water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

Determination of Water Resources Classes and Associated Resource Quality Objectives in the Berg Catchment (WP10987)

RESOURCE UNITS AND INTEGRATED UNITS OF ANALYSIS DELINEATION

DWS REPORT NO: *RDM/WMA9/00/CON/CLA/0416*

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Department of Water and Sanitation
Private Bag X313
Pretoria, 0001
Republic of South Africa

Tel: (012) 336 7500/ +27 12 336 7500
Fax: (012) 336 6731/ +27 12 336 6731

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Prepared by:

Aurecon South Africa (Pty) Ltd in sub-consultancy association with Southern Waters Ecological Consulting, Anchor Environmental and Delta-H Water Systems Modelling

Title: *Resource Units and Integrated Units of Analysis Delineation*

Author: *Dr James Cullis, Louise Lodenkemper, Dr Karl Reinecke, Dr Jane Turpie, Dr Barry Clarke, Helen Seyler, Prof André Görgens, Erik van der Berg*

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Approved for the PSP by:

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Erik van der Berg *Date*

Technical Director

DEPARTMENT OF WATER AND SANITATION

Chief Directorate: Water Ecosystems

Approved for DWS by:

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Ndileka Mohapi

Chief Director: Water Ecosystems

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List of Abbreviations

CD: WE	Chief Directorate: Water Ecosystems
DWA	(Previous) Department of Water Affairs
DWS	Department of Water and Sanitation
DM	District Municipality
EC	Ecological Category
EIS	Ecological importance and sensitivity
EWR	Ecological water requirements
FSP	Fine Scale Planning
GEF	Global Environmental Fund
GDP	Gross Domestic Product
IUA	Integrated Unit of Analysis
IWRM	Integrated Water Resource Management
IWRMP	Integrated Water Resources Management Plan
LM	Local Municipality
NFEPA	National Freshwater Ecosystem Priority Areas
NWA	National Water Act
PES	Present Ecological Sate
RQOs	Resource Quality Objectives
RDM	Resource Directed Measures
RUs	Resource Units
SEZ	Socio-Economic Zones
WCWSS	Western Cape Water Supply System
WMA	Water Management Area
WRC	Water Resource Class
WRCS	Water Resource Classification System

Executive Summary

INTRODUCTION

It has been recognised that some water resources, by virtue of their ecological importance, do require a high level of protection, whereas other water resources may serve the country's developmental and economic growth needs. In response to Chapter 3 of the National Water Act (NWA) (Act 36 of 1998), the Department of Water and Sanitation (DWS) has established a Water Resources Classification System (WRCS) and Resource Quality Objectives (RQOs) process to achieve these goals.

Against this background DWS has commissioned this Study to determine the Water Resource Classes and associated Resource Quality Objectives for the water resources of the Berg catchment consisting of the former Berg Water Management Area (WMA). This Report deals with the first component of the first step of the Classification procedure, which is to delineate the integrated units of analysis (IUAs). The second component of the first step of the Classification procedure is to describe the status quo of the water resources which is in a separate report.

The IUAs represent the spatial units that are defined as significant water resources. Each IUA represents a relatively homogeneous area which requires its own specification of the Water Resources Class. The objective of defining IUAs is to establish broader-scale units for assessing the socio-economic implications of different catchment scenarios and to report on ecological conditions at a sub-catchment scale. Delineation of IUAs is required as it would not be appropriate to set the same Water Resource Class for all water resources in a catchment. This Report outlines the process of delineating and determining the IUAs.

IUA DELINEATION APPROACH

This Study followed the delineation approach defined in the WRCS Guidelines, Volumes 1 and 2 (DWAF, 2007f). The following was considered for the delineation of IUAs within the Berg catchment:

- Socio-economic zone, including similar characteristics of land-use and economic activities
- Ecoregion
- Geomorphic zone
- Hydrological characteristics
- Present ecological status
- Vegetation bioregion
- Catchment boundaries

PROVISIONAL DELINEATION OF IUAs

The composition of the individual provisional IUAs is outlined in Table ES1, where it can be seen that both individual Socio-Economic Zones and individual River Resource Units may incorporate more than one provisional IUA. The locations of the individual IUAs and nodes are indicated in Figure ES1.

Table ES1: Composition of individual provisional IUAs delineated for the Berg Catchment

Socio-economic Zone	Zone Code	IUA Name	IUA Code	Quaternary Catchments
West Coast	A	Berg Estuary	A1	G30A, G10M
		Langebaan	A2	G10M
		West Coast	A3	G21A, G21B
Lower Berg	B	Lower Berg	B4	G10K, G10L. G10J, G10H, G10F
Tulbagh Fruit Area	C	Berg Tributaries	C5	G10G, G10E
Winelands	D	Eerste	D6	G22G, G22H, G22F
		Sir Lowry's	D7	G22J, G22K. G40A
		Upper Berg	D8	G10C, G10B, G10A
		Middle Berg	D9	G10D
		Diep	D10	G21C, G21D, G21E, G21F
Cape Town	E	Peninsula	E11	G22B, G22A
		Cape Flats	E12	G22C, G22D, G22E

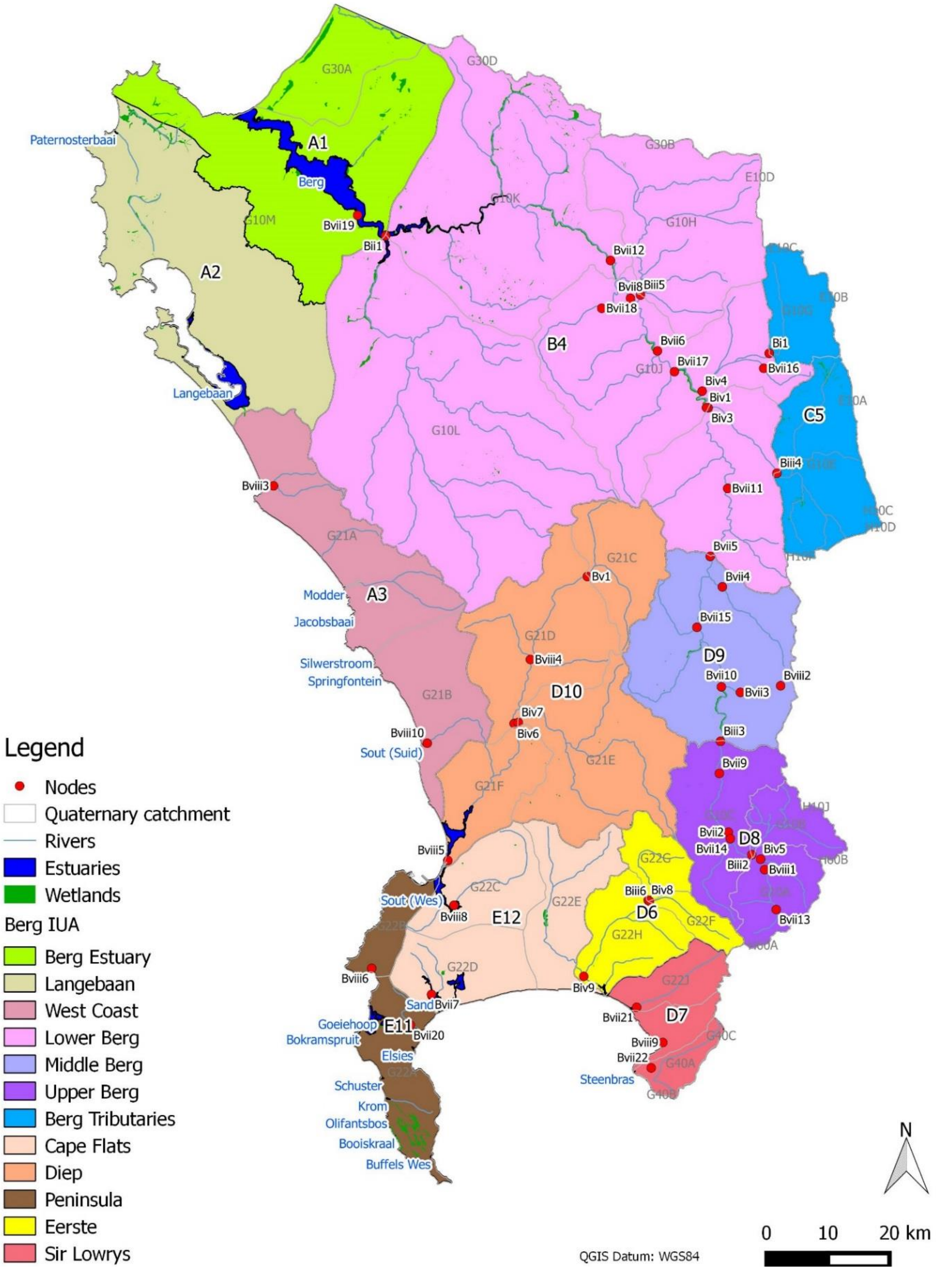

Figure ES1: Integrated Units of Analysis (IUAs) and biophysical nodes for the Berg catchment.

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1 INTRODUCTION

1.1 Background

Chapter 3 of the National Water Act (NWA: No. 36 of 1998) lays down a series of measures which are together intended to ensure protection of the water resources. In accordance with these measures, the Department of Water and Sanitation (DWS) in line with Section 12 of the NWA, established a (Water Resource Classification System (WRCS) that is formally prescribed by Regulations 810 dated 17 September 2010. The WRCS provides guidelines and procedures for determining Water Resource Classes, Reserve and Resource Quality Objectives.

Section 13 of the NWA states that “as soon as reasonable practicable after the Minister prescribed a system for classifying water resources, the Minister must, subject to subsection (4), by notice in the gazette, determine for all or part of every significant water resource-

a) A class in accordance with the prescribed classification system; and
b) Resource quality objectives based on the class determined in terms of paragraph (a).

The Chief Directorate: Water Ecosystem has therefore commissioned a study to determine Water Resource Classes (WRCs) and associated Resource Quality Objectives (RQOs) for all significant water resources in the Berg Catchment. This consists of the area of the former Berg WMA, including catchments G1 and G2.

The Berg River is the largest catchment in the Study Area, which also includes a number of smaller catchments such as the Diep, Kuils, Eerste, Lourens, Sir Lowry’s, Steenbras, as well as various small catchments on the Cape Peninsula and along the West Coast, as shown in Figure 1.1.

1.2 Objectives of the Study

The main objectives of the Study are to undertake the following:

- Co-ordinate the implementation of the Water Resource Classification System (WRCS), as required in Regulation 810 in Government Gazette 33541, by classifying all significant water resources in the former Berg WMA as part of the Berg-Olifants WMA.
- Determine Resource Quality Objectives (RQOs) using the Department of Water and Sanitation’s (DWS) Procedures to Determine and Implement RQOs for all significant water resources in the former Berg WMA as part of the Berg-Olifants WMA.

1.3 Purpose of this Report

The first step of the classification procedure is to delineate the IUAs and describe the status quo of the water resources. The IUAs represent the spatial units that will be defined as significant water resources. Each IUA represents a homogenous area which requires its own specification of the WRC. This report outlines the process for delineating and determining the IUAs for the water resources in the study area.

The purpose of this report is therefore:

- To provide the information used to delineate the IUAs,
- To detail a network of significant resources (river, dam, wetland, estuary and groundwater),
- To establish biophysical and allocation nodes for determining environmental water requirements,
- To detail the defined set of delineated IUAs within the study area.

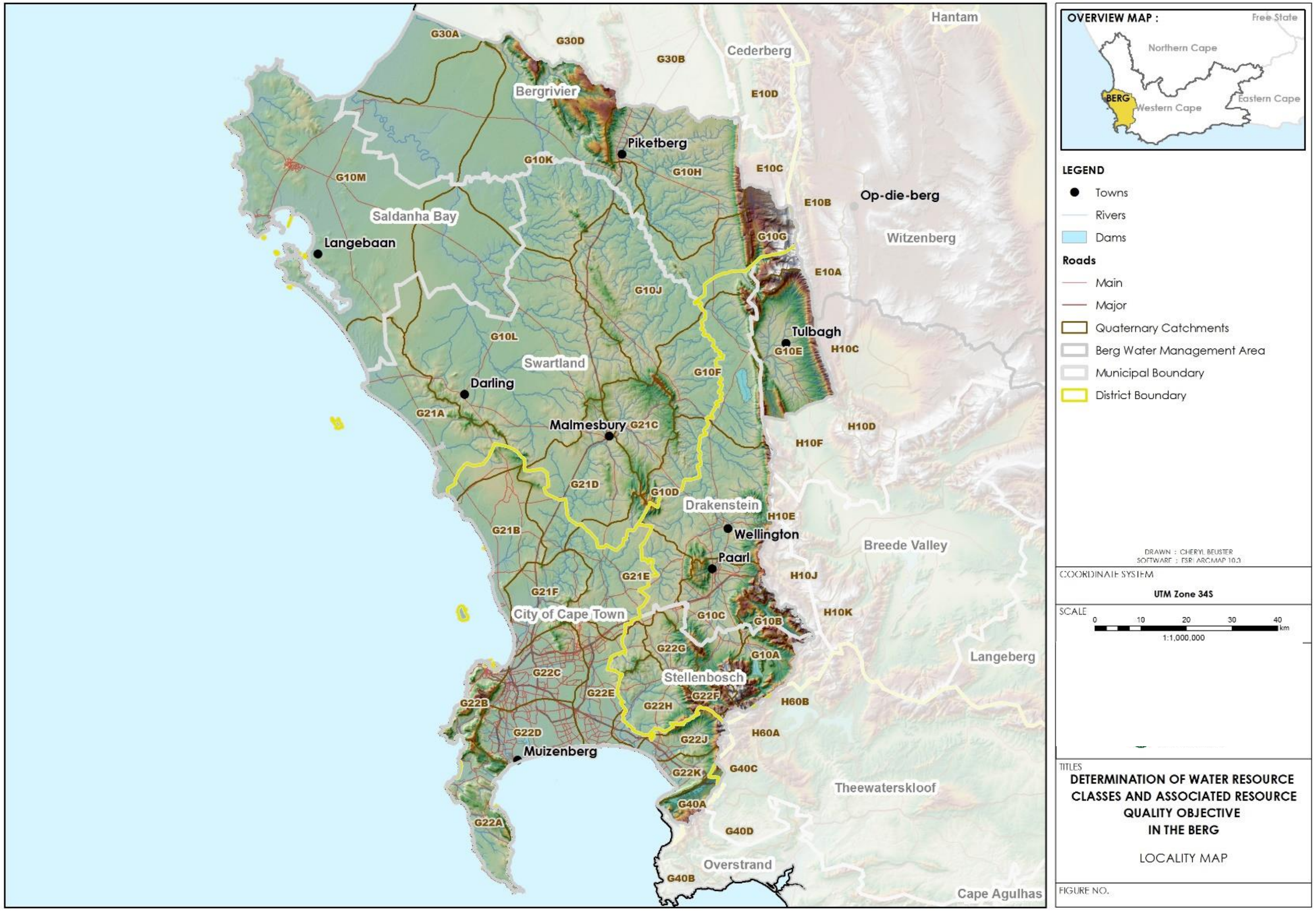

Figure 1.1. Map of the study area.

