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

GAP ANALYSIS REPORT

June 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

WP11340

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Reports as part of this project:

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ACRONYMS AND ABBREVIATIONS

BAS	Best Attainable State
BHN	Basic Human Needs
CSIR	Council for Scientific and Industrial Research
CMA	Catchment Management Agency
CWAC	Coordinated Waterbird Counts
DEA	Department of Environment Affairs
DEADP	Department of Environmental Affairs and Development Planning (Western Cape Government)
DFFE	Department of Forestry, Fisheries and the Environment
DRIFT	Downstream Response to Imposed Flow Transformation
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EcoSpecs	Ecological Specifications
EcoStatus	Ecological Status
EGSA	Ecosystem Goods, Services and Attributes
EIS	Ecological Importance and Sensitivity
EISC	Ecological Importance and Significance Category
EMC	Ecological Management Category
EMP	Estuary Management Plan
EWR	Ecological Water Requirements
FBIS	Freshwater Biodiversity Information System
FEPA	Freshwater Ecosystems Priority Areas
FRAI	Fish Response Assessment Index
GAI	Geomorphological Driver Assessment Index
GDP	Gross Domestic Product

GIS	Geographic Information System
GRDM	Groundwater Resource Directed Measures
GRU	Groundwater Resource Unit
HDI	Human Development Index
HDAI	Hydrological Driver Assessment Index
HGM	Hydrogeomorphic
HRU	Hydrological Resource Unit
ICMA	Integrated Coastal Management Act
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
NCMP	National Chemical Monitoring Programme
NEMA	National Environmental Management Act
NFEPA	National Freshwater Ecosystem Priority Area
NGA	National Groundwater Archive
NMU	Nelson Mandela University
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)
PMC	Project Management Committee
PSA	Potato South Africa
PSC	Project Steering Committee
PWR	Preliminary Water Requirements
RDM	Resource Directed Measures
REC	Recommended Ecological Category
REI	River Estuary Interface
REMP	River EcoStatus Monitoring Programme
RHAM	Rapid Habitat Assessment Method
RQO	Resource Quality Objective
RU	Resource Units
RWQO	Resource Water Quality Objective
SANBI	South African National Biodiversity Institute
SPATSIM	Spatial and Time Series Modelling
TEC	Target Ecological Category
TMG	Table Mountain Group
TT	Task Team
VEGRAI	Vegetation Response Assessment Index
VEMF	Verlorenvlei Estuary Management Forum
V&V	Validation and Verification
VIGTT	Verlorenvlei Inter-Governmental task team
WARMS	Water Use Authorisation and Registration Management System
WCBSP	Western Cape Biodiversity Spatial Plan
WMA	Water Management Area
WMS	Water Management System
WRAP	Wetland Rehabilitation and Assessment Protocol

WR2012	Water Resources 2012
WRC	Water Research Commission
WULA	Water use licence application

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.
ANISOTROPIC	Properties that vary according to the direction from which they are observed
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.
GYPSIFEROUS	Containing or yielding gypsum.
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
INTERGRANULAR AQUIFER	An aquifer in which groundwater flows in openings and void space between grains or weathered rock.
INVERTEBRATE	Animal without a backbone.
KARST AQUIFERS	Aquifers that occur within limestone geology, where the limestone (or other easily dissolved rock) has been partially dissolved so that some fractures are enlarged into passages that carry the groundwater flow.
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.

METASEDIMENTARY	A sedimentary rock that shows evidence of having been subjected to metamorphism.
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.

STAKEHOLDER	May be (a) a person, an organ of state or a community or (b) an indigenous community.
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 confidence Reserve determination. The Verlorenvlei within the study area was designated as a Wetland of International Importance (Ramsar Site) on 28 June 1991 under the Ramsar Convention on Wetlands of International Importance Especially as Waterfowl Habitat. In addition, peat wetlands have been identified to occur in the area that is associated with the Verlorenvlei that provide important ecological services but are under severe threat and require urgent protection. It is therefore crucial that the Reserve calculations are revisited and the water resources with the Sandveld catchments addressed holistically, with a clear understanding of the surface and groundwater interactions and interdependencies being well researched and documented.

1.2 Objectives

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

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

1.3 Purpose of this Report

The purpose of this report is to document the identified key gaps relevant to the determination of the Reserve in the F60 and G30 catchments (**Figure 1)** of the Berg-Olifants Water Management Area, based on current information and data from previous studies undertaken.

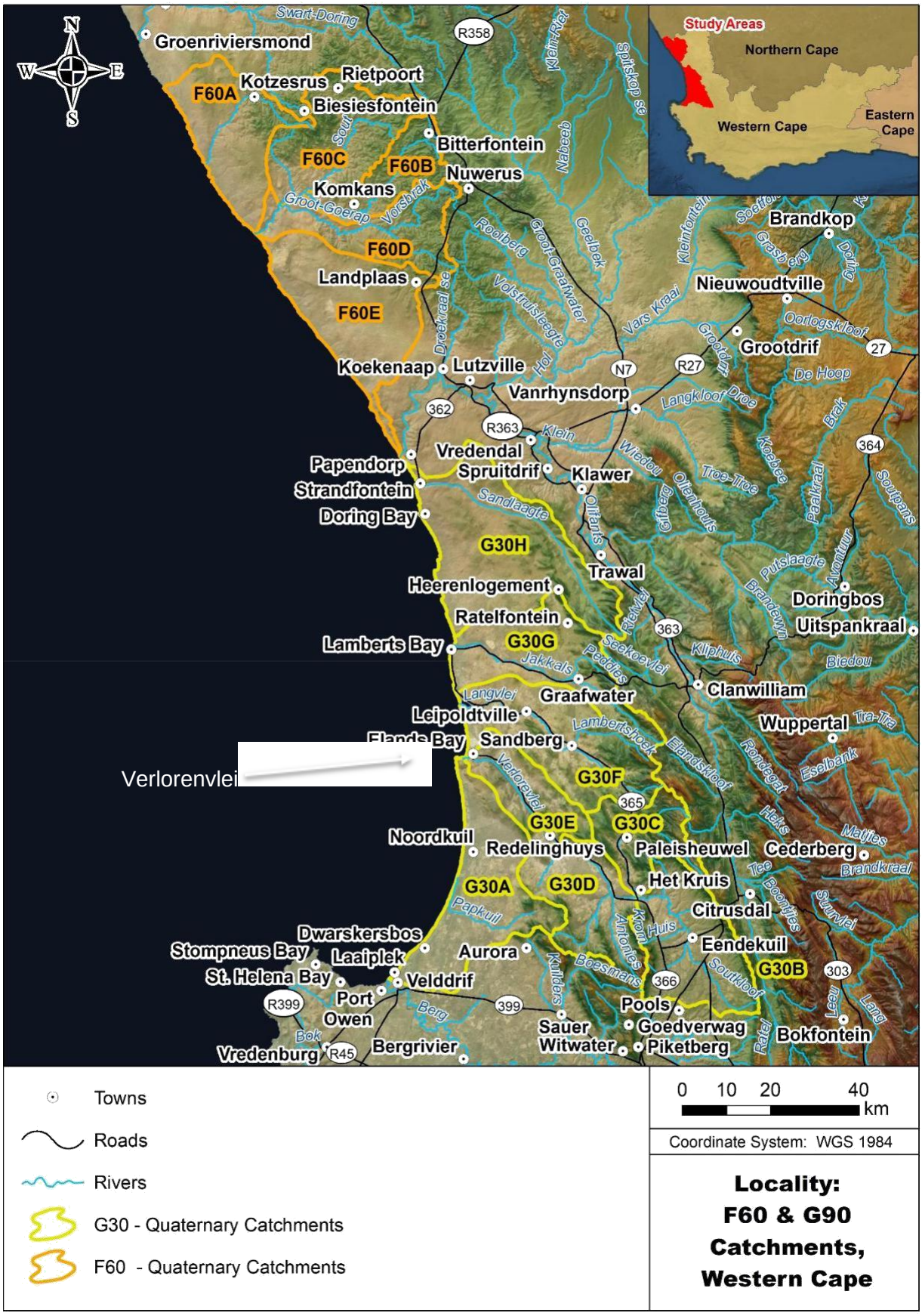


Figure 1: Map of the study area with the location of the F60 and G30 Catchments and main aquatic features shown

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;
- Cedarberg Local Municipality; and
- Matzikama Municipality.

A small section of the most northerly 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 the three parallel seasonal river and longitudinal wetland systems, namely Jakkals, Langvlei and Verlorenvlei. The catchments drain westwards through the Sandveld and consist of a combination 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 near 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 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, namely the Endangered Verlorenvlei redfin *Pseudobarbus Verlorenvlei*, Data Deficient Cape Galaxias *Galaxias zebratus* and the Data Deficient Cape kurper *Sandelia capensis*. Similarly, the macroinvertebrate communities comprise mainly low diversities of hardy species and air-breathing taxa. A low amphibian species richness also occurs, with a total of 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 and only breach to the sea during periods of high inflow. 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. It was felt that the Best Attainable State 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 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 occupy much of the system. In general, 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 and that is mostly in the southeast portion of the catchment.

Groundwater in the G30 (Sandveld) catchment enables extensive agricultural activity and is the sole source of freshwater for most of the towns and settlements within the catchments. Only the towns at the northern tips of the catchments (Strandfontein and Doringbaai) can obtain additional sources through the Olifants River canal system. Although surface water plays a significant role in the study area, particularly for the aquatic ecosystems, groundwater plays a more significant role in sustaining these systems.

The catchments contain both fractured and intergranular areas. The average yield ranges from very low (0.5 l/s) to high yielding (> 5 l/s), with identified paleochannels producing boreholes of a yield higher than 25 l/s. The main recharge areas have been identified as the mountainous areas towards the east of the study area that form part of the Cederberg and Piketberg Mountain ranges. For G30, the water quality is overall good, with many areas displaying EC between a range of 60 – 120 mS/m. Although areas of poorer quality can also be found (EC<300 mS/m), the quality of groundwater within the G30 catchments is, in general, much better than what can be found in F60 catchments.

The F60 catchments are overall drier and groundwater availability is much lower than in the G30 catchments. Furthermore, the geological setting of the area is more complex. Quaternary deposits are still present toward the coast but include calcareous and gypsiferous units as well as thick calcrete beds within the deposits. These sediments are underlain by igneous formations that form part of the Bushmanland and Richtersfeld Sub-province, which in turn falls under the Namaqua Metamorphic Province. The area has been classified as containing both intergranular and fractured

aquifers (DWAF, 2005). The regional expected yields are very low (0.1 - 0.5 l/s) with higher-yielding boreholes (up to 2 l/s) at the most southern point of the F60 catchments. Groundwater quality across the catchment is generally categorised as being poor, with EC values of over 1000 mS/m.

Water abstraction from surface and groundwater and many instream dams have significantly modified the flow of the aquatic ecosystems, particularly reducing flow in summer. Typically, there is no flow in the river 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 largely of livestock farming (sheep and goats), with small areas being used for dryland farming. Intensive irrigation of citrus and potatoes is undertaken in the south. Urban and rural areas are small, with the main towns being Redelinghuys, Elands Bay, Eendekuil, Leipoldtville, Graafwater, Lamberts Bay, Strandfontein and Bitterfontein.

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. Therefore, a dynamic approach is required, where DWS are in a position to update the Reserve as new data or information becomes available.

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., PES of the water resource at the 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. The data collected will however not indicate the ecological condition or responses at another time under different conditions, i.e., drier or wetter periods. Where possible, data for extreme conditions such as the recent drought are being incorporated into the study.

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. This relates not only to flow and water quality monitoring but also River Eco-Status monitoring. Ideally, an implementation plan for the Reserve and the associated management of the water resources, especially the Ramsar site, is essential.

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 will be followed in the study. Recognition of the need for a slightly adapted approach for the Sandveld and Knersvlakte Rivers in the F60 and G30 Tertiary Catchments is proposed to be undertaken. This adapted approach is deemed to be necessary to address the following:

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

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

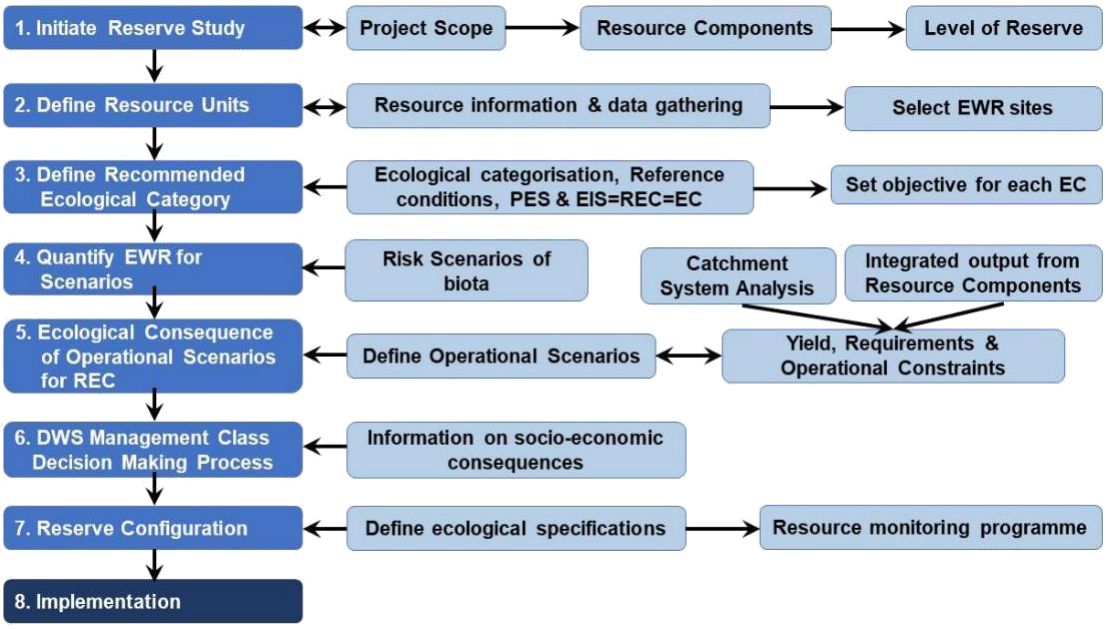


Figure 2: The Reserve Determination Process (adapted from DWAF, 2008)

2. DATA AND INFORMATION GAPS

2.1. Geohydrology

Lack of data across the F60 sub-catchments can impact the level of certainty of the calculated Reserve. For the G30 sub-catchments, the lack of baseflow monitoring data and the widespread un-documented groundwater abstraction can provide additional uncertainty. For both catchment clusters, there is a significant lack of information of reference “pre-groundwater development” conditions.

With regards to the geological description, the latest geological maps available will be used and have been acquired. Only a few recharge values and aquifer parameters are available for both catchment areas. With regards to the recharge, it will need to be analytically calculated for each resource unit with the data available. Where recharge estimations have been identified (such as those calculated for the Verlorenvlei catchment areas using chloride mass balance method in Watson, 2020), they will be used together with those calculated in this study. GRA II recharge estimations that have been done per quaternary catchment will also be used. The aim will be to calculate/estimate recharge through different methods using the data available and then to use an average of the different values that were calculated/estimated and sourced through the GRA II and other literature sources. With regards to site-specific aquifer parameters, some have been identified in the Verlorenvlei area, but in large portions of the G30 and the entire F60 catchments, bulk groundwater parameters will be used.

