reduce levels of inorganic nutrients in inflowing water from the catchment	Provincial Dept Agriculture – Landcare program
• Reduction in fertilizer use in the catchment	Landowners, farmers
• Educate landowners/farmers on the impacts of excessive fertilizer use on the Jakkals River Estuary	DWS, CapeNature, Local municipality, Provincial Dept Agriculture – Landcare program
Reduce direct inputs of inorganic nutrients into the estuary • Eliminate septic and conservancy tanks from properties on the banks of the Jakkals Estuary through the provision of sewage reticulation infrastructure	Local municipality
Institute and enforce appropriate development set-back lines around the estuary that provide adequate protection for estuarine fauna and flora	Local/district municipality, DEADP
Improved compliance in respect of the use of living marine and estuarine resources (legal and illegal fishing)	Department of Agriculture Forestry, Fisheries & Environment (DFFE), CapeNature
Investigate the removal of sediment at the mouth to restore connectivity, e.g. skimming the sand berm to a lower level	Local/district municipality, DEADP

Table 22. Priority non-flow related interventions that need to be implemented by the respective authorities, landowners and other stakeholders to improve the health status of the Sout River Estuary to a D Category.

Measure	Responsibility
Estuary Management Plan to evaluate to what extent the current design and/or operations of the salt works can be improved to restore estuarine habitat and functionality of the upper reaches;	Western Cape Government – DEADP, Local/district municipality
Improve circulation (e.g. culverts in roads)	Department of Mineral Resources, Western Cape Government – DEADP
Restore connectivity with the catchment, i.e. investigate if the weir can be partially removed to allow connectivity with the western arm of the estuary.	DWS, CapeNature, Local municipality; Provincial Dept Agriculture – Landcare program
Reduce levels of inorganic nutrients in inflowing water from the catchment	Provincial Dept Agriculture – Landcare program
Reduction in fertilizer use in the catchment	Landowners, farmers
Educate landowners/farmers on the impacts of excessive fertilizer use on the Sout River Estuary	DWS, CapeNature, Local municipality; Provincial Dept Agriculture – Landcare program

Institute and enforce appropriate development set-back lines around the estuary that provide adequate protection for estuarine fauna and flora against mining impacts.	Local/district municipality, DEADP

6. REFERENCES

ARCHER E, CONRAD J, MüNCH Z, OPPERMAN D, TADROSS M, and VENTER J. 2009. Climate change, groundwater and intensive commercial farming in the semi-arid northern Sandveld, South Africa. Journal of Integrative Environmental Sciences 6, 139-155.

CSIR 2009 Development of the Verlorenvlei estuarine management plan: Situation assessment. Report prepared for the C.A.P.E. Estuaries Programme. CSIR Report No. CSIR/NRE/CO/ER/2009/0153/B Stellenbosch.

DEPARTMENT OF WATER AFFAIRS (DWA), 2013. Determination of Resource Quality Objectives for the Olifants Doorn Water Management Area – Report No. 3 - RQO Determination Report. Prepared by Umvoto Africa (Pty) Ltd in association with Southern Water Ecological Research and Consulting cc (Authors: K Riemann. A Joubert, C. Brown) on behalf of the Directorate : RDM Compliance.

DWA 2012a. Final Project Report for the Classification of significant water resources in the Olifants-Doorn WMA, Department of Water Affairs, South Africa, Belcher A. and Grobler D. 2012.

DWA 2012b. Integrated Socio-Economic and Ecological Specialist Report for the Classification of significant water resources in the Olifants-Doorn WMA, Department of Water Affairs, South Africa.

DWA 2012c. Guideline for identifying levels of Resource Protection Measures for Inland Wetlands: Version 1.0. Joint Department of Water Affairs and Water Research Commission report, prepared by M. W. Rountree, B. Weston and J. Jay. Department of Water Affairs, Pretoria.

DWA 2012d. DRAFT: Review and update of the 1999 Ecological Importance-Sensitivity and the Present Ecological Status (EIS/PES) of South African rivers including expansion to priority tributaries and wetlands according to quaternary catchment: Group 5 - Western Cape WMAs: Breede/Overberg, Berg, Gouritz and Olifants/Doorn. Draft report prepared by Southern Waters for Department of Water Affairs.

DWA. 2010. Directorate Water Resources Planning Systems: Water Quality Planning. Resource Directed Management of Water Quality. Planning Level Review of Water Quality in South Africa. Sub-series No WQP 2.0. Pretoria, South Africa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2003. Sandveld Preliminary (Rapid) Reserve Determinations. Langvlei, Jakkals and Verlorenvlei Rivers. Olifants-Doorn WMA G30. Surface Volume 1: Final Report Reserve Specifications. DWAF Project Number: 2002-227.

DEPARTMENT OF WATER AND SANITATION (DWS). 2014. Determination of Resource Quality Objectives in the Upper Vaal Water Management Area (WMA8): Resource Unit

Prioritisation Report. Report No.: RDM/WMA08/00/CON/RQO/0213. Chief Directorate: Water Ecosystems. Study No.: WP10535. Prepared by the Institute of Natural Resources (INR) NPC. INR Technical Report No.: INR 493/14.(i). Pietermaritzburg, South Africa.

