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

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

STATUS QUO REPORT

DWS REPORT NO: RDM/WMA9/00/CON/CLA/0516

Department of Water and Sanitation
Chief Directorate: Water Ecosystems

Date: February 2017

Published by

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

This report is to be cited as:

Department of Water and Sanitation, South Africa. February 2017. *Determination of Water Resources Classes and Associated Resource Quality Objectives in the Berg Catchment: Status Quo Report*. Project Number WP10987. DWS Report No: RDM/WMA9/00/CON/CLA/0516

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:	*Status Quo Report*
Author:	*Dr James Cullis, Louise Lodenkemper, Dr Karl Reinecke, Dr Jane Turpie, Dr Barry Clark, Helen Seyler, Prof André Görgens, Erik van der Berg*
Project Name:	*Determination of Water Resources Classes and Associated Resource Quality Objectives in the Berg Catchment: WP 10987*
DWS Report No:	*RDM/WMA8/00/CON/CLA/0516*
Status of Report:	*Final*
First Issue:	*October 2016*
Final Issue:	*February 2017*

Professional Service Providers: Aurecon South Africa (Pty) Ltd, Southern Waters Ecological Consulting, Anchor Environmental and Delta-H Water Systems Modelling

Approved for the PSP by:

………………………………………………… ……………………………………………

Erik van der Berg *Date*

Technical Director

DEPARTMENT OF WATER AND SANITATION

Chief Directorate: Water Ecosystems

Approved for DWS by:

…………………………………………………

Ndileka Mohapi

Chief Director: Water Ecosystems

Document Index

Reports that will be produced as part of this project are indicated below.

Bold type indicates this report

Index	DWS Report No.	Report Title and Deliverables
1	RDM/WMA9/00/CON/CLA/0116	Inception Report
2	RDM/WMA9/00/CON/CLA/0216	Stakeholder Identification and Mapping
3	RDM/WMA9/00/CON/CLA/0316	Water Resources Information Gap Analysis and Models
4	RDM/WMA9/00/CON/CLA/0416	Resource Units and IUA Delineation
5	**RDM/WMA9/00/CON/CLA/0516**	**Status Quo Report**
6	RDM/WMA9/00/CON/CLA/0117	Linking the value and condition of the Water Resource
7	RDM/WMA9/00/CON/CLA/0217	Quantification of the EWR and changes in EGSA's
8	RDM/WMA9/00/CON/CLA/0317	Ecological Base Configuration Scenarios
9	RDM/WMA9/00/CON/CLA/0417	Report on evaluation of scenarios
10	RDM/WMA9/00/CON/CLA/0517	Resource Units Prioritisation
11	RDM/WMA9/00/CON/CLA/0118	Evaluation of Resource Units
12	RDM/WMA9/00/CON/CLA/0218	Outline of Resource Quality Objectives
13	RDM/WMA9/00/CON/CLA/0318	Monitoring programme to support RQOs Implementation
14	RDM/WMA9/00/CON/CLA/0418	Confidence Assessment for RQOs
15	RDM/WMA9/00/CON/CLA/0518	Water Resources Classes and RQOs Gazette Template
16	RDM/WMA9/00/CON/CLA/0618	Draft Project Close Out Report
17	RDM/WMA9/00/CON/CLA/0718	Final Project Close Out Report.

List of Abbreviations

AECs	Alternate Ecological Categories
CCT	City of Cape Town
CD: WE	Chief Directorate: Water Ecosystems
CMS	Catchment management strategy
DWA	(Previous) Department of Water Affairs
DWAF	(Previous) Department of Water Affairs
DWS	Department of Water and Sanitation
EC	Ecological Category
Ec	Electrical Conductivity
EGSA	Ecological goods, services and attributes
EI	Ecological Importance
EIS	Ecological importance and sensitivity
ES	Ecological Sensitivity
EWR	Ecological water requirements
FSP	Fine Scale Project
GDP	Gross Domestic Product
GRU	Groundwater Resource Unit
GVA	Gross Value Added
HGM	Hydrogeomorphic Unit
IB	Irrigation Board
ISP	Internal Strategic Perspective
IEI	Environmental importance index
IUA	Integrated Unit of Analysis
IWRM	Integrated Water Resource Management
IWRMP	Integrated Water Resources Management Plan
LM	Local Municipality
MAR	Mean annual runoff
MCA	Multi-criteria Assessment
MPA	Marine Protected Area
NBA	National Biodiversity Assessment
NFEPA	National Freshwater Ecosystem Priority Areas
NSBA	National Biodiversity Assessment
NPV	Net present value
NWA	National Water Act
PES	Present Ecological Sate
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RQO	Resource Quality Objective
RU	Resource Unit
RWQOs	Resource Water Quality Objectives
SAM	Social Accounting Matrix
SCI	Socio-Cultural Importance
SEZ	Socio-Economic Zones
TDS	Total dissolved salts
TFDS	Total Foreign Direct Spends
TMG	Table Mountain Group
WARMS	Water Allocation Registration Management System
WCWSS	Western Cape Water Supply System

WC/WDM	Water conservation and water demand management
WMA	Water Management Area
WRCS	Water Resource Classification System
WRC	Water Resource Class
WReMP	Water Resources Modelling Platform
WR2012	Water Resources of South Africa 2012
WRYM	Water Resources Yield Model
WRUI	Water Resource Use Importance index
WUA	Water User Association
WWTW	Wastewater Treatment Works

Executive Summary

INTRODUCTION

The Chief Directorate: Water Ecosystems of the Department of Water and Sanitation (DWS) has commissioned a study to determine Water Resource Classes (WRC) and associated Resource Quality Objectives (RQO) for all significant water resources in the Berg catchment.

The purpose of the Status Quo Report was to define the current status of the water resources in the study area in terms of the water resource systems, the ecological characteristics, the socio-economic conditions and the community well-being. Identification of the Integrated Units of Analysis (IUA) was provided in a separate report entitled: “Resource Unit Delineation and Integrated Units of Analysis Report”. The outcomes of this report and the “Resource Unit Delineation and Integrated Units of Analysis Report” overlap and therefore should be read in conjunction with each other.

WATER RESOURCES STATUS QUO

The ecological sub-step of the Water Resource Classification System (WRCS) involves describing the water resources of the study area and integrating these conditions with the socio-economic component in order to develop a decision support framework for the study area. The water resources were delineated and significant resources were defined as those that are significant from a user perspective.

Surface water status quo

The surface water resources of the study area were assessed according to rainfall, water allocations and requirements and dams. The more recent WR2012 Study’s WRSM2000/Pitman configurations were considered adequate to support various specialist tasks for the study area.

Groundwater status quo

The groundwater resources of the study area were assessed according to groundwater resource units (GRUs). This delineation considered surface water divides on a quaternary and secondary level, geological structures, river systems recharge and discharge zones, groundwater use and groundwater management. The GRUs were assessed in terms of recharge, discharge, groundwater use and groundwater quality.

Water quality status quo

The water quality targets used for the assessment of water quality in the study area were derived using the Resource Water Quality Objectives Model (Version 4.0) (DWS, 2006). The fitness for use is described using four water quality categories, namely Ideal (blue), Acceptable (green), Tolerable (yellow) and Unacceptable (red). The more blue and green colours visible in the classification tables, the better the water quality, and the more yellow and red, the poorer the water quality. The variables for assessment were Electrical conductivity, Total dissolved solids, Orthophosphate, Ammonia, Nitrate, Chloride, Sulphate, Sodium adsorption ratio and pH.

Estuaries ecological state status quo

A broad level overview of the current state of knowledge of the 8 significant estuaries within the study area was conducted. Estuaries were assessed according to estuarine biota, conservation importance and levels of protection, impacts on estuaries, present ecological status and recommended ecological status based on health and importance.

Wetlands ecological state status quo

Wetlands within the study area were defined according to wetland resource units. The typical wetland types and HGM types for each wetland RU were described. The priority wetlands within each wetland resource unit were also assessed. The major threats and impacts for each wetland resource unit was assessed and the ecological condition for priority wetlands were assessed.

Rivers ecological state status quo

The four main categories used to determine river type were flow, geomorphological zonation, riparian vegetation and adjacent terrestrial vegetation types. The 1999 and 2014 DWS present ecological state (PES) data sets were the main inputs to the status quo descriptions, although ecological condition with post-script dates 1999 or 2014 were used instead of PES.

BIOPHYSICAL NODES

A suite of biophysical and allocation nodes that will be used as modelling points for the Classification Process was provided. For river nodes the biophysical and allocation river nodes for the study area were assessed and for estuary nodes the National Biodiversity Assessment approach was followed.

SOCIO ECONOMICS AND ECOSYSTEM SERVICES STATUS QUO

The objective of the socio-economic component was to define the relationships that will link change in the configuration of the Water Resource Class (WRC) scenario to a resulting economic value and social wellbeing across the study area that will be used to inform the selection of the preferred WRC scenario.

STATUS QUO PER IUA

The IUAs for the study area were presented with socio-economics and ecosystem services, surface water and ecology status quo being described per IUA. The IUAs described were as follows:

- IUA A1: Berg Estuary
- IUA A2: Langebaan
- IUA A3: West Coast
- IUA B4: Lower Berg
- IUA C5: Berg Tributaries
- IUA D6: Eerste
- IUA D7: Sir Lowry’s
- IUA D8: Upper Berg
- IUA D9: Middle Berg
- IUA D10: Diep
- IUA E11: Peninsula
- IUA E12: Cape Flats

Contents

Appendix

Appendix A: Groundwater

Appendix B: Water Quality

Appendix C: Estuaries

Appendix D: Wetlands

Appendix E: Rivers

Appendix F: Socio-economics

Figures

Tables

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 as part of the Berg-Olifants Water Management Area (WMA).

The Berg River is the largest river catchment in the study area, which also includes a number of smaller catchments within the City of Cape Town Metropolitan area 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. In addition there are a number of groundwater aquifers in the study area.

The study area includes the whole of the City of Cape Town metropolitan area as well as parts of the Stellenbosch, Swartland, Bergriver and Saldanha Bay local municipality areas 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 Berg catchment area as part of the Berg and Olifants Water Management Area (WMA).
- Determine Resource Quality Objectives (RQOs) using the Department of Water and Sanitation’s (DWS's) Procedures to Determine and Implement RQOs for all significant water resources in the Berg catchment area as part of the Berg and Olifants Water Management Area (WMA).

The final outcome from the study will be the recommendations for the desired water resource class (WRC) and associated resource quality objectives (RQOs) presented to DWS for gazetting.

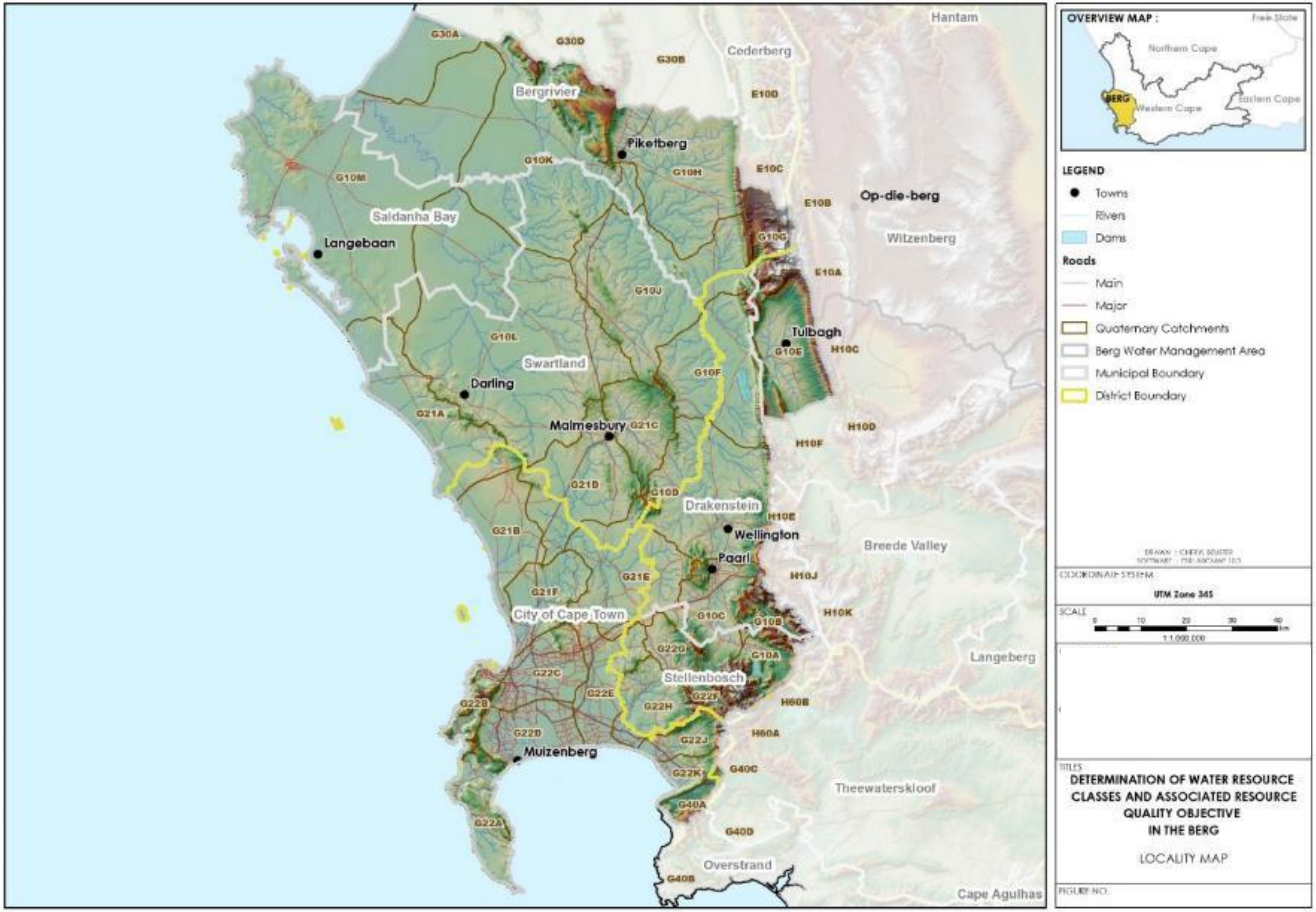


Figure 1.1. Map of the study area.

1.3 Purpose of this Status Quo Report

The first step of the classification procedure, shown in Figure 1.2, is the delineation of Integrated Units of Analysis (IUAs) and describe the status quo of the significant water resources within each IUA. 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 and the status quo assessment will provide background information to support the assessment of classification scenarios later in the study.

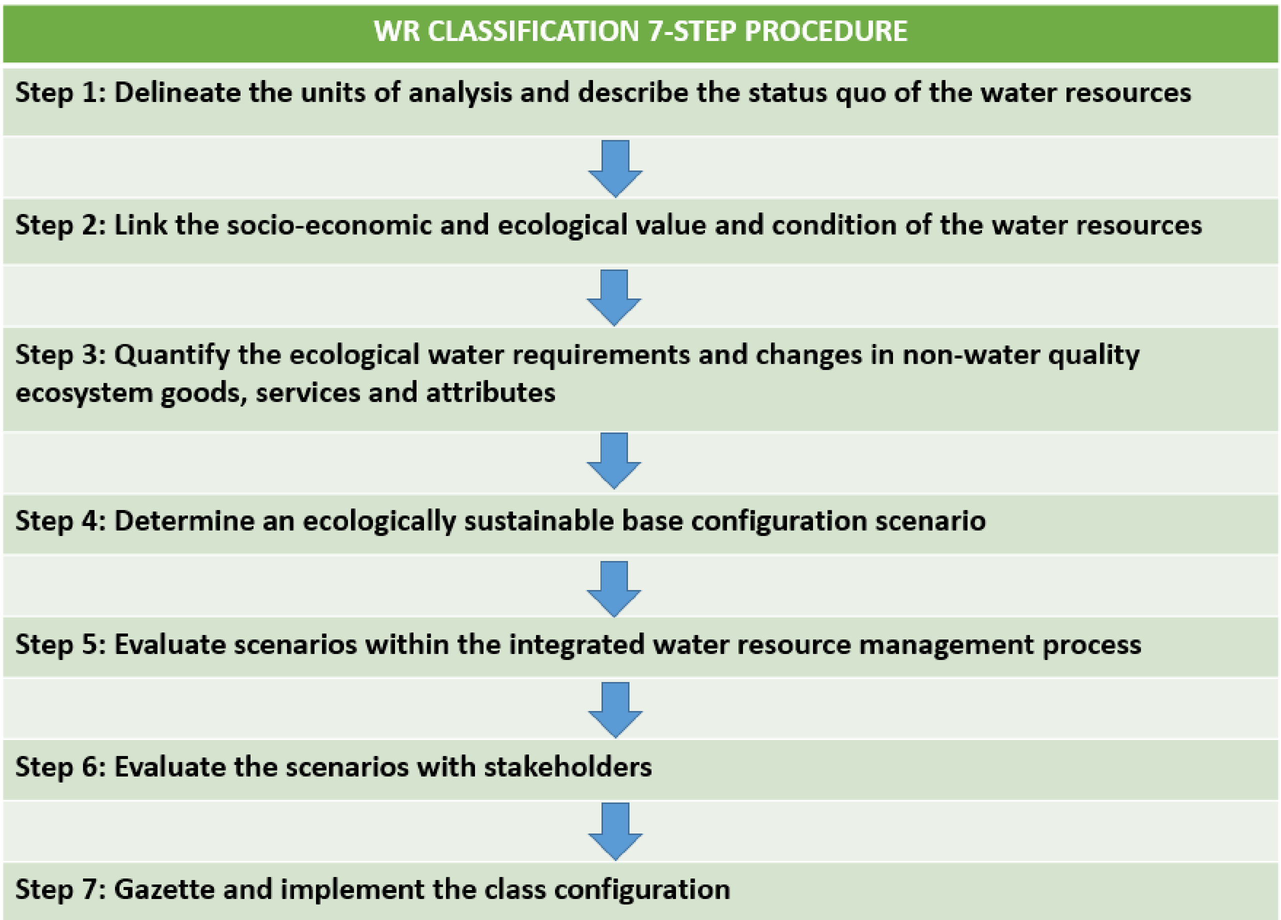


Figure 1.2. WR Classification 7-step procedure (DWAF 2007f).

The delineation of IUAs for the study area is described in the companion document to this Status Quo Report, namely the *Resource Unit Delineation and Integrated Units of Analysis Report* (DWS, 2016).

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. Whilst the *Resource Unit Delineation and Integrated Units of Analysis* Report outlines the IUAs, this Report describes the catchment status quo (Figure 1.3).

The purpose of this Report is therefore as follows:

- provide an overview of the status quo of the water resources in the study area (Chapter 2)
- review the provisional delineation of Resource Units and IUAs and related nodes (Chapter 3)
- provide an overview of the status quo of the socio-economics and ecosystem services (Chapter 4)
- describe the status quo of each individual IUA (Chapter 5)

This report, in combination with the IUA delineation report, presents the information relating to the individual sub-steps under Step 1 of the 7-step classification procedure (DWAF, 2007f) as shown in Figure 1.2.

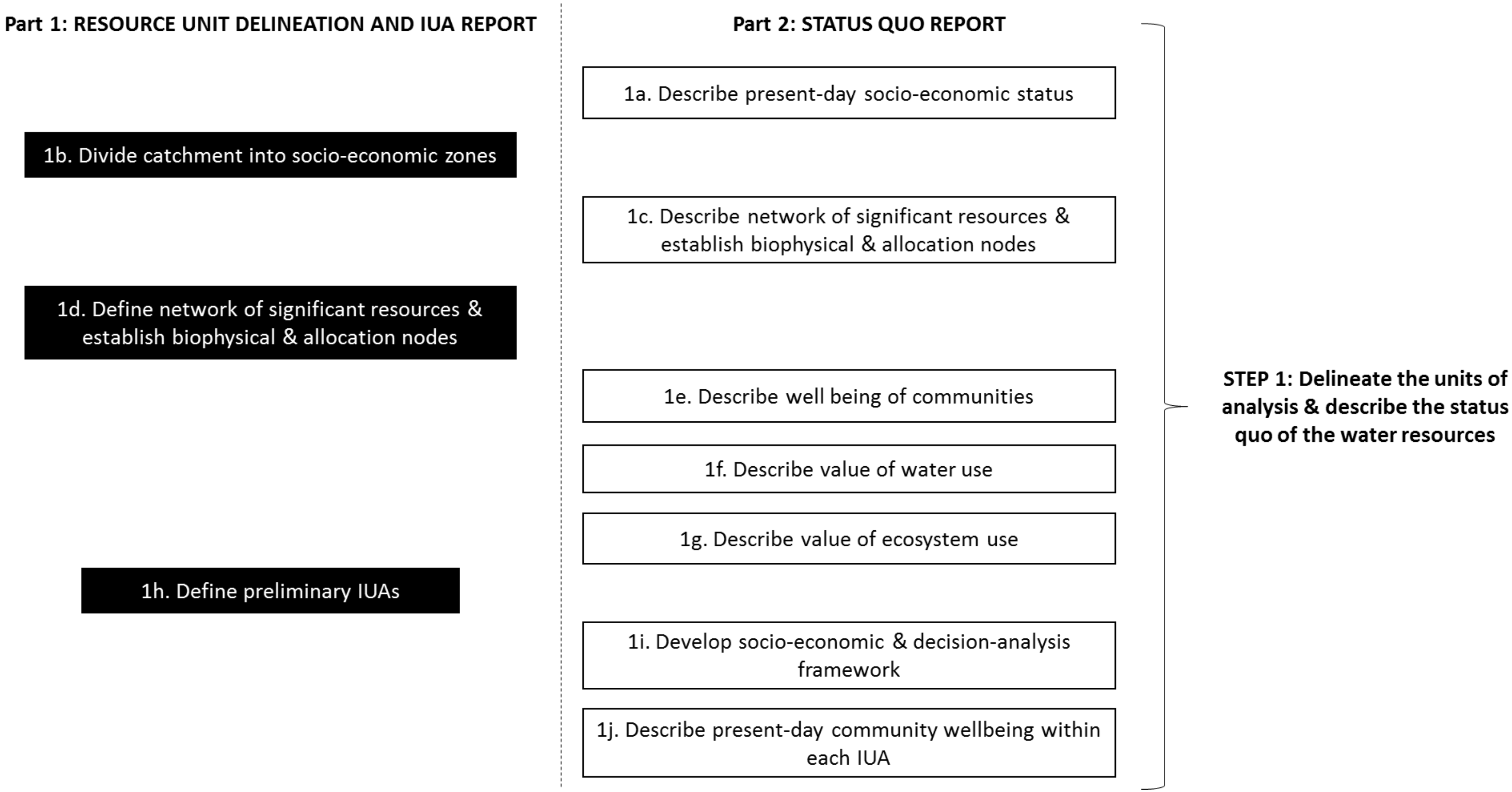


Figure 1.3. The inputs from the two reports which will inform Step 1 of the classification procedure.

2 STATUS QUO OF SIGNIFICANT WATER RESOURCES

The Status Quo of the significant water resources of the study area are described in the following sections.

2.1 Surface Water Infrastructure

2.1.1 Approach

The information presented in this section was derived from various sources, prime among which are the Final Reports on two completed DWS Projects, namely, Development of Integrated Annual and Real Time Operating Rules for the Western Cape Water Supply System (2014) and The Assessment of Water Availability in the Berg Catchment (WMA 19) by Means of Water Resource Related Models (WAAS) (2007), as well as DWS's 2000 Internal Strategic Perspectives (ISPs) Report for the former Berg WMA.

Water availability, water allocations and water use in the study area, as well as bulk surface water infrastructure such as dams, diversion schemes, inter-basin transfer schemes and pipelines are described in this section. The description of the surface water resources is dominated by the Western Cape Water Supply System (WCWSS) whose water supply areas cover about 90% of the study area's water use. The WCWSS is sourced from the entire Berg River catchment, but with significant contributions from impoundments within the Upper Riviersonderend, Palmiet and Steenbras Rivers and lesser contributions by the Eerste River and various dams on streams in the Cape Peninsula Mountains.

The WCWSS serves the City of Cape Town (CCT), urban water users and irrigators along the Berg, Eerste, Steenbras and Palmiet Rivers, domestic and industrial users on the West Coast, and irrigators and urban users in and beyond the Riviersonderend catchment of the Breede-Gouritz Water Management Area. It comprises bulk infrastructure components owned and operated by both the CCT and the DWS and is supported by lesser bulk infrastructure owned by various municipalities.

Additional to the above mentioned rivers that supply the WCWSS, various smaller rivers are present along the Cape Peninsula, False Basy, and West Coast coastlines of the study area, including the Diep/Mosselbank, Lourens, Sir Lowry's Pass, Eerste-Kuils, Liesbeeck-Elsieskraal-Black-Vygekraal, Lotus, Sand-Keysers-Westlake-Diep, Noordhoek and Disa Rivers.

The availability of existing configured rainfall-runoff catchment models, as well as water resources system models, for the various catchments that make up the study area was also examined. These various configured models can provide indispensable decision support for the alternative scenario analyses that guide the Classification/RQO determination processes under this Project. The spatial differences in availability of these various configured models across the study area are outlined in relevant sections below.

2.1.2 Description

2.1.2.1 Rainfall

The spatial distribution of mean annual precipitation (MAP) across the study area is depicted in Figure 2.1.

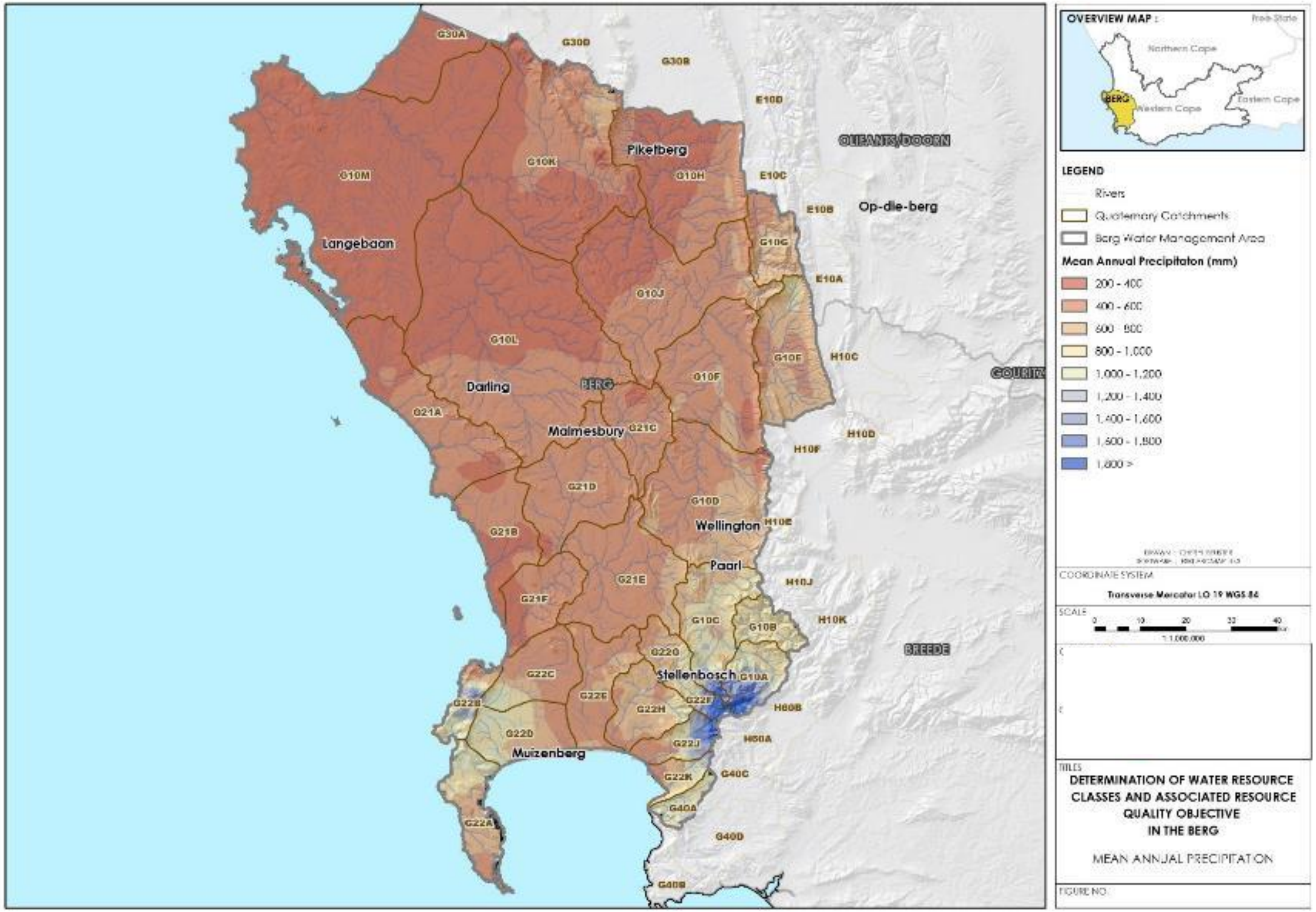


Figure 2.1. Study area mean annual precipitation (MAP) map (mm/a).

The mountainous south-eastern region of the area experiences markedly higher rainfall than the rest of the study area. At many locations in the mountainous areas the MAP exceeds 1000mm. In contrast, the west and north-western coastal plain experiences MAPs as low as 200 to 400 mm.

2.1.2.2 Water allocation and use

The water allocations for the study area according to the WARMS database are compared in Table 2-1 with the 2000 water requirements according to DWS's ISP Report for the then Berg WMA (i.e. this study area), as well as with the water requirements in the most recent configuration of the WCWSS system model consolidated with values reported in the WAAS Study for the smaller coastal rivers.

Table 2-1. Study area water allocations and requirements (million m^3/a).

Sector	WARMS Allocation (Mean Annual Volume)	ISP (2000) (Impact on Yield)	WCWSS Model and WAAS (Mean Annual Volume)
Domestic + Industrial	373	403	357
Irrigation	342	301	299
Afforestation	4	6	34#
Totals	**719**	**710**	**690**

 # Including about 15 million m^3/a surface and groundwater use by invasive alien plants

2.1.2.3 Dams and bulk water infrastructure

The 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.

Details of the main dams, including their contributions to the system yield, are summarised in Table 2-2.

Table 2-2. Major dams of the WCWSS.

Main Dam	IUA	Full Supply Capacity (million m^3)	Incremental 1:50 Year Yield (million m^3/a)	Owner	User
Kogelberg-Rockview	Sir Lowry's	17	23	DWS	CCT; Eskom
Upper Steenbras	Sir Lowry's	32	40	CCT	CCT
Lower Steenbras	Sir Lowry's	34			

Main Dam	IUA	Full Supply Capacity (million m^3)	Incremental 1:50 Year Yield (million m^3/a)	Owner	User
Wemmershoek	Upper Berg	59	54	CCT	CCT; Drakenstein
Voëlvlei	Middle Berg	172	105	DWS	CCT; West Coast; Irrigators
Theewaterskloof (includes Banhoek & Wolwekloof)	Riversonderend Theewaters#	480	219	DWS	CCT; Stellenbosch; Overberg; Irrigators
Berg River Dam and Supplement Scheme	Upper Berg	127	80	TCTA	CCT; Others

The Riversonderend Theewaters IUA occurs within the Breede-Gouritz WMA. Water is transferred from this IUA to the Berg catchment.

The bulk water transfer infrastructure of the WCWSS comprises the Riviersonderend-Berg River Tunnel System and various bulk pipelines from the dams supplying the CCT. This conveyance infrastructure, together with the CCT's bulk water reticulation system, which can distribute water from the various sources throughout most of the Metropolitan Area of the CCT, makes it possible to operate the WCWSS as one integrated system. Figure 2.2 depicts the main bulk water infrastructure of the WCWSS.

From an operational perspective, the WCWSS can be subdivided into three sub-systems and six schemes as summarised in Table 2-3.

Table 2-3. Sub-systems and schemes of the WCWSS.

Sub-system	Scheme
Riviersonderend-Upper Berg-Eerste River	Riviersonderend-Berg River Government Water Scheme
	Berg Water Project
	Wemmershoek Scheme
Lower Berg River	Voëlvlei Government Water Scheme
Palmiet-Steenbras	Palmiet Government Water Scheme
	Steenbras Scheme

The primary bulk infrastructure components of the WCWSS are schematised in Figure 2.2 and described in some detail in the following sections.

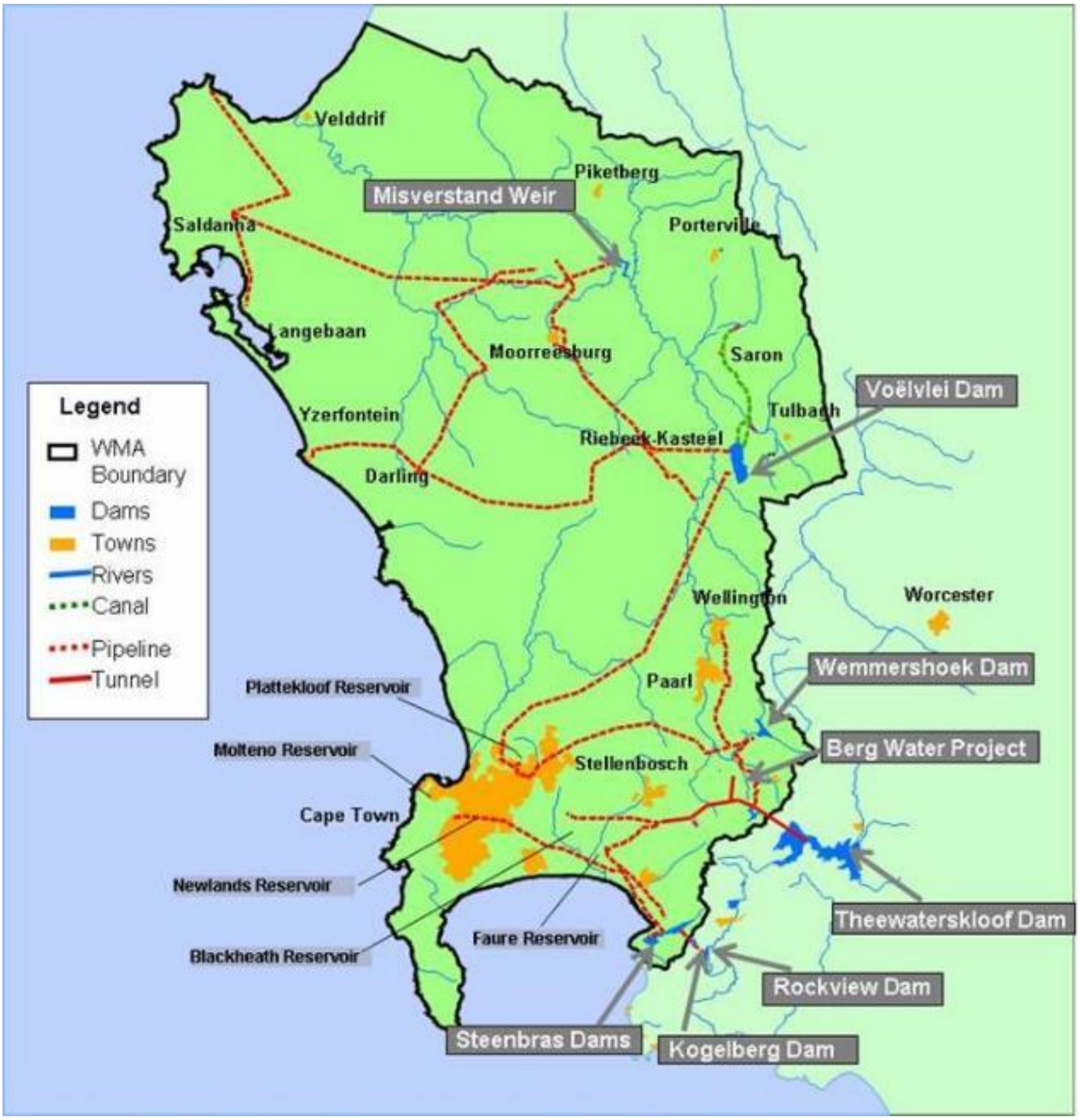


Figure 2.2. Bulk water infrastructure of the WCWSS (from DWS, 2014).

2.1.2.4 Riviersonderend-Upper Berg-Eerste River sub-system

The Riviersonderend-Upper Berg-Eerste River sub-system comprises the Riviersonderend-Berg River Government Water Scheme, the Berg Water Project and the Wemmershoek Scheme. The Riviersonderend-Berg River Government Water Scheme comprises Theewaterskloof Dam, the Riviersonderend-Berg River Tunnel System and Kleinplaas Dam.

- Theewaterskloof Dam is the largest storage dam in the WCWSS with a full supply capacity of 480 million m^3. The dam is filled by runoff from its own catchment, by the diversions during the winter months of the Wolwekloof and Banhoek Rivers, and by water pumped during the winter months from the Berg River Dam into the Riviersonderend Berg River Tunnel System. The demands on Theewaterskloof Dam include direct abstractions from the dam by riparian irrigators, releases into the

Riviersonderend River for downstream irrigators and Overberg Water; and releases to irrigators in the Berg and Eerste Rivers as well as for the CCT and Stellenbosch.

- Kleinplaas Dam is located on the Jonkershoek River and is primarily a balancing dam for the regulation of flow releases from Theewaterskloof Dam en route to Cape Town via the Franschhoek/Jonkershoek Tunnel component of Riviersonderend-Berg River Tunnel System. Kleinplaas Dam also enables the diversion of flow from the Jonkershoek River into the Stellenboschberg Tunnel and river releases are made for downstream irrigators.

- The Wolwekloof and Banhoek diversion structures divert water into the Franschhoek/Jonkershoek Tunnel component of the Riviersonderend-Berg River tunnel system. There is also a diversion structure on the Jonkershoek River upstream of Kleinplaas Dam which supplies water to Stellenbosch.

- The Berg River Dam near Franschhoek has a full supply capacity of 130 million m3 and impounds runoff from the Upper Berg River.

- The Drakenstein Pump Station of the Berg River Supplement Scheme delivers up to 6 m^3/s into the Dam, during winter months, from the Berg River at Bien Donne about 10 km downstream of the Dam and immediately downstream of the Dwars River confluence. During the summer months water for use by downstream irrigators is released from the Dam into the Berg River via the Supplement Scheme pipeline.

- The Dasbos Pump station delivers up to 4 m^3/s from the Dam to the Dasbos Portal of the Dasbos Tunnel of the Riviersonderend-Berg River Tunnel System.

- Wemmershoek Dam is located on the Wemmers River in the mountains near Franschhoek. It has a full supply capacity of 59 million m^3 and supplies water for urban use primarily.

- From the 270 Mℓ/day Wemmershoek Water Treatment Works below Wemmershoek Dam, a pipeline supplies treated water to bulk potable water service dams at Tygerberg with branch pipelines supplying Paarl and Wellington of Drakenstein Municipality.

2.1.2.5 Lower Berg River sub-system

The Lower Berg River sub-system comprises the Voëlvlei Government Water Scheme and Misverstand Dam. The Voëlvlei Government Water Scheme essentially comprises Voëlvlei Dam and canal diversions from the Klein Berg, Twenty-Four and Leeu Rivers, which convey water into Voëlvlei Dam.

- The off-channel Voëlvlei Dam has a full supply capacity of 172 million m^3. It provides water to the CCT and the West Coast District Municipality which distributes water to local authorities and other consumers in the area from Malmesbury to St Helena Bay.

- During winter, the weirs on the Twenty-Four Rivers and on the Leeu River divert up to 34 m^3/s into Voëlvlei Dam. Similarly, a weir on the Klein Berg River diverts up to 20 m^3/s of water into Voëlvlei Dam. Both diversions are via canals.

- The Twenty Four Rivers canal is also used for supplying irrigators along the canal during summer.

- Water is released from Voëlvlei Dam into a canal which discharges into the Berg River downstream of Sonqwasdrift to supply irrigators during the summer months and also to supply the West Coast District Municipality's Withoogte Water Treatment Works, which abstracts water at Misverstand Dam.

- Misverstand Dam has a capacity of 7 million m^3. The main purpose of Misverstand Dam is to divert water to the West Coast District Municipality's pump station which delivers water to the 72 Mℓ/day Withoogte Water Treatment Works and thence to the Vredenburg/Saldanha area. The dam also provides limited regulation of the summer releases from Voëlvlei Dam which are re-released at Misverstand to downstream irrigators.

- Water is conveyed from the CCT's high-lift pumpstation at the Voëlvlei Water Treatment Works, which has a capacity of 273 Mℓ/d, to the Plattekloof Dam on the outskirts of Cape Town.

- Water is also released from the outlet of Voëlvlei Dam to the 30 Mℓ/day Swartland Water Treatment Works of the West Coast District Municipality. From there the water is distributed to various towns.

2.1.2.6 Palmiet-Steenbras sub-system

The schemes which constitute the Palmiet-Steenbras sub-system include the Palmiet River Government Water Scheme and the Steenbras Scheme. The Palmiet River Government Water Scheme comprises the Kogelberg and Rockview Dams. These two dams serve respectively as the lower and upper dams of Eskom's 400 Megawatt dual purpose water transfer and hydro-electric Palmiet Pumped Storage Scheme. The scheme supplements the Steenbras Scheme by pumping water into Rockview Dam that is in excess of the ecological water requirements of the Palmiet River and of the weekly operating requirements of the Pumped Storage Scheme. This excess water that is pumped into Rockview Dam is released via a canal and conduit into the Upper Steenbras Dam.

- Kogelberg Dam has a full supply capacity of 17.3 million m^3.

- Rockview Dam is situated on the watershed between the Palmiet and Steenbras catchments and has a full supply capacity of 17.5 million m^3.

- Arieskraal Dam is not part of the Palmiet River Government Water Scheme but impacts on releases from Kogelberg Dam. It is situated on the Palmiet River some 3km downstream of Kogelberg Dam and has a capacity of 5.5 million m^3. The dam supplies surrounding irrigation users by means of direct abstraction, while it also has bottom outlets for supplying downstream users.

- Upper Steenbras Dam stores water from its own catchment as well as water transferred by the Palmiet Pumped Storage Scheme and has a capacity of 32 million m^3. Its primary purpose is to provide the upper dam for the CCT's 160 Megawatt Steenbras Pumped Storage Scheme, but it also provides storage for water that is subsequently released to the Lower Dam of the Steenbras Pumped Storage Scheme and conveyed to the City's Faure Water Treatment Works.