2.1.1. Water levels and long-term monitoring data

Single water levels that can be used to obtain a general idea of water levels in the area have been sourced from NGA data have been sourced. The data was then supplemented with data from projects that GEOSS has been involved with in the area (**Figure 3**). This database provided many additional data points for the G30 catchments but much less so for the F60 catchments. Mines within the F60 catchments have been contacted but have not allowed the usage of their data at present. Even when they do approve, F60 catchments will largely rely on sparsely placed NGA data that could most likely be outdated. Site visits to these areas are vital in assessing and supplementing the NGA database information.

Sites that have long-term water level monitoring data were obtained through the GEOSS database and the long-running Potato South Africa (PSA) Sandveld monitoring project. Although PSA has not provided final approval to use the data collected for their project, the importance of their data has been communicated and the process is ongoing to obtain the necessary data. Boreholes with continuous water level readings (logger data) were prioritised, but long-term weekly, monthly and even annual hand readings have also been sourced. The University of Stellenbosch also has a few monitoring sites that fall within the Verlorenvlei catchments.

The sites that are being monitored by DWS in both catchments' groups have been listed, but at present, the actual monitoring data have not been obtained and is still a "work in progress".

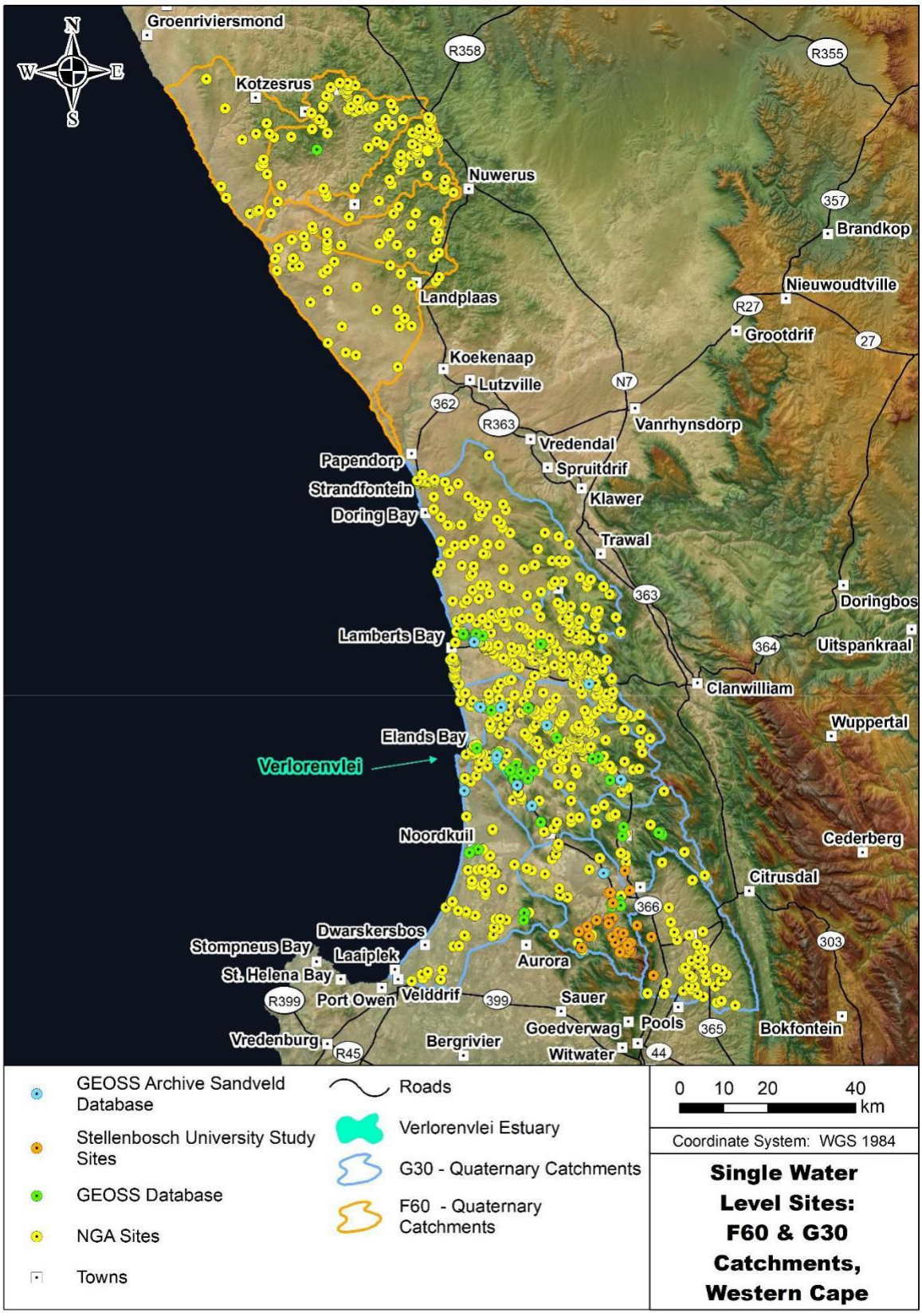


Figure 3. Map of groundwater water level sites in the F60 and G30 Catchments

From **Figure 4** it is clear to see sites containing long term water level monitoring are concentrated in the central portion of the G30 catchments. Only one of the Bitterfontein DWS monitoring sites plot within the F60 catchments and no additional monitoring sites have been found within these catchments from the other databases.

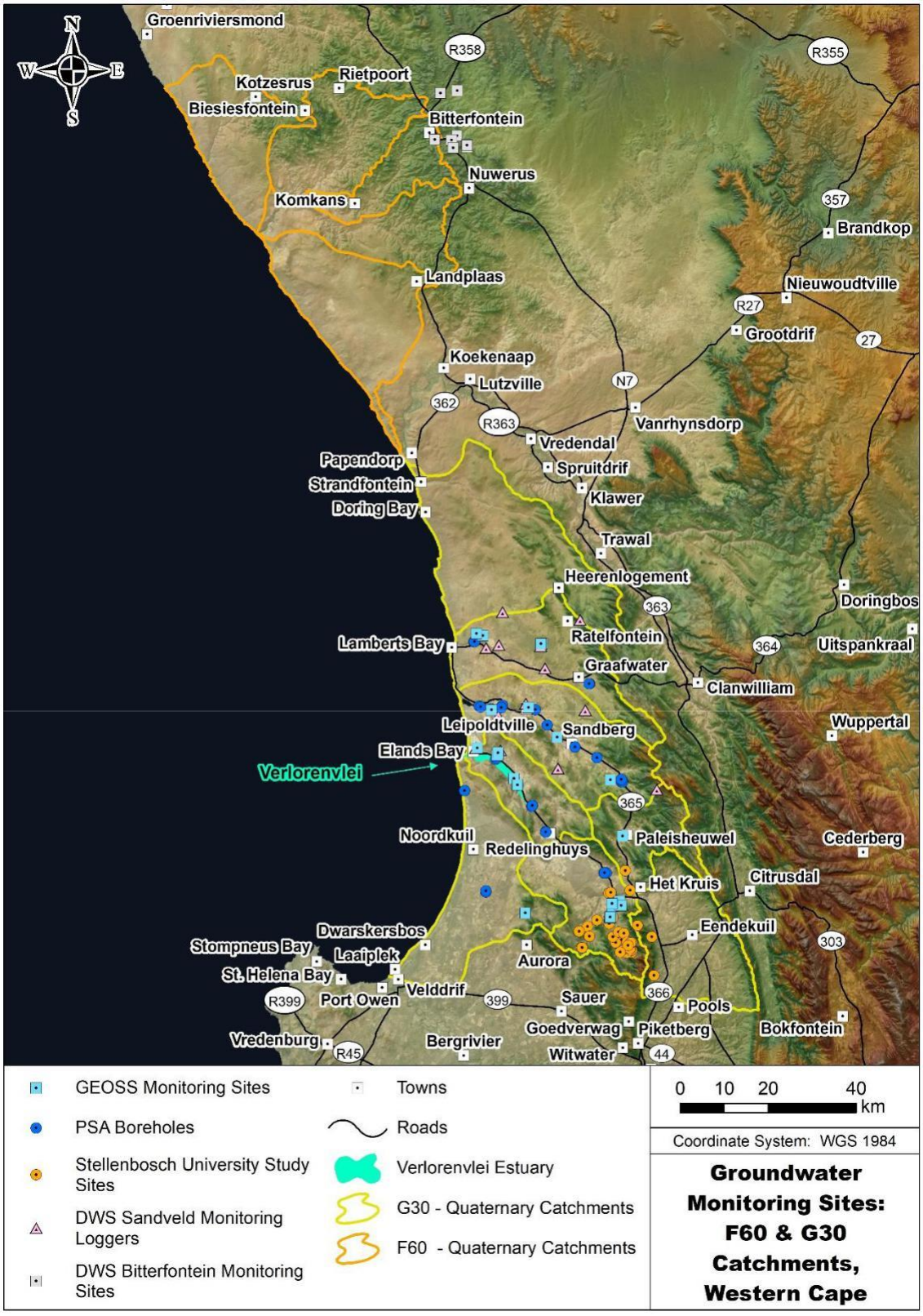


Figure 4. Map of groundwater monitoring sites in the F60 and G30 Catchments

Because a yield test was done according to the National Standard (SANS 10299-4:2003, Part 4 – Test pumping of water boreholes) analysis is a requirement of a groundwater Water Use Licence Application (WULA), it is possible that more water level data could be found. As yet, no WULA-related data or reports have been obtained from DWS, but if the data can be obtained, it would likely provide additional groundwater level data.

2.1.2. Groundwater quality data

Groundwater quality data have been obtained through the same channels as the water level data. Basic water quality in terms of Electrical conductivity (mS/m) and pH have been obtained through the NGA database as well as from projects that GEOSS has been involved in. These data sets came from field data as well as laboratory analysis of samples and are displayed in **Figure 5**.

With regards to basic groundwater quality data, there is a good distribution of data points available for the G30 catchments. For the F60 catchments, the data is more spread out, but multiple points could still be found within each catchment. Only 5 data points could be found for F60A and some field chemistry would likely need to be done to supplement the data found on NGA.

For a more comprehensive groundwater analysis, NGA data could not be used. Laboratory analysis came from older GEOSS projects, municipal reports, University of Stellenbosch projects and the annual analysis that are done through the PSA project have been sourced to obtain a more comprehensive water quality analysis.

With regards to the more comprehensive groundwater analysis results, most of the results are grouped within the central G30 catchments. No comprehensive groundwater analysis could be obtained within the F60 catchments.

Because a comprehensive water quality analysis is a requirement of a groundwater Water Use Licence Application (WULA), it is possible that more water quality data could be found. As yet, no WULA-related data or reports have been obtained from DWS, but if the data can be obtained, it would likely provide additional water quality data.

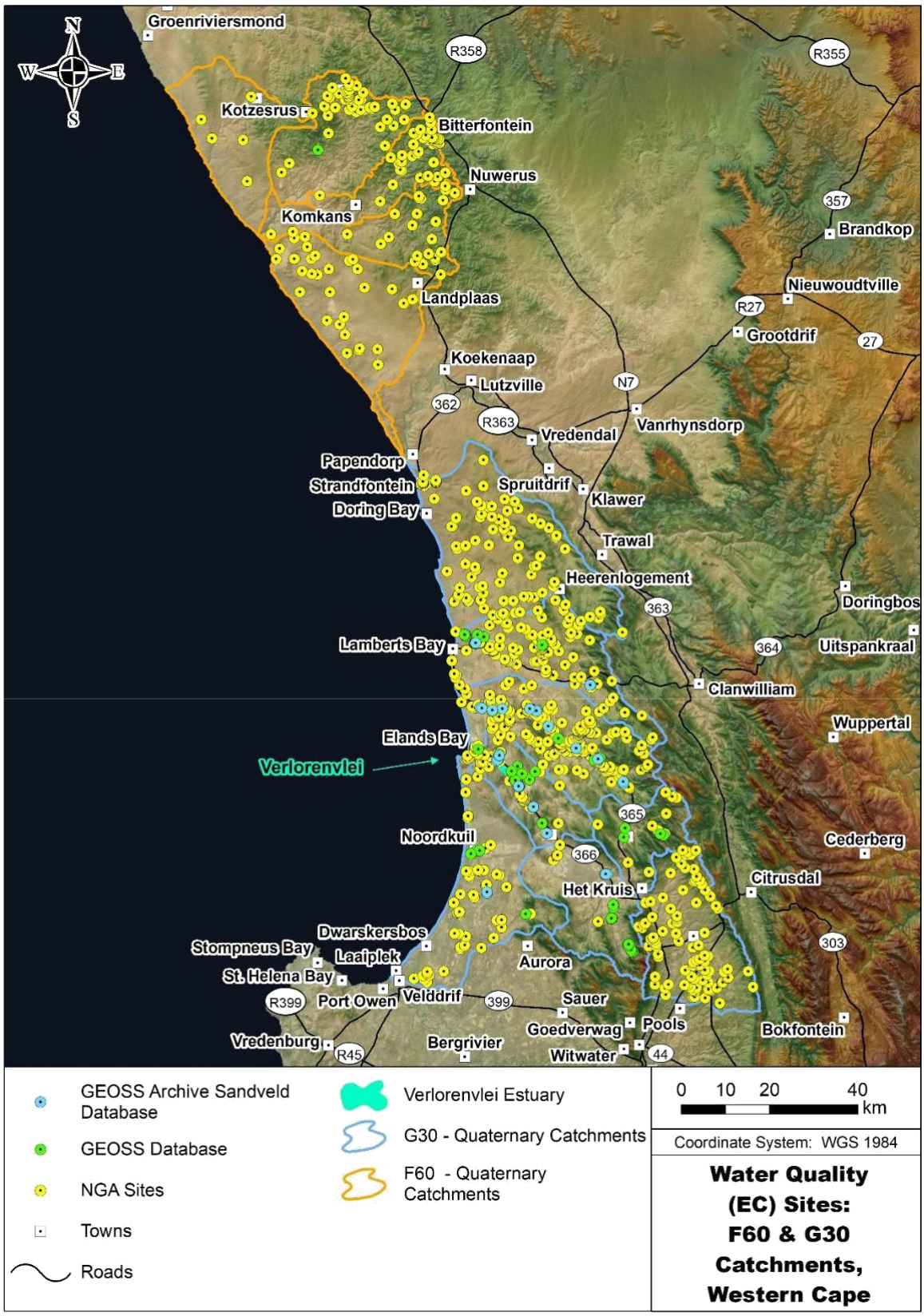


Figure 5. Map of groundwater quality (EC) points in F60 and G30 Catchments

2.1.3. Groundwater abstraction data

Groundwater abstraction volumes are vital when determining the level of stress in each GRU. The data has been sourced through WARMS registered spring and boreholes data. The data was obtained from DWS in January 2021. GEOSS has been unable to obtain more recent WARMS data. The WARMS data did provide a spatially well-distributed data set with regards to the G30 catchments but could not provide any data for the F60 catchments.