2 OUTLINE OF PROCEDURE TO DETERMINE IUAs

2.1 Generic WRCS outline

The WRCS provides for a structured process to identify the agreed trade-off point between resource protection and development of river basins, through an assessment of the economic, social and ecological implications alternative future conditions for a given water resource (DWAF, 2007f). It is designed for use in Classification Processes for every WMA in the country, the outcome of which is the setting, by the Minister or delegated authority, of the Water Resource Class, Reserve and Resource Quality Objectives (RQOs) for significant water resources (river, estuary, wetland and aquifer) in each WMA.

A Water Resource Class, which describes the desired condition of the resource, and concomitantly, the degree to which it can be utilised, is determined for an entire catchment or sub-catchment (DWAF, 2007f).

The Class can range from “minimally” to “heavily” used as defined in Table 2.1, and sets the boundaries for the volume, distribution and quality of the Ecological Reserve and RQOs, and thus the potential allocable portion of a water resource for off-stream use. This has considerable economic, social and ecological implications.

Table 2.1. Definition of Water Resource Classes (DWAF, 2007f).

Class I: Minimally used The configuration of water resources within a catchment results in an overall water resource condition that is minimally altered from its pre-development condition.
Class II: Moderately used The configuration of water resources within a catchment results in an overall water resource condition that is moderately altered from its pre-development condition.
Class III: Heavily used The configuration of water resources within a catchment results in an overall water resource condition that is significantly altered from its pre-development condition.

Many of the steps or procedures of the WRCS are similar to those undertaken as part of Resource Directed Measures (RDM) processes during which, among other things, EWRs are specified. Once gazetted, the WRCS is used in place of the Preliminary Reserves that have been determined to date. For those catchments where Intermediate or Comprehensive Reserve determination studies have already been completed, the WRCS extends the information generated by those studies for use in the Classification Process.

The 7-step procedure prescribed in the WRCS Overview Report (DWAF, 2007f) leading to the recommendation of the Class of a water resource (the outcome of the Classification Process) is summarised in Figure 2.1. It can be seen that the determination of the IUAs represents one component of Step 1 in the 7-step procedure. The other component of the Step 1 is the description of the status quo of the identified significant water resources in the WMA.

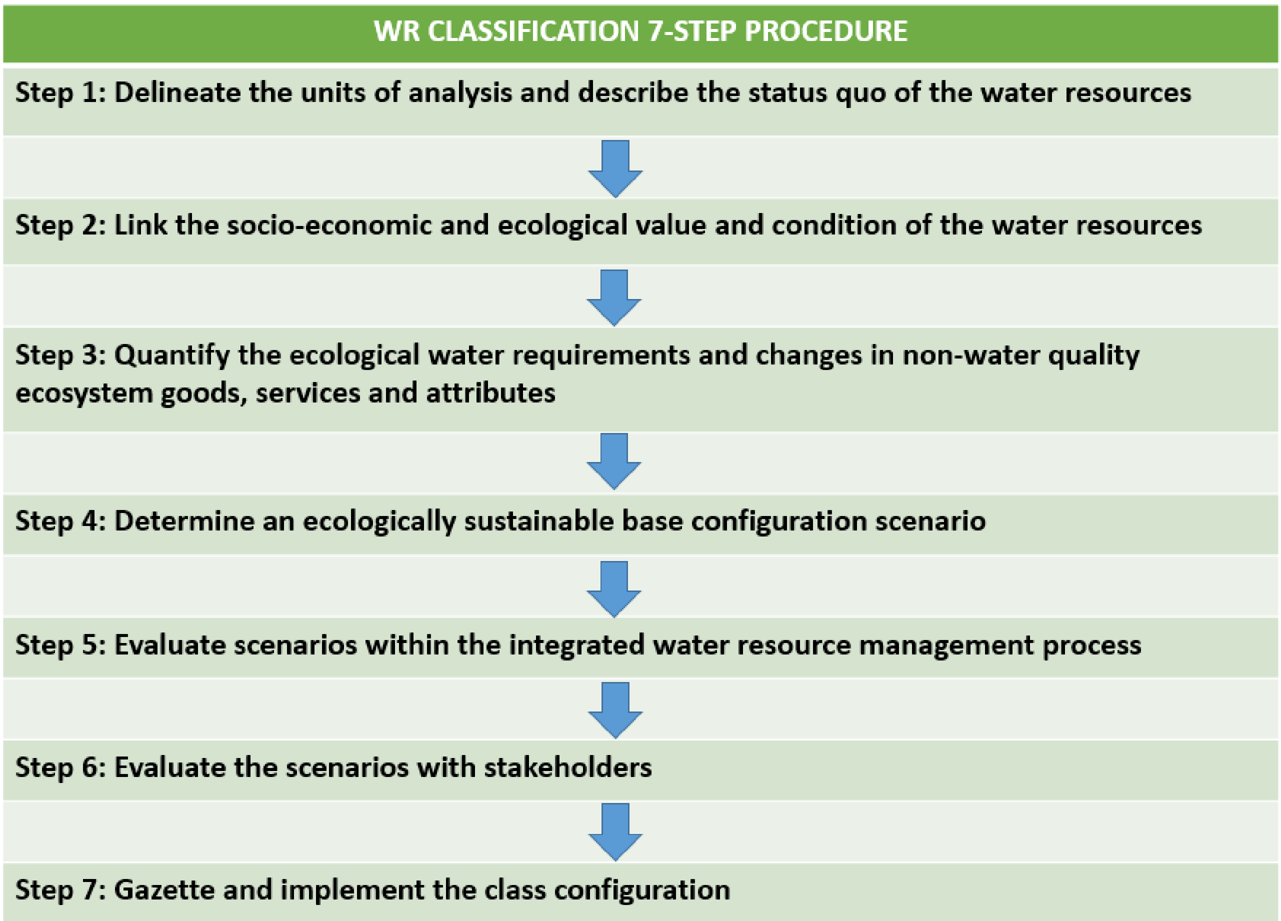

Figure 2.1. WR Classification 7-step procedure (DWAF 2007f).

2.2 Generic outline of IUA determination sub-steps

Figure 2.2, extracted from DWAF (2007f), presents a flow diagram that outlines the sub-steps that need to be undertaken to arrive at final IUA delineations. It is important to note that, although the sub-steps are portrayed sequentially, in reality, various sub-steps are undertaken simultaneously.

(d) Define a network of significant resources and establish bio-physical and allocation nodes

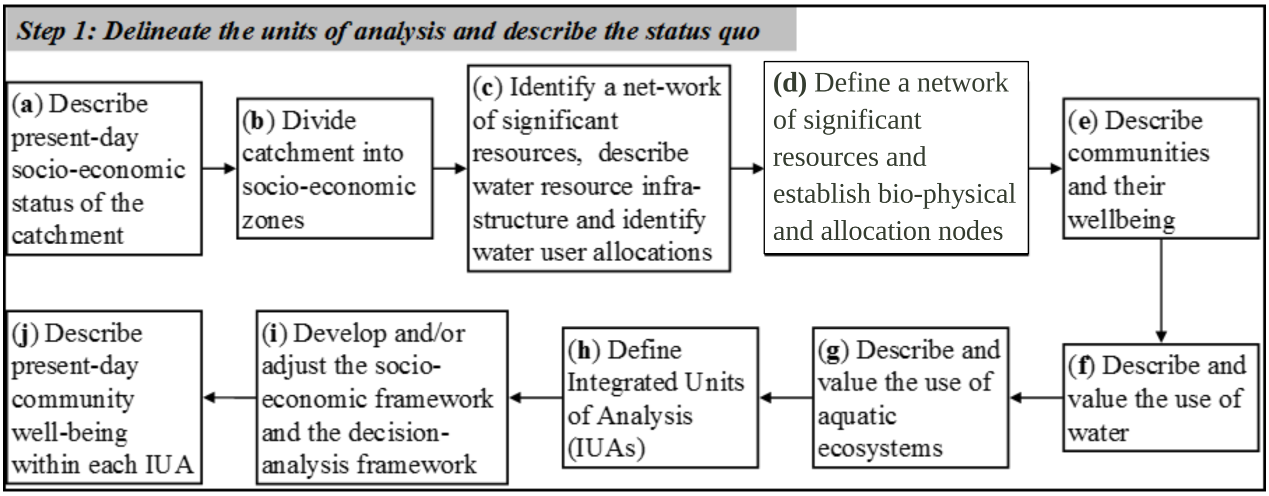

Figure 2.2. Sub-steps of the IUA delineation process (DWAF, 2007f).

2.2.1 Sub-steps 1a and 1b

The purpose of these two sub-steps is to *logically consolidate spatial information on the socio-economic characteristics and aquatic ecosystem services of the study area into socio-economic zones* in order to predict and report the implications of different catchment configuration scenarios on social wellbeing, economic prosperity and ecosystem health at an appropriate spatial scale. This includes the following tasks:

- An overview of land use, population and the use of water in the study area.
- Descriptions of the water user groups and their economic outputs.
- A preliminary description of the value of aquatic ecosystems in terms of the ecosystem services they provide.
- Delineation of socio-economic zones and descriptions of their activities and population characteristics.

2.2.2 Sub-step 1c

The purpose of *identifying a network of significant resources* is to delineate the resources that will be utilised for the Classification Process. Significant water resources are defined as those that are significant from a use perspective and/or for which sufficient data exist to enable an evaluation of changes in their ecological condition in response to changes in water quality and quantity. Significant resources may include main-stem rivers in each quaternary catchment; estuaries, wetlands, dams, aquifers and any other resources considered significant.

The purpose of *describing the water resource infrastructure* is to ensure that the selection of biophysical and allocation nodes (sub-step 1d) takes account of existing water resource infrastructure for (later) modelling and allocation purposes. The description of water resource infrastructure may include major dams, minor dams, farm dam clusters, abstraction infrastructure, canals, and any other water resource infrastructure considered significant.

2.2.3 Sub-step 1d

The purpose of *defining biophysical nodes is to delineate a network of significant resources* that will form the basis of the classification process in the study area. This sub-step comprises the following tasks:

- The determination of ecosystem-specific units (i.e. rivers, estuaries, wetlands, dams and aquifers).
- The identification of areas of interaction between ecosystems (i.e. river-estuary interactions, river-wetlands interactions, river-groundwater interactions, estuary-wetland interactions, estuary-groundwater interactions and groundwater-wetlands).
- The identification of nodes that will account for the interactions between ecosystems.
- The establishment of allocation nodes.

The nodes are used to assess the response of the upstream resources to changes in water quality, quantity and timing. DWAF (2007f) indicates that the biophysical nodes should be located at the end-points of ecosystem reaches that will allow for meaningful trade-offs between different parts of the catchment in terms of the quantity (volume and distribution) and quality of water that remains in the resource, and thus the quantity and quality of water available for off-stream use. The allocation nodes should account for "existing lawful use" and for potential future use.

2.2.4 Sub-step 1e

The objective of *describing communities and their wellbeing* within each socio-economic zone (identified in sub-step 1b) is to provide the baseline from which changes in social wellbeing can be estimated for each of the catchment configuration scenarios evaluated in Steps 5 and 6 of the Classification Procedure. This requires describing the levels of financial, physical, human, social and natural capital available to each community, as well as constructing a measure or index of social wellbeing from the data collected in Steps 1a and 1b.

2.2.5 Sub-step 1f

The objective of *describing and valuing the use of water* is to determine the way in which water is currently being used in each socio-economic zone and to estimate the value generated by that use. This will provide the baseline from which the socio-economic implications of different catchment configuration scenarios can be assessed.

2.2.6 Sub-step 1g

The objective of *describing and valuing the use of aquatic ecosystems* is to determine the way in which aquatic ecosystems are currently being used in each socio-economic zone, and to estimate the value generated by that use. This will provide the baseline against which the socio-economic and ecological implications of different catchment configuration scenarios can be compared.

2.2.7 Sub-step 1h

The objective of *defining IUAs* is to establish broader-scale units for assessing the socio-economic implications of different catchment configuration scenarios and to report on ecological conditions at a sub-catchment scale. IUAs are therefore a combination of the socio-economic zones defined in Step 1b and catchment boundaries, within which ecological information is provided at a finer scale. This requires that the nodes established in Step 1d of the Classification Procedure be nested within the IUAs.

2.2.8 Sub-step 1i

The objective of this sub-step is to *develop and/or adjust the socio-economic framework and the decision-analysis framework* proposed in DWAF (2007f) for a specific application of the Classification Process. For the socioeconomic component of the Classification Procedure, this requires developing and/or adjusting the socio-economic framework that links changes in yield and ecosystem characteristics to socio-economic values to meet the specific requirements of the catchment.

2.2.9 Sub-step 1j

The objective of this sub-step is to *describe the present-day community wellbeing within each IUA* using the index developed in Step 1e. This is to ensure that the ecological and socio-economic implications of different catchment configuration scenarios are reported at the same scale.

2.3 Step 1 outcomes reported in this document

Our appointment brief specifies that the details and outcomes of Step 1 of the Classification Procedure for this study must be reported in two separate documents, namely a *Resource Unit Delineation and Integrated Units of Analysis* Report and a *Status Quo* Report. In accordance with this specification, this document reports only on the outcomes of Sub-step 1b (divide catchment into socio-economic zones), Sub-step 1d (define a network of significant resources and establish the biophysical nodes and allocation nodes) and Sub-step 1h (define the IUAs). The details, methodologies and outcomes of the tasks falling under the other Sub-steps of Step 1 are fully documented in our *Status Quo* Report.

3 SUB-STEP 1b: DEFINE SOCIO-ECONOMIC ZONES

3.1 General approach

The purpose of delineating socio-economic zones is to make it easier to provide descriptions of the socio-economic implications of different classification scenarios that can be readily understood by stakeholders who can relate to the various areas that they depend upon. The rationale for the zonation process was that zones should be relatively homogenous in terms of the relationships of the economic activities in the zones with water. For example, some zones are heavily dependent on irrigation, with associated pressures on water resources, others may be dominated by dryland crops, others by use of natural areas for which ecosystem health is of greatest importance, and others by urban and industrial activities which have a high impact on water resources. In reality the study area contains a high diversity of activities and zones cannot be quite so neatly defined.

