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

SURFACE WATER DELINEATION REPORT

August 2022







Department of Water and Sanitation

Chief Directorate: Water Ecosystems Management

DEPARTMENT: WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS 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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ACRONYMS AND ABBREVIATIONS

BAS	Best Attainable State
CSIR	Council for Scientific and Industrial Research
DEA	Department of Environment Affairs
DEADP	Department of Environmental Affairs and Development Planning (Western Cape Government)
DFFE	Department of Forestry, Fisheries and the Environment
D:RDM	Directorate: Resource Directed Measures
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EcoStatus	Ecological Status
EGSA	Ecosystem Goods, Services and Attributes
EIS	Ecological Importance and Sensitivity
EISC	Ecological Importance and Significance Category
EMC	Ecological Management Category
EWR	Ecological Water Requirements
FBIS	Freshwater Biodiversity Information System
FEPA	Freshwater Ecosystems Priority Areas
GIS	Geographic Information System
HGM	Hydrogeomorphic
HRU	Hydrological Resource Unit
IFR	Instream Flow Requirement
IHI	Index of Habitat Integrity
IUCN	International Union for Conservation of Nature
l/s	Litre per second
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff

MCM	Million Cubic Metres
MIRAI	Macro Invertebrate Response Assessment Index
mm/a	millimetre per annum (precipitation)
mS/m	milliSiemens per meter (measurement of the electrical conductivity of water)
MRU	Management Resource Unit
MSL	Mean Sea Level
NBA-2018	National Biodiversity Assessment 2018
NFEPA	National Freshwater Ecosystem Priority Area
NMU	Nelson Mandela University
NRA	Natural resource unit
NWA	National Water Act
NWM5	National Wetland Map 5
PAI	Physico-Chemical Assessment Index
PES	Present Ecological State
PESC	Present Ecological Status Class
ppt	parts per thousand (measurement of salinity)
RDM	Resource Directed Measures
REC	Recommended Ecological Category
REI	River Estuary Interface
REMP	River EcoStatus Monitoring Programme
RQO	Resource Quality Objective
RU	Resource Units
RWQO	Resource Water Quality Objective
SANBI	South African National Biodiversity Institute
SASS5	South African Scoring System Version 5
TEC	Target Ecological Category
TMG	Table Mountain Group

WCBSP	Western Cape Biodiversity Spatial Plan
WMA	Water Management Area
WQSU	Water Quality Sub-Unit
WRAP	Wetland Rehabilitation and Assessment Protocol
WR2012	Water Resources 2012
WRC	Water Research Commission

GLOSSARY

ABIOTIC	Without life, inanimate; physical environment like temperature, rainfall
AESTHETIC	The overall scenic attraction of the setting, including amongst other things; natural beauty of banks and waters, or any unusual natural phenomena; the appeal of wildlife and aquatic plants; desirable natural landscape for home sites on the shores etc.
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)
ATTENUATION	To make something weaker or have less effect.
BASEFLOW	That part of stream flow contributed by groundwater and discharged gradually into the channel.
BENTHIC	Organisms that inhabit the shallow, bottom habitat of water.
BIOTA	The living organisms occupying a place together, e.g. plants, animals, bacteria, etc in the aquatic biota, or terrestrial biota.
BIOMONITORING	Monitoring of living organisms, usually as indicators of habitat integrity
CALCAREOUS	Composed of, containing, or characteristic of calcium carbonate, calcium, or limestone
CATCHMENT	The area from which any rainfall will drain into the watercourse or watercourses, through surface or subsurface flow.
CONTAMINANT	A foreign agent that is present (e.g. in water, sediment) that may produce a physical or chemical change but may not cause an adverse biological effect
DIFFUSE SOURCE	A general source (e.g. of pollution), the exact location of which is difficult to pinpoint.
DISTURBANCE REGIME	The pattern of natural variability of physical and biological processes, incorporating the return time to a stable condition from extreme conditions.

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.
EROSION	The wearing away and removal of materials of the earth's crust by natural means. Running water, waves, moving ice, and wind currents are examples of erosion.
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.
EUTROPHICATION	The process whereby high levels of nutrients result in the excessive growth of plants.
FLOW REGIME	Recorded or historical sequence of flows used to create a hydrological profile of the water resource.
GEOMORPHOLOGY	The branch of geology that deals with, amongst other things, the form of the earth and the changes that take place in the process of development of landforms.
GRADIENT	The degree of slope or incline. In the context of this course, it refers to the slope of a stream bed or the vertical distance that water falls while travelling a horizontal distance downstream.
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.

HYPERSALINE	An environment that has salinities greater than that of normal seawater.
HYPORHEOS	water flowing over streambeds in lotic environments
IMPACTS	The measurable effect of one thing on another.
IMPOUNDMENT	To retain water artificially by means of a weir or dam.
INDICATOR SPECIES	A species that has been extensively studied to the point that the effect of environmental changes upon its distribution and lifecycle are well known so that knowledge of its status provides information on the overall condition of the ecosystem, and of other species in that ecosystem.
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.
INDIGENOUS SPECIES	A species that occurs, or has historically occurred, naturally in a free state, in nature within an ecologically similar area, but excludes a species that has been introduced from another area or continent as a result of human activity
INVERTEBRATE	Animal without a backbone.
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.
NUTRIENTS	Elements required for life processes: nitrogen, phosphorus and potassium are probably the most important nutrients.
POINT SOURCE	A definable or precise location or source e.g., of pollution.
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.
RIVER ESTUARY INTERFACE	That part of an estuary where the river and estuarine waters mix, and where the vertically integrated salinity is usually less than 10 ppt.
SEDIMENTATION	The act or process of depositing sediment. Sediment comprises fragments of inorganic or organic material that are carried and deposited by water.
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.
TAXON	Biological category (e.g. species) or its name
TERTIARY CATCHMENT	A third-order catchment in a hierarchal classification system in which a primary catchment is a major unit.
SUBSTRATE	The surface to which a plant or animal is attached or on which it grows.
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 F60 and G30 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 the 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 associated with the Verlorevlei that provide essential ecological services but are under severe threat and require urgent protection. Therefore, it is 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 outline the process for delineating the surface water resources and determining the sites selected to determine the Reserve in the F60 and G30 catchments (Figure 1) of the Olifants-Doorn Water Management Area.

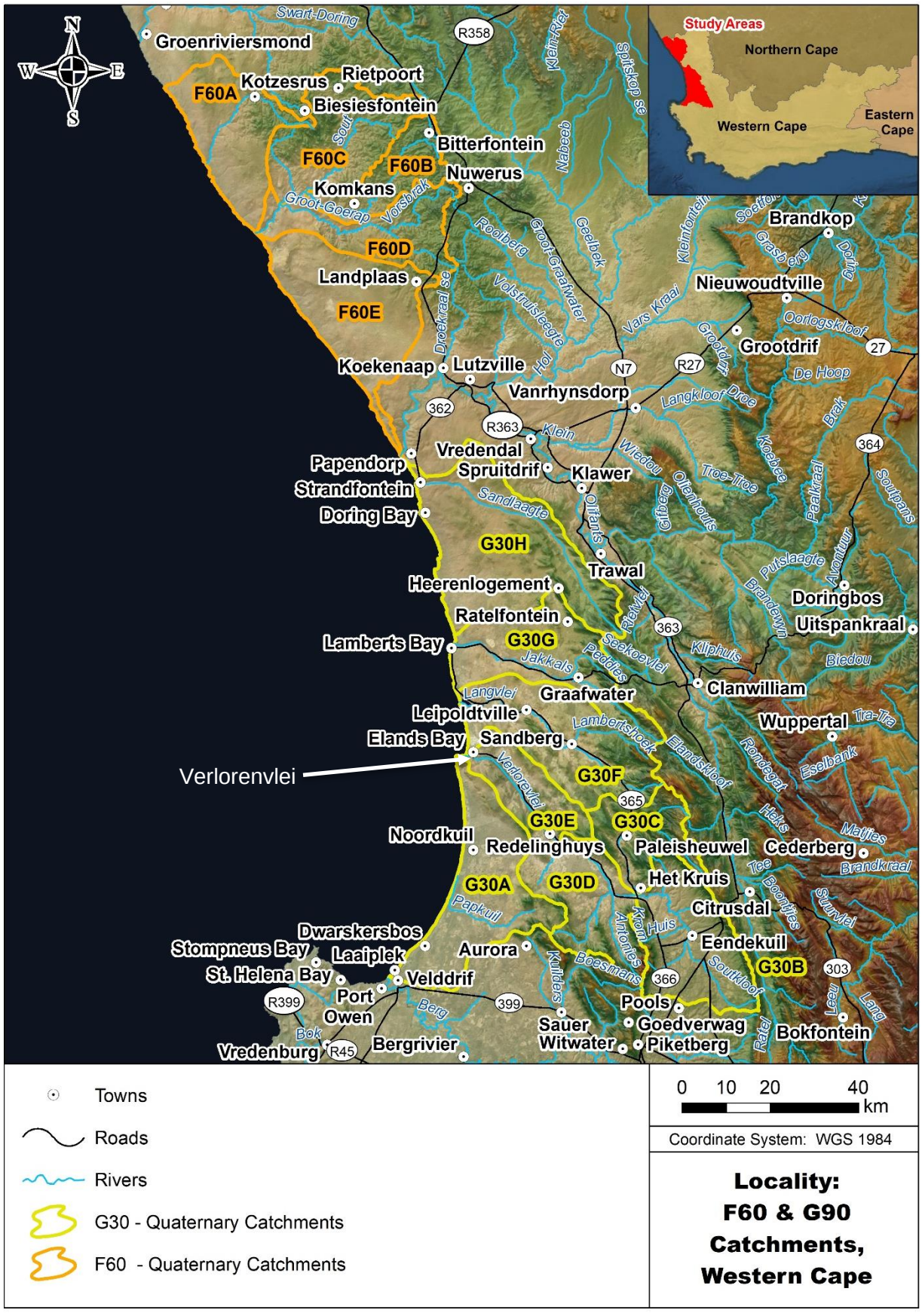

Figure 1: Map of the study area with the location of the F60 and G30 Catchments and main aquatic features shown

1.4. The Study Area

The study area comprises two Tertiary Catchments, the G30 (Sandveld) and the F60 (Knersvlakte) Catchments. The majority of the F60 and G30 Catchment Area falls within three local municipalities located within the West Coast District Municipality in the Western Cape Province, namely:

- Berg River Local Municipality;
- Cederberg Local Municipality; and
- Matzikama Municipality.

A small section of the most northern section of the catchment falls within Kamiesberg Local Municipality 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 comprises mainly three parallel seasonal river and longitudinal wetland systems, namely Jakkals, Langvlei and Verlorenvlei. The catchments drain westwards through the Sandveld and consist of rivers, pans and wetland/vlei systems.

While the seasonal Langvlei, Jakkals and Verlorenvlei longitudinal wetlands are the main wetlands of note in the study area, other relatively large wetland areas comprise of Rocherpan north of the Berg River Estuary; Valley bottom wetland habitats associated with the Papkuil River in G30A; and Several pans in the upper Verlorenvlei Catchment. These wetland areas occur within an arid landscape that has been significantly modified by agriculture and provide valuable habitat for birdlife as well as amphibians.

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. The Ramsar treaty falls under the aegis of the United Nations and the International Union for the Conservation of Nature (IUCN) and member nations - of which South Africa is one and thus has acceded to the Ramsar treaty with its clearly defined responsibility of actively conserving the unique wetland and the biological diversity that it supports.

The Verlorenvlei Estuary is naturally a nearly permanently closed estuarine system and only breaches the sea during high inflow periods. The estuary was determined to be in a “Moderately to largely modified state”, i.e., Category C/D, based on an assessment undertaken in 2009. The Best Attainable State (BAS) is a moderately modified system (i.e., Category C). This provisional health rating of the estuary should be confirmed in this study to determine its Estuarine Recommended Ecological Category (REC) with a confidence that would allow for decisive management actions.

Other estuaries within the G30 catchment comprise the Wadrift Estuary, a small estuarine system of low to average biodiversity importance at the mouth of the Langvlei River; and the Jakkalsvlei Estuary, another small estuarine system of low to average biodiversity importance that is located at the mouth of the Jakkals River. The recommended health status of these estuaries is Largely Modified. This rating will be confirmed in the study.

The Groot Goerap/Sout and Brak River Catchments to the north of the Sandveld are in the even more arid Knersvlakte region that comprises low, undulating hills with isolated patches of white quartz stone and saline soils. The hypersaline Sout River Estuary is classified as an Arid Predominantly Closed System that is nearly always closed to the sea. The estuary is a highly transformed system due to the presence of a salt works which occupies much of the system. The Sout River estuary is not acknowledged as a functional estuary or a noteworthy ecosystem. Due to the poorly developed soils and the low agricultural potential of the area, only a small percentage of the area is cultivated, mostly to the southeast portion of the catchment.

Water abstraction from surface and groundwater has significantly modified the aquatic ecosystems' flow, particularly reducing low flows in summer. Modified flows have reduced, amongst others, the habitat integrity and consequently the goods and services provided by these ecosystems. Land use in the area consists mainly of livestock farming (sheep and goats), with small areas 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.

1.5. Study Methodology and Approach

A Reserve determination study endeavours to provide information at the highest level of confidence possible within the defined time, data availability and financial constraints of the project. These constraints dictate the spatial and temporal extent to which data can be collected and inform the understanding of aquatic ecosystem responses to flow volume and pattern changes. Within such a study, with a one- or two-year data collection period, a picture of the conditions in the ecosystems at the time of the study is formed that may provide greater confidence that the conditions at the time of the study (i.e., Present Ecological Status (PES) of the water resource at the selected EWR site) are accurately recorded and represented. This is of utmost importance to set a management condition for the system (REC or BAS) that would remain at the PES or

would improve. However, the data collected will not indicate the ecological condition or responses at another time under different conditions, i.e., drier or wetter periods.

The Terms of Reference called for a high confidence reserve determination process. However, a lack of data for the water resources in the study area is likely to result in the generic requirements recommended for a Comprehensive Ecological Reserve determination not being met and thus, the level of confidence in the assessment may be lower than comprehensive. Clear recommendations with regards to future monitoring of the water resources must be included in the outcomes of this study to rectify this shortcoming.

The river, wetland, estuarine and groundwater components of the Reserve determinations will use the latest RDM recommended methodologies. While the standard methodologies for the determination of the Basic Human Needs and ecological Reserve would be followed in the study. The need for a slightly adapted approach for the Sandveld and Knersvlakte Rivers in the F60 and G30 Tertiary Catchments is proposed. This adapted approach is deemed to be necessary to address the following:

- Most of the surface water features within the study area are non-perennial with a hydrological regime that has high variability in flow both spatially and temporally with a highly unpredictable surface water flow;
- Surface water ecosystems in these systems are often confined to isolated pools that eventually dry up in the dry season. The aquatic biota associated with these habitats comprises of hardy species with low diversity, although both the habitat and biota may be of high ecological importance;
- The estuaries within the area comprise mainly of coastal lakes or estuarine salt pans, with a low diversity of hardy species. These systems are mostly nearly permanently closed and also have very little freshwater inflow from their associated river systems. As a result, they tend to be hypersaline;
- Very close integration occurs between the surface water ecosystems (rivers, wetlands and estuarine habitats) as well as with the groundwater. Integration of these two specialist fields and the recommended ecological Reserve (quantity and quality) thus needs to take place; and
- The sequencing and interaction between the tasks and disciplines on this project are critical. The products from the groundwater specialists will provide an improved understanding of the surface water ecosystems and the delineation of the river reaches and wetland regions Enough time must be set aside to allow for integration. The wetlands component will especially need to provide inputs to and rely on information from the Rivers and Groundwater specialists. Once the priority wetlands have been determined, an essential step will be to interact with the specialists to obtain assistance in determining EWRs. The River specialists would also need to provide input into the chosen wetland priorities.