Groundwater abstraction data was also sourced from the Validation and Verification (V&V) dataset, provided by the Clanwilliam-based DWS office. This dataset was georeferenced according to the assigned property (**Figure 6**). The data corresponded with the WARMS data in some cases, but with volumes differencing for most of the properties. The V&V data provided preliminary groundwater abstractions and for some farms, these volumes have been finalized with the use of Infra-Red imagery. For those farms where the Infra-Red imagery has been used, the preliminary volume has been lowered in most cases. This discrepancy between the WARMS, the preliminary V &V and the finalized Infra-Red V &V will need to be resolved in a concise manner and will need to be discussed with DWS before any decision is taken on what weight to assign for these different data sets.

Abstraction volumes for municipal use were largely sourced from municipal reports as well as the ongoing Integrated Drought and Water Response project that Provincial Government is currently working on. Final approval to obtain permission to use this data has not been provided, but no foreseen issues have been highlighted and the formal permission is expected soon.

A fourth groundwater abstraction database that is still to be explored as access to it has not yet been obtained from DWS, is the proposed groundwater abstraction volumes mentioned in WULAs. This would be the most up-to-date data set and thus the data is vital in dealing with the discrepancy between the other data sets mentioned above. There are however legal issues with regards to the use of this data that first need to be clarified before third-party data can be released for use in the study. If access to this data can be obtained, the specialist reports that accompany this application could also provide additional water level and water quality data.

As can be seen in **Figure 6**, very little abstraction information has been found for the F60 catchments and only a few farms were identified as using groundwater in the V&V process. Although it is expected that due to the lower yields and overall lower level of intensity with regards to irrigation farming within the F60 catchments compared to the G30 catchments, it can be assumed that there is at least more abstraction occurring than is indicated in **Figure 6**.

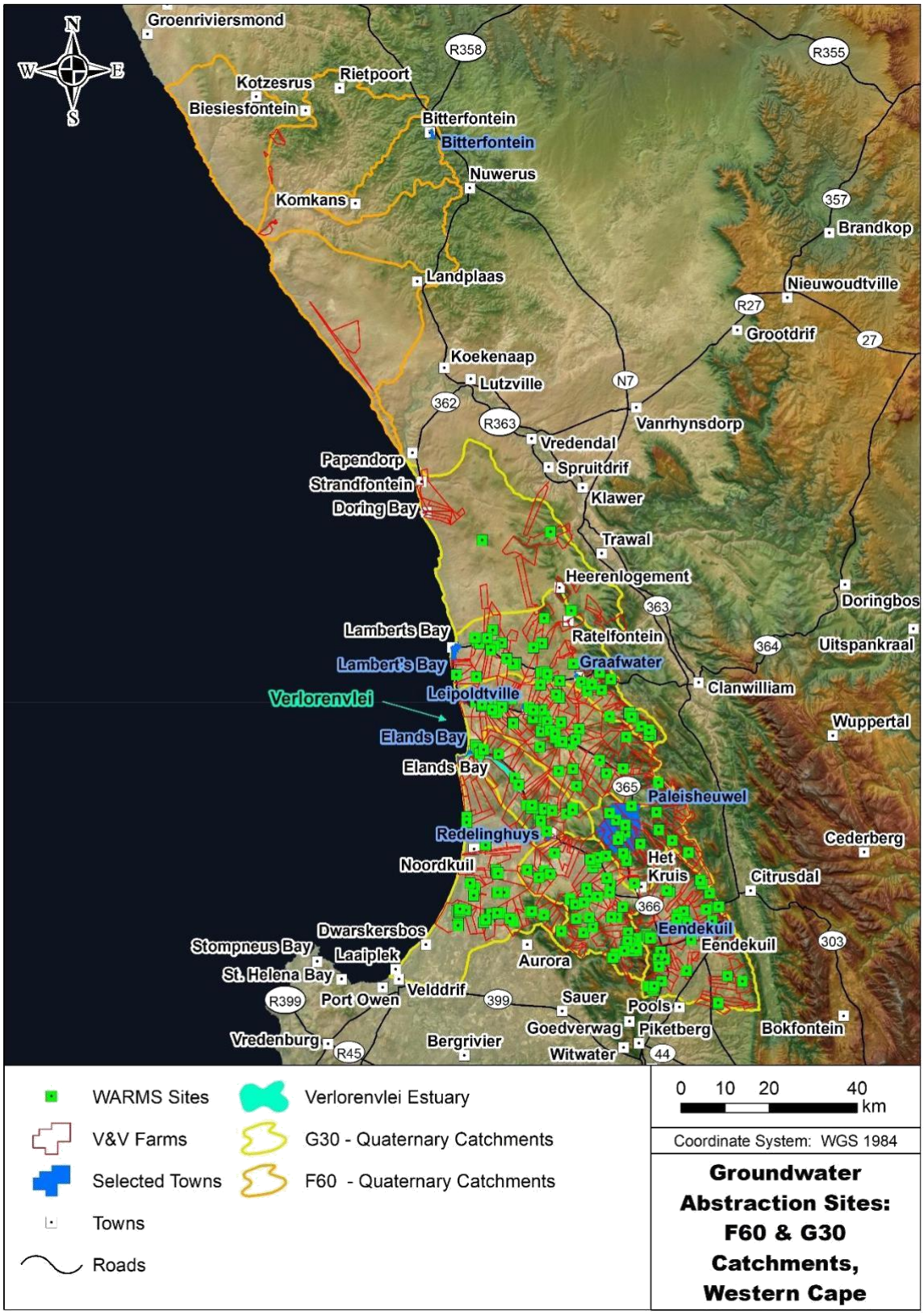


Figure 6. Map of groundwater abstraction points in F60 and G30 Catchments

2.2. Rivers and Wetlands

2.2.1. Hydrology

The hydrology developed for the WR2012 will serve as the basis for the hydrological analysis. The F60 and G30 catchments were modelled as part of the Berg-Olifants WMA and a summary of the mean annual runoff (MAR) for the quaternary catchments in the study area are shown in **Table 1**. The WR2012 configurations will be refined and disaggregated where necessary to suitably represent the conceptual understanding of the contributing sub-catchments and points of interest. The WR2012 hydrology covers the period 1920 to 2009. It will be necessary to obtain rainfall data from relevant sources to extend the hydrological data sets to the 2019 hydrological year for approximately nine active rainfall stations in the area.

Table 1: Mean annual runoff modelled for the quaternary catchments in the study area (WR2012)

Quaternary catchment	Catchment area (km^2)		MAR WR90 (1920-1989)	MAR WR2005 (1920-2004)	MAR2012 (1920-2009)
	Gross area	Net area		Million m^3/a	
G30A	761	761	1.60	9.84	8.51
G30B	658	658	18.90	15.25	16.07
G30C	351	351	11.30	17.50	14.49
G30D	534	534	11.90	14.10	13.69
G30E	352	352	1.90	6.79	5.92
G30F	780	780	4.00	13.26	11.76
G30G	652.6	333	1.80	5.33	4.43
G30H	1077	1077	3.30	6.84	5.86
Tertiary G30	*5165.6*	*4846*	*54.70*	*88.91*	*80.73*
F60A	572	386	0.10	0.19	
F60B	320	320	0.20	0.16	
F60C	622	622	0.20	0.35	1.42
F60D	481	481	0.20	0.28	
F60E	795	120	0.00	0.10	
Tertiary F60	*2790*	*1929*	*0.70*	*1.08*	1.42

There are no active flow gauging stations in the study area. Historically observed flows are available on the Kruismans River at Tweekuilen (DWS flow gauge G3H001 – See **Figure 7**) for the period 1971 to 2005. This weir is the only streamflow gauge in the Verlorenvlei catchment and has been used as a means to calibrate rainfall/runoff models in the region (Watson *et al*., 2019, 2018). The gauge has data between 1970 to 2006, shown in **Figure 8** and was decommissioned after a flood in November 2006. Reinstatement of flow gauging stations, particularly in the Verlorenvlei Catchment, is critical to the future implementation of the Reserve and the protection of important aquatic ecosystems.

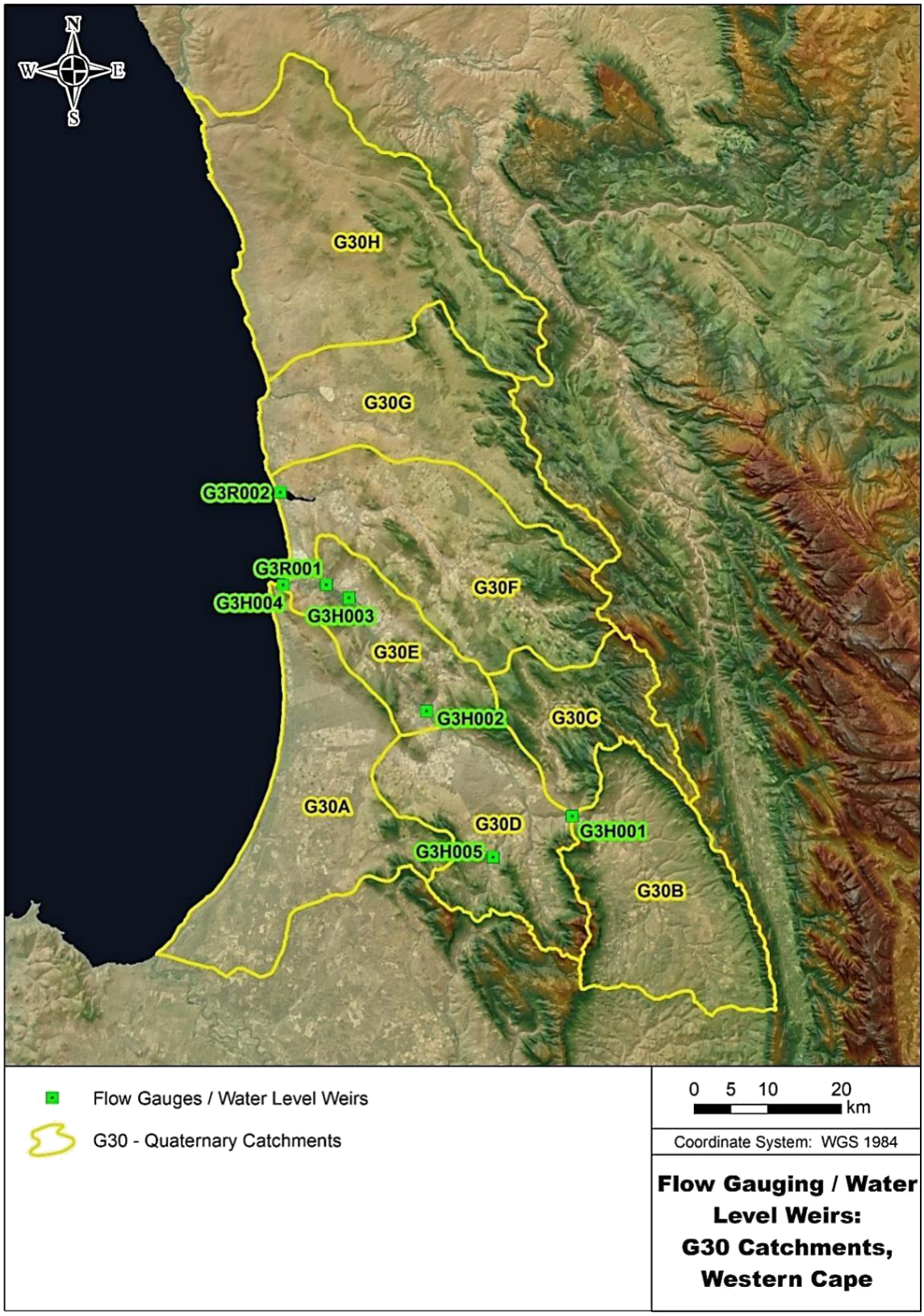


Figure 7. Map of surface water flow monitoring sites

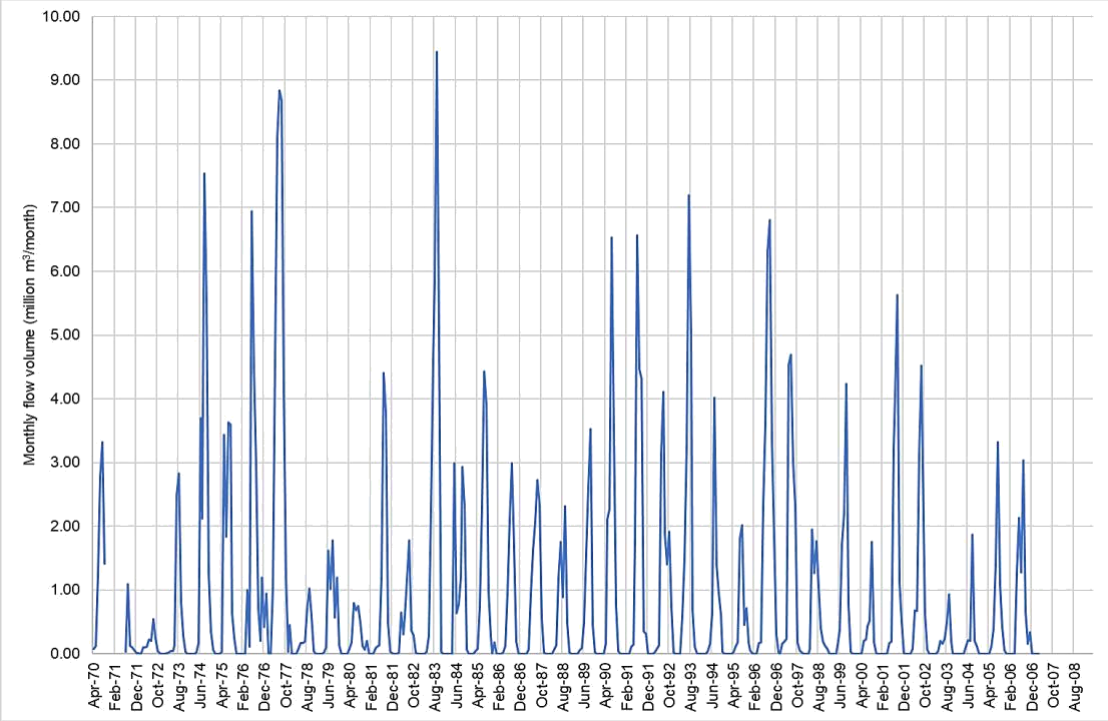


Figure 8. Observed monthly flows at G3h001 (April 1970 to Dec 2006)

A more detailed examination of the raw data shows two distinct periods of hydrological characteristics: a period from 1986-1993, which has sharp monthly streamflow peaks and a period from 1994-2006 where the peaks are completely flattened. The cause of these changes has yet to be identified but could be related to a leaking gauge, streamflow impacts due to irrigation (farm dams and river abstraction) or the natural variability of precipitation. The impacts of small farm dams and irrigation on streamflow are currently under investigation as the source of hydrological change.