3.2 Delineation of Socio-Economic Zones

Socio-economic zones were delineated after detailed inspection of a range of spatial information on geography, climate, drainage, vegetation and land use. The zones were demarcated primarily on the basis of agricultural land use. Layers that were the most important in this process included:

- Land Cover 2014
- Agricultural Census, which shows spatial information on crops planted at the sub-farm level
- Homogenous Farming Areas

Although Homogenous Farming Areas initially seemed to provide a good guide, there were significant discrepancies between these zones and the census and land cover data, so the latter were taken as the primary determinants of land use zones. Initial boundaries were then compared with river characteristics and catchment boundaries. After input from the rest of the team, some of the socio-economic boundaries were slightly realigned in order to facilitate the summarising of data between the different disciplines. The socio-economic zones for the study area are listed in Table 3.1 and shown in Figure 3.1 and Figure 3.2.

Table 3.1. A list of the five socio-economic zones delineated for the study area. The map code relates to the position of each zone shown in Figure 3.1 and Figure 3.2.

Map Code	Socio-economic zone
A	West Coast
B	Lower Berg
C	Tulbagh Fruit Area
D	Winelands
E	Cape Town

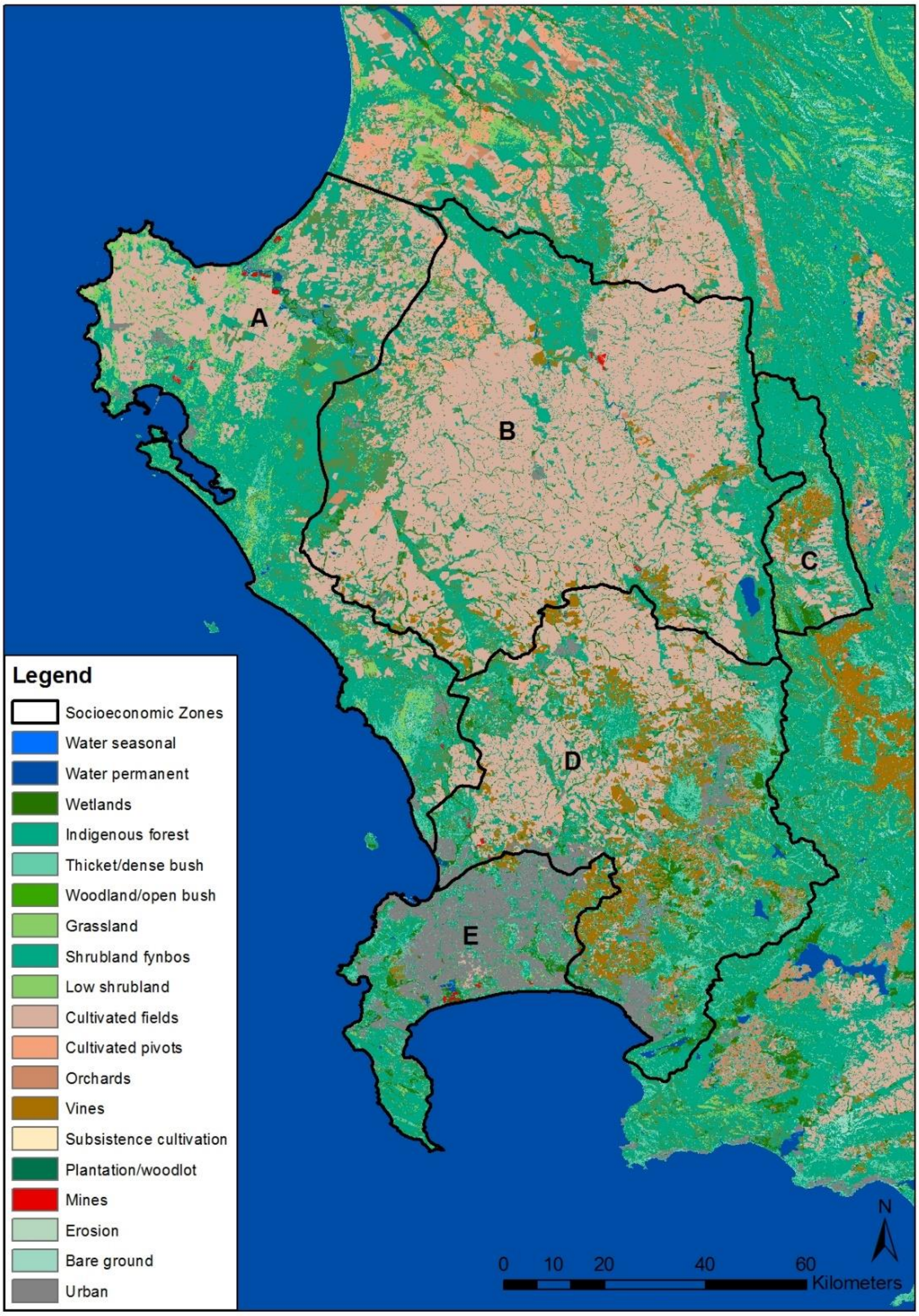

Figure 3.1. The five socio-economic zones in relation to the 2013/14 land cover.

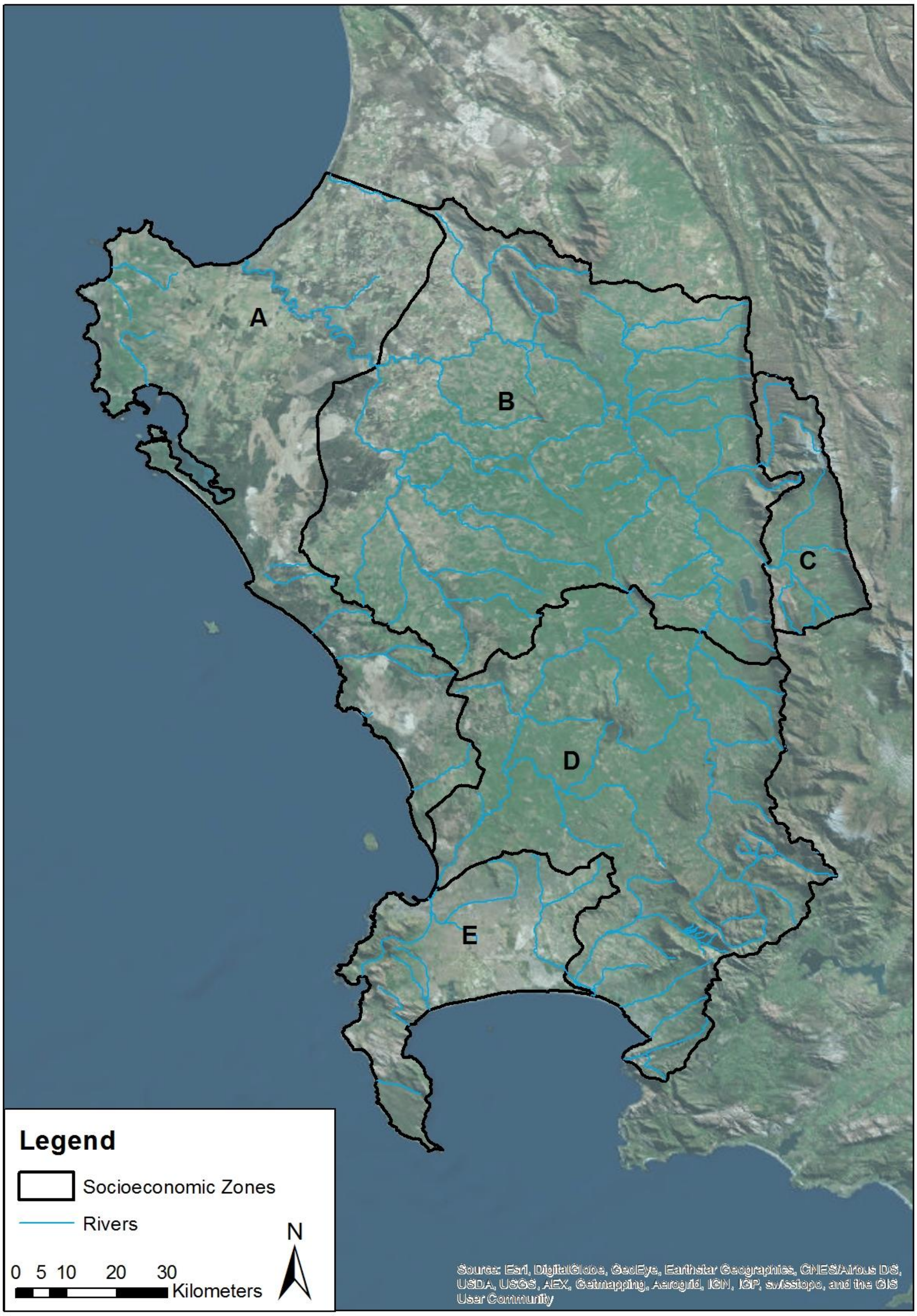

Figure 3.2. The five socio-economic zones in relation to topography.

4 SUB-STEP 1d (i): DEFINE RESOURCE UNITS

4.1 River Resource Units

4.1.1 General approach

The general approach followed to define the boundaries of the significant surface water resources comprising the River Resource Units (River RUs), was to overlay six different sets of spatial data that are ecologically relevant on a base map of major catchment boundaries, infilled with quaternary catchment boundaries. This enabled the derivation of River RUs which, in ecologically-relevant terms, are internally consistent. These six sets of overlaying spatial data were as follows:

- ecoregions
- geomorphic zones
- hydrological index
- present ecological status (PES)
- aquatic vegetation classes
- vegetation bioregions.

The detailed data sets and mapping used for this delineation are reported in full in the Status Quo Report.

The delineation of the river resource units (RUs) for the Berg study area started by separating the quaternary catchments of the main Berg River into the upper, middle and lower sections. Initially the Sout River was considered separately from the lower Berg (as shown in Figure 4.1), but this was later combined with the rest of the Lower Berg rivers based on similar characteristics and impacts on the estuary.

The contributing tributaries from the Kleinberg where separated out on the basis of the present ecological status (PES). The Berg River estuary was also initially considered separately along with Langebaan lagoon. The Dwars River and other smaller rivers on the west coast were combined into a single resource unit. The Diep River catchment was also delineated separately.

The Cape Town rivers were delineated according to the City of Cape Town delineated catchment boundaries and separated into the Pensinsula Rivers, the Cape Flats rivers and the combined Eerste and Kuils Rivers. The Steenbras catchment was also combined with the Eerste and the Kuils Rivers.

The provisional delineation of the River RUs are shown in Figure 4.1 and given in Table 4.1.

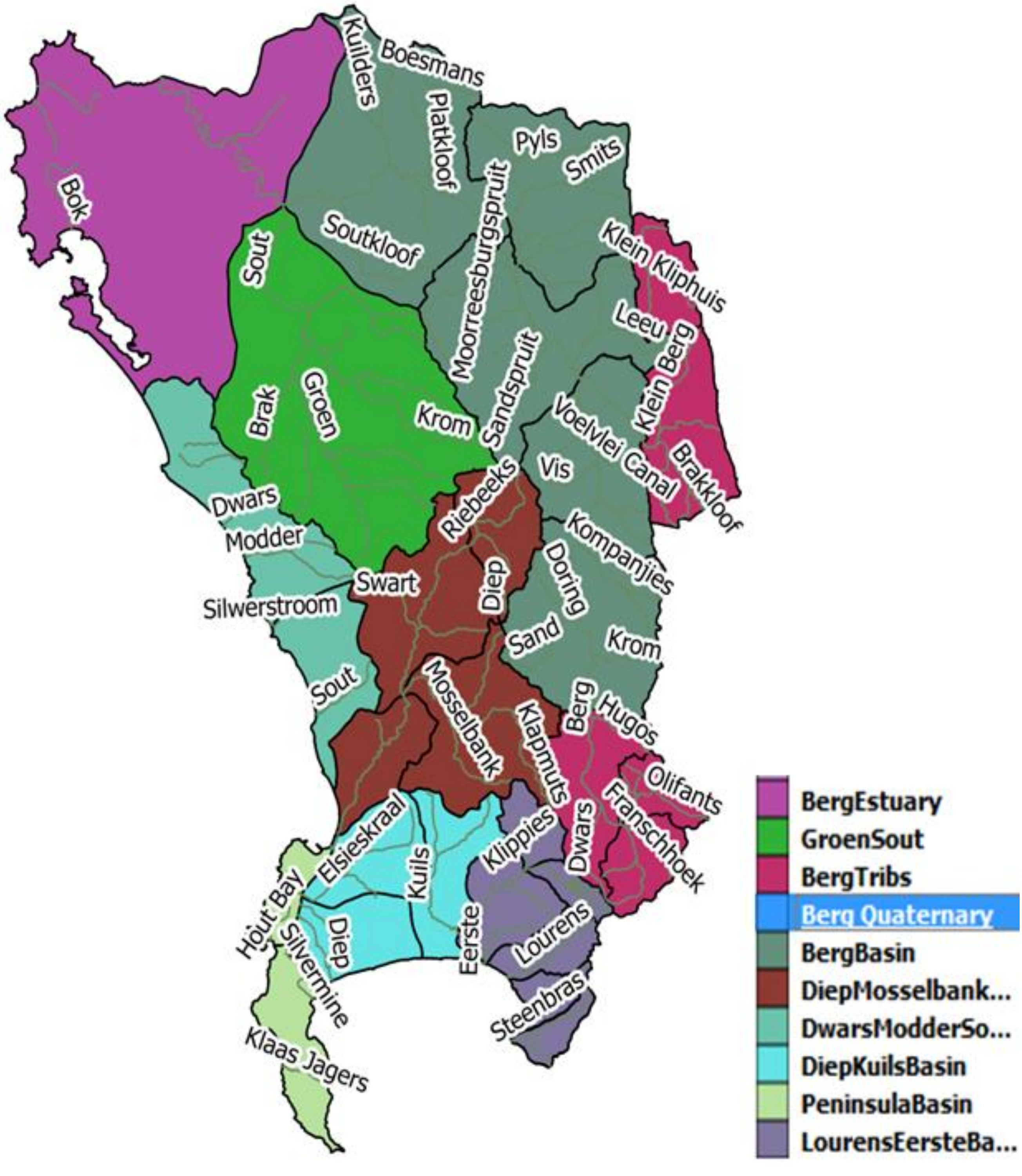

Figure 4.1. Preliminary delineation of River resource units for the study area.