- Lower Steenbras Dam has a storage capacity of 34 million m^3. It supplies water to the 150 Mℓ/day Steenbras Water Treatment Works. From there, the three Steenbras Pipelines convey water by gravity to the higher lying zones of the City of Cape Town.

2.1.2.7 Minor schemes

The major schemes of the WCWSS are operated in an integrated manner, whereas the minor schemes supply individual municipalities, and/or limited areas of the City of Cape Town, and/or irrigators. Table 2-4 outlines details of those municipalities that are either entirely dependent on their own supplies or partially dependent on the main WCWSS Schemes described in the previous sections.

Table 2-4. Municipality-owned schemes in the WCWSS.

Town	Local Schemes		
	Raw Water Source	Areas Supplied	Scheme Capacity (million m^3/a)
Paarl	Nantes Dam; Bethel Dam; Berg River Pumpstation	Paarl	2.8
Wellington	Antoniesvlei (supplementing supply from Wemmershoek)	Wellington	0.5
Stellenbosch	Eerste River at Jonkershoek	Stellenbosch	5.5
Piketberg	Voëlvlei Dam and Local Sources	7 750 people	1.0
Saron	Twenty-four Rivers Canal	Saron	0.34
Porterville	Local Sources	4 350 people	0.6
Tulbagh	Local Sources	4 700 people	0.6
Franschhoek	Local Sources	4 500 people	0.6
Pniel	Local Sources	2 150 people	0.04

Table 2-5 outlines details of minor schemes which supply limited areas of the City of Cape Town.

Table 2-5. Minor Supply Schemes to CCT.

Scheme Name	Raw Water Source	Area Supplied	Scheme Capacity (million m^3/a)
Table Mountain and Southern Peninsula Water Supply Scheme	Hely-Hutchinson Dam; De Villiers Dam; Victoria Dam; Alexandra Dam; Woodhead Dam; Albion Spring, Brooklands Dam	Cape Metropolitan Area	5
	Kleinplaas Dam; Lewis Gay Dam	Simon's Town	1.8
Atlantis Water Supply Scheme	36 Boreholes (Atlantis Aquifer)	Atlantis; Mamre	6.0
Somerset West	Land-en-Zeezicht Dam; Boreholes	Somerset West	2.0
Strand	Lourens River	Strand	0.8

2.1.3 Status quo assessment

2.1.3.1 Models for surface water decision support

The rainfall-runoff catchment and water resources system analysis models that have been configured in previous studies for all or parts of the study area are outlined in Table 2-6.

Table 2-6. Surface water decision support models configured in previous studies.

Model	Year Configured	Catchments and River Systems	Project Owner
WRYM	2014	The entire WCWSS.	DWS
WRPM	2014	The entire WCWSS.	DWS
WRSM2000/Pitman	2013/2014	The entire study area.	WRC

The DWS updated earlier WCWSS configurations of the WRYM and WRPM system models as part of the recently-completed Study: *Development of Integrated Annual and Real Time Operating Rules for the Western Cape Water Supply System* (2014).

The WRC's 2005 national water resources survey was updated and extended by the WRC in a more recent project known as WR2012, with both natural and current-day monthly streamflows, up to the hydrological year 2009/2010 (WRC, 2015). During this process, the earlier WRSM2000 rainfall-runoff catchment model configurations countrywide were updated, while the model itself was improved and is now called WRSM2000/Pitman (after the model's original developer).

2.1.3.2 Surface water status quo

For this sub-section, extracts from DWS's 2014 updated WRYM configuration for the WCWSS were combined with relevant extracts from the WR2012 Study for some smaller coastal rivers to provide relatively recent information on the surface water situation across the study area. Table 2-7 presents an approximate water balance for the primary catchments in the study area.

Table 2-7. Approximate water balance for the study area (million m3/a).

Region	Natural MAR	Present-day MAR	Total Demand#	Groundwater Use
Berg & Cape Peninsula & Cape Flats & West Coast	898	655	552	33
Eerste & Sir Lowry's	126	87	63	4
Diep	70	42	75	28
Study area Total	**1094**	**784**	**690**	**65**
Total Imports from Riviersonderend, Palmiet and Steenbras catchments: 227 million m^3/a				
Total 1:50 Year Yield of the WCWSS: 559 million m^3/a				

#: Demands from both surface water and groundwater sources, including local sources outside the WCWSS.

2.1.3.3 Present-day water demands per IUA

A consolidation of both sectoral and total present-day demands from surface water and groundwater sources was performed, including demands from local sources outside the WCWSS.

Table 2-8 presents the estimated annual present-day water demands per IUA.

Table 2-8. IUA present-day water demands per primary sector (million m^3/a).

IUA	Urban / Industrial	Irrigation	Afforestation & Alien Plants	Total
Upper Berg	24	52	12	88
Middle Berg	9	73	3	85
Lower Berg	10	55	1	65
Berg Tributaries	0	15	5	20
Eerste	7	68	5	80
Sir Lowry's	18	19	7	44
Cape Flats	229	14	2	245
Peninsula	27	0	2	29
Diep	0	67	1	68
West Coast	6	0	1	7
Langebaan	18	0	1	19
Total Demand	**348**	**363**	**40#**	**750**

Including about 15 million m^3/a surface and groundwater use by invasive alien plants

2.2 Groundwater

The delineation of groundwater resource units depends on the hydrogeological characteristics of the area (amongst other factors), and it is practical to consider the status quo for groundwater resources in respect of groundwater resource units. As such, the hydrogeological characteristics of the area, the delineation of resource units and status quo of resource units are presented together in this report. Section 2.2.2 includes an overview of the geology and hydrostratigraphy of the study area, followed by the delineation of groundwater resource units (GRUs). The groundwater status quo assessment (section 2.2.3) includes a description of key groundwater characteristics (recharge, discharge, groundwater use and groundwater quality) across the groundwater resources units. A detailed status quo and trend analysis of groundwater level and groundwater quality per groundwater resource unit is included in Appendix A.

2.2.1 Approach

All available point data (borehole geology, abstraction, groundwater level, groundwater quality) was collated (Refer to Report on Water Resources Information Gap Analysis and Models), and interrogated for the trend analysis, and points with sufficient time-series including recent data is analysed to provide a current status quo. Sources of data used to populate the tables included in the trend analysis per GRU include:

- National Groundwater Archive,
- HYDSTRA database
- WMS datasets
- WARMS data
- Point data extracted from various reports assessing the response to bulk abstraction (i.e. municipal monitoring reports)
- Data from DWS project All Towns Reconciliation project (Phase 1 and Phase 2)
- Various reports (as referenced in the trend analysis per GRU)

The trend analysis (Appendix A) is presented in a standard table format per groundwater resources unit (GRU). Very few data points (boreholes) are available with water level, water quality, and geology log details enabling the data to be assigned to a particular aquifer. Surface geology has been assigned to all data points, but this is not a conclusive indicator of aquifer penetrated. Within each GRU groundwater quality and water level trends are rather described for water use clusters, with an indication of the surface geology of the data presented.

In addition to the data combined into the project database, and interrogated for trend analysis, groundwater monitoring is also undertaken by municipalities for variety of reasons; i.e. to monitor the response to bulk (point) abstraction (or by consultants on behalf of the municipality), or to monitor potential pollution sources such as waste sites. This data is rarely reported uploaded to DWS databases, only the monitoring reports are shared. As such, it is likely that some municipal wellfield and point pollution monitoring is not incorporated within the datasets collated, and hence in the trend analysis. The datasets collated rather contain long term DWS-owned monitoring boreholes, and any other boreholes for which there is long term data (a significant number of private boreholes). These boreholes are dispersed, and are capable of illustrating the background trends in particular locations or aquifers. Given the predominance of disperse agricultural abstraction (71% of registered groundwater abstraction is for agricultural irrigation, this data is likely to be sufficient for an indication of regional trends and typical water levels and water qualities in particular aquifers and locations. This will form a valuable basis for future phases of the project. The existence of additional data not yet incorporated in the trend analysis is mentioned in the status quo assessment where this is known. Additional monitoring data (i.e. illustrating the response to bulk point abstraction at municipal wellfields) will be sought where necessary for prioritised GRUs.

This status quo analysis does not include an assessment of groundwater availability, which will be incorporated in future stages of the project.

2.2.1.1 Study boundary

The delineation of groundwater units relate specifically to hydrogeological criteria and might not necessarily correlate to quaternary surface water catchments or surface water IUAs, nor therefore to the overall study boundary which is a surface water derived management boundary (former Berg WMA). The groundwater resource units delineated do differ from the study boundary in the north of the Berg. The entire GRU has been delineated, but just the part of the GRU that falls within the study area is considered in the analysis.

2.2.1.2 Theoretical background for groundwater level trend analysis

Under natural conditions an aquifer is in a state of dynamic equilibrium: wet and dry years balance out, aquifer discharge equals the recharge, and the groundwater levels (equivalent to the stored volume) are constant over the long-term. When an aquifer is pumped this equilibrium is disturbed, and "water withdrawn artificially from an aquifer is derived from a decrease in storage in the aquifer, a reduction in the previous discharge from the aquifer, an increase in the recharge, or a combination of these changes" (Theis, 1940). On pumping, water levels will therefore decline, natural discharge may decline, and recharge may increase. Over time (and with the same rate of pumping), a new dynamic equilibrium will form in response to the changes fluxes (i.e. new discharge mechanisms to abstraction, reduced discharge and or enhanced recharge). Once the new dynamic equilibrium is formed, there is no further loss from storage i.e. groundwater levels no longer decline in response to abstraction.

The time taken to reach this new dynamic equilibrium (the "response time") can vary from relatively short to hundreds of years, depending on the aquifer parameters and location of abstraction compared to aquifer boundaries (Sophocleous 2000; Bredehoeft and Durbin, 2009). The magnitude of storage depletion (water level change before new equilibrium is met), is also dependent on the aquifer parameters and location of abstraction.

If the abstraction can be met by changes in the aquifer fluxes (reduced discharge, enhanced recharge) and a new equilibrium can be established (halting water level decline), then the abstraction can be considered maintainable (note, not sustainable) (Delvin and Sophocleous, 2005; WRC, 2016). If "sustainable groundwater use" is defined as groundwater use that is socially, environmentally (ecologically), and economically acceptable, then abstraction of a maintainable yield is not necessarily sustainable. A critical step from quantification of a maintainable aquifer yield to quantification of sustainable groundwater use, is to determine the volume contribution from each source under the new dynamic equilibrium (projected reduced discharge, enhanced recharge, impact on storage / groundwater levels), and then take a socio-economic-environmental decision as to whether this is acceptable (Sophocleous, 2000, Alley and Leake, 2004, WRC, 2016). Projection of the impact of pumping on storage / water levels can be completed (for simple situations) with analytical models that derive a characteristic water level decline over time when pumped ("pump curves", Kruseman and de Ridder, 1991). Determination of the impact on natural discharge or enhanced recharge generally requires a numerical model to be setup for the aquifer in question to simulate the abstraction and impacts on flow regime.

Not all abstraction can be maintained. Abstraction from groundwater without an active flow regime (fossil groundwater) simply harvests stored groundwater and groundwater levels continue to fall. "Runaway" drawdown, in which the rate of decline of groundwater level increases over time, is an indication that the abstraction rate cannot be met by changes in the aquifer fluxes (it is not maintainable).

The above-mentioned theory is relevant to the status quo trend analysis. Water level decline is to be expected in response to pumping. Groundwater level decline (alone) is not an indication of abstraction rates being too high or not maintainable, and certainly not an indication of un-sustainability (using the definition of sustainable groundwater use mentioned above). Water level decline is simply a reflection of the aquifer transitioning to a new dynamic equilibrium after commencement of pumping. Water level analysis using numerical / analytical equations to determine whether abstraction yields are maintainable, and to determine the maximum drawdown that is to be expected under the abstraction conditions, is not possible within this regional study. Barring this level of detail, some comments on monitored water level decline and what it might represent are nevertheless possible through comparing the shape of the water level decline by eye to characteristic pump curves, and through consideration of rainfall changes.

2.2.2 Description

2.2.2.1 Geology

The geology of the Berg catchment exerts a dominating control on the topography, provides an orographic control over precipitation hence influencing direct recharge, influences the drainage, and even influences the agricultural crops and land-use potential, through and the widely variable geochemical composition of the different formations (DWAF, 2008).

The oldest rocks in the area are the meta-sediments of the Malmesbury Group which, excluding the Cape Peninsula, underlie almost the entire Berg catchment, in places buried beneath Cenozoic cover. Granite plutons of the Cape Granite Suite have intruded into the Malmesbury Group and outcrops are evident throughout the study area (Figure 2.3), forming rocky hills such as the Vredenberg and Darling batholith. Dolerite dykes of the ~136 Ma-old False Bay Suite also intrude the basement rocks in the Cape Flats region.

The basement is unconformably overlain by the Cape Supergroup, of which only the lower Table Mountain Group (TMG) outcrops in the catchment, with the stratigraphically higher Bokkeveld Group and Witteberg Group outcropping further east in the Breede catchment. The TMG outcrops in the east of the catchment in the Upper Berg, its resistant arenaceous formations (the Peninsula and Skurweberg Formations) responsible for the mountainous ridges that give rise to the Berg catchment boundary. The TMG also outcrops as an inselberg in the Peninsula, primarily composed of the Peninsula Formation of the TMG.

Tertiary and Quaternary (Cenozoic) deposits unconformably overlie the older (primarily basement) geology in various areas of the catchment, consisting mostly of unconsolidated to semi-consolidated shelly, calcareous sands of the Sandveld Group. The thickness of the Sandveld Group sediments varies greatly, related to the basement topography. They reach significant thicknesses closer to the coast, at the Cape Flats, Atlantis, and West Coast Aquifers. There are also deposits of alluvium consisting of clay, sand, pebbles and boulders occurring in the valleys of major Rivers and their tributaries, i.e. in the Berg River (DEA&DP, 2011). The geological succession of the region, with the associated thickness and lithological compositions, is summarised in Figure 2.4.

2.2.2.2 Structural geology

The Cape Fold Belt is the dominant structural feature in the greater Southern and Western Cape area. Rocks of the Cape and Karoo Supergroups were deformed by what is termed the Cape Orogeny which is the dominant cause of the outcrop pattern of the geology, characterized by mega-anticlinal mountain ranges separated by synclinal intermontane valleys. It is postulated that the horizontal bedding of Table Mountain (and the Peninsula) and the steeply dipping TMG in the Hottentots Holland Mountains is the result of a major syncline and anticline structure (with its trough at Table Mountain, and the Hottentots Holland Mountains forming the east limb).Major erosion of this ancient landscape has exposed the basement geology in much of the Berg catchment (Compton, 2004).

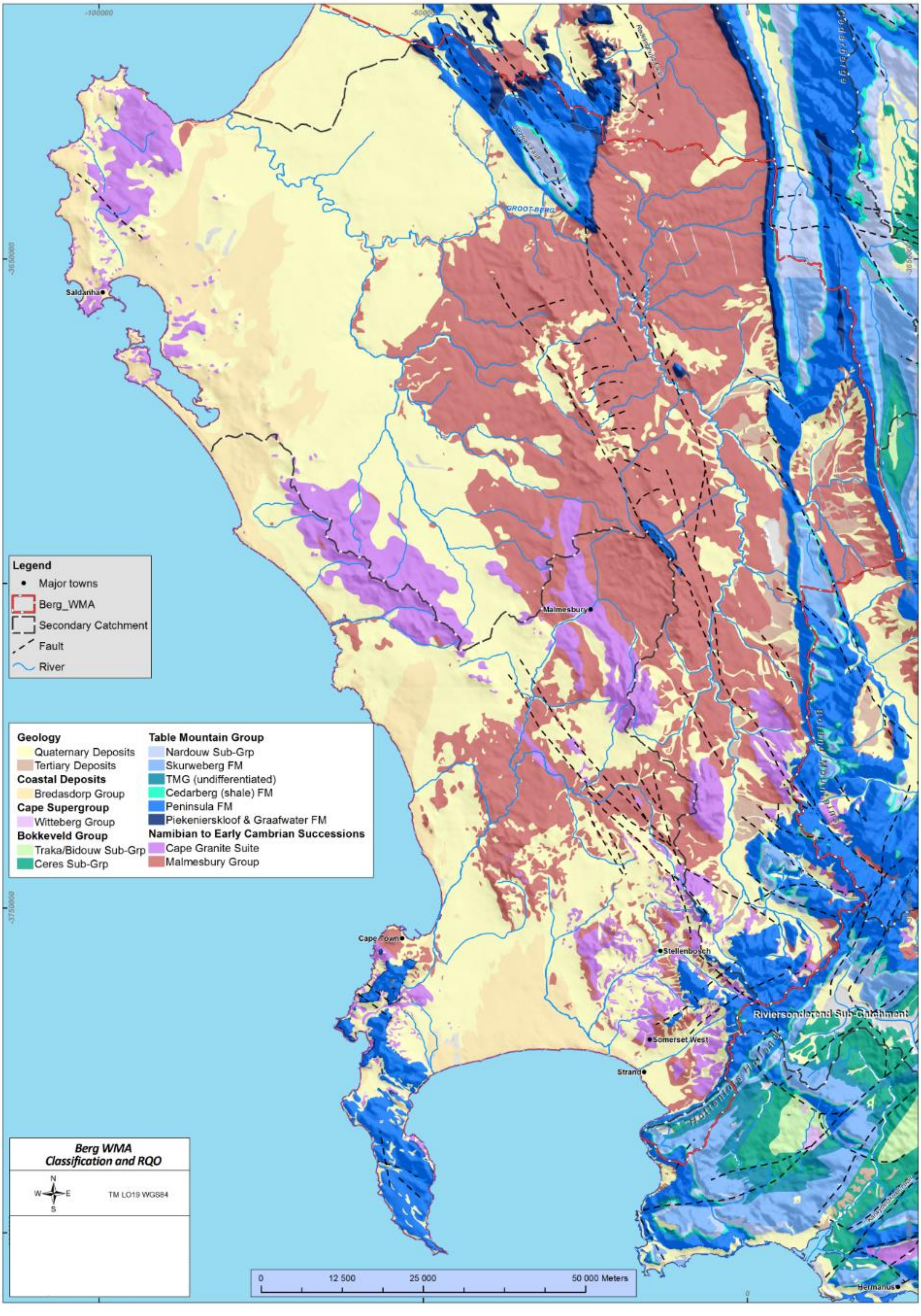


Figure 2.3. Regional Geology.

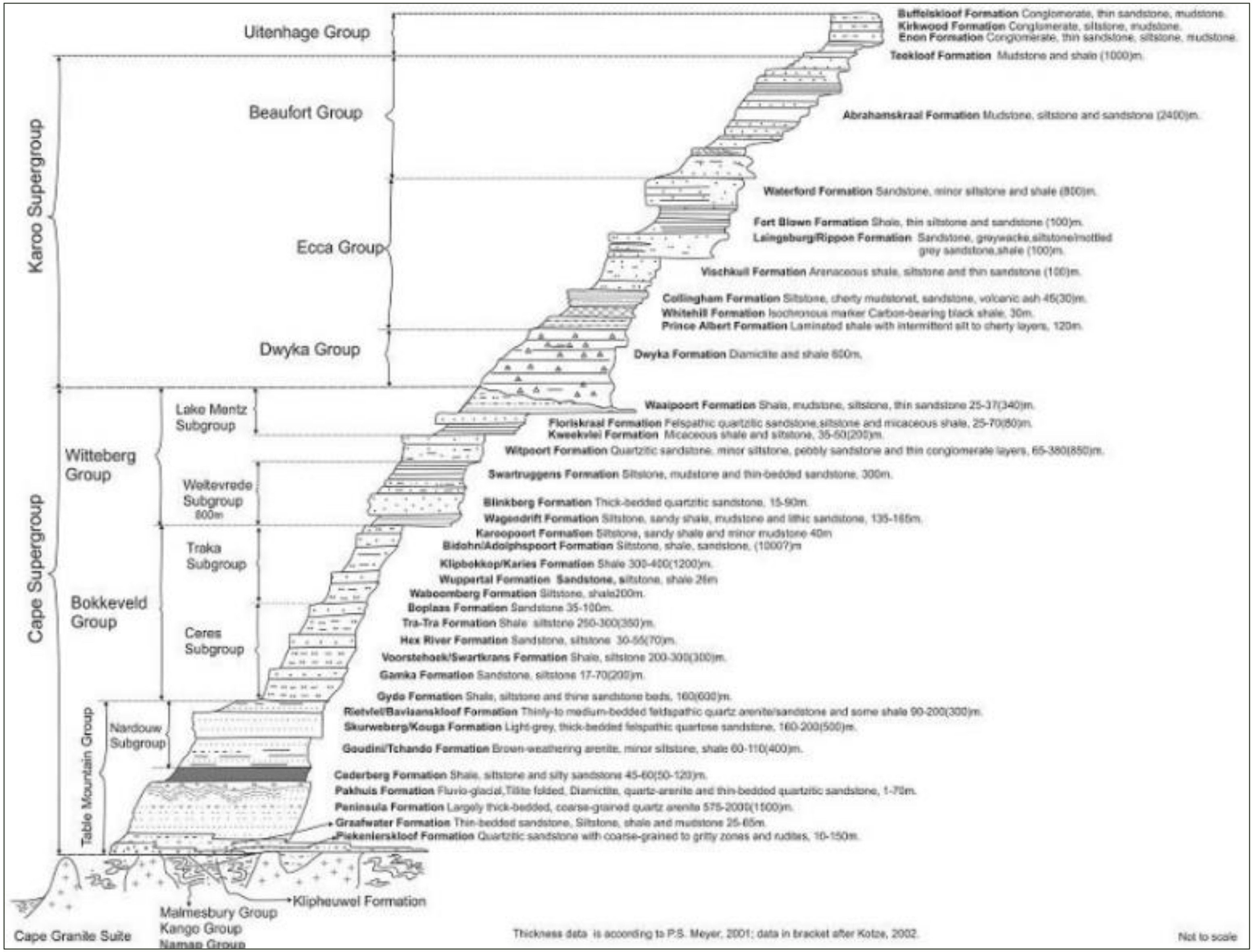


Figure 2.4. Geological sequences in the region (from Wu, 2005).

The Cape Fold Belt consists of three structural provinces, a northern branch from Vanrhynsdorp to Ceres, a syntaxis around Worcester and to the southwest to False Bay, and a southern branch from Touwsriver to Port Elizabeth (Mielke and De Wit, 2009). The Cape Orogeny largely also produced a series of south dipping imbricate thrusts affecting both basement and cover rocks. The most noticeable is the regional Kango-Baviaanskloof and Worcester south-ward-dipping faults (east of the Berg catchment), which are usually regarded as regional boundaries of groundwater regimes (WRC, 2009), at least to flow across them. Although much of the Cape Fold Belt mountainous outcrop is beyond the study area, the faulting of the Cape Orogeny affected basement rocks (which were also deformed by pre-Cape age faulting, DWAF, 2008), and regional structural features extend across the study area. DWAF (2008) identified major fold (syncline and anticline), and major fault structures across the study area. Fault structures were further separated into major water bearing fault structures (parallel to the fault structure), therein termed hydrotects. Several of these traverse the area (DWAF, 2008).

2.2.2.3 Aquifer Types

The lithology and structural characteristics of the underlying geology control the flow of groundwater in the study area. The various geological (stratigraphic) units that occur throughout the study area can be related to hydrogeological units (aquifers/aquitards) and distinct aquifer types. However, for the purpose of this regional study only the major hydrogeologically significant aquifers will be elaborated on as these form the basis for resource delineation. The existing 1: 500 000 hydrogeological mapping of the study domain is shown in Figure 2.5. The map presents the distribution of aquifer types based on surface outcrop of lithology and further subdivided based on borehole yield.

Three types of aquifer occur within the study area, namely

- Intergranular (“primary” or porous sandy aquifers),
- fractured (“secondary” aquifers),
- Intergranular-and-fractured (also termed “regolith” aquifers),

Intergranular aquifers

The Sandveld Group calc-arenites and unconsolidated sands form an extensive aquifer, in which the granular interstices and pore spaces contain groundwater. The aquifer dominates in the west of the study area, stretching from the Cape Flats to north of Velddriff, beyond the northern catchment boundary. The thickness of the aquifer is related to the basement topography: in the west of the study area the aquifer reaches significant thicknesses, and it thins to the east close to basement outcrops. Intergranular aquifers are also present away from coastal areas, composed of alluvium consisting of clay, sand, pebbles and boulders, and occur predominantly within river valleys for example associated with the Berg River. The Berg River Alluvial Aquifer is a locally significant intergranular aquifer, infilling the valley around Franschhoek.

Fractured aquifers

Units of the TMG form the most important fractured aquifers, while rocks of the Malmesbury (basement) can yield water where fractured.

The TMG is made up of the Nardouw Sub-Group (including the Skurweberg Formation considered a fractured aquifer), and the Peninsula Formation (Peninsula Aquifer), separated by the Cedarberg (shale) Formation which forms an aquitard between the two main aquifers. The Peninsula Aquifer usually outcrops at higher altitudes. The Peninsula and Skurweberg Formations units are composed of thick quartzite successions of high compressive and tensile strength, and are therefore capable of supporting open, permeable fractures to depths of several kilometres.

Generalising broadly, where the Nardouw outcrops, the Nardouw aquifer can be considered to be an unconfined aquifer while the Peninsula is confined by the Cedarberg Aquitard (WRC, 2009). In the Peninsula outcrop areas where the Cedarberg formation has been denuded, the Peninsula aquifer becomes unconfined (and the Nardouw aquifer is absent, which is the case for the majority of TMG outcrop within the study area).

If sediments younger than the TMG outcrop (i.e. the Bokkeveld Group and Karoo Supergroup, west of the Berg study area), both the Peninsula and Nardouw can be regarded as confined aquifer system because overlying Gydo Formation at the base of the Bokkeveld is usually regarded as an aquitard. In these situations, the TMG can be buried at significant depth, yet an active flow systems remains, as evidenced by hot springs located indicating that groundwater circulation of depths of up to 2 000 m can occur (WRC, 2002). This deep circulation is however limited within the Berg study area; as the two key aquifers are not significantly buried in the Berg study area (the Bokkeveld Group and Karoo Supergroup do not outcrop).

Intergranular (weathered) and Fractured aquifers

Fractured and intergranular (also termed weathered or regolith) aquifers coincide with exposures of the Cape Granite Suite. However, the Malmesbury Group can also be termed a ‘regolith’ aquifer and was classified as such during the Berg Catchment water availability assessment study (DWAF, 2008)

At a local scale where their surfaces are weathered (certainly in outcrop), the Cape Granite Suite and Malmesbury Group (i.e. the basement) both form low-yielding (1 l/s) or minor weathered (regolith) or intergranular and fractured aquifers. These aquifers are important for agricultural irrigation in many areas of the catchment (Paarl, Stellenbosch, Franschhoek). As a weathered shale and granite with associated clay content, the water quality is relatively poor (3 parameters falling in class 2, one in class 3, Table 2-16) giving rise to high salinity which also affects streams and rivers that overlie the basement in the Middle and Lower Berg (CCT, 2012).

Because the different geological groupings directly relate to aquifer types (basement forming regolith aquifers; TMG generally forming fractured aquifers, Cenozoic deposits forming intergranular aquifers), it is possible to group the geology into these major geological groups for hydrogeological interpretation.

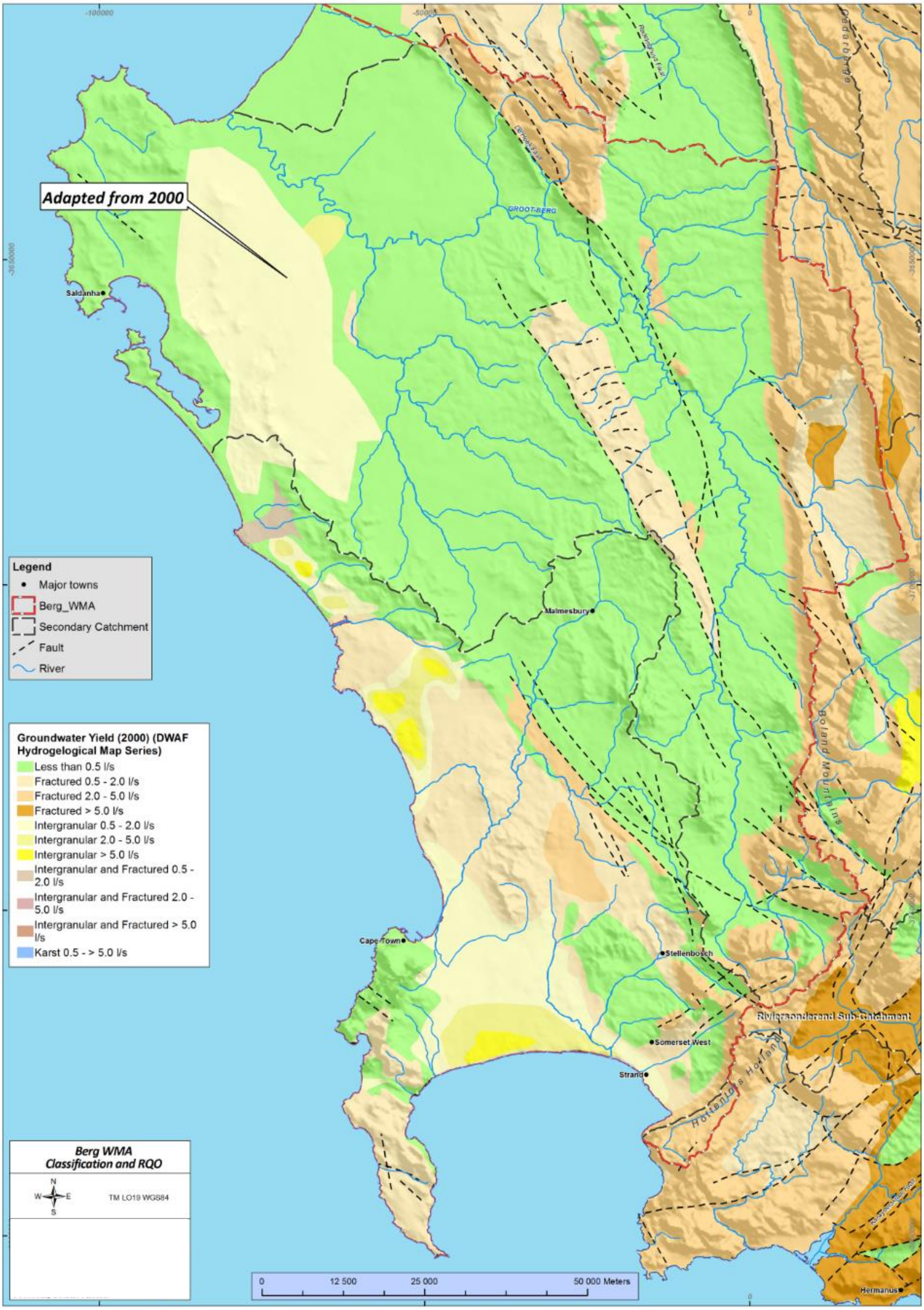


Figure 2.5. Aquifer type and yield.

2.2.3 Status Quo Assessment

2.2.3.1 Delineation of 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.

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 2.6). 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.

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 2.7).

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.

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.

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 GRUs 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 GRUs. 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 2.8. 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.

The delineation of GRUs 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 2-9.

The spatial distribution of the GRUs in relation to geology and surface catchments is shown in Figure 2.9.

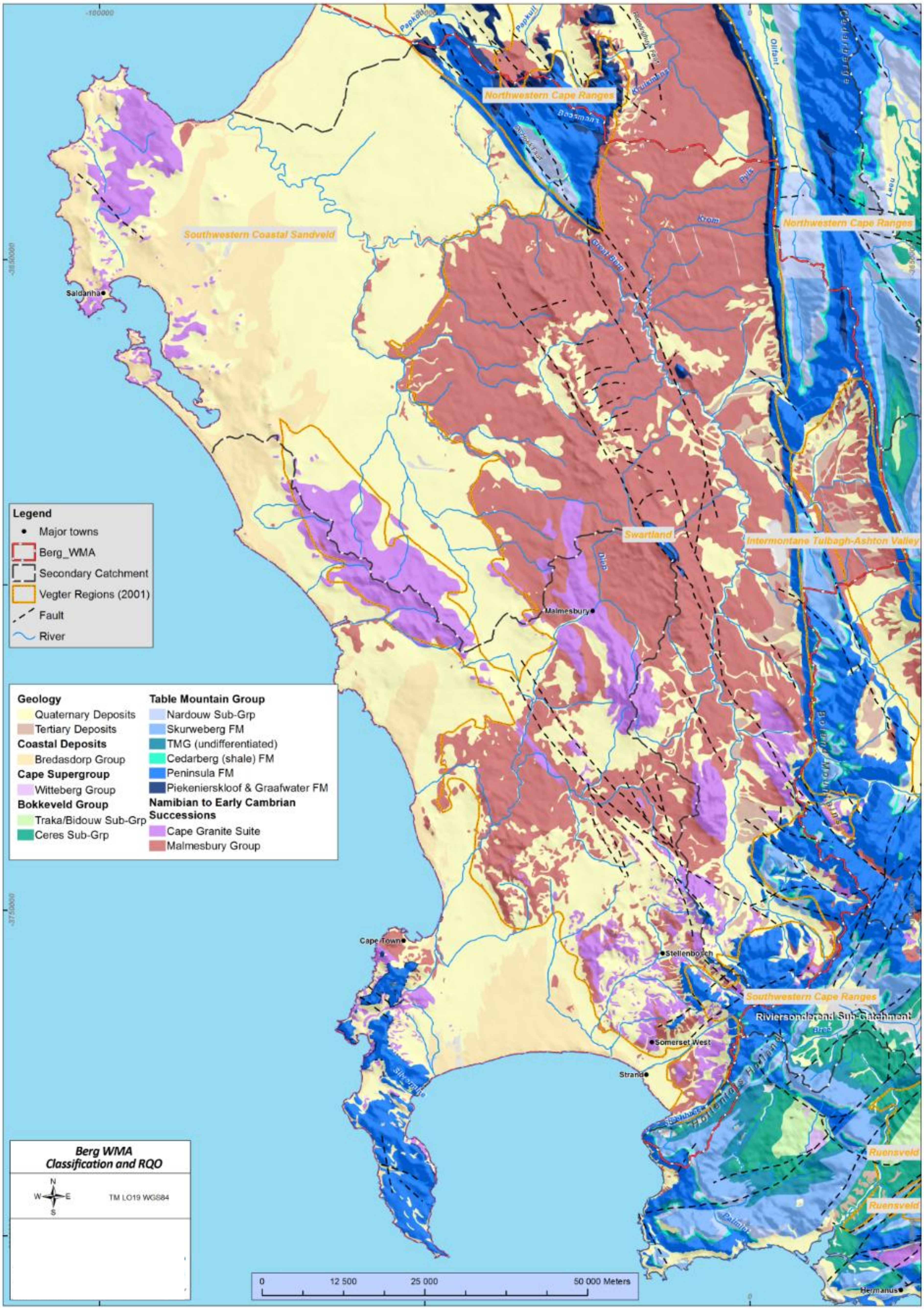


Figure 2.6. Groundwater Regions (after Vegter, 2001).

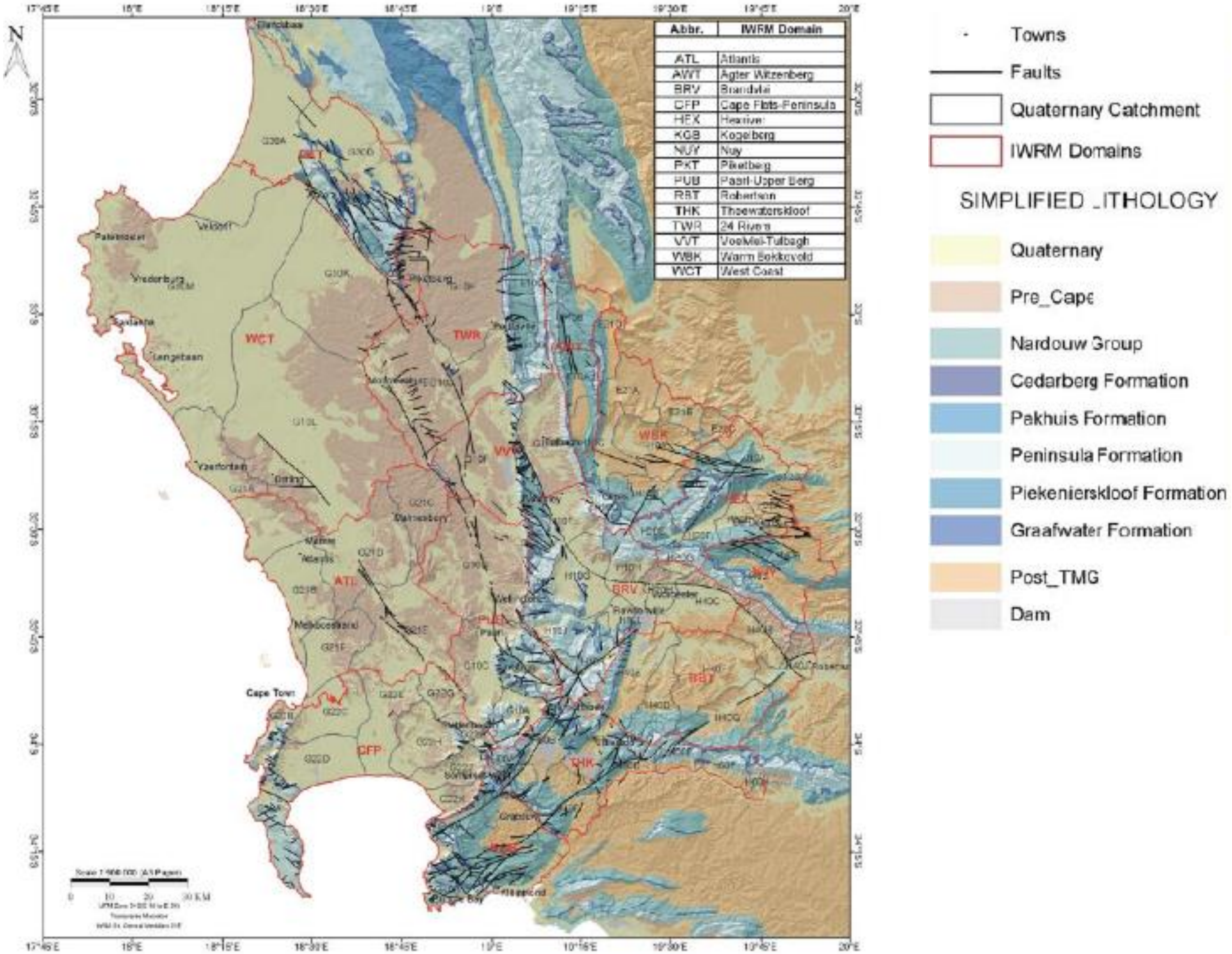


Figure 2.7. Regional delineation of eight IWRM domains (Adapted from DWAF, 2008).

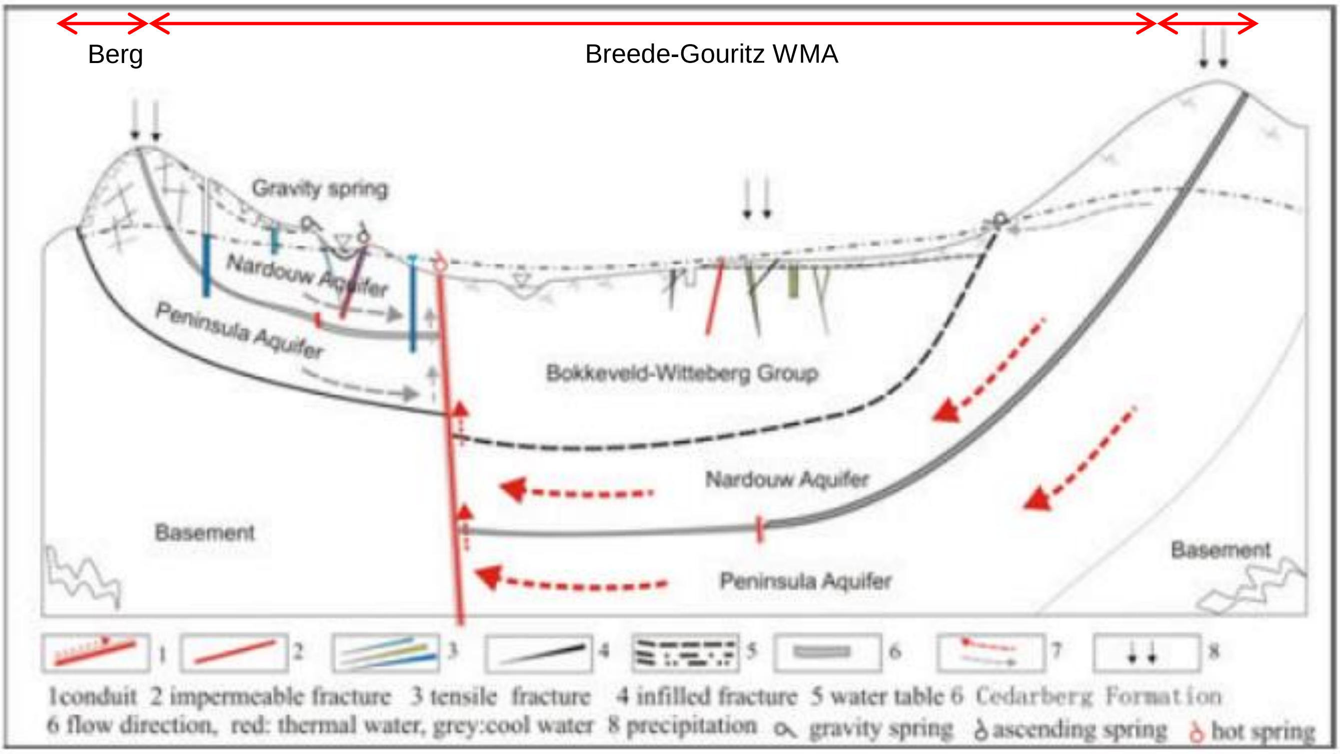


Figure 2.8. Cross-section of TMG flow (Adapted from Wu, 2005).