DWS. 2016. Development of Procedures to Operationalise Resource Directed Measures. Water quality tool analysis and standardisation Report. Prepared by Scherman, P-A and Koekemoer, S for: Rivers for Africa eFlows Consulting (Pty) Ltd. Report no RDM/WE/00/CON/ORDM/0816.

DWS. 2017a. Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA. Buffels, Swartlintjies, Spoeg, Groen and Sout Estuaries Ecological Water Requirement. Authored by CSIR: L van Niekerk, J Adams, SJ Lamberth, S Taljaard for Rivers for Africa. DWS Report No: RDM/WMA06/00/ CON/COMP/0316.

DWS. 2017b. Development of Procedures to Operationalise Resource Directed Measures. Main Report. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Report no RDM/WE/00/CON/ORDM/0117.

DWS. 2018a. Determination of Water Resource Classes and Associated Resource Quality Objectives in the Berg Catchment: Resource Units Prioritisation Report. Project Number WP10987. DWS Report NO: RDM/WMA9/00/CON/CLA/0517.

DWS 2018b. Determination of Water Resources Classes and Resource Quality Objectives in the Breede-Gouritz Water Management Area: Resource Unit Prioritisation Report. Report No: RDM/WMA8/00/CON/CLA/0517.

DWS. 2022. Hydrological Services - Surface Water (Data, Dams, Floods and Flows). [Online] June 2022. https://www.dws.gov.za/Hydrology/Default.aspx.

GEOSS, 2005. Groundwater Reserve Determination required for the Sandveld, Olifants-Doorn Water Management Area. GEOSS Report Number: 2005/04-20. GEOSS - Geohydrological & Spatial Solutions International (Pty) Ltd. Stellenbosch, South Africa.

GEOSS, 2021. Annual monitoring of groundwater quantity and groundwater quality from selected boreholes in the potato growing region of the Sandveld for Potatoes South Africa, Western Cape. GEOSS Report Number: 2021/06-28. GEOSS - Geohydrological & Spatial Solutions International (Pty) Ltd. Stellenbosch, South Africa.

KLEYNHANS CJ, LOUW MD. 2007. Module A: EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No.

LOUW D, BIRKHEAD, D, EWART-SMITH J, HUGGINS G, KOEKEMOER S, LOTTER A, MACKENZIE J, MULLINS W, SAMI, K, SCHERMAN P, VAN NIEKERK L, VAN ROOYEN P. 2017. Development of Procedures to Operationalise Resource Directed Measures. Main Report. Prepared by: Rivers for Africa eFlows Consulting (Pty) Ltd. Report no RDM/WE/00/CON/ORDM/0117. Department of Water and Sanitation, South Africa.

MILLER, J.A, TURNER, K.B, WATSON, A, MOLNAR, M, TURI, M AND PALSCU, L. Under review. Characterization of groundwater types and residence times in the Verlorenvlei

catchment, South Africa to constrain recharge dynamics and hydrological resilience. Journal of Hydrology.

OLLIS DJ, SNADDON CD, JOB NM AND MBONA N. 2013. Classification System for Wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland Systems. SANBI Biodiversity Series 22. South African National Biodiversity Institute, Pretoria.

MACFARLANE DM, OLLIS DJ AND KOTZE DC, 2020. WET-Health (Version 2.0). A refined suite of tools for assessing the Present Ecological State of wetland ecosystems. Technical Guide. WRC Report No. TT 820/20. Water Research Commission, Pretoria.

NEL, J. 2005. Assessment of the Geohydrology of the Langvlei Catchment. Report No: GH 4000.

POOL-STANVLIET R, DUFFELL-CANHAM A, PENCE G AND SMART R 2017. The Western Cape Biodiversity Spatial Plan Handbook. Stellenbosch: CapeNature.

REPUBLIC OF SOUTH AFRICA. DEPARTMENT OF WATER AND SANITATION. 2015. Proposed Classes of Water Resources and Resource Quality Objectives for Catchments of the Olifants Doorn Government Gazette no. 39001, Government Notice No 609, 17 July.

ROUNTREE MW AND KOTZE DC 2013. Specialist Appendix A3: EIS Assessment. In: Rountree MW, Malan HL and Weston BC (eds.); Manual for the Rapid Ecological Reserve Determination of Inland Wetlands (Version 2.0). WRC Report No. 1788/1/13. Water Research Commission, Pretoria, pp. 42-46.

SEAMAN, M.T., M.F., WATSON, M., KING, J., ARMOUR, J., BARKER, C.H., DOLLAR, E., DU PREEZ, P.J., HUGHES, D., ROSSOUW, L., VAN TONDER, G., 2010. Developing a method for determining the environmental water requirements for non-perennial systems. WRC Report No TT 459/10.