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

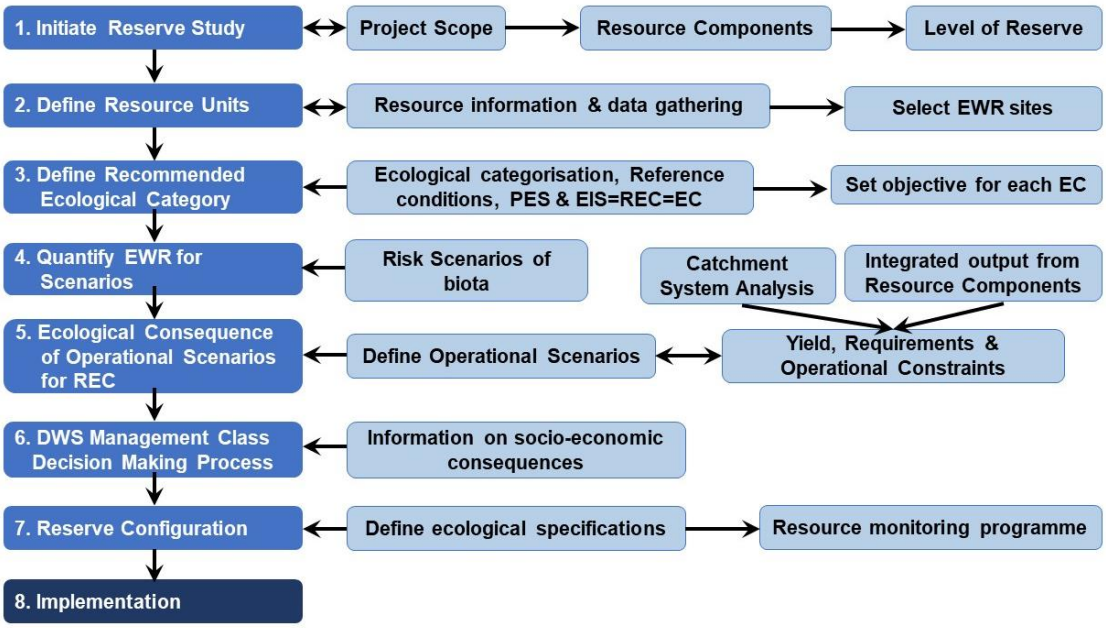

Figure 2: The Reserve Determination Process (adapted from DWAF, 2008)

2. OUTLINE OF PROCEDURE TO DELINEATE SURFACE WATER RESOURCE UNITS AND IDENTIFY SITES

The delineation of the surface water resource units is an important step in the ecological Reserve determination process. It is the determining factor in all that follows, defining the boundaries of the work and the characteristic of the surface water features within each resource unit. Important in such a delineation process is consideration of the following:

- Catchment boundaries, relevant political boundaries, roads and towns;
- The characteristic topography, vegetation, land use, and geomorphological zones;
- The main rivers and tributaries, wetlands and estuaries;
- Aquatic ecosystem conservation priority areas and ecosystems likely to be especially vulnerable to flow;
- Land and water use activities that alter the aquatic ecosystem character, such as key water-resource infrastructure; and
- Socially, culturally and economically important activities and/or areas.

A defined water resource unit should as far as possible comprise:

- Homogeneous surface and sub-surface hydrological zones;
- Homogeneous geomorphological zones for river systems of similar wetland types;
- Homogeneous chemical and thermal zones;
- Homogeneous biological zones along the river system; and
- Homogeneous socio-economic areas with links to the river system.

Once the surface water resource units have been delineated, representative sites in each unit have been identified and characterised in terms of ecological condition and use. Budgetary constraints, however, limit the number of sites for the study area and those most meaningful for the Reserve recommendations have been prioritised. These sites will form the focus of all field data collection, hydrological/ hydraulic modelling, indicator selection, and results reporting for the study.

Important considerations when choosing sites are as follows:

- Availability of reasonably accurate hydrological, water quality and biological data;
- Less impacted areas that are still representative of the relationships between flow and biotic responses;
- Suitability for doing hydraulic or hydrodynamic modelling of water depths, velocities, widths and inundations areas;

- Areas expected to be particularly vulnerable to changes in flow or sediment regimes, such as shallow rapids or cobble bed riffles; channels with intermittently flooded floodplains; channels vulnerable to silting up or eroding deep into their bed.
- Areas of high conservation importance;
- Accessibility and safety; and
- Areas of high social use or dependence on the goods and services or where potential water conflicts are high.

3. RIVER RESOURCE UNITS

3.1. General Approach to Delineation of River Resource Units

It is necessary to delineate the catchment into Resource Units (RUs) when undertaking an ecological Reserve determination for large study areas, as is the case in this study. RU comprises sections of river that have significantly different drivers in terms of flow, water quality, and geomorphology. Thus, they respond differently to stress according to their character and sensitivity and require individual specifications of the Reserve appropriate for that reach.

The breakdown of a catchment into RUs to determine the Reserve for rivers is therefore done primarily on a biophysical basis. Ecoregions and geomorphic zones are thus the main criteria considered. These are referred to as Natural Resource Units (NRUs). Over and above the delineation of NRUs, water resource management requirements should also be considered in the delineation process. Large instream dams or water abstraction and transfer schemes may significantly impact the character of river reaches. These are called Management Resource Units (MRUs).

The final recommended River RU is an integration of the NRUs and MRUs and often requires expert judgement. The practicalities of dealing with numerous reaches within one study must also be considered to determine a logical and practical suite of MRUs.

3.2. Current Water Resource Classification, RQOs and Reserves

During the early Reserve determination study undertaken for the Sandveld from 2003 to 2005, the PES, Ecological Importance and Sensitivity (EIS) were determined at the EWR sites. These categories are summarised in Table 1.

Table 1. Summary of Sandveld Rapid Reserve assessment

EWR Location	Quaternary	PES	EIS	REC
Langvlei River	G30F	E/F	Moderate	C
Wadrif Wetland	G30F	F	High	C
Wadrif Pan	G30F	E	Moderate	C
Jakkals River	G30G	D	Moderate	C
Jakkalsvlei/Estuary	G30G	E	Moderate	C
Verlorenvlei (Kruis)	G30D	C	High	C
Verlorenvlei (Redelinghuys)	G30E	C	High	B
Verlorenvlei Lake/Estuary	G30E	C	High	B

The Water Resource Classification Study for the larger Olifants-Doorn Water Management Area was then completed in April 2012, followed by the Determination of Resource Quality Objectives (RQO) completed in March 2013. The categories for the quaternary catchments in the Olifants-Doorn WMA recommended by the Classification project (DWA 2012) and updated in the RQO project are provided in Table 2.

Table 2. Summary of PES and Recommended Ecological Categories from the Classification and RQO projects for the F60 and G30 catchments

Quaternary	PES (2011)	REC - Incremental	REC - Cumulative
F60A	B	B	B
F60B	B	B	B
F60C	B	B	B
F60D	B	B	B
F60E	B	B	B
G30A	C	C	C
G30B	C	C	C
G30C	C	C	C
G30D	C	C	C
G30E	C	C	B
G30F	C	C	C
G30G	C	C	C
G30H	C	C	C

3.3. Hydrological Resource Units

The preliminary delineation of the hydrological resource units for the Sandveld (G30) and the Knersvlakte (F60) study area started with the quaternary catchmentfor analysis and further analysis sub-dividing these catchments based on surface water tributaries and thereafter taking into consideration the contributions from springs and seepage areas. The sub-division also took into account zones of high and low rainfall, elevation and hydrological characteristics of the catchments.

According to the WR2012 study, the G30 tertiary catchments have low rainfall along the coast with a MAP of approximately 200 mm increasing from the west to south-east of the study area. The MAP increases up to 500 mm in the Banghoek mountains. Overall, the Sandveld MAP is approximately 290 mm/a. The catchment is characterised by endorheic areas in the Papkuils (G30A) and the Langvlei (G30F) catchments, and most runoff generated in the Kruismans (G30B), the Bergvallei (G30C) and the Krom Antonies and the Hol Rivers in G30D.

According to the WR2012 study, the F60 tertiary catchments have a relatively uniform rainfall distribution with mean annual precipitation (MAP) of 115 mm/a. The runoff characteristics are uniform, with an estimated mean annual runoff of 0 - 2.5 mm. More than half the catchment area is considered endorheic and does not contribute to the surface water runoff.

Table 3 summarises the preliminary delineation of catchments for the hydrological resource units and will be further refined as required in consultation with the project team.

Table 3: Summary of the delineated hydrological resource units

Quaternary Catchment	River/Tributary name	Catchment ID	Presence of Springs or Seepage
G30A overall	Papkuil	G30A	4 Springs, 1 Seepage area
G30B	Soutkloof	1	None
G30B	Upper Kruismans	2	None
G30B	Huis	3	Kruisrivier_SP2
G30B	Tributary to Kruismans	4	None
G30B	Tributary to Kruismans	5	None
G30B overall	Kruismans	G30B	6 Springs
G30C	Jansekraal	6	None
G30C	Kleinvlei	7	None
G30C overall	Bergvallei	G30C	1 Spring
G30D	Krom Antonies	8	15 Springs
G30D	Hol	9	5 Springs
G30D	Tributary to Verlorenvlei	10	Seepage areas
G30D overall	Verlorenvlei in G30D	G30D	25 Springs
G30E	Kruisfontein	15	4 Springs
G30E overall	Verlorenvlei in G30E	G30E	12 Springs
G30F	Langvlei	11	1 Spring
G30F	Lambertshoek	12	None

G30F overall	Langvlei G30F	G30F	1 Spring
G30G	Jakkals	13	None
G30G	Peddies	14	None
G30G overall	Jakkals G30G	G30G	None
G30F overall	Sandlaagte G30F	G30F	None

3.4. Water Quality Resource Units

Delineation and prioritising resource units and selecting the study or EWR sites is an important step in identifying high priority areas as these would be where more detailed work would be undertaken. These priority areas are selected based on ecological (fish and macroinvertebrate), socio-cultural and water resources importance. They are often areas of high ecological importance where water resources are stressed or may be stressed in future (Department of Water and Sanitation, 2016). The prioritisation acts as a filter to allow one to focus on specific areas in the various ecosystems. Study sites where more detailed fieldwork is undertaken are selected within high priority Resource Units, i.e., sites can only be selected after the prioritisation process.

When considering delineation of resource units from a water quality perspective, the study area should be divided into zones of homogenous water quality based on the following (Department of Water Affairs and Forestry, 2008):

- The location of dams, town, tributaries, and point source pollution entry points in the river and the placement within the RU are important considerations. A single RU may therefore consist of more than one WQSU (water quality sub-unit) due to changes in water quality across the RU. For an Intermediate / Comprehensive study the present state assessment for water quality is therefore conducted at the level of the WQSU, and not only the EWR site. However, this may not be possible in both the F60 and G30 catchment, especially during the dry season, as water can sometimes be limited to pools within the river with no continuous flow. The fact that these non-perennial rivers are fed from different water sources (groundwater, surface water runoff and springs) does not enable one to confidently extrapolate water quality characteristics from one EWR site to the next. Close cooperation between the specialists from the wetlands, groundwater and rivers is required to understand the flow interaction between the different water resources, as each of the resources can have a different chemical footprint depending on its origin (Seaman *et al*., 2010);
- It is important to include tributaries with water quality that is naturally or anthropogenically different from the river's main stem. In G30, the Krom-Antonies River, a tributary of the Kruismans River, has lower Total Dissolved Salts concentrations than the Kruismans River and improves the salt concentrations in the Kruismans River downstream of their confluence;

- Very little to no Reference Condition (RC) data are available and one would use existing data or reports, geological information, land use characteristics, local (indigenous) knowledge and expert judgement to define the RC; and
- Identify the data/sites that will be used to define the Present Ecological State (PES) per WQSU. As the objective of Ecoclassification is to assess deviation from a natural state, it is essential also to define the natural conditions or RC for water quality.

The priority areas where data collection needs to take place will be at the EWR sites. However, additional sampling will probably be required to better understand the WQSU within the RU, especially during the dry season when continuous river flow will not necessarily be the norm.

The position of the DWS gauging weirs or water quality data collection points in the WQSU must be shown in relation to the EWR sites and the RUs, as this will assist in defining the confidence in the water quality assessment for the EWR site. In perennial rivers, data from adjacent areas in the same EcoRegion (Level II) can also be used for the assessment, but this will impact the confidence of the assessment. However, as the rivers in the study area are primarily non-perennial, this is not advised as there may already be significant differences in water quality within the same RU.

This resource delineation task identified the initial proposed river reaches for the EWR sites. The water quality resource units will be aligned with the identified EWR sites and will be updated after the ground-truthing task has been completed.

<u>G30</u>

- G30B/G30C - Lower Bergvallei/Kruismans (DWS weir G3H001 is in this quaternary catchment);
- G30D - Lower Krom Antonies;
- G30D/G30E - Lower Verlorenvlei River in the Verlorenvlei River System (DWS weir G3H005 is located in this quaternary catchment);
- G30F - Lower Langvlei River, upstream of Wadrift Wetland and Pan;
- G30G - Lower Jakkals River, upstream of Jakkalsvlei;
- G30A - Lower Papkuils River; and

<u>F60</u>

- F60D - Lower Groot Goerap River, upstream of the Sout Estuary.

3.5. Natural Resource Units

The primary classification of rivers is a division into Ecoregions. Ecoregions are groups of rivers within South Africa that share similar physiography, climate, geology, soils and potential natural vegetation. For this study, the ecoregional classification presented in DWAF (1999), which divides the country's rivers into ecoregions, was used. Ecoregions within the study area are:

- South Western Coastal Belt (most of the G30 catchment);
- Western Coastal Belt (most of the F60 catchment);
- Western Folded Mountains (eastern extent of the G30 catchment); and
- Namaqua Highlands (north eastern extent of the F60 catchment).

Rivers within an ecoregion are further divided into sub-regions. Sub-regions (or geomorphological zones) are groups of rivers, or segments of rivers, within an ecoregion, which share similar geomorphological features, of which gradient is the most important. The use of geomorphological features is based on the assumption that these are a major factor in determining the distribution of the biota. Figure 3 provides the mapping of Ecoregions and Geomorphological zones for the study area. These characteristics are also included in the summary table for the River RUs in Table 4.

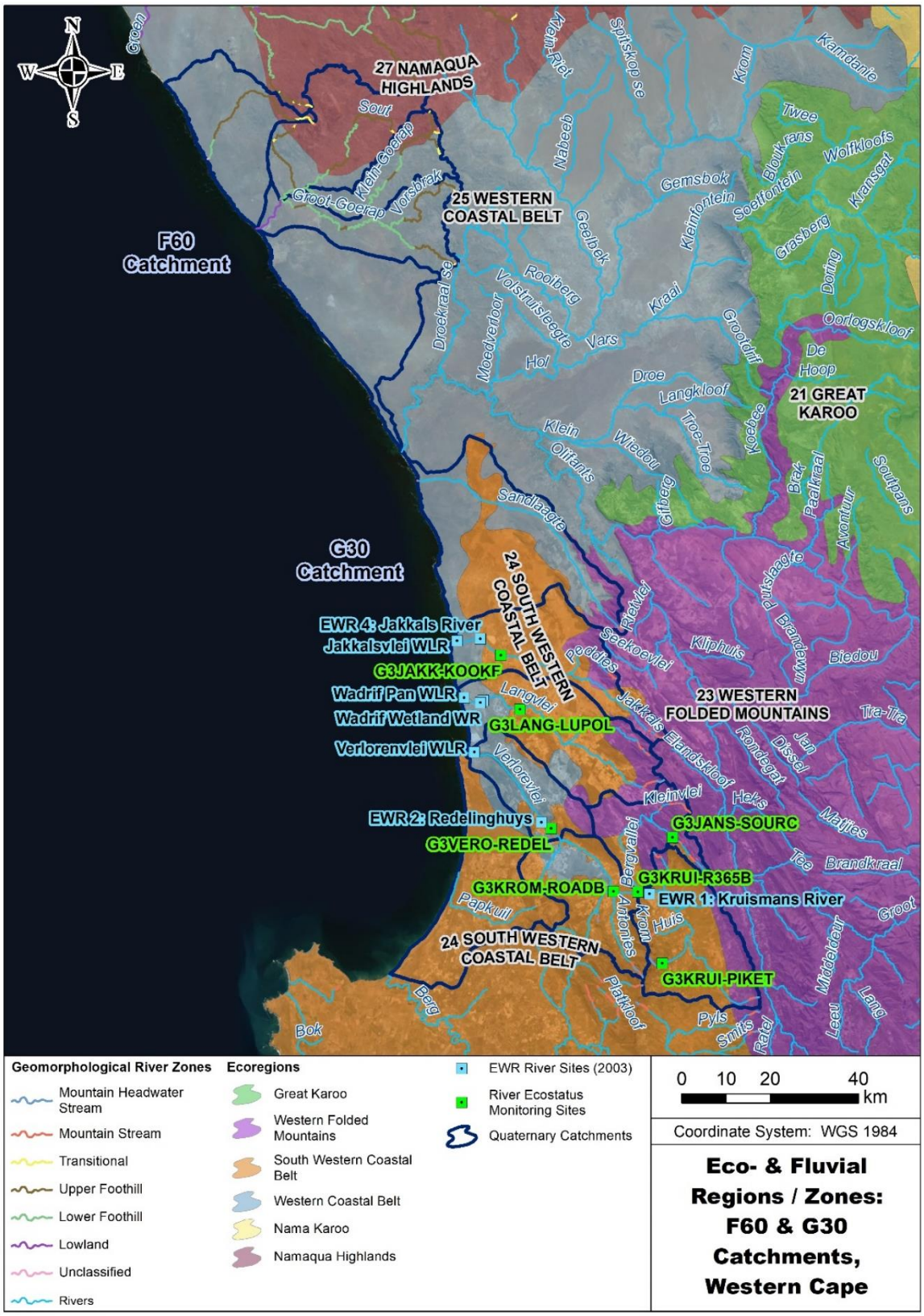

Figure 3. Map of the study area with the Ecoregions and Geomorphological Zones shown

3.6. Freshwater biota

Macroinvertebrates

Because the rivers within the study area are primarily non-perennial, flowing for only part of the year, the macroinvertebrate communities occurring in these watercourses tend to have a low diversity that comprises mainly of less sensitive taxa. This becomes increasingly so as one travels from the south and the Verlorenvlei Catchment northwards into the Sout and Brak Rivers. In addition, most of the river systems, such as the Langvlei River, comprise wetland habitat that has low dissolved oxygen levels and flow and thus inherently does not contain a diverse population of sensitive macroinvertebrates and is poorly suited to the macroinvertebrate sampling technique developed in South Africa for rivers (South African Scoring System version 5 or SASS5).