To further investigate whether the Het Kruis measurements are realistic in a regional context, a recent study compared the hydrological simulations of Verlorenvlei modelled using JAMS/J2000, with models built for Berg, Breede, Eerste, Bot (**Figure 9**) (Watson *et al*., 2021). The findings of this study will be reviewed and incorporated into the extended hydrology for these catchments as they provide valuable insights into the hydrology of the area especially considering the interactions with groundwater. The position of the Het Kruis gauge in a sub-basin dominated by Malmesbury group shales results in baseflow from the Table Mountain Group (TMG) aquifer not being measured. This is likely the root cause of the hydrological process simulation difference between Velorenvlei and the larger catchments (Berg and Breede), with little to no baseflow observed for Het Kruis.

While model uncertainty for the JAMS/J2000 setups is unique and will likely be different in SPATSM-Pitman, the issue of not having a good understanding of baseflow from the Moutonshoek and Bergvallei sub-basins will impact the hydrological simulation and the overall water balance. It is therefore recommended that when performing the calibration at Het Kruis, the parameter set should have a secondary validation for sub-basins with TMG contributions, such as in the Berg.

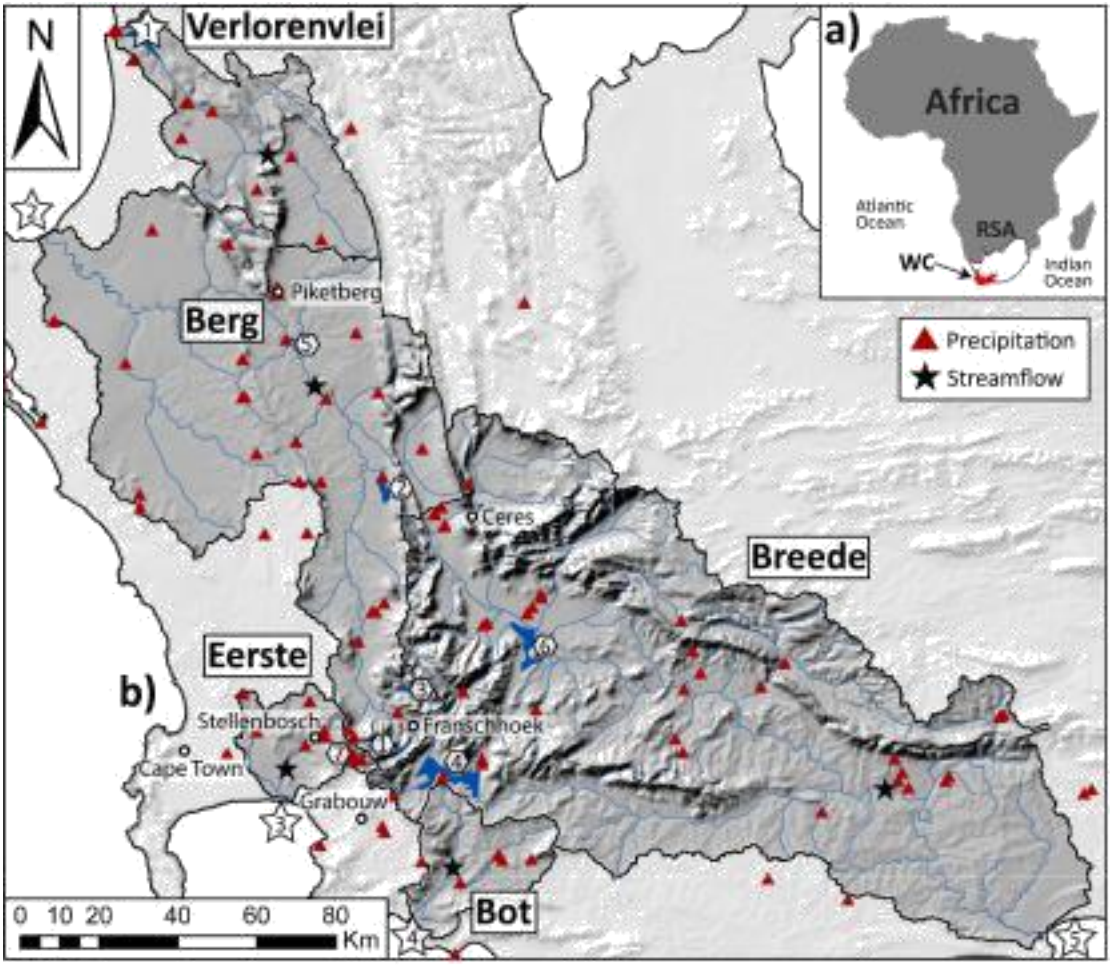


Figure 9. The Verlorenvlei, Berg River, Eerste, Bot and Breede study catchments showing modelling extent, precipitation and gauging station locations within the Western Cape (Watson *et al*., 2021)

DWS has access to the Mzansi Amanzi (Water South Africa) product by Geoterra Image (https://geoterraimage.com/mzanzi-amanzi/), which may assist with understanding the hydro-periodicity of the systems in the area and, in particular, the wetlands. Data will be obtained from DWS: Spatial and Land Use Management.

2.2.2. Water quality

The riverine quantity Reserve determinations are proposed to be undertaken at an intermediate level for the Verlorenvlei, Langvlei and Jakkals Rivers and at a rapid level for the other rivers in the study area. It is assumed that the water quality Reserve determinations are to be undertaken at the same proposed levels.

The major information gap for the water quality Reserve determination is the limited water quality data which will impact the confidence of the Reserve results. The shortage of water quality data for the rivers is largely due to the fact that the rivers are dry for most of the year.

The limited water quality data makes it challenging to determine reference conditions and even more challenging is the fact that both F60 and G30 quaternary catchments have non-perennial rivers linked to wetlands with definite wet and dry rainfall seasons with and without interaction with the groundwater and springs in the study areas. Reference conditions will have to be determined by following the non-perennial river methodology as described in Seaman *et al,.* 2010, in which the catchment and not only the EWR site is included in the evaluation of the reference condition.

The Present Ecological Status was determined on a desktop level in 2011 and based on the results, the PES for the F60 catchment is a B and the water quality results from the field surveys during the wet and dry seasons at the EWR sites are not expected to be much different from the reference conditions. However, the PES for the G30 catchment is a D except for the Sandlaagte River, which is an E. This implies that the water quality has probably also deteriorated over time and local knowledge will have to be interrogated to determine to what extent the water quality has changed. The only two long-term water quality monitoring stations will also be used to assess change over time, although these sites will not necessarily be close to the EWR sites.

Water quality monitoring data is available on the DWS Water Management System (WMS) and is part of the National Chemical Monitoring Programme (NCMP) which monitors the chemical water quality of South Africa's surface water resources. It is the longest-running of the national monitoring programmes, with some sample sites having data dating back to the 1970s and earlier. Gaps in NCMP include routine monitoring of metals, organic pollutants in rivers and reservoirs, turbidity and suspended sediments, river and in-lake vlei temperature and oxygen concentrations, all of which are important for determining the water quality status of rivers.

From an examination of the spatial distribution of water quality sampling points in the study area, it appears as if there is a good distribution of monitoring points that could be used to describe the spatial changes in water quality. However, a more detailed examination of the water quality data associated with each monitoring point reveals that these points were mostly associated with once-off, longitudinal river water quality surveys and that the only monitoring points in the G30 tertiary catchment where there is a longer data record, are at the Kruis River at Tweekuilen/Eendekuil and the Hol River at Wittewater Papkuilsvlei gauging sites, referred to as G3H001 and G3H005 respectively. **Figure 10** shows the distribution of water quality sampling sites within the G30 catchment and an indication of the number of samples taken at these sites.

At the G3H001 sampling site (Kruis River at Tweekuilen/Eendekuil), some 374 samples were collected from 1970 to 2017, while 102 samples were collected at G3H005 (Hol River at Wittewater Papkuilsvlei) between 1978 and 2017. Sampling frequency started at monthly intervals but was later reduced to *ad hoc* sample collection. The historical data record at both sampling stations will therefore be examined for seasonal changes to determine if there are differences in water quality between the wet and dry seasons. There are no long-term water quality monitoring data available in the F60 tertiary catchment.

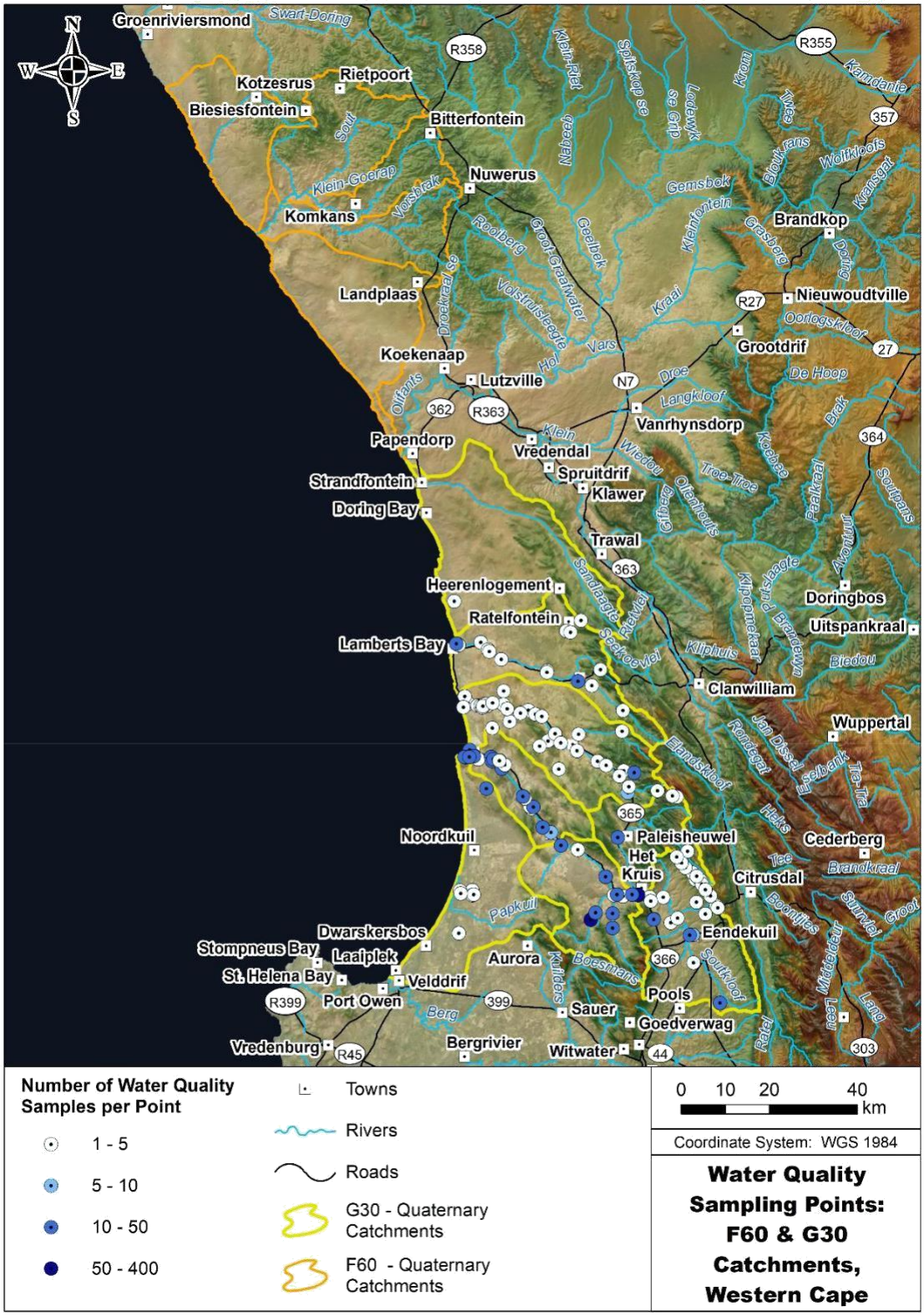


Figure 10. Map of surface water quality monitoring sites in the F60 and G30 Catchments

In summary, although there are a large number of water quality monitoring points registered in the DWS database for parts of the study area, these were mostly associated with once-off surveys or routine sampling that was terminated in the early

1980s. The survey data will thus be used to examine “snap shots” of spatial changes in water quality to better understand how water quality changed along the length of the surveyed rivers. This will add to the knowledge base of water quality behaviour in the catchments.

No recent surface water quality samples were collected in the study area after 2017 for the National DWS Monitoring system. However, the Western Cape Regional Office has been monitoring the water quality since 2019 in some rivers in the G30 catchment and the data collected to date has been requested from the Western Cape Regional Office.

It is, therefore, safe to conclude that the study area is very poorly monitored, in terms of its surface water resources, for water quality and even more so in the F60 quaternary catchment. The non-perennial nature of most of the rivers in the two study areas is probably the reason for the poor water quality data records.

2.2.3. Rivers

The lower reaches of the Verlorenvlei, Langvlei and Jakkals Rivers comprise extensive longitudinal wetlands with localised and weak riverine components. Short sections of morphologically distinct river channels exist in the upper catchments (e.g., Upper Kruis, Bergvallei, Krom Antonies Rivers and the headwaters of the Langvlei tributaries – the Alexandershoek and Lambertshoek). Important secondary characteristics are the presence of multiple freshwater springs or ‘eyes’, occurring along the length of all three systems. Lateral intrusions of brackish to saline water also occur that result in distinct variations in water quality and plant species throughout each of the three systems. In essence, portions of these systems exist as a series of wetlands, connected by surface channels in places, but mostly by flow through the hyporheos.

All the systems, particularly within their lower wetland sections, are largely groundwater driven or are groundwater-dependent ecosystems. Thus, although the discussions below describe these systems as rivers, they comprise rather a mix of river and wetland and are fed from both ground and surface water. In their lowest reaches, the habitat changes quickly from riverine to wetland and then to estuarine. This implies that the ecological Reserve recommendations for these systems need to take cognisance of the aquatic habitat type, the associated water required to maintain that habitat and to understand where the water supply comes from, ground or surface water or a combination thereof depending on the season. This requires good integrations between the various disciplines contributing to this Reserve study.

2.2.3.1. River Ecological Assessments

The previous Ecological Reserve (Rapid Level), undertaken by Southern Waters for the G30 Catchment in 2003, comprised assessments of the Kruismans Tributary of the Verlorenvlei River, the lowest reach of the Verlorenvlei River, the lowest reach of the Langvlei River and the lowest reach of the Jakkals River (**Figure 11**). A PESC

assessment was undertaken at each site that included water quality, macroinvertebrates and habitat integrity assessments. The EISC was also determined for each site. The result from the assessments is provided in **Table 2**.