SCHULZE, RE AND DAVIS, NS. 2021. Practitioners' handbook for undertaking current and projected climate related risk and vulnerability assessments for the Berg-Olifants Water Management Area. Draft WRC Report K5/2833/xx, Water Research Commission.

SCHÜTTE, S, SCHULZE, RE, AND CLARK, DJ (Eds). 2022. A National Assessment of Potential Climate Change Impacts on the Hydrological Yield of Different Hydro-Climatic Zones of South Africa. WRC Report K5/2833/1&2, Water Research Commission.

VAN DEVENTER, H., SMITH-ADAO, L., COLLINS, N.B., GRENFELL, M., GRUNDLING, A., GRUNDLING, P-L., IMPSON, D., JOB, N., LÖTTER, M., OLLIS, D., PETERSEN, C., SCHERMAN, P., SIEBEN, E., SNADDON, K., TERERAI, F. & VAN DER COLFF, D. 2019. South African National Biodiversity Assessment 2018: Technical Report. Volume 2b: Inland Aquatic (Freshwater) Realm. CSIR report number CSIR/NRE/ECOS/IR/2019/0004/A. South African National Biodiversity Institute, Pretoria.

VAN NIEKERK, L, ADAMS JB, JAMES, N, LAMBERTH S, MACKAY F, RAJKARAN A, TURPIE J, WEERTS S, WHITFIELD AK. 2020. An Estuary Ecosystem Classification that encompasses biogeography and a high diversity of types in support of protection and management. African Journal of Aquatic Science, 45: 199-216.

VAN NIEKERK L, ADAMS, JB, LAMBERTH, SJ, TALJAARD, S, & VAN ROOYEN P 2016. Development of Procedures to Operationalise Resource Directed Measures. Estuaries and Marine tool analysis and standardisation Report. Prepared by: CSIR for Rivers for Africa. Report no RDM/WE/00/CON/ORDM/0716. Department of Water and Sanitation, South Africa, October 2016.

VAN NIEKERK, L. AND TURPIE, J.K. (EDS) 2012. South African National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch.

WATSON, A., EILERS, A., MILLER, J., 2020a. Groundwater characterisation and recharge estimation using CMB and environmental isotopes in a semi-arid agricultural region and implications for sustainability of the Verlorenvlei estuarine system, South Africa. Water (Switzerland) 12, 1–26. https://doi.org/10.3390/w12051362.

WATSON, A., KRALISCH, S., KÜNNE, A., FINK, M., MILLER, J., 2020b. Impact of precipitation data density and duration on simulated flow dynamics and implications for ecohydrological modelling in semi-arid catchments in Southern Africa. J. Hydrol. 590, 125280. https://doi.org/10.1016/j.jhydrol.2020.125280.

WATSON, A., MIDGLEY, G., KÜNNE, A., KRALISCH, S., HELMSCHROT, J., 2021. Determining Hydrological Variability Using a Multi-Catchment Model Approach for the Western Cape, South Africa. Sustain. 13, 1–26. https://doi.org/https://doi.org/10.3390/

WATSON, A., MILLER, J., FINK, M., KRALISCH, S., FLEISCHER, M., DE CLERCQ, W., 2019. Distributive rainfall-runoff modelling to understand runoff-to-baseflow proportioning and its impact on the determination of reserve requirements of the Verlorenvlei estuarine lake, west coast, South Africa. Hydrol. Earth Syst. Sci. 23, 2679–2697. https://doi.org/10.5194/hess-23-2679-2019.

WESTERN CAPE GOVERNMENT: DEPARTMENT OF ENVIRONMENT AND DEVELOPMENT PLANNING AND DEPARTMENT OF AGRICULTURE, 2018. Sandveld Environmental Management Framework.

WRC. 2022. Water Resources of South Africa, 2012 Study. [Online] June 2022. https://waterresourceswr2012.co.za/.

APPENDIX A: DETAILED EWR RECOMMENDATIONS FOR EWR SITES

River 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).

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

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

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

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

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

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

Estuary EWRs

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.

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

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.

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

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).

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	Total
Max	0.12	0.85	0.22	0	0	0	0.38	3.12	7.36	9.8	5.49	0.75	16.72
95%	0	0	0	0	0	0	0.08	0.85	2.01	1.59	0.99	0.42	4.45
90%	0	0	0	0	0	0	0	0.36	0.97	0.81	0.56	0.18	3.7
80%	0	0	0	0	0	0	0	0.05	0.57	0.45	0.17	0.02	1.73
70%	0	0	0	0	0	0	0	0	0.22	0.21	0.1	0	1.14
60%	0	0	0	0	0	0	0	0	0.13	0.12	0.03	0	0.7
50%	0	0	0	0	0	0	0	0	0.08	0.05	0	0	0.43
40%	0	0	0	0	0	0	0	0	0	0	0	0	0.25
30%	0	0	0	0	0	0	0	0	0	0	0	0	0.14
20%	0	0	0	0	0	0	0	0	0	0	0	0	0.06
10%	0	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	0
Min	0	0	0	0	0	0	0	0	0	0	0	0	0