Table 4.1. Quaternary catchments belonging to preliminary River Resource Units (RUs).

River Resource Unit	Quaternary Catchments
Upper Berg	G10C, G10B, G10A
Middle Berg	G10D
Lower Berg	G10K, G10L. G10J, G10H, G10F
Berg Estuary and Langebaaan Lagoon	G30A, G10M
Berg Tributaries (Kleinberg River)	G10G, G10E
Dwars and Coastal	G21A, G21B
Diep River	G21C, G21D, G21E, G21F
Peninsula Rivers	G22B, G22A
Cape Flats Rivers	G22C, G22D, G22E
Lourens, Eerste, and Steenbras Rivers	G22G, G22H, G22F, G22J, G22K. G40A

4.2 Groundwater Resource Units

The 'Groundwater Reserve' is usually determined per quaternary catchment, which is used as the primary delineation of water resource units in Resource Directed Measures (RDM) assessments. The delineation of groundwater resource units (GRUs) relate specifically to hydrogeological criteria and might not necessarily correlate to quaternary surface water catchments or surface water units of analysis. Due to the very different characteristics of each of the major geology groups (namely the basement, the TMG and the Sandveld Group) corresponding to different aquifer types, and the strongly compartmentalised nature of the TMG due to faults or fault zones, the aquifer boundaries mostly do not coincide with surface water catchment boundaries. The delineation of resource units requires knowledge of the recharge zone and the discharge zones of the flow paths of the various aquifers. Previous hydrogeological divisions of the area were reviewed to provide insight into the approach for delineating resource units for the Berg study area.

4.2.1 Previous hydrogeological delineations

Based on the type of porosity– primary or secondary – lithostratigraphy, physiography and climate, Vegter (2001) divided South Africa into 64 groundwater regions (Figure 4.2 Table 4.2). The majority of the Berg falls within either the Southwestern Coastal Sandveld Region, or the Swartland Region.

The Southwestern Coastal Sandveld Region essentially includes all the coastal Sandveld Group deposits including (from south to north) the Cape Flats aquifer, Atlantis aquifer, Grootwater aquifer (Yzerfontein area), Elandsfontein Aquifer System, Langebaan Road Aquifer System, and Adamboerskraal Aquifer. The region also includes the Cape Peninsula, formed by the Peninsula Formation outcrop, and the Cape Granite Suite Batholiths at Vredenburg, and Darling.

The Swartland Region groups areas underlain by basement (Malmesbury Shale and Cape Granite Suite), extending from Somerset West in the South, to beyond the Berg in the north. Three other groundwater regions cover parts of the Berg at its boundaries:

1. the TMG outcrop in the Aurora region in the north of the Berg, and the TMG in the (southern part of) the Groot Winterhoek in the northeast of the Berg both fall within what is delineated as the Northwest Cape Ranges,
2. The Tulbagh area which is within the Berg, is delineated as the Intermontain Tulbagh-Ashton Valley
3. The TMG outcrop east of Stellenbosch (Jonkershoek and Hottentots Holland areas) and north of Franschhoek lie within the Berg, and are delineated within the Southwestern Cape Ranges.

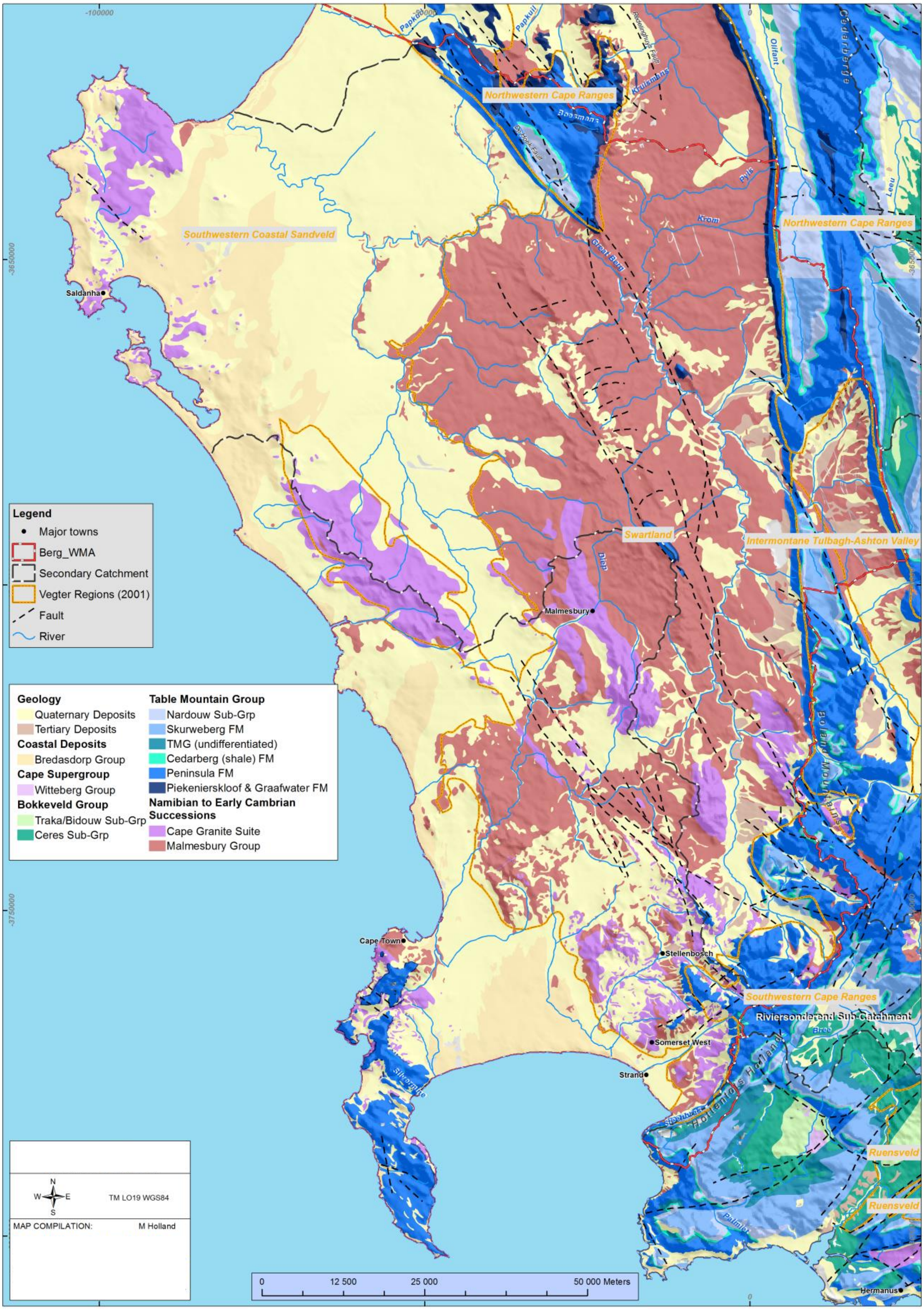

Figure 4.2. Groundwater Regions (after Vegter, 2001).

The concept of an Integrated Water Resources Management (IWRM) domain was applied during the Berg Water Availability Assessment Study (DWAF 2008), with the main purpose of establishing domains/units to “initiate the planning for the groundwater modelling as well as the Water Resource Yield Model (WRYM) development and to promote the integration of surface water, groundwater and ecological monitoring within a domain that conceivably responds differently in time but has the same boundary conditions” (DWAF 2008). Based on the hydraulic principles of the definition of the IWRM domain several units were delineated by DWAF (2008) in the Berg catchment (Figure 4.3). Boundaries generally follow major watersheds and topographic divides, and/or important lithological boundaries (aquifer-aquitard contacts).The IWRM domain is defined around a potential water resource development scheme that integrates the local surface-water resource with one or more components of the groundwater system in that area. They generally combine between two and ten quaternary catchments.

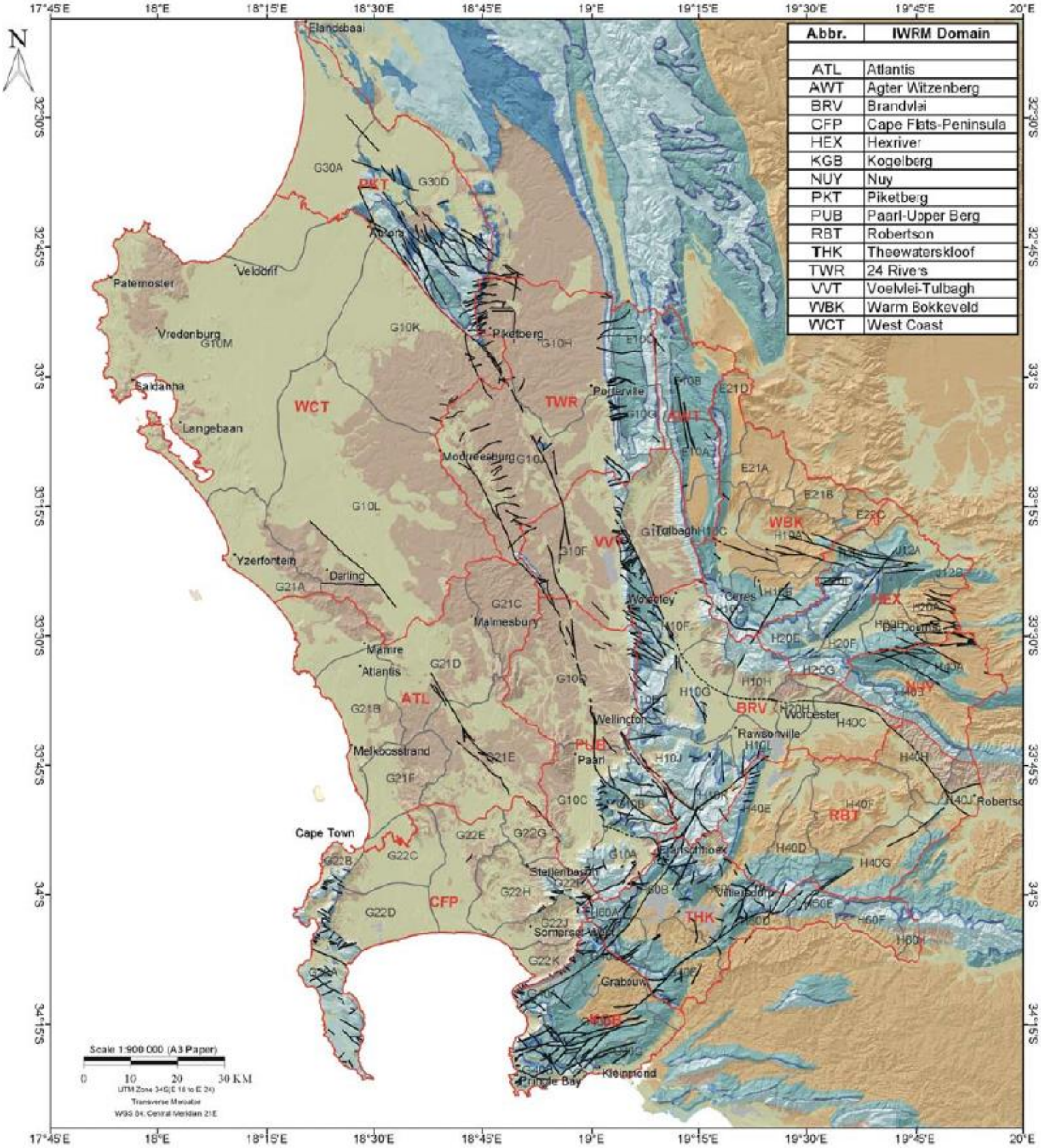

Figure 4.3. Regional delineation of eight IWRM domains (Adapted from DWAF, 2008).

4.2.2 Surface water catchments

The study area comprises of 29 quaternary catchments with rivers cutting through various formations and structural units of the area that produce diverse watercourses and slope systems, which lead to both the rugged surface and different relief, mountain and hill systems. These influence the groundwater systems in terms of recharge locations, interflow behaviours, and corresponding groundwater circulations.

4.2.3 Delineation approach and results

In hydrogeological settings where the geology is relatively uniform across large areas, and the primary groundwater flow paths are shallow and likely mimic topography, delineation of groundwater resource units may generally be able to adhere to surface water catchments. Ridges formed by the Peninsula Formation represent in most cases surface water catchment divides, with the Peninsula Formation forming the head water of major (surface) drainage system, true in the case of the eastern boundary of the Berg catchment. These outcrop areas of the TMG aquifers (i.e. unconfined recharge areas), and specifically the Peninsula Formation in the Berg catchment, are often connected to deep buried (sub-crop) areas with active deep confined flow paths. These do not necessarily mimic shallow groundwater flow paths. It is this geological setting of the TMG that leads to a complex delineation of resource units. It's generally observed that the Skurweberg aquifer contributes more directly to river baseflow both via the river bottom and via springs at the Nardouw – Cedarberg contact, while the Peninsula contributes to river flow mainly as surface run-off (WRC, 2003).

DWAF (2008) recognised that a groundwater balance for the TMG based on (surface water) catchment boundaries may lead to erroneous recharge allocated to a (surface water) catchment if this recharge in fact moves in deep groundwater flow paths in a different direction to surface water. To overcome this DWAF (2008) differentiated between the Peninsula Formation outcrop area and the confined Peninsula Formation (i.e. Peninsula Formation that is covered by other geological units), but determined the direction of any deep flow paths and flow from outcrop areas. This approach was partly adapted here for the current delineation for classification, but the resulting groundwater unit was not limited to the Peninsula Aquifer alone.

For consistency during the delineation process the contact between the top of the Peninsula Formation and the reminder of the TMG and the overlying Cape Supergroup was used in cases where it was deemed necessary (i.e. main recharge/run-off area). An example of this GRU delineation approach is shown in a section Figure 4.4. Very generally, much of the eastern boundary of the GRUs in the study area follow this schematic representation. Using standard procedures the groundwater classification can be applied to each of the Berg resource units. Shallow groundwater flow in the Peninsula Formation would be accommodated within the same GRU as the recharge area, yet deep flow in the Peninsula will flow across GRU boundaries, contributing to the Breede-Gouritz. These links can be quantified by applying different recharge estimates for lithology's and disaggregating the quaternary baseflow estimates into resource units.