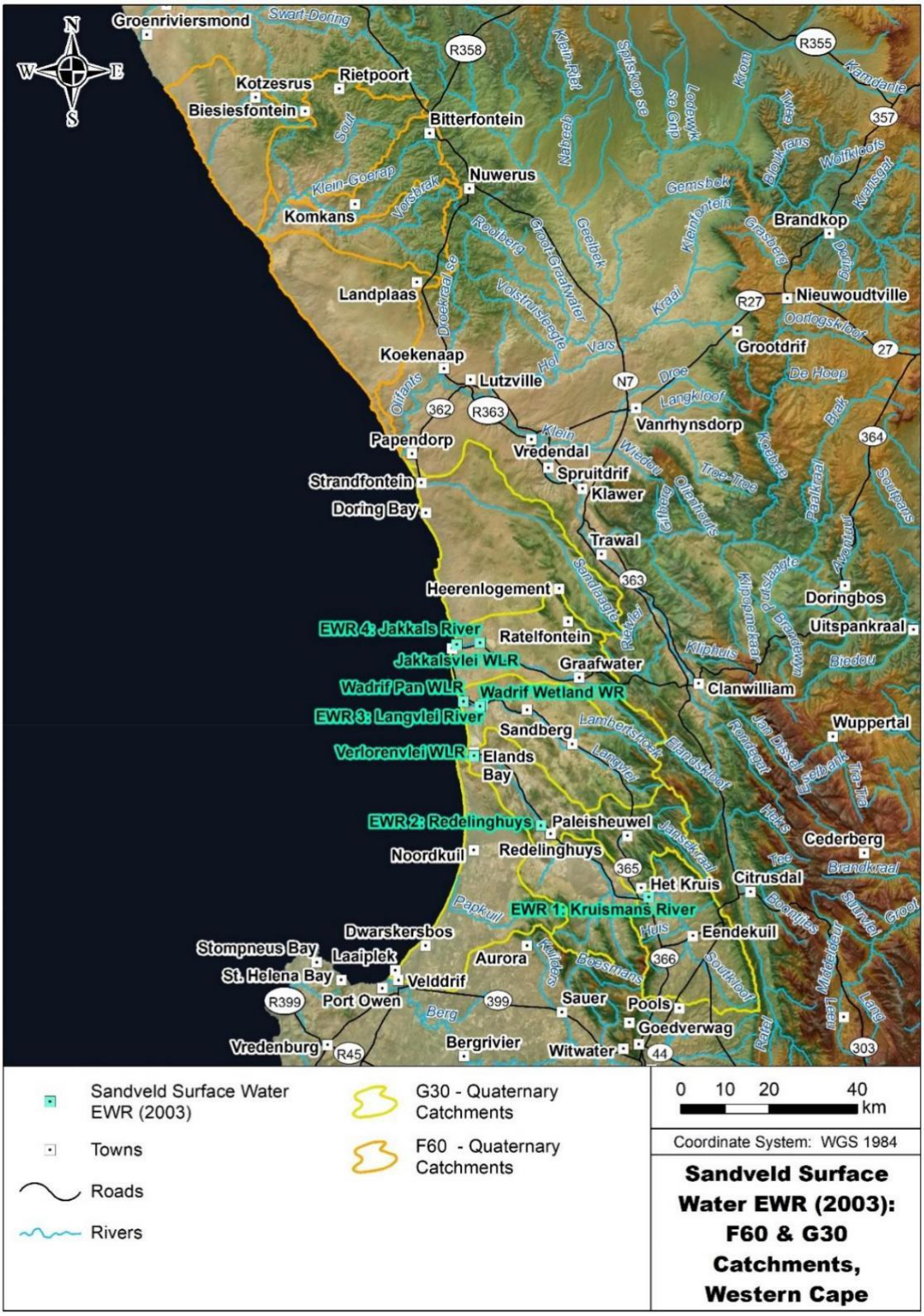


Figure 11. Map of surface water EWR sites for the Sandveld Reserve determination undertaken in 2003

Table 2. Summary of the PESC and EISC for the Sandveld Ecological Reserve Determination in 2003

River	Present Ecological State Category (PESC)	Ecological Importance & Sensitivity Category (EISC)	Recommended Ecological Category
Langvlei	E/F	C	C
Jakkals	D	C	C
Kruismans (Verlorenvlei) at Duikerfontein	C	B	C
Verlorenvlei at Redelinghuys	C	B	B

In 2006 a State of Rivers Report was completed for the Olifants/Doring and Sandveld Rivers (DWA, 2006) that included an assessment of the habitat integrity, geomorphology, riparian vegetation, macroinvertebrates, fish and water quality at five sites in the Verlorenvlei River System (upper and lower Kruismans, Bergvallei, Krom Antonies and the Verlorenvlei at Redelinghuys), and one site each on the Langvlei and Jakkals Rivers. The Ecological Importance (EI) and Ecological Sensitivity (ES) were also assessed and a desired ecological state recommended. An additional site was also included in the Sout/Goerap River that comprised habitat integrity and riparian vegetation assessments.

The seven River Eco-status Monitoring sites (indicated as Macroinvertebrate sites in **Figure 12**) have been sampled between three and ten times over the period between 2004 and 2015. There are an additional 17 fish once-off sampling sites sampled primarily in the Verlorenvlei River but also in the Langvlei, Jakkals and Papkuils Rivers. Eight once-off sampling sites for adult dragonflies have also been undertaken in the Sandveld Rivers. The Freshwater Biodiversity Information System (FBIS) also displays the Odonata (dragonfly and damselfly) data from the Odonata Map Virtual Museum, FitzPatrick Institute of African Ornithology at the University of Cape Town. Eight records of dragonfly observations occur within the study area on the FBIS.

In 2012, the national level desktop assessment of the PES, EI and ES (DWS, 2014) was undertaken for 28 river reaches in the G30 Catchment and 14 river reaches in the F60 Catchment. The outcomes of these assessments, which included the results from the River Eco-status assessments, were incorporated into the Water resources classification for the Berg-Olifants WMA (including the rivers of the F60 and G30 catchments at a quaternary catchment level), which was completed in 2012 and gazetted in 2014. Resource quality objectives (RQOs) were gazetted for these rivers in 2015 (Notice No. 609 of 2015 published in Government Gazette 39001 dated 17 July 2015) and included RQOs for the lower Verlorenvlei, Langvlei, Jakkals and Sandlaagte Rivers.

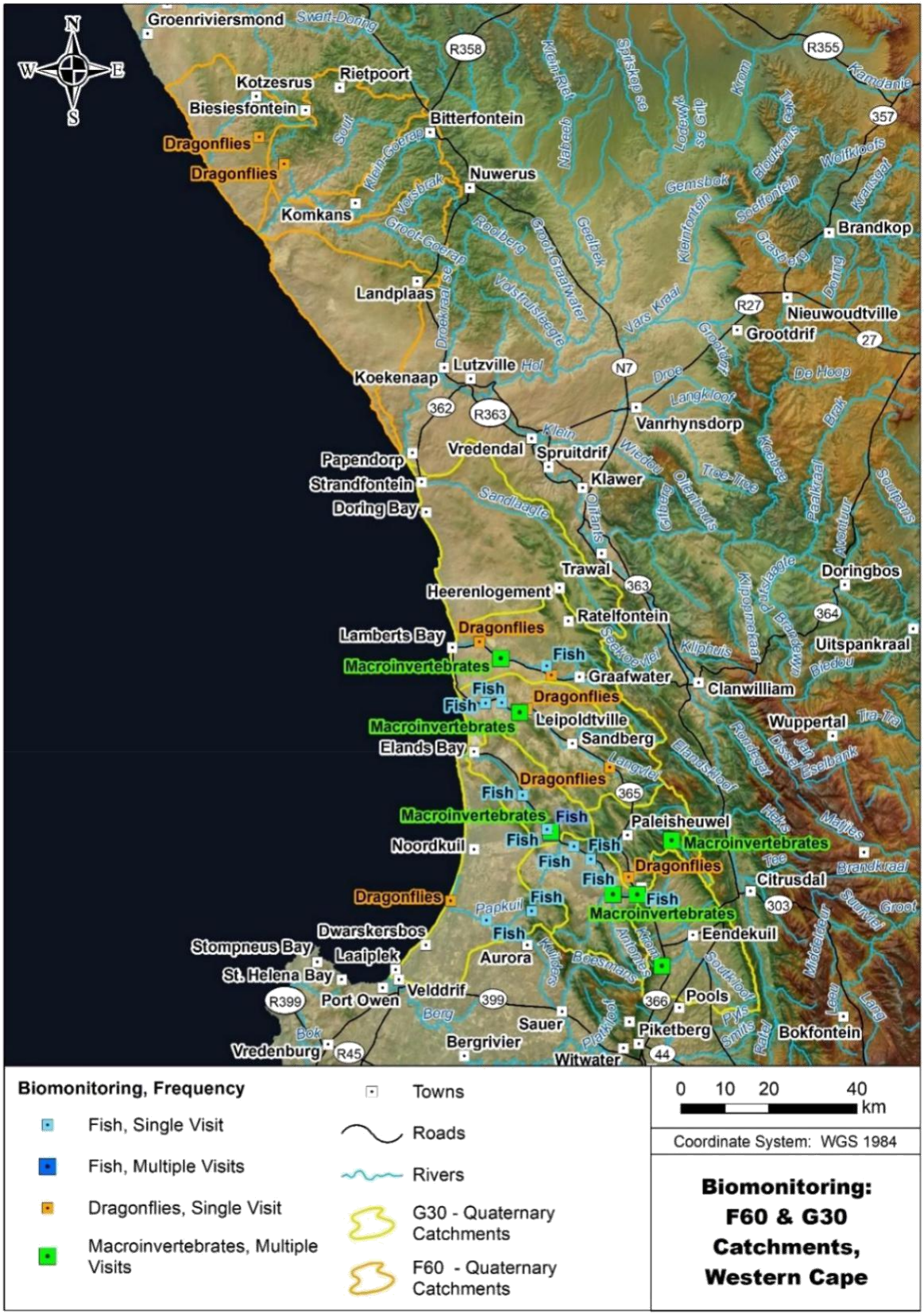


Figure 12. Map of surface water biomonitoring points in F60 and G30 Catchments

2.2.3.2. Riverine Biodiversity Conservation Importance

The C.A.P.E. fine-scale planning project for the Sandveld-Saldanha Planning Domain was undertaken in 2008 and included a river typing exercise that divided the rivers according to broadly similar flow, similar surrounding landscape characteristics, similar sediment transport characteristics and supporting broadly similar biota. A desktop-level river ecological integrity assessment was also undertaken where most of the rivers were considered to be in a moderately modified ecological condition (C category). No rivers in the F60 Catchment were included in the assessment. Fish sanctuary and fish connectivity catchments were identified for the area that included the Kruismans/Verlorenvlei and Langvlei Rivers.

The National Freshwater Ecosystem Priority Areas (NFEPA) mapping in 2011 (Nel *et al*., 2011) incorporated the fish sanctuary and fish connectivity catchments. The entire Verlorenvlei and Langvlei Catchments comprise a mix of sub-catchments that are mapped either as River Freshwater Ecosystem Priority Area (FEPA), Fish Support Areas, Upstream Management Areas or Phase 2 FEPAs.

The Western Cape Biodiversity Spatial Plan (WCBSP) 2017 (Pool-Stanvleit *et al*., 2017) has mapped all of the larger rivers in the study area as regionally important Aquatic Critical Biodiversity Areas (CBAs), while the smaller tributaries are mapped as Ecological Support Areas (ESAs) which require safeguarding to ensure the continued existence and functioning of species and ecosystems, including the delivery of ecosystem services, across terrestrial and freshwater realms.

2.2.3.3. Geomorphology, Sedimentation and Hydraulics

The main aspects with regards to the required sedimentation studies relate to sediment yields from the catchments and potential changes in sediment loads. These changes are due to the construction of instream dams, channel modifications and changes to the composition of bed and bank materials.

The most important documents that are of relevance are:

- The Sediment Yield Map of Southern Africa (Rooseboom *et al*., 1992);
- As there is little data available regarding sediment yields that have been measured within the study area as a whole, there is a great deal of uncertainty regarding sediment yields and loads across the catchments; and
- The channel shape as well as the characteristics of bed and bank materials, varies greatly along the rivers in the study area. Sampling sites, as well as sampling procedures, will therefore have to be selected with care.

2.2.4. Wetlands

Very little information is available for wetlands in Quaternary Catchments G30 and, especially, F60. Firstly, the coverage and accuracy of the mapping of wetlands in these study areas is not particularly good. Except for the bigger, more well-known systems

(such as Wadrift wetland, Verlorenvlei, Langvlei and Jakkalsvlei), most of the wetlands have been mapped at a low level of confidence only based on desktop-based information. The most recent comprehensive coverage of wetlands in the study area is the desktop-based National Wetland Map 5 (NWM5) (see **Figure 13** and **Figure 14**), produced as part of the South African Inventory of Inland Aquatic Ecosystems (Van Deventer *et al*., 2018), which formed the basis of the wetland component of the National Biodiversity Assessment 2018 (NBA-2018) (Van Deventer *et al*., 2019).

The earlier NFEPA project (Nel *et al*., 2011) also mapped wetlands in the study area and identified FEPA wetlands considered to be of particular conservation importance, while the WCBSP (after Pool-Stanvleit *et al*., 2017) includes wetlands that have been mapped in the study area and categorised as regionally important Aquatic CBAs.

The mapping of wetlands by NWM5 and NFEPA did include desktop-based information on the types of wetlands (as shown on the maps of NWM5 wetlands in **Figure 13** and **Figure 14**), while NFEPA and the NBA-2018 also included some modelled estimates of the Present Ecological State (PES) of the wetlands based on available land cover data (as explained by Nel *et al*., 2011 and Van Deventer *et al*., 2019, respectively). Information on the hydrology, geomorphology and water quality of wetlands in the F60 and G30 catchments is, however, severely lacking, as is information on the biota associated with the wetlands.

No EWR studies have been completed for wetland ecosystems in Quaternary Catchment F60. The most detailed information collected to date for wetlands in Quaternary Catchment G30, especially in relation to EWR studies, is that which was collected for the Sandveld Preliminary (Rapid) Reserve Determinations for the Langvlei, Jakkals and Verlorenvlei systems (DWAF, 2003). All three systems are essentially extensive longitudinal wetlands with localised and weak riverine components, according to the Reserve report (DWAF, 2003). Despite this reality, the only Resource Unit that was dealt with as a "wetland" in this study was the Wadrift wetland, forming part of the Langvlei system. The other units were treated as estuarine or river ecosystems.

The Wadrift Wetland is a small wetland at the point of discharge of the Langvlei River onto the coastal plain, immediately upstream of and grading into the Wadrift Pan. As such, the wetland was classified as a floodplain wetland system by Southern Waters (DWAF, 2003), but with a high degree of riverine character in its upper reaches, and pan shoreline at the downstream end where it grades into the Wadrift Pan (estuarine ecosystem). The wetland has a very high degree of groundwater dependence, according to Southern Waters (DWAF, 2003).