Table 2-9. Description of delineated GRUs for the study area and the link to surface water units.

Sub-Region	Groundwater Resource Unit	Surface Water Quaternary Catchments
Greater Cape Town	1-Peninsula	G22A and G22B
	2-Cape Flats	G22C, G22D and G22E
	3-Helderberg	G22G; G22H; G22K and G22J
Upper Berg	4-Paarl-Upper Berg	G10A; G10B; G10C and G10D
	5-Tulbagh Valley	G10E and G10F
	6-24 Rivers	G10G; G10H and G10J
Lower Berg	7-Piketberg	G30A and G30D
	8-West Coast	G10K; G10M; G10L and G21A
	9-Atlantis	G21B
	10-Malmesbury	G21C; G21D and G21E

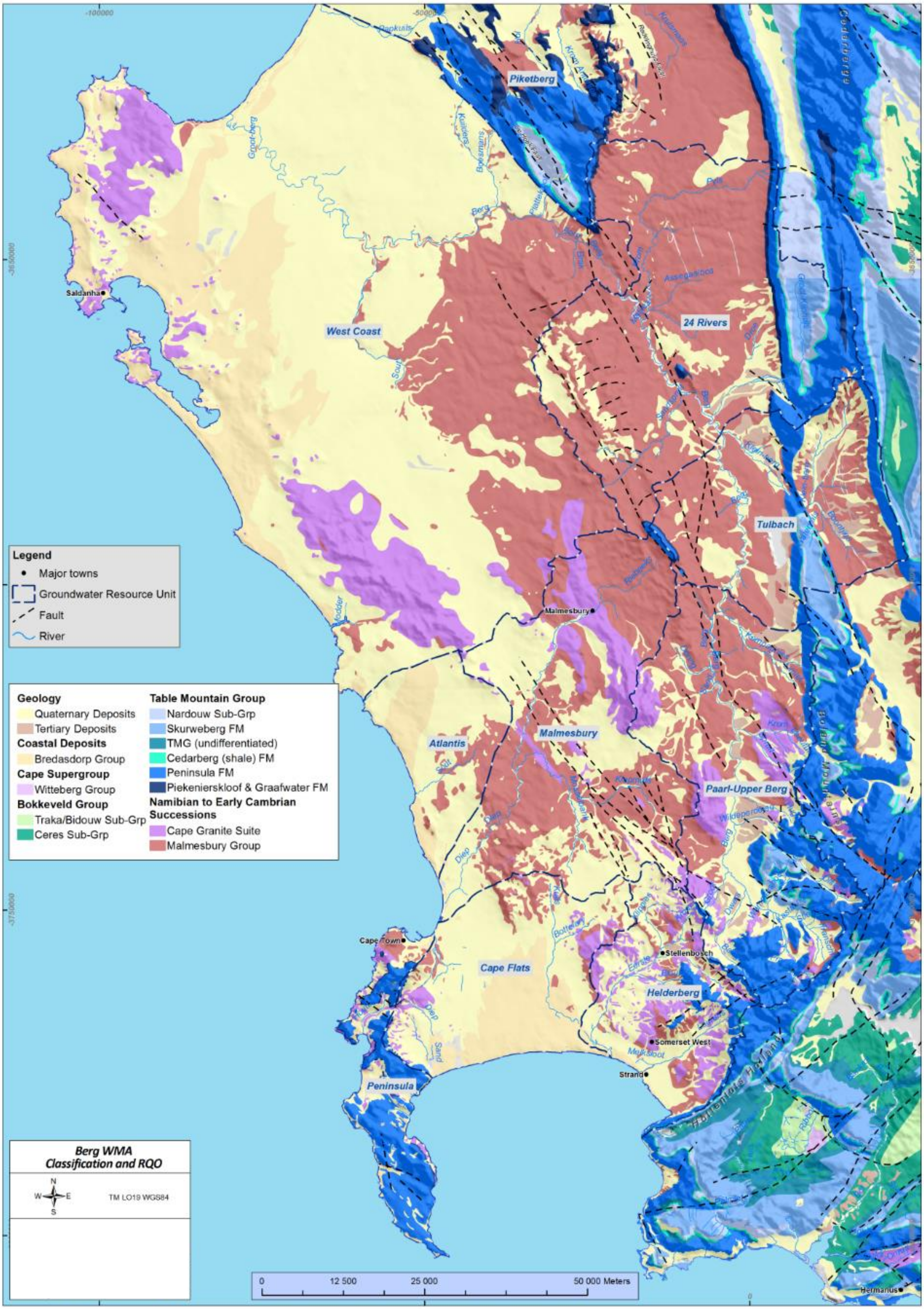


Figure 2.9. Delineated GRUs.

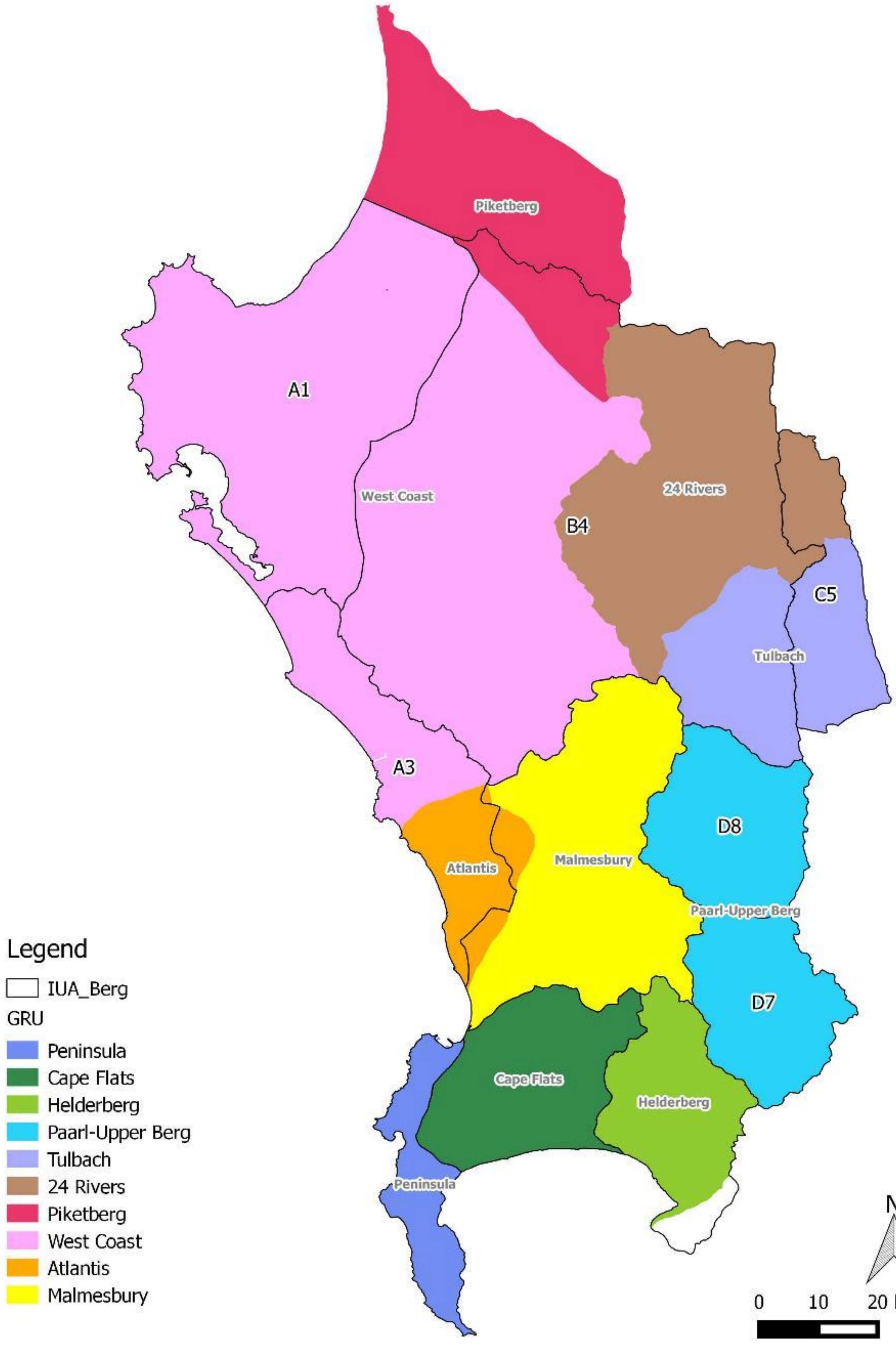


Figure 2.10. Delineated GRUs within the Berg IUAs.

2.2.3.2 Status Quo Assessment

Recharge

The latest nationally available recharge dataset, GRAII (DWAF, 2006) is shown in Figure 2.11, and summed in Table 2-10 (per GRU) and Table 2.11 (per major geology), and also in Appendix A (per GRU per geology). The recharge distribution is largely controlled by the precipitation distribution, which in turn is related to the topography. At the broadest scale, areas of high rainfall largely correspond (at least in the theoretical datasets) to areas of high recharge. In certain areas the correlation is not direct and the underlying geology, and aquifer type, influences the recharge.

Table 2-10. Recharge sum and average (GRAII, DWAF 2006) per GRU.

GRU	Recharge sum (million m3/a)	Average recharge (mm/a)
24 Rivers	59.61	35
Atlantis	16.36	40
Cape Flats	66.13	86
Helderberg	88.08	145
Malmesbury	48.52	35
Paarl-Upper Berg	197.13	150
Peninsula	50.68	146
Piketberg	31.56	23
Tulbagh	50.86	54
West Coast	112.36	21
Total	**721.31**	**n/a**

Table 2-11. Recharge sum (GRAII, DWAF 2006) per major geology.

Major geological unit	Recharge sum (million m3/a)
Other1	5.81
Basement and Intrusive	192.21
Coastal Cenozoic Deposits	316.12
TMG	207.18
Total	721.31

It is intuitive therefore that recharge is higher along the western borders of the Berg catchment and in the Cape Peninsula including the Helderberg, Paarl Upper Berg and Peninsula GRUs. These areas include the TMG-formed mountainous areas where rainfall is high. Recharge reduces significantly to the west and north

[1] "Other" refers to areas in the geology spatial data that are not classified as a rock type, for example water bodies

of the Berg study area towards the West Coast GRU, related largely to reduced rainfall (as the Sandveld Group surface geology is highly permeable to enable infiltration). The available recharge datasets provide information on recharge derived from direct infiltration only. This is only one mechanism by which recharge occurs. There is however no regional spatial dataset for information on rivers that recharge groundwater ("losing rivers"). Recharge mechanisms and groundwater flow dynamics will be expanded during the subsequent project phases.

Discharge

One groundwater discharge mechanism is through discharge to surface water systems, as groundwater contribution to baseflow (river baseflow, springs and seeps). The available baseflow information for the region is a national dataset derived from the GRAII assessment and at quaternary catchment scale (DWAF, 2006), shown in (Figure 2.11). The distribution of groundwater contribution to baseflow closely correlates with the distribution of recharge. Rainfall has a dominant control on recharge, and aquifers with high recharge, can also be reasonably expected to have high groundwater discharge, given a state of dynamic equilibrium in the long term.

This dataset is often the only or major (natural) discharge considered from groundwater. It is simply the only one for which there is a spatial dataset available. Interflow between aquifers, oceanic discharge, direct evapotranspiration, are discharge mechanisms for which there is not readily available spatial data at regional scale. A widely applied equation for groundwater availability equates availability to recharge minus use (existing abstraction and groundwater contribution to baseflow) minus the reserve. This equation simply yields un-quantified groundwater discharge. All natural discharge (and some enhanced recharge) may be available, or only a small portion of it, depending on the ability to capture this yield. This is mentioned here in the context of discharge datasets for the status quo, and will be built upon in later stages of the project.

Groundwater use

The sum of registered groundwater use per GRU is shown in Table 2-12, and a map showing the distribution of registrations is in Figure 2.12. This map also illustrates a density function which sums the groundwater registration (l/s) per km2, emphasising clustered use and high registrations.

Table 2-12. Groundwater use as registered in WARMS, per GRU.

GRU	Sum of registrations (million m3/a)
Cape Flats	11.62
Paarl-Upper Berg	10.77
Malmesbury	10.50
West Coast	8.21
Atlantis	7.51
Piketberg	6.20
Tulbagh	5.66
Helderberg	3.33
24 Rivers	2.00
Peninsula	0.10
Total	**65.89**

Groundwater use in terms of distribution, is significantly higher in the east and south of the Berg study area where use is >0.1l/s/km^2 (Figure 2.12), particularly in areas such as the Tulbagh valley (Tulbagh GRU), the Franschhoek valley and Stellenbosch region and the Paarl and Wellington region (Paarl Upper Berg GRU), wider Klapmuts area (Malmesbury GRU), the Cape Flats (Cape Flats GRU), and Atlantis (Atlantis GRU). Groundwater use reduces towards the north of Malmesbury (with the exception of Piketberg).

The Cape Flats is the GRU with the highest use with both farmers, some businesses, and private residences in the CCT tapping into this resource, however these sums are affected by the size of the GRU, and the existence of one or two higher registrations. For example, the West Coast GRU shows relatively high total use whilst there are few and disperse registrations, because of its large size and the bulk abstraction registered to the West Coast District Municipality (1.5 million m^3/a for domestic supply at Langebaan Road wellfield). The high use in the east and south coincides with the high rainfall, recharge and high baseflow region, and with agricultural areas.

The registered groundwater use per water use sector for the whole study area is given in Table 2-13 and further illustrates the dominance of groundwater use for agriculture: 71% of the registered groundwater use is registered to agricultural irrigation. Only 2% of the registered use is for water supply services

Table 2-13. Groundwater use as registered in WARMS, per water use sector.

Water Use Sector	Sum of registrations (million m^3/a)
AGRICULTURE: IRRIGATION	47.05
WATER SUPPLY SERVICE	1.40
INDUSTRY (URBAN)	13.38
AGRICULTURE: WATERING LIVESTOCK	3.02
SCHEDULE 1	0.16
INDUSTRY (NON-URBAN)	0.22
RECREATION	0.01
AGRICULTURE: AQUACULTURE	0.53
MINING	0.04
URBAN (EXCLUDING INDUSTRIAL &/OR DOMESTIC)	0.08
Total	**65.89**

The surface geology at each groundwater registration point has been determined, and the use per major geological grouping summed (Table 2-14). This suggests that the highest abstraction occurs from Cenozoic deposits (including the Sandveld Group, undifferentiated Quaternary and Tertiary deposits). With the point data available it is a challenge at regional scale to determine aquifer-specific use. A borehole whose surface geology is Cenozoic will in certain areas likely penetrate deeper formations, for example where Cenozoic deposits are thin on the edges of outcrop of Malmesbury Shale (i.e. Klapmuts region), the borehole would likely penetrate the Malmesbury Shale however in this process it be classified as abstraction from Cenozoic deposits. It is also simplistic given abstraction from one deposit (even where the borehole only penetrates one geological unit), may derive groundwater laterally from another aquifer source, for example scree slopes at the base of the Peninsula outcrops at the eastern boundary of much of the Berg study area, which receive lateral recharge from the surrounding Peninsula Formation particularly where the Peninsula meets the Malmesbury and may decant to the scree (DWAF, 2008). Nevertheless, the results at least indicate that the majority of abstracted groundwater is derived from Cenozoic deposits (44 million m^3/a), followed by the basement aquifers (14 million m^3/a), and the least from the TMG (7 million m^3/a). These numbers are again related to the percentage outcrop area in the study area, and the TMG outcrop area is minor. The TMG has the highest average abstraction rate per registration (>80 000 m^3/a), closely followed by the Cenozoic deposits (>70000 m^3/a), with lower rates registered in the basement rocks (~40 000m^3/a). Further details for water use (registered use per water use sector, per major geology per GRU) is included in Appendix A.

Table 2-14. Groundwater use as registered in WARMS, per major geological division.

Geological grouping	Sum of registrations (million m^3/a)	Number of registrations	Average registration rate (m3/a)
Coastal Cenozoic Deposits	44.42	628	70729
TMG	7.09	88	80579
Basement And Intrusive	14.38	362	39718
Total	65.89	1078	n/a

Domestic groundwater supply makes up only 2% of the total use, and groundwater is not heavily relied upon for domestic supply in the study area, generally due to the availability of surface water, and extensive use of the Berg River via the Western Cape Water Supply System. Only two settlements in the Berg are considered “sole groundwater supply” i.e. groundwater makes up >50% of the supply source (as defined by DWS, 2011); Aurora and Redelinghuys. Redelinghuys lies beyond the Berg catchment boundary but within the Piketberg GRU, hence may have influence over groundwater within the Berg (Table 2-15).

Table 2-15. Settlements supplied by groundwater within the Berg, showing the GRU, the % groundwater supplied, and current groundwater yield.

GRU	Settlement	% GW supplied	GW Yield (million m3/a)
Atlantis	City of Cape Town (Atlantis Wellfield)	2	18.42
Cape Flats	City of Cape Town (Albion Spring)		
24 Rivers	Piketberg	25	0.24
	Porterville	23	0.20
Malmesbury	Malmesbury, Abbotsdale	1	0.02
Paarl-Upper Berg	Franschhoek & Groendal, La Motte, Wemmershoek, Roberstvlei	13	0.22
Piketberg	Redelinghuys[2]	100	0.05
Tulbagh	Tulbagh	4	0.03
	Riebeek Kasteel	1	0.003
West Coast	Aurora	100	0.06

[2] Redelinghuys lies beyond the Berg boundary, but within the Piketberg GRU hence is included here

GRU	Settlement	% GW supplied	GW Yield (million m3/a)
	Hopefield	30	0.16
	Langebaan, Langebaanweg, Saldanha	17	1.35

A further 12 towns / settlements utilise generally small quantities of groundwater (<50%) as part of the supply source.In addition to those settlements listed, large-scale groundwater use is a potential for the City of Cape Town (CCT). The CCT is considering the feasibility of large-scale groundwater abstraction (50 million m^3/a) from TMG aquifers located beyond the Berg boundary, the west of the Breede catchment (DWS, 2015), and also considering the feasibility of using the Cape Flats Aquifer for bulk supply (DWS, 2016). Although not currently considered as a resources intervention option by the West Coast District Municipality (WCDM, 2009), or the Saldanha Bay local Municipality, several reports have illustrated the underutilisation of groundwater in the West Coast area (WCDM, 2009), and more recently specifically the Langebaan Road Wellfield has been shown to be significantly underutilised (WRC, 2016a).

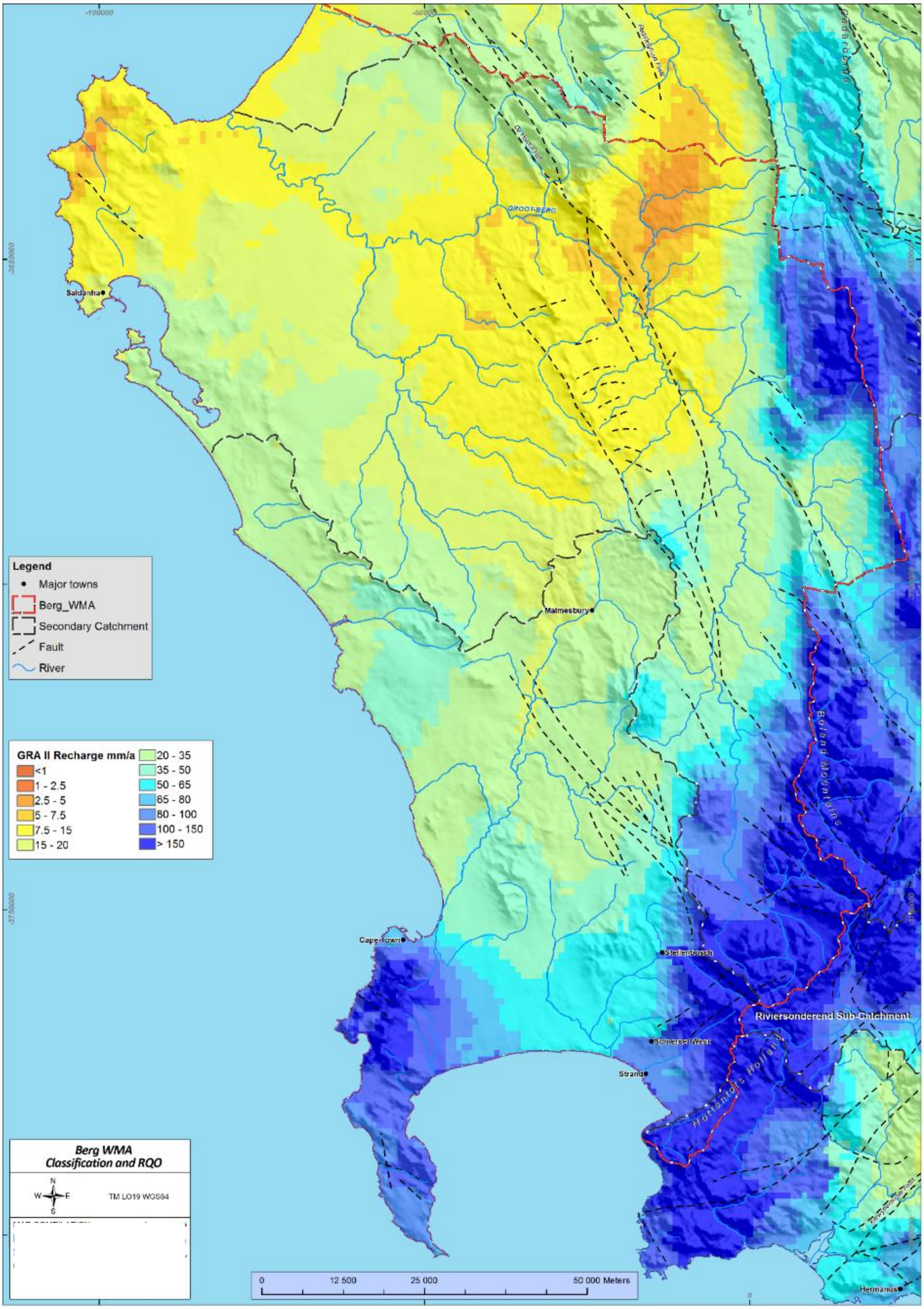


Figure 2.11. Groundwater recharge distribution (GRAII, 2006).

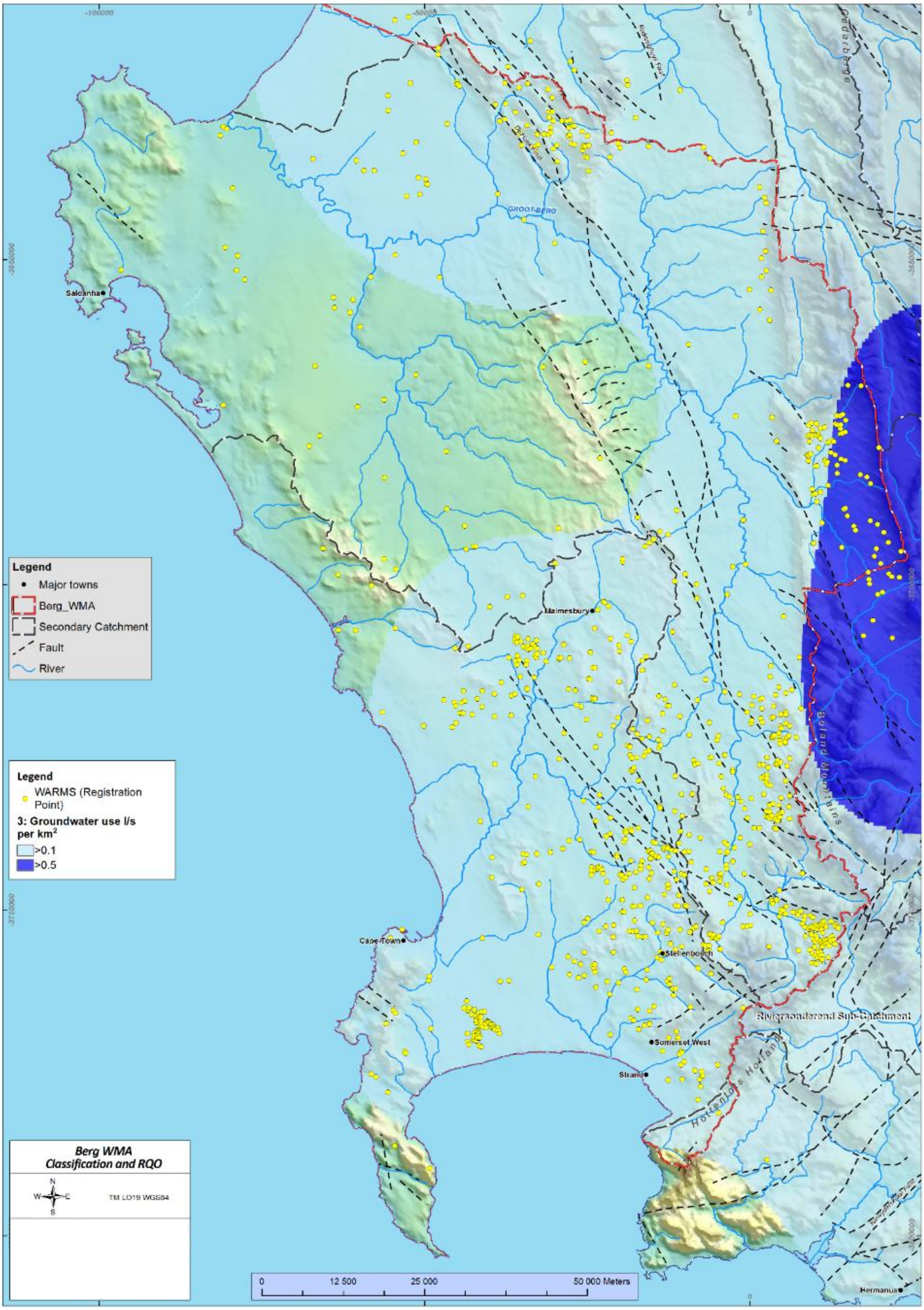


Figure 2.12. Map showing distribution of WARMS registered groundwater abstraction (points) and groundwater use density function (l/s/km²) as shaded areas.

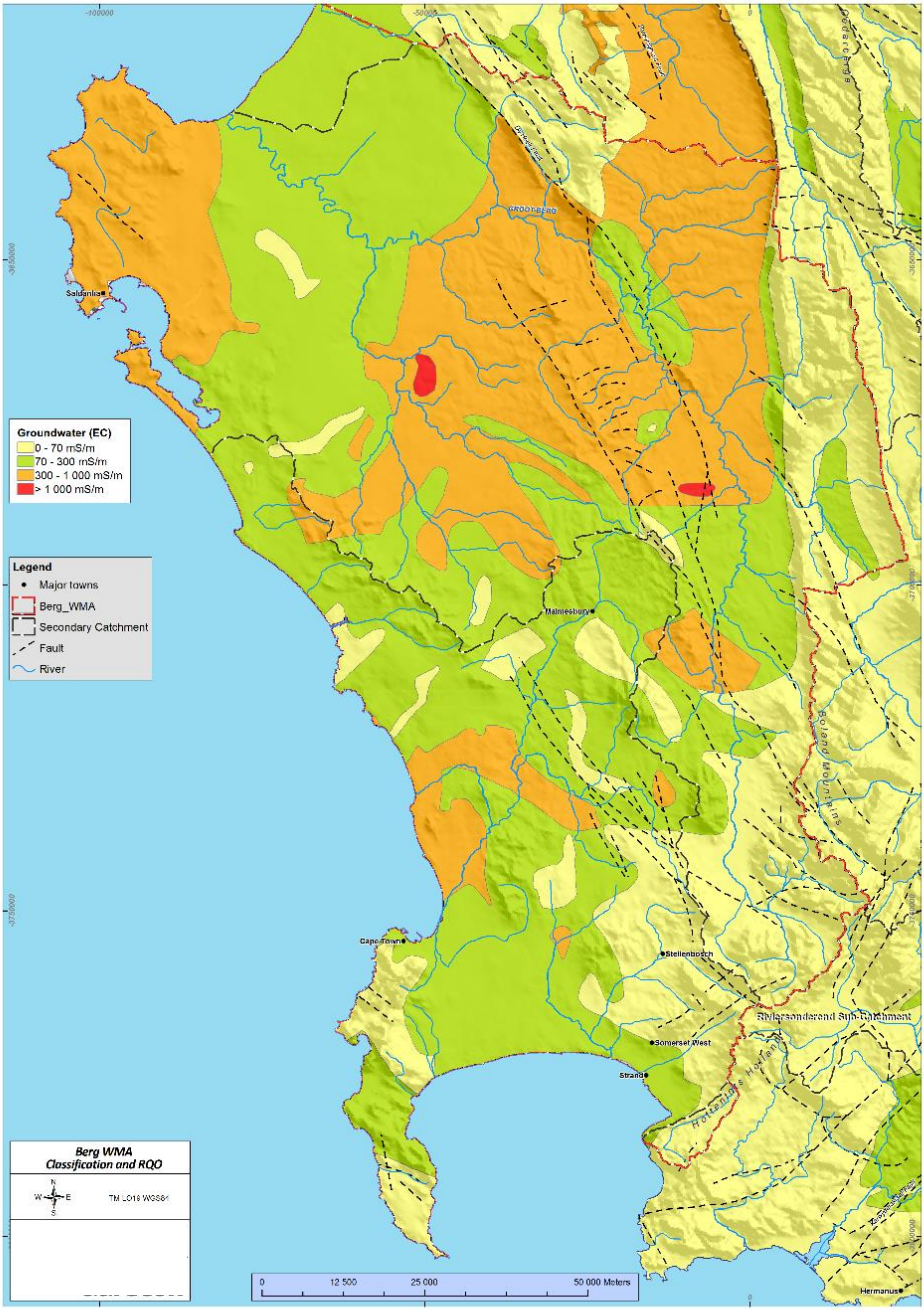


Figure 2.13. Map showing distribution of Groundwater Electrical Conductivity (DWAF Hydrogeological Series, 1995)

Groundwater quality

Average (mean) groundwater quality parameters are shown in Table 2-16, calculated based on all available groundwater quality data. This data is presented per GRU in Appendix A. Medians are preferable for analysis of groundwater quality however due to the large datasets automated averaging was necessary which does not accommodate medians. The values should be considered over-estimates as a mean can be significantly skewed by outliers. Groundwater quality will also vary significantly spatially, based on aquifer setting and local influences. Nevertheless, natural groundwater quality is directly related to geology, and recharge, and therefore results can provide an illustration of the relative water quality differences between the major geological units. The spatial variability of groundwater quality (using electrical conductivity as an indicator for quality) is shown in Figure 2.13.

Groundwater quality, on average, is excellent in the TMG with all parameters falling below or within Class 1 Drinking Water Quality (Table 2-16). The water quality is related to high recharge (i.e. high influx of fresh water), and the almost pure quartzite content of the Peninsula and Skurweberg Formations (into which most of the boreholes for which water quality is available will be situated). The Cenozoic deposits also have good water quality with all parameters falling below Class 1, within Class 1, and only EC, sodium and chloride content falling within Class 2.

Water quality is generally poorer in the basement, (i.e. chloride falling within Class 3), which relates to higher clay contents, and lower recharge values. High salinity in surface waters (i.e. several tributaries to the lower Berg) can be attributed to a combination of factors, including the contribution of salts from underlying geology. Again, these results are a broad generalisation and considered an over-estimate; some individual units in the basement and individual locations will maintain excellent quality. Furthermore, in some cases the TMG has high iron requiring pre-treatment. It is also important to note that Class 3 natural groundwater quality does not preclude its use for domestic supply: surface water is not expected to be of Class 0 drinking water quality on abstraction, it is treated prior to use.

The above description of baseline average groundwater quality and the analysis of recent trends in water quality (Appendix A) are together sufficient to establish water quality targets for the RQOs. An appraisal of the extent of water quality impacts or pollution incidents across an aquifer and GRU has not been completed. Areas of known pollution, or areas at high risk of pollution (for example the Cape Flats Aquifer), can prioritised for more detailed assessment (i.e. input to Resource Units Prioritisation report).

Table 2-16. Average water quality parameters for major geological groupings, compared to DWAF Drinking Water Quality Limits[3].

Major Geology Grouping	Number of locations	pH Value at 25^{0}C	Conductivity at 25^{0}C	Sodium (Na)	Calcium (Ca)	Magnesium (Mg)	Fluoride (F)	Chloride (Cl)	Sulphate (SO_4)	Total Alkalinity ($CaCO_3$)	NO_3 -N
		mg/l	mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Basement	487	7.37	329.76	530.83	60.08	80.56	0.64	985.62	120.83	124.25	4.25
TMG	53	6.31	70.18	96.52	11.56	14.57	0.27	181.24	25.46	25.46	1.74
Coastal Cenozoic Deposits	1472	7.25	185.34	272.21	55.01	42.23	0.40	521.88	81.06	97.65	2.80
	Drinking Water Quality Limits - DWAF, 1996; DWAF, DOH and WRC, 1998*										
	Class 1	*5-6 or 9-9.5*	*70-150*	*100-200*	*80-150*	*30-70*	*0.7-1*	*100-200*	*200-400*		*6-10*
	Class 2	*4-5 or 9.5-10*	*150-370*	*200-600*	*150-300*	*70-100*	*1-1.5*	*200-600*	*400-600*		*10-20*
	Class 3	*3.5-4 or 10-10.5*	*370-520*	*600-1200*	*>300*	*100-200*	*1.5-3.5*	*600-1200*	*600-1000*		*20-40*

[3] Note: mean averages are presented. Medians are preferable for analysis of water quality however due to the large datasets automated averaging was necessary which does not accommodate medians. The values should be considered maximums as a mean can be significantly skewed by outliers.

2.3 Water quality

2.3.1 Approach

Assessment of the present water quality status quo was based on assessing the fitness for use of the water for key water user sectors, namely irrigation water use, domestic water use, and aquatic ecosystems. The assessment was aligned with the methodology that was used in the Olifants WMA classification study (DWA, 2011). The water quality targets used for the assessment (Table 2-17) were derived using the Resource Water Quality Objectives (RWQOs) Model (Version 4.0) (DWAF, 2006) which uses as its basis the South African Water Quality Guidelines (DWAF, 1996), Quality of Domestic Water Supplies: Assessment Guide, Volume 1 (WRC, 1998) and Methods for determining the Water Quality Component of the Reserve (DWAF, 2008) and are based on the strictest water user criteria (thus represent fairly conservative limits).

Table 2-17. Water quality criteria used to assess the present water quality status.

Variable	Units	Bound	Ideal	Sensitive user	Accept able	Sensitive user	Tolerable	Sensitive user
Alkalinity ($CaCO_3$)	mg/l	Upper	20	AAq	97.5	AAq	175	AAq
Ammonia (NH_3-N)	mg/l	Upper	0.015	Eco	0.044	Eco	0.073	Eco
Calcium (Ca)	mg/l	Upper	10	Dom	80	BHN	80	BHN
Chloride (Cl)	mg/l	Upper	40	In2	120	In2	175	In2
EC	mS/m	Upper	30	In2	50	In2	85	Eco
Fluoride (F)	mg/l	Upper	0.7	Dom	1	Dom	1.5	Dom
Magnesium (Mg)	mg/l	Upper	70	Dom	100	Dom	100	Dom
NO_3 (NO_3-N)	mg/l	Upper	6	Air, Eco	10	AIr	20	AIr
		Upper	≤ 8	In2	<8.4	In2		
pH	units	Lower	≥6.5	Air, Aaq, In2	>8.0	Air, Aaq, In2		
Potassium (K)	mg/l	Upper	25	Dom	50	Dom	100	Dom
PO_4-P (Rivers)	mg/l	Upper	0.025	Eco	0.075	Eco	0.125	Eco
PO_4-P (Dams)	mg/l	Upper	0.005	Eco	0.015	Eco	0.025	Eco
SAR	mmol/l	Upper	2	AIr	8	AIr	15	AIr
Sodium (Na)	mg/l	Upper	70	AIr	92.5	AIr	115	AIr
Sulphate (SO_4)	mg/l	Upper	80	In2	165	In2	250	In2
TDS	mg/l	Upper	200	In2	350	In2	800	In2
Si	mg/l	Upper	10	In2	25	In2	40	In2

Note on sensitive users: Air = Agriculture: Irrigation users, AAq = Agriculture: Aquaculture users, BHN = Basic human needs users, Dom = Domestic users, Eco = Aquatic ecosystems, In2 = Industrial 2 users

The fitness for use is described using four water quality categories, namely Ideal (blue), Acceptable (green), Tolerable (yellow), and Unacceptable (red) for concentrations greater than the upper boundary of the Tolerable range. The more blue and green colours that are visible in the classification tables, the better the water quality. The more yellow and in the classification tables, the poorer the water quality.

2.3.2 Description

The primary source of data for the water quality analysis was the Directorate Resource Quality Information Services of the Department. Historical data for water quality monitoring points in the study area were obtained from the national monitoring network (Water Management System). The monitoring network is described in the Report on Water Resources Information Gap Analysis and Models. The routine DWS river and reservoir water quality monitoring points for the study area are listed in Table 2-18.

Table 2-18. River and reservoir water quality monitoring points in the study area (i.e. former Berg WMA). The number of samples, first and last date refers to the complete data record.