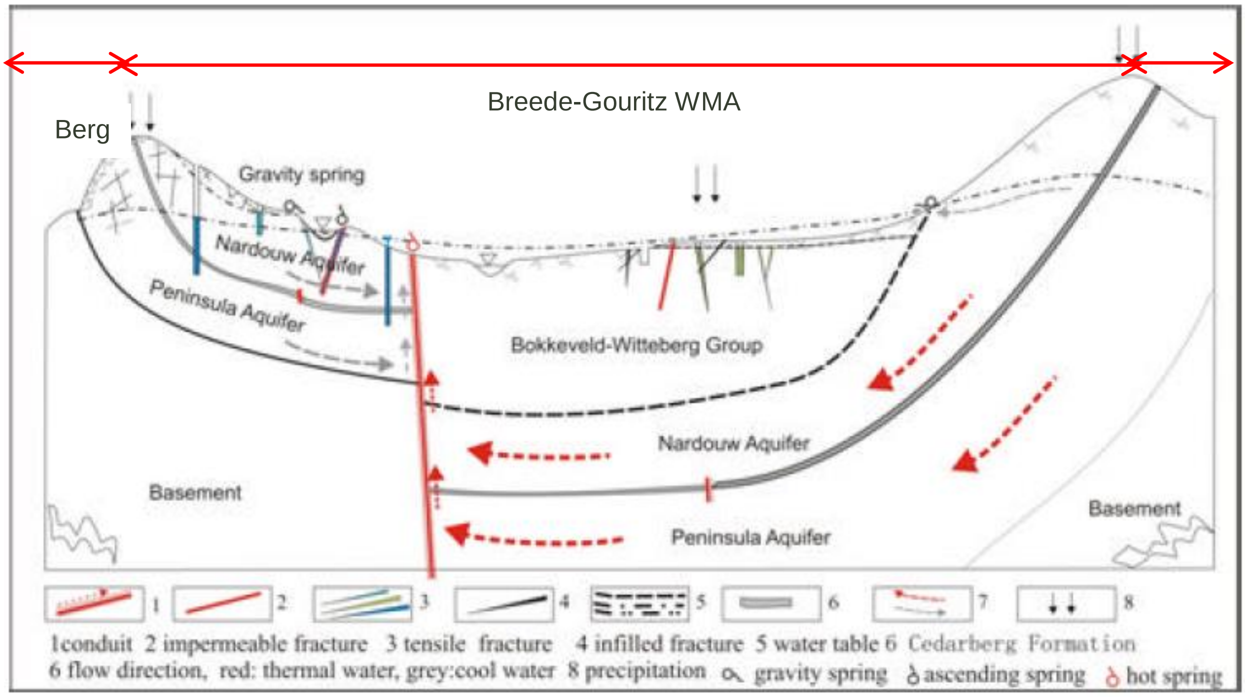

Figure 4.4. Cross-section of TMG flow (Adapted from Wu, 2005).

The delineation of resource units is largely a GIS based exercise with taking the following into consideration:

- Surface water divides on a quaternary and secondary level
- Geological structures (i.e. fault, hydrostratigraphy or lithological contact zones)
- River systems
- Recharge and discharge zones
- Groundwater use
- Groundwater management (size and extent of units)

The resource units were grouped primarily into the different sub-catchments with consideration of the groundwater system in that area. The delineated resource units generally combine a couple of quaternary catchments so that the integration of surface water and groundwater systems can be achieved. A summary for each of the ten groundwater resource units delineated in the Berg catchment is listed in Table 4.2.

The distribution of the resource units in relation to geology and surface catchments is shown in Figure 4.5.

Table 4.2. Description of delineated GRUs for the study area.

Sub-Region	GRU	Quaternary	Summary description
Greater Cape Town	1-Peninsula	G22A and G22B	The Cape Peninsula is dominated by the presence of the Table Mountain Group, mostly Peninsula Formation, overlying basement, composed of Cape Granite Suite along the length of the Peninsula, and Malmesbury Group under the City Bowl and Devils Peak. This unconformity/nonconformity dips gently to the south, from around 400m in the north, around the city, to below sea level south of Fish Hoek. The TMG outcrop generates the rugged areas, which are mostly delineated within the Table Mountain National Park. Recharge in the GRU is mainly from rainfall, but may also occur from cloud moisture, especially from the south-east wind in summer. Although recharge on the Peninsula is significantly higher than surroundings, and the Peninsula Formation can form a significant aquifer, its geological setting in this GRU (as an exposed inselberg) means that aquifer storage

Sub-Region	GRU	Quaternary	Summary description
			is low; recharge leads to discharge within a short time frame (a year), as the aquifer decants as streams cascading off the steep cliffs of TMG. Some of these are permanent seeps, other mountain streams and wetlands may be localized groundwater flow systems. Scree aprons occur on the slopes of the Peninsula-formed mountain, especially around Table Mountain itself, and are recharged by the streams cascading off the steep cliffs. Various springs emanating from the scree aquifers (ultimately dependent on the Peninsula Formation aquifer) cumulatively discharge over 100L/s to the City Bowl and Newlands areas combined (GEOSS, 2015). Cenozoic sands occur in the Fish Hoek Valley where high water tables support wetlands and streams around Fish Hoek and Noordhoek. The boundary between GRU1 and GRU2 is based on the surface water catchment divide, and will represent a flow divide for at least shallow groundwater in the Peninsula Formation. Deep groundwater flow is unlikely to be significant, although some drainage from GRU1 may moves onto the Cape Flats (GRU2) and recharge surface water and groundwater.
	2-Cape Flats	G22C, G22D and G22E	The Cape Flats is an area of subdued topography, where thick Sandveld Group deposits outcrop, overlying the basement (of Malmesbury Shale and Cape Granite Suite). The Sandveld Group forms a significant primary aquifer. Basement outcrops around the periphery of the GRU, and the thickness of the Sandveld Group increases towards the west of centre of the GRU. The thickness is greatest where the Sandveld group sediments infill palaeochannel(s) carved into the basement topography, one of which coincides with the Philippi Farms area (DWAF, 2008). Surface water and groundwater can be considered in hydraulic connection, with a high groundwater table (depth to water on average 3.4m, with a 1.9m average range, WRC, 2016b). Various wetlands across the Cape Flats are likely expressions of the water table. The effects of urbanization have significantly altered the Cape Flats aquifer: runoff is concentrated into modified natural drainage lines within which surface-groundwater interactions will be reduced from a natural state, and groundwater quality is affected from a variety of sources. Domestic water supplies are imported from elsewhere (GWRUs 9 & 11, and the Breede Gouritz), and groundwater may be recharged from leaks from reticulation and sewer networks, whilst hard surfaces will dramatically reduce recharge (WRC, 2016b). The boundaries of GRU2 are based on surface water divides, and shallow groundwater flow from the Cape Peninsula (GRU1) to the west and the Helderberg (GRU3) to the north-east and east is possible. The Cape Flats discharges to surface water (65% of recharge), to abstraction (17% of recharge), and by discharge to the coast (19% of recharge; WRC, 2016b).
	3-Helderberg	G22G; G22H; G22K and G22J	This area is underlain predominantly by Malmesbury Group and Cape Granite Suite plutons, the latter forming higher rocky hills, in contrast to the generally weathered lower rolling hills of the former. Rocks of the lower TMG suite, predominantly Peninsula Formation, outcrop to the west and form the Stellenbosch and Jonkershoek mountains in the east. The Peninsula Aquifer is unconfined in this GRU, and similarly to GRU1, although the Peninsula Formation can form a significant aquifer, its geological setting in this GRU means stored groundwater volumes are low, and recharge decants as mountain streams (the Lourens River originates in the Peninsula Formation mountains). In the basement formations, groundwater flow is mainly restricted to weathered zones or granite scree slopes on the pluton flanks and little regional flow can be expected.
Upper Berg	4-Paarl-Upper Berg	G10A; G10B; G10C and G10D	The GRU comprises sequences of basement rocks (Malmesbury Group, the Cape Granite Suite) dominating outcrop in the undulating northern areas, Table Mountain Group outcropping in the mountainous south east

Sub-Region	GRU	Quaternary	Summary description
			and on the eastern boundary, with younger Cenozoic sediments infilling valleys, more extensively in the southern part. Rainfall and direct recharge is high in the TMG formed mountains in the southeast of the GRU. The TMG is dominated by outcrop of Peninsula Formation, forming an unconfined aquifer (excluding an area of Nardouw Group outcrop surrounding the Wemmershoek valley, where the Peninsula Formation will form a confined aquifer at depth), overlying basement, with the contact sometimes visible in the base of the mountain slopes. The TMG generates discharges to mountain streams and rivers and several perennial rivers including the Berg River (and its tributaries including the dammed Wemmershoek) have their source in the Drakenstein and Franschhoek Mountains south of Franschhoek within the GRU. Alluvial sediments of the Sandveld Group are well developed around the Berg River in the Franschhoek valley as far as Paarl, and are likely to receive recharge from the TMG (interflow) where in connection, and discharge to the Berg River. In the basement formations, groundwater flow is focussed in weathered zones and little regional flow can be expected. Several tributaries to the Berg River traverse the basement outcrops, and groundwater will discharge to these. The south eastern boundary follows the quaternary catchment boundaries of the upper G10 catchment. The eastern boundary is limited to the Boland Mountain range (also the study area boundary) and is associated with the topographic high. The divide between the G10D and G10F catchments forms the northern boundary. Shallow groundwater flow will generally adhere to these boundaries, and some deep flow from this GRU towards the east into the Breede-Gouritz is likely.
	5-Tulbagh Valley	G10E and G10F	This area is predominantly underlain by Malmesbury Group with thin and discontinuous Cenozoic cover in only a few places, such as gravel terraces from the palaeo Breede River, in the Klein Berg catchment. In the east of the GRU, the Tulbagh Valley is bounded on east, west and north by slopes of the TMG (predominantly Peninsula Formation). The western wall of the Tulbagh valley (Waterval Mountains Nature Reserve) comprises a syncline of the TMG, exposing Nardouw Group in the centre. The valley is open to the south, continuing into the Breede River catchment, with a surface water catchment divide separating the north flowing Boontjies (tributary to Klein-Berg and in turn, Berg) from the south flowing . West of the Tulbagh valley, the GRU is dominated by Malmesbury Group outcrop. Groundwater in the basement aquifers is generally minimal, occurring only in the weathered zone and some deeper structures. Few natural wetlands would have occurred before agricultural development, other than in the streamlines. The boundaries of the GRU are related to surface water divides. Shallow groundwater flow will generally adhere to these boundaries, and some deep flow within the Peninsula Formation, from this GRU towards the east into the Breede-Gouritz, is likely.
	6-24 Rivers	G10G; G10H and G10J	The GRU is dominated by outcrop of Malmesbury Formation in the centre and southwest, and by TMG outcrop of the Groot Winterhoek Wilderness Area in the east of the GRU. The TMG in the Groot Winterhoek has been folded into a syncline, exposing the Peninsula Formation in the limbs forming steep mountain sides to the valley, and the Nardouw Group at the centre, with the Groot-Kliphuis River closely following the syncline axis. The folding continues to the west and an anticline structure exposes the base of the TMG (Piekenierskloof and Graafwater Formation) close to the eastern GRU boundary. The TMG aquifers are significant in the GRU, with high recharge and high discharge to surface water, as evidenced by the perennial Groot-Kliphuis River. Limited transfer of groundwater from the TMG to basement aquifers is expected, because of the generally poor permeability of the Malmesbury Group. Exceptions are scree cones and minor weathered zones that receive TMG water and in turn decant to surface water systems. Some

Sub-Region	GRU	Quaternary	Summary description
			degree of groundwater flow in the Malmesbury basement aquifers is also evidenced by their use (see below), and by the several tributaries to the Berg that traverse the Malmesbury basement aquifer in the GRU (and are not connected to TMG). The Berg River itself drains the centre of the GRU and can be assumed to receive baseflow from the Malmesbury basement aquifer. The north-eastern GRU boundary, specifically where it traverses east-west across the Nardouw outcrop, is a surface water divide, and can be assumed to also reflect a shallow groundwater divide (note: a divide, but not hydraulic boundary). This will not act as a deep groundwater flow divide for the Nardouw Group aquifers nor the Peninsula Formation aquifer, both of which will be in hydraulic connection across the boundary.
Lower Berg	7-Piketberg	G30A and G30D	This mountainous area is dominated in the south by the Table Mountain Group. Basement occurs at the base of the mountain on the eastern side - this forms a no-flow boundary for groundwater on the southeast of the Piketberg GRU, except for minor flow into screes and weathered zones of the Malmesbury Group. The Sandveld Group overlie flat areas and screes on the mountain slopes, and overlies the TMG and basement to the northwest of the GRU. The TMG is highly faulted here causing the Piekenierskloof and Peninsula Formations to be in contact in places. The general dip of strata is towards the west, and groundwater flow has been shown to largely flow to the northwest in the TMG (DWAF, 2008), but with much local variation due to topography, structure and rainfall gradients. The Aurora fault, part of a major fault system running NNW from Wellington, through the Swartland, forms the southern boundary of the Piketberg GRU. Although minor flow may occur in the fault system and into minor aquifer units in the abutting West Coast (GRU8), this boundary can be treated as a no-flow boundary. Groundwater will discharge from all aquifers to the various rivers and streams in the area, and eventually to the coastline.
	8-West Coast	G10K; G10M; G10L and G21A	The West Coast region is formed by basement (Malmesbury Group and various plutons of the Cape Granite Suite), overlain by the Sandveld Group which is laterally continuous over large areas, and also reaches significant thicknesses. Excluding the Berg River which traverses the GRU towards the ocean at St Helena Bay, surface water is limited in the region, related to low rainfall, subdued topography and the highly permeable sand-dominated geology. Several ephemeral streams emanate from the granite hills after heavy rain. Palaeo-courses of the Berg River, (Timmerman, 1985a, 1985b and 1985c, DWAF, 2008) have generated incisions in the basement topography, which are infilled by fluvial sediment (the Elandsfontyn Formation, within the Sandveld Group), and represent high yielding aquifers. The hydraulic properties, areal extent and thickness of the Sandveld Group aquifers, make them a significant resource for the region. Previous research (notably Timmerman, 1985a, 1985b and 1985c, and summarised in WRC, 2016a), has divided the area spatially into the following aquifer systems: Grootwater Aquifer around Yzerfontein in quaternary catchment G21A Elandsfontein Aquifer System comprising a lower and upper sand aquifer separated by clay unit, between Hopefield and Langebaan Lagoon, discharging to Langebaan Lagoon and to the Berg River. The Elandsfontein Aquifer System and Grootwater Aquifer are separated only by a groundwater flow divide around the G10M and G21A catchment divide, but are in hydraulic connection. The Langebaan Road Aquifer System between the Berg River and Saldanha Bay, north of the Elandsfontein Aquifer System, also comprising a lower and upper sand aquifer separated by clay unit. The Langebaan Road Aquifer System discharges to Saldanha Bay, St Helena Bay and the Berg River. The division between the Langebaan Road Aquifer System and Elandsfontein Aquifer System should simply be considered a spatial one, as the two are in hydraulic connection in both the shallow and deep aquifers (WRC, 2016a). The Adamboerskraal Aquifer System, north of the Berg River, also comprising a lower and upper sand aquifer separated by clay unit, and discharging to St Helena Bay and the Berg River. There is likely a hydraulic connection between