The rivers in the F60 catchment tend to flow for very short periods, and as a result, there is no available macroinvertebrate data available for the rivers. Within the G30 catchment, seven river ecostatus monitoring sites exist that have been sampled for macroinvertebrates (SASS5) more than twice. Only three of the sites within the Verlorenvlei River Catchment contain data from which reference conditions can be derived. These are in the upper Kruismans River (G30B), the lower Kruismans at the flow gauging weir (G3H001) and in the Verlorenvlei at Redelinghuys.

As defined by the SASS5 Score and Average Score per taxa, the expected reference conditions range from more than 150 and 7 respectively in the upper Kruismans River to more than 115 and 6.4 in the Verlorenvlei at Redelinghuys (DWS generated MIRAI for the River Ecostatus monitoring sites; March 2022).

Freshwater fishes

The study area has a depauperate native freshwater fish ichthyofauna, comprising three recognised fish species, namely the Endangered Verlorenvlei redfin *Pseudobarbus verlorevlei*, Data Deficient Cape Galaxias *Galaxias zebratus* and the Data Deficient Cape kurper *Sandelia capensis*. However, ongoing genetic and morphological studies indicate a richer fish fauna, especially in the much larger Verlorenvlei River System which has four fish taxa, comprising the Endangered Verlorenvlei redfin, an Endangered and distinct Galaxias lineage *Galaxias* sp. ‘zebratus Verlorenvlei’, a distinct Cape kurper lineage *Sandelia* sp. ‘capensis west coast’ and another Galaxias lineage (Chakona *et al*., 2019, Chakona pers. comm.). Both the redfin and Galaxias sp. ‘zebratus Verlorevlei’ are endemic to the Verlorenvlei River System (Chakona *et al*., 2019). The other river systems are much smaller and contain at most two taxa, namely a Cape Galaxias lineage and a Cape kurper lineage. The Verlorenvlei River system is hence especially important to freshwater fish conservation at a provincial and national level. It is a recognised Important Fish Area (previously called “fish sanctuary”) (Nel *et al*., 2011). Figure 4 provides a map of the potential fish distributions in the study area.

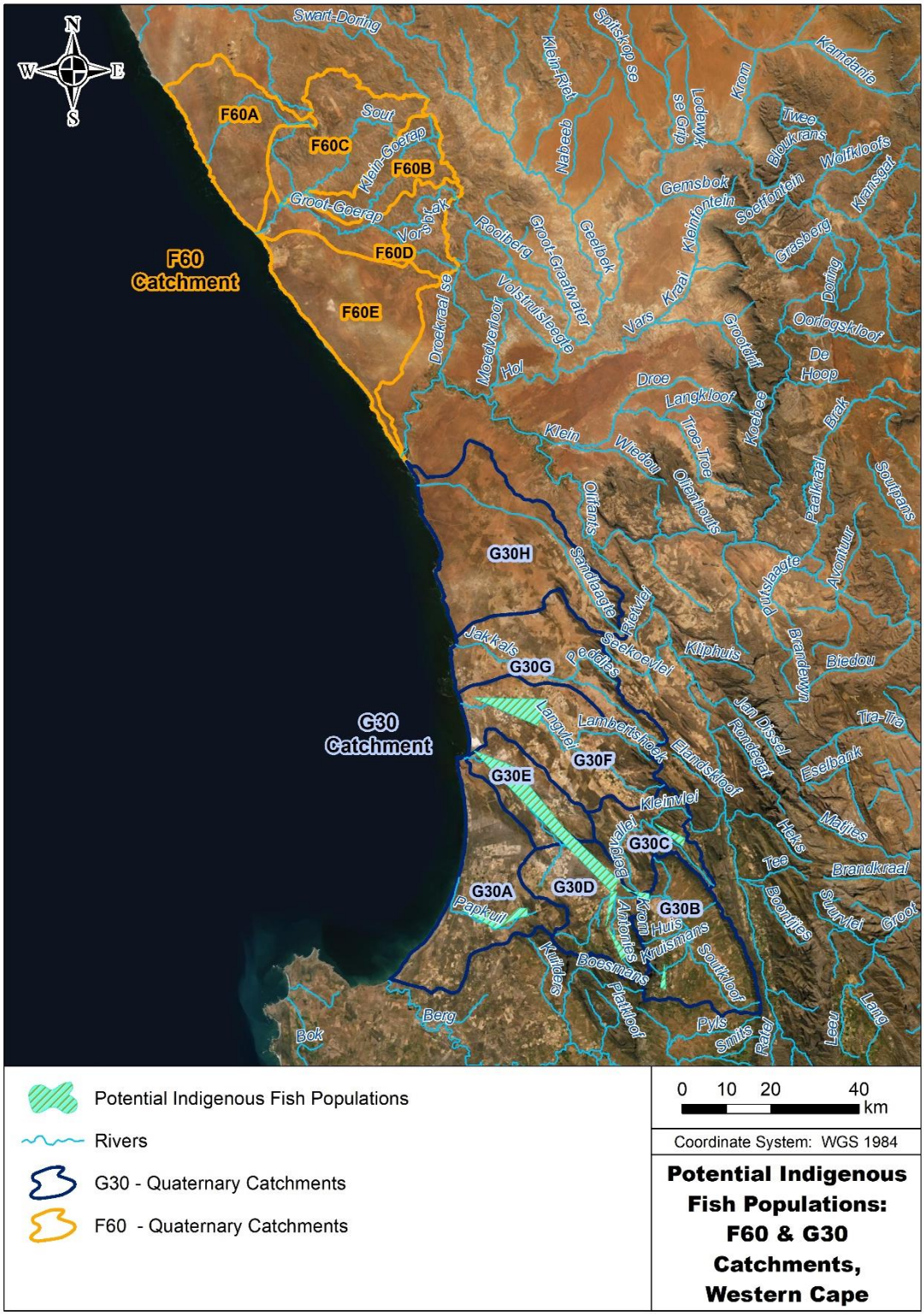

Figure 4. Map indicating the potential indigenous fish populations in the F60 and G30 Catchments

Since 2015, when the last major survey of the Verlorenvlei system took place, there has been a severe drought, one of the worst in living memory in the south-western Cape. This increased the number of boreholes sunk into groundwater aquifers, and so the study area is under increased water abstraction pressure relative to 2015. The field

trip undertaken by the study team from 15 – 18 March highlighted the considerable pressure on ground and surface waters in the study area at this time of the year (end of the dry season) as surface water for fish habitat was extremely limited.

Fish data sources (e.g. Freshwater Biodiversity Information System, Chakona *et al*., 2019) indicate that native freshwater fishes are likely to be found in remnant pools of adequate size and depth (>1m) in the middle and lower reaches of the Verlorenvlei, Papkuils and Langvlei River Systems in the F60 when the first fish survey of this project takes place (end of March). This is where remnant pools are likely to be found at this dry time of the year, and obviously, for fish to survive, they must find these refuges. It is likely that deeper and larger pools (expected mostly in the bigger Verlorenvlei catchment) will have very large native fishes (more than 50 per species). In the Verlorenvlei, some tributaries arise in the higher rainfall Piketberg (e.g. Kruismans, Krom Antonies). We expect to find native fishes in pools and riffles of adequate depth in the upper reaches. Note that we can expect to get three species in the Verlorenvlei (Verlorenvlei redfin, Cape kurper and Cape Galaxias – the latter has two lineages), and two species in the other smaller systems (Cape kurper and Cape Galaxias).

Likely, non-native fishes will also be found in remnant pools in all three systems, especially in the middle and lower reaches. The most likely species to be found is the Banded tilapia *Tilapia sparrmanni*. In the lower Verlorenvlei River, close to the vlei, we may find Mozambique tilapia *Oreochromis mossambicus*, Largemouth bass *Micropertus salmoides* and Carp *Cyprinus carpio* in bigger pools. Hopefully, no new invasive fish will be located in this study, as finding any new invasive fish will place further pressure on the unique and highly threatened native fish community.

Riparian Vegetation

The arid river systems within the northern half of the study area tend to be dry for most of the year, with intermittent flow only after good rains. The rainfall is low, with a MAP around 150mm and most rainfall occurring between June and August. The rivers typically occupy broad river valleys, with sandy alluvial soils with some clayey depressions and sandstone, granite or shale bedrock. These systems also tend to be slightly saline in places. The dominant vegetation type is Azonal Namaqualand River vegetation (AZi 1). The vegetation type is characterised by a mix of succulent shrubs and patches of grasses and, in places, a narrow band of medium to tall trees – usually *Vachellia karroo,* along the edge of the active riverbed.

To the south, the lower river systems are associated with Cape Inland Salt Pans or Marshes. This vegetation type is dominated by small succulent shrubs like *Sarcocornia* spp., common reeds (*Phragmites australis*) rushes such as *Juncus kraussii* and grasses such as *Cynodon dactylon*. The botanical diversity within the river riparian zones is low.

The vegetation mapping for the study area is shown in Figure 5.

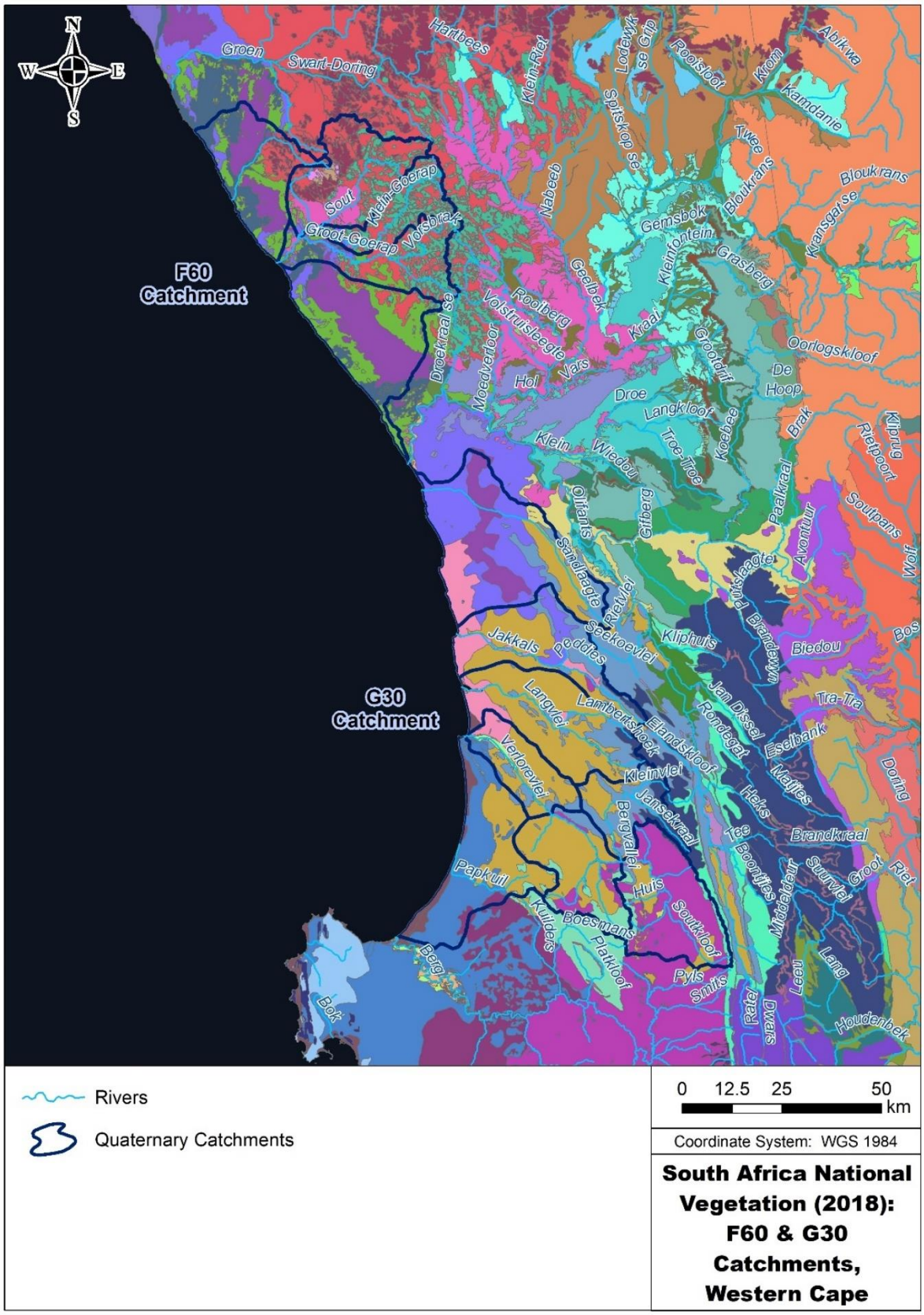

Figure 5. Map of the vegetation types occurring within the F60 and G30 Catchments (the legend for the map is provided on the following page).

3.7. Land and Water Use

The main activity within the G30 catchment is cultivation (potatoes, wheat, mealies, vegetables, rooibos and citrus). In the F60 catchment, cultivation is primarily restricted to the southeastern portion of the catchment, in the upper Groot Goerap Catchment.

Farming with livestock occurs more in the F60 catchment. The 2020 landcover map is included in Figure 6.

Expansion of centre-pivot irrigation followed the introduction of Eskom power lines to the area in the mid-1980s. The unconsolidated sands of the Sandveld are particularly well-suited to the cultivation of potatoes; however, these sands are nutrient-poor, with low moisture retention capacity. Thus significant input of water and nutrients are required for the growing of potatoes.

Between 5 000 and 7 500 ha of potatoes are planted annually in the Sandveld (Potatoes SA regional information for the Sandveld for the period 2013-2018) for the production of seed potatoes, potatoes for the fresh market and potatoes for the processing industry (French fries, crisps and frozen products). A farmer wanting to cultivate 20 hectares of seed potatoes would need to clear four 20 ha circles (80 ha) and cultivate one circle per year, moving the center pivot to the appropriate field each year.

Natural indigenous vegetation, mostly Strandveld, is being cleared to cultivate potatoes. The total number of centre pivots in the potato production area of the Sandveld has been calculated as 1 773 (with a combined area of 30 740 ha) using satellite imagery (2003/4). Analysis of the trend of expansion of the industry between 2000 and 2010 showed that, in the core of the production area (Wadrif to Paleisheuwel to Moutonshoek to Elandsbaai) the number of centre pivot fields increased from 599 to 1 355 and the area from 12 384 ha to 22 871 ha. This was an increase of 84 % in size and 126 % in the number of circles. Over more recent years, the area has shown a trend to change from potatoes to citrus, particularly in the upper parts of the catchment.

Water use by the potato industry in the Sandveld has conservatively been estimated at 46.9 Mm^3/a (Knight *et al.*, 2007; Conrad and Helme, 2007), which equates to about 20% of the (groundwater) recharge for the area. The G30F catchment is the largest but is also the most intensively cultivated and the fastest-growing agriculture area in the Sandveld.

Towns in the Sandveld are all small, and most are supplied from local sources via infrastructure owned and operated by local authorities. The exceptions are Strandfontein and Doringbaai, where there is a transfer of 0.4 million m^3/a of water from the Olifants River Canal near Ebenhaezer via a pipeline from the Lower Olifants Government Scheme to these towns and rural domestic consumers in the vicinity. The other potable water supply schemes in the Sandveld are Graafwater (0.21 million m^3/a from boreholes), Elandsbaai (0.07 million m^3/a from 7 boreholes) and Lambert's Bay (0.8 million m^3/a from a groundwater wellfield). There are no major dams in the area. However, there are many smaller storage dams throughout the area, including both in-channel and off-channel storage dams. The dams are used entirely for agriculture and there are no dams for town water supply purposes.