IUA	Monitoring Point Name	Type	Quat	n	First	Last
A1	BE-05 KERSEFONTEIN @BERG ESTUARY	Estuary	G10M	8	2013/11/12	2014/12/20
	BE-01 LAAIPLEK VLAMINKE VALEY 54 - @ BERG ESTUARY	Estuary	G10M	7	2014/01/29	2014/12/20
	G1H023Q01 (BE06) - JANTJIESFONTEIN 69 - AT BERGRIVIER TOWN ON GROOT-BERG RIVER	Rivers	G10M	367	1971/07/29	2016/08/10
	BE03 -G1HO24Q01 KLIPHOEK @SISHEN/SALDANHA RAILWAY BRIDGE ON BERGRIVIER	Rivers	G10M	328	1972/03/15	2016/06/07
	BE02 - CMNT-BERG RIVER-BERG G VLAMINKE VLEI 54 - @ R27 ROAD BRIDGE (CARINUSBRUG) ON GROOT- BERGRIVIE	Rivers	G10M	14	2007/10/11	2013/11/12
	CMNT-BERG RIVER-BERG F KERSFONTEIN 129 - @ KERSFONTEIN BRIDGE ON GROOT-BERGRIVIER	Rivers	G10M	11	2007/10/11	2013/02/07
A3	G201/01A1 ROOIPAN - 3318AC	Wetland	G21A	6	1988/08/02	2012/08/27
	G201/02B1 YZERFONTEIN SOUTPAN - 3318AC	Wetland	G21A	6	1988/08/02	2012/08/27
	G201/08C1 YZERFONTEIN SOUTPAN INFLOW - 3318AC	Wetland	G21A	6	1988/08/02	2012/08/27
	G201/04B1 RONDEBERG 718 - 3318AD	Wetland	G21A	6	1988/08/04	2012/08/29
	G201/06A1 MODDER RIVER 721 - 3318AD	Wetland	G21A	6	1988/08/05	2012/08/29
	G2H018Q01 SILWERSTROOM RIVER AT BUFFELS RIVER	Rivers	G21B	303	1974/11/23	1993/06/16
	G201/07A1 WITSAND AQUIFER RECHARGE BASIN - 3318CB	Wetland	G21B	1	2012/08/29	2012/08/29
B4	G1R001Q01 VOELVLEI DAM ON VOELVLEI: NEAR DAM WALL	Dam / Barrage	G10F	2011	1969/03/15	2015/10/22
	G1H040Q01 VIS RIVER AT LA FONTEINE	Rivers	G10F	532	1980/05/14	2016/08/05
	NO 6 SCHOENEMAKERSFONTEIN 486 SARON @ GOEDVERWAG BRIDGE ON BERGRIVIER	Rivers	G10F	587	2004/03/02	2013/07/09
	G1R003Q01 MISVERSTAND 333 - MISVERSTAND DAM ON BERGRIVIER: @ DAM WALL	Dam / Barrage	G10J	1788	1977/02/23	2010/10/07
	G1H013Q01 AT DRIEHEUVELS ON BERG RIVER	Rivers	G10J	1534	1965/09/01	2016/06/08
	G1H029Q01 LEEU RIVER AT DE HOEK ESTATES	Rivers	G10J	603	1973/05/17	2014/10/02

IUA	Monitoring Point Name	Type	Quat	n	First	Last
	G1H034Q01 MOORREESBURG SPRUIT AT HOLLE RIVER	Rivers	G10J	1368	1972/06/28	2016/06/08
	G1H035Q01 AT MATJIESFONTEIN ON MATJIESRIVER	Rivers	G10J	841	1971/10/23	2015/10/28
	G1H043Q01 AT VRISGEWAAGD ON SANDSPRUIT	Rivers	G10J	482	1980/09/09	2015/08/26
	BERG RIVER SITE 4 - D/S OF G1H013Q01 DRIEHEUVELS	Rivers	G10J	24	2003/01/19	2005/11/15
	BERG RIVER SITE 5 - D/S OF G1H013Q01 DRIEHEUVELS	Rivers	G10J	21	2003/01/19	2005/11/15
	G1H031Q01 AT MISVERSTAND DIE BRUG ON BERG RIVER	Rivers	G10K	1557	1974/06/14	2016/06/08
	BERG RIVER SITE 6 - D/S OF G1R003Q01 MISVERSTAND DAM	Rivers	G10K	23	2003/01/19	2005/11/15
	CMNT-BERG RIVER-BERG H ZUURFONTEIN 139 - @ R399 ROAD BRIDGE ON BOESMANSRIVIER	Rivers	G10K	10	2007/10/11	2013/11/12
	CMNT-BERG RIVER-BERG A KLIP FONTEIN 709 - @ R315 ROAD BRIDGE ON GROENRIVIER	Rivers	G10L	5	2007/10/11	2009/11/12
	CMNT-BERG RIVER-BERG B LELIE BLOEM 536 - @ R307 ROAD BRIDGE ON GROENRIVIER	Rivers	G10L	9	2007/10/11	2013/11/12
	CMNT-BERG RIVER-BERG C VOGELSTRUISFONTEIN 433 - @ R307 ROAD BRIDGE ON SOUTRIVIER	Rivers	G10L	8	2007/10/11	2013/11/12
	CMNT-BERG RIVER-BERG D SCHAFPLAATSFONTEIN 345 - @ R45 ROAD BRIDGE ON TRIBUTARY OF SOUTRIVIER	Rivers	G10L	14	2007/10/11	2013/11/12
	CMNT-BERG RIVER-BERG E HOPEFIELD - @ R45 ROAD BRIDGE ON SOUTRIVIER	Rivers	G10L	14	2007/10/11	2013/11/12
	G103/01A1 KIEKOESVLEI - 3318AD	Wetland	G10L	1	2012/08/28	2012/08/28
	G103/02A1 KOEKIESPAN - 3318AB	Wetland	G10L	6	1988/08/03	2012/08/28
	G103/03A1 BURGERSPAN - 3318AD	Wetland	G10L	1	2012/08/28	2012/08/28
C5	G1H008Q01 NIEUWKLOOF 198 - ON KLEIN BERG RIVER	Rivers	G10E	1287	1955/08/27	2016/06/09
	G1H009Q01 AT KNOLVLEI FOREST RESERVE ON BRAKKLOOF TRIBUTARY	Rivers	G10E	320	1971/08/20	2016/08/04
	G1H010Q01 KNOLVLEI SPRUIT AT KNOLVLEI FOREST RESERVE	Rivers	G10E	156	1974/10/21	2016/05/12
	G1H011Q01 WATERVALS RIVER AT WATERVALSBERGE/UPPER WATERVALS	Rivers	G10E	134	1977/10/18	2008/05/05
	G1H012Q01 WATERVALS RIVER AT WATERVALSBERGE/LOWER WATERVALS	Rivers	G10E	560	1977/10/18	2015/10/27
	G1H021Q01 LITTLE BERG RIVER AT MOUNTAIN VIEW	Rivers	G10E	463	1969/10/07	2016/08/04
	AT TULBAGH ROAD BRIDGE ON KLEIN-BERG RIVER	Rivers	G10E	542	2003/05/06	2013/07/09
	EILANDPLAAS @DWARS RIVER (CERES)	Rivers	G10E	19	2013/01/22	2014/02/20
	OEWERBRUG (KIEWIETSTR.) @DWARS RIVER (CERES)	Rivers	G10E	19	2013/01/22	2014/02/20
	RIOOLPLAAS-BRUG @DWARS RIVER (CERES)	Rivers	G10E	21	2013/01/22	2014/03/27
	G1H028Q01 VIER EN TWINTIG RIVER AT DRIE-DAS-BOSCH	Rivers	G10G	763	1972/03/14	2014/08/28

IUA	Monitoring Point Name	Type	Quat	n	First	Last
D6/7	G2R001Q01 JONKERSHOEK PLANTATION - KLEINPLAAS DAM ON JONKERSHOEKRIVIER: NEAR DAM WALL	Dam / Barrage	G22F	212	1992/11/05	1999/08/12
	G2H002Q01 AT JONKERSHOEK ON BOSBOUKLOOF	Rivers	G22F	86	1981/06/16	1996/11/21
	G2H003Q01 AT JONKERSHOEK ON BIESEVLEI	Rivers	G22F	100	1983/08/03	1993/06/17
	G2H004Q01 TIERKLOOF RIVER AT JONKERSHOEK	Rivers	G22F	70	1983/08/03	1993/06/17
	G2H005Q01 KLEINPLAAS DAM ON JONKERSHOEK RIVER: DOWN STREAM	Rivers	G22F	766	1981/09/02	2009/12/01
	G2H006Q01 ABDOLSKLOOF RIVER AT JONKERSHOEK	Rivers	G22F	45	1983/08/03	1995/04/04
	G2H007Q01 LANG RIVER AT JONKERSHOEK	Rivers	G22F	81	1982/02/16	1996/10/15
	G2H008Q01 JONKERSHOEK RIVER AT JONKERSHOEK/KLEINPLAAS	Rivers	G22F	558	1977/10/28	1994/10/06
	G2H009Q01 LAMBRECHTSBOS SPRUIT A AT JONKERSHOEK	Rivers	G22F	75	1983/08/03	1990/06/06
	G2H010Q01 LAMBRECHTSBOS SPRUIT B AT JONKERSHOEK	Rivers	G22F	77	1983/08/03	1996/08/29
	G2H028Q01 SWARTBOSCHKLOOF SPRUIT AT JONKERSHOEK	Rivers	G22F	59	1985/02/07	1990/06/06
	G2H037Q01 KLEINPLAAS	Rivers	G22F	148	2002/01/03	2010/02/01
	CMNT-ER720B1 STELLENBOSCH AT DIE BOORD MALL U/S PLANKENBRUG CONFLUENCE ON EERSTERIVIER	Rivers	G22F	34	2006/10/19	2013/12/12
	CMNT-STELLENBOSCH-ER720A1- AT ASSEGAAIBOS BRIDGE	Rivers	G22F	102	1995/02/14	2013/12/12
	CMNT-STELLENBOSCH-ER720B - AT LOW-WATER DRIFT BEFORE RUGBY GROUND	Rivers	G22F	37	2004/11/22	2013/12/12
	UNDER KAYAMANDI BELOW COROBRICK BRIDGE ADJACENT TO PLANKENBRUG	Rivers	G22G	842	2000/07/26	2013/07/11
	CMNT-STELLENBOSCH-KROM RIVER-KR720A-AT HOLE IN THE WALL	Rivers	G22G	116	1994/02/02	2013/12/12
	CMNT-STELLENBOSCH-KROM RIVER-KR720A1-BELOW INFRUITEC	Rivers	G22G	300	1995/02/14	2013/12/12
	CMNT-STELLENBOSCH-KR720B-BEFOR E CONFLUENCE WITH PLANKENBRUG	Rivers	G22G	281	1994/02/02	2013/12/12
	CMNT- STELLENBOSCH - PR720A - AT CLOETESDAL FARM BRIDGE ON R304	Rivers	G22G	216	1994/02/02	2013/12/12
	CMNT-STELLENBOSCH-PR720B-BELOW KHAYAMANDI	Rivers	G22G	171	1994/02/02	2013/12/12
	CMNT-STELLENBOSCH-PR720C-UNDER ADAM TAS BRIDGE	Rivers	G22G	59	2004/11/22	2013/12/12
	CMNT - STELLENBOSCH - PR720D - OPPOSITE DIE BOORD SHOPPING MALL	Rivers	G22G	46	2000/05/15	2007/06/28
	G2H015Q01 AT FAURE ON EERSTE RIVER	Rivers	G22H	816	1968/06/08	2016/08/31
	G2H019Q01 AT STELLENBOSCH ON EERSTERIVIER	Rivers	G22H	136	1977/05/10	1982/05/05
	G2H020Q01 AT FLEURBAAI STELLENBOSCH ON EERSTERIVIER	Rivers	G22H	943	1979/04/17	2016/06/08
	ZANDVLIET BRIDGE DOWNSTREAM OF ZANDVLIET WWTW	Rivers	G22H	849	2000/07/26	2013/07/09

IUA	Monitoring Point Name	Type	Quat	n	First	Last
	AT DIE BOORD D/S OF EERSTERIVIER AND PLANKENBRUG CONFLUENCE	Rivers	G22H	827	2000/07/26	2013/07/11
	CMNT - ER720B2 STELLENBOSCH AT ROKEWOOD ROAD PUMP STATION ON EERSTERIVIER	Rivers	G22H	24	2006/10/19	2010/02/25
	CMNT-B0720A1 SPIER 491 STELLENBOSCH AT WINE CORP SPIER ON BONTERIVIER (SEE 1000010229)	Rivers	G22H	29	2006/10/19	2013/12/12
	CMNT-STELLENBOSCH-VR720A-AT WELGRO NURSERY	Rivers	G22H	172	1988/02/09	2013/12/12
	CMNT-STELLENBOSCH-VR720B-BELOW SOLID WASTE SITE	Rivers	G22H	162	1993/06/07	2013/12/12
	CMNT-STELLENBOSCH-VR720C-POLKE DRAAI ROAD	Rivers	G22H	144	1995/03/14	2013/12/12
	CMNT-STELLENBOSCH-ER720C-AT SFW CRICKET GROUNDS	Rivers	G22H	45	1990/05/15	2005/11/23
	CMNT-STELLENBOSCH-ER720D-ON GOEDVERTROUW FARM	Rivers	G22H	149	1995/02/14	2013/12/12
	CMNT- STELLENBOSCH - ER720E - KLEIN WELMOED AT FRANS SE WEIR	Rivers	G22H	130	1995/02/14	2013/12/12
	CMNT-STELLENBOSCH-ER720F-AT BRIDGE TO MACASSAR WWTW	Rivers	G22H	121	1995/02/14	2013/12/12
	CMNT-BO720A SPIER 491 STELLENBOSCH DIE VLEIE FARM ON BONTERIVIER (SEE 189732)	Rivers	G22H	61	1996/04/16	2006/11/30
	CMNT- STELLENBOSCH - BL720A - BLAAUKLIPPEN RIV ON DE KLEINE ZALZE FARM	Rivers	G22H	108	1996/04/14	2013/12/12
	G2H016Q01 LOURENS RIVER AT SOMERSET WEST	Rivers	G22J	300	1970/08/10	1992/06/15
	G2H029Q01 LOURENS RIVER AT STRAND	Rivers	G22J	401	1987/03/18	2015/02/26
	G2H038Q01 LOURENS RIVER AT STRAND	Rivers	G22J	700	1990/09/25	2016/08/31
	CMNT-CCT-LOURENS RIVER AT STRAND BEACH BRIDGE	Rivers	G22J	120	1996/08/06	2013/11/18
	G2H039Q01 SIR LOWRY S PASS RIVER AT GUSTROUW	Rivers	G22K	529	1990/09/25	2016/08/31
	CMNT-CCT-SIR LOWRY S PASS RIVER AT GORDON S BAY	Rivers	G22K	103	1996/08/06	2013/11/18
	G4R001Q01 STEENBRAS CATCHMENT AREA 306 - STEENBRAS DAM ON STEENBRAS RIVER: NEAR DAM WALL	Dam / Barrage	G40A	295	1968/04/05	2016/04/01
D8	G1H003Q01 AT LE MOUILLAGE LA MOTTE ON FRANSCHHOEKRIVIER	Rivers	G10A	852	1966/01/06	2010/10/07
	G1H004Q01 AT BERGRIVIERSHOEK DRIEFONTEIN ON BERGRIVIER	Rivers	G10A	962	1965/08/23	2010/10/07
	G1H038Q01 WOLWEKLOOF RIVER AT FRANSCHHOEK (TUNNEL INLET)	Rivers	G10A	761	1983/10/07	2010/10/01
	BERG RIVER TRIBUTARY SITE 1	Rivers	G10A	21	2003/01/18	2005/11/15
	BERG RIVER SITE 2	Rivers	G10A	24	2003/01/18	2005/11/15
	G1H004A02 UPSTREAM OF ROBERTSVLEI ON BERGRIVIER	Rivers	G10A	40	2003/04/03	2007/07/26
	G1H004A03 DOWNSTREAM OF SKUIFRAAM ON BERGRIVIER	Rivers	G10A	39	2003/05/01	2007/08/09

IUA	Monitoring Point Name	Type	Quat	n	First	Last
	50M D/S OF CONFLUENCE WITH STIEBEUEL RIVER ON FRANSCHHOEK RIVER	Rivers	G10A	677	2003/05/06	2013/07/09
	G1R002Q01 WEMMERSHOEK DAM ON WEMMERS RIVER: NEAR DAM WALL	Dam / Barrage	G10B	395	1968/05/11	2013/08/29
	G1R002Q02 WEMMERSHOEK DAM ON WEMMERS RIVER: POINT IN DAM	Dam / Barrage	G10B	5	1985/12/02	1986/01/13
	G1H014Q01 ZACHARIASHOEK RIVER AT ZACHARIASHOEK	Rivers	G10B	52	1975/11/28	1995/10/05
	G1H015Q01 KASTEELSKLOOF SPRUIT UPPER AT ZACHARIASHOEK	Rivers	G10B	41	1983/08/04	1998/11/05
	G1H016Q01 KASTEELSKLOOF SPRUIT LOWER AT ZACHARIASHOEK	Rivers	G10B	55	1975/11/27	1990/06/05
	G1H017Q01 ZACHARIASHOEK SPRUIT UPPER AT ZACHARIASHOEK	Rivers	G10B	45	1983/08/04	1998/09/17
	G1H018Q01 AT ZACHARIASHOEK ON BAKKERSKLOOF	Rivers	G10B	161	1981/09/10	1995/05/25
	G1H019Q01 AT JONKERSHOEK THE SANCTUARY ON BANGHOEKRIVIER	Rivers	G10C	1144	1974/09/17	2010/10/01
	G1H020Q01 AT DAL JOSAFAT NOORDER PAARL ON BERG RIVER	Rivers	G10C	1444	1965/08/25	2016/07/08
	G1H032Q01 AT BOSMANSHOEK ON BANGHOEKRIVIER	Rivers	G10C	51	1977/03/04	2002/04/18
	G1H062Q01 @ BOSMANSHOEK BANGHOEK COMPENSATION H2O & IN SHAFT	Rivers	G10C	7	1999/03/11	1999/09/30
	G1H064Q01 @ BOSMANSHOEK COMPENSATION H2O ON BANGHOEKRIVIER	Rivers	G10C	797	1983/10/07	2010/10/01
	BERG RIVER SITE 3	Rivers	G10C	2	2003/01/18	2003/01/18
	BETWEEN RAILWAY AND ROAD BRIDGES AT R45 ON DWARS RIVER	Rivers	G10C	51	2003/05/06	2004/02/19
D9	G1H007Q01 @ FARM 187 KATRYNTJIESDRIF WELLINGTON ON BERGRIVIER	Rivers	G10D	79	1965/09/01	2012/04/11
	G1H036Q01 AT VLEESBANK HERMON BRIDGE ON BERG RIVER	Rivers	G10D	1109	1978/03/08	2016/06/03
	G1H037Q01 KROM RIVER AT WELLINGTON	Rivers	G10D	633	1979/04/17	1992/06/23
	G1H039Q01 AT GRENSPLAAS DIEPE GAT ON DORINGRIVIER	Rivers	G10D	562	1979/06/12	2016/08/05
	G1H041Q01 KOMPANJIES RIVER AT DE EIKEBOOMEN	Rivers	G10D	1022	1979/09/11	2016/07/07
	D/S OF PAARL WWTW DISCHARGE AT RIVIERA FARM ON BERGRIVIER	Rivers	G10D	644	2003/05/06	2013/07/09
	BRIDGE D/S OF WELLINGTON WWTW AT OUDEBRUG PUMPHOUSE ON BERGRIVIER	Rivers	G10D	669	2003/05/06	2013/07/09
	AT PAARL DOWNSTREAM OF WWTW & INFORMAL SETTLEMENT ON BERG	Rivers	G10D	592	2004/01/08	2013/07/09
D10	CMNT-DIEP+MB-DR A-DIEP AT PAARDEBERG	Rivers	G21C	31	1998/06/08	2009/11/18
	CMNT-DIEP+MB-DR B-DIEP ABOVE MALMESBURY AT RUSTFONTEIN	Rivers	G21C	51	1997/11/25	2009/11/18
	G2H012Q01 DIEP RIVER AT MALMESBURY	Rivers	G21D	691	1966/06/19	2015/09/17
	500M D/S OF MALMESBURY WWTW DISCHARGE ON DIEPRIVIER	Rivers	G21D	658	2003/05/06	2013/07/11

IUA	Monitoring Point Name	Type	Quat	n	First	Last
	CMNT-DIEP+MB-MR720J-MOSSELBANK UPSTREAM OF DIEP CONFLUENCE	Rivers	G21D	96	1996/05/13	2005/11/16
	CMNT-DIEP+MB-DR C-DIEP IN MALMESBURY TOWN	Rivers	G21D	54	1997/11/25	2009/11/18
	CMNT-DIEP+MB-DR D-DIEP BELOW MALMESBURY WWTP	Rivers	G21D	5	2004/07/21	2005/11/16
	CMNT-DIEP+MB-DR E-DIEP AT ABBOTSDALE	Rivers	G21D	117	1997/11/25	2013/03/06
	CMNT-DIEP+MB-DR F-DIEP AT KALBASKRAAL	Rivers	G21D	74	1997/11/25	2011/08/25
	CMNT-DIEP+MB-DR G-DIEP ABOVE MOSSELBANK CONFLUENCE	Rivers	G21D	55	1997/11/25	2009/11/18
	CMNT-DIEP+MB-DR H-DIEP AT GOEDEONTMOETING	Rivers	G21D	60	1997/11/25	2009/11/18
	CMNT-DIEP+MB-DR J-SWART RIVER AT GROENRIVIER STATION	Rivers	G21D	38	1998/06/08	2009/11/18
	CMNT-DIEP+MB-DR K-UNNAMED TRIB TO DIEP EX PHILADELPHIA-G21D	Rivers	G21D	28	1999/08/03	2009/11/18
	G2H013Q01 MOSSELBANK RIVER AT KLIPHEUWEL	Rivers	G21E	336	1966/07/04	1992/03/03
	CMNT-DIEP+MB-MR720A-ON MATJIESKUIL FARM	Rivers	G21E	57	1996/05/13	2009/11/18
	CMNT-DIEP+MB-MR720B-AT ROAD BRIDGE AT FISANTEKRAAL	Rivers	G21E	74	1996/06/10	2011/08/25
	CMNT-DIEP+MB-MR720D-MOSSELBANK AT BRAAM VOERKRALE	Rivers	G21E	107	1996/05/13	2011/08/25
	CMNT-DIEP+MB-MR720G-KLAPMUTS RIVER BEFORE M/BANK CONFLUENCE	Rivers	G21E	49	1996/05/13	2009/11/18
	CMNT-DIEP+MB-MR720H-MOSSELBANK AT KLIPHEUWEL BRIDGE	Rivers	G21E	97	1996/05/13	2013/03/06
	CMNT-DIEP+MB-MR720L-KLAPMUTS RIVER AT KLAPMUTS	Rivers	G21E	21	1998/05/18	2009/11/18
	G2H042Q01 ADDERLEY 155 - ON DIEP RIVER	Rivers	G21F	104	2005/06/23	2016/06/02
	G2H014Q01 AT VISSERSHOK ON DIEPRIVIER	Rivers	G21F	315	1966/06/03	2005/05/23
	OTTO DU PLESSIS BRIDGE AT MILNERTON ON DIEP	Rivers	G21F	651	2003/05/06	2013/07/11
	CMNT-DIEP+MB-DR I-DIEP AT N7 BRIDGE	Rivers	G21F	62	1997/11/25	2009/11/18
	CMNT-DIEP+MB-DR L-DIEP AT TABLEVIEW BRIDGE	Rivers	G21F	141	1996/08/06	2011/08/25
	CMNT-DIEP+MB-DR M-DIEP AT OTTO DU PLESSIS BRIDGE	Rivers	G21F	155	1996/08/06	2013/03/06
E11	G203/01A1 KLEINPLAATS WEST 976 - 3418AB	Dam / Barrage	G22A	1	2013/04/18	2013/04/18
	G203/17A1 SILVERMINE SOURCE - 3418AB	Rivers	G22A	0		
	G203/18A1 SILVERMINE DAM INFLOW - 3418AB	Rivers	G22A	6	1988/09/06	2012/09/26
	G203/19A1 SILVERMINE RIVER FLOODPLAIN - 3418AB	Rivers	G22A	6	1988/09/06	2012/09/26
	CMNT-CCT-ELSE RIVER AT GLENCAIRN	Rivers	G22A	91	1996/01/10	2013/11/18
	CMNT-CCT-SILVERMINE RIVER AT CLOVELLY	Rivers	G22A	123	1996/08/06	2013/11/18
	G203/12A2 NOORDHOEK SOUTPAN - 3418AB	Wetland	G22A	6	1988/06/15	2012/06/27

IUA	Monitoring Point Name	Type	Quat	n	First	Last
	G203/04A1 GROOT RONDEVLEI 1 (CAPE POINT) - 3418AB	Wetland	G22A	1	2013/08/01	2013/08/01
	G203/05A1 KLAASJAGERS ESTUARY - 3418AB	Wetland	G22A	1	2013/08/01	2013/08/01
	CMNT-CCT-HOUT BAY RIVER AT BRIDGE ON PRINCESS ROAD	Rivers	G22B	192	1996/09/02	2013/11/18
E12	CMNT-CCT-ABOVE CONFLUENCE OF BLACK AND LIESBEEK RIVERS	Rivers	G22C	120	1996/10/01	2013/11/18
	CMNT-CCT-SALT RIVER OUTLET TO TABLE BAY	Rivers	G22C	114	1996/10/01	2013/11/18
	CMNT-CCT-SANDVLEI AT YACHT CLUB	Estuary	G22D	86	1996/08/06	2013/11/18
	PRINCESS VLEI CAPE TOWN	Pan	G22D	14	2005/02/09	2006/09/01
	CMNT-CCT-SANDVLEI CANAL AT ORCHARD VILLAGE	Rivers	G22D	131	1996/08/06	2013/11/18
	CMNT-CCT-SAND RIVER AT MARINA DA GAMA	Rivers	G22D	126	1996/08/06	2013/11/18
	CMNT-CCT-ZEEKOEIVLEI CANAL ON BADEN POWELL DRIVE	Rivers	G22D	136	1996/08/06	2013/11/18
	CMNT-CCT-ZEEKOEIVLEI CANAL DOWNSTREAM OF ZEEKOEIVLEI OUTLET	Rivers	G22D	95	1996/08/06	2013/11/18
	CMNT-CCT-MNANDI STORMWATER CANAL AT MNANDI BEACH	Rivers	G22D	124	1996/10/01	2013/11/18
	CMNT-CCT-LITTLE LOTUS RIVER INTO ZEEKOEIVLEI	Rivers	G22D	137	1996/08/06	2013/11/18
	CMNT-CCT-BIG LOTUS RIVER INTO ZEEKOEIVLEI	Rivers	G22D	135	1996/08/06	2013/11/18
	CMNT-CCT-KEYSERS RIVER ON MILITARY ROAD BRIDGE	Rivers	G22D	132	1996/08/06	2013/11/18
	G203/13A KENILWORTH - 3318CD	Wetland	G22D	1	2012/07/25	2012/07/25
	G2H021Q01 KUILS RIVER AT KUILS RIVER	Rivers	G22E	366	1979/04/17	1987/10/28
	100 M D/S OF BELVILLE WWTW DISCHARGE POINT ON KUILSRIVIER	Rivers	G22E	700	2003/05/08	2013/07/09
	CMNT-CTT-MONWABISI STORMWATER CANAL-MONWABISI PUMP STATION	Rivers	G22E	119	1996/08/06	2013/11/18
	G204/02A1 KHAYELITSHA POOL - 3418BA	Wetland	G22E	1	2013/03/03	2013/03/03

The water quality status assessment has been based on the routine monitoring data collected by the Department in the past 5 years. The present day water quality status at key points for the period 2010 to 2015/16 was assessed by categorising the current water quality state using the fitness for use criteria (Table 2-18). For each sampling point the median (50^{th} percentile), 75^{th} percentile, and 95^{th} percentile statistics were calculated for nine water quality variables that are of concern to the key water user sectors in the study area. The median statistic is representative of average water quality conditions, the 75^{th} percentile statistic means that 75 percent of the concentrations were lower or equal to the statistic, and the 95^{th} percentile represents the high concentrations observed at the sampling point.

The variables that were selected for the assessment were Electrical conductivity (EC), Total dissolved solids (TDS), Orthophosphate (PO_4-P), Ammonia (NH_3-N), Nitrate (NO_3+NO_2-N), Chloride (Cl-), Sulphate (SO_4), Sodium adsorption ratio (SAR) and pH.

The selection of the variables was based on the following reasoning:

- Electrical Conductivity (Ec) and Total dissolved salt (TDS) provides an indication of the salinity of water resources;

- Orthophosphate (PO_4-P) and Nitrate plus nitrite nitrogen (NO_3+NO_2-N) are indicators of the nutrient enrichment in water resources;
- Sulphate (SO_4) is an indicator of mining and industrial mining impacts, as well as sea water intrusion in coastal rivers;
- Chloride (Cl) in an indicator of agricultural impacts, sewage effluent discharges and industrial effluent impacts;
- Unionised ammonia (NH_3-N) is an indicator of aquatic ecosystem toxicity;
- Sodium adsorption ratio (SAR) is a measure of the effects of irrigation water on soil physical conditions, and
- pH (pH units) is an indicator of acidity/alkalinity, particularly mining impacts as well as natural variability.

In the IUA description, colour coded tables are used to indicate the fitness for use category of the median, and the 95th percentile concentration.

2.3.3 Status quo assessment

Waste pollution from sewerage treatment plants and informal settlements along riverbanks threaten the river systems of the study area. During the late summer months (dry season) there is too little flow left in the rivers to dilute the pollutants and with a damaged river ecology pollutants can no longer be cleaned effectively. Salinity and siltation problems occur in the rivers of the southern region of the study area. Salinity problems occur in the northern tributaries of the Berg River.

Water quality in the study area varies not only between the individual river basins but also within individual river systems. The natural geology, agricultural practises, point and non-point source pollution all play a role in determining the quality of water in this area.

Most of the rivers in the water management area rise from the Table Mountain Group mountain catchments which provide very good quality of water with total dissolved solids concentrations of less than 60 mg/l. The Berg River arises in the mountains near Franschhoek and the runoff is characterised by ideal water quality. However, the quality deteriorates in a downstream direction as a result of human activities. In Paarl (G1H020) the water is still regarded as "ideal" although phosphate concentrations are a concern. In the Upper Middle Berg area, which corresponds largely to the southern portion of the Drakenstein Municipal Area, the water quality of the Berg River has been severely impacted as a result of agricultural activities (coupled with river modification, water abstraction and runoff of pollutants), treated wastewater discharges from the Paarl and Wellington WWTW, and general urban and informal settlement developments at Paarl and Wellington. Water quality at Hermon (G1H036) is regarded as "ideal" to "acceptable" although phosphate concentrations are still unacceptably high and a concern. If WWTW are operated well and they meet their licence conditions, then their impacts tend to be low. However, if substandard or partially treated effluent is discharged, then the impacts can be substantial.

Discharges from the Paarl and Wellington WWTWs are probably responsible for the elevated phosphate concentrations in this part of the river. In the Lower Middle Berg area at Drie Heuwels (G1H013) the water quality has been severely affected by diversion weirs, disruption of flow patterns in the Klein Berg and Vier-en-Twintig Rivers, and as a result of agricultural activities (largely the building of flood-protection levees, irrigation return flows, and the use of agro-chemicals). Water quality in this reach is regarded as "acceptable" in terms of salinity. By the time the river reaches the Misverstand Weir where water is abstracted for distribution to the West Coast towns and industries at Saldanha, salinity has increased to levels where the water is regarded as "acceptable". Phosphate concentrations are still unacceptably high. Many of the lower Berg River tributaries are underlain by Malmesbury shales of marine origin and therefore have naturally high salinity concentrations. Industrial users (steel manufacturers) in the Saldanha area need to pre-treat their water before being able to utilise it in their industrial processes. Irrigators are also limited to the types of crops they can cultivate, due to increased salinity levels. Water quality in the lower Berg

River at G1H023 is poor with salinity and phosphates at “unacceptable” levels and sulphates at “acceptable” levels.

Water quality in the Klein Berg River which originates in the mountains near Tulbach is regarded as “ideal” at G1H008 where water is diverted into Voëlvlei Dam. Phosphate concentrations are high due to treated domestic and winery effluent from the Tulbach area. Nitrate concentrations are high during the winter months as a result of irrigation return flows leaching nitrates from the soils.

Treated wastewater effluents and poor quality runoff from informal and high-density settlements into the Eerste River in the Stellenbosch area is a concern. By the time the Eerste River drains into the sea, the water quality is regarded as “acceptable” in terms of salinity, phosphate concentrations are “unacceptable” and “acceptable” for ammonia and nitrates. This is a reflection of urban and intensive agricultural activities in the catchment. Serious concerns have been expressed about the microbiological quality of the Eerste River in Stellenbosch due to stormwater runoff and dry-weather flows from in informal settlements with poor sanitation services.

Water quality in the upper Diep River at Malmesbury (G2H012) is regarded as “unacceptable” in the upper reaches; a result of the geology (saline Malmesbury shales) and agricultural practices. In the lower reaches at G2H042 the river was not classified in terms of salinity and phosphates but is regarded as “acceptable” to “ideal” in terms of nitrogen compounds. The Malmesbury WWTW discharges into the middle reaches of the Diep River. The Rietvlei wetland, a highly valued ecosystem, and the Milnerton lagoon receives treated effluent from the Potsdam WWTW and its impacts are of particular concern with respect to water quality and ecosystem health.

The Lourens River, most of the Peninsula Rivers, the Cape Flats rivers and vleis have been impacted by urban runoff. The Kuils River and Salt River are also impacted by large wastewater discharges that have changed these seasonal rivers into perennial rivers. These urban rivers can probably not be rehabilitated but their condition must at least be maintained at levels that will not introduce social, health and aesthetic problems.

Water quality trends over time in the lower Berg River at G1H023 shows an increasing trend in salinity, sulphates and ammonia nitrogen. This increasing trend is probably a reflection of cumulative effects of intensive agriculture in the upper and middle Berg River catchment. In the upper Diep River at G2H012 all the variables except pH showed an increasing trend. Again this is probably a reflection increased agricultural impacts in the catchment.

High level concerns in the study area include:

- **Salinity in the middle and lower Berg River** - A significant water quality concern to irrigation and industrial users, and to a lesser extent o bulk water suppliers in the Berg River catchment is salinisation in the middle and lower reaches. This is caused by leaching from the natural geology, which from the north of Paarl and extending to the Berg River mouth, consists of Malmesbury shale, as well as agricultural practises and the wash-off of salts from irrigated and dryland agricultural lands. The problem is exacerbated during the first winter rains, when accumulated salts are washed into the river resulting in elevated salinity in Misverstand Dam where water is abstracted for domestic and industrial users on the West Coast.
- **Nutrient enrichment in the Berg River** - A further concern in the Berg River is nutrient enrichment as a result of the discharge of treated sewage effluent from WWTWs, irrigation with winery effluent and the direct discharge of winery effluent. Diffuse pollution from informal settlements in the Klein Berg catchment impacts on the quality of water diverted into Voëlvlei Dam. This has led to increasing problems with nuisance algae in Voëlvlei Dam and higher domestic water treatment costs.
- **Microbiological water quality** - Concerns have been expressed about the microbiological quality of rivers affected by treated wastewater effluent discharges, failing sewerage infrastructure, and runoff from informal settlements. Rivers such as the Plankenberg and Eerste River near

Stellenbosch, Stiebeul River near Franschhoek, and the Kuils River in Bellville are affected by poor quality effluents and runoff from informal settlements and high density settlements with poor sanitation services. Some improvements in microbial water quality have in recent time been achieved in areas such as Stellenbosch and Paarl/Wellington due to interventions by the local municipalities.

- **Water quality problems in Urban Rivers** - Many of the urban river systems in the study area serve as conduits for treated effluent discharged to the sea. The Bellville, Scottsdene, Zandvliet, Stellenbosch and Macassar WWTWs discharge treated effluent into the Kuils/Eerste River system resulting in high bacterial counts in the Kuils River (Haskins, 2014). Borcherds Quarry and Athlone WWTWs discharge into the Black/Salt River and the Potsdam WWTW discharges into the lower Diep River, which feeds into the ecologically sensitive Rietvlei wetland system. The Cape Flats WWTW discharges into the canal downstream of the Zeekoevlei outlet control weir. These rivers no longer display seasonal flow patterns, and some, notably the Black/Salt and Kuils Rivers have become severely modified. High residual nutrients can lead to eutrophication related problems such as nuisance algal growth (both free-floating phytoplankton and attached filamentous algae) and excessive growth of aquatic weeds. Other problems associated with urban rivers include leaking sewers, contaminated stormwater runoff, litter, oil and toxic spills. Solid waste and litter is another concern associated with urban rivers. The breakdown of solid waste impact on the oxygen regime as a result of decomposing organic material, bacterial loads from disposable nappies and animal wastes, poses a safety risk to recreational users, impede flow and destabilise urban river banks, aesthetic impacts, ingestion by aquatic organisms, trace metals from batteries and corroding metals, and hydrocarbon pollution from dumping used motor oil into stormwater drains.
- **Agro-chemicals and endocrine disrupting chemicals** - There are concerns about the accumulation of pesticide and herbicide residues in the surface waters, biota and sediments downstream of intensive irrigation areas. Concerns have also been expressed about the presence of endocrine disrupting chemicals (EDCs) in surface waters near intensive irrigation systems and in treated wastewater discharges. EDCs interfere with the hormonal balance of aquatic organisms and can be found in the breakdown products of pesticides, pharmaceuticals, natural and synthetic hormones, plasticizers, cosmetic products, household products and industrial chemicals. Persistent organic pesticides and EDCs are not monitored in a routine basis in the study area although research have been conducted on EDCs in Western Cape Rivers.

2.4 Estuaries

2.4.1 Approach

This section provides a broad level overview of the current state of knowledge (based on published reports) of the eight significant estuaries within the study area. It does not include detailed descriptions of each estuary, which can be found elsewhere, e.g. ecological reserve determination (RDM) studies and situation assessment reports for estuary management plans (EMPs). This desktop report provides a comparative account of the different types of estuaries, the biota inhabiting them, anthropogenic impacts, the current ecological health and conservation status of the significant estuaries found within the study area.

Key resources used in compiling this chapter include the Estuaries of the Cape (Eds: Heydorn & Morant) series published by the CSIR and the South African National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component (Van Niekerk & Turpie 2012), and the various Situation Assessment reports and Management Plans that have been developed for these estuaries (Anchor Environmental Consultants 2008, 2009, Coastal & Environmental Consulting 2010a, b, 211a, b).

2.4.2 Description

There are several classifications of estuaries in terms of their physical characteristics. The geomorphological classification used by Harrison et al. (2000) recognises six main types based on mouth condition (open or closed), size and the presence of a bar. Whitfield's (1992) better known classification recognises five types based on size of the tidal prism, mixing process and salinity (Box 1). Of these, estuarine bays, permanently open estuaries and river mouths tend to remain open to the sea on a permanent basis, whereas estuarine lakes and temporarily open/closed systems close periodically, sometimes for periods of years. Temporally open estuaries comprise the largest group of estuaries in South Africa (222 systems, 77%), while the other groups account for a much smaller proportion (23%, Table 2-19).

Table 2-19. Typical characteristics of the five types of estuaries defined by Whitfield (1992) and their relative prevalence in South Africa (289 estuaries) Turpie *et al.* 2012.

Type	Typical size	Typical mouth condition	Number in South Africa	%	Total area (ha)	%
Bay	Large	Open	3	1%	5 118	6%
Permanently open	Med to large	Open	44	15%	17 944	20%
River mouth	Small to large	Open	11	4%	4 947	5%
Lake	Large	Closed	9	3%	56 205	62%
Temporarily open	Small to med	Closed	222	77%	6 631	7%
TOTAL			**289**		**90 844**	

Box 1. Whitfield's (1992) Physical Classification of Estuaries

Type	Tidal prism	Mixing process	Average salinity *
Estuarine Bay	Large (>10 x 10^6 m^3)	Tidal	20 - 35
Permanently Open	Moderate (1-10 x 10^6 m^3)	Tidal/riverine	10 - >35
River Mouth	Small (<1 x 10^6 m^3)	Riverine	<10
Estuarine Lake	Negligible (<0.1 x 10^6 m^3)	Wind	1 - > 35
Temporarily Open	Absent	Wind	1 - > 35

* Total amount of dissolved solids in water in parts per thousand (ppt) by weight (seawater = ~35)

(a) ***Estuarine bay:*** Water area exceeds 1 200 ha. Natural bays (Knysna) and artificially formed bays (Durban Bay) are permanently linked to the sea and the salinity within them reflects this. Hypersaline conditions are not common and water temperatures are strongly influenced by the sea. Marine and estuarine organisms dominate these systems and extensive wetland/mangrove swamps occur.

(b) ***Permanently open estuaries:*** Vertical and horizontal salinity gradients are present and are modified by the river flow, tidal range and mouth condition. Wetlands (salt marshes), as well as submerged macrophyte beds are common and the fauna is predominantly marine and estuarine. Hypersaline conditions in the upper reaches can occur during times of severe drought. Water temperatures in this estuary type are controlled by the sea during normal conditions and by river input during flood conditions.

(c) ***River mouths:*** Riverine influences dominate the physical processes in these estuaries. Oligohaline conditions are often found. The mouth is generally permanently open but the tidal prism is small and strong riverine outflow prevents marine intrusion. During strong flood conditions the outflow of these mouths can influence the sea salinity for many kilometres. Heavy silt loads are frequent in these estuaries often resulting in shallow mouths (<2m). Water temperatures are strongly influenced by river inflow although the sea can influence bottom waters.

(d) ***Estuarine lakes:*** Water area exceeds 1 200 ha. These are usually drowned river valleys filled in by reworked sediments and separated from the sea by vegetated sand dune systems. The dune can result in complete separation of the lake from the sea that then results in a loss of estuarine characteristics and the system can be referred to as a coastal lake. Estuarine lakes can be either permanently or temporarily linked to the sea and salinity within them is highly variable. Freshwater input, evaporation and the magnitude of the marine connection are the main causes of this large salinity fluctuation. The tidal prism is small, and marine and river input have little influence on water temperatures, which are directly related to solar heating and radiation. Estuarine, marine and freshwater organisms all occur depending on the salinity condition of the system.

(e) ***Temporarily open estuaries:*** Sand bars often form in the mouths of these estuaries blocking off connection with the sea. Sand bars form as a result of a combination of low river flow conditions and longshore sand movement on the adjacent coast. Flooding is frequently the cause of mouth opening, which also results in large amounts of sediment removal. However, infilling from marine and fluvial sediment can be rapid. Hypersaline conditions occur in these estuaries during times of drought. Tidal and riverine inputs control the water temperature in these systems when the mouth is open, but is independent of them when the mouth is closed. Marine, estuarine

The study area experiences a Mediterranean climate with short wet winters and long dry summers. Average rainfall increases to the south and east of the catchment and most of the significant estuaries within the study area are found within the CCT borders (Figure 2.14).

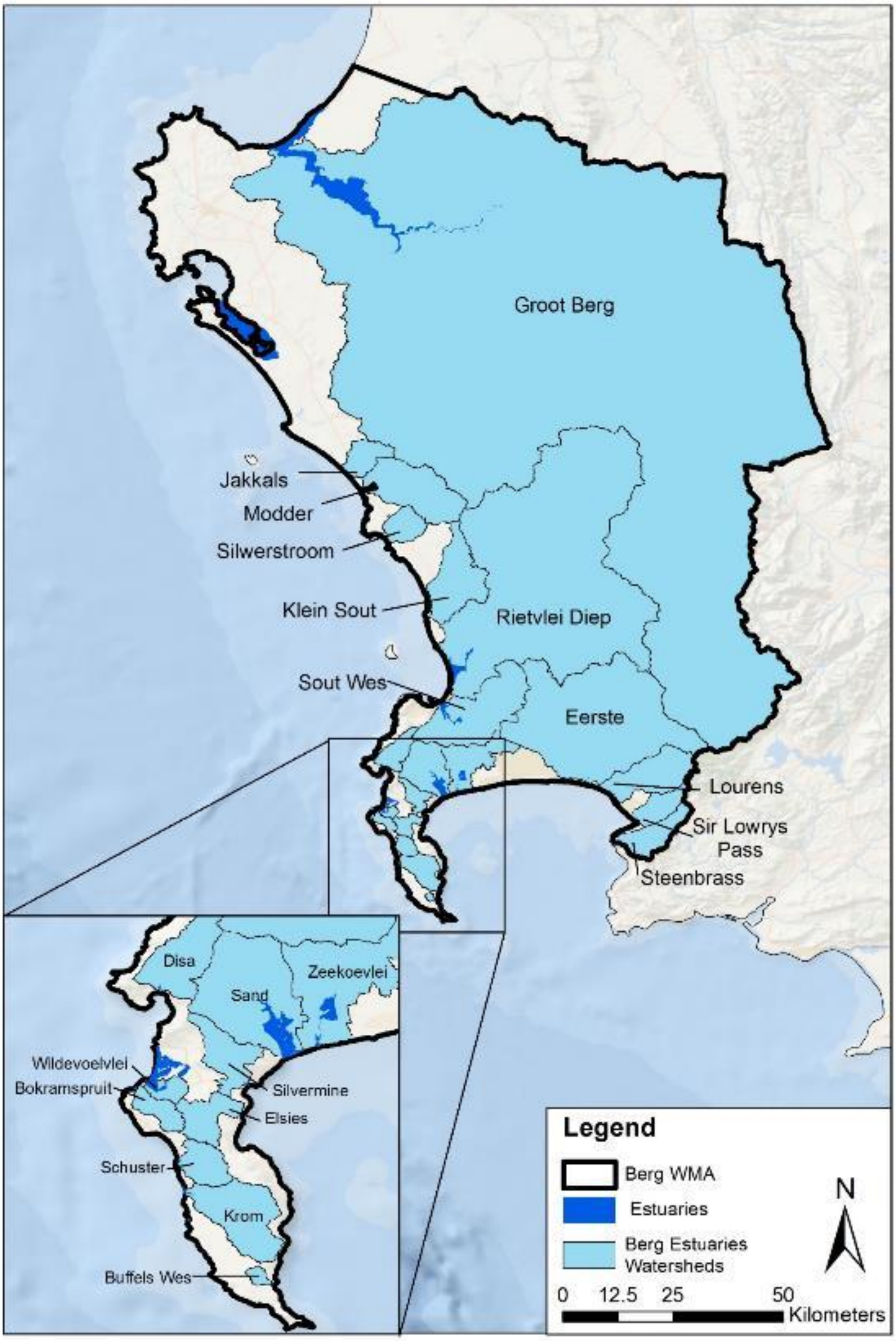


Figure 2.14. **Locations and catchment extent of the eight significant estuaries within the study area.**

The eight significant estuaries within the study area include two permanently open systems (Berg and Zeekoe), one estuarine bay (Langebaan) and five temporarily open estuaries (Table 2-20).