Sub-Region	GRU	Quaternary	Summary description
			the Adamboerskraal Aquifer System and the Langebaan Road Aquifer System, beneath the Berg River (WRC, 2016a).
	9-Atlantis	G21B	The GRU is an area of subdued topography, where thick Sandveld Group deposits outcrop, overlying the basement (of Malmesbury Shale and Cape Granite Suite). The Sandveld Group forms a significant primary aquifer. Basement outcrops in the higher lying areas east of the GRU, from where the Sout River originates. Some surface water drainage from the basement hills of the Malmesbury (GRU10) may increase recharge. Groundwater will discharge to the Sout River, minor wetlands in coastal dunes are sustained by groundwater, and to submarine discharge. Major groundwater abstraction occurs for Atlantis water supply and some artificial recharge of stormwater/treated wastewater occurs in constructed basins. Iron-rich biofouling on borehole screens reduced borehole efficiency. The boundaries of the GRU are formed by quaternary catchment boundaries. The various aquifer units are continuous across these boundaries hence they can be considered groundwater flow divides (but not hydraulic boundaries).
	10-Malmesbury	G21C; G21D and G21E	The GRU is underlain predominantly by Malmesbury Group intruded by Cape Granite Suite plutons, the latter forming higher rocky hills, in contrast to the generally weathered lower rolling hills of the former. Groundwater flow is mainly restricted to weathered zones or granite scree slopes on the pluton flanks and little regional flow can be expected. However, the relatively extensive use of the basement aquifers, and the existence of the Malmesbury Hot Spring, (about 4L/s of 34ºC water), indicates that deep fracture systems exist and are capable of reasonable yields. The Malmesbury Hot Spring has been associated with major regional fractures (the “Du Toitskloof-Moorreesburg Megafault Zone (DMM), an extension between the Du Toits Fault and the Malmesbury Fault”; DWAF, 2008), and its chemistry, with high sulphur content, confirms derivation of water from Malmesbury Group (UCT, 1995). Relatively thin and laterally discontinuous outcrops of the Sandveld Group scatter the GRU. Groundwater mostly discharges to streamflow along the various streams and perennial rivers (notably the Diep River) in this very agriculturally dominated area.

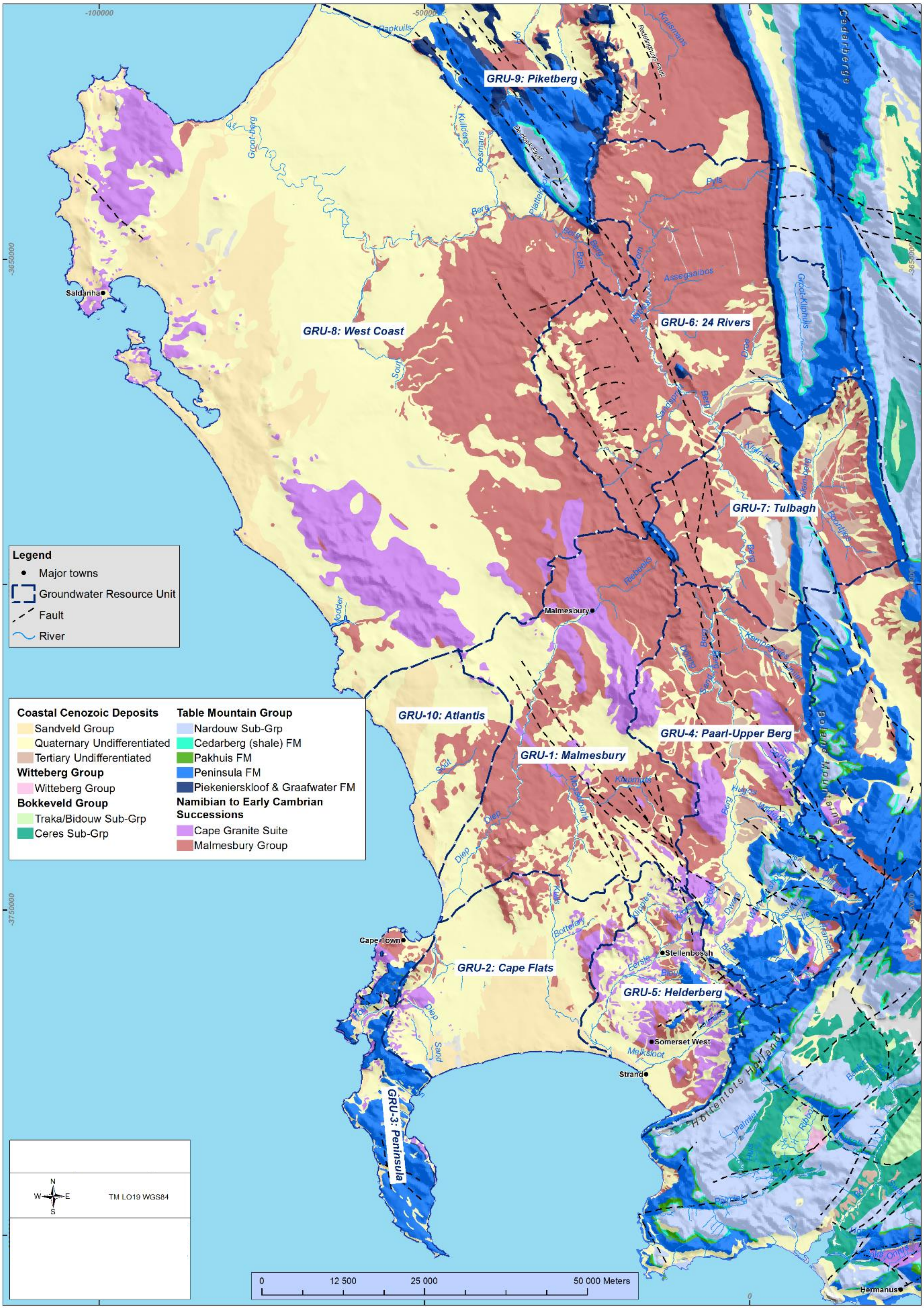

Figure 4.5. Delineated groundwater resource units

4.3 Preliminary Dams Resource Units

The Western Cape Water Supply System (WCWSS) comprises six large dams: the Upper and Lower Steenbras and Wemmershoek Dams owned by CCT; the Voëlvlei and Theewaterskloof dams owned by DWS; the Berg River Dam and Supplement Scheme that is owned by the Trans Caledon Tunnel Authority (TCTA) and operated by DWS. In addition, there are a number of smaller dams and weirs including the Kogelberg and Rockview Dams which serve Eskom's Palmiet Pumped Storage Scheme and the water transfer scheme, Kleinplaas Dam in the Jonkershoek River on the route of the Riviersonderend-Berg River Tunnel System and Misverstand Dam on the Berg River.

The main dams, including their respective contributions to the system yield, are summarised in Table 4.3.

Table 4.3. Major dams of the WCWSS.

<table>
<tr><th>Main Dam</th><th>IUA</th><th>Full Supply Capacity

(million m^3)</th><th>Incremental 1:50 Year Yield

(million m^3/a)</th><th>Owner</th><th>User</th></tr>
<tr><td>Kogelberg-Rockview</td><td>N/A</td><td>17</td><td>23</td><td>DWS</td><td>CCT; Eskom</td></tr>
<tr><td>Upper Steenbras</td><td>Lourens Eerste</td><td>32</td><td rowspan="2">40</td><td rowspan="2">CCT</td><td rowspan="2">CCT</td></tr>
<tr><td>Lower Steenbras</td><td>Lourens Eerste</td><td>34</td></tr>
<tr><td>Wemmershoek</td><td>Upper Berg</td><td>59</td><td>54</td><td>CCT</td><td>CCT; Drakenstein</td></tr>
<tr><td>Voëlvlei</td><td>Middle Berg</td><td>172</td><td>105</td><td>DWS</td><td>CCT; West Coast; Irrigators</td></tr>
<tr><td>Theewaterskloof

(includes Banhoek & Wolwekloof)</td><td>N/A</td><td>480</td><td>219</td><td>DWS</td><td>CCT; Stellenbosch; Overberg; Irrigators</td></tr>
<tr><td>Berg River Dam and Supplement Scheme</td><td>Upper Berg</td><td>127</td><td>80</td><td>TCTA</td><td>CCT; Others</td></tr>
</table>

There are a number of other smaller dams in the catchment and many small farm dams. These were not considered to be sufficiently large to be considered in terms of initial delineation of resource units.

Additional key dams may however be identified when considering RQOs for dams in the catchment.

4.4 Wetland Resource Units

4.4.1 General approach

The National Freshwater Ecosystems Priority Areas (NFEPA) wetlands map (Nel et al., 2011) was used as a starting point to identify wetlands in the study area. The NFEPA approach is based on the SANBI classification system for wetlands and other aquatic ecosystems in South Africa (SANBI, 2009 & 2013). This system uses hydrological and geomorphological traits to distinguish the direct factors that influence wetland function. This is presented as a 6-tiered structure with four spatially nested primary levels that are applied in a hierarchical manner between different wetland types on the basis of these direct factors. Level 1 distinguishes between marine, estuarine and inland ecosystems based on the degree of connectivity the systems have with the ocean. Level 2 categorises the regional wetland setting using a combination of biophysical attributes at the landscape level. Level 3 assesses the topographical position of inland wetlands and Level 4 concerns the hydrogeomorphic (HGM) units, defined by landform, hydrological characteristics hydrodynamics. The HGM unit is considered the focal point for the system as the upper levels are meant to classify the broad bio-geographical context for grouping functional wetland units at the HGM level, whilst the lower levels provide more descriptive detail.

For certain areas where the NFEPA maps lacked enough detail the maps developed by Cape Nature (2008) as part of the GEF-funded CAPE Fine-Scale Biodiversity Planning Project, the so-called FSP maps, were also used and the maps developed by the City of Cape Town (CCT) were also referred to. As the NFEPA, FSP and CCT maps indicate priority wetlands, these wetlands were identified as priority wetlands for the study area.

For the final delineation of the Wetland RUs the approach reported in DWAF (2010), which emphasised that geology was a key factor in the delineation of Wetland RUs was followed. For instance the Cape Folded Mountain EcoRegion is dominated by Table Mountain Sandstones with shale intrusions, which weather to form steep valleys and act as a limiting factor in the development of extensive wetlands. In contrast, the South Eastern Coastal Belt EcoRegion is characterised by a flatter topography, with characteristically flat drainage lines of low energy areas which favour the development of wetlands. The Wetland RUs were further delineated according to the similarity of wetland types and functions located within them. Whilst the Wetland RU defines the regional setting, the HGM unit is used as the defining characteristic for the Wetland RU.

Apart from rivers, the wetland types that occur in the study area are the following:

- Floodplain wetlands - occur on mostly flat areas adjacent to and formed by an alluvial river channel.
- Valley-bottom wetlands - occur mostly on flat areas located along the valley floor and can be either channelled or un-channelled.
- Depressions - defined as a wetland or aquatic ecosystem with closed (or near closed) elevation contours within which water accumulates and may be flat-bottomed (often described as pans), or extend over large areas termed “wetland flats” or “floodplain flats”.
- Seeps - a wetland area located on gentle to steeply sloping land, dominated by colluvial, uni-directional movement of water and material down-slope.

4.4.2 Wetland RU delineation

The locations of the Wetland RUs, mapped and named (i.e. priority) wetlands for the study area is indicated in Figure 4.6 for the study area. Descriptions of the individual Wetland RUs are presented in Table 4.4, including descriptive names for certain wetlands included from the Western Cape Wetlands Inventory.

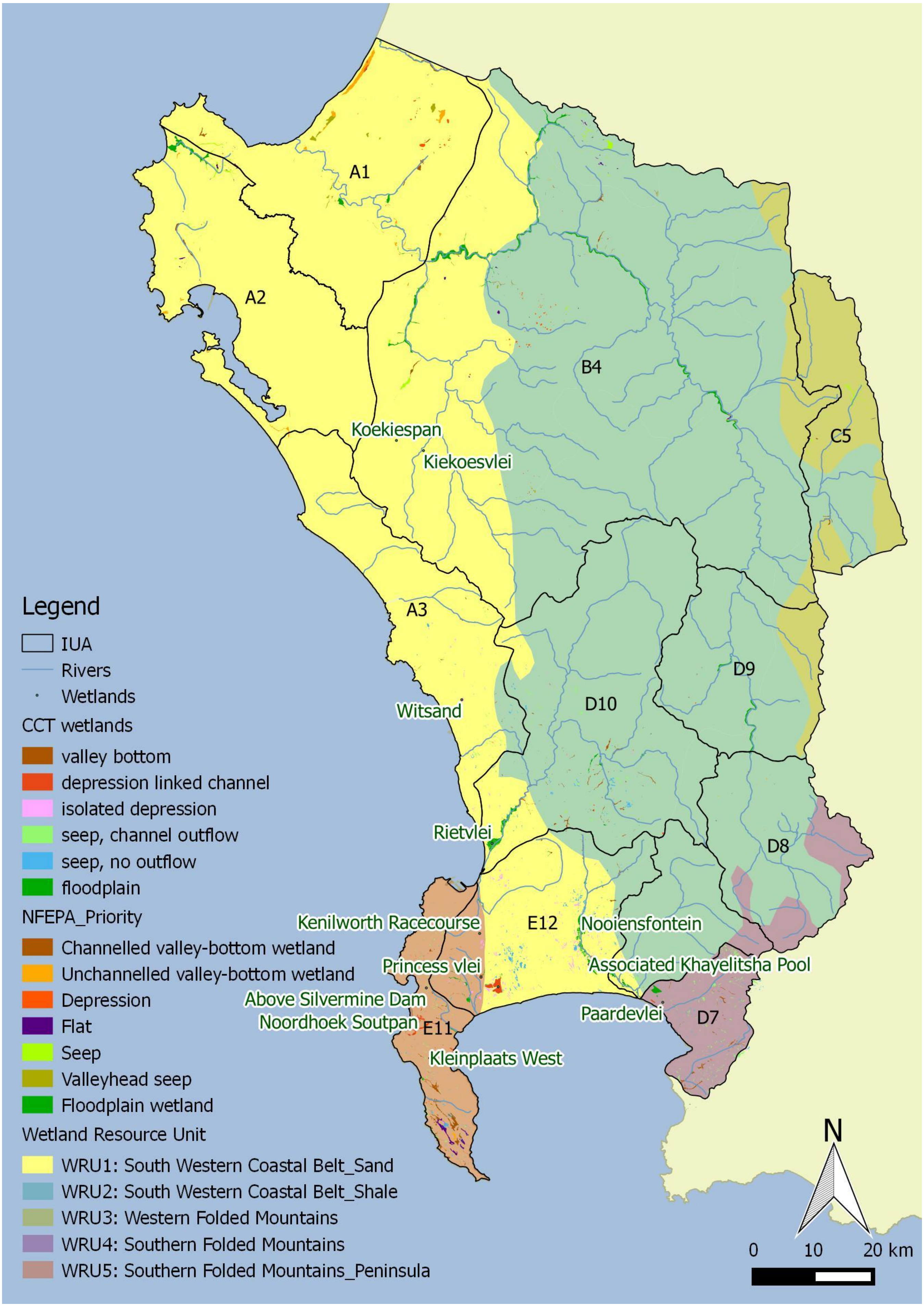

Figure 4.6. Wetland Resource Units delineated for the study area.

