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

GROUNDWATER DELINEATION REPORT

August 2022

Department of Water and Sanitation

Chief Directorate: Water Ecosystems Management

DEPARTMENT: WATER AND SANITATION

CHIEF DIRECTORATE: WATER ECOSYSTEMS MANAGEMENT

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

WP11340

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DOCUMENT INDEX

Reports as part of this project:

Bold type indicates this report.

REPORT INDEX	REPORT NUMBER	REPORT TITLE
1.0	RDM/WMA09/00/CON/0121	Inception Report
2.0	RDM/WMA09/00/CON/0122	Gap Analysis Report
3.0	**RDM/WMA09/00/CON/0123**	**Groundwater Delineation Report**
4.0	RDM/WMA09/00/CON/0124	Surface Water Delineation Report

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

BAS	Best Attainable State
BH	Borehole
BHN	Basic Human Needs
CSIR	Council for Scientific and Industrial Research
CMA	Catchment Management Agency
DEA	Department of Environment Affairs
D:RDM	Directorate: Resource Directed Measures
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
GA	General Authorisation
GIS	Geographic Information System
GRDM	Groundwater Resource Directed Measures
GRU	Groundwater Resource Unit
ha	hectare
l/s	Litre per second
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MCM	Million Cubic Metres
m	metres
m^3/a	cubic metres per annum
$m^3/ha/a$	cubic metres per hectare per annum
mbgl	metres below ground level
mg/L	milligrams per litre
mm	millimetre
mm/a	millimetre per annum (precipitation)

mS/m	milliSiemens per meter (measurement of electrical conductivity)
MRU	Management Resource Unit
MSL	Mean Sea Level
NGA	National Groundwater Archive
NWA	National Water Act
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
RQO	Resource Quality Objective
RU	Resource Units
RWQO	Resource Water Quality Objective
SANAS	South African National Accreditation System
SANS	South African National Standard
TMG	Table Mountain Group
V & V	Validation and Verification
WARMS	Water Use Authorisation and Registration Management System
WCBSP	Western Cape Biodiversity Spatial Plan
WGS84	The official co-ordinate system for South Africa (since 1 January 1999) is based on the World Geodetic System 1984 ellipsoid, known as WGS84, with the ITRF91 (epoch 1994.0) co-ordinates of the Hartebeesthoek Radio Astronomy Telescope used as its origin. This new system is known as the Hartebeesthoek94 Datum.
WL	Water Level
WMA	Water Management Area
WMS	Water Management System
WRC	Water Research Commission
WULA	Water use licence application

GLOSSARY

AQUIFER A geological formation, which has structures or textures that hold water or permit appreciable water movement through them [from National Water Act (Act No. 36 of 1998)].

BASEFLOW That part of streamflow contributed by groundwater and discharged gradually into the channel.

BOREHOLE Includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer, or recharging an aquifer [from National Water Act (Act No. 36 of 1998)].

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

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 seawater can be diluted, to a measurable extent, with freshwater drained from land.

FLOW REGIME Recorded or historical sequence of flows used to create a hydrological profile of the water resource.

FRACTURED AQUIFER Fissured and fractured bedrock resulting from decompression and/or tectonic action. Groundwater occurs predominantly within fissures and fractures.

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.

GROUNDWATER water found in the subsurface in the saturated zone below the water table or piezometric surface, i.e. the water table marks the upper surface of groundwater systems.

GYPSIFEROUS Containing or yielding gypsum.

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.

INTERGRANULAR AQUIFER The intergranular aquifer is the primary aquifer and is described as an aquifer in which groundwater is stored within the flows through open pore spaces in the unconsolidated Quaternary deposits.

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.

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

MODIFIED Changed, altered.

PERMEABILITY The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (expressed as m/d). It is an intrinsic property of the porous medium and is independent of the properties of the saturating fluid; not to be confused with hydraulic conductivity, which relates specifically to the movement of water.

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.

QUATERNARY CATCHMENT A fourth-order catchment in a hierarchical system in which the primary catchment is the major unit.

RECHARGE The addition of water to the zone of saturation, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.

RIPARIAN Of, on, or relating to the banks of a watercourse, including the physical structure and associated vegetation. The land area adjacent to a stream or river is influenced by stream-induced or related processes.

SATURATED ZONE The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.

STORATIVITY The volume of water released from storage per unit of aquifer storage area per unit change in head.

SURFACE WATER All water that is exposed to the atmosphere, e.g., rivers, reservoirs, ponds, the sea, etc.

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.

WATER TABLE The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is at atmospheric pressure, the depth to which may fluctuate seasonally.

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 no. 36 of 1998).

1. INTRODUCTION

1.1 Background

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

1.2 Objectives

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

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

1.3 Purpose of this Report

The purpose of this report is to outline the process for delineating the groundwater resources for the determination of the Reserve in the G30 and F60 catchments (**Figure 1)** of the Olifants-Doorn Water Management Area.

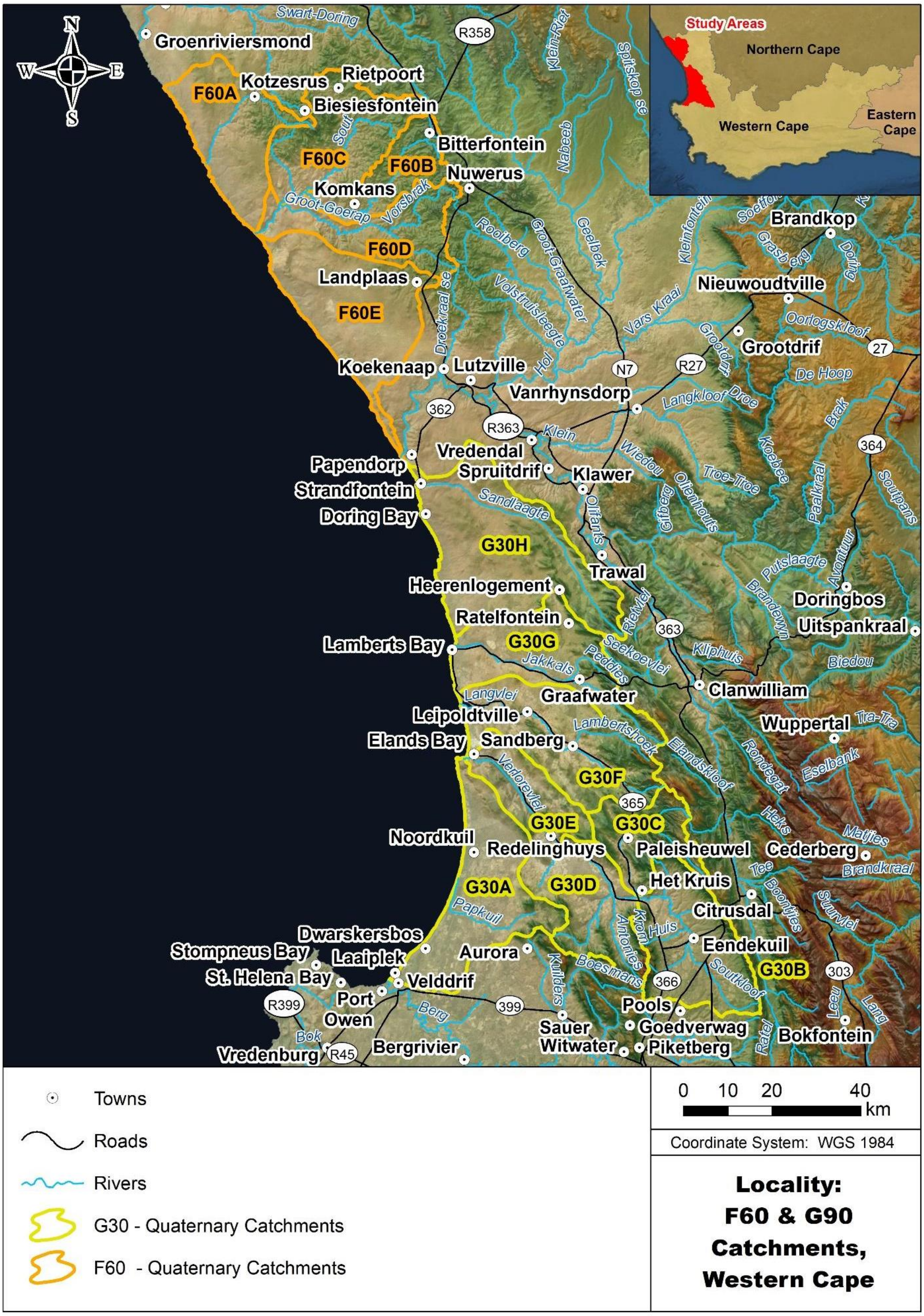

Figure 1: Map of the study area with the location of the G30 and F60 Catchments and main aquatic features shown

1.4. The Study Area

The study area comprises two Tertiary Catchments, the G30 (Sandveld) and the F60 (Knersvlakte) Catchments. The majority of the G30 and F60 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.

1.4.1 G30 Catchments

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. Groundwater in the G30 (Sandveld) Catchments plays an essential role in environmental functioning. It 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.

Distinct variations in water quality and plant species occur through the study area. 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 main recharge areas have been identified as the mountainous areas towards the east of the study area that form part of the Cederberg, Citrusdal and Piketberg Mountain ranges (GEOSS, 2019). These mountains are made up of the Table Mountain Group (TMG) formations, located in some instances outside the study area.

For the G30 catchments, geology is not as complex as for the F60 catchments (**Table 1**). The Malmesbury Group Formations are shale rich and seen as the basement rocks of the area. This is overlain by the Table Mountain Group formations. The TMG generally produces good quality water and are seen as good aquifers (Peninsula and Piekenierskloof), although some formations are shale rich (Graafwater) and generally yields poorer quality water. For most of the G30 catchments, these hard rock units are covered by thick sand deposits. TMG formations outcrop towards the eastern boundaries of the main Sandveld area and form the mountains found in the G30D, G30B and G30C catchment areas. The Geology is displayed in **Figure 2**.

Table 1: General Geology for G30 catchments

Code	Formation	Group	Description
	-	Quaternary to Tertiary Deposits	Alluvium
Q1	Springfontein Formation		Sandy Soil
Q2	-		Sand and sandy loam from the hillocky veld
Q5	Witzand Formation		Dune sand, highly calcareous in places
QP	Varswater Formation		Consolidated and unconsolidated phosphatic sand, clay and shelly gravel
C1Q1	Peninsula Formation	Table Mountain Group	Quartzitic sandstone with minor shale and conglomerate lenses
C1S1	Graafwater Formation		Reddish brown shale, sandy shale and siltstone
C1Q1R	Piekenierskloof Formation		Quartzitic sandstone and conglomerate
Kl	Klipheuwel Formation	Malmesbury Group	Brightly coloured shale, sandstone, greywacke and conglomerate,
MaQg	Piketberg		Chlorite schist, calcareous schists, phyllite, greywacke layers with meta-carbonate lenses
MaS	Porterville Formation		Phyllitic shale, schist and greywacke, with scattered thin grit lenses
MaQw2	Moorreesburg Formation		Greywacke, phyllite and quartz schist with thin lenses of limestone and grit

With regards to hydrogeology, in the more mountainous catchments where hard rock is exposed or sand cover shallow, boreholes are drilled mostly into the fractured hard rock aquifer. In the coastal areas, where thick sand deposits are found, boreholes are drilled into the sand. These zones of alluvium are generally parallel to the larger rivers, in this case, the Verlorenvlei. The sandy overburden is generally underlain by unconsolidated to semi-consolidated sand, clay and sometimes beach gravels. The Quaternary age deposits were identified by Vandoolaeghe (1982) as the optimum source of groundwater. The properties of the Quaternary deposits vary significantly.

Within the sand, yields differ from dry to very high (> 20L/s). Historically, these areas were referred to as paleochannels (Jolly, 1992). Paleochannels refer to an old or ancient channel that continues to act as a groundwater conduit, even if the actual river path on the surface changes or meanders. In the Sandveld, these are in some areas very distinctly visible from the air as bands of lighter sand areas that are generally northwest-southeast trending. High yielding boreholes and seepage areas are found within these areas, although at irregular intervals. From data collection and general field observations, a hypothesis has been proposed that links these groundwater rich saturated sands with discontinuous groundwater upwelling from faults underlying the sand in some areas, while in other, more typical paleochannel structures occur.

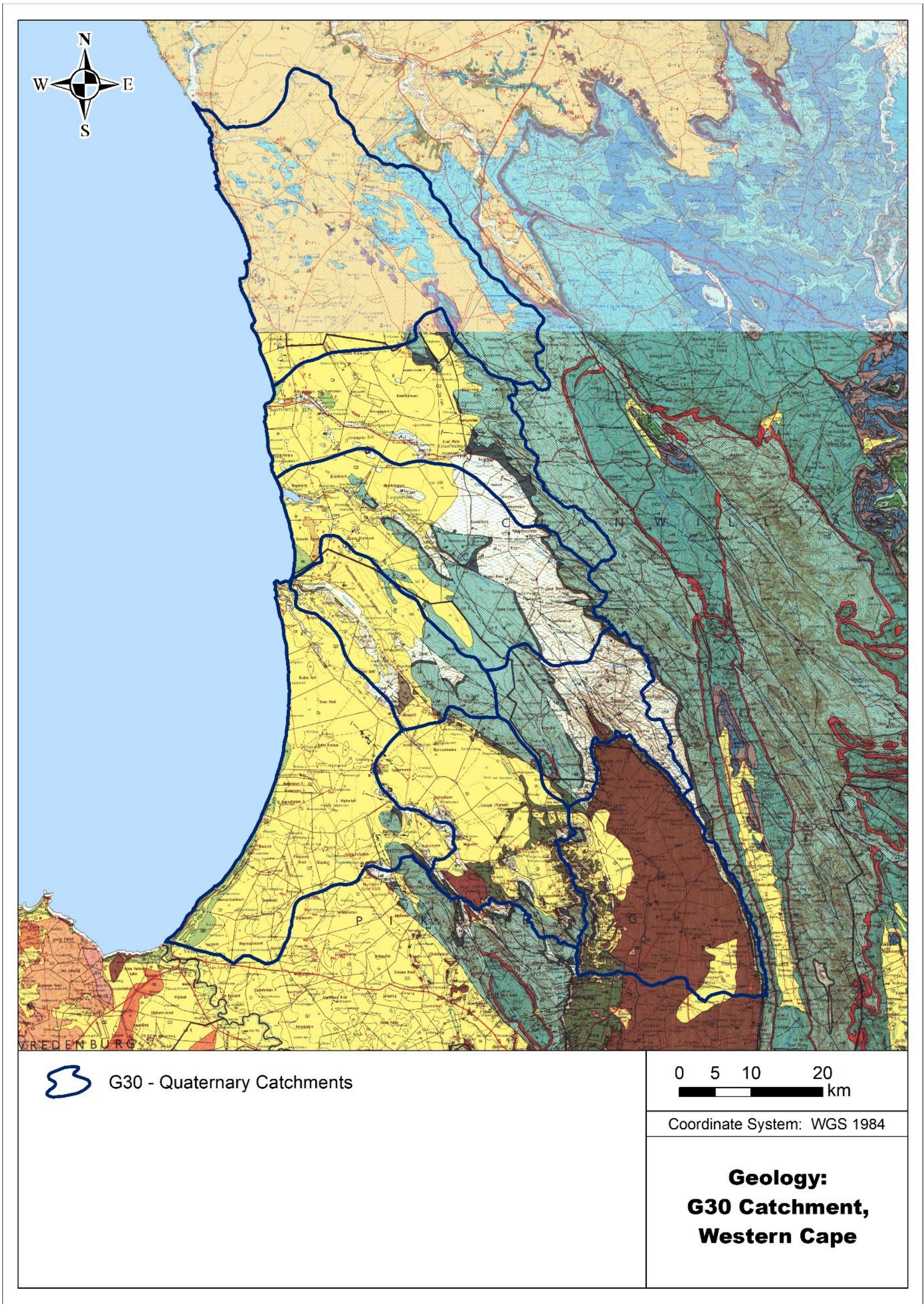

Figure 2: Geological setting of the G30 catchments (Clanwilliam,3218 & Calvinia, 3118) (CGS, 1973 & CGS, 2001)

The catchments thus contain both fractured and intergranular areas (**Figure 3**) (DWAF 2005). 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. Groundwater quality (**Figure 4**) is described as being good across the G30 catchments (DWAF 2005). This needs to be checked with more recent water quality data. Fewer monitoring boreholes exist in the upper reaches of the catchments.

As mentioned, groundwater forms the only source of freshwater for the vast majority of the human settlements located within these catchments. Groundwater abstraction for agricultural irrigation use is the main groundwater use in the area. The Sandveld has over time, transitioned from integrated livestock and rainfed crop production systems to irrigated vegetable production systems within the last 30 years. Although still an important potato producing area, the crops have diversified to include the production of other irrigated vegetables and, in recent years, citrus. These crops are labour intensive and have contributed to the economic growth of the towns in the catchments. The growth of the town and agricultural water uses has placed an increase in the groundwater demand for the area, and thus stress on the water resources.

Monitoring data is available in the form of water level readings from DWS, individual farms and the Potato SA monitoring project (GEOSS, 2019). Data reflecting the actual use for agricultural purposes is lacking. The distribution of these monitoring boreholes is towards the coast. Much development has occurred in the last 20 years that the Validation and Verification (V & V) process has not accounted for. This gap in data has been highlighted recently when across the G30 catchments, the V&V process was finalised and showed that the majority of the farmers are using more groundwater than what has been calculated during the V & V.

Springs and seepage points were incorporated in the delineation process and will act as focal points within the GRUs. Some of the springs have been visited and for some, comprehensive data is available (flow and chemistry data available for Matroosfontein seepage area that supplies Redelinghuys), while other springs have not been verified with the location being supplied by farmers in the area. Most of these spring sites are minor and are used up completely for domestic and agricultural uses.