Table 2-20. Catchment and estuary dimensions, mean annual runoff (MAR) and estuary type of the eight significant estuaries within the study area. MAR excludes WWTW inputs.

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

2.4.2.1 Permanently open estuaries

Berg

The large catchment of the Berg estuary includes mountainous areas within the Cape Fold Mountains where three major dams have been built, including the Wemmershoek Dam (66 ML), the Vöelvlei Dam (170 ML), and the Berg River Dam (130 ML). Numerous smaller farm dams are also found throughout the catchment, the majority of which is natural vegetation (42%) and cultivated land (54%). In total the Berg River is 285 km long, and with exception of the mountainous upper catchment, the remainder of the catchment is largely flat. The Berg River flows northwest past the towns of Paarl and Wellington, crosses the coastal plain and finally enters the sea at the town of Laaiplek on the shore of St Helena Bay. The estuary has a very flat gradient and extends some 69 km inland (as defined by tidal action) from the canalised mouth, whilst seawater penetration extends a maximum of approximately 40 km inland during low flow periods (Anchor Environmental Consultants 2008).

The Berg estuary is flanked by an extensive, seasonally-inundated floodplain up to 4 km wide that together with the large estuary channel makes up the largest estuary functional zone within the study area (Table 2-20). The present-day annual runoff of the Berg River is estimated to be around 562 Mm^3/a, about 20% lower than under natural conditions. Historically runoff was probably sufficient to ensure that the mouth remained permanently open, whilst canalization and dredging for the fishing harbour ensures that the mouth now remains open despite reduced flows.

Zeekoe

The Zeekoe catchment encompasses the Big and Little Lotus Rivers, Zeekoevlei and Rondevlei. Under historical conditions, movement of estuarine biota, particularly fish such as mullet, white steenbras and eels, into both Zeekoevlei and Rondevlei apparently occurred (Bickerton 1983). The estuary channel now extends from the Zeekoevlei weir (that prevents upstream movement of estuarine biota into the vleis), to the sea, a distance of approximately 3 km.

There has been little reduction in MAR from reference conditions (current runoff is estimated at 93 % of reference), but the estuary also receives effluent from the Cape Flats Waste Water Treatment Works (WWTW) approximately 400 m upstream from the estuary mouth. This additional freshwater input (a monthly average of 3.6 Mm^3) severely limits sea water penetration up the estuary and effectively precludes the development of estuary conditions above this point. The effluent quality has resulted in degradation of this system, and these additional flows also ensure that the Zeekoe mouth remains permanently open. The estuary is surrounded by City infrastructure including the Coastal Park Landfill site to the north and the Cape Flats WWTW to the north east. Baden Powell Drive crosses the Zeekoevlei estuary outlet channel a short distance upstream of its entry point to the sea. The outlet channel has been reinforced on the eastern side to constrain meandering. Meandering to the west sometimes occurs and this threatens the coastal dune cordon and Baden Powell Drive. Due to this, the mouth occasionally needs to be manipulated or redirected more directly to the sea.

2.4.2.2 Temporarily open estuaries

Rietvlei/Diep

The mouth of the Diep Estuary enters the sea in Table Bay, approximately 5 km north of Cape Town Central Business District (CBD). The estuary is made of two main sections – Rietvlei and Milnerton Lagoon (the estuary channel) which together with the associated floodplains cover an area of approximately 834 ha (Table 2-20). The predominant land use within the catchment is agriculture; however, the area immediately surrounding the estuary is mainly urban residential and industrial areas. The estuary itself lies within a reserve proclaimed in terms of NEM:BA Section 23 as a local Nature Reserve which is protected in perpetuity and managed by the City's Biodiversity Management Branch (Environmental Resource Management Department).

The Diep River catchment is the second largest in the study area and extends from the Riebeek Kasteel Mountains in the north-east to the Durbanville Hills in the South-west (Table 2-20). The main tributaries of the Diep River are the Mosselbank, Swart and Riebeeks rivers; however all these tributaries merge into the Diep River before entering the top of estuary. Despite the large catchment, MAR is relatively low and the Diep River in its upper catchment dries up completely in summer months due to low rainfall and agricultural abstractions (Table 2-20).

Historically the Diep estuary was considerably deeper, had two mouths and was connected to the Salt River (forming Paarden Eiland) with which it shared the second mouth (Grindley and Dudley 1988). Present day runoff has been reduced to 61% of reference flows, but discharges from the Potsdam WWTW (~1.6 $Mm^3.month^{-1}$) keep the mouth permanently open in the present day and has led to a decline in the salinity of the estuary (Viskich et al. 2016).

Wildevoelvlei

The Wildevoelvlei estuary comprises the two connected vleis, a 0.75 km estuary channel and the backshore lagoon on the southern half of Noordhoek beach. There is no defined river that feeds into the Wildevoelvlei although there is evidence that a relic connection existed between the Wildevoelvlei, the Lakes (previously the Noordhoek saltpans, which are now enclosed within a private gated residential development know as Lake Michelle) and Papkuilsvlei (Heinecken 1985). Under natural conditions the Wildevoelvlei comprised of a series of seasonal pans. Data collected in the 1970s shows the pans to be hypersaline (TDS >150 mg/l) and nearly empty (Heinecken 1985). Since the construction of the municipal Wildevoelvlei WWTW in 1976 the Wildevoelvlei estuary has contained water perennially, with nearly all the summer inflow attributed to treated effluent (Heinecken 1985).

Natural runoff from the catchment has not been reduced significantly compared to the reference flow (94%) and the catchment is mostly (74 %) natural vegetation with 25% urban development. Prior to the construction of the WWTW, sea water ingress into the Wildevoelvlei occurred during high tides with saline waters, seaweed and other marine flotsam present (Heinecken 1985). The estuary has become increasingly freshwater dominated with monthly average wastewater volumes of 0.28 Mm^3 limiting sea water penetration, probably to the backshore lagoon area. The mouth does still close when a sandbar forms during the summer months, and the estuary then drains into the backshore lagoon.

Sand

The catchment of the Zandvlei estuary is approximately 92 km^2 and bordered by Muizenberg Mountain, Silvermine Plateau and Constantiaberg to the West, Wynberg Hill to the North with a smaller, less noticeable eastern boundary (Table 2-20). The main streams draining the catchment and feeding into the Zandvlei are the Westlake Stream, Keysers River, and the combined Langvlei Canal and Sand River Canal. The estimated contribution of flow for each river is about 45%, 43% and 12% coming from the Keysers, Sand and Westlake rivers respectively (Coastal & Environmental Consulting 2010a). The current MAR is estimated at 93% of the reference condition and there are no WWTWs discharging into the estuary or its source rivers. The estuarine area is located within an area that has been proclaimed in terms of NEM:BA Section 23 as a local Nature Reserve which is protected in perpetuity and managed by the City's Biodiversity Management Branch (Environmental Resource Management Department). A residential development known as Marina da Gama is located along a series of artificial canals that are linked to the main estuary body on the eastern edge. Under natural conditions the estuary was temporarily open and during the open mouth phase, there would have also been a significant tidal influence through the estuary mouth. This tidal influence is now greatly altered due to canalization, the presence of a low rubble weir and artificial mouth management. The latter management of the mouth of the Zandvlei estuary is undertaken in order to meet and balance different objectives, including protecting a sewage pipeline which traverses the base of the estuary near the mouth, allowing recreational activities to occur in the estuary as well as protecting lower lying buildings in the Marina da Gama area from potential flood damage. These largely human requirements are also balanced with the need to ensure the system maintains some estuarine characteristics such as saline influence and facilitating the movement of estuarine species into and out of the system.

Eerste

The combined catchments of the Kuils and Eerste Rivers that feed the Eerste estuary are approximately 628 km^2, making it the third largest catchment within the study area (Table 2-20). The Eerste River catchment is predominantly agricultural land, whilst low income, high-density, urban industrial, commercial and residential areas dominate in the Kuils River catchment. There are also a number of informal settlements located within both the Kuils and Eerste catchment areas, some of which border directly on the river or its tributaries.

The Eerste River meanders through the coastal dunes near Macassar and then forms an elongated lagoon in the slack of the backshore area of the beach. The extent of the lagoon and the location of the mouth are both highly variable depending on outflow as well as wind and wave action. Present day MAR is estimated at 88% of reference condition but this excludes the substantial input from five WWTWs within the catchment (one of which, the Mancasser WWTW discharges directly into the estuary) that process approximately 50 Mm^3.year^{-1}. Historically the Eerste estuary was a temporary open system and seawater intrusion created estuarine conditions up to 2.5 km from the mouth (CCT 2014). In the present day, the mouth of the estuary remains open due to the additional flow provided by the WWTWs, and there is limited tidal influence into the estuary. Sea water can only penetrate into the estuary under certain mouth and river flow conditions. Water quality in the estuary has been significantly impacted by WWTW effluent discharges and many other land use activities in the contributing catchment area.

Lourens

The catchment for the Lourens Estuary is approximately 92 km^2 (Table 2-20). The upper reaches of the Lourens River begin in mountains where the natural vegetation is mainly intact and under conservation in the Hottentots Holland Nature Reserve. The river then flows through mostly agricultural land, cuts across the flat coastal plain through the towns of Somerset West and Strand before emptying into False Bay.

At the mouth of the Lourens River, a small estuary of approximately 0.7 km^2 forms in the slack of the beach bar. The lagoon that forms is usually along the east/west orientation and is approximately 300 m long and 30-40 m wide. The beach sand bar is built up by the strong wave action and often the channel must extend some several hundred metres to find a low-lying course to the sea. Present day runoff is about 85% of reference flows and no longer receives any WWTW discharge (Strand WWTW closed in 1978) The estuary mouth is open most of the year, however was known to close periodically during dry summer months in the past (Cliff and Grindley 1982).

2.4.2.3 Estuarine Bays

Langebaan

Classification of the 16 km long Langebaan Lagoon that adjoins Saldanha Bay on the West Coast about 100 km north of Cape Town, has been debated for some time. At 3-4 km wide, with channels 5 m deep, the system is larger than conventional lagoon, whilst saltmarsh (*Sarcocornia* and *Spartina* spp.), reed (largely *Phragmites australis)* and sedges (*Juncus kraussii*) vegetation on the eastern and southern margins of the system reveal the influence of substantial groundwater input (Van der Linden 2014, Van Niekerk and Turpie 2012). There is however, no clear salinity gradient in the lagoon which remains 33-35 (equivalent to sea water) throughout most of its length (Christie 1981).

Detailed salinity monitoring in the vicinity of estuarine vegetation has however, not been undertaken to date. In addition to the groundwater input, Langebaan does have many characteristics of an estuary in that the waters are sheltered and during the summer months are sun warmed to well above that of the surrounding ocean. Langebaan Lagoon is connected to Big Bay Saldanha by two channels either side of Schaapen Island. Water exchange with Big Bay is tidally driven with high currents occurring in this region (Anchor Environmental Consultants 2016). Thermal stratification during summer prevents ingress of cooler, deeper marine water that contains high levels of dissolved nutrients (nitrates and phosphates) due to coastal upwelling. As a result the water remains clear throughout much of the lagoon and benthic microalgae and submerged macrophytes (mostly *Gracilaria gracilis* and *Zostera capensis*) are important generators of primary production. Both the NBA (Van Niekerk and Turpie 2012) and Van der Linden (2014) recommend that Langebaan should be considered a unique estuarine system. In this study, Langebaan Lagoon is considered an Estuarine Bay as it meets the definition provided by Whitfield (1991) with marine dominated physical and biotic components. With just over 4 000 ha of open water, Langebaan comprises the largest estuary channel area within the study area and the second largest estuarine functional area (Table 2-20).

2.4.3 Status quo assessment

2.4.3.1 Estuarine biota and their distribution in relation to the estuaries of the study area

Estuarine biogeography

South African estuaries fall within three biogeographical zones: the Cool Temperate zone on the west coast, the Warm Temperate zone which extends approximately from Cape Point to the Mbashe River in the Eastern Cape, and the Subtropical Zone on the east coast (Figure 2.15). While relatively high numbers of estuaries are found in both the Warm Temperate and Subtropical zones, dry climatic conditions result in relatively few estuaries in the Cool Temperate zone on the west coast. In general, estuaries increase in density along the coast from west to east. Estuaries within the three zones have been shown to have relatively distinct faunal communities, and have also been found to differ significantly in their physico-chemical characteristics (Harrison 2004). Estuarine water temperatures follow the trend for marine coastal waters, being coldest on the west coast. Warm temperate estuaries are characterised by high salinities and low turbidities due to low rainfall and runoff, high seawater input and evaporative loss, while cool temperate, and especially subtropical, estuaries tend to have lower salinities and higher turbidity, due to relatively high runoff (Harrison 2004). The study area estuaries fall entirely within the cool temperate zone.

Figure 2.15. Distribution of estuaries in relation to the three biogeographic zones and secondary catchment areas (Turpie *et al.* 2012). Not all estuaries are labelled on this map.

Microalgae

With the other primary producers, microalgae are at the base of the food web and they are therefore of major importance to the ecological functioning of every estuary. The important microalgae groups are the microphytobenthos (sediment-associated microalgae), phytoplankton (water-column based) and epiphytes (attached to plants). High biomass is generally dependent on stable water and high light conditions and increases in response to nutrient inputs. Phytoplankton biomass in temporarily closed estuaries tends to be lower than in permanently open estuaries whilst the converse is true for benthic microalgae. Large changes in microalgae biomass occur in response to the alternation of open and closed mouth phases in temporarily closed estuaries. Microalgae biomass is controlled by invertebrate and fish grazing. In some temporarily open/closed estuaries, zooplankton can graze up to 70% of the available phytoplankton biomass (Kibirige and Perissinotto 2003). Microalgae distribution and abundance are influenced by a host of factors including salinity, water volume and velocity, sediment type, turbidity (light penetration), nutrient availability and biological interactions (particularly grazing) (Table 2-21).

Table 2-21. Key drivers influencing the composition and abundance (and biomass) of microalgae in estuarine systems (Source: Clark *et al*. 2014).

Microalgae group	**Key drivers**			**Other influencing factors**
Benthic microalgae	Stable sediment *Strong flow (> 5 m^3 s^{-1}), water movement from winds or tides will result in suspension of sediment and low biomass.*	Nutrients *High biomass is associated with nutrient rich conditions often indicated by*	High light conditions *Turbid waters will limit subtidal benthic microalgae biomass. However this is not a*	Grazing by zooplankton, benthic macrofauna and fish.

Microalgae group	Key drivers			Other influencing factors
		muddy organic rich sediments.	*limitation in the intertidal zone.*	
Phytoplankton	Water volume *No water means no phytoplankton.*	Nutrients *Biomass increases in response to available nutrients.*	High light conditions *Phytoplankton biomass is higher where irradiance is high.*	Grazing by zooplankton.
Epiphytes	Available host substrate *Submerged macrophyte and inundated emergent vegetation area available for colonization.*	Nutrients *Biomass increases in response to available nutrients.*	High light conditions *Necessary for photosynthesis and growth.*	Grazing by zooplankton, benthic macrofauna and fish.

Limited research has been conducted on microalgae within the estuaries of the study area. The exception is the Berg estuary that was the focus of research by Adams & Bates (1994 & 1999) in a comparative study of phytoplankton and benthic microalgae in estuarine systems in the Eastern and Western Cape provinces. Diatoms, flagellates, dinoflagellates, euglenoids, green and blue-green algae groups are found in estuaries, but diatoms are probably the most responsive to changes in water quality, whilst flagellates and dinoflagellates increase in abundance when stratification and lower nutrient levels set in (Adams & Bates 1999). In the summer months the lower Berg estuary receives substantial nutrient input from the inflowing upwelled sea water during flood tides that supports large blooms of coastal marine species. During winter months riverine nutrient input is increased, which has a positive effect on microalgae production; but turbidity also increases and water retention times decrease, both of which have negative effects on production. The large intertidal mudflats on the Berg estuary support benthic microphytobenthos in areas where macro algal mats are not dominant. Chlorophyll-a values in the Berg estuary averaged 56 $mg.m^{-2}$ on intertidal areas and 26 mg.m-2 in subtidal mudflats, which is low (25-50%) of the average values reported for six other estuaries in the Southern and Eastern Cape (Goukou-Sundays) (Adams & Bates 1999).

All of the other open and temporary open estuaries in the study area generally have high microalgae abundance due to the excessive nutrient input from WWTWs, agricultural and urban runoff. “Problem blooms” of (sometimes toxic) blue green algae Cyanophyceae sometimes develop in the Rietvlei/Diep, Wildevoelvlei and the Sand estuaries during low flow, high temperature, summer periods, whilst a golden algal *Prymnesium parvum* bloom in the Sand estuary during 2012 led to fish kills (www.capetown.gov.za). The 2012 desktop National Health Assessment rated microalgae health as “Fair” in the Berg estuary and “Poor” in the Rietvlei/Diep, Wildevoelvlei, Sand, Eerste and Lourens estuaries. The microalgae communities in Langebaan Lagoon was studied by Christie (1981) and Fielding et al (1991). Benthic microalgae (mostly diatoms) in Langebaan Lagoon are found as deep as 30 cm below the sediment surface, attributed to high levels of bioturbation by macroinvertebrates (mostly prawns) (Fielding et al 1991). Production by benthic microalgae ranges from 63-253 g $C.m^{-2}$ $year^{-1}$ and rivals that of phytoplankton, producing 22% of the primary production in the Lagoon (Fielding et al 1991). Phytoplankton production followed the summer trend in nitrate concentration and decreases from the mouth of the lagoon up towards the southern end, ranging from 12-115 g $C.m^{-3}$ $year^{-1}$ (Christie 1981). Phytoplankton contributes an estimated 23% of the primary production of carbon (Fielding et al 1991). The balance of primary production (55%) is attributed to macrophytes, mainly saltmarsh *Sarcocornia* species, *Spartina* and *Gracilaria* (Fielding et al 1991).

Macrophytes

Macrophytes are important as primary producers; they produce detritus, modify the physical environment and create a variety of habitats for estuarine biota. Submerged macrophytes provide a substratum for epiphytes, which in turn provide food for invertebrate fauna and refuge for juvenile fish. The extensive reed and sedge habitats that are often associated with estuaries stabilise banks and prevent erosion. Macrophytes also play an important role in carbon sequestration, wave attenuation, shoreline protection, sediment trapping, turbidity reduction, nutrient cycling and nutrient export. Groundwater fed communities consists of reeds, sedges and grasses. Key drivers for the different macrophyte components are salinity, nutrients, sediment type, water level and velocity and grazing (Table 2-22). Major groups of macrophytes found in estuaries include macroalgae, submerged macrophytes, reeds & sedges, grass & shrubs, salt marsh (succulent), swamp forest, and floating macrophytes.

Table 2-22. Key drivers influencing the distribution and abundance (and biomass) of macrophytes in estuarine systems. (Source: Clark *et al*. 2014).

Group	Key drivers			Other influencing factors
Macroalgae	**Depth/ water level** Available habitat decreases in response to drop in water level. Light availability is affected too	**Water velocity** Optimum velocities for growth are between 0.5 and 0.8 m s^{-1}	**Nutrients** Respond rapidly to an increase in nutrients	**Salinity** Occur over a wide range of salinity 0-40
Submerged macrophytes	**Depth / water level** Occur at water depth < 1.2 m and > 0.5 m but dependent on available light, sensitive to exposure and desiccation	**Water velocity / sediment stability** Unstable sediment at > 1 m s^{-1} and no colonization	**Salinity** *Ruppia cirrhosa* (<50) *Stukenia pectinata* (<20) *Zostera capensis* (15-45)	**Turbidity and nutrients** High silt load will reduce light available to the plants. Respond rapidly to an increase in nutrients
Reeds & sedges	**Salinity** Grow best at a salinity <20	**Depth/water level** Will die if permanently inundated > 3 m	**Groundwater seepage and nutrients** Groundwater provides favourable waterlogged habitats	Shading by swamp forest can reduce growth and expansion. Strong waves can reduce cover. Grazing of new shoots as well as fire can cause damage.
Grass & shrubs	**Salinity** < 20 ideal for growth and expansion	**Water level** A water level >1.5 msl will cause die-back. Saline grasses are better adapted to submerged conditions than succulent salt marsh.	**Grazing** Grazing by mammals and aquatic herbivores	Loss of habitat due to invasive plant species.
Salt marsh (succulent)	**Salinity** Grow best in saline soils (10-35). Salt crusts prevent seedling establishment	**Water level** Inundation >3 months will kill salt marsh. Sensitive to desiccation.	**Dry sediment** Adapted to survive saline, dry soils	.
Swamp forest	**Salinity** Prefer low salinity conditions <10	**Water level** Prolonged inundation has negative effect on growth	**Water flow** Prefer flowing water to standing water	Groundwater seepage is important for maintenance of suitable conditions

Floating macrophytes	Water velocity	Salinity	Water depth	Nutrients
	Optimum velocities for growth are below 0.5 m s^{-1}	Restricted to areas where < 5	Restricted to shallow waters between 0.5 and 1.2 m	Invasive aquatics respond rapidly to an increase in nutrients

Macroalgae

Macroalgae in estuaries may be intertidal or subtidal, attached or free floating. Genera such as *Enteromorpha*, *Chaetomorpha* and *Cladophora* are common mat forming algae, although they require a firm substrate for initial cell attachment and filament growth. They have wide salinity tolerance ranges and are often indicative of non-turbulent water (closed mouth conditions) and nutrient enrichment. Inorganic nutrients (especially N and P) are known to stimulate the abundance of ephemeral and epiphytic macroalgae in shallow coastal waters. *Ulva*, *Enteromorpha* and *Cladophora* often form accumulations due to their filamentous nature and higher nutrient uptake rates than thicker algae (Karez et al. 2004). These accumulations can reduce the water quality of estuaries, not only by depleting the oxygen in the water column upon decomposition but also causing anoxic sediment conditions when large mats rest on the sediment under low flow conditions (Sfriso et al. 1992). Proliferation of macroalgae often peaks in the late summer/autumn period when temperatures and nutrient retention due to low flows are highest, thereafter they rapidly scenese. Decaying mats of filamentous algae have been shown to adversely impact the social acceptability of water in estuaries and are often the reason for the manipulated opening of estuary mouths (Adams et al. 1999).

During the warmer summer months large macro algae mats form on mudflats and sandbanks of the lower Berg estuary. These algal mats were erroneously identified as being from the genus *Cladophora* in the past but have recently been confirmed as comprising two species of *Enteromorpha* - *Enteromorpha prolifera* and *E. flexuosa* (Clark et al. 2008). *E. flexuosa* is a common in northern European estuaries but has not previously been recorded in southern Africa and is most likely an introduced (alien) species. *Enteromorpha prolifera,* however, is an indigenous species. There is some evidence to suggest that the abundance of these macroalgae in the Berg estuary is increasing, which is of some concern given that they tend to cover large areas of sand and mud flat and either kills the invertebrates that live in these areas or at least prevent the birds that feed on these species from accessing their main food source (DWAF 2007). Similar macro algae mats occur in all the other estuaries throughout the study area during summer months when flow rates are low or closed mouth conditions develop. The exception is Langebaan Lagoon with its marine dominated waters and strong tidal flushing does not develop these macro algal mats on the intertidal sandbanks.

Submerged macrophytes

The distribution of submerged macrophytes is controlled by water depth, turbidity and velocity, salinity, nutrient and light availability, substratum and temperature. High water clarity, low sedimentation rates and low water velocity are optimum growing conditions for submerged macrophytes. Two types of growth forms for submerged macrophytes exist: meadows and canopies. Meadows are characterized by basal meristems and biomass is distributed equally over depth. Examples include *Zostera* and *Ruppia*. Canopies however have apical meristems and their biomass is concentrated towards the canopy or surface (*Stuckenia*) (Madsen et al 2001). The two forms have significantly different effects on water flow and sediments; therefore a distinction between the two is important (Madsen et al 2001). Loss in substratum, refuge, the associated biota and productivity generally result if there was a loss of submerged vegetation such as *Ruppia* (Tyler-Walters 2001).

Current velocity also has an effect on suspended sediments and turbidity of the water (Jha 2003). It has been shown that light is limiting to submerged macrophyte growth and turbidity is a significant factor that limits light availability. Re-suspension of sediment is caused by an increase in current velocity, which reduces the amount of light available for growth and prevents gas exchange. Macrophytes can however, also decrease the current velocity and therefore turbidity, via sedimentation (Madsen et al. 2001). Silt carried in by river flow, phytoplankton blooms and the re-suspension of sediment all cause an increase in turbidity. Reductions in submerged macrophyte biomass are expected when high turbidity conditions exist over long periods, however if plant matter remains, regrowth can take place once favourable conditions return (Boardman 2003). Conversely, a decrease in the suspended sediment concentration will increase water clarity and therefore growth of the submerged macrophyte (Tyler-Walters 2001).

Nutrient sources for uptake by submerged macrophytes are possible by both sedimentary and aqueous solutions. The two most important nutrients for the maintenance of growth of submerged macrophytes are nitrogen and phosphorous. Nutrient enrichment may however stimulate epiphyte growth and phytoplankton blooms that will shade out light, increase turbidity and compete for nutrients, which will have negative effects on the productivity of the submerged macrophytes. *Stuckenia pectinata* grows in nutrient enriched, low oxygen waters with high nitrogen and phosphorus concentrations (Tyler-Walter 2002). The ideal salinity range for the submerged macrophyte *Zostera capen*sis is 10 to 46 ppt and 0 to 55 ppt for *Ruppia cirrhosa* (Adams and Bate 1994). *Stuckenia pectinata* grows best in salinities of less than 20 ppt (Gordon et al. 2008). *Ruppia* seeds require a short period of low salinity to germinate, therefore seasonal variation in salinity is necessary for the growth of the species (Boardman 2003). *Stuckenia* species are known to replace R*uppia* in low salinity habitats if turbidity is high (Tyler-Walters 2001) and vice versa in salinities greater than 16 (Kantrud 1990).

Excessive nutrient inputs from WWTW have negatively impacted submerged macrophyte communities in several of the estuaries within the study area (Diep, Wildevöelvlei Zeekoe and Eerste), whilst in others e.g. the Sand estuary, excessive macrophyte growth (e.g. *Potamogetan pectinatus*) is problematic due to the system being used for recreational activities and annual harvesting from defined areas around the vlei and adjacent residential marina is undertaken in terms of a protocol which also identifies ‘nursery’ areas which are never (or only infrequently) harvested. Macrophyte communities in Langebaan lagoon and the Berg estuary are in a much healthier state than other estuaries within the study area. Recent studies however have shown that the aerial extent of seagrass *Zostera capensis* beds in Langebaan Lagoon has declined by an estimated 38% since the 1960s, this being more dramatic in some areas than others (e.g. seagrass beds at Klein Oesterwal have declined by almost 99% over this period). Corresponding changes have been observed in densities of benthic macrofauna and some waders that utilize sea grass habitat (Anchor Environmental Consultants 2015). The Berg and Langebaan estuaries are two of only seven estuaries nationally that are considered to have large areas of *Zostera capensis*, whilst Langebaan is one of the only two areas (Knysna is the other) to have formal protection (Adams 2016).

Reeds and sedges

Reeds and sedges serve as important habitats for bird, invertebrates and fish species. Their distribution is dependent on a number of factors such as water depth, salinity, light availability, sediment type and nutrients (Adams & Riddin 2005). The maximum salinity concentration that reeds and sedges can tolerate is 25 ppt. *Phragmites australis* is the dominant reed in South African estuaries and grows optimally from 0-15 ppt (Adams and Bate 1999) and is found at freshwater seepage sites (Adams 1994, Nondoda 2012). An increase in salinity significantly decreases shoot height and overall plant growth (Adams & Riddin 2005).

Waterlogged conditions are necessary for growth of these emergent macrophytes and death is predicted after one month if they do not persist. Conversely, death is also inevitable if plants are completely covered (submerged) for a month or more (Adams 1994). Wave action also has an effect on growth and distribution of reeds, sedges and pondweed. Their adaptations to withstand wave action include flexibility (for bending), nodes which add stabilisation, strength of the plant and the formation of dense stands (Adams & Riddin 2005).

Extensive reed beds dominated by *Phargmites australis* and *Typha capensis* (the bulrush) are prevalent along the middle and upper reaches of all estuaries within the study area (Table 2-23). With the exception of Langebaan that receives groundwater input, reed beds appear to have expanded considerably in the remaining significant estuaries within the study area (CCT 2014). Increased nutrient input, sedimentation and freshwater from WWTW are probable causes of reed bed expansion. Reed beds are an important habitat especially for birds, and provide an important ecosystem service via nutrient uptake and filtration, significantly improving estuary water quality.

Salt marsh

Salt marsh plants provide numerous ecosystem services such as filtering and detoxification, nursery function for fisheries, protection from floods and sea storms and carbon sequestration (Barbier et al. 2011). Although it is agreed that abiotic, rather than biotic factors, are responsible for the zonation of salt marsh species, there is disagreement on the level of importance of each factor (Cooper 1982). Therefore, the eco-physiological responses of estuarine plants are important with regards to predicting their survival and growth under different scenarios (Adams & Bate 1994). Adams et al. (1999) believed that the two most important abiotic factors that determine distribution of salt marsh are inundation and salinity. As the soils of salt marshes are periodically inundated with seawater, causing waterlogging and changes in salinities, a physically stressful environment is created for the angiosperms which grow there (Pennings et al. 2005). Salt marsh plants do not survive in saline conditions over 30 ppt and grow optimally in salinities ranging from 10-35 ppt (Chapman 1974).

Die back of the salt marsh after three months of submergence is predicted and if the sediment dries out, the plants are only expected to survive for six months (Adams 1994). Adams et al. (1999) observed that dieback of *Sarcocornia natelensis* was caused by the closure of the mouth of the Great Brak Estuary, which caused inundation for more than 2 months. Reeds and sedges often take over when tidal influence stops (with mouth close) as they are more tolerable of freshwater water and longer inundation conditions (Adams & Riddin 2005).

The Berg and Langebaan estuaries contain the vast majority of intertidal (99%) and supratidal salt marsh (100 %) within the study area (Table 2-23). These two systems contain a significant proportion of the total intertidal (approximately 74%) and supratidal (~ 50%) salt marsh habitat nationally in all South African estuaries. Wildevöelvlei, Diep and the Sand estuary also contain small areas of intertidal saltmarsh, whilst sedge marsh vegetation that contains several salt marsh species have been invaded by vlei grass *Paspalum vaginatum* in the Diep estuary (Jackson et al 2011).

Table 2-23. Area (in hectares) covered by different plant communities in the seven significant estuaries within the study area. Source: Van Niekerk & Turpie (2012), Van der Linden (2014).

Estuary	Intertidal salt marsh	Supratidal salt marsh	Submerged macrophytes	Reeds & sedges	Sand/mud banks	Channel	Total
Berg (Groot)	1 667	2 545	206	1 588	?	644	6650
Langebaan	524	792	86	124	9.2	4 113	5648
Rietvlei/Diep	No data	No data	No data	No data	No data	229	229
Wildevoëlvlei	12.7	0	0	15.38	172	22	222
Sand	11.6+	0	0	39.76	7.02	119	177
Zeekoe	0	0	0.2	0.66	1.48	327	329
Eerste	0.29	0	0	1.36	6.15	9	17
Lourens	0	0	0	0.58	4.01	2	6.6

Invertebrates

Estuarine invertebrates are abundant in productive systems and are the link between primary producers and higher trophic levels such as fish and birds. Estuarine invertebrates include those found in the water column (zooplankton), as well as those that are primarily benthic (benthos). Frequently the larvae of benthic species such as bivalves, gastropods, crabs and polychaetes, and fish are also planktonic (meroplanktonic forms) and seasonally are abundant components of the estuarine zooplankton.

Zooplankton

The zooplankton component that spends its entire cycle in the water column (holoplankton) is, under typically estuarine conditions, dominated by a few genera of copepods and mysid shrimps (Woodridge

1999). These include copepods of the genus *Pseudodiaptomus* and *Acartiella*, and mysid species belonging to the genera *Gastrosaccus*, *Mesopodopsis*, *Rhopalophthalmus* and *Tenagomysis*. Copepods tend to dominate estuarine zooplankton numerically but mysids are often more important in terms of biomass (Woodridge 1999). Temperature, salinity, seasonality, mouth state, water depth, resident time and predation are all important drivers of estuarine zooplankton (Woodridge 1999). Copepods tend to be most abundant in the middle and upper estuarine areas where mesohaline conditions exist and abundance is positively linked to freshwater pulses. Zooplankton biomass tends to be higher in estuaries with pronounced axial salinity gradients and estuarine zooplankton are therefore are expected to be more abundant in permanently open systems and positively related to river flow (Woodridge 1999).

Historical studies recording the diversity and occasionally abundance of zooplankton in estuaries in the study area are scarce with limited data on individual systems available in the Estuaries of the Cape series. The exceptions are the Berg estuary where seasonal zooplankton sampling was undertaken during the Berg River Baseline Monitoring Programme and seasonal sampling conducted on the Berg, Diep and Lourens estuaries (DWAF 2007, Montoya-Maya & Strydom 2009). Major groups represented in the Berg River zooplankton were copepods, mysids and fish larvae, particularly larvae of the estuarine round herring *Gilchristella aestuaria* (Wooldridge 2007). Species numerically dominating communities in the Great Berg are also dominant species in estuaries on the south and east coast of South Africa. In the Great Berg, maximum population densities of zooplanktonic species were mostly present in the middle estuary (Wooldridge 2007). The Diep and Lourens estuaries had similar overall zooplankton abundance to the other estuaries sampled by Montoya-Maya & Strydom (2009), but had lower diversity (Figure 2.16). It is likely that the other freshwater dominated estuaries in the study area, particularly those with WWTW inputs have similar depauperate zooplankton assemblages. The zooplankton of Saldanha Bay and Langebaan lagoon was reported on by Grindley (1977). The plankton of Langebaan Lagoon is somewhat distinct from that found in Saldanha Bay and at the head of the lagoon the plankton community is estuarine in character (Grindley 1977). Zooplankton biomass was highest in the middle reaches of Langebaan Lagoon and lowest at the head of the lagoon where the lowest diversity index also was recorded (Grindley 1977).

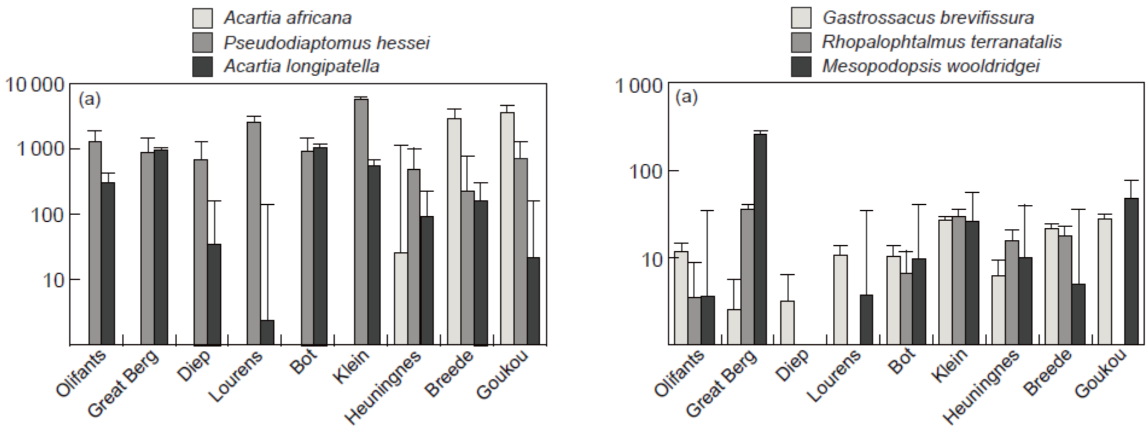


Figure 2.16. Relative abundance of the three most abundant calanoid copepod species (left) and mysid species (right) in the zooplankton assemblages of selected south and west coast estuaries. Bars denote standard error. (Source: Montoya-Maya & Strydom 2009).

Macrobenthos

Most studies on estuarine invertebrates have focused on the study of macrobenthos, which are invertebrates greater than 0.5 mm or 1 mm. Quantitative studies of estuarine macrobenthic communities are relatively scarce on a national level, with De Villiers et al. (1999) reporting that such surveys have only been undertaken on 38 individual systems (13% of 289 estuaries). The macrobenthic fauna of estuaries within the study area has been relatively well studied with some information available on the Berg, Langebaan, Diep, Sand and Lourens (Table 2-24). The very large range of invertebrate diversity is partly related to geographical area and individual estuary characteristics, but also reflects variation in sampling effort and methodology between the systems. Both the Berg estuary and Langebaan Lagoon have been subject to intensive invertebrate surveys over several years , and the relatively high diversity reported for these two systems compared to the other six estuaries partly reflects the higher sampling effort, but is also indicative of their large size and relatively good ecological health status (Table 2-24).

The permanently open estuaries of the study area tend to have greater species richness than those that are often closed (Table 2-24). Many invertebrate species found in estuaries may have obligate marine larval phases and this explains the relatively low diversity of benthic invertebrate taxa in temporarily open systems (De Villiers et al. 1999). Permanently open estuaries that have a high freshwater input also tend to have low invertebrate diversity. This appears to be the case for the Diep estuary where additional freshwater input in the form of WWTW effluent is implicated in a decrease of invertebrate diversity from 47 species in the 1950s to just 23 species in 2014, including several new freshwater forms not previously reported (Viskitch et al 2016).

The sandprawns *Callichirus kraussi* and mud prawns *Upogebia africana* and *U. capensis* dominated the macrobenthos in samples collected in Langebaan lagoon over the period 2004-2016 (Anchor Environmental 2016). Within the diverse microbenthic community found in this marine dominated estuarine bay, prawns, amphipods and crabs were common, and crustaceans were the most abundant group, followed by polychaetes (Anchor Environmental 2016). Prawns are collected by anglers for bait, and form an important component of the diet of many fish in the system such as white stumpnose *Rhabdosargus globiceps* and white steenbras. The burrowing activities of the sand prawn have led to the species been referred to as an ecosystem engineer and it has a significant influence on organic turnover with estuaries. Other common crustacean species include brachyuran crabs such as *Hymenosoma orbiculare* that are particularly abundant amongst submerged seagrass beds.

In the Berg estuary, subtidal benthos is numerically dominated by amphipods in both summer and winter. (Wooldridge & Deyzel 2009). However, the pattern changed along the estuary; Amphipods were more prevalent in the middle estuary and polychaetes nearer the mouth (Wooldridge & Deyzel 2009). The intertidal benthos was dominated by polychaetes. The Berg estuary macrobenthic community comprised euryhaline species that are resilient to temporal and spatial salinity changes (Wooldridge & Deyzel 2009).

Historically, the Diep estuary probably had a similar macrobenthic community to the Berg estuary, but anthropogenic impacts have resulted in a depauperate, freshwater dominated fauna (Viskitch et al. 2016). Sand prawn populations in the Diep estuary crashed by 75% since the late 1990s (Viskitch et al 2016). The macrobethos in the Wildevoelvlei and Eerste estuaries is similarly impacted. The macrobenthos in the Sand and Lourens estuaries have not been surveyed in several decades but are probably not as severely impacted. In the Sand estuary, surveys over the last three years have shown that prawn densities are highly variable annually. Densities greater than the maximum found in previous studies occurred just after the 2012 golden algae bloom and densities lower than ever measured before were recorded in 2014 (Joshua Gericke, personal communication).

Table 2-24. Macrobenthic invertebrate species diversity in five significant estuaries within the study area.

Estuary	Number of species	Source
Berg	44	Wooldridge & Deyzel (2009)
Langebaan	188	Anchor Environmental (2016)
Diep	23	Viskitch et al (2016)
Sand	22	Morant & Grindley (1982)
Lourens	6	Cliff & Grindley (1982)

Fish

The warm, productive and sheltered habitats found in estuaries comprise important breeding, nursery and feeding grounds for a large numbers of coastal fish species. Whitfield (1994, 1998) has classified fish species occurring in estuaries based on their origins and life cycle linkages to estuaries. He recognized five major categories of estuary associated fish species and several subcategories (Table 2-25). Category Ia, IIa and V fish species are either entirely, or mostly dependent on estuaries for critical life history phases.

Table 2-25. Estuarine dependence categories for fish (Whitfield 1998).

I.	Estuarine residents: Ia: Resident species not recorded spawning in marine or freshwater environment Ib: Resident species also having marine and/or freshwater breeding populations
II.	Euryhaline marine species usually breeding at sea with juveniles showing varying degrees of dependence on estuaries, further divided into: IIa Juveniles dependent on estuaries as nursery areas IIb Juveniles occurring mainly in estuaries, but also found at sea IIc Juveniles occur mainly at sea, but also found in estuaries
III.	Marine species that occur in estuaries in small numbers but are not dependent on estuaries
IV.	Euryhaline freshwater species whose penetration into estuaries is determined primarily by salinity tolerance. Includes some species which may breed in both freshwater and estuaries
V.	Catadromous species which use estuaries as transit routes between the marine and freshwater environments but may also occupy estuaries in certain regions, further divided into: Va Obligate catadromous species which require a freshwater phase in their development Vb Facultative catadromous species which do not require a freshwater phase in their development but use estuaries as nursery areas

A comprehensive assessment of the ichthyofauna in the Berg estuary was undertaken during the Berg River Baseline Monitoring Programme over the period 2003-2006, and during several earlier surveys conducted over the period 1993-1996 (Clark et al 2009, DWAF 2007). Langebaan Lagoon has also been subjected to annual fish sampling using comparable methods (experimental seine netting) since 2005 (Anchor Environmental 2016). The other six estuaries in the study area have been subject to less intensive fish sampling, with the Diep and Sand estuaries been sampled quarterly for several years since 2000 (SJ Lamberth, DAFF, pers. Comm.). The Sand and Eerste estuaries were also sampled in the early 1990s by Clark et al (1994), and the Wildevoelvlei and Lourens have been sampled occasionally on an ad-hoc basis.

The variation in sampling effort in the various estuaries in the study area means that results from these surveys are not comparable as species diversity is directly related to sampling effort and species accumulation curves only level off (if at all due to the increased probability of encountering novel marine vagrants over time) after approximately 70 hauls (Turpie & Clark 2007).