Table 4.4. Wetland Resource Units for the study area.

WRU name	Typical wetlands	HGM types	Wetland names
WRU1 South Western Coastal Belt_Sand			Witsand Yzerfontein Soutpan
			Zeekoevlei Wetlands associated with Khayelitsha Pool Nooiensfontein
			Koekiespan Kiekoesvlei
			Rietvlei
WRU2 South Western Coastal Belt_Shale			
WRU3 Western Folded Mountains	Small valley bottom and seep wetlands.	Seep Valley bottom	
WRU4 Southern Folded Mountains			
WRU5 Southern Folded Mountains_Peninsula	Range from mountain seeps, riverine systems and isolated depressions	Depression Seep Valley bottom	Kenilworth Racecourse Princess Vlei
			Kleinplaats West Noordhoek Soutpan Wetlands above Silvermine Dam

4.5 Estuary Resource Units

4.5.1 General approach

The Estuary Component of the National Biodiversity Assessment (NBA) definition for the estuarine functional zone (EFZ) was used. This extends the lateral boundaries of an estuary up to the 5 m contour, with the downstream boundary taken as the estuary mouth and the upstream boundary taken as the limits of tidal variation or salinity penetration, whichever penetrates furthest. Protection and rehabilitation of the estuarine functional zone are considered essential for protection of estuarine biodiversity and associated ecological processes.

There are 22 estuaries located in the Berg catchment area including Langebaan Lagoon, which receives freshwater inputs from groundwater. The location of the estuaries in the study area and their contributing catchments are indicated in Figure 4.7. Desktop level health assessments were completed for 17 of these systems in 2011 (excluding Langebaan), while a Comprehensive level EWR study was undertaken by Anchor Environmental for the Berg River Estuary as part of the feasibility studies for the augmentation of the WCWSS (DWA, 2012d).

Only eight of these estuaries are considered to be significant and used to define the estuary resource units (RUs) for the study area. Informal discussions with estuarine scientists as part of this Study has resulted in consensus regarding the fact that to qualify as a significant estuary, an outlet must meet the definition of an estuary in the National Water Act (1998) and the open water area of which, averaged over several years, exceeds 2 ha in extent and is dominated by estuarine (as opposed to freshwater) biota. The details of the identified significant estuaries identified in the study area are presented in Table 4.5.

Table 4.5. Summary details of the significant estuaries of the study area.

Estuary	Catchment size (km^2)	MAR (million $m^3.yr^{-1}$)	Estuary Functional Zone (ha)	Channel area (ha)	Type Whitfield (1992)
Berg (Groot)	7 765	562	9 197	644	Permanently open
Langebaan	502	Groundwater	6 260	4 113	Estuarine Bay
Rietvlei/Diep	1 522	37	834	229	Temporarily open
Wildevöelvlei	7	5.9	266	22	Temporarily open
Sand	87	30	307	119	Temporarily open
Zeekoe	60	17	366	327	Permanently open
Eerste	628	101	55	9	Temporarily open
Lourens	27	59	38	2	Temporarily open

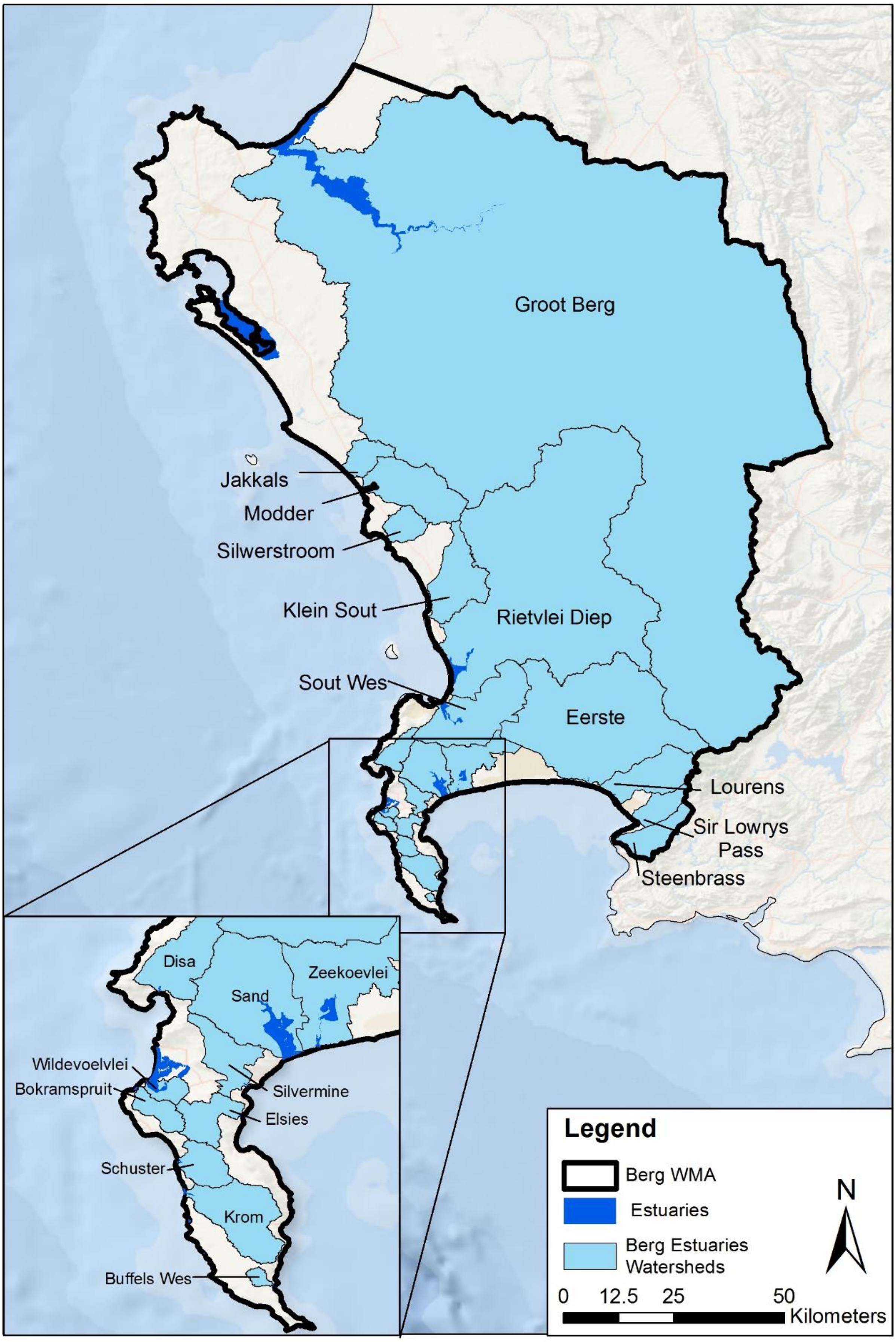

Figure 4.7. Identified significant estuaries and contributing catchment areas of the study area.

5 SUB-STEP 1d (ii): DEFINE BIOPHYSICAL & ALLOCATION NODES

5.1 General approach

For rivers the biophysical and allocation river nodes for the Study Area were defined according to the procedures described in DWAF (2007f). Eleven “tiers” of information were sequentially assessed, and rules applied, in order to establish nodes for each tier. Nodes were added sequentially for Tiers I to Tier VIII, where after rationalisation rules were applied to eliminate nodes for which EWRs were not required, e.g., impoundments (Tier VII).

Then additional nodes were added as required for Tiers V-IX, and rationalisation rules were applied again to eliminate nodes for which appropriate hydrological information was not available and/or nodes that were too close to each other (Tier IX). Thereafter, nodes were again added where additional information was likely to be needed at a particular sub-quaternary catchment level for planning or allocation purposes.

For estuaries the National Biodiversity Assessment approach was followed in which the estuarine functional zone (EFZ) was formulated as the lateral boundaries of an estuary up to the 5 m contour, with the downstream node taken as the estuary mouth and the upstream node taken as the limits of tidal variation or salinity penetration, whichever penetrates furthest.

5.2 Biophysical and Allocation Nodes

A total of 47 biophysical and infrastructure allocation nodes (including major dams, weirs and abstractions) where identified in the Berg study area. The location of the nodes are given in Figure 5.1. Additional information of the location, river and present ecological condition of the nodes are given in Table 5.1.

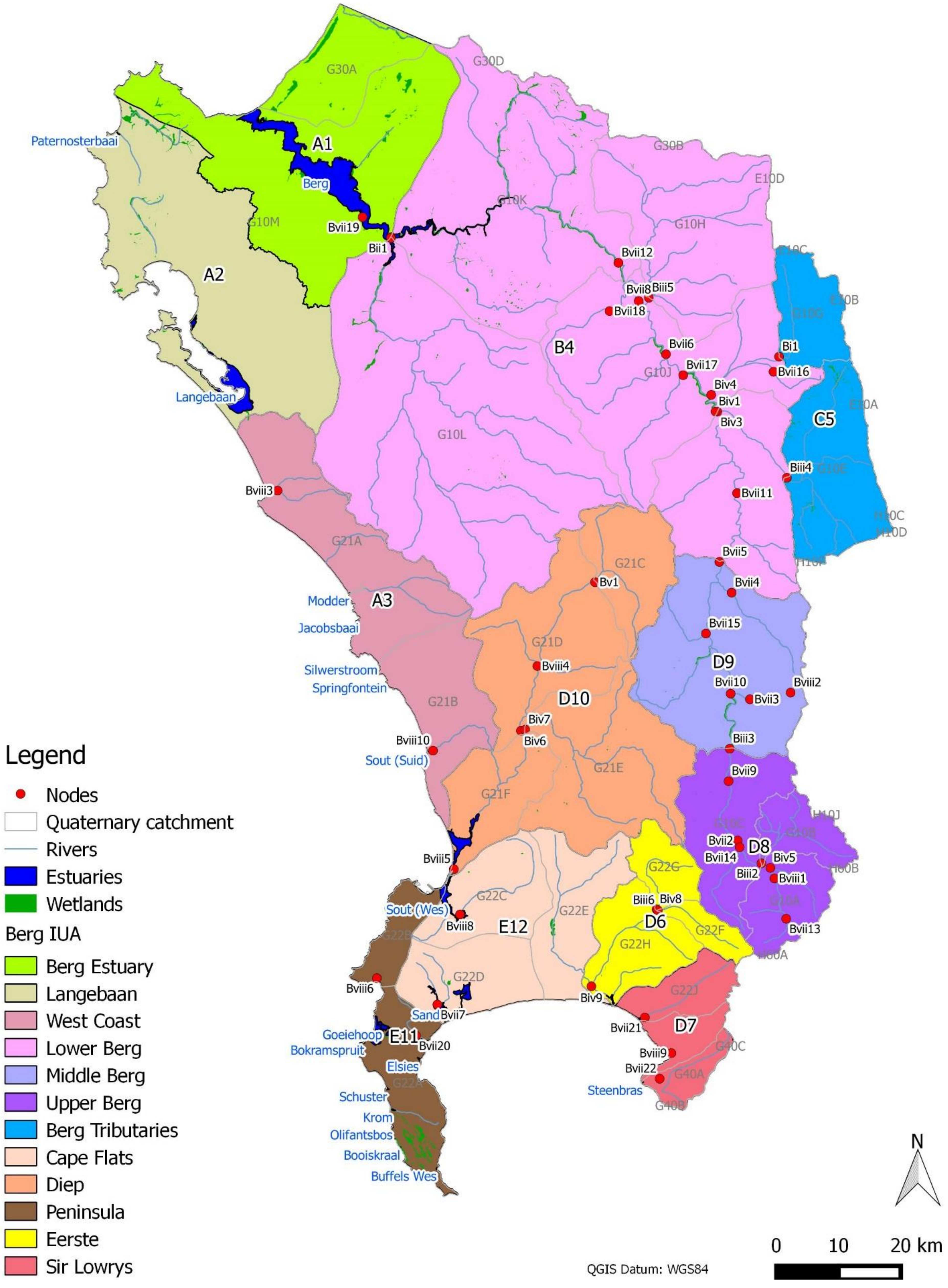

Figure 5.1. Biophysical and allocation nodes in the study area.

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Table 5.1. Locations of biophysical and allocation nodes for the study area.