Springs/Seepage points that are still relatively strong and likely still contribute to surface water is:

- Papkuils Seepage Area (G30A)
- Sandfontein Spring (G30F)
- Kruisfontein Springs (G30E)
- Seepage Areas at Matroosfontein and Uitvlug (G30D)
- Seepage Areas at Moutonshoek and Vrede and Kromvlei Spring 1 (G30D)
- The minor springs next to the Verlorenvlei in G30E (Klaarfontein Spring), although these are minor and flow is being impacted from boreholes nearby.

Springs/Seepage points where contribution to surface water are unknown and need to be investigated:

- Possibly the reported springs in the Bergvallei, although they have reportedly dried up recently (G30C)
- Possibly the reported springs in the southwestern corner of G30B
- Possibly the Kruisrivier Springs, although they are mostly used up for domestic and agricultural uses (G30B)
- Possibly the Eselshoek Spring (G30D)

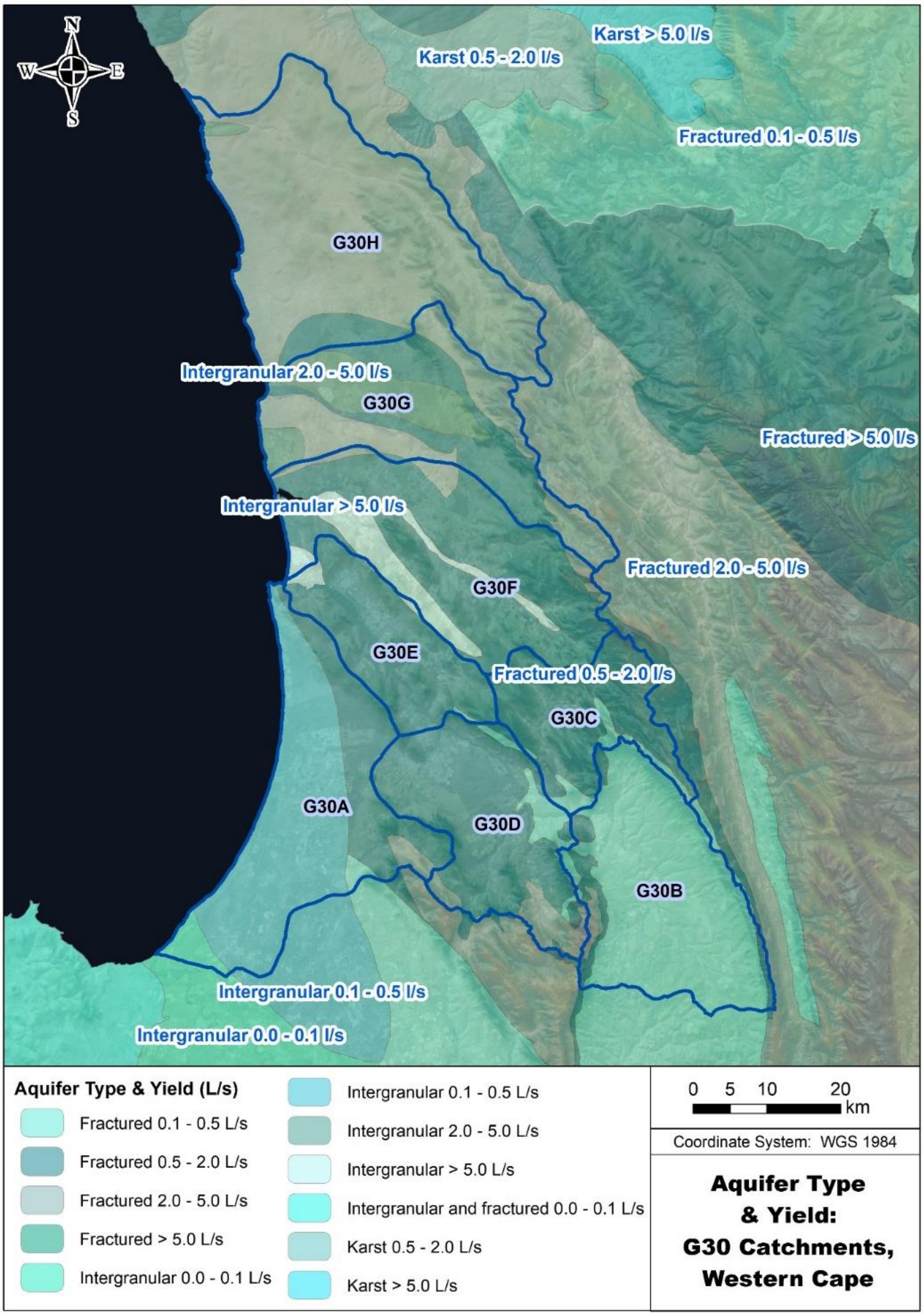

Figure 3: Regional aquifer yield for the G30 Catchments from the 1:1 000 000 scale groundwater map (DWAF, 2005)

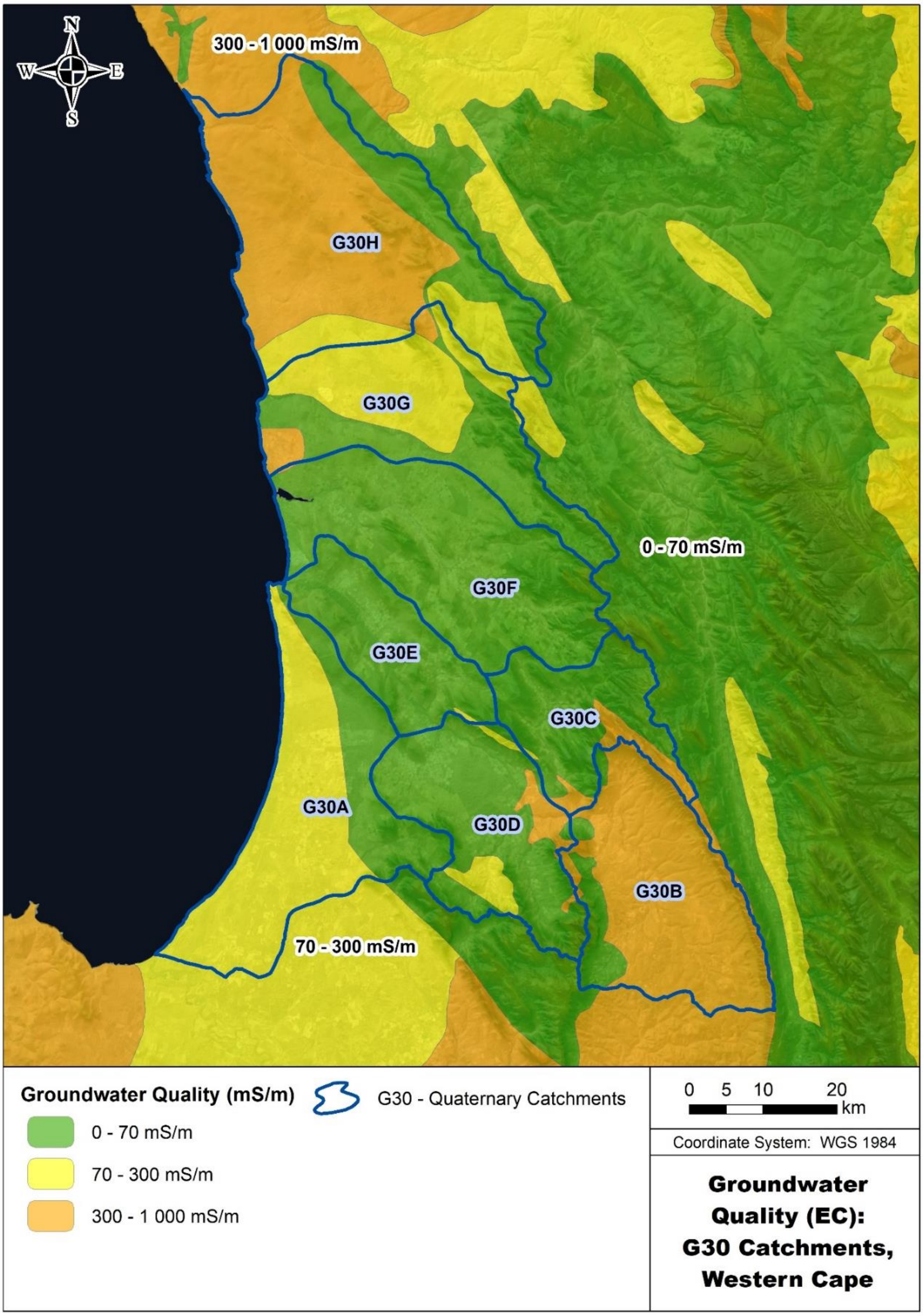

Figure 4: Regional groundwater quality (EC in mS/m) from (DWAF, 2005), for the G30 Catchments

1.4.2 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. The geology is dominated by the igneous and metamorphic rock units that are overlain by quaternary deposits. Quaternary deposits are still present toward the coast but include calcareous and gypsiferous units as well as thick calcrete beds within the deposits. The only sedimentary units found within the F60 catchment area refers to the Peninsula Formation that underlies the sand deposits at the most southern point of G60E and the Flaminkberg Formation in F60B.

The area is mostly underlain by different age granite and gneiss variants of the Koegel Fontein Complex, Spektakel Granite Suite, Little Namaqualand Suite and Kamiesberg Group (**Figure 5**). There are several younger dike intrusions mapped are, with some being unmapped. These dykes, as well as faults (mostly northwest-southeast) are targeted during groundwater exploration. **Table 2** discusses the geology in more detail as well as displaying the chronological order of the geology units in the area.

The poor quality in the area is linked to the lack of recharge, but also to the geology. Some faulted areas provide groundwater that cannot be used due to the poor quality of the groundwater that had reacted to the host rocks high in salts and minerals. It has also been reported that although water can be found if drilling in or near dry riverbeds, the water found here is, in some cases, very saline. For such areas, groundwater exploration is sometimes moved away from drainage channels and are drilled against hillsides and away from riverbed to target dykes or fracture zones.

Very little hard rock formations are exposed in areas towards the coast and geological boundaries between rock formations and faults are not defined. These coastal sedimentary deposits host some of the richest placer deposits in the world. They are targeted and mined for heavy minerals, such as zircon, garnet, ilmenite, rutile and magnetite. Because of this, there is interest in opening more mines in the area. These could potentially impact the very limited groundwater resource.

Boreholes drilled along the coast target saturated sand or weathered rock overlying hard rock units, while boreholes inland target the fractured hard rock formations or the dykes as mentioned above.

With the number of mines increasing across the catchment, local interested parties have raised concern regarding the increased demand being placed on a very scarce natural resource.

Table 2: General Geology for F60 catchments

Code	Formation/Unit	Group/Suite	Description
	-	Quaternary to Tertiary Deposits	Alluvium, colluvium, eluvium
Q-r_2	-		Calcareous and gypsiferous soil
Q-t	-		Quarts Scree
Qwi	Witzand Formation		Dune sand, highly calcareous in places
E-si	-		Silcrete
E-c	-		Calcrete
Δ Δ	-		Scree
E-s/Qkk	-		Red aeolian sand
Qh	Hardevlei Formation		Pale-red to red dune sand
Qpa	Panvlei Formation		Granitic soil with calcrete and dorbank, sometimes gypsiferous
Tdt	De Toren Formation		Silicified scree, sandstone and duricrust
Tbf	-	Bietjies Fontein Suite	Olivine melilitite and nephelinte plug
Kr	Rietpoort Granite	Koegel Fontein Complex	Alkali feldspar leucogranite
Kzr	Zout River Basalt/dykes		Tholeiitic basalt plug
Krb	Ribbokrug Alkali Syenite		Aegerine syenite and/or fenite
Ksa	Sandkop Syenite		Quartz-hornblende syenite, quartz-biotite syenite
Op	Peninsula Formation	Table Mountain Group	Quartzitic sandstone with minor shale and conglomerate lenses
Nfl	Flaminkberg Formation	Vanrhyndorp Group	Blue, white and red sandstone with subordinate conglomerate, shale and arkose
Nat	Aties Formation	Gariep Supergroup	White quartzite, graphitic phyllite, iron gossans
Nwi	Widouw Formation		Limestone and dolomitic marble
Nkr	Karoetjes Kop		Conglomerate, diamictite, quartzite, biotite schist
Nhf	Hangsfontein Granite	Spektakel Suite	Quartzo-feldspatic granite with biotite and minor garnet
Nbk	Bloukop Granite		Blueish-grey, reddish-brown weathering megacrystic granite
Nstf	Strandfontein Granite		Charnockitic, megacrystic, gneissic granite
Njk	Jakkalshoek Granite		Leucocratic, megacrystic granite to gneissic granite
Nnu	Nuwerus Gneiss	Little Namaqualand Suite	Biotite augengneiss
Nlp	Landplaas Gneiss		Medium-grained pink quartz-feldspar-biotite gneiss, medium- to fine-grained quartz-feldspar gneiss, minor quartz-feldspar-amphibole gneiss
Nme	Mesklip Gneiss		Pink augen gneiss, equigranular gneiss and leucogneis

Nhb	Hunboom Gneiss		Grey leucogneiss and biotite gneiss, augen gneiss
Mks	-	Kamiesberg Group	Quarts-muscovite-biotite-garnet
Mbt	Bitterfontein Formation		Metapsammitic cordite-garnet gneiss, lenses and bands of calc-silicate rock and mafic granulite
Mru	Ruiter-se-Berg Formation		Feldspathic quartzite, garnet bearing quartzite
Mkg	-		Meta-psammitic gneiss
Mkq	-		Metaquartzite (feldspatic, glassy, ferruginous) Leucogneiss
Mbm	Boegoekom Formation		Schistose biotite gneiss
Mja/Mkq	Jakkalsfontein Formation		Flaggy feldspathic quartzite with thin laminae of iron oxides
Mst	Stoffelskop		Quartz-muscovite schist (kyanite bearing), feldspathic and glassy
Mlr/Nlek	Louisrus Formation		Fine to medium-grained grey quartz-feldspar gneiss, quartz-feldspar-sillimanite gneiss, quartz-feldspar-biotite gneiss; lenses and bands of glassy quartzite, pelitic biotite-garnet-sillimanite gneiss, calc-sillicate gneiss, amphibolite and rare biotite-cordierite-hypersthene gneiss

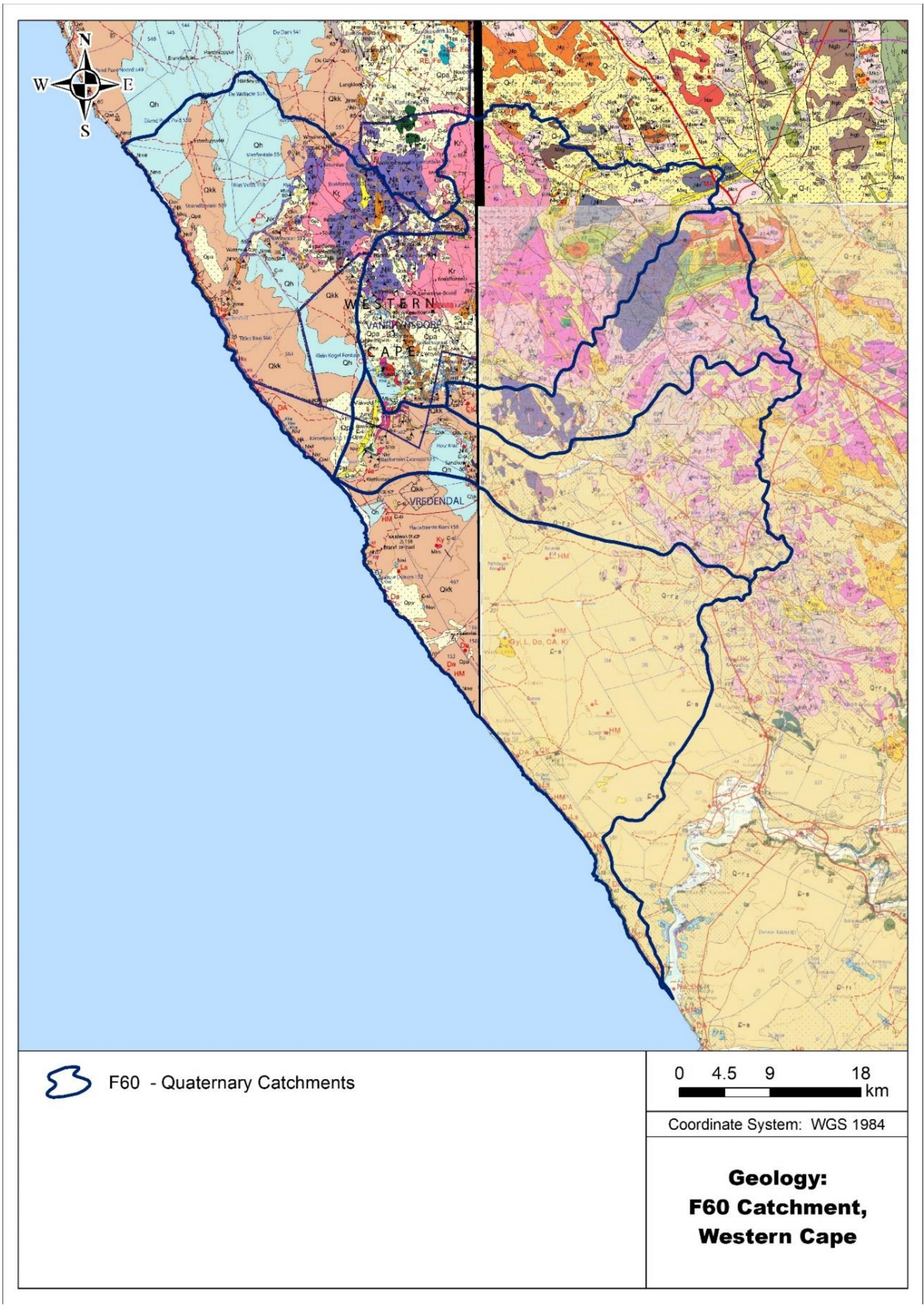

Figure 5: Geological setting of the F60 catchments (Calvinia, 3118, Garies, 3017 & Loeriesfontein, 3018) (CGS, 2001; CGS, 2010 & CGS, 2010)

Groundwater is the only reliable source of freshwater in the area and all the human settlements are completely reliant on groundwater and rainwater collection. Farms are mainly livestock focussed and are reliant on the groundwater for domestic use as well as for human and animal consumption. This is mainly due to the lack of good quality groundwater.