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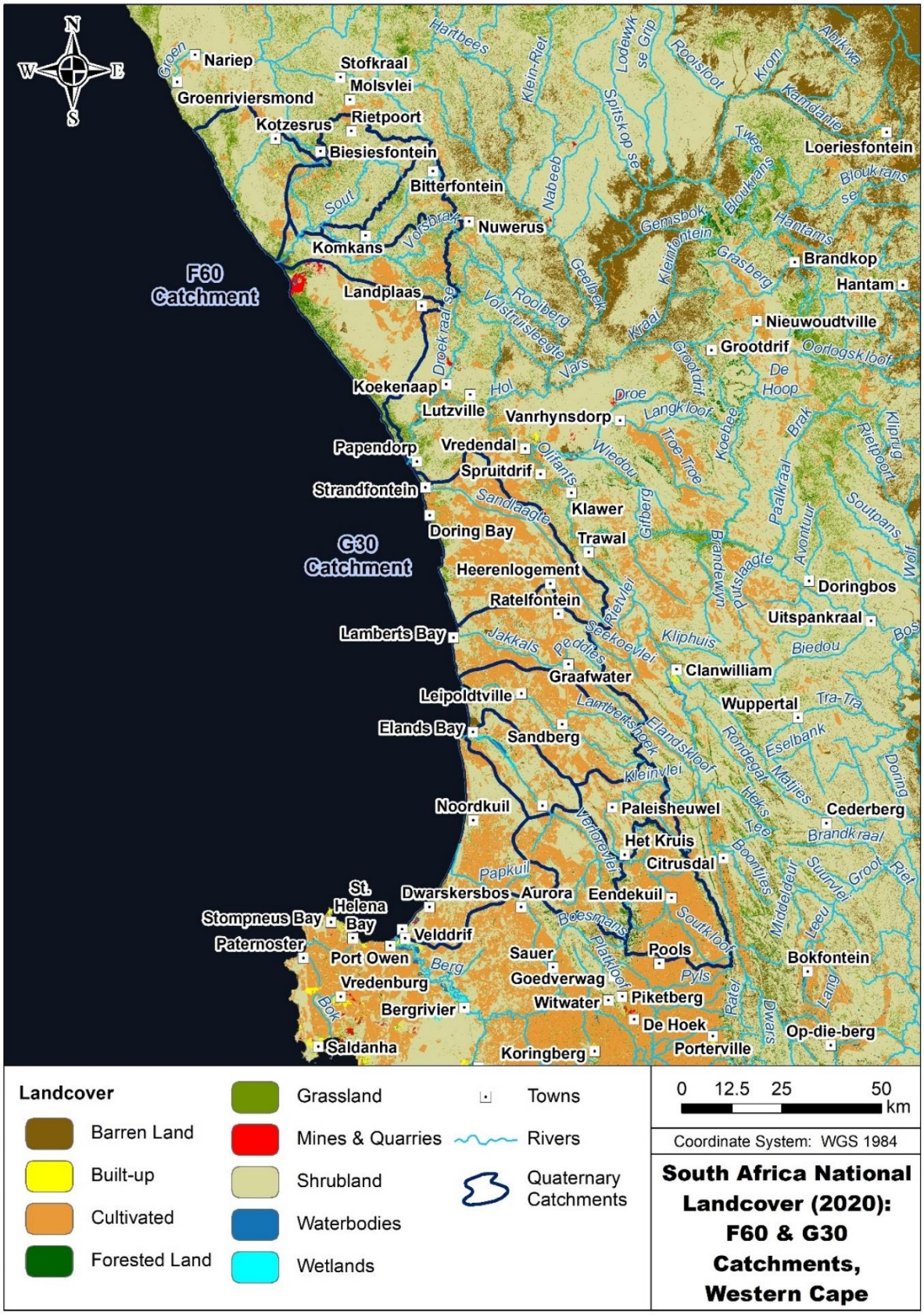

Figure 6. Landcover map (2020) for the F60 and G30 Catchments

3.8. Aquatic Present Ecological Status, Ecological Importance and Ecological Sensitivity

The desktop Present Ecological Status (PES), Ecological Importance (EI) and Ecological Sensitivity (ES) has been determined the various river reaches within the study area, following the procedures in Kleynhans and Louw (2007). The Desktop PES, EI and ES are available at the sub-quaternary level (DWA, 2013) and are summarised in Table 1. Also of significance is the National Freshwater Ecosystem Priority Area (NFEPA) and mapped aquatic Critical Biodiversity Areas. These have been included in Table 4 and Table 9.

3.9. Key River Resource Units

From a rivers perspective, the most logical resource unit is the river catchments. The study area comprises of seven river catchments (Papkuils, Verlorenvlei, Langvlei/Wadrif, Jakkals and Sandlaagte in the G30 catchment and the Sout and Brak in the F60 catchment). The only catchment within the study area that makes sense to subdivide further is the Verlorenvlei and split this into the upper catchment, upstream of the Krom Antonies Tributary, and the lower catchment that includes the Verlorenvlei and Krom Antonies Rivers. The river RUs are shown in Figure 7. The characteristics for each of these RUs is provided in Table 4 and Table 9.

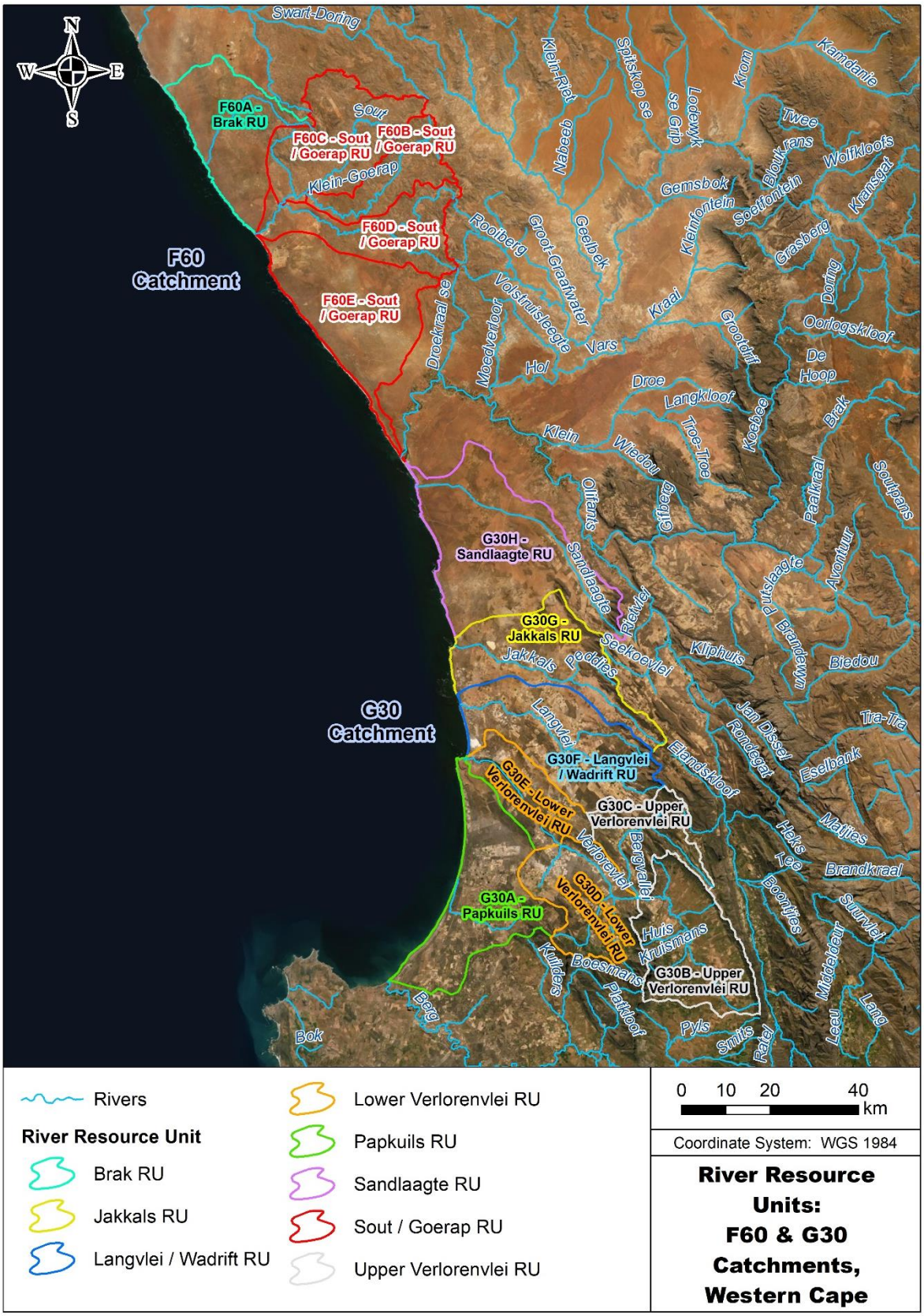

Figure 7. Map showing the River Resource Units within the study area

Table 4: Summary of the main characteristics of the River Resource Units within the F60 Catchment

RIVER RESOURCE UNIT	QUATERNARY	ECOREGION	MAIN RIVER	HYDROLOGICAL INDEX	GEOMORPHIC	ALTITUDE (M)	BIOREGION	GEOLOGY	LANDUSE	EI&ES	PES	REC	RESERVE REGION
Brak RU	F60A	Western Coastal Belt; Namaqua Highlands	Brak	Ephemeral	Mountain Stream to Lower foothill	0-500	Northwest Fynbos, Namaqualand Sandveld & Hardeveld	Marine terrace gravel & sand, red dune sand, loamy & granitic sand, calcrete, dorbank, white calcareous sand	Largely natural with some livestock	High/ High	B	B	West Karoo
Sout/Goerap RU	F60B	Western Coastal Belt; Namaqua Highlands	Klein-Goerap	Ephemeral	Mountain Stream to Lower foothill	0-500	Namaqualand Hardeveld	Aeolian material overlying granites & gneisses of Namaqualand Metamorphic Complex and marine sediments	Largely natural with some livestock; groundwater abstraction at Bitterfontein	High/ High	B	B	West Karoo
	F60C	Namaqua Highlands; Western Coastal Belt	Sout	Ephemeral	Mountain Stream to Lower foothill	0-450	Knersvlakte & Namaqualand Hardeveld	Aeolian material overlying granites & gneisses of Namaqualand Metamorphic Complex and marine sediments	Largely natural with some livestock	High/ High	B	B	West Karoo
	F60D	Western Coastal Belt	Groot Goerap	Ephemeral	Mountain Stream to Lowland	0-500	Knersvlakte, Namaqualand Sandveld & Hardeveld	Aeolian material overlying granites & gneisses of Namaqualand Metamorphic Complex and marine sediments	Largely natural with some livestock	High/ High	B	B	West Karoo
	F60E	Western Coastal Belt	None	N/A	N/A	0-350	Northwest Fynbos, Namaqualand Sandveld & Hardeveld	Aeolian material overlying granites & gneisses of Namaqualand Metamorphic Complex and marine sediments	Largely natural with some livestock; mining activities	N/A	N/A	N/A	West Karoo

Table 5: Summary of the main characteristics of the River Resource Units within the G30 Catchment

RIVER RESOURCE UNIT	QUATERNARY	ECOREGION	MAIN RIVER	HYDROLOGICAL INDEX	GEOMORPHIC	ALTITUDE (M)	BIOREGION	GEOLOGY	LANDUSE	EI&ES	PES	REC	RESERVE REGION
Papkuil RU	G30A	South Western Coastal Belt	Papkuil	Ephemeral	Upper foothill to Lowland	0-550	West Strandveld & Northwest Fynbos	Aeolian sand with underlying greywacke and phyllite and lenses of quart schist, limestone and grit of the Moorreesburg Formation; Malmesbury Group.	Natural areas with planted pastures/crops and groundwater abstraction	Moderate/ High	D	C	West Karoo
Upper Verlorenvlei RU	G30B	South Western Coastal Belt; Western Folded Mnts	Kruismans	Perennial	Mountain Stream to Lower foothill	0-1400	West Coast Renosterveld & Northwest Fynbos	Phyllitic shale, schist, greywacke with limestone and quartzitic sandstone and conglomerate beds of the Porterville Formation; Malmesbury Group.	Natural areas with dryland (wheat) and irrigated (grapes) agriculture; livestock; surface and groundwater abstraction; farm dams	Moderate/ High	D	C	W Cape (dry)
	G30C	South Western Coastal Belt; Western Folded Mnts	Bergvallei	Perennial	Upper foothill to Lowland	0-1250	Northwest Fynbos	Quartzitic sandstone with grit, conglomerate and shale of the Piekenierskloof Formation; Table Mountain Group and shale, schist and greywacke of the Porterville Formation; Malmesbury Group	Natural areas with dryland (rooibos) and irrigated (grapes, citrus, potatoes) agriculture; surface and groundwater abstraction; farm dams	Moderate/ Very High	D	C	W Cape (dry)

RIVER RESOURCE UNIT	QUARTERNARY	ECOREGION	MAIN RIVER	HYDROLOGICAL INDEX	GEOMORPHIC	ALTITUDE (M)	BIOREGION	GEOLOGY	LANDUSE	EI&ES	PES	REC	RESERVE REGION
Lower Verlorenvlei RU	G30D	Western & South Western Coastal Belt	Krom Antonies	Perennial	Mnt headwater to Lowland	0-200	West Coast Renosterveld & Northwest Fynbos	Aeolian sand with some feldspathic grit, greywacke, quartz schist, conglomerate and limestone beds with lenses of phyllite of the Piketberg Formation; Malmesbury Group	Natural areas with dryland (pastures) and irrigated (grapes, citrus, potatoes) agriculture; surface and groundwater abstraction; farm dams	Moderate/ Very High	D	C	W Cape (dry)
	G30E	Western & South Western Coastal Belt; Western Folded Mnts	Verlorenvlei	Seasonal	Mnt headwater to Lower foothill	0-500	Northwest Fynbos & West Strandveld	Aeolian sand with mainly quartzitic sandstone and shale of the Piekenierskloof and Graafwater Formations	Natural areas with dryland (rooibos) and irrigated (grapes, citrus, potatoes) agriculture; surface and groundwater abstractions: Elands Bay abstraction	Moderate/ Very High	D	B	W Cape (dry)
Langvlei/ Wadrif RU	G30F	Western & South Western Coastal Belt; Western Folded Mnts	Langvlei	Ephemeral	Mnt Stream to Lower foothill	0-1200	Northwest Fynbos & West Strandveld	Aeolian sand with mainly quartzitic sandstone and shale of the Piekenierskloof and Graafwater Formations	Natural areas with dryland (rooibos) and irrigated (pastures, wheat, potatoes) agriculture; livestock; groundwater abstractions; Leipoldville and Lamberts Bay groundwater abstraction	Moderate/ Very High	D	C	West Karoo
Jakkals RU	G30G	Western & South Western Coastal Belt; Western Folded Mnts	Jakkals	Ephemeral	Mnt Stream to Lower foothill	0-800	Northwest Fynbos & Namaqualand Sandveld	Aeolian sand with underlying marine sediments with quartzitic sandstone	Natural areas with dryland (pastures, rooibos) and irrigated (wheat) agriculture; livestock; groundwater abstraction	Moderate/ Very High	D	C	West Karoo
Sandlaagte RU	G30H	Western & South Western Coastal Belt	Sandlaagte	Ephemeral	Mountain Stream to Lower foothill	0-700	Northwest Fynbos & Namaqualand Sandveld	Aeolian sand with underlying marine sediments with quartzitic sandstone	Natural areas with dryland (pastures) agriculture; groundwater abstraction	Moderate/ Very High	D	C	West Karoo

4. Wetlands

When the rapid Reserve determination study was undertaken for the Sandveld area (DWAF, 2003), the only EWR site that was selected within a Wetland Resource Unit was the site within the Wadrift peatland wetland at the lower end of the Langvlei system (see list of EWR sites and Resource Units in Table 1, Section 3.2). All the other sites were treated as part of River or Estuary Resource Units. As such, one of the key aims of the current study is to provide a much better representation of wetland ecosystems in the F60 and G30 catchment areas and to derive EWRs for a number of Wetland Resource Units, in addition to (or together with) those that are to be derived for River and Estuary Resource Units.

4.1. Approach taken to the selection of Wetland Resource Units

The selection of appropriate Wetland Resource Units was rather challenging, with such a large study area containing a great number and diversity of wetlands. The main goal of the exercise was to select wetlands that constitute significant inland aquatic ecosystems within the study area, which are either critical for sustained water supply or under threat from water use activities in the study area in addition to being of ecological and importance. This is somewhat different to the usual goal of wetland prioritisation in a biodiversity planning (e.g. Snaddon & Day, 2009; Nel *et al*., 2011) or wetland rehabilitation (e.g. Snaddon & Nieuwoudt, 2019) context, where the aim is typically to identify a subset of wetlands that are most worthy of conservation or rehabilitation, respectively.

The goal in the current project is also different to that in a RQO study, where one is selecting sites within Integrated Units of Analysis for the setting of RQOs as part of a water resource classification process. One of the particular challenges of the current study is that only a small number of Wetland Resource Units could be selected because of budgetary constraints and the need to determine EWRs at a relatively high degree of confidence and resolution. Consequently, it was not possible to follow the same procedures for wetland prioritisation that have been used in these other types of studies and a tailor-made approach was required.

The approach taken to the selection of Wetland Resource Units in Tertiary Catchments F60 and G30 was as follows:

- Wetlands already captured on National Wetland Map Version 5 (NWM5) (after Van Deventer *et al*., 2018) were clipped to the study area, and features categorised as "river" or "estuary" were removed so as to create a preliminary inland wetland map for the study area.
- Wetlands captured in the wetland layer of the National Freshwater Ecosystems Priority Areas (NFEPA) project (after Nel *et al*., 2011) and which were not captured on NWM5 were added to the preliminary map by performing a "difference" operation in GIS and then joining the additional non-estuarine and non-riverine features that were greater than 3 ha in extent.

- Each wetland feature was categorised into one of the following HGM types (after Ollis *et al*., 2013) by using the HGM typing from NWM5 and (for wetlands not included on NWM5) NFEPA: Floodplain wetland (FP), Channelled valley-bottom wetland (CVB), Unchannelled valley-bottom wetland (UVB), Seep, Depression (DEP), and Flat.

- All wetland features smaller than 1 ha in size were removed from the combined NWM5-NFEPA wetland map for the study area, so as to only retain wetlands of potential significance and to reduce the number of wetlands that needed to be considered in further analyses.