Figure 13. Wetlands in the F60 catchments, categorised according to HGM type, as mapped and categorised by National Wetlands Map 5

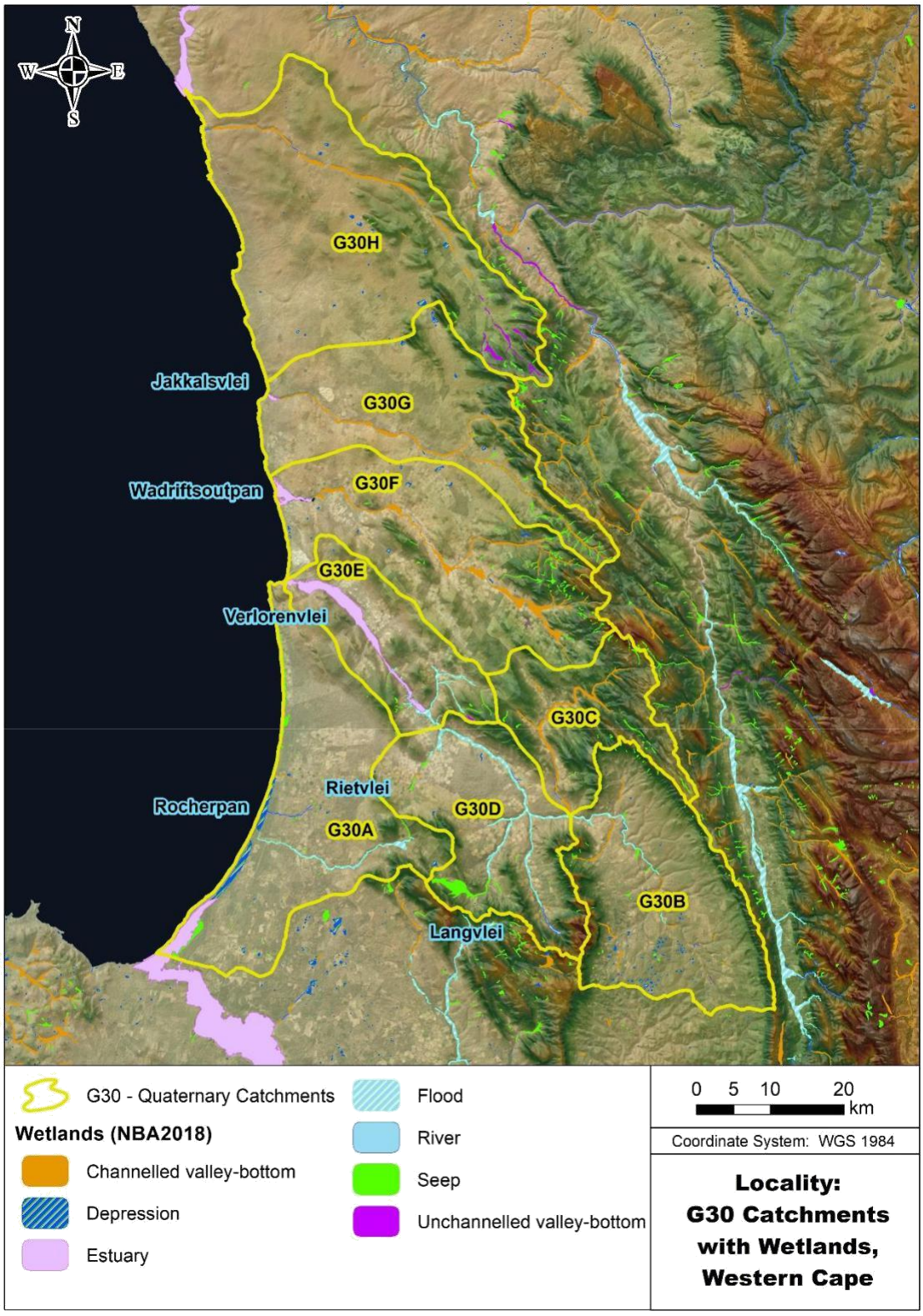


Figure 14. Wetlands in the G30 catchments, categorised according to HGM type, as mapped and categorised by National Wetlands Map 5

In the absence of readily available and tested methods for Wetland RDM studies at the time, the following pilot approach was employed by Southern Waters (2003) for the preliminary determination of the water requirements for the Wadrift wetland:

1) Identification and description of the reference conditions;
2) Identification of the key drivers, cause and effect functions and stressors that underpin the ecological, functional and socio-economic functioning of the wetland;
3) Undertaking of preliminary level hydrology, hydraulics, water quality and biotic (floral and faunal – inclusive of sediments) verification of the condition of the wetland and its (transect-based) association with its upland (terrestrial) environment, and longitudinal connections up- and downstream;
4) Determination of the Present Ecological Status Class (PESC) using the Wetland Rehabilitation and Assessment Protocol (WRAP) that was in development by Southern Waters at the time of the study;
5) Determination of the Trajectory of Change of the identified key components of system functionality;
6) Determination of the Ecological Importance and Significance (EISC) of the system – using a specialist workshop process and other pertinent information;
7) Identification of key indicators that support the identification of water levels and durations of inundation;
8) Determination of the desired Ecological Management Category (EMC);
9) Determination of the preliminary water requirements (PWR) to meet the EMC;
10) Comparison and contrasting of the PWR with the availability of water from the IFR assessment to link the PWR to the system hydrology;
11) Specification of the degree of confidence in the recommendations and identify such further work as may be required to develop the required level of understanding.

The above information is thus available for the Wadrift wetland, but from almost 20 years ago (2002-2003). One of the key recommendations to emerge from the study was that a protocol should be developed for the integration of riverine, groundwater and surface water requirements in interlinked and interdependent systems such as the Wadrift wetland (DWAF, 2003). To our knowledge, the availability of such a protocol is still a major gap.

In the study to determine RQOs for the then Olifants Doorn WMA (DWA, 2013), narrative and numeric RQOs were included for the Wadrift wetland (discussed above in relation to the EWR) and some narrative RQOs were included for the Sandlaagte wetlands in Catchment G30H. No RQOs have been set to date for any other wetlands in Quaternary catchments G30 or F60, due to a lack of sufficiently detailed information at this point in time. It was recommended by DWA (2013) that additional Priority Resource Units should be identified in the broader Olifants Doorn WMA, for which RQOs will then need to be determined. This is particularly important for wetland ecosystems in Quaternary Catchments F60 and G30.

In summary, the major data and information gaps for the determination of the Reserves for priority wetlands in Quaternary Catchments F60 and G30 are:

- Low confidence (mainly desktop-based) mapping of wetlands;
- Lack of information and data pertaining to the hydrology, geomorphology, water quality and biota of wetlands;
- Lack of EWR data on wetlands, with only one Wetland EWR study (for the Wadrift wetland in Catchment G30) having been completed (at a low confidence) to date; and
- Lack of information relating to RQOs, with RQOs to date only having been set for two wetlands in Catchment G30.

The above-mentioned gaps are exacerbated by the non-perennial and often groundwater-dependent nature of many of the wetland systems in the study area. This makes it especially difficult to "draw the line" between rivers, wetlands and estuarine ecosystems in preparation for the collection of EWR information. Despite the non-perennial nature of many of the smaller wetland systems in the relatively arid study area, most of the larger wetland systems are associated with a more perennial supply of water, often from groundwater sources, resulting in the formation of permanently saturated conditions within portions of some of these wetlands. These permanently saturated conditions, in certain cases (such as parts of Verlorenvlei and Wadrift Pan), have led to the formation of peat, which creates particularly unique and important wetland ecosystem types in the arid region. This aspect, which has not been given due recognition in the past, will need to be taken into account in the prioritisation of wetland resource units.

2.2.5. Freshwater biota

2.2.5.1. Aquatic Vegetation

Surveys of riparian and instream vegetation have been undertaken as part of the 2003 Reserve Determination for the Jakkals, Langvlei and Verlorenvlei Rivers by Coastec. Assessments of the riparian vegetation of the above rivers were also undertaken at seven sites as part of the River Eco-status Monitoring Programme and, in particular informed the Olifants/Doring and Sandveld Rivers: State of Rivers Report, dated 2006. These assessments were before the development of the VEGRAI. A single eco-status assessment of the riparian vegetation of the Sout/Goerap River within the F60 Catchments was undertaken. Additional surveys will be carried out as part of this study.

2.2.5.2. Macroinvertebrates

SASS5 assessments of macroinvertebrates at seven sites in the Jakkals, Langvlei and Verlorenvlei Rivers were undertaken from 2004 until recently as part of the River Eco-status Monitoring Programme. The assessments informed the Olifants/Doring and Sandveld Rivers: State of Rivers Report, dated 2006. The state of river assessments was undertaken before the development of the MIRAI. Additional surveys will be carried out as part of this study.

2.2.5.3. Fish

Knowledge of the diversity of the freshwater fish fauna

The study area, especially the Verlorenvlei River System, has been surveyed for fishes several times, mainly by the staff of CapeNature, the provincial conservation agency, focusing on the river sections (**Figure 12**), but also by the staff of the Department of Forestry, Fisheries and the Environment (DFFE) undertaking fisheries surveys in the Verlorenvlei. This vlei is situated very close to the sea, and estuarine-dependent fishes such as mullet enter the vlei for recruitment purposes. An intensive fish survey was undertaken of the Verlorenvlei River System in 2015 (Chakona *et al*., 2019), providing an accurate and up-to-date knowledge of the diversity of freshwater fish fauna of this key river system. The other river systems are very small and hence have only been occasionally surveyed for fish (**Figure 12**). Hence, knowledge of the overall freshwater fish diversity of the study area is very good.

Knowledge of the distribution of the freshwater fish fauna

The intensive fish survey of the Verlorenvlei River System in 2015 (Chakona *et al*., 2019) has provided comprehensive and up-to-date knowledge of the distribution of freshwater fishes, especially native fishes, across this system, including tributaries and headwater areas. This publication also provided valuable information on the densities of the native fishes in this system and highlighted which river areas are especially important for the conservation of the endangered native fishes.

Knowledge of the distribution of the Galaxias and Sandelia lineages in the other and much smaller river systems is patchier, and it would be valuable to have several sites in each system, to improve knowledge of fish distribution in them.

Knowledge of the conservation status of and threats to the native fish species

The Verlorenvlei redfin was described as a new species recently (Chakona *et al*., 2014) and is listed as endangered by the IUCN (Chakona *et al*., 2017a). The species has its strongest population in the Krom Antonies River, a perennial tributary of the Verlorenvlei River System. Its major threats are well known, which include excessive water abstraction (surface and groundwater), habitat degradation, pollution and invasive non-native fishes (carp, banded tilapia, Mozambique tilapia) (Chakona *et al*., 2017a).

The unique Galaxias lineage was recently listed as endangered by the IUCN and had its strongest population in the Kruismans River, a tributary of the Verlorenvlei River System (Chakona *et al*., 2017b). Its key threats are the same as for the Verlorenvlei redfin.

The Cape kurper present in the study area has been identified as *Sandelia* sp. ‘capensis west coast’, which is largely confined to the Langvlei, Verlorenvlei, Diep and Berg River Systems (Bronaugh *et al*., 2019). The conservation status of this taxon has not been assessed yet (Chakona *et al*., 2019). It would appear to be most common in the Upper Krom Antonies and lower Verlorenvlei rivers (Chakona *et al*., 2019).

Knowledge of the habitat requirements of the freshwater fish fauna

Chakona *et al*. (2019) studied the habitat associations of the native fishes of the Verlorenvlei River System, providing valuable information to guide this study in terms of their ecological requirements. This is one of the first studies on habitat requirements of Verlorenvlei redfin, Cape Galaxias and Cape kurper.

The only value of the non-native fishes is in terms of very limited angling and for food consumption (likely minor value), which is restricted to Verlorenvlei itself. Hence, their habitat requirements are of little relevance to this study.

Gaps for fishes

Fortunately, there are no major gaps for freshwater fishes in terms of this Reserve study. It will be important to undertake a fish survey of all river systems as part of this study to determine if native fish persist in good numbers and assess the extent of threats with other study team members. Fish communities also change over time, and there is always the risk of new fish invasions e.g., sharptooth catfish, which have aggressively spread across the Cape Floristic Region since the 1990s, due to illegal introductions by anglers. This makes an updated fish survey of all known native fish strongholds very important.

2.2.5.4. Amphibians

Some data exists for the area. As the study area is a relatively dry region, it has a low amphibian species richness. A total of 11 frog species are known or expected to occur in this area. Of the 11 frog species in the study area, eight are reliant on the annual inundation of wetland habitats. The three *Breviceps* species breed independently of wetland habitat.

The amphibians of the study area can be roughly grouped into two guilds, i.e., terrestrial and aquatic lifestyles. The terrestrial guild can be further subdivided according to wetland types that these frogs are specifically associated with, as has been indicated in **Table 3** below.

Table 3: List of amphibian species known or likely to occur in the study area, with their respective IUCN conservation status and ecological guild category

Family	Genus	Species	Common name	IUCN status	Endemic	Guild*
Brevicipitidae	*Breviceps*	*gibbosus*	Cape Rain Frog	Near Threatened	WC	AG1e
Brevicipitidae	*Breviceps*	*namaquensis*	Namaqua Rain Frog	Least Concern	SA	AG1e
Brevicipitidae	*Breviceps*	*rosei*	Sand Rain Frog	Least Concern	WC	AG1e
Bufonidae	*Sclerophrys*	*capensis*	Raucous Toad	Least Concern	SA	AG1abcd

Bufonidae	*Vandijkophrynus*	*angusticeps*	Cape Sand Toad	Least Concern	WC	AG1abd
Bufonidae	*Vandijkophrynus*	*gariepensis*	Karoo Toad	Least Concern	0	AG1abd
Pipidae	*Xenopus*	*laevis*	Common Platanna	Least Concern	0	AG2abcd
Pyxicephalidae	*Amietia*	*fuscigula*	Cape River Frog	Least Concern	SA	AG1abcd
Pyxicephalidae	*Cacosternum*	*capense*	Cape Caco	Near Threatened	WC	AG1ad
Pyxicephalidae	*Strongylopus*	*grayii*	Clicking Stream Frog	Least Concern	SA	AG1abd
Pyxicephalidae	*Tomopterna*	*delalandii*	Cape Sand Frog	Least Concern	SA	AG1abcd

Where:

Terrestrial (AG1): The terrestrial amphibian guild is comprised of frogs that spend the majority of their lives outside of water. Most members of this guild typically forage and live away from water bodies when not breeding but tend to congregate at water bodies during the breeding season. They may shelter under rocks, logs, amongst vegetation and underground, with many species aestivating during the dry season. Although some members of this guild (e.g., *Amietia* species) have strong affinities with wetlands throughout the year, they are still considered to be terrestrial because they spend most of their lives on land as opposed to in the water. Some species (e.g., *Breviceps*) breed independently of wetland habitats, i.e., through direct development without free-swimming tadpoles.

Aquatic (AG2): Aquatic amphibians are species that typically live in water for almost all of their lives, only emerging onto land during dispersal events, and even then usually in wet conditions. Aquatic frogs call, breed, feed and shelter beneath the water surface. During dry spells when wetlands may dry up, these frogs can aestivate underground until the wetlands fill up again.