The regional expected yields are very low (0.1 - 0.5 L/s) (**Figure 6**). The area has been classified as containing both intergranular and fractured aquifers (DWAF 2005). Higher yielding boreholes have been found at the most southern point of the F60 catchments, along the coast where calcareous and gypsiferous layers within the quaternary deposits create karst aquifers with an average yield potential of 0.5 – 2 L/s. Higher yielding boreholes have also been drilled into dykes and fracture plains in the Bitterfontein area.

A karst aquifer exists in calcareous areas which possess a topography peculiar to and dependent upon the underground solution as well as the diversion of surface waters to underground routes. Usually, in the Western Cape, intergranular (water moving through sand grains) and fractured (water moving through faults and fracture plains in hard rock) is more common.

Groundwater quality across the catchments is generally categorised as being poor, with EC values of over 1 000 mS/m expected across the different quaternary catchments within the F60 cluster (**Figure 7**) (DWAF 2005). The best quality seems to be found around certain areas around Bitterfontein, where some boreholes yield water with an EC value ranging between 120 - 500 mS/m. The Peninsula formation found under the sand deposits in the southern portion of G60E could potentially also produce better quality water, but boreholes have not been drilled to verify this hypothesis.

Bitterfontein has a desalination plant that treats groundwater to drinking water standard. The treated water from Bitterfonetin boreholes is then piped to the Nuwerus, Rietpoort, Stofkraal, Molsvlei and Put-se-kloof, as well as being used in Bitterfontein itself. Most of the Bittefontein boreholes are situated in the neighbouring quaternary catchment, E33D. Kliprand makes use of its own boreholes for town supply.

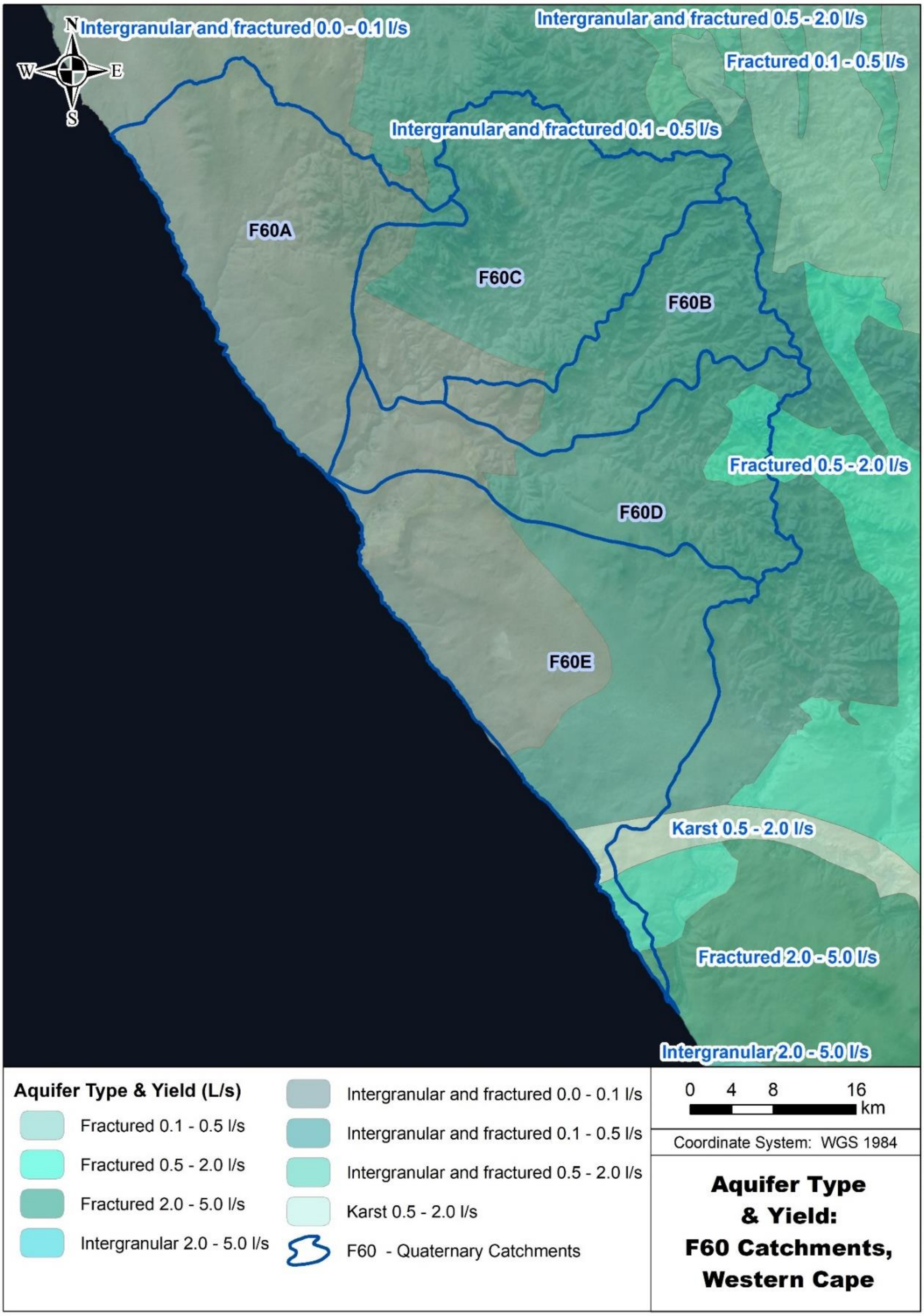

Figure 6: Regional aquifer yield for the F60 Catchments from the 1:1 000 000 scale groundwater map (DWAF, 2005)

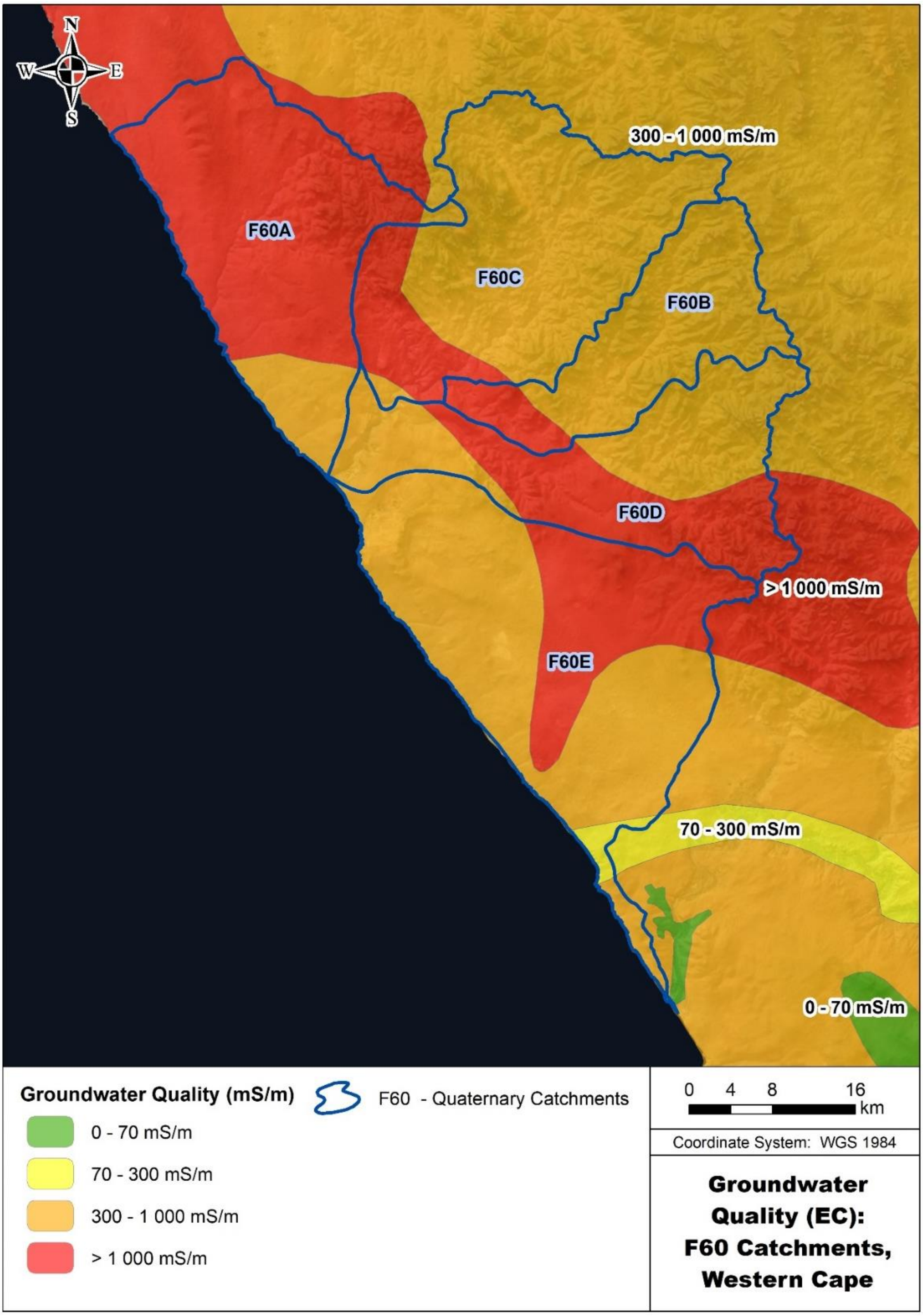

Figure 7: Regional groundwater quality (EC in mS/m) from (DWAF, 2005), for the F60 Catchments

1.4.3 Groundwater/Surface Water Interaction

There is seasonal interaction between surface water and groundwater, although river flows in the hot, dry summer months become negligible. Based on an assessment of groundwater levels (in the summer months), a number of comments can be made. For the **Jakkals River** catchment (G30G), in the area around Graafwater to 8 km downstream from Graafwater, there is **no perceived contribution from groundwater to surface water flow** and the river system is a losing system (recharging groundwater) (GEOSS, 2005). Although historically, springs did occur (Kookfontein) towards the coast along the Jakkals River, these dried up many years ago. The only gaining section on the Jakkalsvlei River is situated midway between Graafwater and Lamberts Bay. In the Langvlei, the gaining reaches within the catchment are short.

For the Verlorenvlei, the gaining sections are thought to be of significant length, with the longest gaining reach being downstream of the confluence of the Hol, Krom Antonies and Kruismans Rivers. At Redelinghuys and at the headwaters of Verlorenvlei, there are also stretches of gaining river. The Kruismans Tributary is regarded as the largest tributary and is mainly derived from surface runoff (Watson *et al*., 2019). Thus far, the Bergvallei Tributary is regarded as the largest groundwater flow contributor using the J2000 rainfall/runoff model, with strontium isotope ratios confirming this (Sigidi, 2017). Decreasing water levels have been recorded towards the bottom area of these catchments and it is known that many additional boreholes and dams have been constructed over the last 20 years. The over-abstraction will be investigated further. The Krom Antonies Tributary is regarded as the largest, in terms of area-weighted flow contribution, with the TMG playing a critical role in terms of baseflow. While the Hol Tributary is saline (Watson *et al*., 2020a), it is significant in that baseflow is more sustained due to the dominance of slow groundwater flow from the Malmesbury shale aquifer. Areas with clear groundwater-surface water interactions can be seen where seepage areas occur.

The recharge in Verlorenvlei is mainly generated in the TMG aquifer, which is a secondary porosity aquifer system and water is held in the fracture network. The recharge rates into the TMG aquifer have been estimated to be 37.6 to 50 mm/year using the Chloride Mass Balance (CMB) (Watson *et al*., 2020a) and agree with bulk rainfall/runoff modelling estimates (Watson *et al*., 2018). The fractured TMG aquifers receive the highest amount of direct recharge (~22-25% of MAP) (Umvoto, 2021). Isotope data has been used to understand dominant groundwater flow paths and was instrumental in identifying groundwater mixing relationships between the upper, middle and lower Krom Antonies sub-basin (Watson *et al*., 2020a). Furthermore, the use of isotope dating techniques conducted for the catchment essentially shows three distinct aquifer systems which are mixed before reaching the Verlorenvlei itself (Miller *et al*., submitted scientific paper for publication). These mixing relationships suggest and show the connection between the TMG and primary alluvial aquifer as well as the connection between the TMG and Malmesbury shale aquifer.

The connection between the Malmesbury and alluvial aquifer is not clear, but these two systems must interact as pumping data shows that water can move between the alluvial and Malmesbury aquifer, although this is an interpretation of a single observation borehole, which could have multiple sourced water (Watson *et al*., 2020a).

In terms of the dating outputs, the results show that the TMG and the alluvial aquifer is actively recharged, comprised of young water (34-57 years), with the Malmesbury aquifer being mainly comprised of very old groundwater but has not yet been successfully isolated due to mixing.

Getting a better idea of the composition of the Malmesbury aquifer is a critical part of understanding this aquifers flow contribution; therefore identifying a borehole that shows limited mixing is important in constraining this. While this has already been done in the Berg River (Harilall, 2020), a more in-depth selection is required for Verlorenvlei.

For the F60 catchments, groundwater/surface water interaction is much less understood and due to a lack of springs and seepage areas, it is very difficult to delineate such areas. It has been noted that in some of the coastal areas, the overlying sand deposits could be receiving lateral recharge from fault and fracture systems within the hard rock. This will be investigated further after additional data has been collected during the field visits.

1.5. Study Methodology and Approach

A Reserve determination study endeavours to provide information at the highest level of confidence possible within the defined time, data availability and financial constraints of the project. These constraints dictate the spatial and temporal extent to which data can be collected and inform the understanding of aquatic ecosystem responses to flow volume and pattern changes. Within such a study, with a one- or two-year data collection period, a picture of the conditions in the ecosystems at the time of the study is formed that may provide greater confidence that the conditions at the time of the study (i.e., 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.

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

The river, wetland, estuarine and groundwater components of the Reserve determinations will use the latest RDM recommended methodologies. While the standard methodologies for the determination of the Basic Human Needs and ecological Reserve would be followed in the study. Recognition of the need for a slightly adapted approach for the Sandveld and Knersvlakte Rivers in the G30 and F60 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 hardy species with low diversity, although both the habitat and biota may be of high ecological importance;
- The estuaries within the area comprise mostly coastal lakes or estuarine salt pans, with a low diversity of hardy species. These systems are mostly nearly permanently closed and also have very little freshwater inflow from their associated river systems. As a result, they tend to be hypersaline;
- Very close integration occurs between the surface water ecosystems (rivers, wetlands and estuarine habitats) as well as with the groundwater. Integration of these two specialist fields and the recommended ecological Reserve (quantity and quality) thus needs to take place; and
- The sequencing and interaction between the tasks and disciplines on this project are critical. The products from the groundwater specialists will provide an improved understanding of the surface water ecosystems and the delineation of the river reaches and wetland regions. Enough time must be set aside to allow for integration. The wetlands component will especially need to provide inputs to and rely on inputs from the Rivers and Groundwater specialists. Once the priority wetlands have been determined, a key step will be to interact with the specialists to obtain assistance in determining EWRs. The River specialists would also need to have input into the wetland priorities chosen.

The revised generic procedure is provided in **Figure 8** (DWAF, 2008) 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.

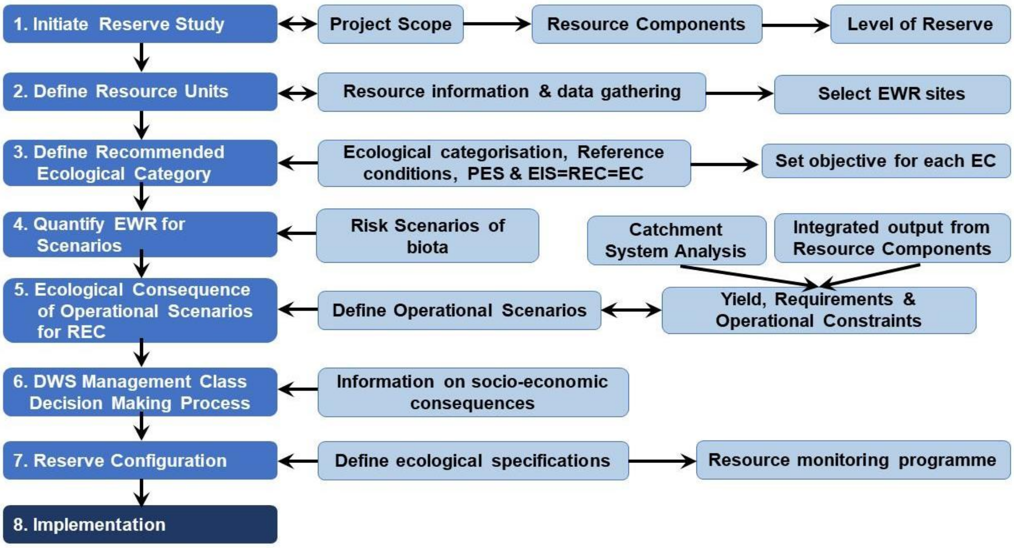

Figure 8: The Reserve Determination Process (adapted from DWAF, 2008)

2. GROUNDWATER RESOURCE UNIT DELINEATION

2.1 Delineation approach

As part of the reserve determination process, the first step is to delineate the units of analysis and define Groundwater Resource Units. The delineation of Groundwater Resource Units (GRUs) was done at a desktop level and discussed with other hydrogeologists within GEOSS before being reviewed by the other specialists involved in the study.