- Consideration was given to the inclusion of wetlands mapped as part of the Western Cape Biodiversity Plan (after Pool-Stanvliet *et al*., 2017) and the Namakwa District Biodiversity Sector Plan (after Desmet & Marsh, 2008), but the mapping of wetlands from both of these strategic biodiversity conservation planning initiatives did not incorporate categorisation of the HGM type and categorised all wetland features as Critical Biodiversity Areas (CBAs) instead of distinguishing between wetlands in terms of their relative conservation importance. Furthermore, upon investigation of the mapping in the study area, most of the wetland areas mapped through these initiatives were captured by the mapping completed for NWM5 and/or NFEPA. The wetlands included in these spatial plans were thus not incorporated into the desktop-based wetland map prepared for the current project.

- Bioregions of southern Africa (after Rutherford *et al*., 2006), which were originally derived for the National Vegetation Map (Mucina & Rutherford, 2006) and used for the wetland component of the National Biodiversity Assessment of 2018 (NBA-2018) (Van Deventer *et al*., 2019), were clipped to the study area to aid in the bioregional grouping of wetlands.

- Bioregion Groups were derived by amalgamating the smaller Bioregions in each Tertiary Catchment area into the larger neighbouring Bioregions, so as to reduce the complexity and avoid small regions with few wetlands, as recommended in the procedures developed for the setting of RQOs for wetlands (Bredin *et al*., 2019). In Catchment F60, the Namaqualand Hardeveld Bioregion was amalgamated with the Knersvlakte Bioregion to form the "Hardeveld-Knersvlakte Bioregion Group", while in Catchment G30 the relatively small area of the South-West Fynbos Bioregion in the study area was amalgamated with the larger North-West Fynbos Bioregion (also present in Catchment F60) to form the "NW-SW Fynbos Bioregion Group".

- For each Tertiary Catchment within the study area, a summary table was produced showing the number of wetlands greater than 1 ha in extent of each HGM type within each Bioregion Group, so as to provide an indication of the diversity and distribution of wetland types within the study area.

- The Freshwater Ecosystem Priority Area (FEPA) wetlands identified through the NFEPA project were overlaid on the desktop-based wetland map that was produced for the study area, to assist in the identification of wetlands of conservation importance.

- Consideration was also given to the Ecosystem Threat Status (ETS) of the various wetland types, as derived through the wetland component of NBA-2018, and the

size of the mapped wetlands. Priority was given to threatened ecosystem types and to larger (typically more significant) wetlands and, in the case of valley-bottom and floodplain wetlands, to wetlands lower down in the Quaternary catchment areas where the setting of EWRs generally provides a more integrated environment. Wetlands known to be under threat from abstraction-related impacts (e.g. the Wadrift wetland at the lower end of the Langvlei system in Catchment G30) or of particular conservation importance (e.g. Rocherpan) were also prioritised for selection.

- An additional factor that was taken into account was the potential supply of ecosystem services by the mapped wetlands. This was simply based on the HGM-specific assumptions about wetland ecosystem service provision developed for the desktop-based application of WET-EcoServices Version 2 (after Kotze *et al*., 2020), instead of a more complex modelling exercise based on land use and other variables, such as that used in the Breede-Gouritz Wetland RQO study (DWS, 2018) and put forward in the procedures developed to determine RQOs for wetlands (Bredin *et al*., 2019). In particular, for the current study, the provision of streamflow regulation in the study area, especially Tertiary Catchment G30, was considered to be important. This water-stressed catchment has been subject to the abstraction of significant quantities of groundwater, which would typically sustain baseflows to wetlands during the dry season. Seeps with channelled outflow are rated to be of the greatest importance for this service in semi-arid to arid regions, according to Kotze *et al*., (2020), as indicated by a score of 3 (out of a maximum of 4) in Table 5. The location of known springs and groundwater seepage areas, as supplied by GEOSS, were used to aid in the selection of wetland areas where the ecosystem services of water provision and streamflow regulation are likely to be provided to a relatively high degree by wetlands.

- Potentially important wetland "target areas" in each of the study areas were demarcated through the process described above. Thereafter, a reconnaissance field trip was undertaken by the study team (from 16-18 March 2022) to refine the selection, taking into account factors such as the observed PES of the wetlands and accessibility.

Table 5 contains the results from a preliminary rating of the ecosystem services potentially supplied by the wetland type within the study area when taking into account their climatic settling.

Table 5: Preliminary rating[1] of the ecosystem services potentially supplied by a wetland based upon its hydrogeomorphic (HGM) wetland type, and climatic setting (scores for humid to sub-humid regions in green; scores for semi-arid regions in orange) [from Kotze *et al*., 2020]

Ecosystem services: / HGM types	Flood attenuation	Sediment trapping	Erosion control	Streamflow regulation	Water quality regulation	Carbon storage	Water provision	Grazing	Plants for crafts & construction	Medicinal plants	Indigenous/ wild foods	Cultivated foods	Tourism & recreation
Floodplain wetland[2]	3.5	3	3	1	3	2.5	3	4	3	3	3	4	4
	4	3.5	3	0.5	2.5	1.5	2	4	2	2.5	3	4	4
Valley-bottom wetland, channelled	2	3	3	2	3.5	2.5	3	3	3	4	2	3	3
	3	3	3	1.5	3	1.5	2	3	2.5	3	2	3	2.5
Valley-bottom wetland, unchannelled	2.5	4	4	1.5	4	4	3	3	4	3	2	3	3
	3.5	4	4	1	3.5	2	2	3.5	3.5	2.5	2	3	2.5
Seep with channelled outflow[3]	1.5	1	3	3	2	3	4	3	3	4	2	3	2
	2	1	3	3	1.5	2	3	3	2.5	3.5	2	3	2
Seep without channelled outflow	1.5	1	2	1	1.5	2.5	1.5	3	2	3	1	3	2
	2	1	2	0.5	1	1	0.5	2	1.5	2	1	2	1.5
Depression, exorheic[4]	2	1	1	1	2	3	3	3	2	1	3	2	3
	2.5	1	1	0.5	1.5	1.5	1	1.5	1.5	1	3	2	2
Depression, endorheic	2	1	1	0	1	2	1	2	1	1	3	1	3
	2.5	1	1	0	0.5	1	0	1	0.5	0.5	2	0	2
River channel	2	2	3	2	2.5	1	4	2	2	2	3	1	4
	2.5	2	3	2	2	0.5	2.5	2	2	2	3	1	3

[1] *A score of 0 indicates a likely absence of the service, 2 an intermediate importance and 4 a very high importance.*

[2] *A floodplain wetland is taken as typically comprising predominantly floodplain flat with floodplain depressions contained within the flat. If a particular floodplain unit is characterized by the very limited extent of depressions, then this unit is probably best treated as a channelled valley bottom unless it is particularly wide (i.e. > 500 m).*

[3] *A seep with channelled outflow is assumed to be supplied with a sustained source of sub-surface water, including groundwater and deep interflow.*

[4] *Exorheic depressions generally experience flushing, which prevents the accumulation of solutes. However, under arid conditions this flushing will often be inadequate to prevent such accumulations, and therefore under arid conditions these depressions may need to be treated as endorheic in terms of water provision.*

It is important to note that the selection of Wetland Resource Units for EWR determination in the study area was not a semi-automated desktop-based exercise but rather involved the application of expert judgement, including that obtained through discussions between team members during the reconnaissance field trip. The rationale for selecting each Resource Unit is provided in Section 4.4, below, following a presentation of the results of the desktop-based mapping of wetlands in the study area and a brief description of the selected Units.

4.2. Desktop-based mapping of wetlands in the study area

Maps of the wetlands greater than 1 ha in extent delineated on a desktop basis in the study area are presented below for Tertiary Catchments F60 (Figure 8) and G30 (Figure 10), and within each bioregion in Figure 9 and Figure 11.

Figure 8. Map of Wetlands in the F60 Catchment

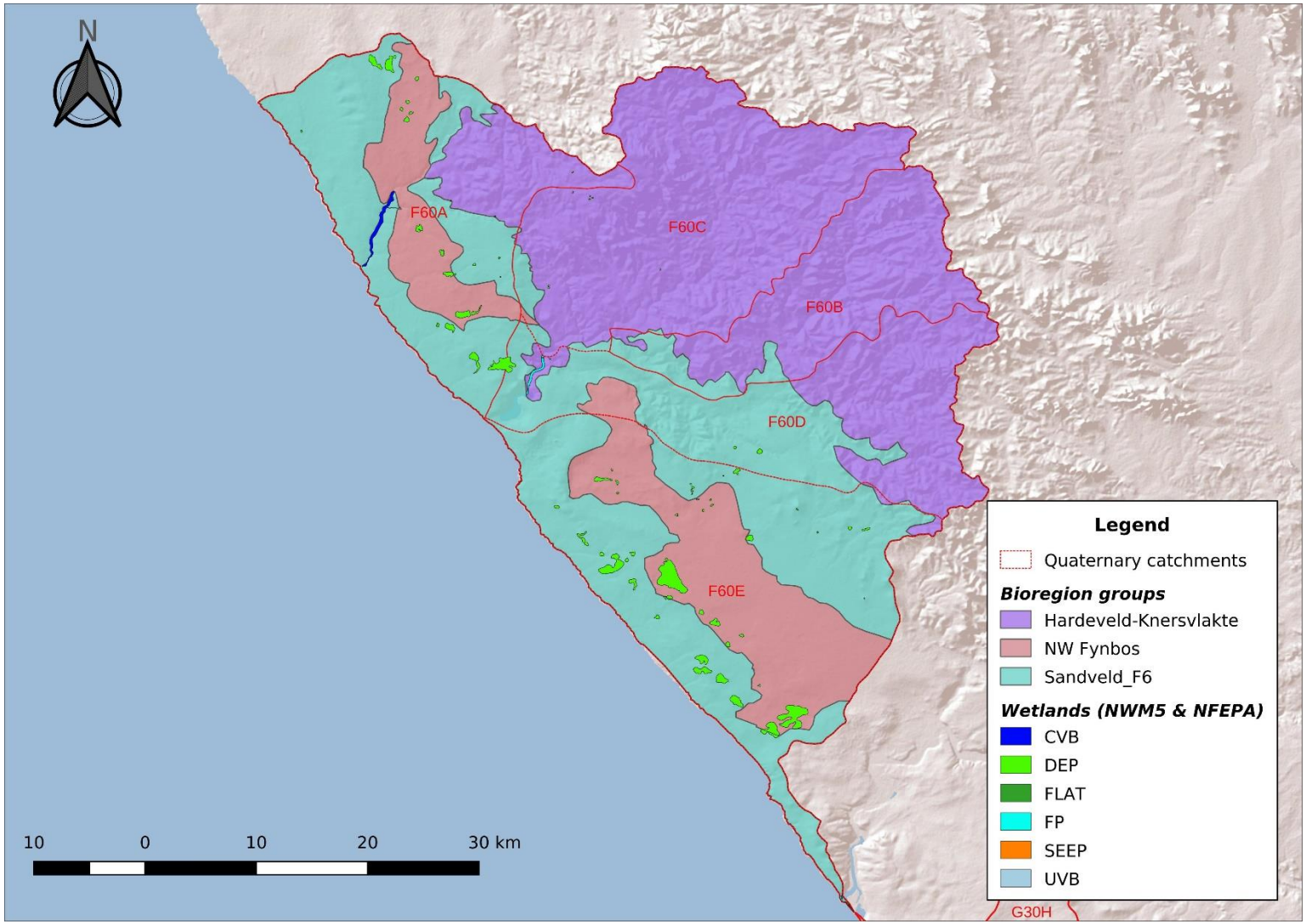

Figure 9. Map of wetlands in Tertiary Catchment F60, categorised by HGM type, shown in relation to the Bioregion Groups in the Catchment

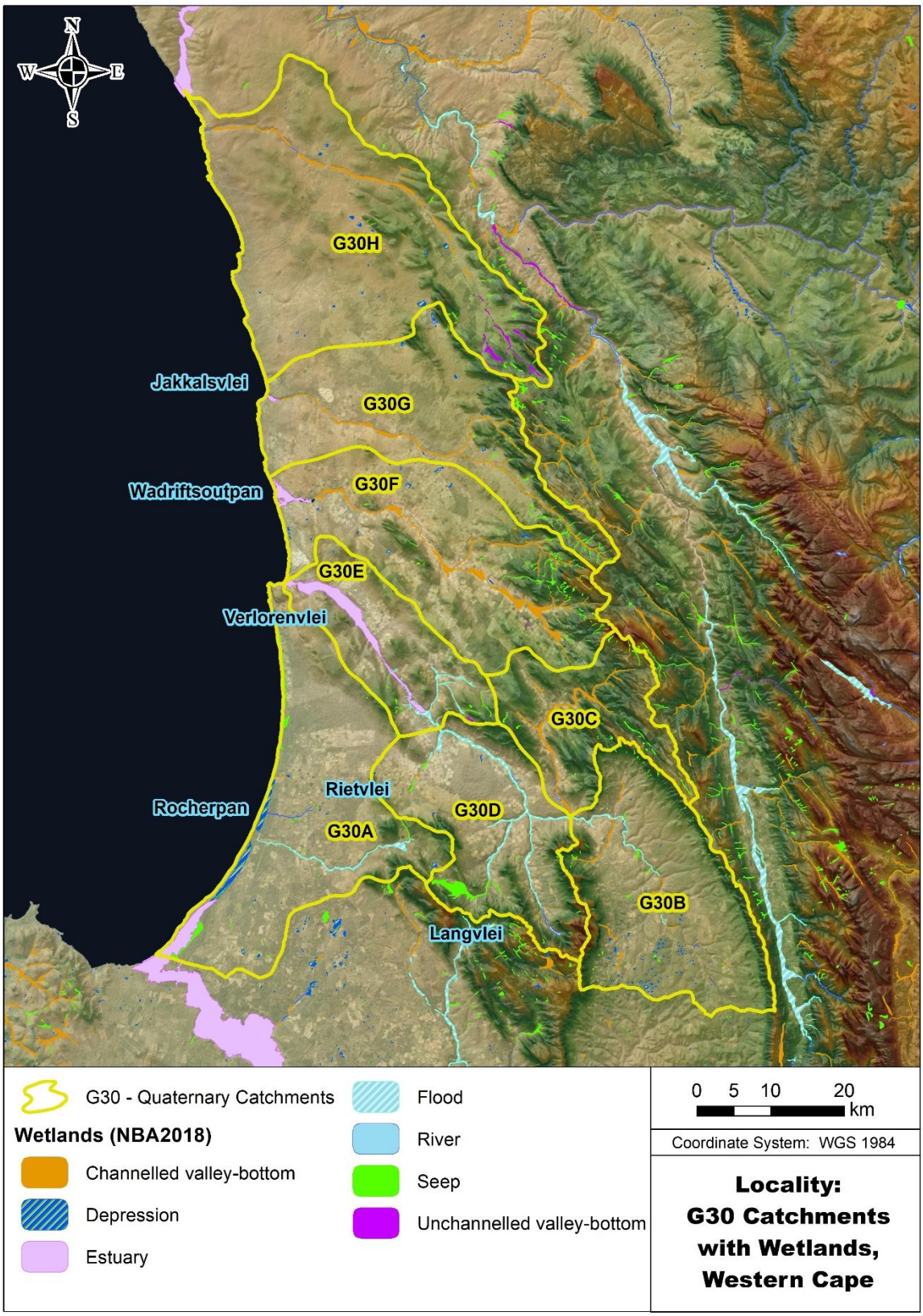

Figure 10. Map of Wetlands in the G30 Catchment

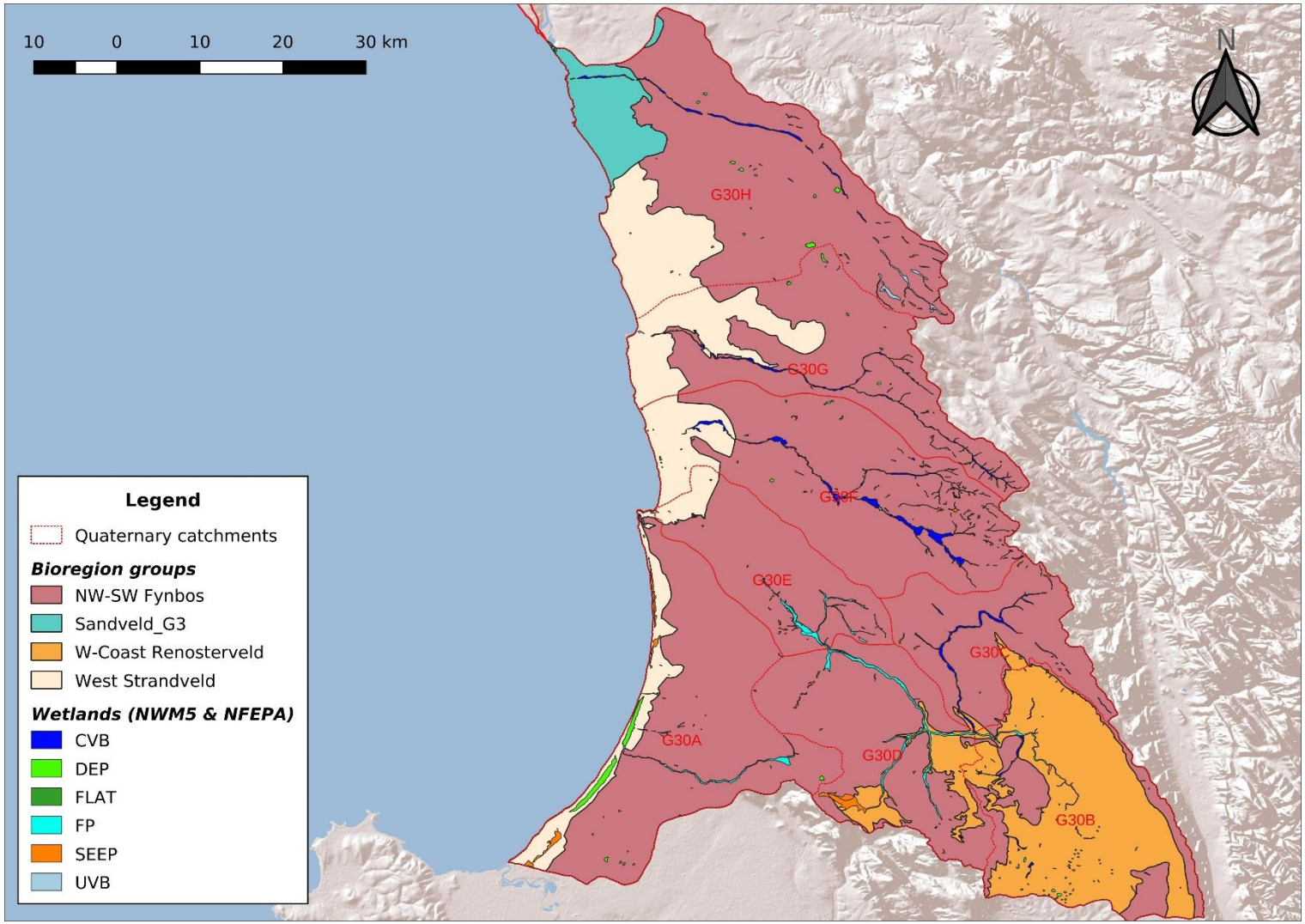

Figure 11. Map of wetlands in Tertiary Catchment G30, categorised by HGM type, shown in relation to the Bioregion Groups in the Catchment

A summary table of the results is presented in Table 6, below.