The Harrison (1999) fish surveys produced what is arguably the most useful dataset for comparisons between systems in that his methodology was consistent and sampling effort was scaled according to the size of the estuary. The Harrison (1999) data set however, did not include Langebaan Lagoon, and the sampling effort in the very large Berg estuary is considered inadequate to effectively quantify the fish fauna throughout the system. The Berg River Baseline Monitoring Programme data were therefore used for the Berg estuary, the Anchor Environmental annual State of the Bay data were used for Langebaan Lagoon, whilst the Harrison (1999) data were used for the remaining six systems, to compare the relative importance of the different significant estuaries within the study area in terms of fish habitat (Table 2-26).

A total of 39 fish species have been recorded in the six estuaries of the study area. The most diverse icthyofauna has been recorded in the Berg (27) and Langebaan (24), which is probably linked in part to the substantially greater sampling effort in these two systems than in the other six estuaries (Table 2-26). Indeed, Harrisson (1999) only recorded ten species in the Sand (also known as the 'Zandvlei') estuary, whilst the Zandvlei Estuary Nature Reserve records reveal that a total of 40 fish species have been recorded in this estuary to date (Joshua Gericke, personal communication). Many of these "additional" fish species recorded in the Sand estuary are however, marine vagrants at the western extreme of their distributional range.

The Harrison (1999) data also show low ichthyofaunal diversity in the other four systems, partly due to the lower sampling effort, but also probably a result of significant deterioration of habitat quality. Viskitch et al. (2016) report that there has been a decline in fish diversity in the Diep estuary, from 12 species in the 1950s, to just five in 2014. They attribute this (and other bio-physical changes) to habitat degradation. It is plausible that similar habitat degradation and declines in fish diversity have occurred in the Wildevoelvlei and Eerste estuaries, which also receive substantial volumes of WWTW effluent.

The total number of fish estimated in each estuary was related to estuary size and the relative density of fish in each system (Table 2-26). The Berg estuary contained the vast majority (89%) of fish in the study area, with Langebaan containing a further 8.5% (Table 2-26). The Diep, Wildevoelvlei and Sand estuaries contained a further 2.75 % of the regions estuarine fish abundance, with relatively very low abundance in the Eerste and Lourens estuaries.

Table 2-26. Estimated total number, number of species and percentage of the population of fish found in 7 of the 8 significant estuaries in the study area.

Species/Estuary	**EDC**	**Berg***	**Langebaan**	**Diep***	**Wildevoël vlei***	**Sand***	**Eerste**
Amblyrhynchotes honckenii	III						100
Atherina breviceps	IB	60.8	37.5			1.71	0.01
Blennophis	III		100				
Caffrogobius sp	IB	88.3	8.45	3.24		0.03	
Clarias gariepinus	IV	100					
Chelidonichthys capensis	III		100				
Clinus heterodon	III		100				
Clinus latipennis	III		100				
Clinus superciliosus	IB	75.3	25				
Cyprinus carpio	IV	100					
Dasyatis marmorata	III	100					
Engraulis capensis	III	100					
Diplodus sargus capensis	III		100				
Galeichthys feliceps	IIB	100					
Gambusia affinis	IV	100					

Species/Estuary	EDC	Berg*	Langebaan	Diep*	Wildevoël vlei*	Sand*	Eerste
Gilchristella aestuaria	IA	87.1				13	
Haploblepharus pictus	III	100					
Heteromycteris capensis	IIB		72.3	5.99		22	
Lichia amia	IIA	54.6	0.75			45	
Lithognathus	IIA	100					
Liza dumerilii	IIB					100	
Liza richardsonii	IIC	91.8	6.2	1.41	0.37	0.13	0.03
Micropterus dolomieu	IV	100					
Myliobatis aquila	III	73.8	26.2				
Mugil cephalus	IIA	93.2		2.16		4.6	0.05
Parablennius cornutus	III		100				
Pomatomus saltatrix	IIC	98.1	2				
Poroderma africanum	III		100				
Psammogobius knysnaensis	IB	38.2	62			0.06	0.09
Rhabdosargus globiceps	IIC	4.0	94			1.65	0.04
Rhabdosargus holubi	IIA	5.5	94				
Rhinobatos blockii	III	16.9	83				
Sardinops sagax	III	100					
Sarpa salpa	IIC	3.8	96				
Solea bleekeri	IIB	99.7	0.3				
Spondyliosoma emarginatum	III		100				
Syngnathus temminckii	IB	94.3	2	3.85			
Trachurus	III		100				
Oreochromis mossambicus	IV	100					
Total		88.75	8.47	1.28	0.29	1.16	0.03
Number species		27	24	5	1	10	6

Species/Estuary	EDC	Berg*	Langebaan	Diep*	Wildevoël vlei*	Sand*	Eerste
EDC = estuarine dependence category after Whitfield (1998). Fish data for the Berg from DWAF (2007); Langebaan from Anchor Environmental (2016) and the remaining estuaries from Harrison (1999). Species of fisheries importance are in bold font.*: Estuaries ranked as very important fish nurseries by Van Niekerk & Turpie (2012).							

Estuaries containing a high number of estuarine dependent species (Categories Ia, IIa and V) include the, Berg and the Sand estuaries, whilst the marine dominated Langebaan had a low proportion of estuary dependent species and a high proportion of marine species considering the large size of the system (Table 2-27). Three fish species that occur in estuaries in the Berg WMA are included on the IUCN red list – white Steenbras *L. lithognathus* (endangered), white stumpnose *R. globiceps* (vulnerable) and the spotted eagle ray *Myliobatis aquila* (near threatened). All four species have been reported from the Berg estuary and most also from Langebaan, and some from the Sand and Eerste estuaries. It is likely that most (if not all) of these species would have been present historically in the Diep estuary as well.

Table 2-27. Relative proportion (%) of fish by Estuarine Dependence Category (EDC) found in significant estuaries within the study area.

Estuary/EDC	IA	IB	IIA	IIB	IIC	III	IV
Berg	87.1	69.5	92.6	79.7	91.7	28.0	100
Langebaan		28.3	0.4	13.8	6.3	71.8	
Diep		1.3	2.1	1.1	1.4		
Wildevoëlvlei					0.4		
Sand	12.9	0.9	4.9	5.4	0.1		
Lourens	0.001	0.005	0.01		0.04		
Eerste		0.01	0.05		0.03	0.23	

The estuaries in the study area comprise nursery or feeding habitat for the endangered white steenbras *Lithognathus lithognathus*) as well as several important fishery species (Table 2-27). Historically a commercial gill net fishery targeting mullet *Liza richardsonii*, with a substantial bycatch of elf *Pomatomus saltatrix* operated on the Berg estuary for more than a century (it was officially closed in 2003 but continues as an illegal fishery to this day), whilst commercial gill net fishing for mullet by approximately 10 rights holders takes place in Langebaan lagoon (Hutchings et al 2002a, 2002b, 2008). Recreational, estuarine angling has increased in popularity in several of the estuaries and is of economic importance in the Berg and Langebaan systems (and possibly the Sand estuary). The populations of two estuarine dependent fishery species, white steenbras and leervis *Lichia amia* have collapsed (Mann 2013).

There are few functioning estuaries along the west coast of South Africa, and the remaining ones (e.g. Berg, Langebaan, Sand) are important in providing scarce nursery habitat to estuarine dependent and marine species. Estuaries have been shown to serve as refuge for a variety of estuarine associated fish species during unfavourable environmental conditions in the nearshore marine environment e.g. low oxygen events (Lamberth et al 2010). The 2011 NSBA identified four of the eight significant estuaries within the study area as very important fish nurseries (Van Niekerk & Turpie 2012). Langebaan was omitted due to its unique characteristics, but should be included in this list

Birds

Very few data were collected on South Africa's estuarine birds before the 1970s. In the summers of 1979-81, a count was undertaken of all estuaries and lagoons of the entire South African coast apart from the former Ciskei and Transkei coasts (Ryan & Cooper 1985, Ryan et al. 1986, Underhill & Cooper 1984). The gaps were filled in later counts (Turpie 2004, Turpie *et al.* 2014). Although a complete count has never been repeated, an increasing number of estuaries has been monitored since the 1990s through the Co-ordinated Waterbird Counts (CWAC) programme managed by the Avian Demography Unit at the University of Cape Town. In addition, Ryan (2012) partially repeated the coastal count in the Western Cape.

The 1979-81 counts, augmented by counts from other studies where they existed, were used by Turpie (1995) in an analysis of the importance of estuaries for waterfowl, and subsequently in the computation of the conservation importance of estuaries (Turpie et al. 2002). Turpie & Clark (2007) collated all available CWAC data on temperate estuaries for a conservation plan for temperate South African estuaries as part of the CAPE Project. Turpie *et al*. (2012) updated these data and added additional estuaries in their national-scale estuary conservation plan for the country as part of the National Biodiversity Assessment. There are still many estuaries for which there are no recent data or no data at all.

Based on available data, some 82 waterbird species have been recorded in the estuaries of the study area, representing most species recorded in temperate South African estuaries. The number of bird species and individuals found in individual systems varies greatly, and is determined primarily by the size and physical habitat diversity of the systems, which in turn influence food availability, foraging, resting and breeding opportunities for birds.

Bird communities in South Africa's temperate estuaries suggest four main groupings for birds (Figure 2.17, Turpie & Clark 2007). Type A estuaries are large open systems that support diverse waterbird communities and are characterised by high numbers of waders. Type B estuaries are systems that have restricted or closed mouths, frequently have brackish lake characteristics, and support large waterfowl communities. Some systems (A/B) can have a mixture of these characteristics. Type C are typically medium to large sandy estuaries, often support gull and tern roosts, but have relatively low overall diversity. Type D systems are depauperate and are generally small and nutrient poor.

However, it is also important to distinguish between subset communities and distinct communities. In effect, types A and B are relatively distinct, whereas types C and D support subsets of the communities found in type A (Figure 2.18). This suggests that for birds it would be best to concentrate conservation efforts on type A and B systems. Furthermore, since type B communities are likely to bear some resemblance to freshwater wetland systems, the main effort should be on type A systems. Thus, Whitfield's (2002) estuary typology, though widely used, does not necessarily make sense as an ecosystem typology from a biodiversity perspective. Neither fish nor bird communities group according to this classification (Turpie & Clark 2007).

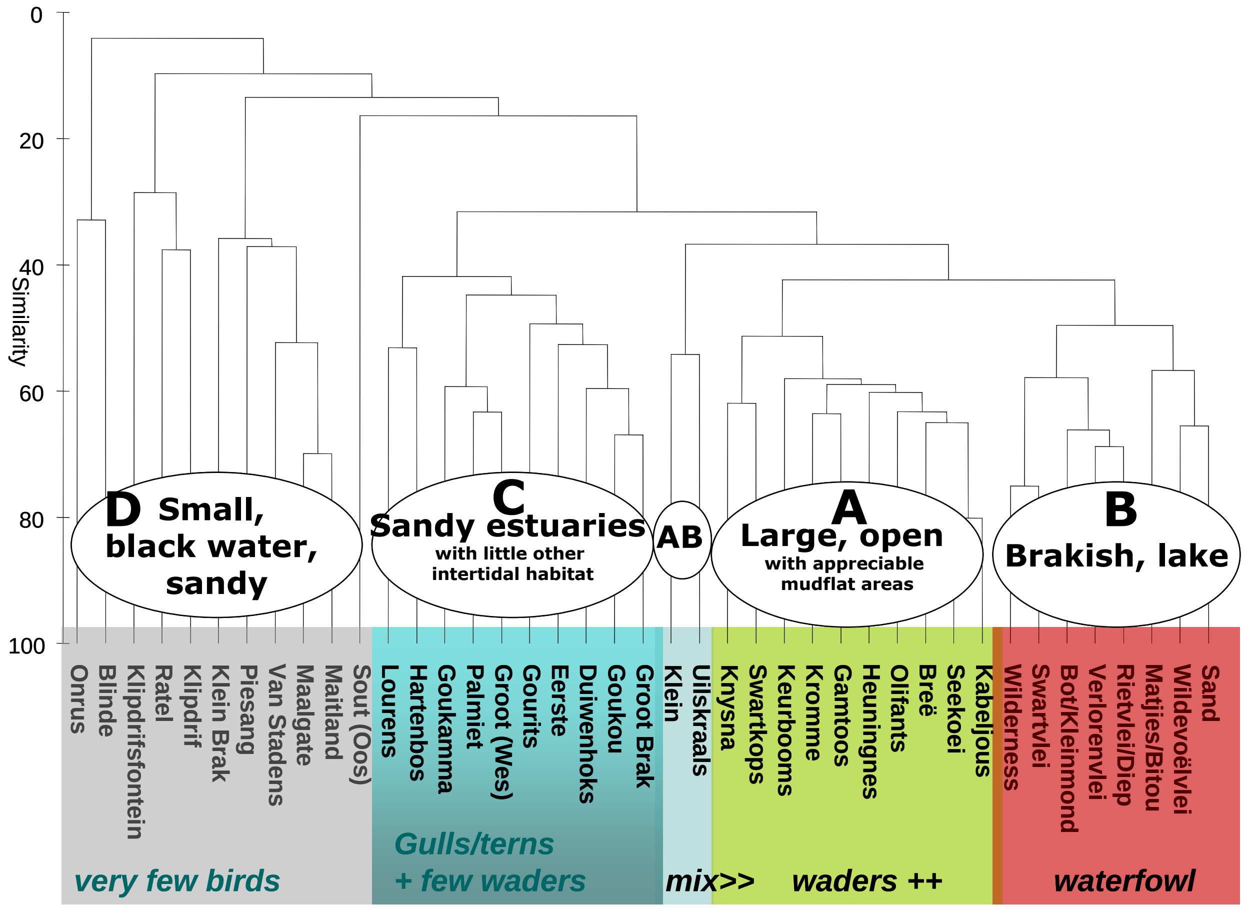


Figure 2.17. Cluster diagram showing groupings of estuaries on the basis of bird community structure (Source: Turpie & Clark 2007).

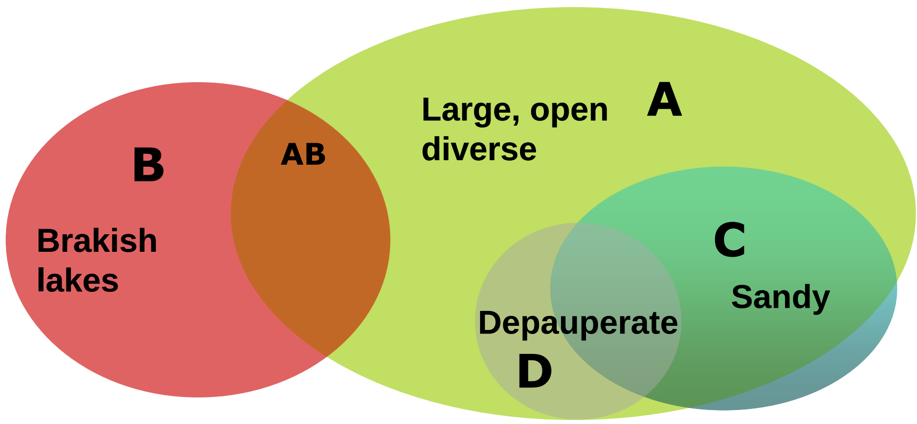


Figure 2.18. Schematic of the overlap between bird communities of the different estuary types (Source: Turpie & Clark 2007).

Waders account for 72% of summer waterbirds in the estuaries of the study area (Table 2-28), with gulls and terns being the next most abundant groups. This is due to the extensive areas of intertidal mudflats and saltmarsh found in the estuaries, most of which are found in the three largest systems. While waders, gulls and terns are mainly found in the larger systems, the Lourens estuary supports a large tern roost. The composition of waterbirds in Langebaan is different from the remaining systems, mainly due to the lack of a low salinity area. Although there are no estuarine lakes in this study area, most of the remaining systems have significant areas of relatively freshwater habitat, and so support a significant proportion of waterfowl, with ducks making up 5% of estuarine waterbirds in the study area. As well as extensive freshwater marshes, the Berg estuary also includes saltpans that are favoured by flamingos and a range of other species.

The community composition of the significant estuaries in the study area is compared in Table 2-28 Langebaan Lagoon accounts for 64% of all the estuarine waterbirds, and 74% of the estuary-dependent waterbirds. The Berg Estuary, and to a lesser extend the Diep Estuary account for most of the rest. Relatively few birds are supported by the smaller estuaries of the Cape Peninsula and False Bay coasts (Table 2-28). There are almost no birds in the remaining micro-estuaries and river outlets (pers. obs). A similar pattern is found if just estuary-dependent species are taken into consideration (see Turpie et al. 2012).

Table 2-28. Numbers of estuary dependent species of waterbirds, by group, in the study area, and percentage distribution among the estuaries of the study area, based on the only comparable single count series undertaking in January 1981.

Estuary dependent species, by group	Total of study area (#)	Estuaries (percentage distribution figures)							
		Berg	Lange-baan	Diep	Wilde-voëlvlei	Sand	Zeekoei	Eerste	Lourens
Grebes	292	20	-	5	52	23	-	-	-
Pelicans	378	29	1	9	-	1	59	-	-
Cormorants	2 544	62	24	2	1	2	1	2	6
Darters	118	35	-	19	4	41	-	<1	-
Herons & egrets	333	47	23	13	10	6	-	1	<1
Ibis & spoonbill	208	46	25	21	6	2	-	-	-
Flamingos	1 718	77	21	1	-	-	-	1	-
Ducks	3 144	38	4	40	6	10	-	2	<1
Birds of prey	12	57	8	13	13	8	-	2	-
Skulking rallids	58	11	-	34	41	13	-	1	-
Coots	1 799	12	1	16	21	49	-	<1	-
Waders	44 844	15	80	5	<1	<1	<1	<1	<1
Gulls	3 272	27	35	18	3	4	9	1	3
Terns	3 525	19	38	7	<1	<1	<1	5	30
Kingfishers	76	66	3	6	5	17	-	2	-
Wagtails	268	36	38	19	1	5	-	1	-
Total birds	**62 588**	**21**	**64**	**8**	**2**	**3**	**1**	**1**	**2**
Estuary dependent birds	**52 119**	**17**	**74**	**4**	**<1**	**<1**	**1**	**<1**	**2**
Red data species		9	8	7	3	3	2	5	2

Most recent assessments of birds in the study area suggest that estuarine waterbird numbers have declined significantly over the past three decades. Ryan (2012) found that while certain larger species had increased in number, including Egyptian Goose and three species of ibises, most small birds had decreased in abundance, apart from African Black Oystercatcher. These included both resident and migratory waders. Numbers of the four most abundant migrant waders had decreased by more than 50% and in two cases over 90%. In Langebaan Lagoon, bird numbers have declined by over 80% since the 1970s (Anchor

Environmental Consultants 2015, Figure 2.19). These are likely attributed to external conservation issues such as hunting and loss of breeding areas in the northern hemisphere. However, declines in the numbers of resident waders suggest that local level disturbance also plays a role (AEC, op cit). The impacts associated with changes in the quality and quantity of freshwater inflows have also played a significant role in determining the present ecological status of bird communities on estuaries (Anchor Environmental Consultants 2008),

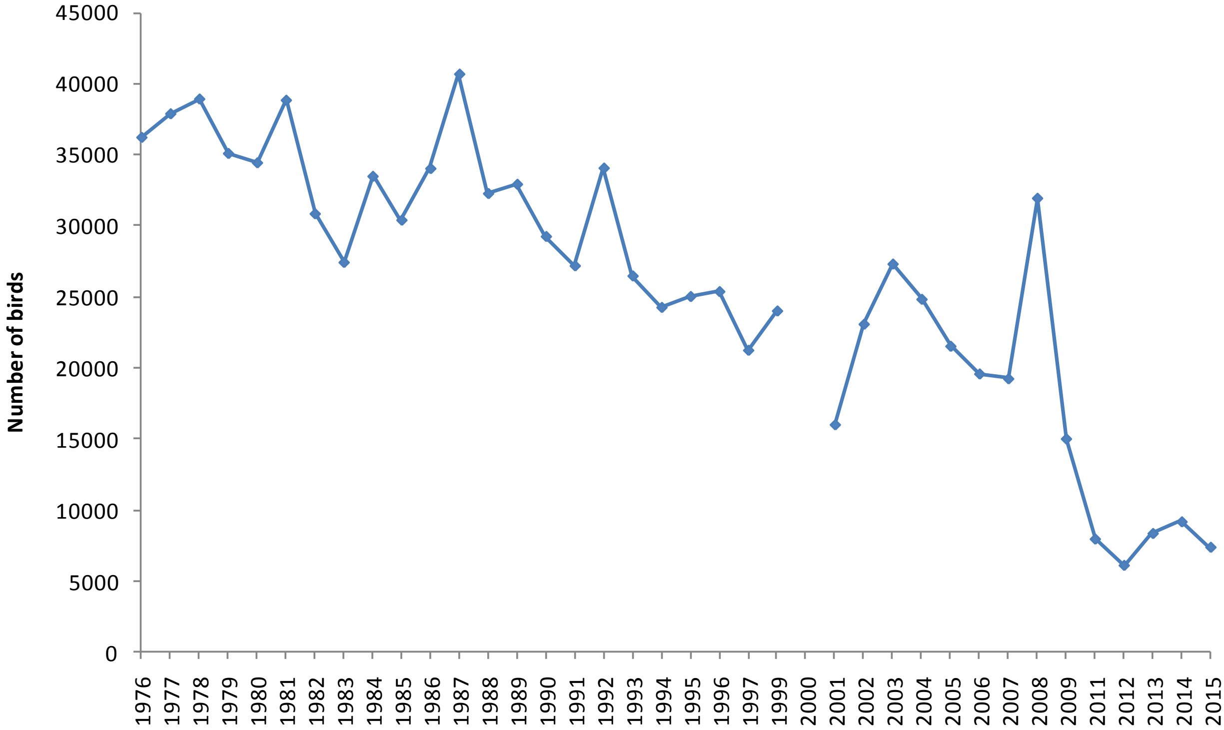


Figure 2.19. Long term trends in the numbers of summer migratory waders on Langebaan Lagoon (Anchor Environmental Consultants 2015).

2.4.3.2 Impacts on estuaries

Changes in catchment land use/cover

The rivers that feed estuaries within the study area have catchments that are largely transformed with only Langebaan Lagoon having 73% of the catchment natural vegetation, waterbodies or wetlands remaining, some of which falls within the West Coast National Park (Table 2-29). The catchments of the Groot Berg and the Diep are approximately half agricultural land, whilst the remainder of the Langebaan catchment and 29% of the Eerste River catchment is agricultural land. The catchments of estuaries that fall within the City of Cape Town are largely urbanised (22-61 %). Urban development is almost always concentrated on the coast, and with all estuaries there is some urban development in the estuary functional zones.

Table 2-29. Habitat types and developments in the catchments of the eight significant estuaries within the study area. All values percentage of total catchment area.

Catchment Description	Indigenous vegetation	Natural Veget-ation	Wet-lands	Water-bodies	Cultivated land	Mines	Forestry	Urban
Groot Berg	27.8	12.1	1.9	0.9	54.0	0.1	<1	1.1
Langebaan	65.8	6.9	<1	<1	23.7	<1	<1	1.5

Diep	23.8	10.8	4.1	0.5	52.9	0.2	<1	6.1
Wildevoelvlei	38.1	23.3	9.6	2.7	0.0	0.9	<1	25.0
Sand	15.8	17.3	1.8	1.6	5.6	<1	6.3	51.2
Zeekoevlei	11.7	7.0	5.0	5.1	6.2	3.4	<1	60.8
Eerste	22.7	17.7	3.4	1.1	29.4	0.3	3.1	21.8
Lourens	22.2	22.6	<1	1.1	7.1	0.2	<1	46.1

Changes in quantity and quality of flows

All the estuaries in the study area have experienced some reduction in natural flows compared to reference conditions (Table 2-30). In the case of the Berg, dams that have been built in the catchment and substantial water extraction for irrigation are the causes of the 20 % reduction in flows, whilst abstraction for irrigation of agricultural lands have reduced natural flows in the Diep Lourens and Eerste.

The other three systems have experienced only small reductions (<10 %) in natural flows. Four systems receive treated wastewater and in all cases this has elevated present day flows to above the reference level, by a large degree in most cases (Table 2-30). These wastewater inputs have dramatically altered the physical, chemical and biological status of all four systems, with high volumes of poor quality freshwater changing the natural mouth state, reducing the penetration of sea water and leading to significant habitat deterioration. Stormwater inputs from surrounding urban areas (that are likely to contain contaminants) are qualitatively rated as high for four systems (Diep, Sand Zeekoe and Eerste), medium for two estuaries (Wildevöelvlei and Lourens), and low for the Berg and Langebaan (Table 2-30).

Table 2-30. Modelled changes in MAR from reference to present including wastewater treatment works (WWTW) input for the identified eight significant estuaries in the study area.

Estuary	Reference MAR (million $m^3.yr^{-1}$)	Current MAR (million $m^3.yr^{-1}$)	Current as (% reference)	WWTW input (million $m^3.yr^{-1}$)	Current (% Reference Incl. WW)	Stormwater N/L/M/H
Groot Berg	699	562	80		80	L
Langebaan						L
Diep	61	37	61	26.5	105	H
Wildevoelvlei	6.3	5.9	94	3.4	147	M
Sand	32	30	93		93	H
Zeekoe	18	17	93	42.5	325	H
Eerste	115	101	88	67.3	147	H
Lourens	70	59	85		85	M

Levels of human disturbance within functional zone

Developments in the estuary functional zones of the eight significant estuaries within the study area have been qualitatively assessed in broad categories using Google Earth (Table 2-31). The Berg estuary is subject to the full range of identified activities, but these are largely concentrated in the lower 10 km of the estuary where it borders the towns of Veldrif and Laaiplek and is zoned as a fishing harbour. Industrial activities on this part of the Berg estuary include boat repairs, saltworks and fish processing. Numerous jetties are found predominantly on the northern bank of the lower estuary and the Port Owen Marina is also in this area. The R27 coastal road bridge and the Saldanha-Sishen railway bridge also cross the estuary in the first 10km above the mouth. Much of the remaining approximately 50 km of the Berg estuary flows through agricultural land and is subject to minimal developments (the odd private jetty or boathouse).

Lying within the West Coast National Park, the margins of most of the Langebaan estuary are in a natural state, with the exceptions of Langebaan town, Kraalbaai and Churchaven, where residential and recreational developments are found. The WWTW within the estuary functional zones of the Diep, Wildevoelvlei, Zeekoe and Eerste estuaries were included under “industrial” developments, and there are few or no recreational development on the latter three systems.

Boat launching sites and marinas/boat moorings are found on the three systems that are extensively used by recreational boaters, sailors and fishers, namely the Berg, Diep and Sand estuaries. Recreational fishing and/bait collecting are popular on four of the eight estuaries within the study area, whilst commercial net and line fishing is also undertaken in Langebaan. Permanently open systems experience the highest levels of fishing pressure due to the availability of marine species and the immigration of fish into the estuaries which helps to sustain catches (to some extent). Due to poor water quality (and possibly lack of marine or estuarine species), fishing is not regularly undertaken in the Wildevoelvlei, Zeekoe or Eerste estuaries, although commercial seine netting does take place in the surf zones adjacent to the latter two estuaries. Illegal fishing using gillnets is known to occur in the Berg, Diep and Sand estuaries.

Table 2-31. Qualitative assessment of developments within or abutting the estuary functional zones of the identified eight significant estuaries in the study area.

Estuary	Residential	Industrial	Roads /Railways	Bridges	Footpaths	Jetties	Marinas/ boat mooring	Launch sites	Fishing/bait collecting	Recreation al area s
Groot Berg	X	X	X	X	X	X	X	X	X	X
Langebaan	X		X		X	X	X	X	X	X
Diep	X	X	X	X	X	X		X	X	X
Wildevoelvlei	X	X			X					
Sand	X		X	X	X		X	X	X	X
Zeekoe		X	X	X						
Eerste		X	X	X						
Lourens	X		X	X	X					

Invasion by alien organisms

Invasive alien species pose a significant threat to estuaries where they cause both ecological and economic damage. Alien species can exert a significant impact upon community structure and functions, by modifying spatial and food chain resources, with direct or indirect effects on the occurrence of indigenous species (Van Niekerk & Turpie 2012). The combination of brackish waters colonised by physiologically generalist species and potentially unsaturated ecological niches leads to the highest potential infection rate for any aquatic system. In addition, estuaries are also subjected to a two-sided invasion pressure by alien species, via the ocean and via inland waters (Van Niekerk & Turpie 2012).

Invasive alien plants in estuaries include aquatic (e.g. water hyacinth, water fern, parrot's feather) and terrestrial species such as *Sesbania* and Australian *Acacia* species (Adams et al. 1999). Alien aquatic alien plants are problematic in several of the estuaries in the study area. Labour intensive/job creation programmes to remove water hyacinth have been undertaken in the Berg, Diep and Sand estuaries. Terrestrial alien plant species, particularly Australian Acacia species have, colonised the estuary margins of many systems in the study area. Invasive alien grasses, vlei grass *Paspalum vaginatum* and kikuyu (*Pennisetum clandestinum*) are problematic in the Diep and probably several of the other urban estuaries. *Enteromorpha flexuosa*, a species of macroalgae originally from Europe, is common in the Berg estuary (Clark et al. 2007).

At least 10 freshwater alien fish species are likely to be found in most of the estuaries (Table 2-32). Most of these were introduced from the northern hemisphere in the late 1800s until the 1970s, either to enhance freshwater angling, or as fodder fish to feed the larger introduced species or as mosquito control. In addition to these alien species, translocations of southern African species either as angling fish or in the hope of establishing an aquaculture industry have also taken place. Extra-limital *Tilapia* species *Tilapia sparrmanii* and *Oreochromis mossambicus* now occur in the upper reaches of most of the estuaries. Range expansion of both introduced and translocated species throughout South Africa was further facilitated by interbasin transfer schemes, irrigation and stormwater networks as well as intentionally or inadvertently by recreational anglers and other water users as they moved between water bodies (Van Niekerk & Turpie 2012). Migration of catadromous eels or mullet, recruitment of the larvae and juveniles of estuary-dependent marine species, and the survival of the eggs and young of estuary residents, may be severely compromised through predation by introduced fish in estuarine headwaters (Van Niekerk & Turpie 2012).

Table 2-32. Freshwater alien fish species likely to occur in estuaries within the Berg study area (Source Van Niekerk & Turpie 2012).

Species name	Common name	% occurrence (130 estuaries)	SA range
Micropterus salmoides	Largemouth bass	31	Olifants -Mhlathuze
Micropterus dolomieu	Smallmouth bass	24	Olifants - Thukela
Cyprinus carpio	Carp	23	Orange - Thukela
Lepomis macrochirus	Bluegill sunfish	14	Olifants - Thukela
Micropterus punctulatus	Spotted bass	14	Olifants - Thukela
Oncorhynchus mykiss	Rainbow trout	10	Sand - Thukela
Gambusia affinis	Mosquitofish	9	Berg - Knysna
Salmo trutta	Brown trout	3	Olifants - Thukela
Tinca	Tench	2	Lourens - Breede
Ctenopharyngodon idella	Grass carp	2	Zeekoei - Thukela

A total of 86 introduced alien marine invertebrates species are known from South African waters with the highest numbers of species within the *Ascidiacea* (18), *Amphipoda* (17) and *Cnidaria* (15) (Mead et al. 2011). Not all alien marine species however, have been found in estuaries in the different biogeographic regions. The majority of alien species are restricted to harbours (e.g. *Ciona intestinalis*, *Carcinus maenas*, *Metridium senile*) and sheltered estuaries (Robinson et al. 2005). Robinson et al. (2004) lists three alien species that are present in Langebaan Lagoon – Mediterranean mussel, Mytilus galloprovincialis, the periwinkle *Littorina saxatilis*, the anemone *Sagartia ornate* – while Anchor Environmental Consultants (2016) have reported on the recent introduction of a fourth alien species in the Lagoon – the Western Pea crab *Pinnixa occidentalis*. The tube building polychaete *Ficopomatus enigmatica* is abundant in the Berg, Diep and Sand estuary and is probably an introduced alien species (McQuaid & Griffiths 2014).

2.4.3.3 Present ecological status

The 2011 NBA conducted a desktop assessment of the health of nearly 300 South African estuaries (Van Niekerk & Turpie 2012). The ecological health category was determined by an ecological water requirement study in cases where one had been completed; alternatively the assessment was based on expert knowledge. This health assessment is presented in Table 2-33 with updated information for the Berg that had an ecological reserve determination study completed in 2010 (DWA 2010); and a preliminary health assessment for Langebaan based on Anchor Environmental's long-term (2004-2016) monitoring of this system on behalf of the Saldanha Bay Water Quality Forum Trust. Langebaan is considered largely natural, the Berg and Lourens moderately modified, the Wildevoelvlei and Sand largely modified and the remaining three estuaries (Diep, Zeekoe and Eerste) as highly degraded.

Table 2-33. Desktop National Health Assessment (NBA 2011), with individual ecological components graded from Excellent (dark blue), good (blue), fair (green) to poor (brown). Present Ecological Status is also provided. Sources: Van Niekerk & Turpie (2012) & DWA (2010).

Estuary	Health Condition											
	Hydrology	Hydrodynamics	Water Quality	Physical habitat	Habitat State	Microalgae	Macrophytes	Invertebrates	Fish Final	Birds	Biological State	Estuary Health State (Mean)	Ecological Category
Groot Berg	green	dark blue	brown	brown	green	green	green	green	green	blue	green	green	C
Langebaan	blue	dark blue	dark blue	dark blue	dark blue	blue	green	blue	blue	green	blue	blue	B
Rietvlei/Diep	green	brown	brown	brown	brown	brown	brown	brown	brown	green	brown	brown	E
Wildevoëlvlei	green	brown	brown	green	green	brown	green	brown	green	green	green	green	D
Sand	green	brown	brown	brown	green	brown	green	green	green	green	green	green	D
Zeekoei	green	brown	brown	brown	brown	brown	brown	brown	brown	brown	brown	brown	E
Eerste	green	brown	brown	brown	brown	brown	brown	brown	brown	brown	brown	brown	E
Lourens	blue	blue	green	green	green	green	green	green	green	green	green	green	C

2.4.3.4 Recommended ecological status based on health and importance

The conservation importance of South African estuaries was scored based on their size, habitat importance score, zonal type rarity score and biodiversity importance score (Turpie & Clark 2007). The significant estuaries ranked in terms of these conservation scores as well as the present ecological status and recommended ecological class as reported in the 2011 NBA or updated RDM studies are shown in Table 2-34 (Van Niekerk & Turpie 2012). Five of the eight significant estuaries in the study area have an estuarine importance score of >80 and are considered highly important, the Eerste is considered moderately important and the Lourens as of low to average importance (Table 2-34).

Table 2-34. The present ecological status (PES), conservation importance (scale of 1-100) and recommended future ecological class (REC) of the 8 significant estuaries within the study area. Sources: Turpie and Clark 2007, Van Niekerk & Turpie (2012), DWA (2010), AEC (2016).

Estuary	PES	Importance	REC
Groot Berg	C	98	Best attainable state
Langebaan	B	Highly important	Best attainable state
Diep	E	96	C
Wildevoelvlei		86	
Sand	D	92	C
Zeekoe	E	Low importance	D
Eerste	E	65	D
Lourens	C	52	D

2.5 Wetlands

An assessment was made to identify wetland resource units (WRUs) in the study area. The assessment was conducted as a desktop exercise, making use of the National Freshwater Ecosystems Priority Areas (NFEPA) wetlands map (Nel et al., 2011), the Cape Nature CAPE Fine-Scale Biodiversity Planning Project FSP maps (Pence, 2008; Job et al., 2008a), the CCT wetlands map (Ewart-Smith et al., 2008) and the DWAF Ecoregion maps (Kleynhans et al., 2005).

This assessment, as described in the Resource Unit and Integrated Units of Analysis Delineation Report (RDM/WMA8/00/CON/CLA/0416), allowed for the determination of WRUs in the study area. Additional background information for WRUs was also collated from Job et al. (2008) and Malan et al. (2015).

2.5.1 Approach

As described above, the description of the delineation of the wetlands is outlined in the Resource Unit an IUA Delineation Report. The steps followed to define priority wetlands in the study area were as follows:

- NFEPA wetland dataset as defined for the study area (FEPA wetland GIS layer from BGIS: http://bgis.sanbi.org/)
    - Removal of the artificial wetlands and estuaries
    - Removal of NFEPA non-priority wetlands
    - Removal of heavily to critically modified wetlands (NFEPA condition DEF and Z1-3)
    - Removal of wetlands smaller than 500m^2
- Level I and Level II Ecoregions (from http://www.dwaf.gov.za/iwqs/gis_data/RHPdata.htm)
    - Defined Wetland Resource Units according to the Ecoregions
    - Also used Simplified Geology map from AGIS (http://www.agis.agric.za/agisweb/agis.html)
- FSP maps
    - Sandveld-Saldanha Planning Domain
    - Used for detailed description of the status quo of each wetland system
    - Removal of FSP wetlands with Integrity of wetland being less than 80% (INTEG80_all condition of Z)
- CCT maps
    - Snaddon and Day (2009) Prioritisation of City of Cape Town wetlands (as used in the CCT Biodiversity Network (Holmes and Pugnalin, 2016))

This methodology was followed to define the Wetland Resource Units (Wetland RUs) within the study area. The Wetland RUs were defined according to the underlying Ecoregion, in order to provide an understanding of the biophysical constraints on wetland formation. This methodology is consistent with the methodology used in the determination of priority wetlands for the Gouritz Reserve Determination Study (DWS, 2015). Following this assessment the Wetland RUs were defined according to Hydrogeomorphic Unit (HGM) in order to determine the different wetland types within each Wetland RU. The status quo descriptions relied on both the NFEPA PES data, as well as the Wetland Integrity data from the FSP maps where applicable. The status quo of the Wetland RUs were described in more detail within each IUA.

2.5.2 Description

In terms of the National Water Act (Act No. 36, 1998) a wetland may be defined as:

“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.”

This indicates that wetlands must have one or more of the following characteristics:

- Hydromorphic soils: characteristic soils of prolonged saturation;
- Hydrophytes, at least occasionally: highly saturated plants;
- High water table: a high water table that results in saturation at or near the surface, leading to anaerobic conditions.

These characteristics are indicative of the relationship between hydrology, topography and vegetation in determining the characteristics of a wetland in the landscape. Considering the long term controls that topography exerts on wetland occurrence and behaviour, Ecoregions were considered a useful way to interpret wetland occurrence in the study area.

The Level I Ecoregions associated with the study area are mainly the South Western Coastal Belt, Southern Folded Mountains and the Western Folded Mountains regions (Figure 2.20).The Level II Ecoregions reflect the underlying geology to a large degree (Figure 2.21), therefore when overlaid with a simplified geological map the Level II Ecoregions are given appropriate context.

Across the study area there are numerous wetlands, with many of the wetlands being considered conservation priorities. As there are numerous wetlands within the study area, Wetland Resource Units (RUs) were defined according to the Ecoregion classification, taking cognisance of the controls exerted by underlying geology. There were 5 Wetland RUs defined for the study area, with priority wetlands occurring within the Wetland RUs and IUAs of the study area.

The Wetland RUs accorded a top-down approach to defining the wetland characteristics within the study area. These provided an overview of the typical characteristics of wetlands and the associated HGM type within each Wetland RU. Following from this assessment, wetlands with relevant baseline data (Malan et al., 2007) were assessed in terms of EIS and PES.

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: occurs mostly on flat areas located along the valley floor. A channelled valley-bottom wetland has a channel running through it; with an un-channelled valley-bottom wetland having no channel running through it.
- Depressions: a wetland or aquatic ecosystem with closed (or near closed) elevation contours within which water accumulates. Depressions may be flat-bottomed (often described as pans), or extend over large areas, whereby they may be 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.

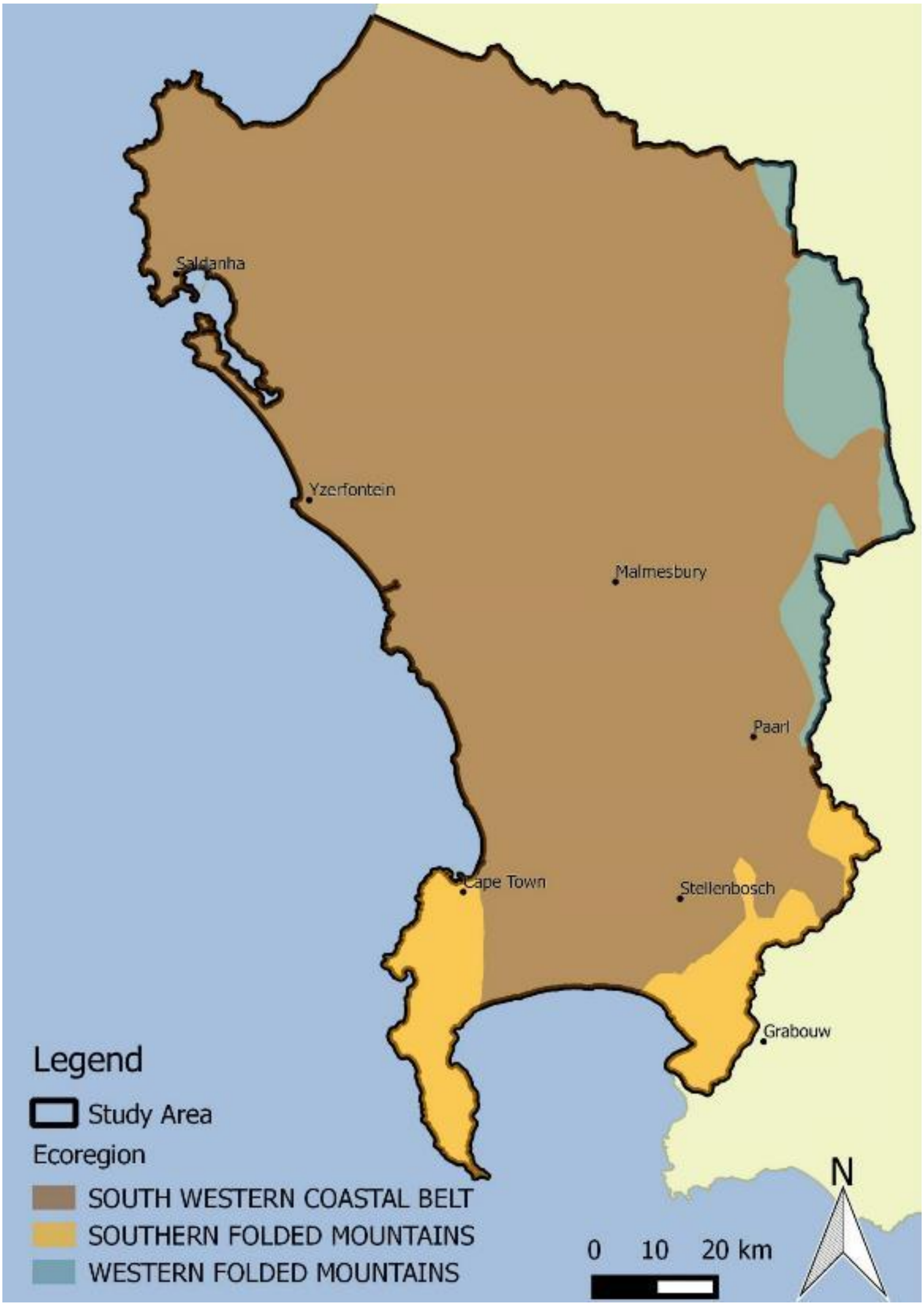


Figure 2.20. Level I Ecoregions within the study area.