The rationalisation process for GRU selection is based on reviewing multiple datasets. Geological, hydrological and meteorological data were combined with general knowledge of the area and comments from residents. Projects that GEOSS has been involved in were also used to obtain data and support assumptions and hypothesises made during the course of the delineation process.

Cape Farm Mapper was used to assist with rainfall (Schulze 2009), depth to groundwater and wetland (NWM5) data. Water levels and EC values collected from NGA data was interpolated and groundwater flow and groundwater quality contour maps for the two catchment areas were constructed. The interpolation technique used is referred to as Bayesian interpolation, where water levels are correlated with the surface topography (Tripol, 1996). When the interpolated data did not reveal clear paths with which delineation could be done, other methods were used.

The type of groundwater and aquifer system were taken into account during the process of delineation of the GRUs within F60 and G30 catchments. Because the groundwater reserves and RQOs that are linked to them will ultimately have to be linked to surface water RQOs and the quaternary catchments, it was decided to use these boundaries were possible. Where the aquifer, geology or recharge changed in such a way that it would have an effect on the results calculated, additional boundaries were defined.

The GRUs that have been defined will be discussed in detail in **Section 2.2** and **Section 2.3** of this report.

2.2 G30 GRU Delineation

Taking into account the nature of the groundwater system within the G30 catchments, it was decided to mostly stick to the existing quaternary boundaries as they do tend to each incorporate a single valley that relates well with perceived groundwater flow (**Figure 9**). G30D was split into a northern and southern GRU, as the southern portion includes much higher rainfall mountainous areas that would be linked to higher recharge. G30F has also been split into a northern and southern GRU as this quaternary catchment includes two valleys that each have a separate paleochannel type feature. The delineation is discussed per GRU below.

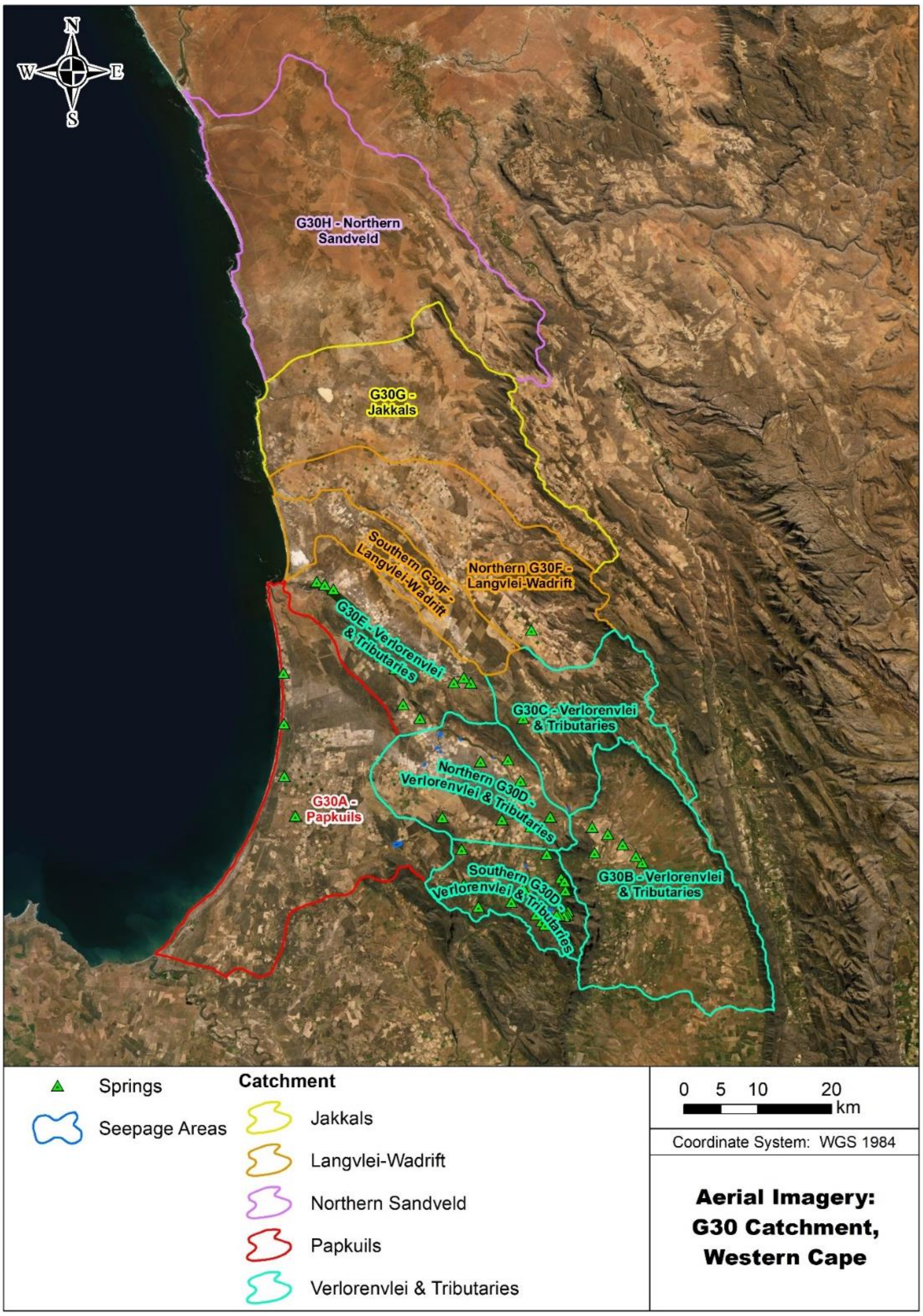

Figure 9: Combined map of delineated GRUs for the G30 catchments

2.2.1 Papkuils-G30A GRU

Grouping: Papkuils

GRU Name: G30A

Groundwater Use: Moderate to high (in areas with available groundwater)

Delineation:

The groundwater unit falls within the quaternary catchment boundaries. Papkuils seepage area forms the only significant observed groundwater/surface water interaction site in this unit, and this spring site is a significant one.

The majority of the GRU is low-lying coastal flats. Thick sand is underlain by TMG formations and Malmesbury shales, although boundaries between formations are undefined due to thick sand cover. Boreholes are drilled into the alluvial sand. Water quality is good around the Papkuils seepage area and along the eastern area of the GRU, where a "paleochannel type structure" has been observed.

It has been hypothesized that these saturated sand zones could be caused by discontinuous groundwater upwelling from fault zones. It has been observed that where sand is underlain by TMG sandstone, water quality in the sand is generally better than where the sand is underlain by Malmesbury shales. This can also be observed on aerial photography, the darker red sand areas indicating areas where sand is underlain by clay (**Figure 10**).

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

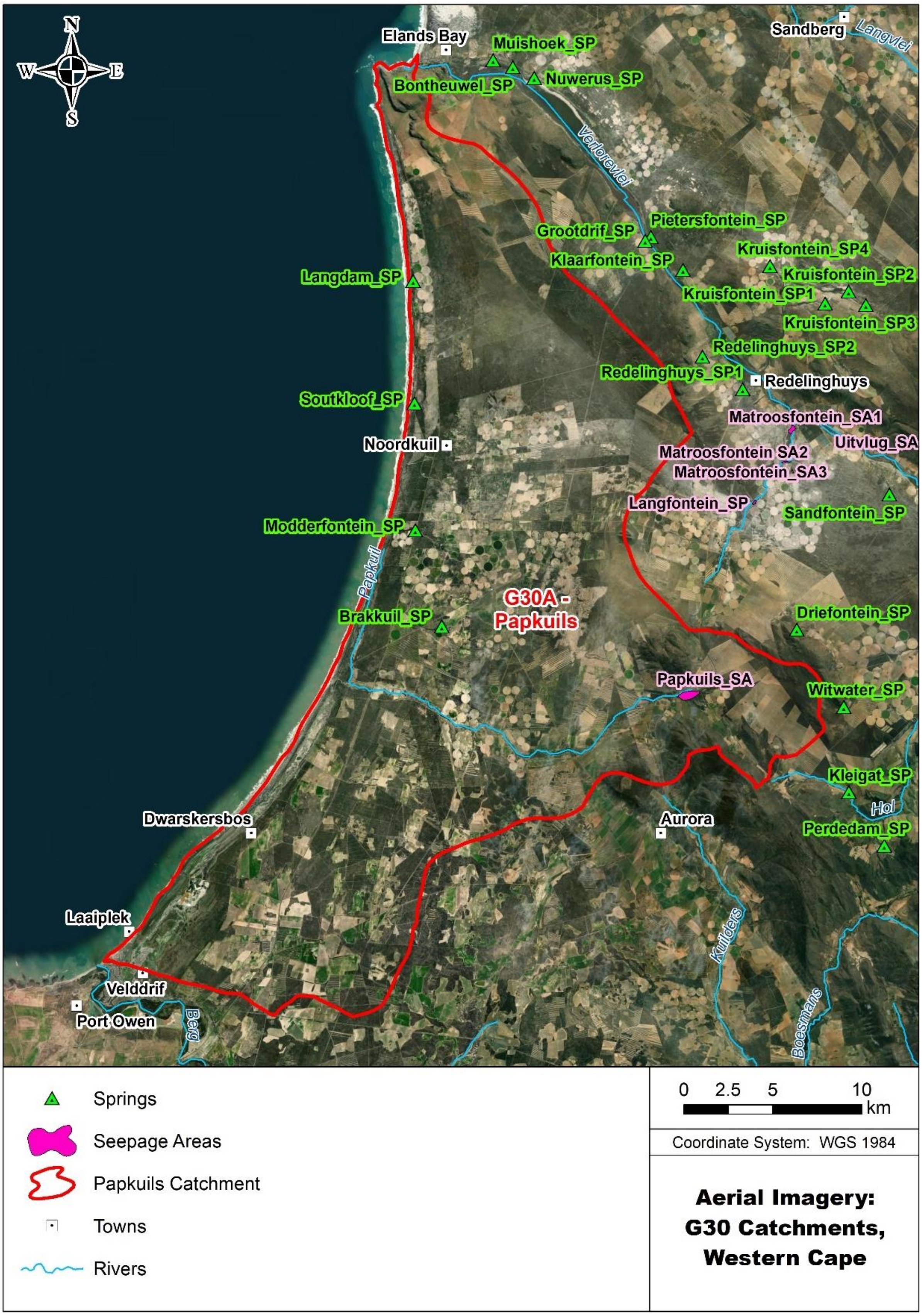

Figure 10: Delineation of the Papkuils-G30A GRU

2.2.2 Verlorenvlei & Tributaries-Southern G30D GRU

Grouping: Verlorenvlei & Tributaries

GRU Name: Southern G30D

Groundwater Use: Extensive

Delineation:

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

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

Boreholes drilled into hard rock mostly, although a few high yielding boreholes have been recorded to have been drilled into the sand in the southwestern portion of the valley. This sandy area also contains seepage areas that could provide baseflow to the Krom-Antonies catchment (**Figure 11**).

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

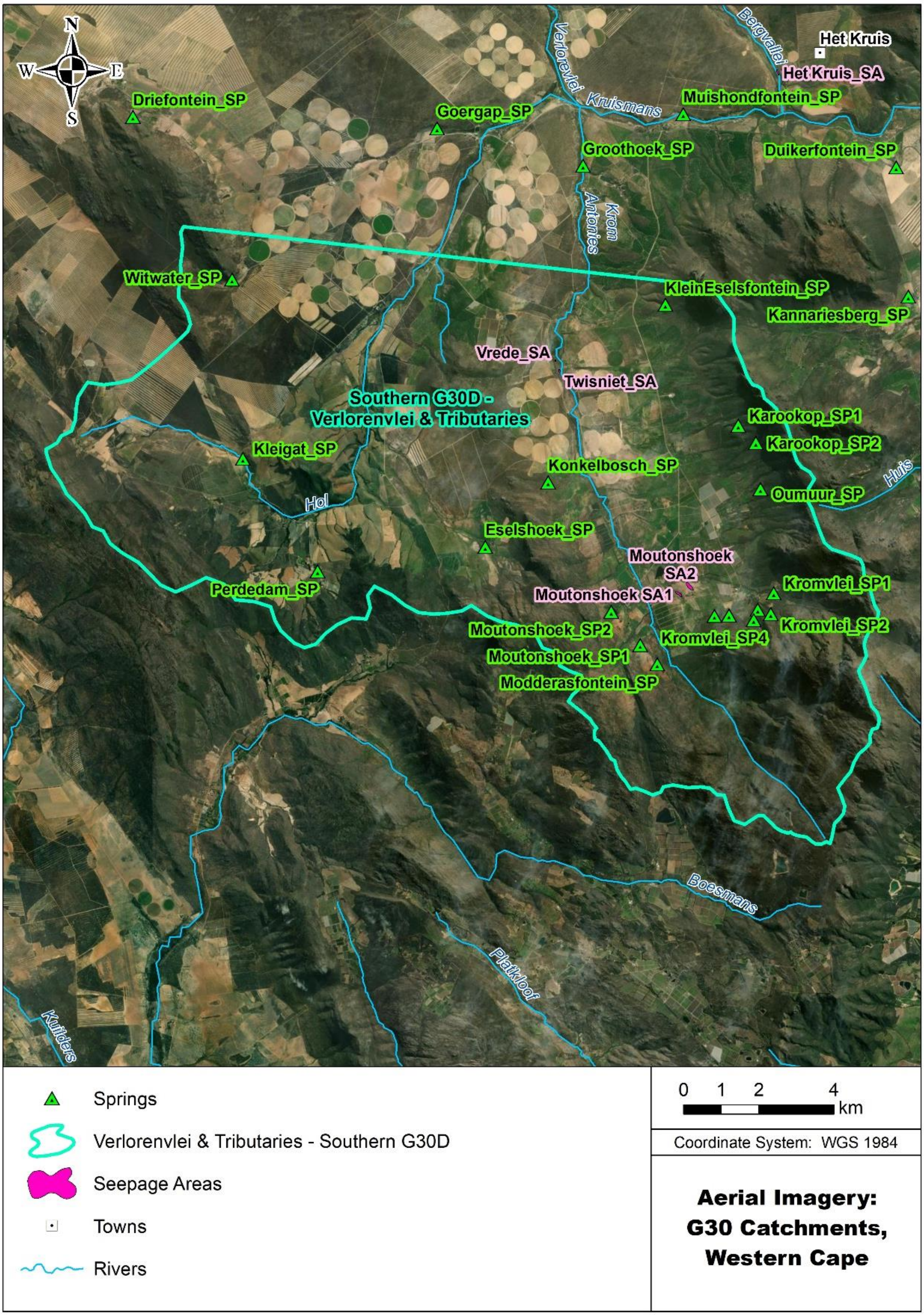

Figure 11: Delineation of the Verlorenvlei & Tributaries-Southern G30D GRU

2.2.3 Verlorenvlei & Tributaries-Northern G30D GRU

Grouping: Verlorenvlei & Tributaries

GRU Name: Northern G30D

Groundwater Use: Moderate to high

Delineation:

Groundwater unit made up of the lower reaches of the Hol, Krom-Antonies and Kruismans rivers and well as where the rivers meet to form the Verlorenvlei river. Malmesbury shales and TMG are overlain by quaternary sands.

The Matroosfontein spring/seepage area to the northern end (**Figure 12**) of this unit is the only major spring observed, although seepage areas within the Verlorenvlei river have also been reported in the northern portion of this unit. It has been hypothesized that discontinuous groundwater upwelling along inferred and mapped fault lines could be introducing older water from the fractured rock aquifer into the sand deposits overlying it.