Table 6: Number of wetlands of each HGM type* within each of the Bioregion Groups delineated in Tertiary Catchments F60 and G30 (Ecosystem Threat Status of each wetland type/group also given, according to the NBA-2018 wetland assessment)**

Catchment	Bioregion group	HGM type	NBA-2018 ETS	Number of wetlands		
F60	Hardeveld-Knersvlakte	FP	CR	1	11	86
		UVB	CR	1		
		SEEP	CR	1		
		DEP	LC	8		
	NW Fynbos	DEP	EN	29	29	
	Sandveld_F6	FP	CR	2	46	
		CVB	CR	1		
		SEEP	LC	1		
		DEP	CR	41		
		FLAT	n/a	1		
G30	NW-SW Fynbos	FP	CR	21	280	429
		CVB	CR	48		
		UVB	CR	14		
		SEEP	VU	148		
		DEP	EN	48		
		FLAT	n/a	1		
	Sandveld_G3	FP	CR	2	8	
		CVB	CR	3		
		SEEP	LC	1		
		FLAT	n/a	2		
	W-Coast Renosterveld	FP	CR	4	99	
		CVB	CR	15		
		UVB	CR	1		
		SEEP	CR	32		
		DEP	CR	47		
	West Strandveld	FP	CR	6	42	
		CVB	CR	8		
		UVB	CR	3		
		SEEP	CR	10		
		DEP	CR	15		

** HGM types: FP = Floodplain wetland; CVB = Channelled valley-bottom wetland; UVB = Unchanneled valley-bottom wetland; SEEP = Seep; DEP = Depression; FLAT = Wetland Flat*

*** Ecosystem Threat Status (ETS) rating categories: CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern*

These results show that the Bioregion groups with the least wetlands are the Hardeveld-Knersvlakte in Catchment F60 (11 mapped wetlands in the entire Bioregion area) and the Sandveld Bioregion in Catchment G30 (only eight mapped wetlands) and that the most abundant HGM type within all of the Bioregion groups in Catchment F60 is clearly depressions.

The NW-SW Fynbos Bioregion group contains the most wetlands (280), approximately half of which are seeps. Depressions, Channelled Valley Bottom (CVB) wetlands and,

to less degree, Floodplain (FP) wetlands are also well represented in this Bioregion area.

Seeps and depressions are the most common HGM types, followed by CVB wetlands, in both the W-Coast Renosterveld and West Strandveld Bioregion areas. In total, only 86 wetlands greater than 1 ha in extent were mapped in Catchment F60, versus a total of 429 in Catchment G30.

4.3. Description of selected Wetland Resource Units

A list of the Wetland Resource Units that were selected in each of the two Tertiary Catchments making up the study area is provided in Table 7 and Table 8. Maps showing the location of the Resource Units in Tertiary Catchments F60 and G30 are presented in Figure 12 and Figure 13, respectively.

Table 7 and Table 8 give the name of each Resource Unit (RU), together with an indication of the Quaternary catchment and Bioregion group that each RU falls into as well as the HGM type of the RU. In addition, the modelled PES of each Wetland RU, as derived on a desktop-basis by the NFEPA-2011 and NBA-2018 assessments, is given together with an indication of the FEPA status (from NFEPA) and Ecosystem Threat Status (from NBA-2018) of each RU. A brief description of the EWR site that was chosen for each Wetland RU is also provided in the tables. The selection of EWR sites is discussed in more detail in Section 4.5 and Chapter 5.

Table 7: List of Wetland Resource Units (RUs) that were selected in Tertiary catchment F60, together with descriptive information for each RU

Tertiary catchment	Quaternary catchment	Wetland RU name	Site	Bioregion group	HGM type	PES_NFEPA (FEPA status)	PES_NBA'18 (ETS)
F60	F60A	Lower Brak River VB wetland	Above EFZ on Farm RE/559 Strandfontein	Sandveld_F6	CVB	A/B (non-FEPA)	- (CR)
	F60A	NW Fynbos depression	On Farm RE/641 Nuwe-Begin	NW Fynbos	DEP	A/B (FEPA)	A/B (EN)
	F60C	Knersvlakte depression	On Farm RE/145 Adoonsvlei	Hardeveld-Knersvlakte	DEP	A/B (FEPA)	A/B (LC)
	F60E	Sandveld depression	On Ptn 18/20 of Farm 158 Elsie Erasmus Kloof	Sandveld_F6	DEP	C (non-FEPA)	A/B (CR)

Table 8: List of Wetland Resource Units (RUs) that were selected in Tertiary catchment G30, together with descriptive information for each RU

Tertiary catchment	Quaternary catchment	Wetland RU name	Site	Bioregion group	HGM type	PES_NFEPA (FEPA status)	PES_NBA'18 (ETS)
G30	G30G	Lower Jakkals River VB wetland	Above EFZ on Ptn 3 of Farm 88 Kookfontein	NW-SW Fynbos	CVB	C (FEPA)	D/E/F (CR)
	G30F	Lower Langvlei VB wetland	On Ptn 23 of Farm 226 Branswacht	West Strandveld	UVB	C (FEPA)	D/E/F (CR)
	G30F	Wadrift VB wetland (Lower Langvlei)	On Farm RE/230 Wagendrift	West Strandveld	UVB	C (FEPA)	- (CR)
	G30D	Upper Verlorenvlei River VB wetland	Above R366 bridge on Ptn 1 of Farm 42 Eenheid	W-Coast Renostervel d	CVB	C (FEPA)	D/E/F (CR)
	G30D	Krom-Antonies River FP wetland	u//s Verlorenvlei R confl. on Farm RE/40 Goergap	W-Coast Renostervel d	FP	C (FEPA)	D/E/F (CR)
	G30E	Lower Verlorenvlei River FP wetland	Edge of EFZ on Ptn 4 of Farm 4 Wittedrift	NW-SW Fynbos	FP	C (FEPA)	- (CR)
	G30A	West Strandveld duneslack wetland	Above tar road on Ptn 27 of Farm 277	West Strandveld	DEP	C (FEPA)	D/E/F (CR)
	G30A	Rocherpan	Within Nature Reserve on Farm 272	West Strandveld	DEP	A/B (FEPA)	D/E/F (CR)
	G30A	Lower Papkuils FP wetland	Above railway line on Ptn 1 of Farm 30 Bookram	NW-SW Fynbos	FP	C (FEPA)	D/E/F (CR)
	G30A	Upper Papkuils seep	On Ptn 3 of Farm 18 Rietfontein	NW-SW Fynbos	SEEP	C (FEPA)	D/E/F (VU)

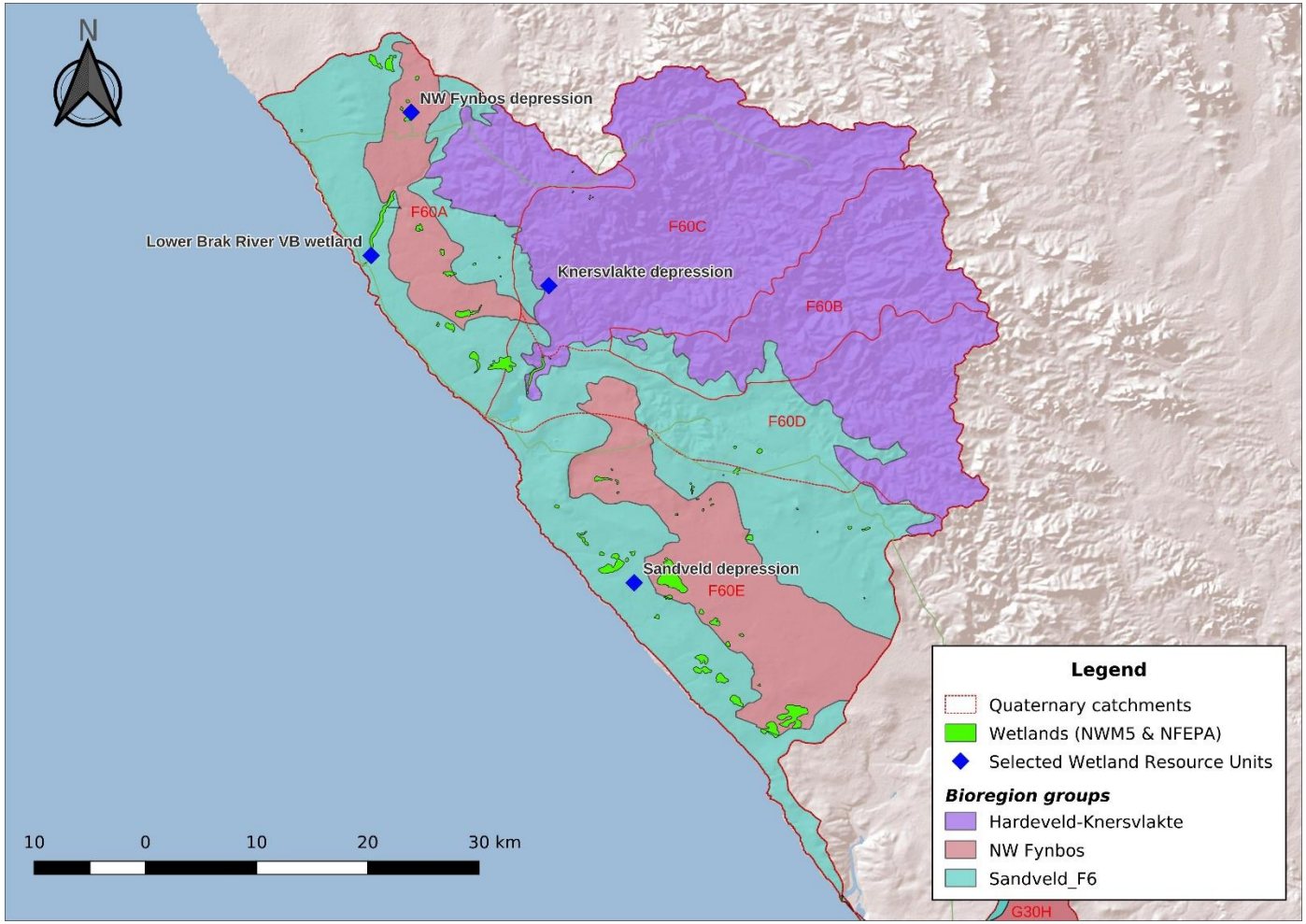

Figure 12. Map of selected Wetland Resource Units in Tertiary Catchment F60, shown in relation to the Bioregion Groups in the Catchment

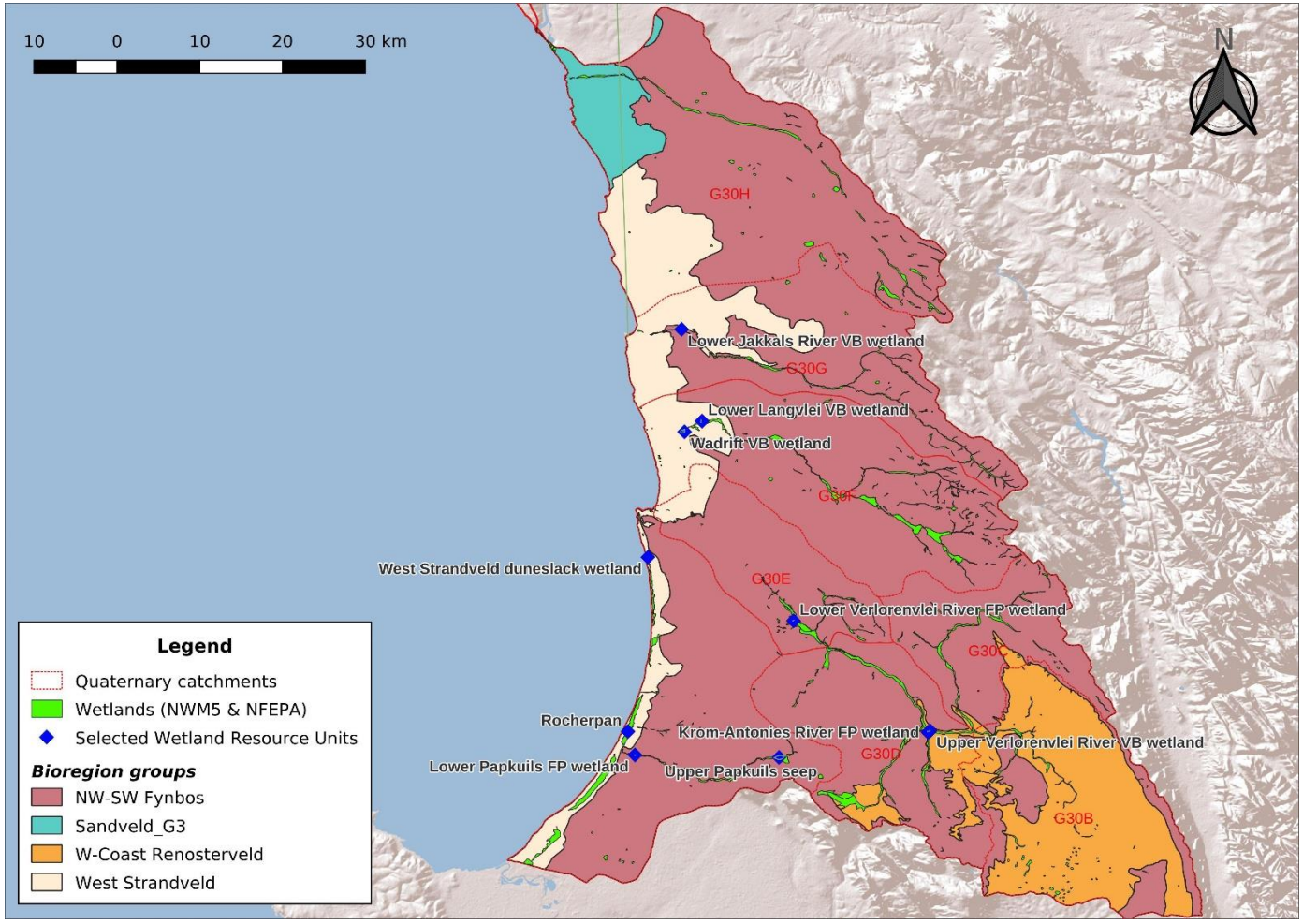

Figure 13. Map of selected Wetland Resource Units in Tertiary Catchment G30, shown in relation to the Bioregion Groups in the Catchment

4.4. Rationale for selection of each Wetland Resource Unit

The rationale for selecting Wetland RUs in each Tertiary Catchment is summarised below.

Tertiary Catchment F60

Lower Brak River VB wetland:

- This is one of the most extensive VB wetland areas upstream of the Estuarine Functional Zone in Catchment F60, according to the mapping by NWM5, NFEPA and WCBSP;
- It is a CR ecosystem type (Namaqualand Sandveld VB wetland) in terms of the wetland component of NBA-2018.
- Portions of the wetland appear to be in a relatively good PES, with intact within-wetland vegetation;
- It is probably the best non-depressional wetland in Catchment F60 to select as a Wetland RU to ensure a good representation of the different types of wetlands in the study area.

NW Fynbos depression:

- A good example of a depression wetland in the NW Fynbos Bioregion within Catchment F60;
- Representative of an EN ecosystem type (NW Fynbos depression) according to the wetland component of NBA-2018;
- It appears to be in reasonable PES compared to other depression wetlands in the same bioregion;
- Is relatively large and thus of significance;
- This wetland does seem to be subject to some usage.