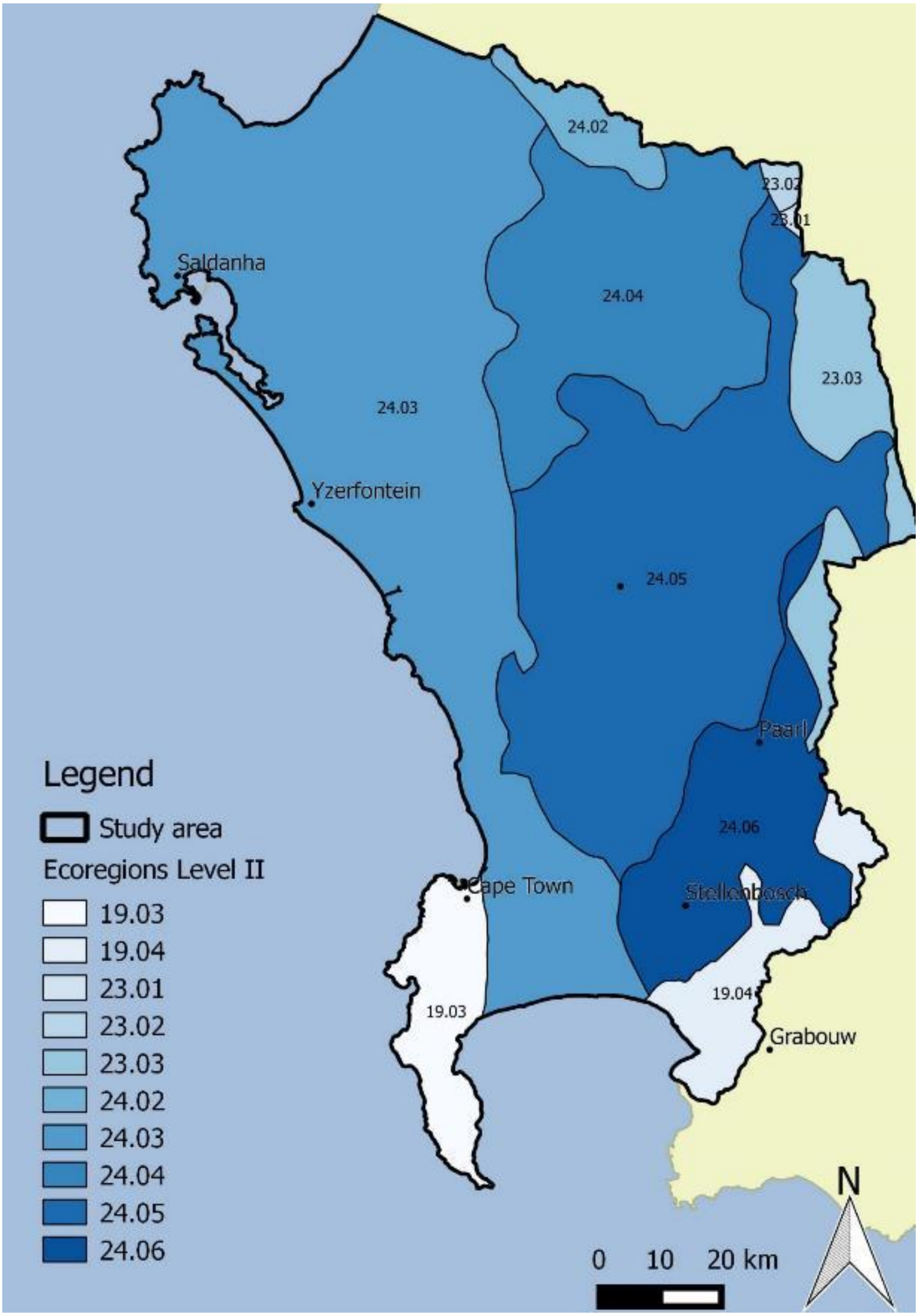


Figure 2.21. Level II Ecoregions within the study area.

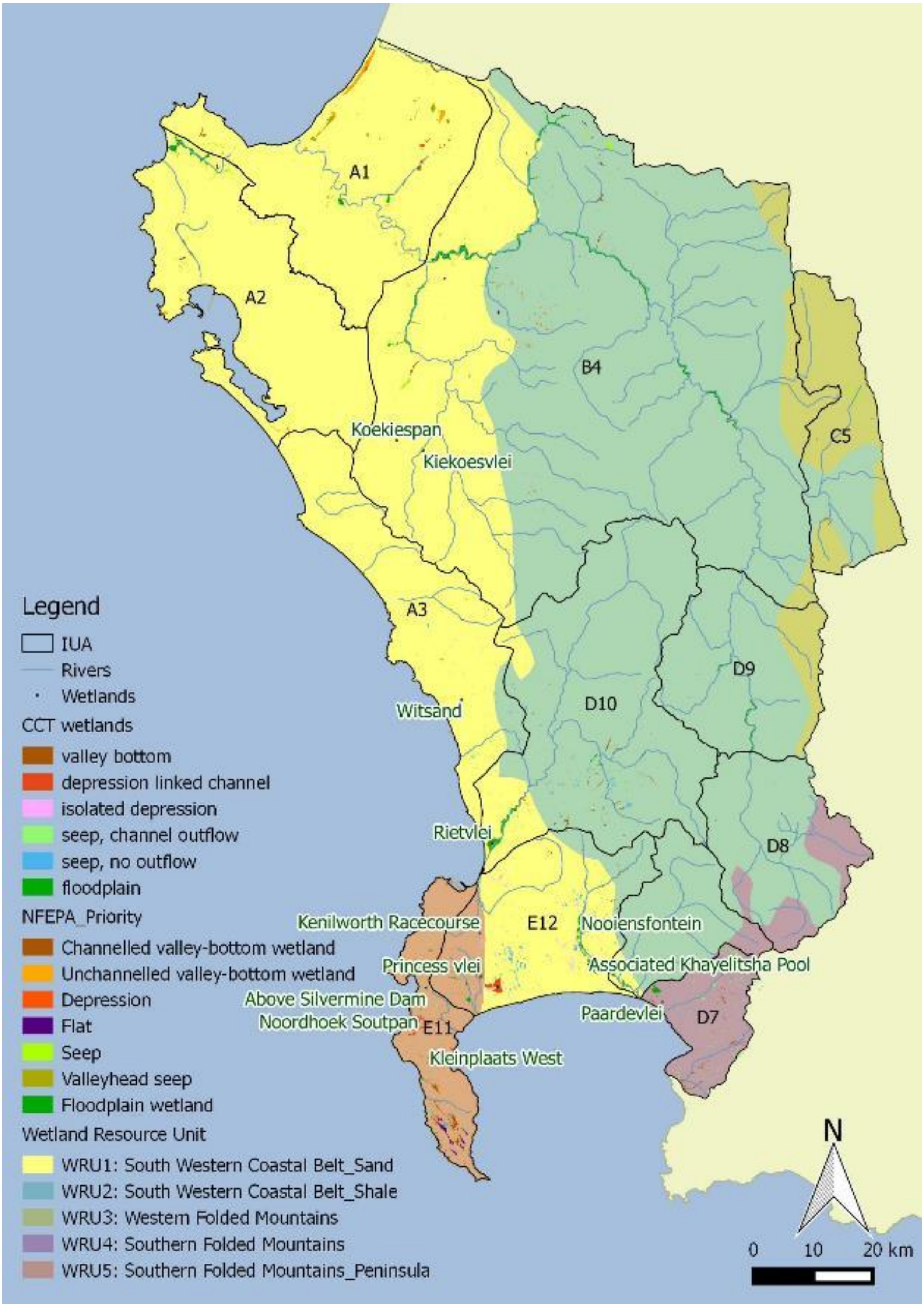


Figure 2.22. **The NFEPA and named wetlands within the study area.**

Table 2-35. The typical wetland types, IUA and important wetlands within each Wetland Resource Unit across the study area.

WRU name	Typical wetlands	IUA code	IUA	Named Wetlands (WC Wetlands Directory)
WRU1 South Western Coastal Belt_Sand	Floodplain	A1	Berg Estuary	Wamakersvlei
				La Rochelle
				Cerebos Saltpans
				Die Plaat
				Hotel Saltpans
				Springersbaai Floodplain wetlands
				Kliphoek saltpans
				Kliphoek River and Floodplain wetlands
				Bloemendal Pan
				Melkplaas Floodplain wetlands
				Olifantskraal marsh
				Kruispad floodplain wetlands
				Langrietvlei floodplain wetlands
				Doornfontein floodplain wetlands
				Kersefontein floodplain wetlands
				Helderwater pan
				Heuwelfontein
				Kersefontein floodplain wetlands
				Berg River floodplain wetlands
		A2	Langebaan	Ultra Soutpan
				Saldanha Lagoon
		A3	West Coast	Yzerfontein Soutpan
				Rooipan
				Jakkalfontein Private Reserve

WRU name	Typical wetlands	IUA code	IUA	Named Wetlands (WC Wetlands Directory)
				Dwars River Mouth lagoon
				Rondeberg
				Modder River Riparian Wetlands
				Silwerstroom Spring
				Witsand Aquifer recharge
		E12	Cape Flats	Blouvlei
				Zoarvlei
				Athlone Waste Water Treatment
				Kreupelboom
				Amandel
				Retention dam/vlei of UWC campus
				Bellville South Waste Disposal
				Kuils River Wetlands
				Nooiensfontein
				Driftsands Nature Reserve
				Padvlei
				Wetvlei
				Cape Corps
				Khayelitsha Pool
				Edith Stevens Wetland Park
				Pelican Park
				False Bay Nature Reserve wetlands (Zeekeovlei, Rondevlei, Strandfontein Sewage Works, Papkuilsvlei, Grootvlei)
		D6	Eerste	Klavervlei
		B4	Lower Berg	Kleigat Pan
				Droevlei

WRU name	Typical wetlands	IUA code	IUA	Named Wetlands (WC Wetlands Directory)
				Burgerspan
				Koekispan
				Kiekoesvlei
				Egbertsvlei
				Hamburg Pan
				Klein Hamburg Pan
		D10	Diep	Rietvlei
WRU2 South Western Coastal Belt_Shale	Floodplain	B4	Lower Berg	Middelskilpadvlei
				Skulpadsvlei
				Voelvlei Dam
				Brakvlei Dam
				Misverstand Dam
				Piketberg Dam
				Radyn Dam
				Berg River Floodplain
		D10	Diep	Driefontein Farm Dam
				Droevlei
				Riverlands Nature Reserve
				Rozenburg
				Byways Dam
				Uitkoms II dam
				Joosfontein
				Joostenbergkloof Dam
				Damara Dam
				Matjieskuil
		D9	Middle Berg	Paarl Sewage Works
				Noord Agter Paarl Irrigation

WRU name	Typical wetlands	IUA code	IUA	Named Wetlands (WC Wetlands Directory)
				Wellington Waste Water Works
				Silent Farm Dam
				Olyfenboomen Dam
				Berg River Floodplain
		D8	Upper Berg	Skuifraam Dam
				Bethel Dam (Paarl)
				Nanties Dam (Paarl)
				Sonstraal Dam
		D6	Eerste	Elsenberg Dam
				Klapmuts Dam
				Landskroon Dam
				Idas Valley Dam
				Vlottenburg Dam
				Vredenburg Dam
				Meerlust Dam
WRU3 Western Folded Mountains	Small valley bottom and seep wetlands.	C5	Berg Tributaries	No named wetlands
WRU4 Southern Folded Mountains	Seeps and valley bottom wetlands.	D8	Upper Berg	Dwarsberg Wetlands
				Wemmershoek Dam
		D7	Sir Lowry's	Paardevlei
				Helderberg Nature Reserve
				Steenbras River Dam
WRU5 Southern Folded Mountains_Peninsula	Range from mountain seeps, riverine systems and isolated depressions	E12	Cape Flats	Kenilworth Racecourse
				Princess Vlei
		E11	Peninsula	Kleinplaats West

WRU name	Typical wetlands	IUA code	IUA	Named Wetlands (WC Wetlands Directory)
				Noordhoek Soutpan
				Silvermine Dam
				Sirkelsvlei
				Schusters vlei
				Glencairn Vlei

2.5.3 Status quo assessment

The wetlands of the City of Cape Town jurisdiction mainly occur within **WRU 5 Southern Folded Mountains_Peninsula** and **WRU1 South Western Coastal Belt_Sand**. Towards the northern boundary of the area there tends to be a drier trend with Blaauwberg and Kraaifontein areas (WRU1) having fewer wetlands than surrounds and the mountainous and foothill parts of the City having numerous wetlands (WRU5) (Ewart-Smith et al., 2008). Wetlands are also numerous in low-lying areas of the Cape Flats, such as Kuils River catchment and the Sand River catchment (WRU1). Other catchments have been heavily impacted by development, including wetlands associated with rivers which have been partially drained.

In particular the wetlands in this area range from those located in pristine fynbos (i.e. upper part of Silvermine River, Groot Rondevlei, Kleinplaas Dam) to those located in residential areas (i.e. Noordhoek and Khayelitsha). The depression wetlands of Noordhoek and other isolated depressions dominate the lowlands of the City (Ewart-Smith et al., 2008). Within mountainous areas of Chapman's Peak, City, Hout Bay, Llandudno, Lourens River, Muizenberg, Noordhoek, Silvermine River, Sir Lowry's Pass, South Peninsula, Steenbras River seeps are dominant (Ewart-Smith et al., 2008). Floodplain wetlands are dominant in the Diep River (Milnerton) and Sand River catchments, and the Kuils River catchment. The Diep and Sand rivers both have extensive floodplain flats associated with the lower reaches of the rivers (Rietvlei and Zandvlei) (Ewart-Smith et al., 2008).

Along the West Coast the South Western Coastal Belt Ecoregion is divided into the **WRU1 South Western Coastal Belt_Sand** and **WRU2 South Western Coastal Belt_Shale** due to the influence of underlying geology. WRU1 stretches along the coast and is associated with Aeolian sedimentary deposits of the Kalahari Group. The Langebaan and Berg Estuary occur within this WRU, with associated wetlands occurring along the Berg River. The wetlands along the coast consist of a few isolated pans and the Witzand Recharge Aquifer is completely artificial, receiving purified stormwater from Atlantis (Malan et al., 2015).

2.5.3.1 Major threats and impacts

In natural capital terms wetlands may be seen as important green infrastructure worthy of economic valuation and investment in order to ensure goods and services that they offer can be sustained. This monetary value is rooted to the fact that the primary functioning of a wetland are to process water and regulate runoff. The inherent value of wetlands is that they protect and regulate this water source by acting like sponges, soaking up water during flood events and releasing it during dry periods (DWAF, 2005). By regulating water flows during floods, wetlands may reduce flood damage and help prevent soil erosion. As natural filters wetlands also help to purify water by trapping pollutants, heavy metals and disease causing organisms. These ecosystem services are provided at very little cost but with significant payback for the economy.

Aside from the socio-economic benefits of wetlands, they also serve an important role as a stepping stone for birds, reptiles, invertebrates and amphibians moving across the landscape. This role as a stepping stone is dependent on the degree of permeability in the surrounding area, generally decreasing as the landscape becomes more degraded (Job et al., 2008). Development of the surrounding area also limits the movements of animals, in effect reducing the functioning of a wetland.

Although wetlands provide important ecosystem services many are at risk, with the main issues being draining wetlands for crops and pastures, poorly managed burning and grazing resulting in headcut and donga erosion, planting alien invasive vegetation, mining, pollution and urban development. These have been significant as they alter the natural flow of water in wetlands and as water is the driver of wetland formation it follows that any changes to this fundamental driver could be damaging.

The major threats and impacts for wetlands within each WRU are as follows:

- **WRU1 South Western Coastal Belt_Sand**

  The City of Cape Town efforts to conserve individual wetlands (e.g. Khayelitsha Wetland Park, Witsand Recharge Area) has helped to improve ecological condition (Malan et al., 2015). Alien invasive vegetation has had a severe impact on ecological health of some wetlands (e.g. Yzerfontein), with associated impacts such as reduced runoff, reduced biodiversity and increased vulnerability to erosion (Malan, et al., 2015). Development of housing has had a major impact on wetlands in urban areas, with accompanying changes to hydrology, reductions in connectivity of wetlands to surrounding biodiversity and pollution threats. Alluvial floodplains in the WRU are highly threatened by water abstraction, which is threatening the seasonal inundation of the floodplain, and the persistence of floodplain vegetation and wetlands (Job et al., 2008). The False Bay Nature Reserve has been declared a Wtland of International Importance (Ramsar Site no. 2219) and is South Africa's 22nd Ramsar Wetland. This consists of Rondevlei (a lake within a protected area) and Zeekoevlei (a recreational lake within a residential area). Both lakes support large populations of waterbirds, including pelicans and flamingos and up to 60% of the bird species in the South-western Cape (228 species). The site is also important due to the populations of mammals (including hippopotamus, cape clawless otter, water mongoose) and diversity of plant species (about 256 indigenous plants, including two endemic plant species currently listed as extinct in the wild: *Erica turgida* and *Erica vericillata)*.

- **WRU2 South Western Coastal Belt_Shale**

  Water abstraction is threatening floodplain wetlands within this WRU. The expansion of towns and urban areas (e.g. northern expansion of the City of Cape Town) is likely to increase pressures due to habitat degradation and pollution which may lead to complete loss of some wetlands.

- **WRU3 Western Folded Mountains**

  There are limited wetlands within this area, but the main impact to wetlands in this area would be transformation for agriculture. Some high altitude seeps are important as they contribute to the source of rivers flowing out of the mountains.

- **WRU4 Southern Folded Mountains**

  There are limited wetlands within this area, but the main impact to wetlands in this area would be transformation for agriculture. Some high altitude seeps are important as they contribute to the source of rivers flowing out of the mountains.

- **WRU5 Southern Folded Mountains_Peninsula**

  The proclamation of the Table Mountain National Park has helped to conserve many wetlands in the Peninsula area on a large scale and the effort by the City of Cape Town to conserve individual wetlands (i.e. Silvermine, Kenilworth) has helped on a smaller scale (Malan et al., 2015).

2.5.3.2 Baseline assessment of wetlands ecological state

The Ecological Condition of wetlands within the study area are difficult to define due to limited baseline data. Although the NFEPA wetland maps provide EIS and PES factors, these were done on a coarse national scale and require critical evaluation. It is proposed for this study that the NFEPA wetland maps be used as a first attempt when determining the status of wetland systems, but that fine-scale studies be referred to where available. The FSP maps provide detailed assessment for certain areas across the study area, with the CCT wetland maps (Ewart-Smith et al., 2008) and the Malan et al. (2015) report on the "Trajectory of change in wetlands of the Fynbos Biome from the late 1980s to 2014" provide additional information for important wetlands within the study area.

2.6 Rivers

2.6.1 Approach

Some information pertinent to describing the status quo of rivers has already been summarised in previous reports, namely the data gathered and interrogated during the delineation of river resource units (RUs), biophysical and allocation nodes and that information used to *type* the rivers toward IUA delineation. The useful information from these data toward status quo description are summarised here.

Table 2-36. Scores for Ecological condition and habitat descriptions (Kleynhans and Louw 2007)

Ecological Category	Ecological Condition % Score	Description of the habitat
A A/B	92-100% 87-92%	Still in a Reference Condition.
B B/C	82-87% 77-82%	Slightly modified from the Reference Condition. A small change in natural habitats and biota has taken place but the ecosystem functions are essentially unchanged.
C C/D	62-77% 57-62%	Moderately modified from the Reference Condition. Loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D D/E	42-57% 37-42%	Largely modified from the Reference Condition. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E E/F	22-37% 17-22	Seriously modified from the Reference Condition. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	0-17%	Critically/Extremely modified from the Reference Condition. The system has been critically modified with an almost complete loss of natural habitat and biota. In the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

The following information and GIS layers were required to complete the procedure of selecting nodes:

- Quaternary, secondary and primary catchment boundaries (from http://www.dwaf.gov.za/iwqs/gis_data/RHPdata.htm)
- Rivers on a 1:500 000 scale (from http://www.dwaf.gov.za/iwqs/gis_data/RHP data.htm)
- Level I Ecoregions (from http://www.dwaf.gov.za/iwqs/gis_data/RHPdata.htm)
- Gauging weirs – from Department of Water Affairs and Forestry (DWAF)
- Geomorphic zones by Rowntree and Wadeson (1999) (from Chief Directorate Resource Quality Services, Department of Water Affairs (DWA)
- Environmental Water Requirements (EWR) sites (from relevant Reserve studies).
- Hydrological Index Classes based on the hydrological index of Hughes and Hannart (2003) as modified by Dollar *et al*. (2006) and Brown *et al*. (2006).

- Ecological Importance and Sensitivity categories and Present Ecological Status (or habitat integrity) (from various reports, DWA database, updated and augmented with fieldwork in WCWSS).

River RUs were decided upon by considering a range of information about biophysical drivers known to determine river type and condition, namely flow (perennial or non-perennial), geomorphological zonation, riparian vegetation and adjacent terrestrial vegetation type.

Two DWS data sets describe river ecological condition (PES 1999 and PES 2014). Change from the former to the latter were used to describe trends and where possible, using other data, to infer reasons for change. This must be interpreted with some caution since the 1999 dataset was compiled via a desktop analysis and the 2014 data for the Western Cape were compiled from field assessments and so are inherently more accurate and reported at a finer scale.

Finally the status quo descriptions for each resource unit were focussed at PES 2014, the most comprehensive data set gathered about river ecological condition using a range of biophysical data to date, including that for vegetation, invertebrates, amphibians and fish. Consideration was also paid to the presence and location of conservation priority areas, summarised by National Freshwater Ecosystem Protected Areas (NFEPA, Nel and Driver 2011). Where possible, causes and sources for the ecological condition 2014 were described as being flow or non-flow related.

Examples of the data categories used in the descriptions are provided next.

2.6.2 Description

The four main data categories used to determine river *type* were flow, being perennial or non-perennial, geomorphological zonation, riparian vegetation and adjacent terrestrial vegetation types.

Most rivers in primary drainage basin G1 flow perennially, apart from some of the smaller tributaries (Figure 2.23). The Berg River flows perennially as do many of the upper reach tributaries, there are however some non-perennial tributaries draining into the lower foothills and lowlands (Figure 2.24).

The most prominent riparian vegetation type is Swartland Alluvium Fynbos mostly along the middle Berg River and tributaries. There are also other smaller patches of these other azonal vegetation types; Cape Coastal Lagoons, Cape Estuarine Salt Marshes, Cape Inland Salt Pans, Cape Lowland Freshwater Wetlands, Cape Vernal Pools, Freshwater Lakes and Lourensford Alluvium Fynbos (Figure 2.25).

Southwest Fynbos and West Coast Renosterveld dominate the study area, with smaller areas being occupied by East Coast Renosterveld, Northwest Fynbos and West Strandveld (Figure 2.26). The upper Berg River comprises predominantly Southwest Fynbos while the middle and lower Berg comprise mainly West Coast Renosterveld.

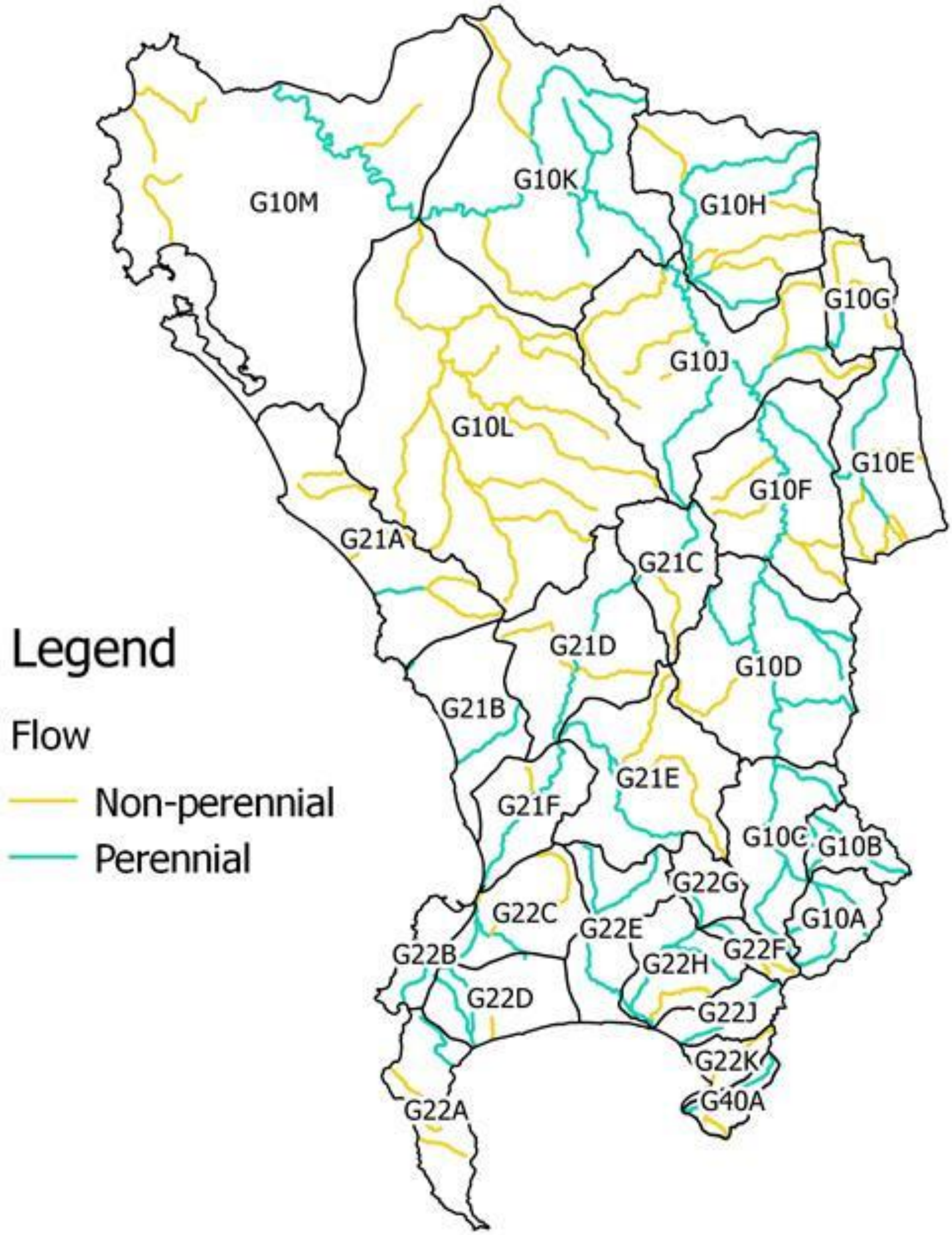


Figure 2.23. Perennial and non-perennially flowing rivers.

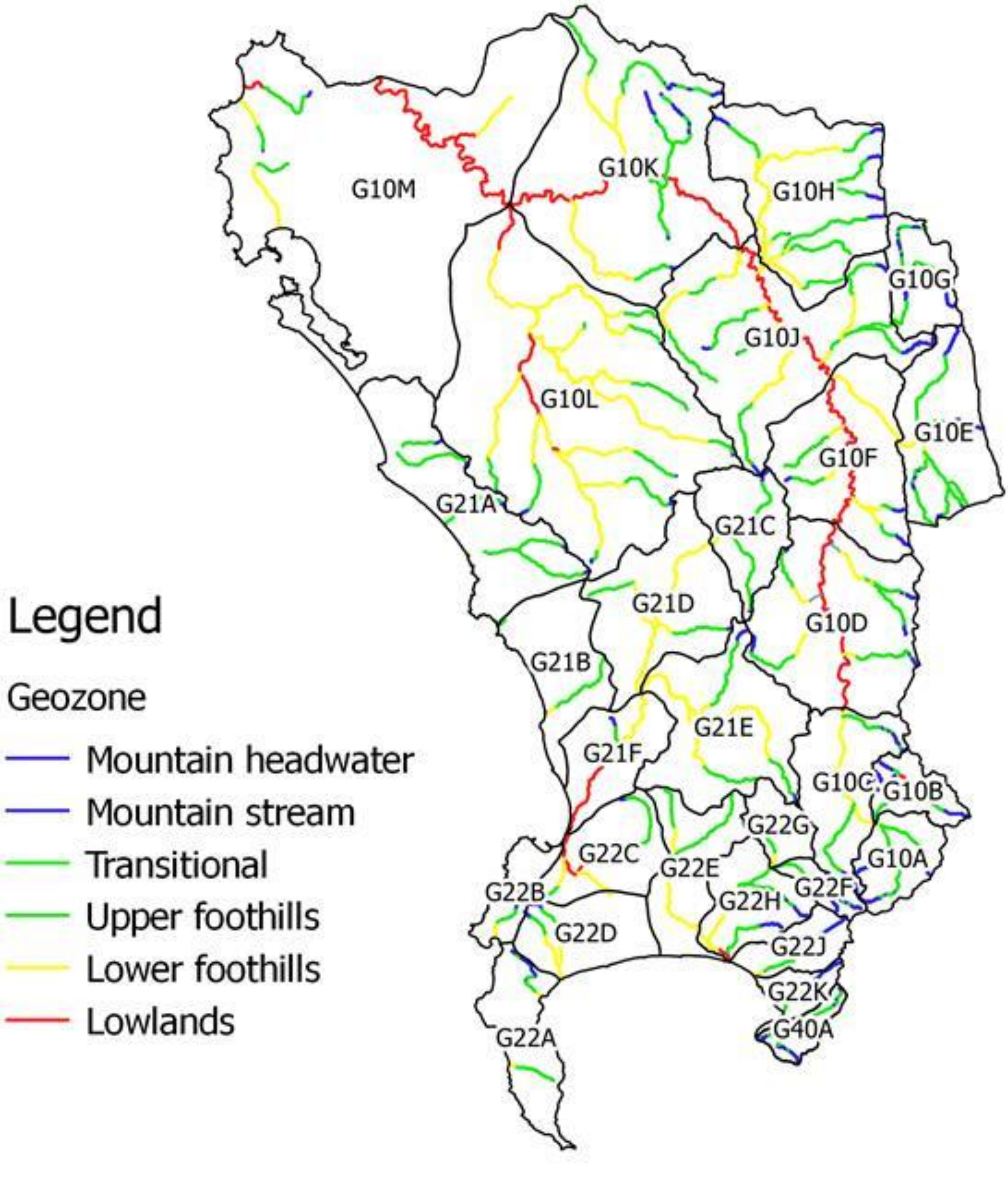


Figure 2.24. Geomorphological zones.

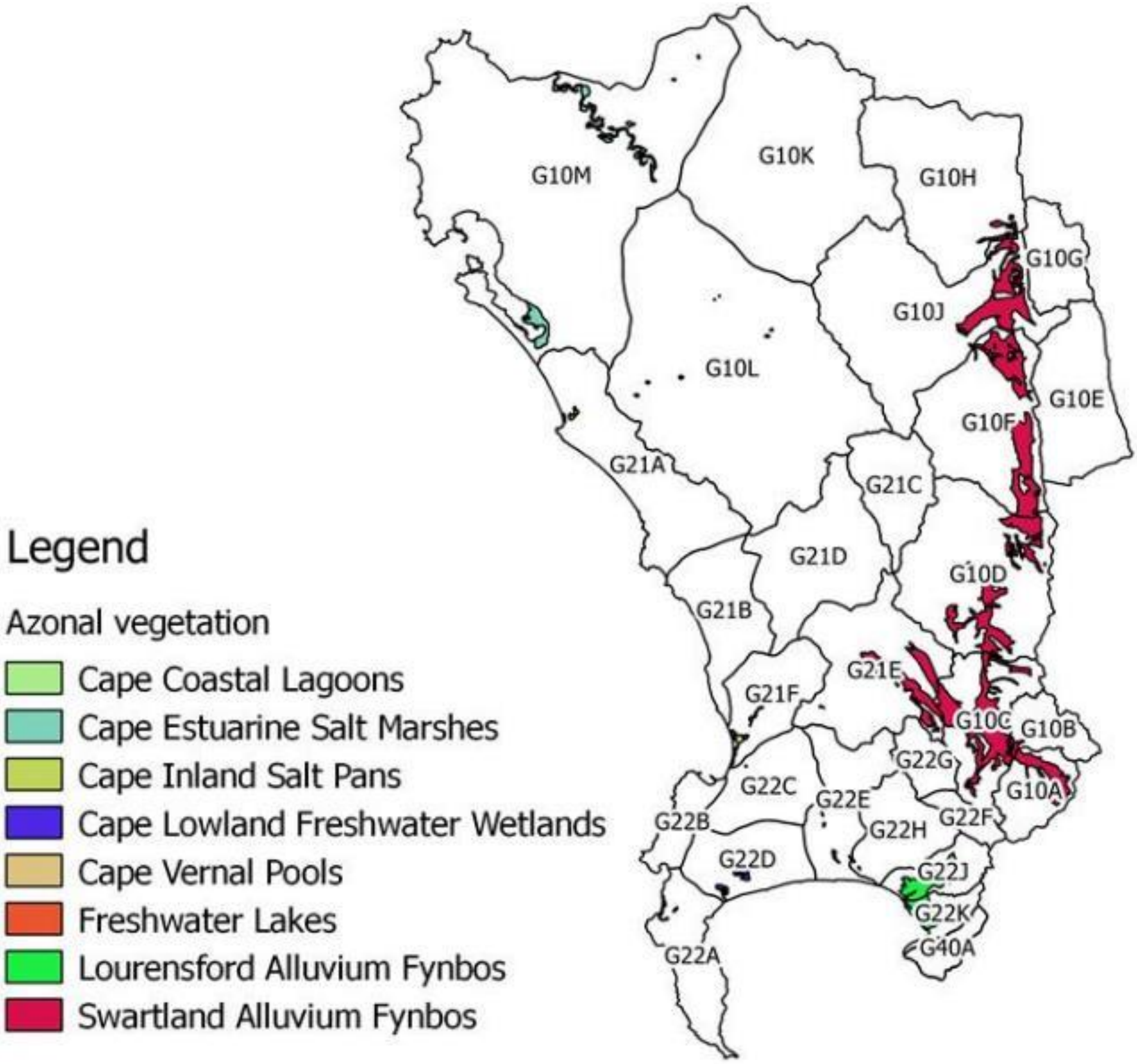


Figure 2.25.Riparian vegetation types.

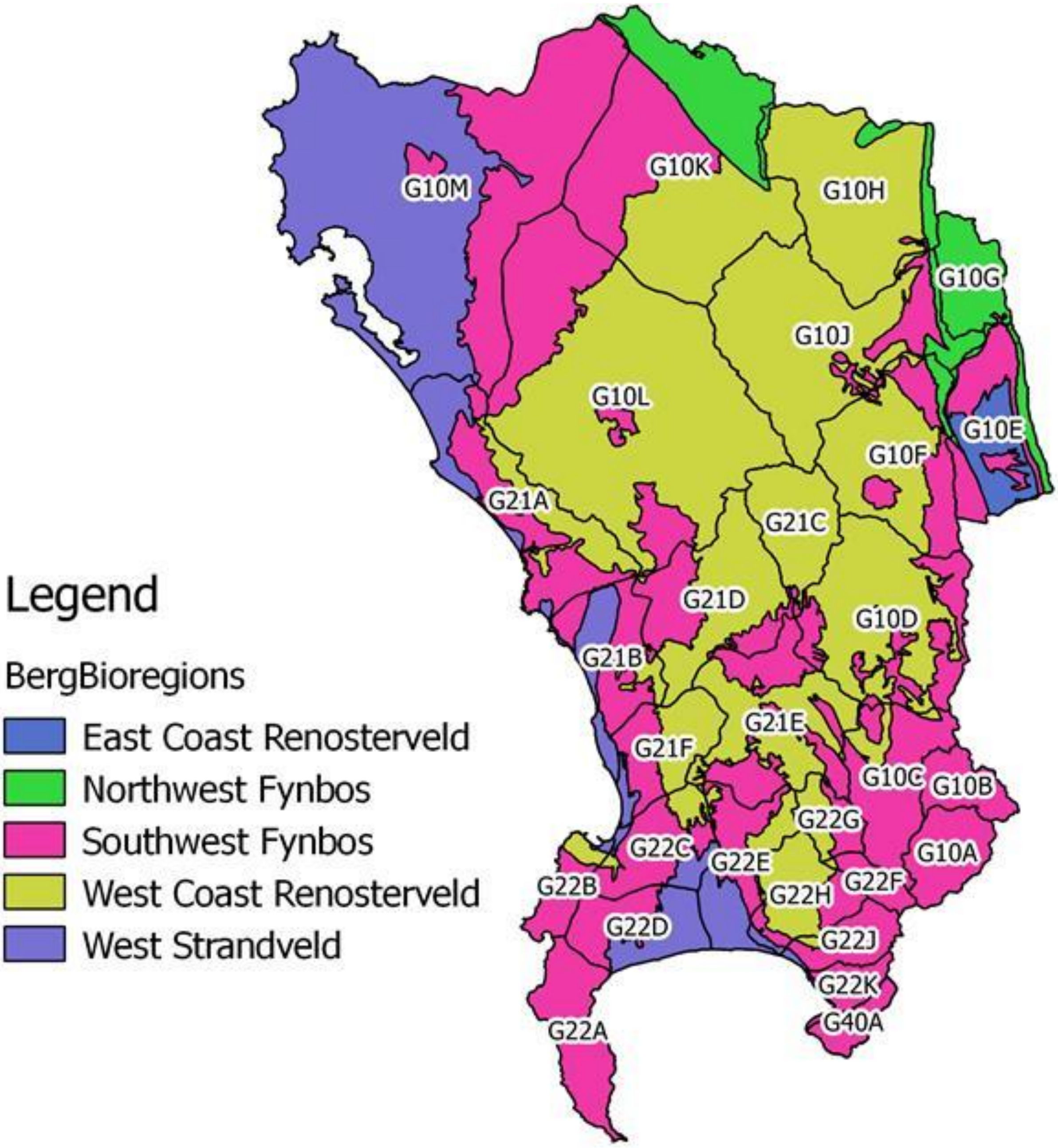


Figure 2.26. Terrestrial vegetation types.

2.6.3 Status quo assessment

The 1999 and 2014 DWS PES data sets were the main inputs into the status quo descriptions. In what follows the terms ***Present Ecological Status*** are misleading and therefore not used in the context of these status quo descriptions; PES 1999 was based on data gathered prior to 1999 and is no longer *PRESENT* or currently valid. PES 2014 is also dated thus no longer considered present. Therefore, the term ecological condition, with the post-script dates 1999 or 2014, was used.

The ecological condition 1999 of the majority of the basin was a C-category, considered to be moderately modified (Table 2-36, Figure 2.27). Three quaternaries were considered to be slightly modified, in a B-category, while three others were in a D-category, largely modified. Only one was in an unacceptably seriously or critically modified condition, EF-category.

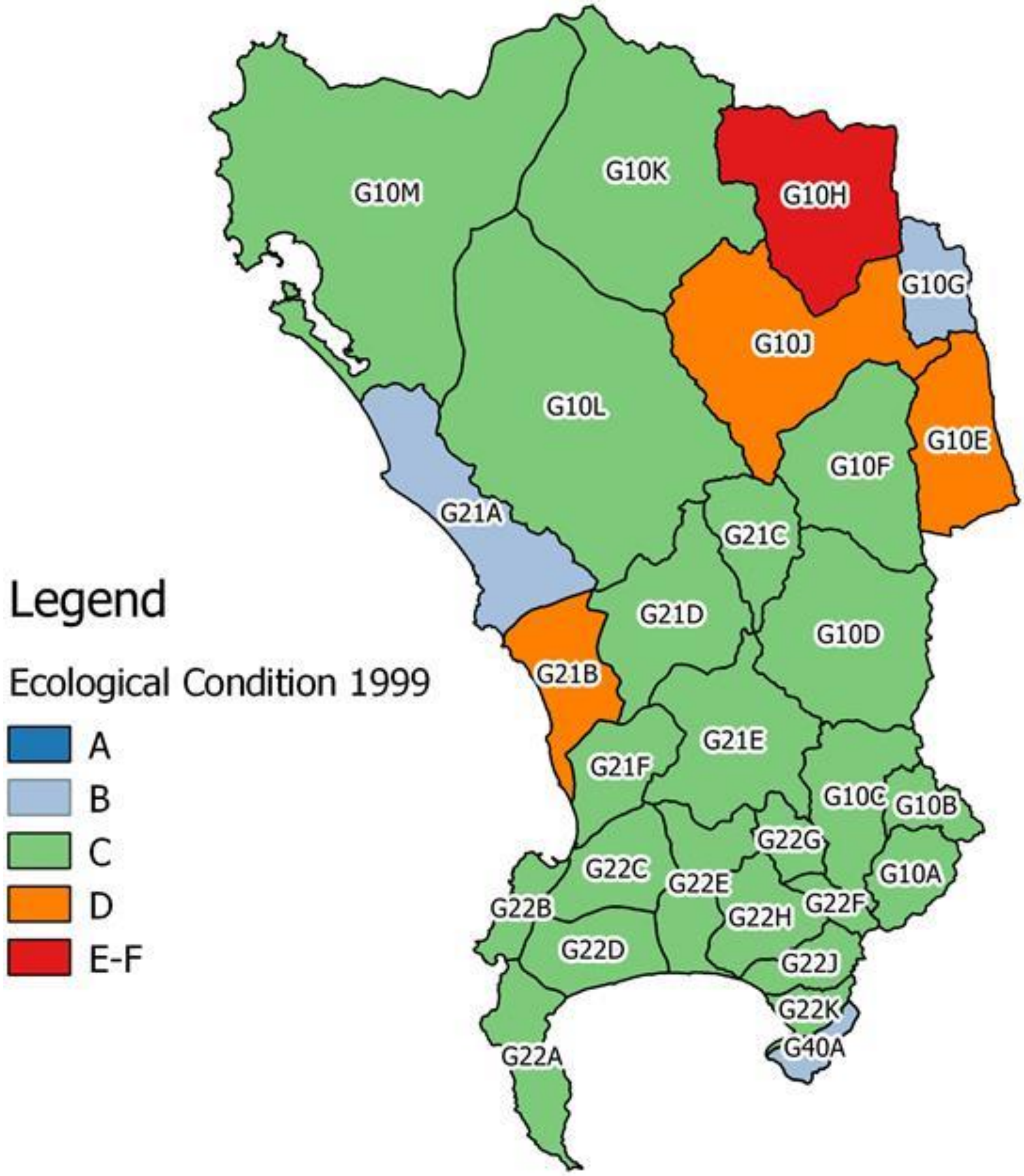


Figure 2.27. Ecological condition (EC 1999) at quaternary catchment level.