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

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

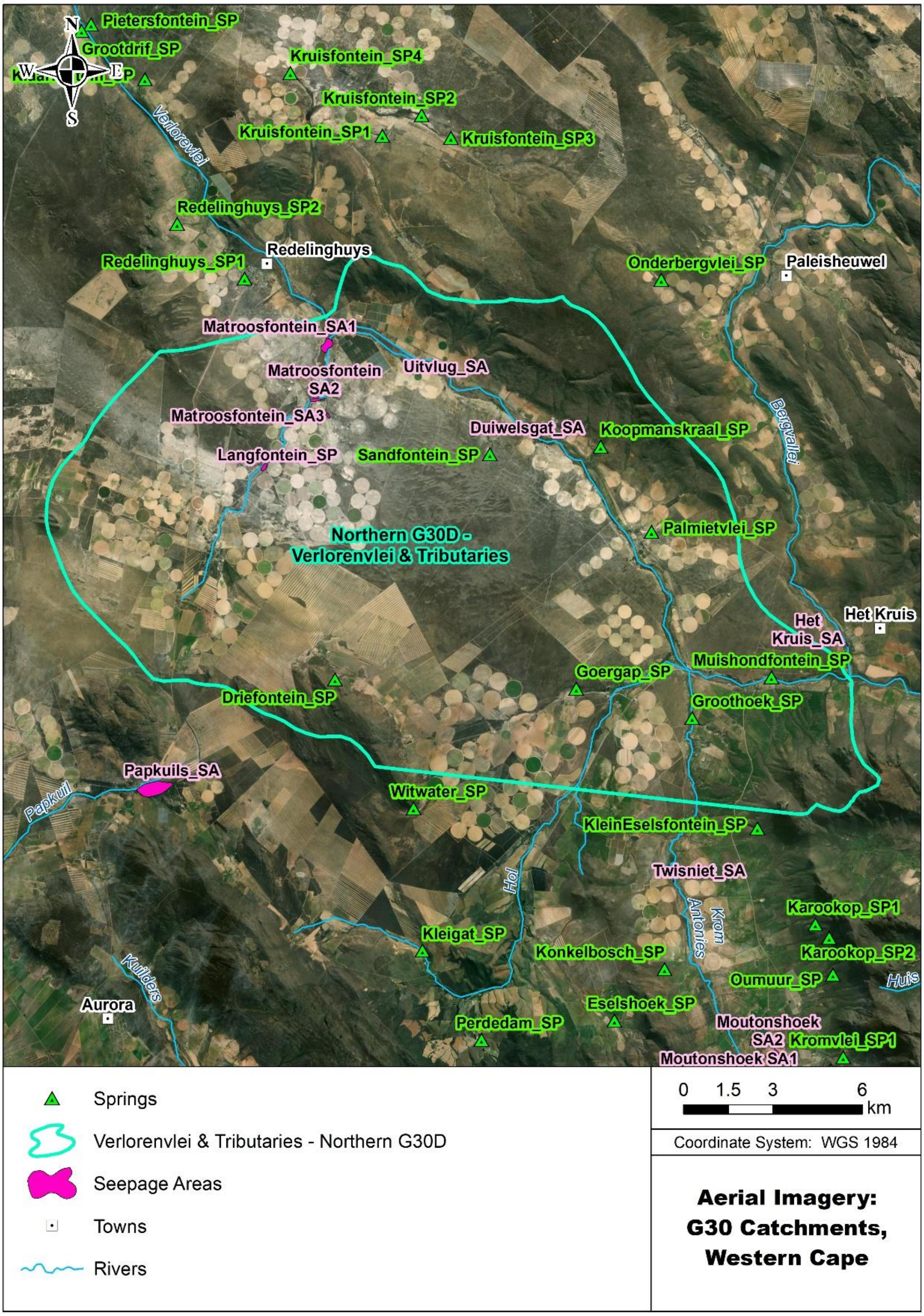

Figure 12: Delineation of the Verlorenvlei & Tributaries- Northern G30D GRU

2.2.4 Verlorenvlei & Tributaries-G30B GRU

Grouping: Verlorenvlei & Tributaries

GRU Name: G30B

Groundwater Use: Moderate to high (south-western portion of GRU)

Delineation:

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

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

A few high yielding (16 – 18 L/s) boreholes have been reported towards the southwestern corner against the Piketberg mountains. Contact and fault springs have been reported along the Piketberg Mountains, as well as some on the Citrusdal side, where TMG formations meet the Porterville formation. The yields of these springs vary, but the quality is usually good. Most of these springs are used for domestic or irrigation supply and no longer contribute to surface water flow (Kruismans river). Some springs have also been reported along the bank of the Kruismans river (**Figure 13**).

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

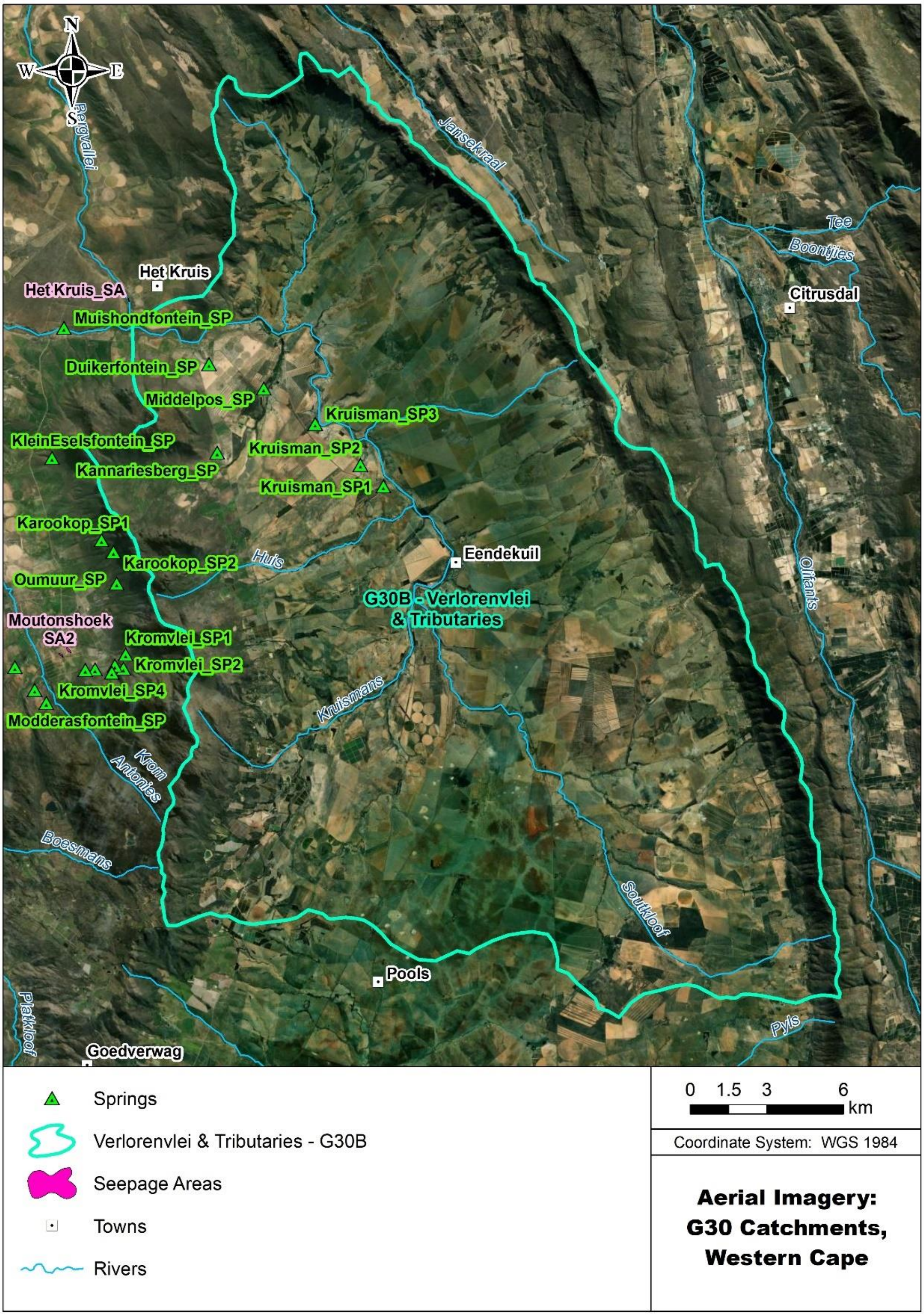

Figure 13: Delineation of the Verlorenvlei & Tributaries- G30B GRU

2.2.5 Verlorenvlei & Tributaries-G30C GRU

Grouping: Verlorenvlei & Tributaries

GRU Name: G30C

Groundwater Use: Extensive

Delineation:

The groundwater unit falls within the quaternary catchment boundaries and is made up of the area known as the Bergvallei valley (**Figure 14**).

Rainfall varies from 460 mm/a in mountainous areas to as low as 300 mm/a around the Het-Kruis area in the northwest. Groundwater use is extensive in the area, and a drop in water levels has been observed in this unit. The entire valley is underlain by the TMG formations. Borehole yields in the area are high (> 20 L/s in some cases), and quality is good.

The upper reaches of the valley have boreholes drilled into the river valley into the shallow hard rock aquifer. Lower down boreholes target the sand deposits overlaying the fractured aquifer.

There is large scale northwest-southeast trending faults in the area. Farmers lower down in the catchment have reported that their water levels are dropping due to increased abstraction in the upper reaches of the valley. This claim will have to be investigated.

The upper reaches of the Bergvallei valley have completely been transformed, and little of the old river channel remains visible. The Het Kruis wetland area has subsequently, with the increased abstraction in the upper reaches of the GRU, also dried up progressively in the last 15 years.

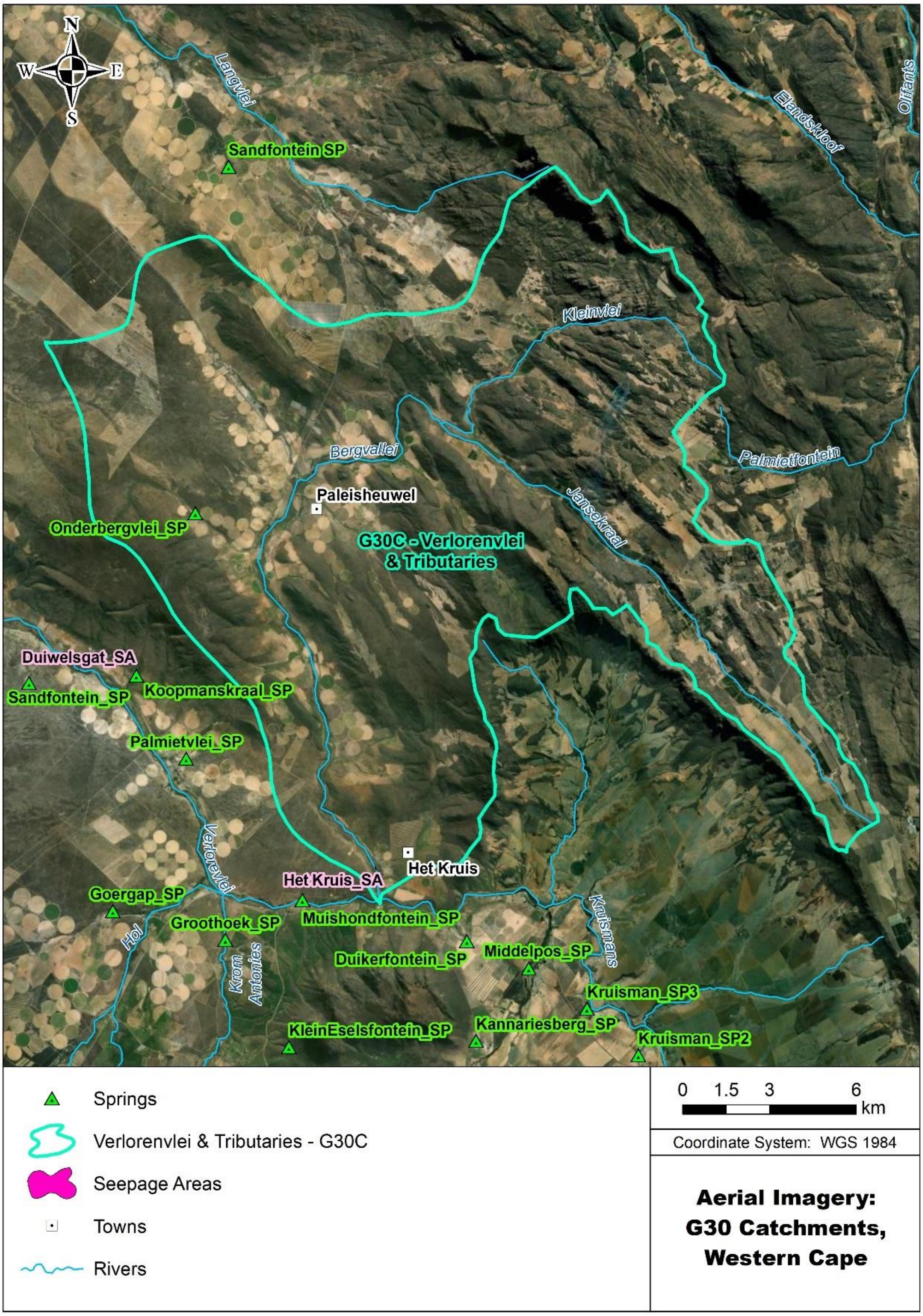

Figure 14: Delineation of the Verlorenvlei & Tributaries- G30C GRU

2.2.6 *Verlorenvlei & Tributaries-G30E GRU*

Grouping: Verlorenvlei & Tributaries

GRU Name: G30E

Groundwater Use: Extensive

Delineation:

The groundwater unit falls within the quaternary catchment boundaries and is made up of the area known as the Verlorenvlei (**Figure 15**).

The geology is characterised by TMG formations and the Klipheuwel Formation (Malmesbury Group) being overlain by thick quaternary sediments. The Klipheuwel Formation is seen as the basement rock for the area and outcrops to the western side of the Verlorenvlei wetland. The groundwater found on this side of the wetland is usually of poor quality with low yields. Boreholes drilled on the eastern side of the wetland in some areas produce very high yielding boreholes (>20L/s) with very good quality (EC<60mS/m). These boreholes are located in close proximity to the inferred large northwest-southeast trending inferred fault that lies towards the east of the wetland and runs along it.

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

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

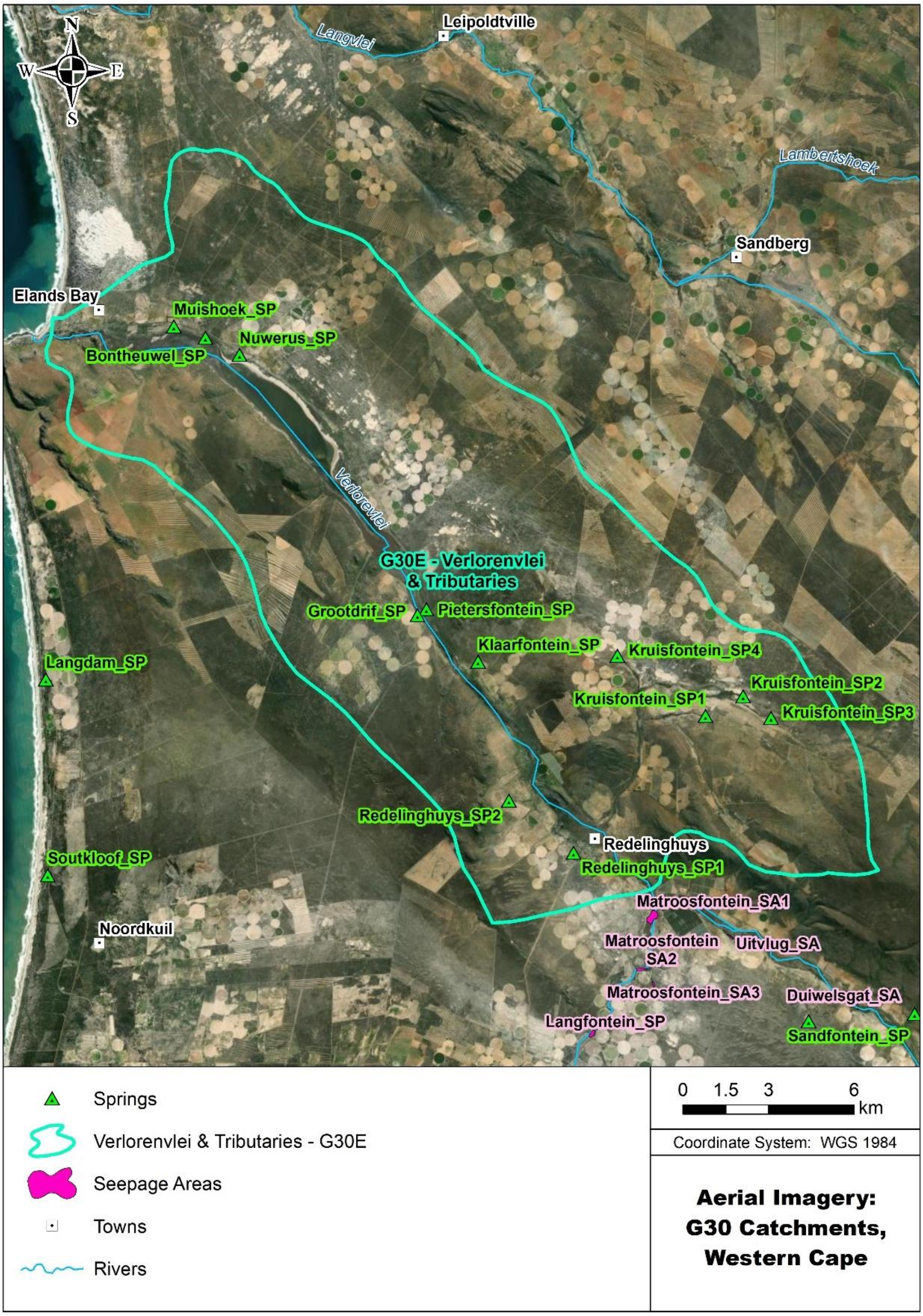

Figure 15: Delineation of the Verlorenvlei & Tributaries- G30E GRU

2.2.7 Langvlei-Wadrift - Northern G30F GRU

Grouping: Langvlei-Wadrift

GRU Name: Northern G30F

Groundwater Use: Extensive

Delineation:

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

In this GRU, groundwater abstraction is extensive. The highest yields and best quality water is found from boreholes in the upper reaches of the GRU, between Sandfontein and Sandberg. Passing Sandberg, groundwater quality deteriorates and becomes more saline.

Boreholes are drilled into the primary sand and, in some cases, into bedrock. The sand layer becomes thicker towards the coast and is underlain by TMG formations that outcrop towards the upper reaches of the GRU.

Rainfall varies from a maximum of around 400 mm/a in the upper reaches of the GRU to as low as 180 mm/a on the coast. It was reported that historically, the area had more springs. Currently, the only significant one that has been observed is Sandfontein (**Figure 16**). Depth to groundwater is around 20 mbgl and shallower in the upper reaches of GRU (< 5 mbgl).