Knersvlakte depression:

- A good example of a depression wetland in the Knersvlakte Bioregion;
- Categorised as a FEPA by the NFEPA project;
- It appears to be in relatively good PES;
- Is relatively large compared to other depression wetlands in the same bioregion.

Sandveld depression:

- A good example of a depression wetland in the Namaqualand Sandveld Bioregion within Catchment F60;
- Representative of a CR ecosystem type (Namaqualand Sandveld depression) according to the wetland component of NBA-2018;
- It appears to be in relatively good PES compared to other depression wetlands in the same bioregion;
- Is relatively large and thus of significance.

Tertiary Catchment G30

Lower Jakkals River VB wetland:

- This is the primary wetland system in Quaternary Catchment G30G;
- Categorised as a FEPA by the NFEPA project;
- It is a CR ecosystem type (NW Fynbos VB wetland) in terms of the wetland component of NBA-2018.
- Portions of the wetland appear to be in a reasonable PES, with intact within-wetland vegetation;
- This wetland does appear to be subject to some usage and is under threat from abstraction in the surrounding catchment area.

Lower Langvlei VB wetland:

- This is the primary wetland system in Quaternary Catchment G30F;
- Categorised as a FEPA by the NFEPA project;
- It is a CR ecosystem type (West Strandveld VB wetland) in terms of the wetland component of NBA-2018.
- This wetland is located upstream of the ecologically important Wadrift wetland (see below) and estuary, and forms an integral component of the Wadrift system;
- This wetland appears to be subject to significant usage. It is under severe threat from abstraction, including the wellfield for water supply to the town of Lambert's Bay, and agricultural impacts in the surrounding catchment area.

Wadrift VB wetland (Lower Langvlei):

- This is the only wetland ecosystem in the study area that was included in the previous EWR study (DWAF, 2003);
- Categorised as a FEPA by the NFEPA project;
- It is a CR ecosystem type (West Strandveld VB wetland) in terms of the wetland component of NBA-2018.
- This is an ecologically important wetland, albeit highly degraded in terms of its PES, which contains peat;
- This wetland has been subject to significant usage and is under severe threat from abstraction, including the wellfield for water supply to the town of Lambert's Bay. It is also affected by direct impacts from the surrounding area, including grazing by livestock and a peat fire that burned continuously for a few years several years ago.

Upper Verlorenvlei River VB wetland:

- This is the main wetland system in Quaternary Catchment G30D;
- Categorised as a FEPA by the NFEPA project;
- It is a CR ecosystem type (W-Coast Renosterveld VB wetland) in terms of the wetland component of NBA-2018.
- This wetland is located upstream of the ecologically important Verlorenvlei Ramsar wetland (largely dealt with as an estuarine ecosystem in the current study);
- Located downstream of the confluence of the Kruismans and Bergvallei Rivers, thus reflecting the impacts from these two upper catchments of the Verlorenvlei system;
- This wetland is subject to significant impacts and is under threat from abstraction-related impacts.

Krom-Antonies River FP wetland:

- The Krom-Antonies catchment is one of the main catchment areas feeding into the Verlorenvlei system;
- FP wetland along the Krom-Antonies River is categorised as a FEPA by the NFEPA project;
- It is a CR ecosystem type (W-Coast Renosterveld FP wetland) in terms of the wetland component of NBA-2018.

- This wetland forms a tributary extension of the ecologically important upper to middle reaches of the Verlorenvlei FP wetland along the Verlorenvlei River;
- This wetland is subject to significant impacts and is under threat from abstraction-related impacts.

Lower Verlorenvlei River FP wetland:

- This is the upper portion of Verlorenvlei, immediately upstream of the estuarine zone;
- Categorised as a FEPA by the NFEPA project;
- It is a CR ecosystem type (NW Fynbos FP wetland) in terms of the wetland component of NBA-2018.
- This wetland essentially forms the upper (non-estuarine) limit of the ecologically important Verlorenvlei Ramsar wetland;
- This wetland is subject to significant impacts and is under threat from abstraction-related impacts.

West Strandveld duneslack wetland:

- A good example of a depression (dune slack) wetland in the West Strandveld Bioregion;
- Representative of a CR ecosystem type (West Strandveld depression) according to the wetland component of NBA-2018;
- Categorised as a FEPA by the NFEPA project;
- Appears to be in relatively good PES compared to other depression wetlands in the same bioregion.

Rocherpan:

- Wetland of very high importance for nature-based tourism, as a birding hotspot within a nature reserve;
- Representative of a CR ecosystem type (West Strandveld depression) according to the wetland component of NBA-2018;
- Categorised as a FEPA by the NFEPA project;
- Is relatively large and thus of significance;

- The artificially manipulated hydrology of this wetland is under threat due to over-abstraction from the Papkuils system (see below), which is diverted into Rocherpan.

Lower Papkuils FP wetland:

- The lower end of the main drainage system flowing through Quaternary Catchment G30A;
- Categorised as a FEPA by the NFEPA project;
- It is a CR ecosystem type (NW Fynbos FP wetland) in terms of the wetland component of NBA-2018.
- Water flowing out of this wetland is diverted into Rocherpan (via a diversion channel) to provide water for wading birds;
- This wetland is subject to significant impacts and is under threat from abstraction-related impacts in the catchment.

Upper Papkuils seep:

- The upper end of the main drainage system flowing through Quaternary Catchment G30A;
- Categorised as a FEPA by the NFEPA project;
- Essentially the source of the Papkuils system, fed by groundwater inflows;
- Wetland appears to be in relatively good PES;
- The best example of a relatively extensive seep wetland (assumed to be of particular importance for provision of streamflow regulation as an ecosystem service) in Quaternary catchment G30A and one of the most extensive seep wetlands in the whole study area.

4.5. Selection of EWR sites within Resource Units

Proposed EWR sites were selected within each of the Wetland Resource Units during the reconnaissance field survey undertaken in March 2022. The EWR sites were selected together with the EWR sites/reaches for the River Resource Units to facilitate integration. Details of all the sites are provided in Chapter 7 and the rationale for their selection.

5. ESTUARIES

5.1. Delineation approach

By nature, estuaries are constantly changing both temporally and spatially, and as a consequence they do not have permanent or static habitat structures. While the total habitat area occupied by various biotic and abiotic habitat types within an estuary tends to remain more or less constant over long time scales, the actual location of these habitats is likely to be highly variable between resetting events (e.g. larger floods on decadal scales).

A fundamental constraint associated with the assessment and management of estuaries is defining their spatial extent (i.e. the smallest management unit or boundary) due to estuarine habitats' dynamic nature (Van Niekerk and Taljaard, 2003). Biodiversity protection and the wise use of our estuarine resources require the protection of estuarine habitat and biota and the protection of the physical processes that sustain ecological and evolutionary processes. To do this, it is important to define the 'space' within which estuaries function over long time scales to safeguard the present and future health – the so-called 'estuarine functional zone' (EFZ) (van Niekerk and Turpie, 2012; Van Niekerk *et al*., 2013).

The delineation of the EFZ needs to be done in a consistent but cost-effective manner to be inclusive of all estuarine physical and biological processes so that it can be used to protect estuarine habitats. South Africa's method for determining the EFZ is described in detail in the NBA 2018 (Van Niekerk *et al*., 2019a). Key aspects that were considered included:

- The EFZs were mapped to their maximum historical extents (based on available data such as the Google Earth time slider tool, aerial photography and satellite imagery). For example, the EFZ included the maximum ranges of the estuary mouth (inlet) or the historical floodplain;
- Upstream boundaries of the EFZ were determined as the limits of tidal variation, back flooding when closed, or salinity penetration; whichever penetrates furthest in alignment with recent scientific studies and the administrative definition of an estuary (DWAF, 2008). This boundary was derived from available literature, expert judgement or field observations. Where no data were available, the boundary was assumed to be the DRDLR:NGI 1:10,000 +5m MSL topographical contour (bearing in mind that the tidal range in South Africa is microtidal [< 2 m] and sand bars across mouths can build up as high as +4.5 m MSL during closed periods); and
- The default lateral boundary was also taken as the DRDLR: NGI 1:10,000 +5m MSL topographical contour. However, for the small, incised estuaries with relative high river flow, the +10 m MSL contour or a combination of the +5 m and +10 m MSL contours was used to accommodate mapping uncertainty and flood processes (e.g. inundation levels and lateral scouring of the riparian area). For systems with no topographic information available, the SRTM 4.1 90 Digital Elevation Model was used to generate +5 m and +10 m MSL contour intervals for delineation of the upstream boundaries. Also included in the EFZ was a contiguous

habitat that is principally (more than 75% of feature) surrounded by estuarine habitat or processes (for example, ‘S-bends’ and ‘islands’ of high-lying ground, which could potentially be eroded in future resetting flood events). Small areas of freshwater ecosystems, identified as contiguous to estuaries (e.g. seeps and springs), were also amalgamated in EFZs.

Following the above approach, the four estuaries in the study area are delineated below in Figure 14.

Figure 14: Location of estuaries in study area

5.2. Verlorenvlei

5.2.1 Geographical Boundaries

The Verlorenvlei is classified as an Estuarine Lake (Van Niekerk *et al*., 2020) located in the Cool temperate region of the Western Cape near the town of Elandsbay (Figure 15). The geographical boundaries of the estuary are defined as follows:

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

Historically the system breaches to sea at an annual timescale (every 2 - 5 years), with mouth opening coinciding with periods of high rainfall. Over the last decades, heavy utilisation of freshwater resources has decreased opportunities for marine connectivity. Salinity varies from hypersaline to fresh in the system. This system is heavily modified, with a PES = D (Table 9).

Figure 15: Geographical Boundary of Verlorenvlei Estuary

Table 9: Summary of the Verlorenvlei Estuary ecosystem classification, importance (biodiversity and conservation), and ecosystem threat status

Name	Verlorenvlei
NBA 2019 Ecosystem type (Van Niekerk *et al*., 2019b)	Cool Temperate - Estuarine Lake
Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie *et al*., 2002, Turpie en Clark 2009)	Important
Biodiversity Conservation Priority (Van Niekerk & Turpie 2012, Turpie and Clark 2007 (CAPE))	South African (NBA), Western Cape
In Marine Protected Area (MPA) or priority area	-
Adjacent terrestrial Protected Area	-

Ramsar status	Yes
Important Bird Area (IBA)	Yes
Ecologically or Biologically Significant Marine Areas (EBSAs)	Adjacent
DFFE Important Fish Nurseries (Very High - Medium = Priority)	Medium
NBA 2019 Ecosystem Threat Status (Van Niekerk *et al*., 2019b)	Endangered
NBA 2019 Ecosystem Condition Status (Van Niekerk *et al*., 2019b)	Heavily
PES (Van Niekerk *et al*., 2019b)	D

5.3 Wadrift

5.3.1 Geographical Boundaries

The Wadrift is classified as an Arid Predominantly Closed estuary (Van Niekerk *et al*., 2020) located in the Cool temperate region of the Western Cape near the town of Lambertsbaai (Figure 16). The geographical boundaries of the estuary are defined as follows:

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

There is no record of the Wadrift estuary being open to the sea in recent times. However, regular overwash from the sea results in a marine to hypersaline salinity regime in the section of Wadrift facing the sea. The landward side of Wadrift is generally fresher. This system is deemed to be severely/ critically modified due to the Sishen-Saldanha railway track bisecting it and severe over-abstraction of surface and groundwater flowing into it, with a PES = E (Table 10).

Figure 16: Geographical Boundary of Wadrift Estuary

Table 10: Summary of the Wadrift Estuary ecosystem classification, importance (biodiversity and conservation), and ecosystem threat status

Name	Wadrift
NBA 2019 Ecosystem type (Van Niekerk *et al*., 2019b)	Cool Temperate - Arid Predominantly Closed
Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie *et al*., 2002, Turpie en Clark 2009)	Low to Average Importance
Biodiversity Conservation Priority (Van Niekerk & Turpie 2012, Turpie and Clark 2007 (CAPE))	-
In Marine Protected Area (MPA) or priority area	-
Adjacent terrestrial Protected Area	-
Ramsar status	-
Important Bird Area (IBA)	-
Ecologically or Biologically Significant Marine Areas (EBSAs)	Adjacent
DFFE Important Fish Nurseries (Very High - Medium = Priority)	Low
NBA 2019 Ecosystem Threat Status (Van Niekerk *et al*., 2019b)	Endangered
NBA 2019 Ecosystem Condition Status (Van Niekerk *et al*., 2019b)	Severely/Critical
PES	E

5.4 Jakkals

5.4.1 Geographical Boundaries

The Jakkals is classified as Large Temporarily Closed estuary (Van Niekerk *et al*., 2020) located in the Cool temperate region of the Western Cape near the town of

Lambertsbaai (Figure 17). The geographical boundaries of the estuary are defined as follows:

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

The Jakkals Estuary seasonally opens to the sea during periods of higher rainfall. The salinity regime in the system varies from fresh to marine, depending on the runoff from the catchment. This system is deemed to be heavily modified, with a PES = D (Table 11).

Figure 17: Geographical Boundary of Jakkals Estuary

Table 11: Summary of the Jakkals Estuary ecosystem classification, importance (biodiversity and conservation), and ecosystem threat status

Name	Jakkals
NBA 2019 Ecosystem type (Van Niekerk *et al*., 2019b)	Cool Temperate - Large Temporarily Closed
Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie *et al*., 2002, Turpie en Clark 2009)	Low to Average Importance
Biodiversity Conservation Priority (Van Niekerk & Turpie 2012, Turpie and Clark 2007 (CAPE))	-
In Marine Protected Area (MPA) or priority area	-
Adjacent terrestrial Protected Area	-
Ramsar status	-
Important Bird Area (IBA)	-

Ecologically or Biologically Significant Marine Areas (EBSAs)	-
DFFE Important Fish Nurseries (Very High - Medium = Priority)	Low
NBA 2019 Ecosystem Threat Status (Van Niekerk *et al*., 2019b)	Critically Endangered
NBA 2019 Ecosystem Condition Status (Van Niekerk *et al*., 2019b)	Heavily
PES (Van Niekerk *et al*., 2019b)	D

5.5 Sout (Noord)

5.5.1 Geographical Boundaries

The Sout (Noord) is classified as an Arid Predominantly Closed estuary (Van Niekerk *et al.,* 2020) located in the Cool temperate region of the Western Cape near the town of Lambertsbaai (Figure 18). The geographical boundaries of the estuary are defined as follows:

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

This estuary is largely transformed as it is used to produce salt, with saltworks infrastructure (e.g. roads, channels and berms) resulting in several disconnected sections, with a PES = E (Table 12). There is no record of the Sout (Noord) estuary being open to the sea in recent times. However, salt water is pumped into various parts of the system artificially, resulting in a marine to hypersaline salinity regime.

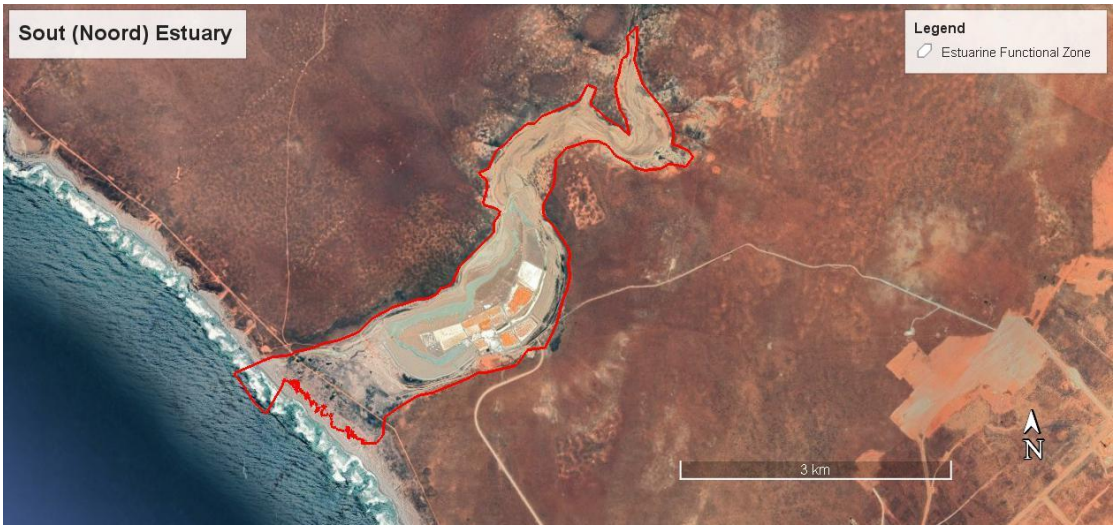

Figure 18: Geographical Boundary of Sout (Noord) Estuary

Table 12: Summary of the Sout (Noord) Estuary ecosystem classification, importance (biodiversity and conservation), and ecosystem threat status

Name	Sout (Noord)
NBA 2019 Ecosystem type (Van Niekerk *et al*., 2019b)	Cool Temperate - Arid Predominantly Closed
Biodiversity Importance Rating (>80 =High Importance, 60 - 80=Important >60 = Average Importance) (Turpie *et al*., 2002, Turpie en Clark 2009)	Low to Average Importance
Biodiversity Conservation Priority (Van Niekerk & Turpie 2012, Turpie and Clark 2007 (CAPE))	-
In Marine Protected Area (MPA) or priority area	-
Adjacent terrestrial Protected Area	-
Ramsar status	-
Important Bird Area (IBA)	-
Ecologically or Biologically Significant Marine Areas (EBSAs)	Adjacent
DFFE Important Fish Nurseries (Very High - Medium = Priority) (Van Niekerk *et al*., 2019b)	Low
NBA 2019 Ecosystem Threat Status	Endangered
NBA 2019 Ecosystem Condition Status	Severely/Critical
PES	E

6. APPROACH TO ADDRESS THE INTEGRATION OF WATER RESOURCES

Nearly all of the river systems within the study area comprise both riverine and wetland habitats. This is driven by the wide sand valley bottoms and the importance of groundwater as a source of water that contributes to the base flow in the systems. This river/wetland habitat also tends to extend into the upper extent of the estuarine function zone. Areas of groundwater contribution to surface water ecosystems was also a key factor.