IUA	SQ Code	NODE	COMMENT	RIVER	LONG	LATI	QUAT	ER	HI	GZ	EISC	EC1999	EC 2014	FEPA	Flow
W C	G21A-08690	Bviii3	Inflow to Yzerfontein salt pan		18.1821	-33.3303	G21A	SCB	2	UF	H	C	D		NP
W C	G21B-08896	Bviii10	Cumulative at outlet G22B	Sout	18.4544	-33.7104	G21B	SCB	2	LF	H	D	E		P
D	G21D-08761	Bv1		Diep	18.7383	-33.4643	G21D	SCB	1	LF	H	D	D	Phase2FEPA	P
D	G21D-08825	Bviii4	U/s of confluence with Diep	Swart	18.6372	-33.5869	G21D	SCB	1	LF	H	D	D	Upstream	P
D	G21D-08906	Biv6		Diep	18.6085	-33.6813	G21D	SCB	1	LF	H	D	D	FishFSA	P
D	G21E-08962	Biv7		Mosselbank	18.6159	-33.6799	G21E	SCB	1	LF	H	D	D	Phase2FEPA	P
D	G21F-09037	Bviii5	Cumulative at outflow G21F	Diep	18.4909	-33.8830	G21F	SCB	1	L	U	C	D	Phase2FEPA	P
C F	G22C-09142	Bviii8	U/s of confluence Black	Elsieskraal	18.5018	-33.9849	G22C	SCB	1	L	M	E	F		NP
C F	G22D-09294	Bvii7	At EWR site	Keysers	18.4621	-34.0798	G22D	CFM	1	LF	H	EF	D		P
Pen	G22B-09261	Bviii6	At EWR site	Hout Bay	18.3561	-34.0416	G22B	CFM	1	LF	H	C	D	FishFSA	P
Pen	G22A-09324	Bvii20	Town	Silvermine	18.4245	-34.1250	G22A	CFM	1	UF	U	C	C	FEPA	P
E	G22F-09205	Biii6		Jonkershoek	18.8483	-33.9249	G22F	SCB	1	UF	H	C	D	FEPA	P
E	G22G-09120	Biv8		Klippies	18.8461	-33.9415	G22G	SCB	1	LF	H	D	D		P
E	G22E-09207	Biv9	U/s confluence Eerste	Kuils	18.7319	-34.0533	G22H	SCB	1	LF	H	D	E		P
S L	G22J-09266	Bvii21	Town	Lourens	18.8257	-34.0987	G22J	SCB	1	UF	H	D	D	FishFSA	P
S L	G22K-09315	Bviii9	Cumulative at outlet G22K	Sir Lowry's Pass	18.8721	-34.1504	G22K	SCB	1	UF	H	D	E	FishFSA	P
S L	G40A-09346	Bvii22	Gauge	Steenbras	18.8516	-34.1876	G40A	CFM	1	MS	VH	C	C		P
U B	G10A-09199	Bvii13	Gauge	Berg	19.0732	-33.9552	G10A	CFM	1	UF	VH	D	A	FEPA	P
U B	G10A-09172	Bviii1	D/s of Berg River dam at EWR 1	Berg	19.0526	-33.89657	G10A	SCB	1	UF	H	D	C	FEPA	P
U B	G10A-09153	Biv5	U/s of confluence with Berg	Franschoek	19.0455	-33.88126	G10A	SCB	1	UF	H	D	D	FishFSA	P
U B	G10B-09136	Biii2	U/s of confluence with Berg	Wemmershoek	19.0303	-33.87662	G10B	SCB	1	UF	VH	D	D	FishFSA	P
U B	G10C-09145	Bvii14	Gauge	Dwars	18.9919	-33.8511	G10C	SCB	1	UF	VH	D	C	Phase2FEPA	P
U B	G10C-09028	Bvii2	Skuifraam pump station area	Berg	18.9882	-33.84149	G10C	SCB	1	LF	H	D	D		P
U B	G10C-09028	Bvii9	U/s of Paarl	Berg	18.9723	-33.75494	G10C	SCB	1	LF	H	D	D		P
U B	G10D-08957	Biii3	At gauging weir G1H020	Berg	18.9743	-33.70766	G10C	SCB	1	LF	H	D	E		P
M B	G10D-08928	Bviii2	At EWR 6 d/s of confluence with Pombers	Kromme	19.0811	-33.62577	G10D	CFM	1	UF	H	D	D	Phase2	P
M B	G10D-08928	Bvii3	North of Wellington, G1H037	Kromme	19.0097	-33.63549	G10D	SCB	1	UF	H	D	D	Phase2	P
M B	G10D-08893	Bvii10	D/s of confluence Kromme, at gauging weir G1H015	Berg	18.9766	-33.62711	G10D	SCB	1	LF	H	D	D		P
M B	G10D-08819	Bvii15	Gauge	Doring	18.9326	-33.5394	G10D	SCB	1	LF	VH	D	D		P
M B	G10D-08803	Bvii4	At gauging weir G1H041	Kompanjies	18.9781	-33.4792	G10D	SCB	1	LF	H	D	D		P
M B	G10F-08726	Bvii5	At gauging weir G1H036 and u/s of EWR 3	Berg	18.9569	-33.4350	G10D	SCB	1	L	H	D	D		P
L B	G10F-08669	Bvii11	U/s of Voelvlei canal	Berg	18.9871	-33.33408	G10F	SCB	1	L	H	D	D		P
L B	G10F-08505	Biv3	U/s of confluence with Berg	Klein-Berg	18.9562	-33.21508	G10J	SCB	1	LF	VH	D	D		P
L B	G10J-08520	Biv1	U/s of confluence Klein-Berg	Berg	18.9503	-33.21477	G10J	SCB	1	L	M	D	D		P
L B	G10J-08464	Bvii16	Gauge	Leeu	19.0511	-33.1561	G10J	SCB	1	UF	VH	D	A	Phase2FEPA	U

IUA	SQ Code	NODE	COMMENT	RIVER	LONG	LATI	QUAT	ER	HI	GZ	EISC	EC1999	EC 2014	FEPA	Flow
L B	G10J-08433	Biv4	U/s of confluence with Berg	Vier-en-twintig	18.9418	-33.1900	G10J	SCB	1	LF	H	D	D		P
L B	G10J-08487	Bvii17	Gauge	Sandspruit	18.8927	-33.1611	G10J	SCB	1	LF	M	D	C		P
L B	G10J-08414	Bvii6	D/s of EWR 4, at gauging weir G1H013	Berg	18.8619	-33.13282	G10J	SCB	1	L	H	D	D		P
L B	G10J-08366	Biii5	At gauging weir G1H035	Matjies	18.8326	-33.04735	G10J	SCB	1	LF	M	D	D		P
L B	G10J-08319	Bvii8	U/s Misverstand reservoir, d/s confluence with Matjies	Berg	18.8148	-33.05225	G10J	SCB	1	L	M	D	D		P
L B	G10J-08322	Bvii18	Gauge	Moreesburg Spruit	18.7637	-33.0670	G10J	SCB	1	LF	M	D	E		U
L B	G10K-08197	Bvii12	3.5 km d/s of Misverstand reservoir, at EWR 5	Berg	18.7792	-32.9960	G10K	SCB	1	L	H	C	D		P
L B	G10L-08287	Bii1	U/s of confluence with Berg	Sout	18.3805	-32.95847	G10L	SCB	2	L	M	D	D	Phase2FEPA	U
L B	G10K-08152	Biv2	U/s of confluence with Sout, head of estuary	Berg	18.3808	-32.95804	G10L	SCB	1	L	H	D	D		P
B T	G10F-08505	Biii4	At gauging weir G1H008	Klein Berg	19.0743	-33.31159	G10E	SCB	1	LF	VH	D	C		P
B T	G10G-08382	Bi1	At gauging weir G1H028	Vier-en-Twintig	19.0608	-33.1339	G10G	SCB	1	T	VH	B	A	FEPA	P
B E	G10M-08178	Bvii19	Gauge	Berg	18.3309	-32.9287	G10M	SCB	1	L	U	C	C	FishFSA	P

IUA = Integrated Units of Analysis: W C = West Coast, D = Diep, C F = Cape Flats, Pen = Peninsula, E = Eerste, S L = Sir Lowry's, U B = Upper Berg, M B = Middle Berg, B T = Berg Tributaries, L B =Lower Berg, B E = Berg Estuary. SQ = sub-quaternary, as used in DWS 2014 PES/EIS dataset. LONG = longitude, LATI = latitude, QUAT = quaternary. ER = Ecoregion: CFM = Cape Fold Mountains, SCB = Southern Coastal Belt. GZ = geozone: UF = upper foothill, T = transitional, LF = lower foothill, L = lowland. EISC = Ecological Importance and Sensitivity: VH = verh high, H = high, M = moderate. EC = Ecological Condition. FEPA = Freshwater Ecosystem Priority Area: FSA = Fish Support Area, Corrid = corridor. Flow: P = perennial, NP = non-perennial. U = unclassified

6 SUB-STEP 1h: DEFINE IUAs

6.1 General approach

Our delineation of the provisional IUAs followed the following approach:

- Tentative socio-economic areas were sketched based on land cover data, homogenous farm areas, vegetation types, topography, etc.
- These were then consolidated into relatively homogenous Socio-Economic Zones.
- The Socio-Economic Zones were overlaid on the River Resource Units that had earlier been delineated.
- Given that the River RUs tend to be oriented North-South whereas Socio-Economic Zones tend to run East-West, the overlaying process resulted in multiple individual overlaps, which provided the first "cut" at the provisional IUAs.
- These prototype IUAs were then rationalised in various ways, followed by aligning individual overlapping sub-zones better, to yield a second version of the provisional IUAs.
- The final step was to refine the selection of quaternaries for each provisional IUA – which yielded the current version of the provision IUAs. In a few cases, the quaternaries had to be cut.

6.2 Provisional delineation of IUAs

The composition of the individual provisional IUAs is outlined in Table 6.1 and shown in **Figure 6.1**.

Table 6.1. Composition of provisional IUAs delineated for the study area.

Socio-economic Zone	Zone Code	IUA Name	IUA Code	Quaternary Catchments
West Coast	A	Berg Estuary	A1	G30A, G10M
		West Coast	A3	G21A, G21B
Lower Berg	B	Lower Berg	B4	G10K, G10L. G10J, G10H, G10F
Tulbagh Fruit Area	C	Berg Tributaries	C5	G10G, G10E
Winelands	D	Eerste	D6	G22G, G22H, G22F
		Sir Lowry's	D7	G22J, G22K, G40A
		Upper Berg	D8	G10C, G10B, G10A
		Middle Berg	D9	G10D
		Diep	D10	G21C, G21D, G21E, G21F
Cape Town	E	Peninsula	E11	G22B, G22A
		Cape Flats	E12	G22C, G22D, G22E

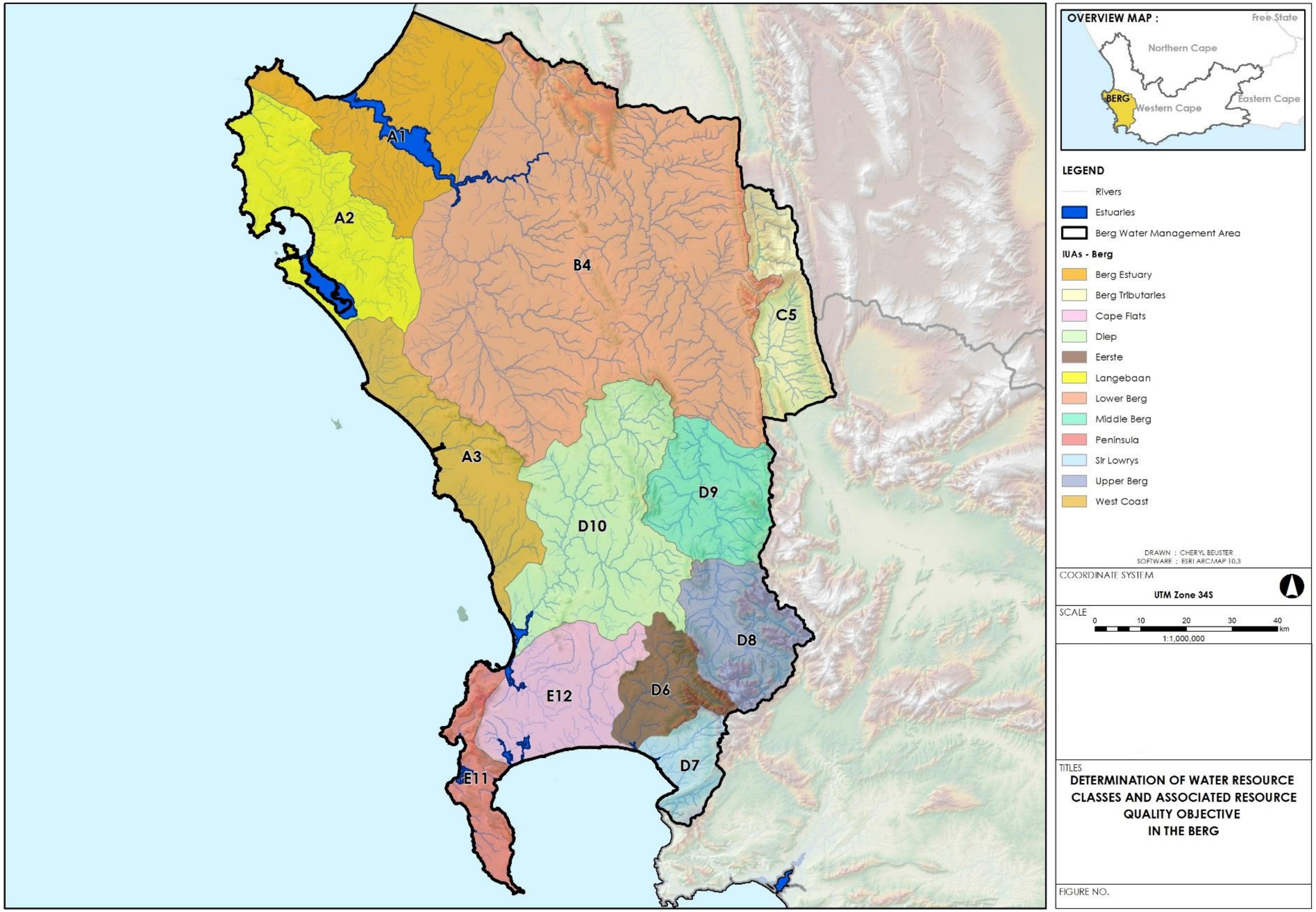

Figure 6.1. **Locations of Integrated Units of Analysis (IUAs) delineated for the study area.**

7 WAY FORWARD

This Report is the first of six Deliverables that constitute the outcomes of the Classification component of this Study. These Deliverables are as follows:

- *Resource Units and Integrated Units of Analysis Delineation Report*
- *Status Quo Report*
- *Report on Linking the Value and Condition of the Water Resource*
- *Report on Quantification of the EWR and Changes in EGSAs*
- *Ecological Base Configuration Scenarios Report*
- *Evaluation of Scenarios Report*

The Status Quo Report will more fully document the detailed evaluations that underlie the above delineation of Socio-Economic Zones, Resource Units, Nodes and provisional IUAs. It will also cover the additional work undertaken to complete Sub-step 1a (describe present-day socio-economic status), Sub-step 1e (describe wellbeing of communities), Sub-step 1f (value of water use), Sub-step 1g (value of ecosystem use), Sub-step 1i (socio-economic framework and decision-analysis framework) and Sub-step 1j (describe present-day community wellbeing in IUAs).

The work leading up to the Status Quo Report will also include re-visiting the provisional IUAs proposed in this Report with a view to adjusting their composition or delineation if deemed necessary on the basis of the Status Quo outcomes.

8 REFERENCES

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