Figure 16: Delineation of the Langvlei-Wadrift - Northern G30F GRU

2.2.8 Langvlei-Wadrift - Southern G30F GRU

Grouping: Langvlei-Wadrift

GRU Name: Southern G30F

Groundwater Use: Extensive

Delineation:

The groundwater unit falls within the quaternary catchment boundaries and makes use of geological and hydrological boundaries to separate this GRU from the Northern G30F GRU.

In this GRU, groundwater abstraction is extensive. The highest yields and best quality water is located towards the sea, in what is known as the upper-Wadrif area. The lower-Wadrif aquifer was historically also a good aquifer (**Figure 17**).

Boreholes were situated around the now extinct Wadrif wetland. This wellfield holds a large number of boreholes that were abandoned when the aquifer was damaged during over-abstraction. The boreholes abstracted too much water, drying up the wetland. With the wetland gone, salt accumulated, and after a few big rain events, the salt infiltrated into the aquifer, making the water too saline to use. Peat fires also damaged the wetland. All of the boreholes have been abandoned. This situation outlines the sensitivity of the area`s aquifer system and emphasizes the importance of managing an aquifer system.

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

The Lambertsbay uses this wellfield for town supply, and a large volume is also being pumped for agricultural uses. Municipal monitoring data has displayed a decline in water level for the past ten years, and this is concerning as vegetation die-off has also been noticed in the old river bed. Rainfall decreased from around 280 mm/a at the top of the catchment to as low as 200 mm/a near the coast.

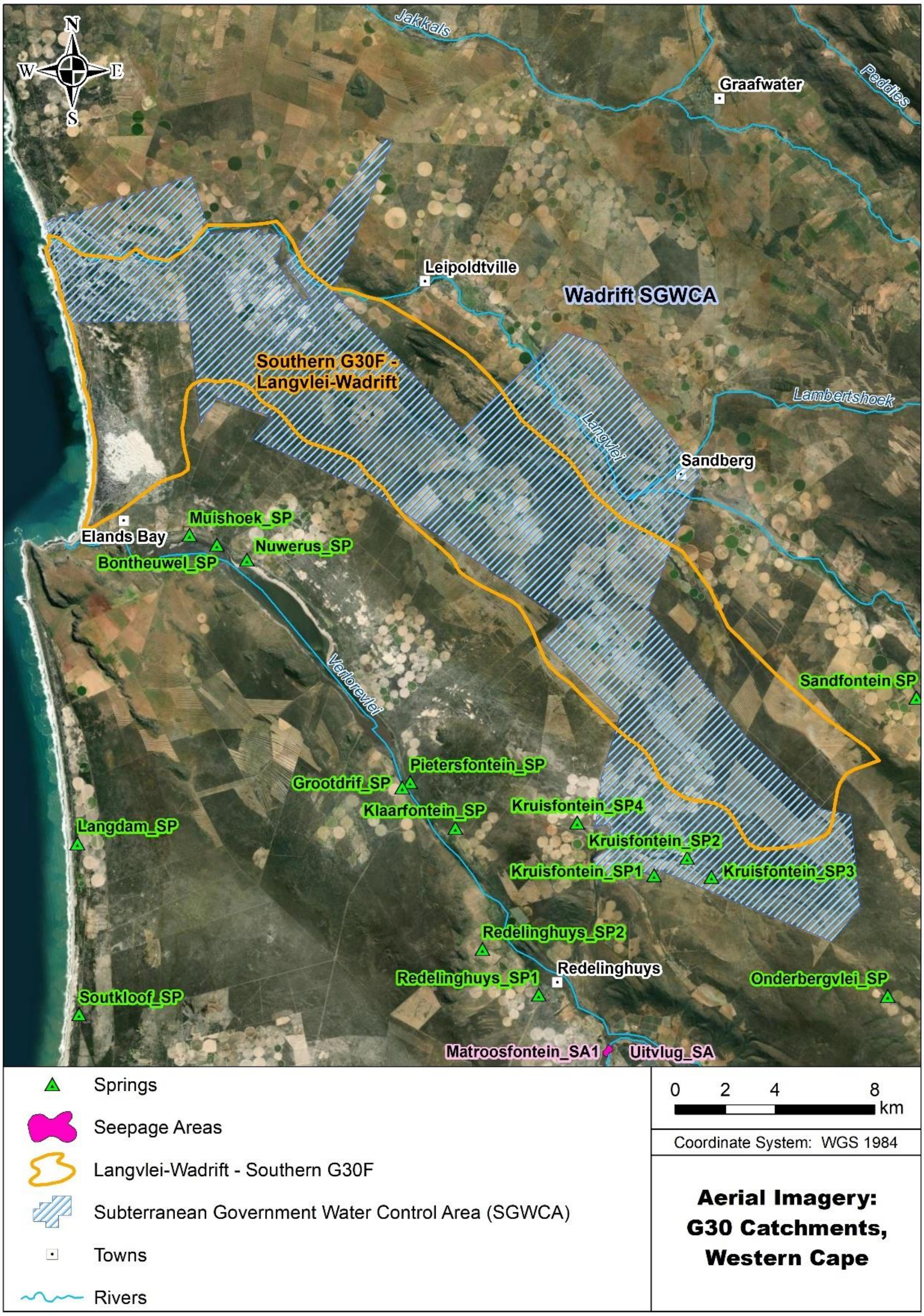

Figure 17: Delineation of the Langvlei-Wadrift - Southern G30F GRU

2.2.9 Jakkals- G30G GRU

Grouping: Jakkals

GRU Name: G30G

Groundwater Use: Extensive in certain areas and Low in others

Delineation:

The groundwater unit falls within the quaternary catchment boundaries and can be referred to as the Jakkals river catchment. Rainfall decreased from around 340 mm/a at the top of the catchment to as low as 190 mm/a near Lambertsbay. This GRU falls within the Graafwater Subterranean Government Water Control Area.

A “paleo channel type structure" exist and has been well documented (Jolly, 1992). Best groundwater yields (12 - 20 L/s) and quality (90 - 130 mS/m) is found towards the bottom of the GRU, north of the Jakkals river and about 7- 12 km east of Lambertsbay, in the area known as Kookfontein and Varsfontein.

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

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

None of the springs in the lower Jakkals river GRU is reportedly still flowing, but this can be investigated. Water levels generally range between 3 – 23 mbgl, but 60 – 70 mbgl have been recorded at some production boreholes. Groundwater use is extensive in areas that are groundwater rich. Much less water is being abstracted in areas north of Graafwater and to the south of Lambertsbay. In such areas, dryland crops are mostly cultivated as well as livestock farming (**Figure 18**).

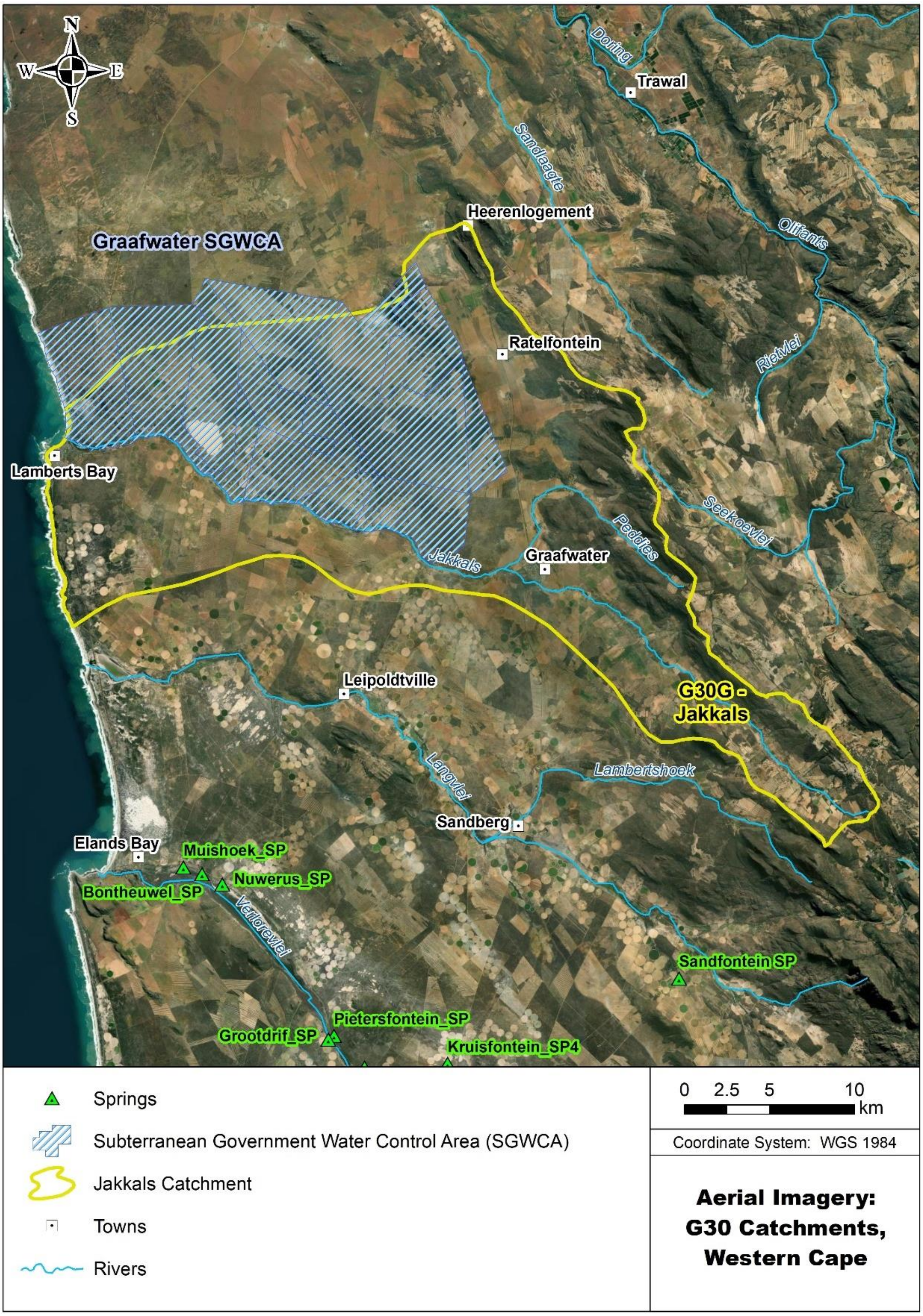

Figure 18: Delineation of the Jakkals- G30G GRU

2.2.10 Northern Sandveld - G30H GRU

Grouping: Northern Sandveld

GRU Name: G30H

Groundwater Use: Low

Delineation:

The groundwater unit falls within the quaternary catchment boundaries and can be referred to as the Northern Sandveld. Groundwater usage in this area is much lower than for the rest of the Sandveld. Groundwater quality is generally poor with EC values higher than 1 000 mS/m being normal for large areas.

Borehole yields are very varied (0.2 - 5 L/s), although some high yielding boreholes have been drilled towards the upper portions of the GRU (8 - 15 L/s). These boreholes are most likely linked to the large northwest-southeast trending fault that runs along the Sandlaagte River. This site also had relatively good quality for the area (360 mS/m) but still had elevated levels of Sodium (500 mg/L) and Chloride (1 000 mg/L). Agriculture is focused on dryland crops and animal farming.

Recently, multiple requests for exploration for heavy minerals along the coast have been submitted. Concerns have been raised about how mining could impact the limited groundwater supply.

As with the rest of the Sandveld, coastal sand deposits are underlain by TMG and Klipheuwel, although sand deposits are shallower in some areas than for the rest of the Sandveld. Resting water levels are much deeper than what is found in the rest of the Sandveld, with water levels getting deeper going from the southeast portion (30 mbgl) to the northern portion (50 mbgl) of the GRU. Some winter seepage areas have been reported towards the upper reaches of the catchment, and this will need to be investigated.

Rainfall ranges from 270 mm/a towards the southwest portion of the GRU to 170 mm/a in the north-western portion around Strandfontein and Doringbaai. Reportedly, these towns are the only ones in the Sandveld that do not use groundwater as their only water supply due to the poor water quality (**Figure 19**).

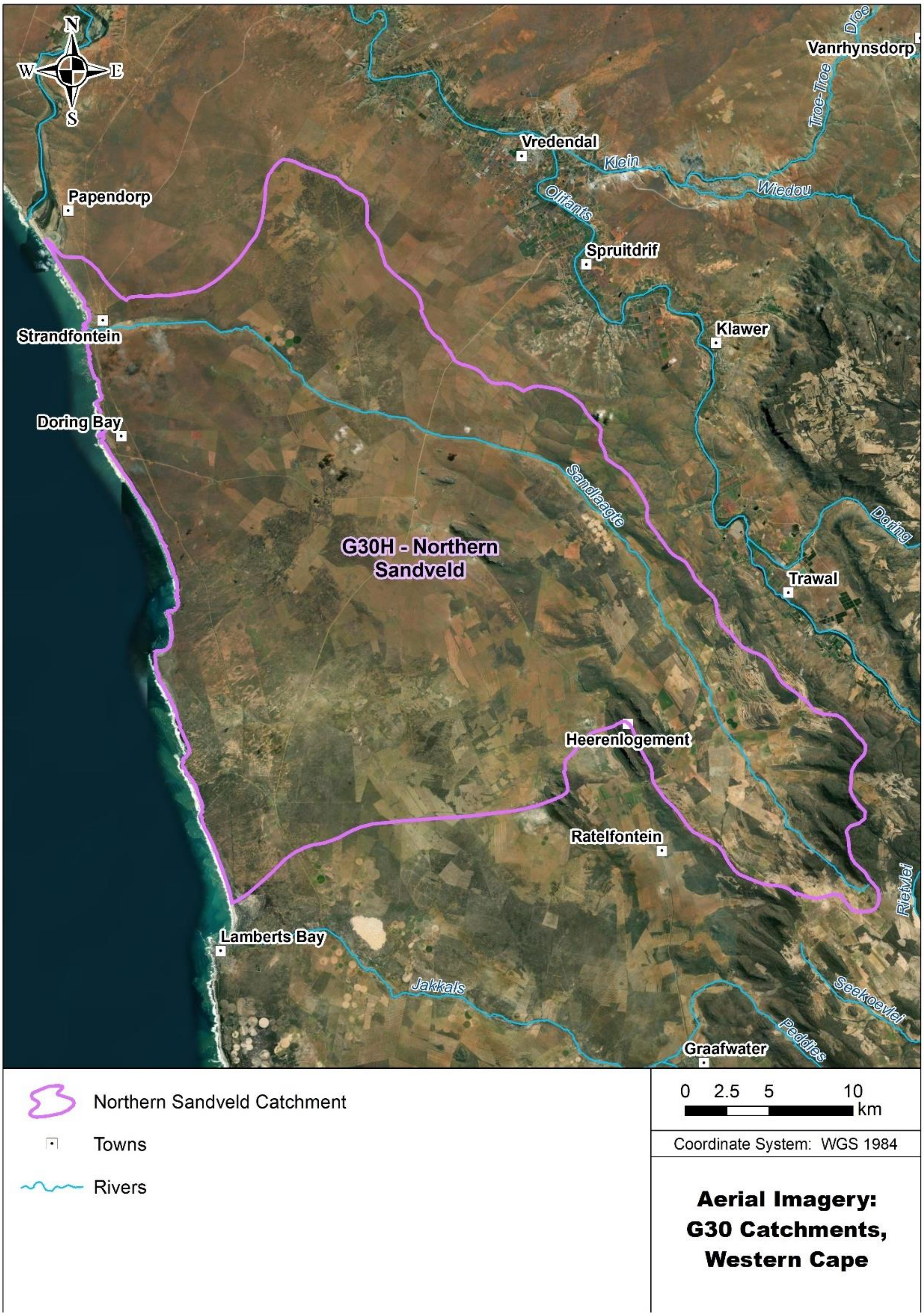

Figure 19: Delineation of the Northern Sandveld - G30H GRU

2.3 F60 GRU Delineation

Taking into account the nature of the groundwater system within the F60 catchments, it was decided to mostly stick to the existing quaternary boundaries (**Figure 20**). F60E was split into a northern and southern GRU, as the southern portion includes different geology and a different aquifer type. Even though it is a small GRU, the groundwater system is different from the rest of the F60 GRUs, and thus it was decided to split this GRU from the rest. The delineation is discussed per GRU below.