Endorheic (a): These systems are depressions that fill up seasonally (rainwater or seepage) and are depleted by evaporation or absorption into the atmosphere (i.e., pans, pools and ponds).

Riverine (b): Systems that are generally contained in a channel but may flood during periods of excessive rainfall (i.e., permanent rivers, dry river beds, floodplains, temporary streams, perennial streams and mountain torrents).

Lacustrine (c): Systems that are larger than 8 ha in topographic depressions with the majority of the water surface open without emergent vegetation (i.e., dams and lakes).

Palustine (d): Shallow marshland systems dominated by emergent vegetation (i.e., vlei, hill slope seepage, inundated grassland).

Terrestrial (e): These are systems with no obvious standing or flowing water (i.e., forest floor, rocky outcrops, sand dunes, open grassland, savannah). Species in this

sub-guild do not need standing water to breed and are therefore of rare occurrence in amphibians.

2.3. Estuaries

Hydrology and Hydrodynamics: The level recorder at Verlorenvlei G3R001 (Active from 1994) does not show when the estuary mouth is open to the sea, thus making it very hard to calibrate a water balance model for Verlorenvlei. This will result in a low to medium confidence level EWR study for the estuaries.

Water Quality: Very little historical information is available on the water quality of Verlorenvlei, Wadrift, Jakkalsvlei or the Sout Estuary. Some data was collected on the Sout Estuary as part of the Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA in 2017 (DWS, 2017a). This will result in low to medium confidence level EWR studies for the estuaries.

Microalgae: No historical information is available on microalgae of Verlorenvlei, Wadrift or Jakkalsvlei. Some microalgae data was collected on the Sout Estuary as part of the Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA in 2017. This will result in low confidence level EWR studies for most of these systems.

Macrophytes: No recent macrophyte maps are available for Verlorenvlei, Wadrift or Jakkalsvlei. The Sout Estuary was visited in 2016 as part of the Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA in 2017 (DWS, 2017a). New macrophyte maps will be prepared as part of this study.

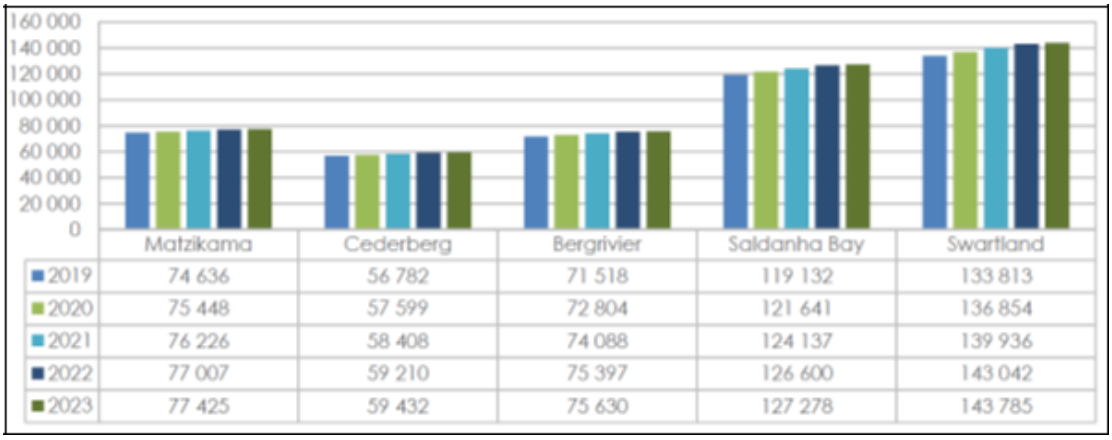
Invertebrates: Very little historical information is available on microalgae of Verlorenvlei, Wadrift or Jakkalsvlei. Some data was collected on the Sout Estuary as part of the Determination of Ecological Water Requirements for Surface water (River, Estuaries and Wetlands) and Groundwater in the Lower Orange WMA in 2017 (DWS, 2017). This will result in low to medium confidence level EWR studies on most of these systems.

Fish: Some fish data are available on Verlorenvlei and Jakkalsvlei. Little fish data are available on Wadrift, while the Sout Estuary is hypersaline and does not support fish (DWS, 2017a). This will result in low to medium-high confidence level EWR studies on most of these systems.

Birds: Some data is available on birds of Verlorenvlei, Wadrift, Jakkalsdrift and the Sout Estuary (e.g., CWAC counts, historical EIAs and DWS, 2017a). However, most of these data sets are not time-series and may thus result in low to medium confidence level EWR studies depending on data availability.

2.4. Socio-Economics

The majority of the study area falls within the Matzikama, Cederberg and Berg River Municipalities. Socio-economic information for these municipalities is available from the Western Cape Provincial Government 2019 Socio-economic Profile for each of the municipalities. The population of the Matzikama, Cederberg and Bergrivier Municipalities in 2022 is estimated to be 77 007, 59 210 and 75 397, respectively (**Figure 15**). Growth rates for the municipalities range between 0.9% (Matzikama) and 4.6% (Cederberg).



	Matzikama	Cederberg	Bergrivier	Saldanha Bay	Swartland
2019	74 636	56 782	71 518	119 132	133 813
2020	75 448	57 599	72 804	121 641	136 854
2021	76 226	58 408	74 088	124 137	139 936
2022	77 007	59 210	75 397	126 600	143 042
2023	77 425	59 432	75 630	127 278	143 785

Figure 15: Population Municipalities in West Coast District Municipality

The Gini coefficient is a statistic that quantifies the amount of inequality that exists in a population. The Gini coefficient is a number between 0 and 1, with 0 representing perfect equality and 1 perfect inequality. The Gini coefficient in 2018 for the municipalities was approximately 0.582. Although the levels are lower than the figures for the district municipality and Western Cape, the coefficients for 2108 were marginally higher for all three municipalities which imply a deterioration of socio-economic conditions and an increase in income disparities. The situation is likely to have been exacerbated by the COVID-19 pandemic of 2020-2021.

The United Nations uses the Human Development Index (HDI) to assess the relative level of socio-economic development in countries. Indicators that measure human development are education, housing, access to basic services and health. There has been a general increase in the HDI in the municipalities within the study area between 2015 and 2018. The HDI figures are similar to the district and provincial HDI. Although there was an improvement in the HDI between 2015 and 2018 these gains are likely to have been impacted by the COVID-19 pandemic of 2020-2021.

In 2017, the two main contributors to the economy and employment in the area were the agriculture, forestry, and fishing sector, followed by the wholesale & retail trade, catering and accommodation sector and the manufacturing sector. The manufacturing sector is closely linked to and supported by the agriculture, forestry, and fishing sector.

Table 4 provides a socio-economic overview of the relevant wards within which the study area is located -Matzikama Municipality Ward 8, 5 and 2; Cederberg Municipality Ward 5; Berg River Municipality Ward 6 and Kamiesberg Municipality Ward 3.

Table 4. Socio-economic overview of the relevant wards within the study area

Category	Matzikama			Cedarberg Ward 5	Bergrivier Ward 6	Kamiesberg Ward 3
	Ward 8	Ward 5	Ward 2			
Population (2011)	8 050	8 595	7 298	9 141	9 428	3 240
Age						
U 18	32.3%	28.1%	31.8%	29.4%	30.4%	29.2%
18-64	59.5%	63.4%	61.3%	61.6%	63.2%	60.2%
65-	8.2%	8.5%	6.9%	9.0%	6.5%	10.7%
Population Group						
Black African	8.5%	5.5%	4.7%	12.4%	13.8%	5.9%
Coloured	77.7%	55.2%	83.7%	71.8%	73.1%	77.45
White	13.1%	38.0%	11.1%	15%	11.9%	15.55
Indian/Asian	0.5%	0.7%		0.5%	0.6%	0.3%
Language						
Afrikaans	92.2%	91.2%	92.5%	85.8%	83.4%	87.9%
IsiXhosa	1.3%	1.7%	0.8%	6.6%	8.3%	0.5%
English	1.8%	2%	1.5%	2.1%	2.2%	0.7%
Education						
None	7.3%	5.7%	0.0%	4.8%	5.2%	4.2%
Matric	17.5%	29.8%	0.0%	24.4%	21%	22.2%
Employment						
Employed	43.1%	68.3%	48.7%	46.3%	51.2%	46.1%
Unemployed	12.1%	2%	13.7%	10.5%	9.7%	14.5%
Households						
Households (2011)	2 373	2 823	2 025	2 654	2 979	987
House	76.8%	83%	89.9%	83.6%	76.2%	87.9%
Shack			1.9%	7.8%	4.4%	
Annual Income						
Under R4800	14.8%	4.6%	12.5%	13.9%	18.9%	9.1%
R5K – R20K	28.3%	15%	21.9%	20.7%	19.6%	20.6%
R20 – R40K	23.7%	22.9%	26.5%	24.3%	22.7%	23.2%
Water Supply						
Service Provider	74.3%	61.3%	87.1%	87.2%	81.4%	84.3%
Borehole/Dam	12.8%	27.7%	7.5%	10.5%	10.3%	8.4%
Sanitation						
Flush toilet	59.2%	56.3%	62.8%	87.9%	86.2%	72.8%
Bucket	9.3%	1.4%	5.4%	3.9%	2.7%	1.7%
Refuse						
Service	70.5%	48.2%	65%	82.4%	80.3%	85.5%
Own dump	24.2%	41.3%	20.8%	12.9%	15%	12.4%

Figure 16 **on** the next page contains a map of the municipality boundaries and the relevant wards.

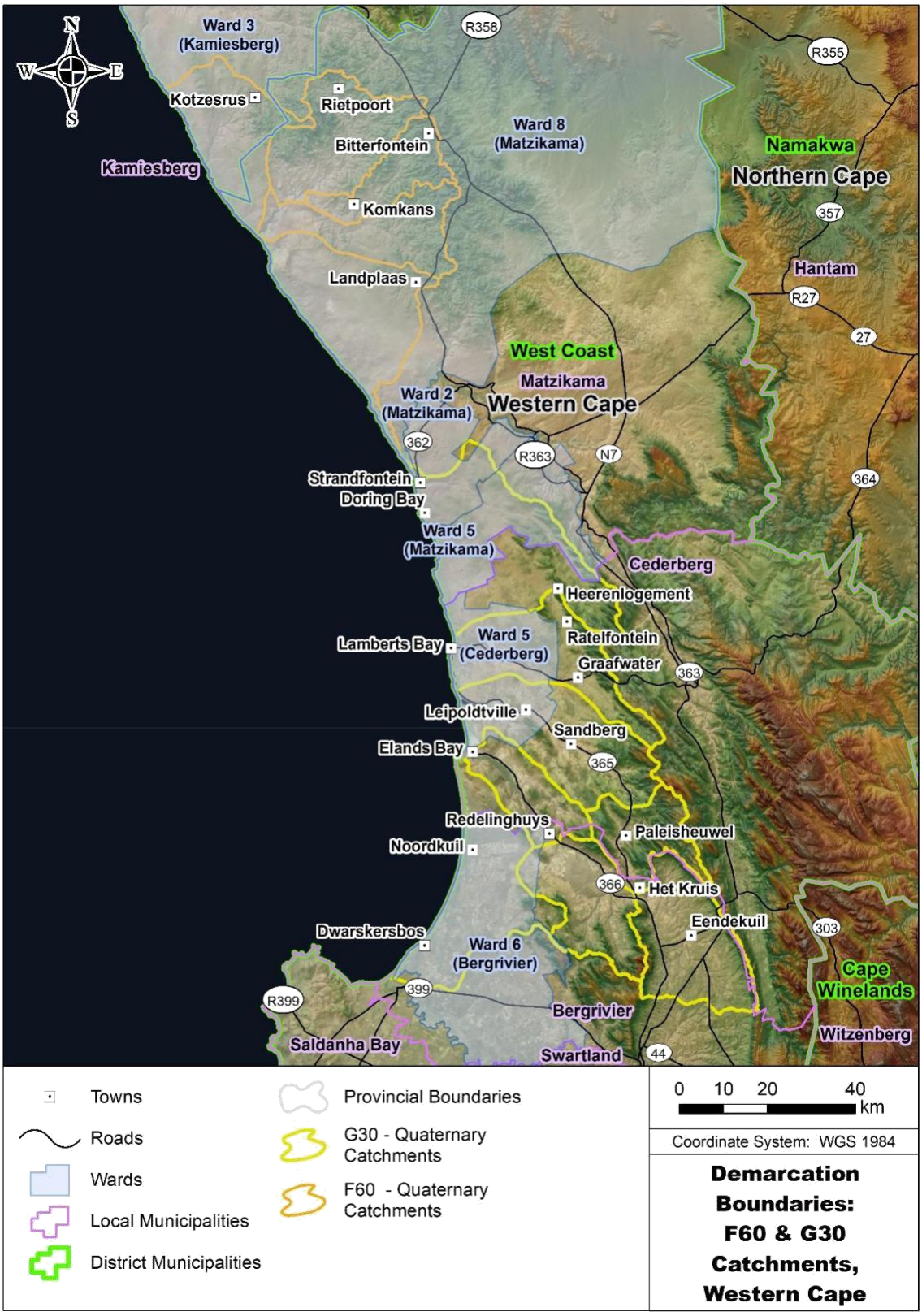


Figure 16. Map of the demarcation boundaries within the F60 and G30 Catchments

3. APPROACH TO ADDRESSING THE INFORMATION GAPS

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. This allows for greater confidence that the conditions at the time of the study (i.e., PES of the water resource at the EWR site) are accurately recorded and represented. This is of utmost importance in setting a management condition for the system (REC or BAS), which would remain at the PES or would improve. The data collected will however 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.

3.1. Hydrological Data and Modelling

A review of water resources information and data including a review of available water resources planning studies, including the availability of the latest water resources models, will be undertaken. An inventory of current water resources models (catchment hydrology rainfall-runoff models, water resource system models, groundwater models, estuary models, etc.) will be compiled and evaluated in terms of their applicability to the Study. Our current understanding is that the WR2012 version of the Pitman Model is the latest available configured model for the study area which is commonly used in Reserve determination studies. The latest Water Resources of South Africa study (WR2012) produced long-term simulated monthly stream flows for all quaternary catchments in South Africa. The Pitman Model configurations for the F60 and G30 catchment will be sourced from that database.

We are also aware of the JAMS/J2000 rainfall/runoff model that has been configured for the Verlorenvlei which will be reviewed and assessed for consideration in the updated catchment models for the area.

It is proposed that the WR2012 hydrology for the F60 and G30 catchments be extended from 2009 to 2019 hydrological year to include the 2015/2016 drought period which will be critical in providing up to date estimates of water availability in the catchment. Rainfall station data will be obtained from the South African Weather Services (SAWS) via the DWS to extend the existing WRMF dataset from 2009 to 2019

- thus 9 years of rainfall data per station per year need to be obtained for approximately 9 stations. The rainfall data will be sourced, screened and patched and formatted as required for input to the Pitman model. This study will extend the WR2012 hydrology from 2009 to 2019 using available rainfall station data and relevant representative periods of observed flows will be used to validate the simulated flows. The validation of flows will be supported by expert knowledge and conceptual understanding of the surface water in the catchments. It will also incorporate the findings of ongoing studies in the catchment (Watson *et al*., 2021) as far as possible.