While the delineation of the RUs for rivers, wetlands and estuaries has been undertaken separately in this study, considering the factors that drive each of these aquatic ecosystems, the EWR site selection was undertaken by the surface water team. The estuaries were initially delineated, based primarily on the estuarine functional areas below the 5m contour. The rivers and wetland team then undertook a combined site selection process to determine where sites would provide meaningful information for the Reserve determination process as well as where they would be representative of the respective RUs. Many of the sites selected thus contain both riverine and wetland habitats.

7. PROPOSED EWR SITES/REACHES

The list of EWR sites is provided in Table 13 and the rationale for that site selection. Further detail and characteristics for each of the sites are summarised in Table 14 and Table 15. Figure 19 shows the locations of the sites on a map of F60 and G60.

Table 13. List of proposed EWR sites and Rationale for selection of proposed River and Wetland EWR sites

EWR Formal site names	Resource Unit	Rationale for site selection
EWR1 RW-F60A BRAK STRAN	Brak River RU; Lower Brak River VB Wetland RU	In the lower Brak River above the estuarine functional zone, relatively unimpacted within a more confined area and contains both river and wetland habitats; access is easy
EWR2 W-F60A DEPR NUWEB	NW Fynbos depression Wetland RU	One of the few FEPA depression wetlands in the NW Fynbos Bioregion within Catchment F60; relatively accessible
EWR3 RW-F60B GRGO KOMKA	Sout/Groot-Goerap River RU	Lowest possible point on the system where access is possible and not impacted; channel also confined
EWR4 W-F60C DEPR ADOON	Knersvlakte depression Wetland RU	The only FEPA depression in the Knersvlakte-Hardeveld Bioregion group within Catchment F60
EWR5 W-F60E DEPR ELSIE	Sandveld depression Wetland RU	A relatively large depression wetland in the Sandveld Bioregion of Catchment F60, which appears to be one of the few depressions in relatively good condition in the Bioregion; relatively accessible
EWR6 RW-G30H SAND HOLLE	Sandlaagte River RU	Lowest possible point on the system where access is possible and not impacted; channel also confined
EWR7 RW-G30G JAKK KOOKF	Jakkals River RU; Lower Jakkals River VB Wetland RU	Lowest possible point on the system where access is possible and not impacted; channel also confined; near long term River Ecostatus monitoring site and near the previous IFR site
EWR8 RW-G30F LANG BRAND	Langvlei River RU; Lower Langvlei VB Wetland RU	Least impacted site on the lower Langvlei that is easily accessible; downstream of a long term River Ecostatus monitoring site and near the previous IFR site
EWR9 W-G30F WADR WAGEN	Wadrift VB Wetland RU	This site was assessed during the previous EWR study in the region and should be re-visited, although the PES of the wetland has become severely degraded
EWR10 RW-G30D VERL EENHE	Upper Verlorenvlei River RU; Upper Verlorenvlei River VB Wetland RU	Least impacted site on the Verlorenvlei above the confluence with the Krom Antonies and below the confluence of the Kruismans and Bergvallei that is easily accessible and where the channel is relatively confined; downstream of a long term River Ecostatus monitoring site and near the previous IFR site
EWR11 RW-G30D KROM GOERG	Krom Antonies River RU; Krom-Antonies River FP Wetland RU	Least impacted site on the lower Krom Antonies that is easily accessible and where the channel is relatively confined
EWR12 RW-G30E VERL WITTE	Lower Verlorenvlei River RU; Lower Verlorenvlei River FP Wetland RU	Least impacted site on the Verlorenvlei above the estuarine functional zone and below Redelinghuys that is easily accessible and where the channel is relatively confined downstream of a long term River Ecostatus monitoring site and near the previous IFR site

EWR13 W-G30A DUNE FA277	West Strandveld duneslack Wetland RU	A relatively minimally impacted example of a dune slack wetland in the West Strandveld Bioregion, compared to most of the other dune slack wetlands in the region
EWR14 W-G30A ROSH FA272	Rocherpan Wetland RU	A wetland of very high importance for wading birds and for eco-tourism, located within a nature reserve; very easy to access and safe to leave sampling equipment in place
EWR15 RW-G30A PAPK BOOKR	Papkuils River RU; Lower Papkuils FP Wetland RU	Least impacted site on the lower Papkuils River that is easily accessible and where the channel is relatively confined
EWR16 W-G30A PAPK RIETF	Upper Papkuils seep Wetland RU	One of the most extensive seep wetlands (assumed to be of importance for streamflow regulation) in the entire study area, which is of particular significance for sustained water supply to the rest of the Papkuils system

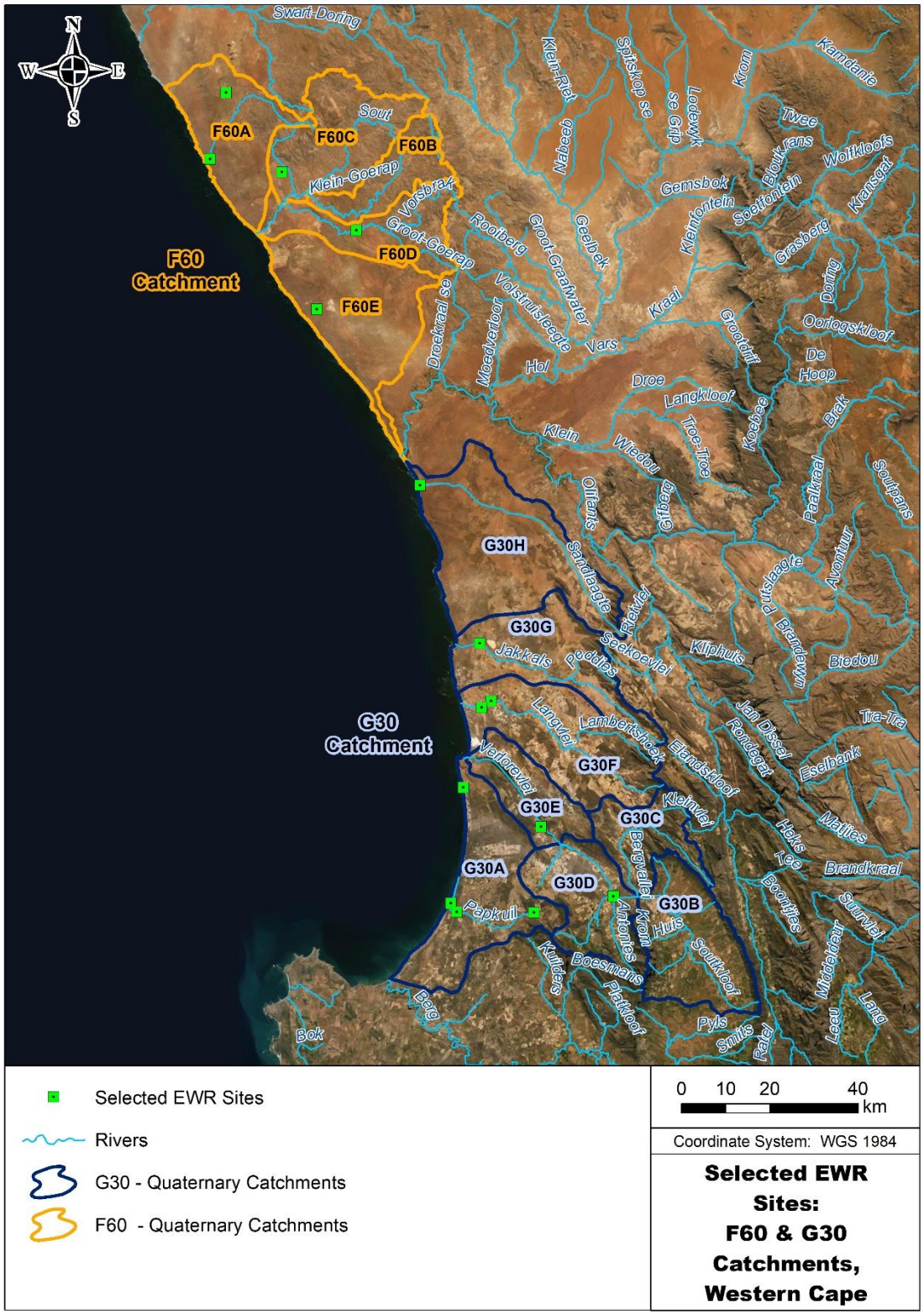

Figure 19. Map of the proposed EWR sites for rivers and wetlands in the F60 and G30 Catchments

Table 14: Short description and geographical context of proposed River and Wetland EWR sites

EWR Formal site names	Description	Quaternary Catchment	Lat/long	Cadastral
EWR1 RW-F60A BRAK STRAN	Combined river and wetland site immediately upstream of the estuarine functional zone of the Brak River	F60A	31° 5'21.84"S; 17°44'18.66"E	Strandfontein 559 Re
EWR2 W-F60A DEPR NUWEB	Isolated depression wetland	F60A	30°57'31.45"S; 17°46'31.76"E	Nuwe-Begin 641 Re
EWR3 RW-F60B GRGO KOMKA	Combined river and wetland site on the lower Groot Goerap River	F60B	31°14'17.91"S; 18° 5'4.26"E	Ptn 4 of Komkans 141
EWR4 RW-G30H SAND HOLLE	River site on the lower Sandlaagte River	G30H	31°45'35.93"S; 18°13'53.10"E	Re of Ptn 13, Hollebakstrandfontein 270
EWR5 RW-G30G JAKK KOOKF	Combined river and wetland site immediately upstream of the estuarine functional zone of the Jakkals River	G30G	32° 4'59.30"S; 18°22'20.10"E	Ptn 3 of Kookfontein 88
EWR6 RW-G30F LANG BRAND	Wetland site on the lower Langvlei River	G30F	32°12'5.82"S; 18°23'54.02"E	Ptn 23 of Branswacht 226
EWR7 W-G30F WADR WAGEN	Wetland site at Wadrif Wetland on the lower Langvlei River	G30F	32°12'52.21"S; 18°22'31.50"E	Wagendrift 230 Re
EWR8 RW-G30D VERL EENHE	Combined river and wetland site on the Verlorenvlei River upstream of the confluence with the Krom Antonies River (upstream R366 bridge)	G30D	32°36'0.58"S; 18°41'34.83"E	Ptn 1 of Eenheid 42
EWR9 RW-G30D KROM GOERG	Combined river and wetland site on the lower Krom Antonies River upstream of confluence with Verlorenvlei	G30D	32°36'4.02"S; 18°41'28.52"E	Goergap 40 Re
EWR10 RW-G30E VERL WITTE	Combined river and wetland site immediately upstream of the estuarine functional zone	G30E	32°27'29.91"S; 18°31'2.19"E	Ptn 4 of Wittedrift 4; Ptn 6 Bonteheuwel 1 Re
EWR11 W-G30A DUNE FA277	Isolated depression/duneslack wetland	G30A	32°22'39.14"S; 18°19'48.28"E	Ptn 27 of Farm 277
EWR12 W-G30A ROSH FA272	Wetland site within Rosher Pan	G30A	32°36'49.34"S; 18°17'55.89"E	Farm 272
EWR13 RW-G30A PAPK BOOKR	Combined river and wetland site immediately upstream of the estuarine functional zone of the Jakkals River	G30A	32°37'53.62"S; 18°18'46.32"E	Ptn 1 of Bookram 30
EWR14 W-G30A PAPK RIETF	Wetland site near the source of the Papkuils River	G30A	32°38'1.26"S; 18°29'56.29"E	Ptn 3 of Rietfontein 18; Rietvlei 19 Re

Table 15: Characteristics of River and Wetland EWR sites

EWR Formal site names	Ecoregion	Geomorphological zone	Bioregion	Vegetation Type	Geology	Main land and water use	Present Ecological Status	Ecological Importance
EWR1 RW-F60A BRAK STRAN	Western Coastal Belt	Lower foothill	Namaqualand Riviere	Inland Saline Vegetation	aeolian sand and alluvium	Largely natural with some livestock	B	High; FEPA and NWM5 Mapped wetland
EWR2 W-F60A DEPR NUWEB	Western Coastal Belt	NA	Namaqualand Sand Fynbos	Northwest Fynbos	aeolian sand and alluvium	Largely natural with some livestock	Not assessed	NWM5 Mapped wetland
EWR3 RW-F60B GRGO KOMKA	Western Coastal Belt	Lower foothill	Namaqualand Riviere	Inland Saline Vegetation	granites and gneisses of the Namaqualand Metamorphic Complex	Largely natural with some dryland annual crops along river; mining downstream	B	High; NWM5 Mapped wetland
EWR4 RW-G30H SAND HOLLE	Western Coastal Belt	Upper/Lower foothill	Namaqualand Riviere; Namaqualand Strandveld	Inland Saline Vegetation; Namaqualand Sandveld	Alluvium and sand deposits and TMG sandstone	Largely natural with some dryland annual crops and fallow land along river; planted pastures; Strandfontein downstream	E	Moderate; FEPA and NWM5 Mapped wetland
EWR5 RW-G30G JAKK KOOKF	Western & South Western Coastal Belt	Upper/Lower foothill	Leipoldtville Sand Fynbos	Northwest Fynbos	aeolian sand and alluvium	Natural areas with intensive planted pastures/crops, groundwater abstraction, Lamberts Bay downstream	D	Moderate; FEPA and NWM5 Mapped wetland
EWR6 RW-G30F LANG BRAND	Western Coastal Belt	Lower foothill	Leipoldtville Sand Fynbos	Northwest Fynbos	aeolian sand and alluvium	Natural areas with intensive planted pastures/crops along river, groundwater abstraction	C	Moderate; FEPA and NWM5 Mapped wetland
EWR7 W-G30F WADR WAGEN	Western Coastal Belt	Lower foothill	Lambert's Bay Strandveld	West Strandveld	aeolian sand and alluvium	Natural areas with planted pastures/crops along river, livestock grazing, groundwater abstraction	E	FEPA and NWM5 Mapped wetland
EWR8 RW-G30D VERL EENHE	South Western Coastal Belt	Lower foothill	Swartland Shale Renosterveld	West Coast Renosterveld	Alluvium, aeolian sand and conglomerate of the Klipheuwel Group	Natural areas with instensive planted pastures/crops along river, groundwater abstraction	D	Moderate; FEPA and NWM5 Mapped wetland
EWR9 RW-G30D KROM GOERG	South Western Coastal Belt	Upper foothill	Swartland Shale Renosterveld	West Coast Renosterveld	Alluvium, aeolian sand and conglomerate of the Klipheuwel Group	Natural areas with intensive planted pastures/crops along river, groundwater abstraction	D	Moderate; FEPA and NWM5 Mapped wetland
EWR10 RW-G30E VERL WITTE	Western & South Western Coastal Belt	Lower foothill	Leipoldtville Sand Fynbos	Northwest Fynbos	Alluvium, aeolian sand and conglomerate of the Klipheuwel Group	Natural areas with intensive planted pastures/crops along river, groundwater abstraction	D	Moderate; FEPA and NWM5 Mapped wetland

EWR11 W-G30A DUNE FA277	South Western Coastal Belt	NA	Seashore Vegetation; Langebaan Dune Strandveld	West Strandveld	Aeolian sand	Natural areas with some planted pastures/crops and groundwater abstraction upslope	Not assessed	FEPA and NWM5 Mapped wetland
EWR12 W-G30A ROSH FA272	South Western Coastal Belt	NA	Seashore Vegetation; Langebaan Dune Strandveld	West Strandveld	Aeolian sand	Natural areas with intensive planted pastures/crops and groundwater abstraction upslope	Not assessed	FEPA and NWM5 Mapped wetland
EWR13 RW-G30A PAPK BOOKR	South Western Coastal Belt	Lower foothill	West Strandveld	Saldanha Flats Strandveld	Aeolian sand	Natural areas with intensive planted crops along river, groundwater abstraction	D	Moderate; FEPA and NWM5 Mapped wetland
EWR14 W-G30A PAPK RIETF	South Western Coastal Belt	Upper foothill	Northwest Fynbos	Leipoldtville Sand Fynbos	TMG sandstone	Natural areas with planted pastures/crops along river, livestock grazing, groundwater abstraction, invasive alien trees	Not assessed	FEPA and NWM5 Mapped wetland

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