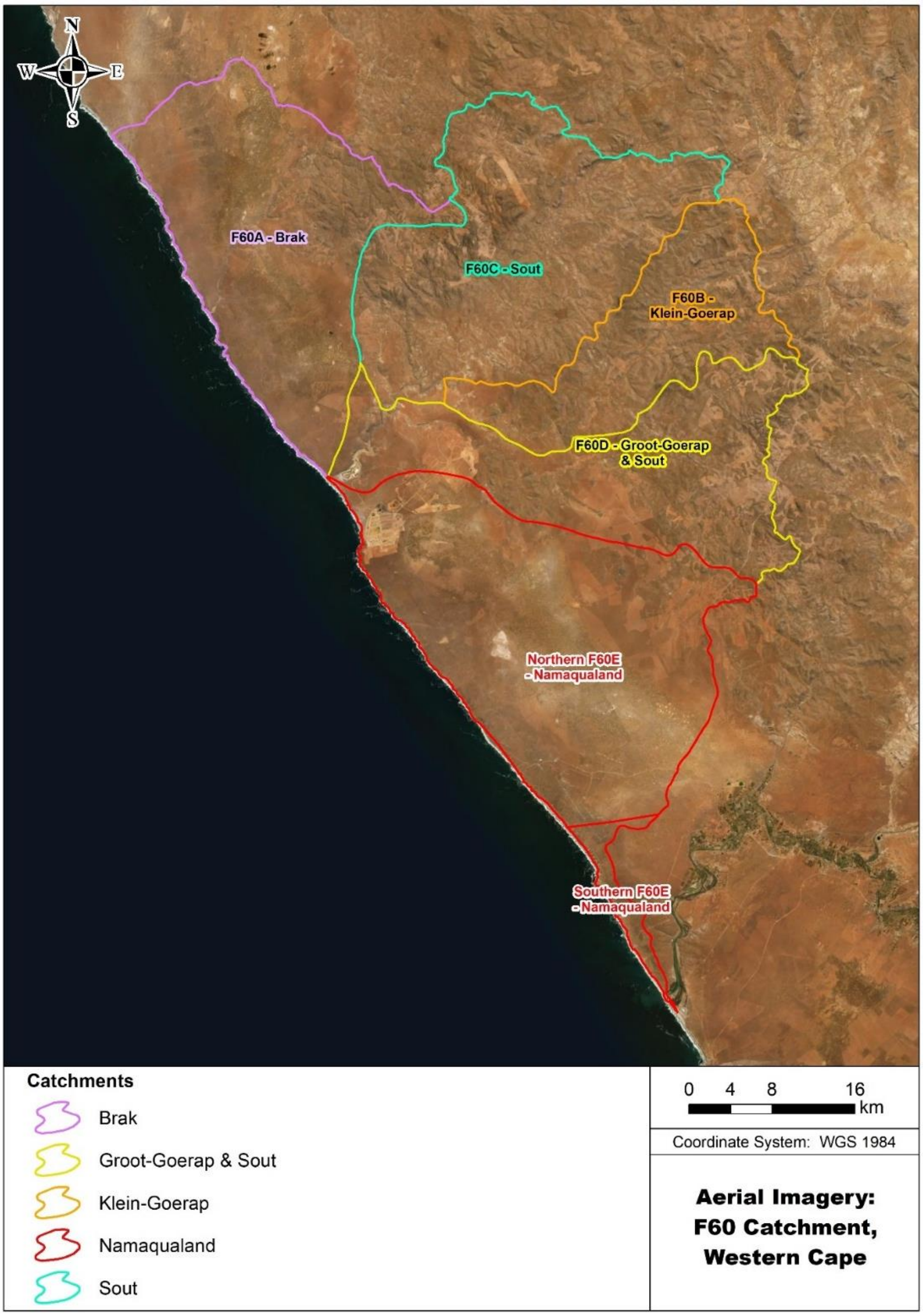

Figure 20: Combined map of delineated GRUs for the F60 catchments

2.3.1 Namaqualand- Southern F60E GRU

Grouping: Namaqualand

GRU Name: Southern F60E

Groundwater Use: Very Low

Delineation:

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

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

The GRU is situated on the coast in the area north of the Olifants River Estuary (**Figure 21**). Rainfall is around 130 mm/a and depth to groundwater between 10 and 50 mbgl. Extremely little groundwater is abstracted. The only known groundwater user that has been identified is Tormin mine. They use borehole water for dust suppression. The volume is yet to be confirmed by the mine. Drinking water is trucked in. The groundwater quality for the region is classified as “poor” in the northern section of the GRU (300 – 1 000 mS/m) and “marginal” in the southern section (70 – 300 mS/m). Yields of 0.5 - 2 L/s are expected, although it has been reported that one higher-yielding borehole does exist, this will need to be confirmed by the mine.

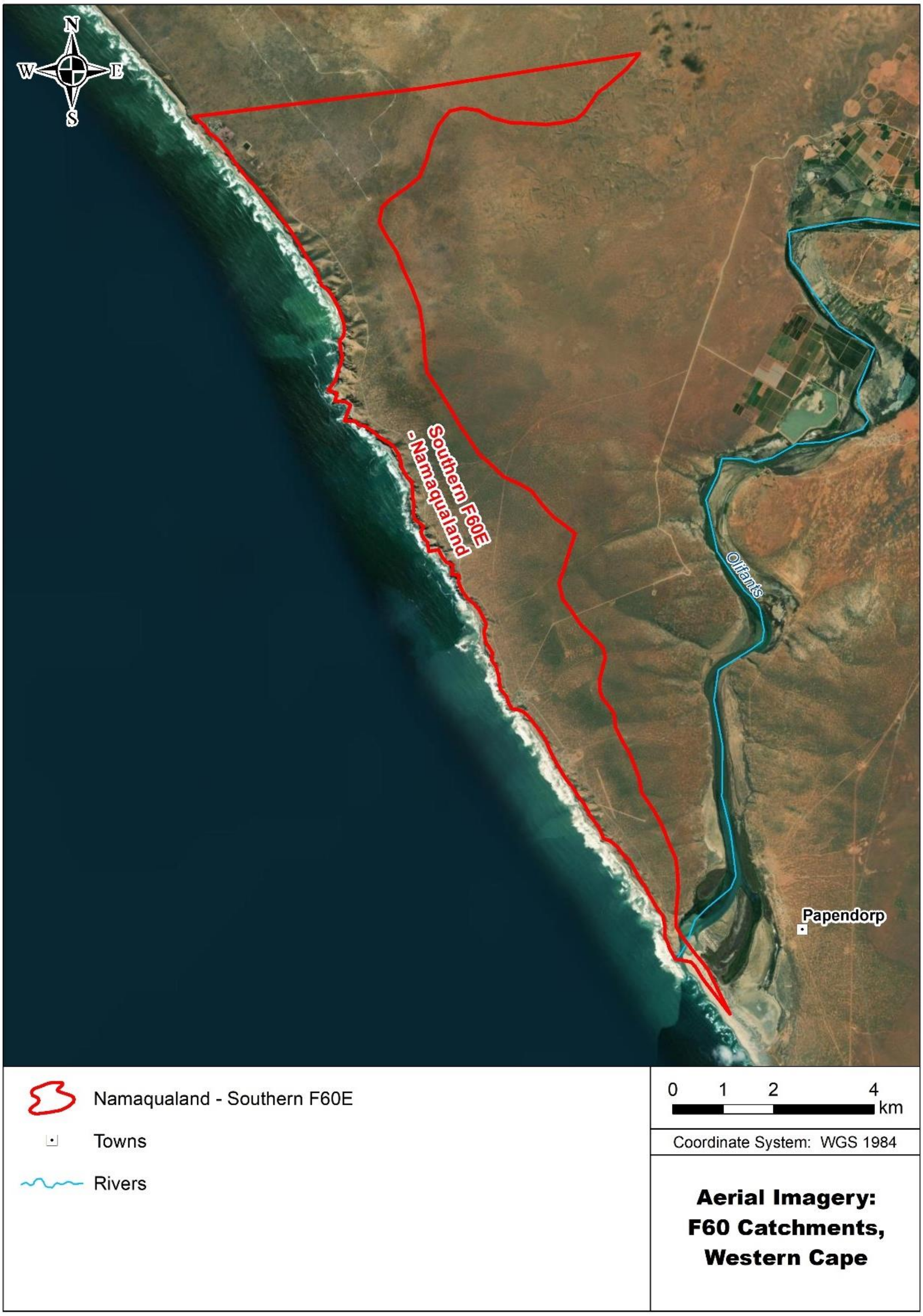

Figure 21: Delineation of the Namaqualand- Southern F60E GRU

2.3.2 Namaqualand- Northern F60E GRU

Grouping: Namaqualand

GRU Name: Northern F60E

Groundwater Use: Low

Delineation:

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

Groundwater abstraction is very low. Namaqua sands mine is located in the northern section of the GRU, and a farm was also identified through the V & V process that noted that they use about 2 200 m^3/a for animal feedlots. No irrigation has been identified, and water is likely mostly only used for animal drinking water and for domestic use where the quality is good enough.

Water quality has been identified as being very poor (300 – 1 000 mS/m) for most of the GRU of the north-eastern section, having been classified as having EC values that exceed 1 000 mS/m. No towns are located in this GRU.

The geology in the GRU is characterised as gneiss and granite formations from the Little Namaqualand Suite being overlain by quaternary sand deposits. Very few hard rock formations are exposed in this area and geological boundaries between rock formations and faults are not defined. The Namaqua Sand Mine is situated to the north of the GRU, where heavy minerals are being mined, such as zircon, garnet, ilmenite, rutile and magnetite. These naturally occurring deposits are some of the richest placer deposits in the world. Because of this, there is interest in commissioning more mines in the area. This could potentially impact the very limited groundwater resource.

Depth to groundwater is around 40 mbgl and is perceived to be shallower to the coastline (although very little data is available currently). Rainfall is between 140- 120 mm/a, with the lowest rainfall occurring along the coast. Recharge to the area is very low, and groundwater recharge is likely to be fault driven. Contact zones between geological units and faults would be targeted for groundwater exploration, although even where water can be found, the quality could likely be too poor for use. The delineated GRU is displayed in **Figure 22**.

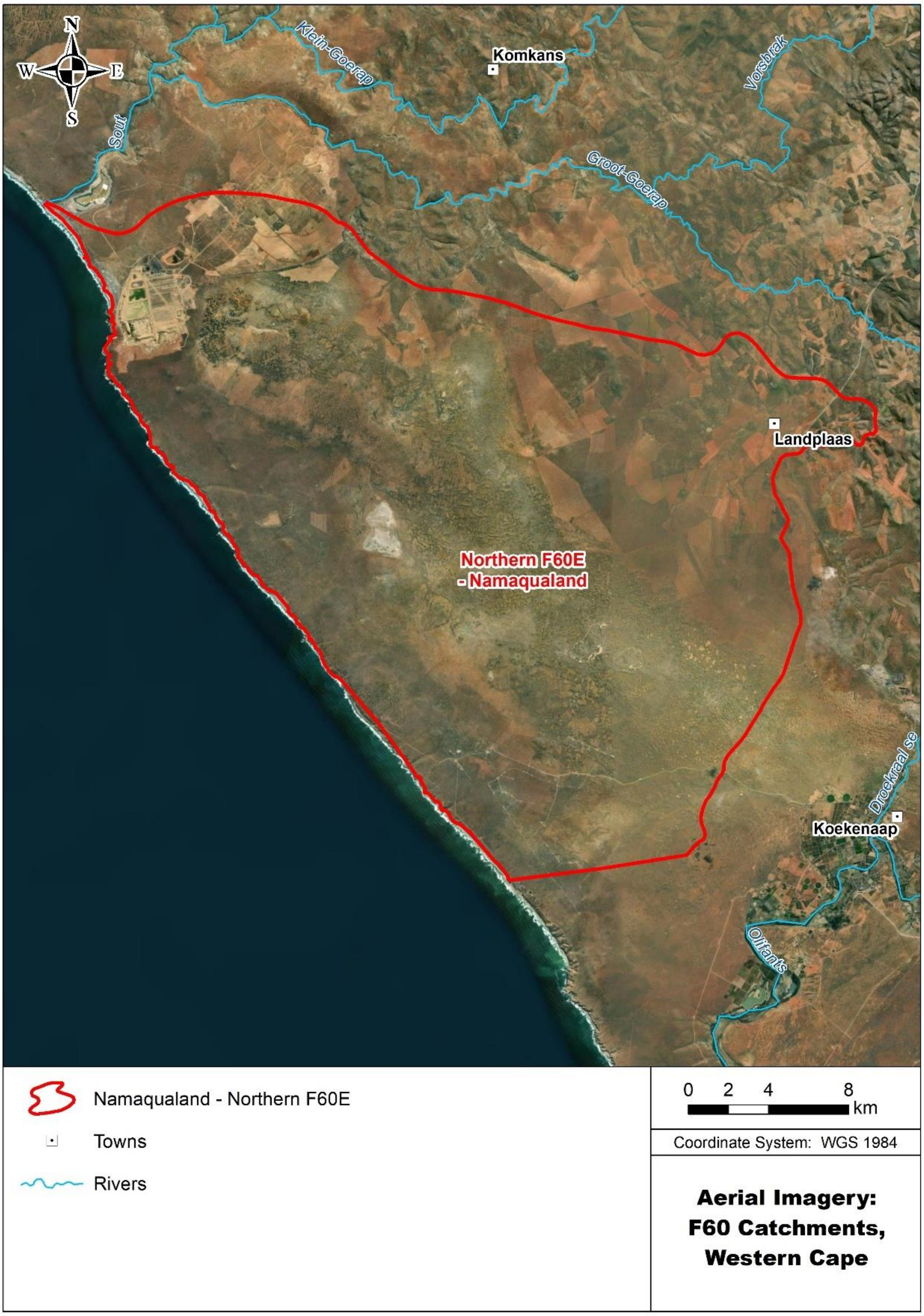

Figure 22: Delineation of the Namaqualand- Northern F60E GRU

2.3.3 Groot-Goerap & Sout - F60D GRU

Grouping: Groot-Goerap & Sout

GRU Name: F60D

Groundwater Use: Low

Delineation:

The groundwater unit falls within the quaternary catchment boundaries and includes the areas surrounding the Groot Goerap and lower Sout River.

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

The underlying geology is very complex and characterised by Quaternary age material consisting of sand and calcareous and gypsiferous soil, underlain by igneous and metamorphic formations. The area is mostly underlain by different age granite and gneiss variants of the Little Namaqualand Suite and Kamiesberg Group. The sandstone Flaminkberg Formation also overlays the older igneous rock units towards the north-eastern corner of the GRU. There are also northwest-southeast trending fault structures cross-cutting the igneous formations towards the eastern portion of the GRU.

It has been noted groundwater intersected in drainage channels sometimes yield extremely salty water. Groundwater quality varies between 800 – 3 000 mS/m, although the south-eastern corner of the GRU has been reported to yield better quality water (200 – 500 mS/m). Yields generally vary between 0.1 and 1 L/s.

The delineated GRU is displayed in **Figure 23**.

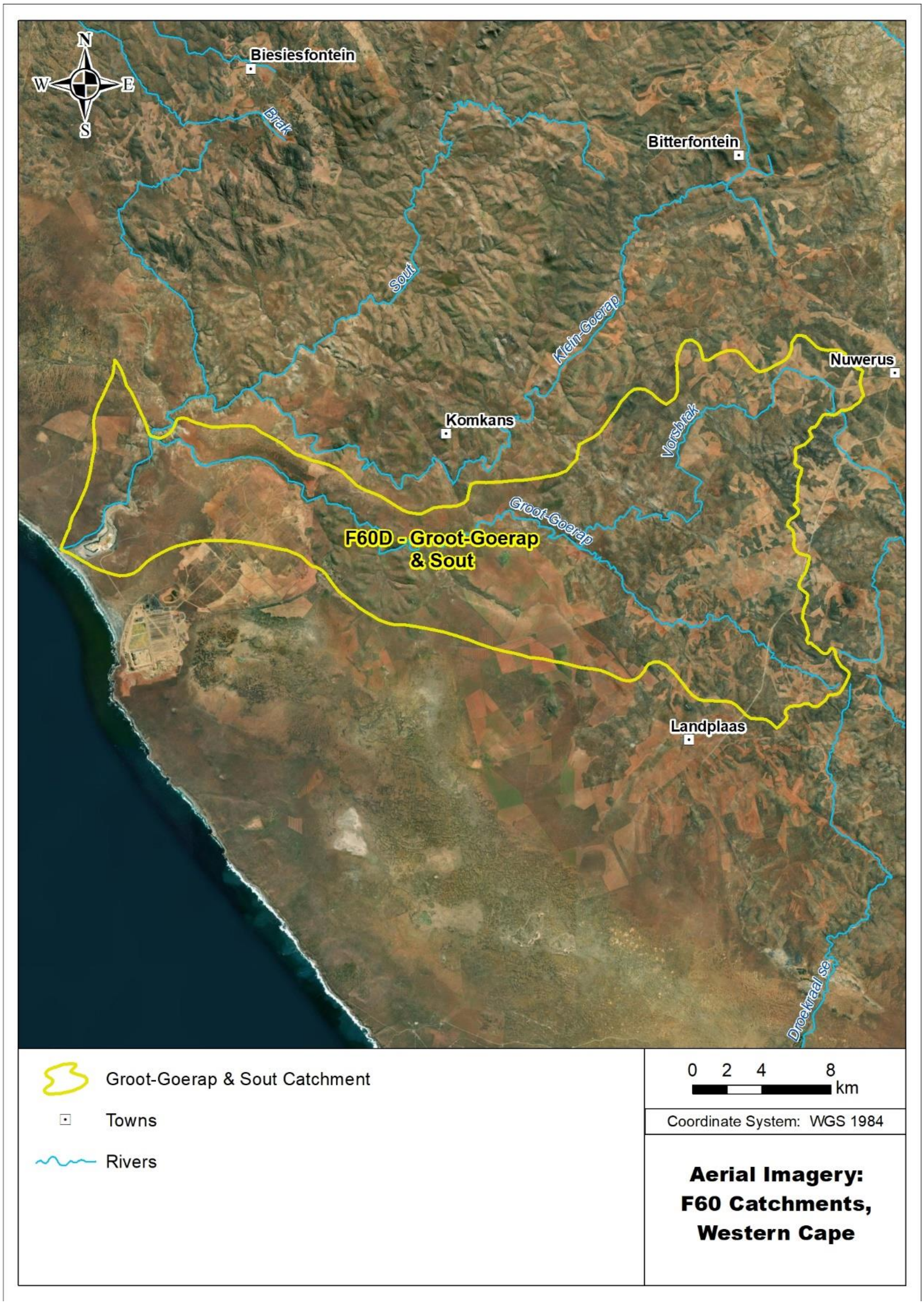

Figure 23: Delineation of the Groot-Goerap & Sout- F60D GRU

2.3.4 Klein-Goerap - F60B GRU

Grouping: Klein-Goerap

GRU Name: F60B

Groundwater Use: Low to moderate (around Bitterfontein)

Delineation:

The groundwater unit falls within the quaternary catchment boundaries and includes the areas surrounding the Klein Goerap River.