Current land use data will be sourced from available data sets, including Cape Farm Mapper and DWS SLIM for an updated dams layer in this catchment. The irrigation water requirements have recently been estimated using the 2017/2018 crop census for the Western Cape as part of the "Western Cape Integrated Drought and Water Response Plan" study currently being undertaken for the Western Cape Provincial Government. It is proposed that these estimates will be incorporated into the updated configuration of the Pitman model for tertiary catchments F60 and G30.

The WR2012 configurations will be refined and extrapolated to the delineated resource units and EWR nodes in the catchment for which actual observations and data collection are not being collected. It is envisaged that the refined WR2012 dataset will be configured in SPATSIM to better accommodate the application of the conceptual understanding of groundwater and surface water interaction. The latest Reserve Determination Model is also built-in to SPATSIM and this will facilitate the extrapolation process of the Reserve to the study area. The output of the Pitman model will be a monthly time series of natural and current-day runoff at the outlet of each quaternary and the EWR nodes in the required format for input to the Desktop Reserve Model. A Water Balance model will be used to balance aquatic ecosystem inflows, outflows and losses from the system.

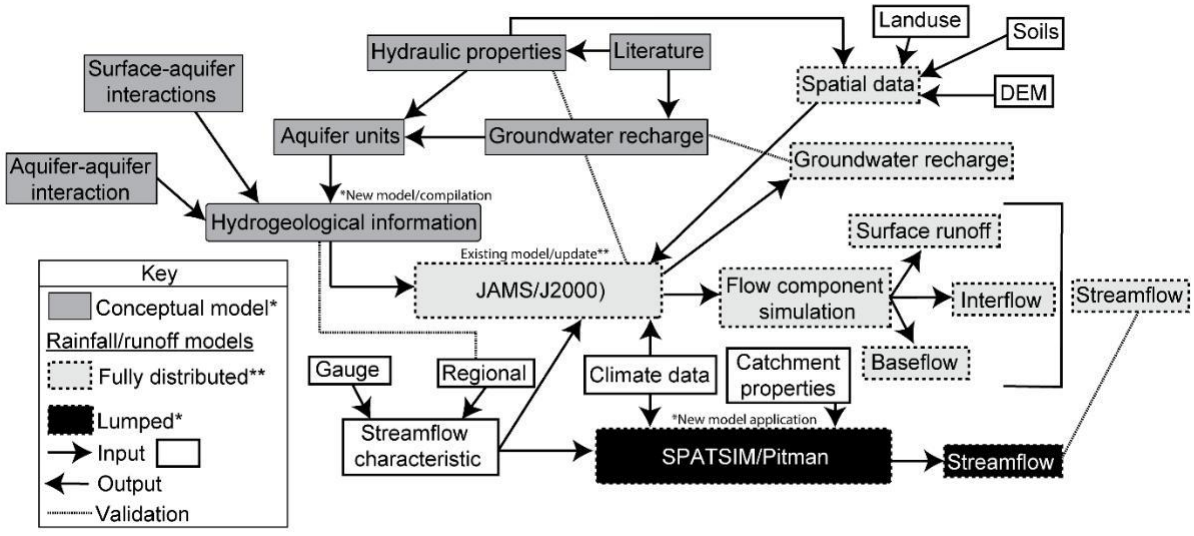


Figure 17. Schematic of the linkages between the modelling aspects for the project

3.2. Water Quality Reserve

The riverine quantity Reserve determinations are proposed to be undertaken at an intermediate level for the Verlorenvlei, Langvlei and Jakkals Rivers and at a rapid level for the other rivers in the study area. It is assumed that the water quality Reserve determinations are to be undertaken at the same proposed levels.

The major information gap for the water quality Reserve determination is the lack of water quality data which will impact the confidence of the Reserve results.

The lack of water quality data also makes it challenging to determine reference conditions and even more challenging is the fact that both F60 and G30 quaternary catchments have non-perennial rivers linked to wetlands with definite wet and dry rainfall seasons with and without interaction with the groundwater and springs in the study areas. Reference conditions will have to be determined by following the non-perennial river methodology as described in Seaman *et al,.* 2010, in which the catchment and not only the EWR site is included in the evaluation of the reference condition.

The non-perennial nature of most of the rivers in the two study areas is probably the reason for the poor water quality data records. For this reason, water quality data for groundwater and in particular springs in the study area will also be assessed using the results from the Groundwater team.

The fact that the rivers are fed from different water resources (groundwater, surface water runoff and springs) does not enable one to confidently extrapolate water quality characteristics from one 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).

A limited budget has been set aside for collecting water samples for chemical analysis at EWR sites where poor data records exist. This will complement *in-situ* measurements made during site visits.

The initially proposed river reaches for the EWR sites were identified and will be confirmed during the resource delineation task. The water quality sites will be aligned with the identified EWR sites.

G30

- G30B/G30C - Lower Bergvallei/Kruismans;
- G30B - Lower Krom Antonies (DWS sampling site G3H001 is located within this quaternary catchment);
- G30D/G30E - Lower Verlorenvlei River in the Verlorenvlei River System (DWS sampling site G3H005 is located within 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

F60

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

During the Reserve determination for each EWR site, water quality is divided into three components physical, chemical and biological and will be assessed accordingly. The values of each water quality variable in the un-impacted state or Reference Condition will be derived. These values will be compared to the current water quality (PES) to assess the level of water quality-related modification.

The Physico-chemical Driver Assessment Index (PAI) model (DWAF, 2008, DWS, 2016) will be utilized where applicable in line with the use of the other assessment indices (HAI, GAI, FRAI, MIRAI and VEGRAI).

One of the major challenges with the current tools is the model requirements compared to the water quality variables generally measured. To determine the water quality reserve, water temperature, dissolved oxygen and turbidity measurements are required. These are seldom measured during routine chemical water quality sampling, so although there are two long term water quality data sets, very little to no data are available for these three variables. Some information may be available from the data collected for the River Health Programme and the Freshwater Biodiversity website (FBIS). Water temperature can be derived from ambient air temperature data (Dallas *et al.*, 2012).

3.3. River Reserve Determination Information

For rivers, existing or easily acquired data will be used to define longitudinal zones that differ in terms of channel morphology, water chemistry and temperature; and biological zones for fish, invertebrates and riparian vegetation. The DWS 2014 PES and EIS database will be utilised in the desktop assessment as well as data from the previous assessments.

The budget makes provision for seven EWR sites, located throughout the study area, but with the emphasis on the Verlorenvlei River System. The intention is that, where appropriate, data obtained at these sites will be used to calibrate the Desktop model for extrapolation of the results to other hydrological nodes (river reaches) in the study area. While seven EWR sites have been budgeted for, the zoning of the river and the choice and number of sites is subject to discussion.

Field assessments will be undertaken to determine the Present Ecological state (PES) and Ecological Importance and Sensitivity (EIS) at each EWR site, as well as to collect critical data to quantify ecological water requirements for the river reach or wetland unit. Field assessments will be undertaken during the wet winter season or in the early spring when there would be flow in these aquatic features and the timing would be

optimal for the collection of biotic data such as vegetation identification as the primary cue for identifying water requirements.

The fish assessment will require the identification of sufficient survey sites on the river systems within the study area that contain suitable fish habitats, to document the present-day fish diversity and population health. These should focus, where possible, on existing sampling sites used by CapeNature and other agencies. Such sites should be surveyed in early summer (November / December) and in early autumn (March). GoPro Video footage and seine and fyke nets will be used for sampling purposes. Where possible, electrofishing would also be undertaken to assist in the fish assessment.

The water quality sites will as far as possible be aligned with existing water quality monitoring sites of the DWS.

3.4. Wetland Reserve Determination Information

The proposed approach to addressing the information and data gaps for wetlands is as follows:

- Compile a consolidated desktop-based map of wetlands in the study area, including the interpretation of available imagery to identify currently unmapped wetlands that can be detected on aerial imagery;
- Undertake desktop-based categorisation of wetlands into different types to aid in the selection of priority systems, in collaboration with other members of the project team (e.g., river and estuarine specialists);
- Obtain additional data and information on wetlands in the study area from consultants and government departments dealing with EIAs and WULAs in the study area;
- Formulate a procedure for prioritising wetlands for the collection of detailed field-based information, following the approach outlined in the Inception Report;
- Refine the methods that are going to be used to collect detailed field-based information from selected wetlands, in consultation with other members of the project team (including the river, vegetation, hydrology and geohydrology specialists); and
- As it is likely that many of the wetlands in the F60 and G30 catchments are fed by various resources, including groundwater, groundwater and surface water interactions (Hydropedology) and surface water runoff, close collaboration between the relevant specialists (hydrogeological, hydropedological, wetland and surface water) will be critically important to describe the complex interactions between these water resources.

Field assessments will be undertaken to determine the Present Ecological state (PES) and Ecological Importance and Sensitivity (EIS) of the wetlands at each EWR site, as well as to collect critical data to quantify ecological water requirements for each wetland unit. Field assessments will be undertaken during the wet winter season or in the early spring when the timing would be optimal for the collection of biotic data such as vegetation identification as the primary cue for identifying water requirements. For the amphibians, surveying is best undertaken during the winter/spring months. Prominent wetland units throughout the study area would be selected where data would be collected by listening to frog choruses (sound monitoring) at night and sampling tadpoles. Baited funnel traps would also be set for the aquatic *Xenopus*.

3.5 Estuary Reserve Determination Information

To address some of the data gaps identified above and familiarise the study team with recent developments in and around the estuaries, once-off reconnaissance level field visits (in spring/summer) will be undertaken to Jakkalsvlei and Wadrift estuaries in accordance with the data requirements specified in the EWR methods for estuaries (DWAF, 2008). While two field surveys (1 detailed and 1 limited) will be conducted on the Verlorenvlei Estuary (a Ramsar site). No new field work will be undertaken on the Sout Estuary, given its severely degraded state as a salt works.

Field data will be collected by a full team of estuarine specialists on the following aspects:

- Water quality (salinity, temperature, dissolved oxygen, pH, and nutrients);
- Microalgae (phytoplankton and benthic microalgae);
- Macrophytes (i.e. ground-truthing of mapped saltmarsh, reeds and sedges, submerged macrophytes habitats);
- Invertebrates (where observed);
- Fish (where observed); and
- Birds.

Abiotic and biotic specialist's report/summary will be produced that assesses the PES of various ecosystem components and their sensitivity to changes in river flow/groundwater as well as the completed EWR template as required in terms of the EWR method (DWAF, 2008). The Verlorenvlei EWR study will also be drawing on work that was done as part of a Water Research Commissions study 'Development of Climate Change Mitigation and Adaptation Strategies for the Estuarine Lakes of South Africa - K5/2931'. As part of this study conceptual models for mouth dynamics, water quality, microalgae, macrophytes and fish were developed for Verlorenvlei. These models, in turn, can now be further refined with the new field observations collected as part of this study.

The confidence in the EWR study largely depends on the confidence in the surface hydrology/groundwater and the availability of historical data sets. It is expected that Verlorenvlei will be at a medium level, while lack of critical data sets will result in Jakkalsvlei and Verlorenvlei being of low confidence. However, it will be critical to developing an up to date simulated monthly time series of recent inflows (i.e., up to November 2021) to Verlorenvlei to resolve key questions that are emerging about the impact of the recent drought on the system. This information is needed to develop a water balance model for Verlorenvlei in the absence of any measured data (i.e., DWS water level recorded is not measuring any water levels since 2016).

As part of this process, additional critical data gaps will also be identified and future monitoring plans developed to be refined at the EWR workshops.

3.6 Groundwater Reserve Determination Information

For the G30 catchment cluster, more data is available, but the system is more complex and existing data does not account for real current conditions, the Reserve determination is thus expected to fall under the intermediate level of confidence. These are based on the initial assessment of the available data and the overall geohydrological setting and could change during the assessment. As both the F60 and G30 catchments have a sole dependency on groundwater for most of the basic human and agricultural requirements, the need for a comprehensive reserve determination is clear. The focus will thus remain on obtaining the highest level of confidence during the study. For both catchments, some areas will have higher levels of confidence assigned to them due to the availability of data.

With regards to water levels, most of the data that has been collected fall within the G30 catchments. The data found within the F60 catchments mainly came from the NGA database and could be outdated and not adequately represent current water levels. The same was found for the long-term monitoring site, although here, only one site could be identified within the F60 catchments. Long-term monitoring data is needed for many of the methods used to calculate recharge (Saturated Volume Fluctuation and Cumulative Rainfall Departure). Single water levels can be collected during site visits, but more extensive monitoring data still be needed.

With regards to Groundwater Quality analysis, basic chemistry such as pH and EC values are more freely available, although still sparse within the F60 catchments. Overall, a good distribution of basic chemistry related to groundwater quality could be found within the G30 catchments.

With regards to groundwater abstraction, multiple data sets were used. For the Municipal abstraction, groundwater abstraction volumes could be found for each town that has confirmed they use groundwater within the F60 and G30 catchments. With regards to the abstraction of groundwater for industrial uses at mines, although multiple mines have been contacted, they have not provided data with regards to their groundwater use. With regards to the abstraction of groundwater for irrigational use, the WARMS and V&V databases have been studied and compared. Discrepancies

between the WARMS, the preliminary V &V and the finalized Infra-Red V &V have been highlighted and will need to be resolved.

Current adequate groundwater level, quality and abstraction data is vital in discerning the stress of each groundwater resource unit as well as being used in some of the recharge calculation methods.

A vital source of data with regards to groundwater water levels, quality and abstraction that has not been explored relates to groundwater data found within specialist reports submitted as part of WULA applications. If data could be collected from all the WULA applications located within the F60 and G30 catchments, additional data could be obtained. Abstraction volumes from proposed WULAs could also then be used to clarify some of the discrepancies found within the abstraction data.

Another avenue that will be explored is contacting individual groundwater users and water user associations. Although this is a valid method, it is very time consuming and, in some cases, redundant when the farm or property has already made their data available through the V&V or WULA application processes. This avenue will be explored together with the fieldwork stage to fill in data gaps after other relevant resources have been reviewed.

3.7 Socio-Economic Information for Reserve Determinations

Develop an understanding of the socio-economic profile of the population utilizing the water resources in the study area as well as their use of the water resources. Groundwater is a particularly important source of water for human use in the drier areas of the catchments under consideration. Determination of the groundwater-dependent population in the area will be undertaken.

“The Basic Human Needs Reserve provides for the essential needs of individuals for subsistence or Schedule 1 use, served by the water resource in question and includes water for drinking, for food preparation and personal hygiene. Typically, this is limited to a total volume of water calculated as the population multiplied by 25 litres per person per day. This is applicable where people do not have any water supplied via pipes or water services systems and where people are directly dependent on the water resource for their daily survival.

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