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

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

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

Like with other GRUs, geology is dominated by the igneous and metamorphic rock units. In this GRU, less of the catchment is covered by quaternary deposits and thus, geological units, boundaries and structures are easier to distinguish. Granites and gneisses from the Little Namaqua Suite and Kamiesberg Group are overlain by quaternary deposits. These igneous formations have experienced multiple phases of deformation and the units have been folded syncline and anticline structures are evident. Northwest-southeast trending fault structures also cross-cut the igneous formations. The delineated GRU is displayed in **Figure 24**.

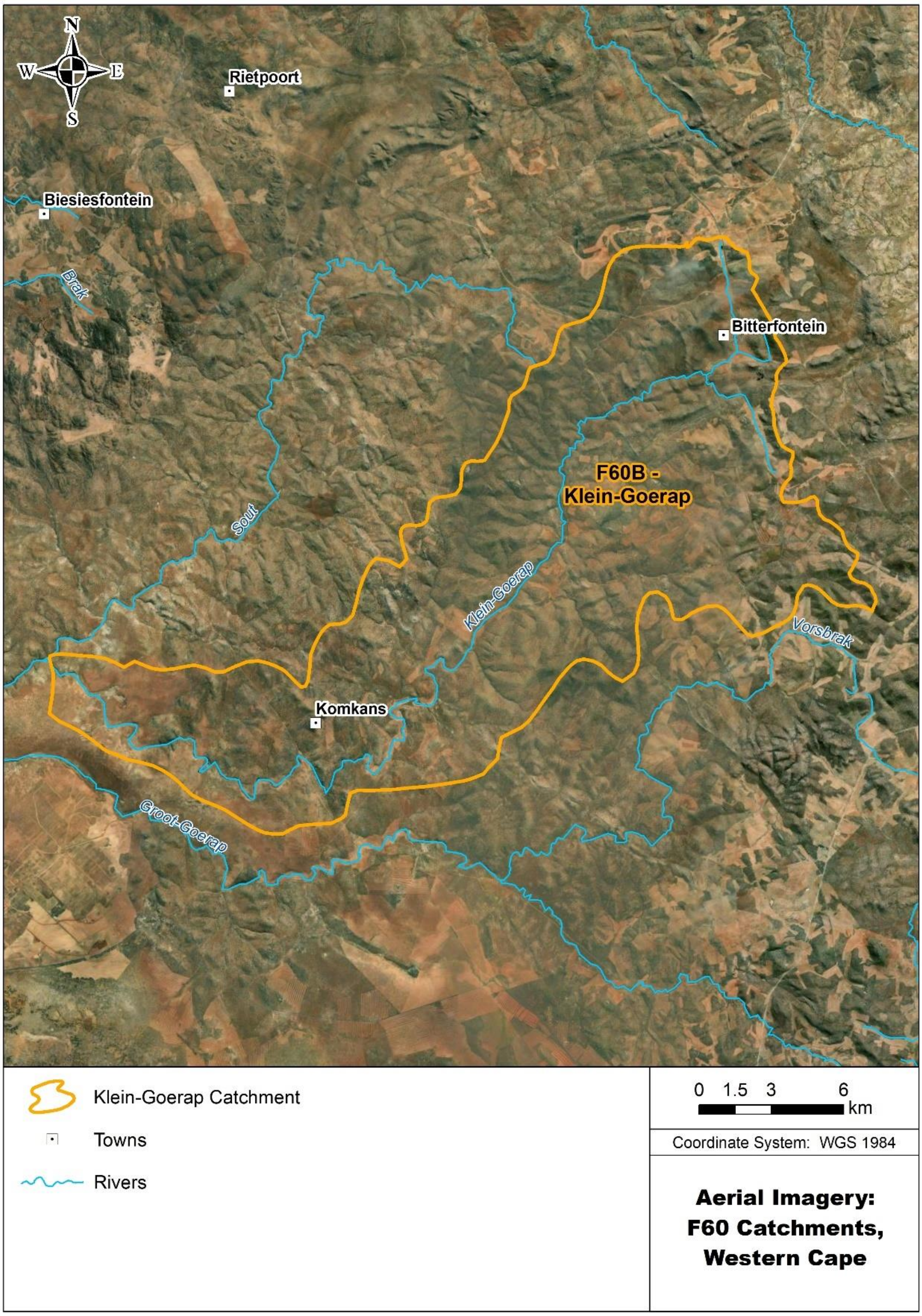

Figure 24: Delineation of the Klein-Goerap - F60B GRU

2.3.5 Sout - F60C GRU

Grouping: Sout

GRU Name: F60C

Groundwater Use: Low

Delineation:

The groundwater unit falls within the quaternary catchment boundaries and includes the areas surrounding the Sout River (before it joins with the Groot-Goerap).

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

The regional geology comprises of Quaternary age material consisting of sand and calcareous and gypsiferous soil, underlain by igneous and metamorphic formations. The area is mostly underlain by different age granite and gneiss variants of the Koegel Fontein Complex, Spektakel Granite Suite, Little Namaqualand Suite and Kamiesberg Group. There are several younger dike intrusions mapped within the GRU, such as the Zout River Basalt plug which can clearly be seen from above as a large dark shape towards the southern border of the GRU (**Figure 25**). There are also northwest-southeast trending fault structures that cross-cut the igneous formations towards the southwest of the GRU.

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

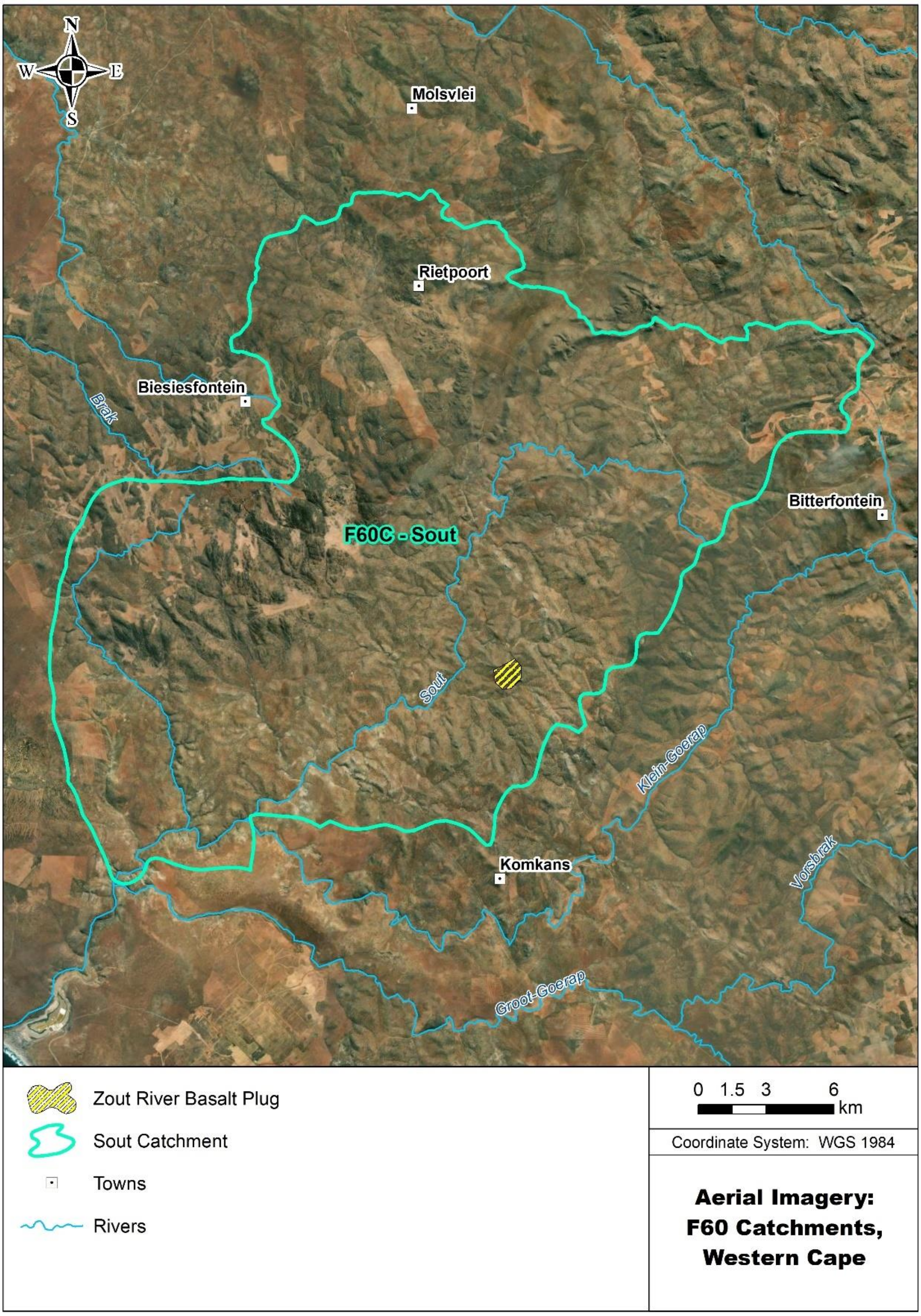

Figure 25: Delineation of the Sout - F60C GRU

2.3.6 Brak - F60A GRU

Grouping: Brak

GRU Name: F60A

Groundwater Use: Very Low to non-existent

Delineation:

The groundwater unit falls within the quaternary catchment boundaries and includes the areas surrounding the Brak River.

Very little to non-existent groundwater abstraction is evident. Mostly dryland and livestock farming and some possible mining activity towards the north. Rainfall is very low (100 - 120 mm/a), and very little recharge is evident.

NGA has recorded few boreholes in the catchment. Matzikama Municipality has not confirmed the water supply for Kotzesrus and Lepelsfontein, but it is suspected to be groundwater. This will be investigated.

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

Most of the GRU is covered by quaternary aeolian sand deposits, with hard rocks only outcropping towards the north-eastern corner and along the coastal terraces. In these areas, the geology is dominated by the granites and gneisses of the Spektakel Suite, as well as the younger Koegel Fontein Complex (mostly the Rietpoort Granite) that intruded the Spektakel units.

Faults have been mapped along the coast, cross-cutting the geology perpendicular to the coastal terraces. The delineated GRU is displayed in **Figure 26**.

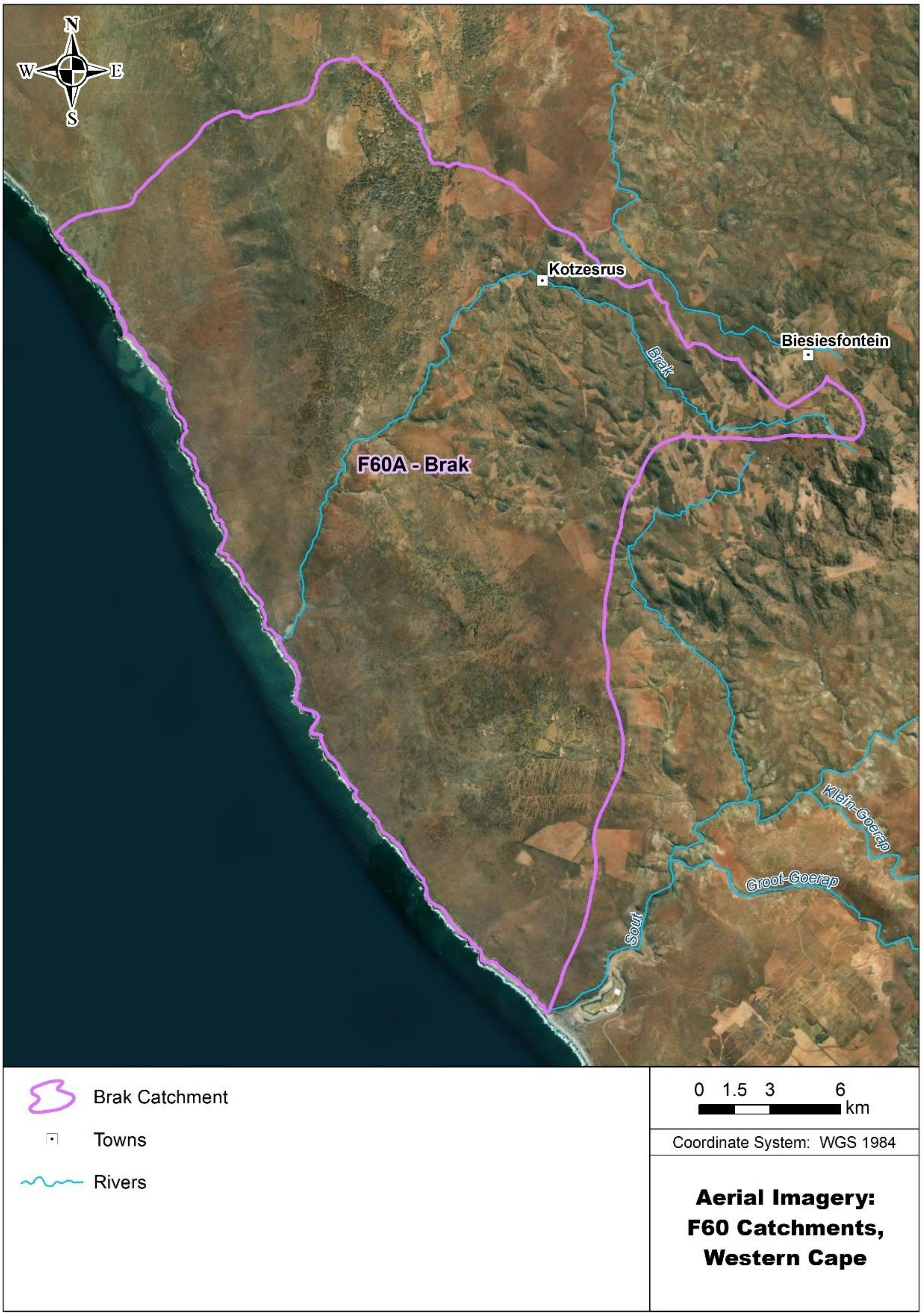

Figure 26: Delineation of the Brak - F60A GRU

3. CONCLUSION

In conclusion, GRUs have been defined for both the G30 and F60 catchments via a desktop approach, using data available. The rationalisation process for the GRU selection is based on reviewing multiple datasets. Geological, hydrological and meteorological data were combined with localized knowledge of the area as well as anecdotal data from residents.

The type of groundwater and aquifer systems were taken into account during the process of delineation of the GRUs within F60 and G30 catchments. Because the groundwater reserves and RQOs linked to them will ultimately have to be linked to surface water RQOs and the quaternary catchments, it was decided to use these boundaries were possible. Where the aquifer, geology or recharge changed in such a way that it would have an effect of the results calculated, additional boundaries were defined.

For the G30 catchments, the area with the highest recharge falls within the TMG formations found along the Piketberg, Citrusdal and Cederberg Mountains. With regards to hydrogeology, in the more mountainous catchments where hard rock is exposed or sand cover shallow, boreholes are drilled mostly into the fractured hard rock aquifer. In the coastal areas, where thick sand deposits are found, boreholes are drilled into the sand. From data collection and general field observations, a hypothesis has been proposed that links these groundwater rich saturated sands with discontinuous groundwater upwelling from faults underlying the sand in some areas, while in others, more typical paleochannel structures occur.

Taking into account the nature of the groundwater system within the G30 catchments, it was decided to mostly keep to the existing quaternary boundaries as they do tend to each incorporate a single valley that relates well with perceived groundwater flow. Only the G30D and G30F catchments were subdivided. For the southern and central G30 catchments, groundwater use is extensive.

For the F60 catchments, geology is much more complex and much less data is available, and this impact directly on the confidence with which the aquifer system can be analysed. Recharge is much lower than for the G30 catchments, and subsequently, the borehole yields and groundwater quality is also much lower and poorer than what is found within the G30 catchments.

Geology also plays a part in the poor water quality of the area. The geology is dominated by the igneous and metamorphic rock units that are overlain by quaternary deposits. Quaternary deposits are still present toward the coast but include calcareous and gypsiferous units as well as thick calcrete beds within the deposits. The area is mostly underlain by different age granite and gneiss variants of the Koegel Fontein Complex, Spektakel Granite Suite, Little Namaqualand Suite and Kamiesberg Group. There are several younger dike intrusions mapped are, with some being unmapped.

Some faulted areas provide groundwater that cannot be used due to the poor quality of the groundwater that had reacted to the host rocks high in salts and minerals. It has also been reported that although water can be found if drilling in or near dry riverbeds, the water found here is, in some cases, very saline. For such areas, groundwater exploration is sometimes moved away from drainage channels and are drilled against hillsides and away from riverbed to target dykes or fracture zones.

Very few hard rock formations are exposed in areas towards the coast, and geological boundaries between rock formations and faults are not defined. These coastal sedimentary deposits host some of the richest placer deposits in the world. They are targeted and mined for heavy minerals, such as zircon, garnet, ilmenite, rutile and magnetite. Because of this, there is interest in commissioning more mines in the area. This could potentially impact the very limited groundwater resource.

During the upcoming site visits, reported claims with regards to over-abstraction, high yielding boreholes, spring sites etc. will be investigated. This will form the main focus of the fieldwork planned for the G30 catchments. Mostly, existing data will be used. For the F60 catchments, where so little updated data is available, the focus will also be to source additional field data. Discussions have been had with the local municipality as well as the Bitterfontein Farmers Association and the mines in the area to accommodate such a field excursion.

With regards to the prioritization of the GRU`s, the final decision will be based on the level of data available and the level to intensity of groundwater use. These two categories have highlighted the southern and central G30 catchments. The Verlorenvlei and tributaries also fall within this section, and special focus will also be placed on groundwater contribution to this system. Regardless of the intensity, the effort will be placed in obtaining as much data as possible for each GRU and calculating recharge and later reserves to the highest level of confidence that the data can achieve. RQOs that are robust and can be implemented will also be a driving factor.

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