Following the more detailed field-based assessment in 2014, and potentially with changes over time for various reasons, there were some changes. G10G improved from a B-category, being slightly modified, to an A-category, in an unmodified state. The other two quaternaries that were in a B-category 1999 now were faring more poorly, with the rivers in G21A being largely modified in a D-category, and the Steenbras River in G40A being largely modified (D-category) in its upper reaches and moderately modified (C-category) downstream of the Steenbras reservoir. The rivers in G10H have improved since being in an EF-category 1999 to now being largely modified (D-category). Unfortunately, by and large, the greatest change is that most of the study area 1999 was considered to be moderately modified (C-category) but now in general, there are few C-category rivers 2014, the majority are D and there are also others in E and F-category condition.

It is unlikely that this apparent degradation is real, rather it is much more likely that the 1999 assessment overestimated the condition since most of these river basins have been farmed more and more intensely since the early 1900s.

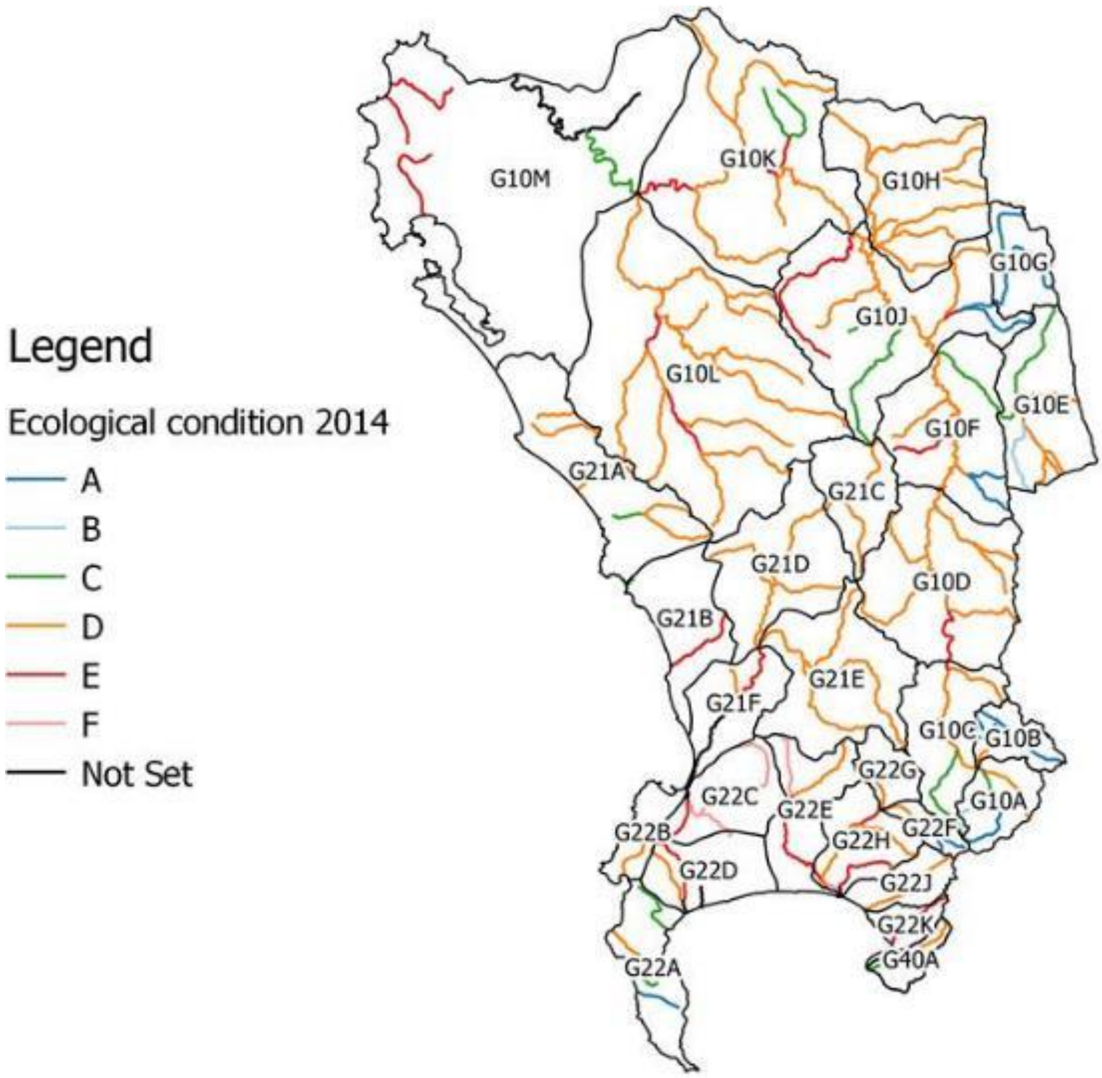


Figure 2.28. River resource unit ecological condition (EC 2014) at a sub-quaternary level.

3 DELINEATION OF IUAs AND BIOPHYSICAL NODES

3.1 Delineation of IUAs

The objective for defining IUAs is to establish broader-scale units for assessing the socio-economic implications of different catchment configuration scenarios and to report on the ecological conditions at a sub-catchment scales. IUAs are a combination of the socio-economic zones and watershed boundaries, within which ecological information is provided at a finer scale. A total of twelve IUAs were identified in the study area. These are summarised in Table 3-1 and shown in Figure 3.1.

Table 3-1: Summary of IUAs defined for the Berg study area and including the link to socio-economic zones and significant water resources (i.e. quaternary catchments).

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

3.2 Biophysical and Allocation Nodes

The objective of Step 1.d of the classification process is to establish a suite of biophysical and allocation nodes that will be used as modelling points for the Classification Process. The nodes will be used to assess the responses of the upstream resources to changes in water quality, quantity and timing. 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 and quality of water that remains in the resources, and thus the quantity and quality of water available for off-stream use.

The biophysical and allocation nodes for the study area were defined according to the procedures described in WRCS (Dollar et al. 2006). Eleven "tiers" of information were sequentially assessed, and rules applied, in order to establish nodes for each tier. Nodes for all significant dams are included as part of River Nodes.

For Estuary Nodes we followed the National Biodiversity Assessment approach 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.

There are 47 biophysical and allocation nodes (including dams, estuaries and other infrastructure) defined for the study area. The location of these nodes relative to the IUAs are given in Figure 3.1 with additional information including the present ecological condition as determine in 1999 and 2014 given in Table 3-2.

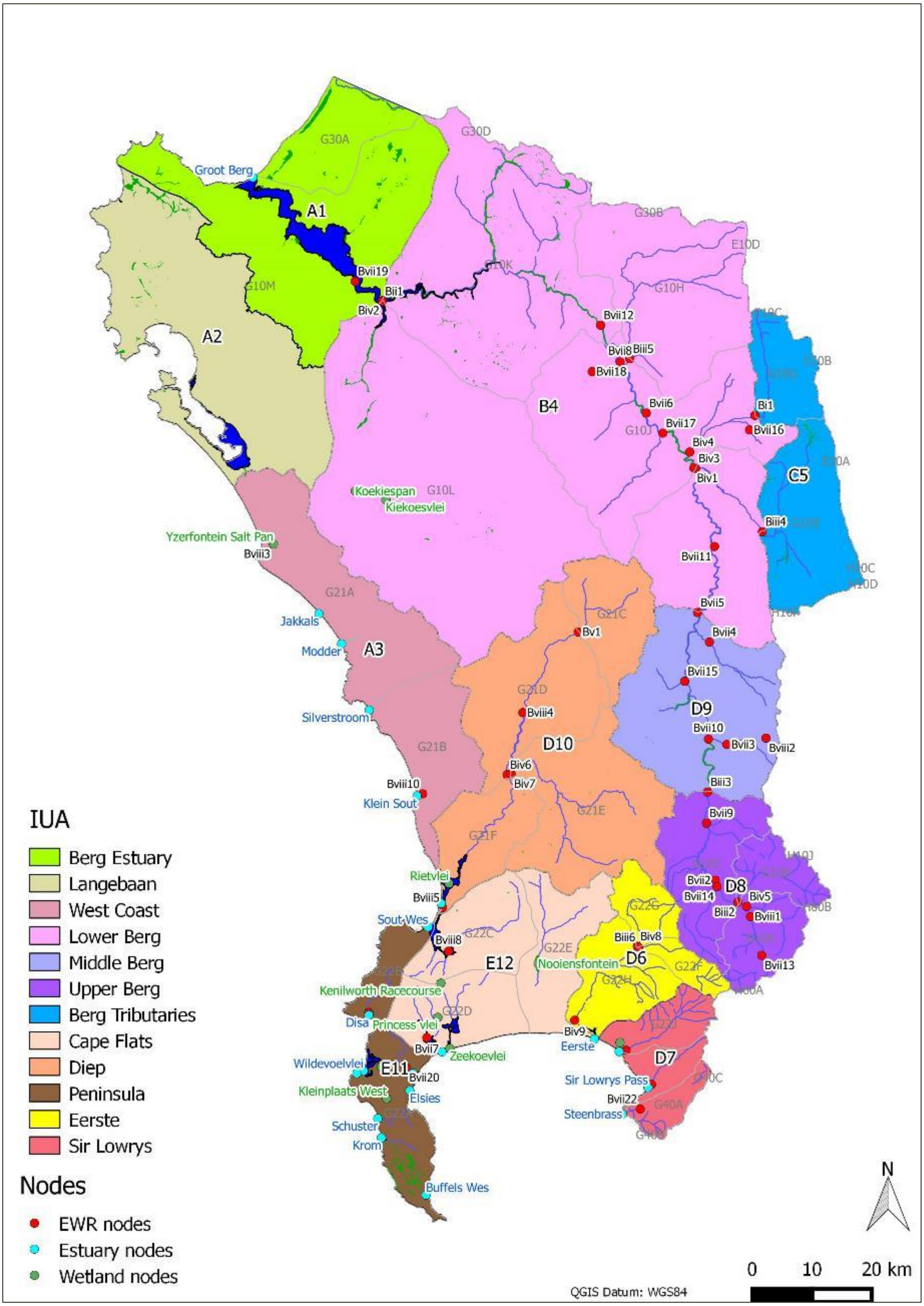


Figure 3.1. Integrated Units of Analysis (IUAs) and biophysical and allocation nodes defined for the study area.

Table 3-2. **Biophysical and allocation nodes defined 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
Di	G21D-08761	Bv1		Diep	18.7383	-33.4643	G21D	SCB	1	LF	H	D	D	Phase2F EPA	P
Di	G21D-08825	Bviii4	U/s of confluence with Diep	Swart	18.6372	-33.5869	G21D	SCB	1	LF	H	D	D	Upstream	P
Di	G21D-08906	Biv6		Diep	18.6085	-33.6813	G21D	SCB	1	LF	H	D	D	FishFSA	P
Di	G21E-08962	Biv7		Mosselbank	18.6159	-33.6799	G21E	SCB	1	LF	H	D	D	Phase2F EPA	P
Di	G21F-09037	Bviii5	Cumulative at outflow G21F	Diep	18.4909	-33.8830	G21F	SCB	1	L	U	C	D	Phase2F EPA	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
SL	G22J-09266	Bvii21	Town	Lourens	18.8257	-34.0987	G22J	SCB	1	UF	H	D	D	FishFSA	P
SL	G22K-09315	Bviii9	Cumulative at outlet G22K	Sir Lowry's Pass	18.8721	-34.1504	G22K	SCB	1	UF	H	D	E	FishFSA	P
SL	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

IUA	SQ Code	NODE	COMMENT	RIVER	LONG	LATI	QUAT	ER	HI	GZ	EISC	EC1999	EC 2014	FEPA	Flow
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	Wemmersho ek	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	Phase2F EPA	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	Phase2F EPA	U
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

IUA	SQ Code	NODE	COMMENT	RIVER	LONG	LATI	QUAT	ER	HI	GZ	EISC	EC1999	EC 2014	FEPA	Flow
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	Phase2F EPA	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, Di = Diep, C F = Cape Flats, Pen = Peninsula, E = Eerste, SL = 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 = very 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

4 SOCIO-ECONOMICS AND ECOSYSTEM SERVICES

Establishing the socio-economic component requires a suitable socio-economic evaluation framework for the Classification Process. This framework should be able to assess the implications of different catchment configuration scenarios at an IUA level on economic prosperity, social wellbeing and ecological condition. This component requires six sub-steps and two combined sub-steps (Figure 4.1).

The objective of this component is to define the relationships that will link change in the configuration of the Water Resource Class (WRC) scenario to a resulting economic value and social wellbeing across the study area that will be used to inform the selection of the preferred WRC scenario.

4.1 Approach

Section 4 provides a description of the status quo in terms of (1) economic activities, outputs and employment and (2) the characteristics and current socio-economic situation of people living within the study area. The status quo assessment will provide a baseline against which to measure the potential impacts associated with changes in water yields and environmental flows and how this will affect economic output and social well-being under a range of classification scenarios. As well as providing the overall context against which to evaluate change, the descriptions provided in this section highlight these linkages to water and focus on the aspects of economy and livelihoods that are likely to change under changed availability and allocation of water resources.

Economic outputs and social wellbeing are related and are each directly influenced by both water supply and environmental flows in different ways. Economic activities that depend on licenced use of water include irrigation agriculture, plantation forestry and industry. Economic activities whose outputs are linked to the quality of aquatic ecosystems include tourism and freshwater, estuarine and marine fisheries. In addition, the functioning of aquatic ecosystems also plays a role in overall economic productivity through ecosystem services that lead to cost savings, such as flood attenuation, sediment retention and water quality amelioration. These cost savings manifest in both the private and public sector.

Similarly, social wellbeing within the study area is determined by both water supply and instream flows, namely the abstraction and supply of water for domestic purposes, the supply of abstracted or instream water to economic activities which provide employment opportunities, and the supply of instream flows which lead to the provision of instream water, natural resources and opportunities for recreation and spiritual fulfilment.

Ecosystem services are therefore an integral factor influencing the economic and social status of the different parts of the catchment. For this reason they are not treated separately in this report, but are woven into the description of the status quo. We have also avoided as far as possible the potentially confusing use of ecosystem services jargon, although this is explained more fully in Box 4.1.

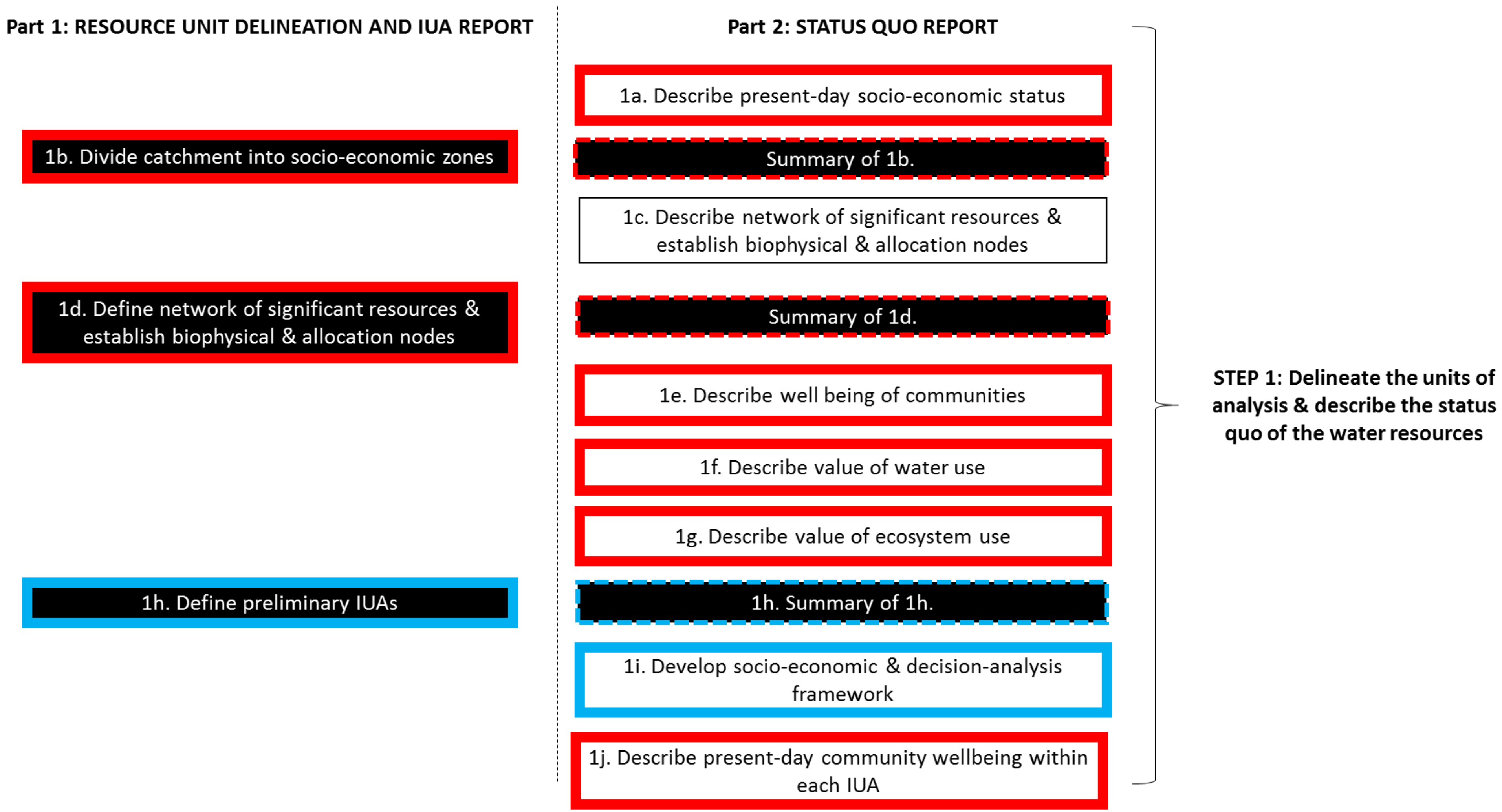


Figure 4.1. The sub-steps for Step 1 of the Classification Procedure, with sub-steps highlighted in red and combined sub-steps highlighted in blue.

The roles of water and aquatic ecosystem services in determining the economic prosperity and the social wellbeing of people living in the study area are summarised in Figure 4.2.

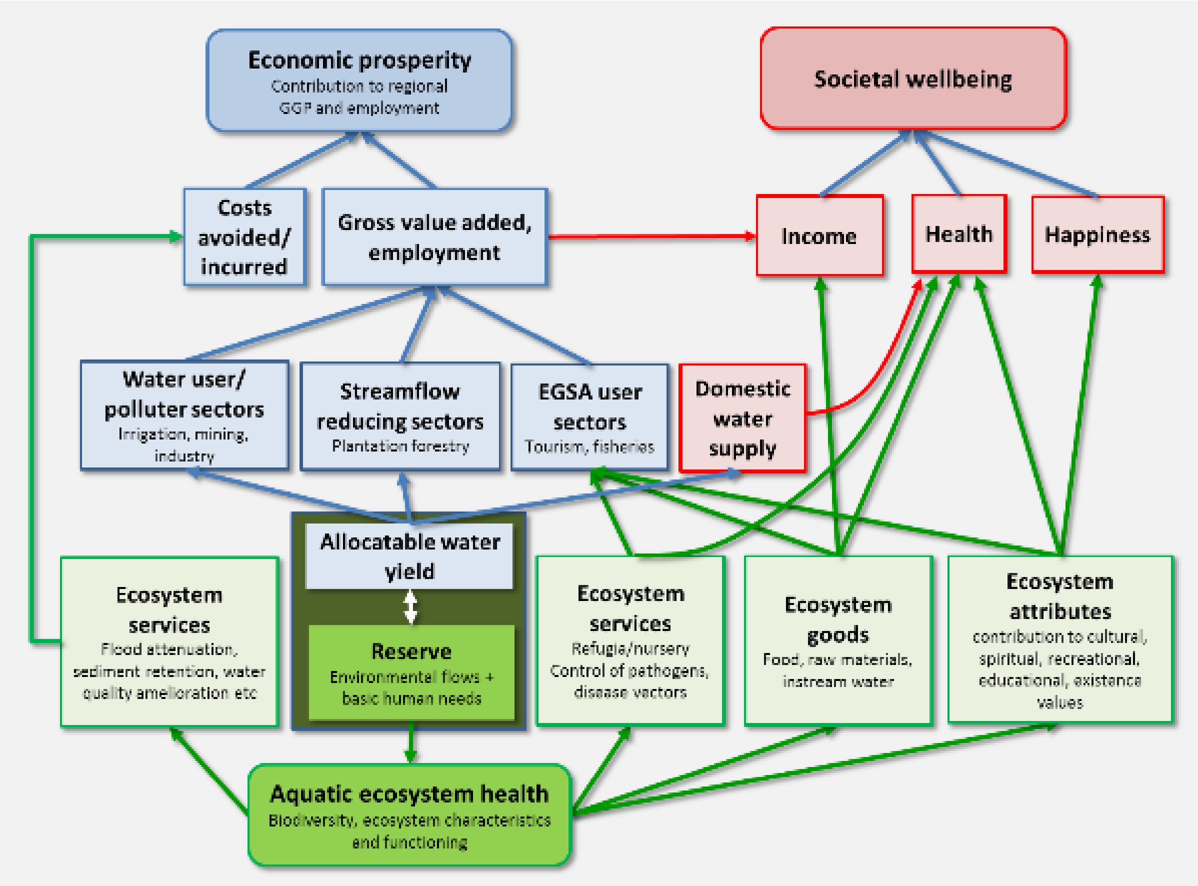


Figure 4.2. Linkages arising from the trade-off between water abstracted for use and water retained for the Reserve (source: Author, modified from Turpie et al. 2006).

Economic outputs are summarised in terms of direct and total gross value added (GVA), and total employment. Direct GVA is the sum of all income generated to business owners and as wages in the activities described. Total GVA includes incomes generated indirectly in all sectors as a result of these activities, such as through the purchase of inputs, and incomes generated as a result of spending by wage earners. Social wellbeing is constructed as a composite index of measures of household income and other benefits (Figure 4.2).

This chapter begins with thematic overviews of the above activities and variables with a description of how they vary across the study area and its socio-economic zones, and then summarises the information by socio-economic zones as well as IUAs for later comparison in the scenario analyses.

Estimates of gross value added (GVA) and employment per sector per socio-economic zone were made for 2015. These were based on the spatial disaggregation of GVA and employment data by mesozone for 2009 from the CSIR Geospatial Analysis Platform (GAP 2011). These figures were adjusted using detailed district municipality GDPR and employment data from the Western Cape Government Municipal Economic Review and Outlook (2014) and then adjusted at the national level from 2013 to 2015 using national GDP nominal growth rate statistics for GVA and real growth rate statistics for employment (StatsSA 2016).

Information on population, income, livelihoods and living conditions was derived from StatsSA Census data for 1996, 2001 and 2011. Where census data had been disaggregated into mesozones by StepSA (2015), these were used to obtain summaries at the level of the socio-economic zone. For other census data, summaries were produced based on data at the slightly larger sub-place (SP) level.

Box 4.1. Ecosystem services, classification and valuation frameworks.

Ecosystem services provided by aquatic ecosystems

- ***Provision of harvested resources***
  Several kinds of living (e.g. reeds, thatching grass, firewood, fish) and non-living resources (e.g. water, clay) are harvested from aquatic ecosystems for food, medicine and raw materials. Wetlands are also used as grazing areas, especially during the dry season and have a higher grazing potential than surrounding uplands.
- ***Flood attenuation***
  Vegetated landscapes, and wetlands in particular, regulate flows through flood attenuation, groundwater recharge and, through this, the maintenance of base flows. Rivers will also perform these roles to some extent, but the bulk of research has focussed on wetlands. Wetlands play an important role in attenuating floods, but providing temporary storage for high flows and slowing their movement through the catchment.
- ***Sediment retention***
  When flows enter wetlands, they are slowed down and part of the load settles out. This enriches the productivity of the wetland and also the agricultural potential of floodplains. In addition, where catchment sediment loads are elevated by erosion, the settling out of sediments in wetlands reduces the damage caused downstream. The ability of wetlands to remove excess sediment loads is related to their ability to reduce water velocity, and is thus closely related to a wetlands flow regulation capacity. This service is therefore linked to flood attenuation.
- ***Waste treatment***
  Aquatic ecosystems play a role in ameliorating water quality either through trapping, absorption and breakdown of organic and inorganic pollutants, or through dilution.
- ***Carbon sequestration***
  The sequestration of carbon by ecosystems acts as a natural offset to damage caused by increasing anthropogenically linked atmospheric carbon and resultant global climate change. Carbon is sequestered when it is taken up by plants in the growth process and stored in above and below-ground plant biomass. In addition, litter production and other processes lead to the accumulation of carbon in soil. Carbon sequestration by aquatic ecosystems is still poorly understood, and values were obtained from available literature sources. The highest rates of carbon sequestration occur within swamp and mangrove forests. Saline marsh areas have a much higher sequestration rate than freshwater marsh areas.
- ***Ecological regulation***
  Some ecosystems support organisms that help to keep pests under control (e.g. fish that eat disease vectors). Aquatic ecosystem degradation can improve conditions for certain pests (e.g. reduction in flows leading to stagnant water ideal for mosquitoes, bilharzias and black fly, or invasive plants such as water hyacinth.
- ***Refugia and nursery functions***
  This service is supplied when an ecosystem provides critical habitat for a population that is utilised elsewhere, such as the nursery function that estuaries provide for certain marine species. This also includes the aquaculture opportunities provided by aquatic ecosystems. Estuaries act as nursery areas for fish and prawns captured in inshore marine fisheries, and also export sediments and nutrients that are vital for offshore crustacean fisheries.
- ***Aesthetic, recreational, spiritual and cultural values***
  The aesthetic, recreational, spiritual and cultural values of ecosystems are derived from their attributes such as beauty and rarity. These attributes determine whether an area is suitable or attractive for recreational use, religious ceremonies or spiritual fulfilment. Some of the more intangible aspects of these values are extremely difficult to estimate, even when applying best-practice comprehensive survey methods. However, some of the more measurable manifestations of these values include the expenditure that people incur in order

to view or visit aquatic ecosystems (tourism value), and the extra amounts, or premiums, that people pay for properties in order to have access to or views of aquatic systems (property value).

Classification of ecosystem services

The concept of ecosystem goods and services stems from the perception of ecosystems as natural capital which contributes to economic production. Ecosystems can be seen to provide a range of 'goods' and 'services' and have 'attributes' that generate value and contribute to human welfare (Barbier 1994, 2011). Goods, services and attributes may be defined as follows:

- **Goods** are harvested resources, such as fish.
- **Services** are processes that contribute to economic production or save costs, such as water purification.
- **Attributes** relate to the structure and organisation of biodiversity, such as beauty, rarity or diversity, and generate less tangible values such as spiritual, educational, cultural and recreational value.

Goods, services and attributes are often referred to collectively as 'ecosystem services', or 'ecosystem goods and services'. More recently, the Millennium Ecosystem Assessment (2003) defined ecosystem services as "the benefits people obtain from ecosystems" and categorized the services obtained from ecosystems as follows:

- **Provisioning services** such as food and water;
- **Regulating services** such as flood and disease control;
- **Cultural services** such as spiritual, recreational, and cultural benefits; and
- **Supporting services**, such as nutrient cycling, which maintain the conditions for life on Earth.

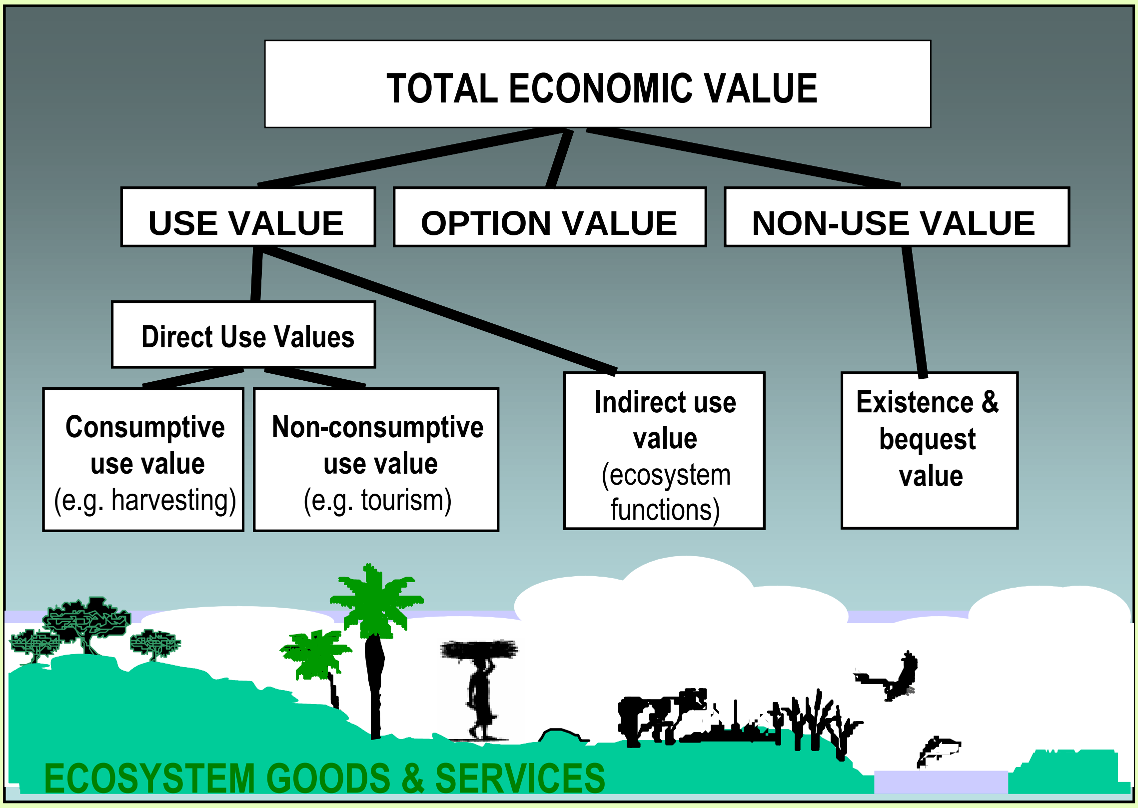
Values and valuation of ecosystem services

The values produced by ecosystem services are also categorised into different types. The Total Economic Value of an ecosystem comprises direct use, indirect, option and non-use values. Direct use values may be generated through the consumptive or non-consumptive use of resources. In the case of South African estuaries, most, if not all, of this use is recreational, and includes both consumptive (fishing and bait collecting) and non-consumptive (e.g. boating, bird watching) activities. Indirect use values are values generated by outputs from estuaries that form inputs into production by other sectors of the economy, or that contribute to net economic outputs elsewhere in the economy by saving on costs. These outputs are derived from ecosystem functioning such as water purification and nursery functions. Non-use values include the value of having the option to use the resources (e.g. genetic) of estuaries in the future (option value), and the value of knowing that their biodiversity is protected (existence value). Although far less tangible than the above values, non-use values are reflected in society's willingness to pay to conserve these resources, sometimes expressed in the form of donations. The relationships between the concepts of ecosystem services and values are shown below.

Broad relationships between the concepts of ecosystem services and values (source: Author)

Ecological descriptors	Ecosystem services		Total Economic Value
	Barbier 1994, 2011	Millennium Ecosystem Assessment 2005	
Natural resource stocks	Goods	Provisioning services	Consumptive use value
Ecological functioning	Services	Regulating & supporting services	Indirect use value

Ecosystem structure and organisation	Attributes	Cultural services	Non-consumptive use value
			Non-use value



The classification of ecosystem values that make up Total Economic Value (based on Turpie *et al.* 1999).

Much of the confusion and debate around categorising and assessing the value of ecosystem services revolves around the extent to which different services should be treated as intermediate versus final services, and the extent to which the ecosystem is responsible for the benefits described (Barbier *et al.* 2011). For example recreational benefits are derived from a combination of natural and man-made capital. These problems only really exist for static assessments of value such as those by Costanza *et al.* (1997, 2014). To some extent, this can be solved by focussing only on the final services in order to avoid double counting. However, since it is often the supporting or intermediate services that are affected by policy changes, it is far more relevant to assess changes in welfare that will result from a change in the state of natural capital. That way, the fact that values depend partly on man-made capital, such as hotels and boats, is not problematic to the analysis.

The way in which values of ecosystem services are expressed also varies. Different measures of value are relevant to different decision-makers. Individuals and firms make decisions on the basis of their own financial and/or utility gains. Governments make decisions on the basis of overall welfare gains (including contribution to income and employment as measured in the national accounts). At a more local level, municipalities may make decisions based on the generation of revenues, e.g. from property rates. It is important to understand value from both an individual/firm perspective and a government or social planner perspective, since the former constitute the market forces of change, and the latter are required to make decisions that are in the overall interest of society. In this study, we take a social planner perspective.

4.2 Description

4.2.1 Economic activities and sectoral outputs

Land use in the study area is dominated by commercial agriculture in the northern half of the study area (Figure 4.2). These crops consist mainly of grain and planted pasture. In the southern half of the study area, much of the land cover is either urban areas or vineyards. The most abundant and economically-important fruit crops include grapes (mainly for wine) and stone fruits.

In addition to the extensive metropolitan area of Cape Town, the study area includes numerous inland and coastal towns and villages. The study area has for a number of years been experiencing significant inward migration from many rural areas of people in search of better livelihoods. These new arrivals are generally low-skilled, without much capital and mostly end up in ever-growing dense informal or semi-formal settlements with relatively low availability of general services on the margins of Cape Town and many of the larger towns in the study area.

Access to water is a major driver (and limiter) of development within the study area. A large proportion of South Africa's irrigated agricultural exports come from within the study area (DAFF 2016a). Water quality issues, especially within the lower reaches of the Berg River, pose a potential risk to these irrigated fruit industries (Aurecon, 2011)

While the interior of the study area is mainly under agriculture, large tracts of land along the west coast are still under natural land cover types. These include sizable protected areas including the Table Mountain National Park along the Cape peninsula and the West Coast National Park surrounding Langebaan Lagoon. In these areas, tourism-related services are some of the most important economic activities. Tourism also plays a vital role within the Cape Winelands area, where it is centred in the towns of Stellenbosch, Franschhoek and Paarl. Within the urban areas of the study area, particularly the City of Cape Town, financial and business services are very important components of the economy.

The study area covers most of the West Coast District Municipality (DM), encompasses almost all of the City of Cape Town DM and also includes a portion of the Cape Winelands DM (Figure 4.3). The sectoral economic profiles of the three main District Municipalities that straddle the study area are presented in Table 4-1 (WCG 2014a).

Table 4-1. Economic profiles of the District Municipalities of the study area in terms of % contribution of sectors to total GDP in 2013 (Source: WCG 2014a).

Economic Sub-Sector	City of Cape Town	West Coast	Cape Winelands
Agriculture, Forestry & Fishing	1.6%	14.5%	11.6%
Mining	0.2%	1.3%	0.3%
Manufacturing	11.5%	13.7%	19.0%
Electricity, Gas & Water	2.5%	1.5%	1.4%
Construction	4.5%	4.8%	4.0%
Trade, retail, catering & accommodation	19.3%	15.8%	17.4%
Transportation & Communication	9.8%	7.8%	7.0%
Finance, Real Estate & Business Services	33.7%	24.4%	21.5%
Community, social and personal services	5.2%	3.8%	5.8%
Government Services	11.7%	12.6%	12.1%

The economy of the study area is closely linked to the economic powerhouse of the City of Cape Town Metropole (WCG 2013). The Cape Town Metropole contributes close to three-quarters of the real value-add generated in the Western Cape Province and is an important contributor to the economic growth in the study area. Economic activity in the study area is quite diverse and includes tourism, irrigation and dryland agriculture, wine-making, canning, food processing, manufacturing, fisheries, commercial forestry, financial services, ITC, nuclear power, hydropower, mining and port operations.

Figure 4.3. Map of the District and Local Municipalities within the study area boundary.

The sheltered Saldanha Bay plays an important role in the Sishen-Saldanha iron-ore project which connects the inland mine to the port via the Sishen Railway. The industry within Saldanha Bay, however, has seen a slump since the economic downturn in 2009, due to the impacts of the recession on the metals industry (WCG 2014b).

The total GVA for the study area was estimated to be R366 billion in 2015 (based on GAP 2011, WCG 2014a, StatsSA 2016) (Figure 4.4, Table 4-2). The highest GVA values were found in Cape Town, followed by the Winelands (Figure 4.4). GVA is lowest in the Tulbagh Fruit Area and Lower Berg zones.

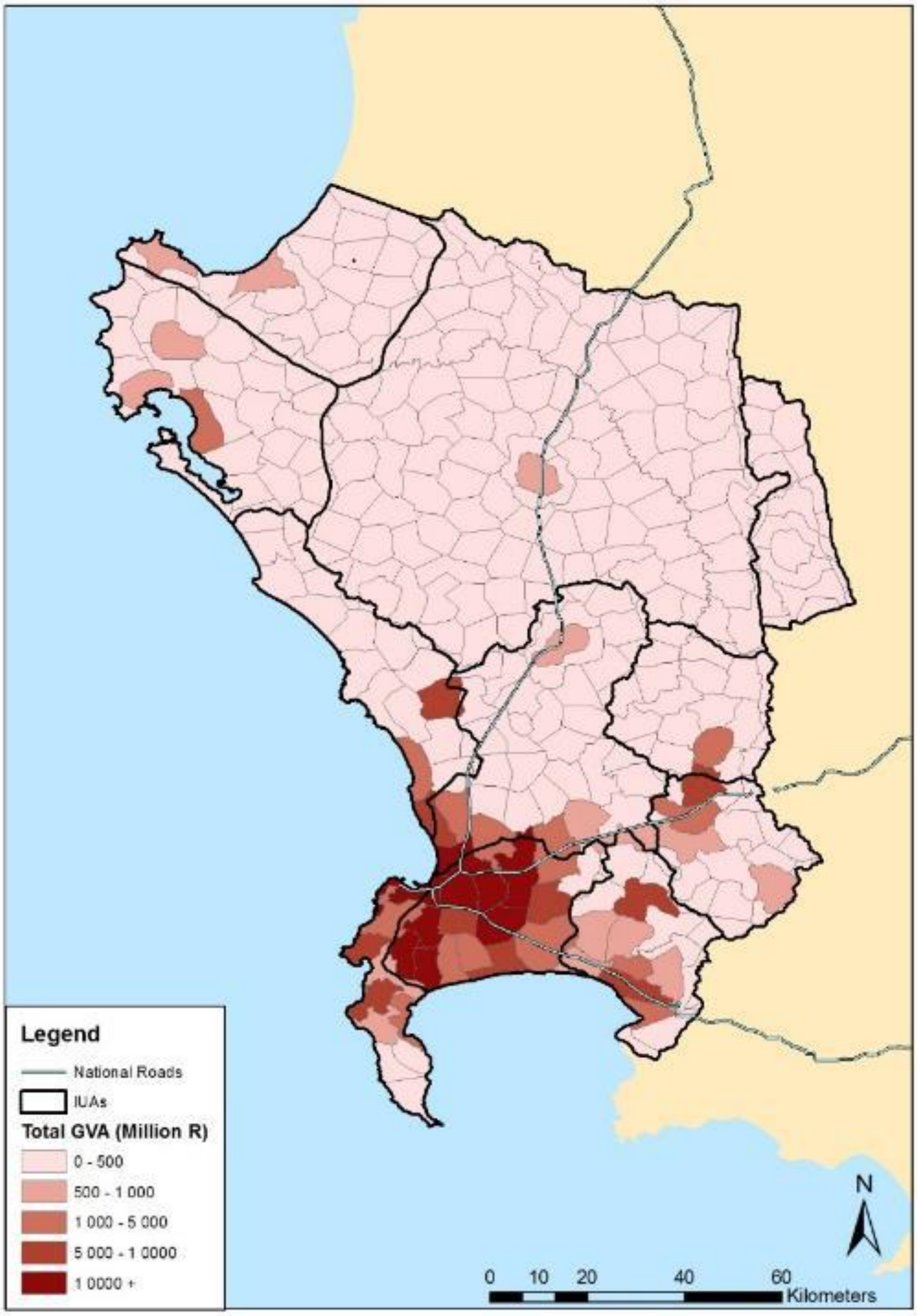


Figure 4.4. Total GVA (R millions) in 2015 for each mesozone within each IUA (Source: GAP 2011, WCG 2014, and StatsSA 2016).

Overall, financial services contributed the most to GVA at R126.4 billion followed by the trade, catering and accommodation sector (R73.6 billion), the community, social and government services sector (R65.5 billion), the manufacturing sector (R46.3 billion) and the transport, storage and communication sector (R36 billion) (Table 4-2). Since 2009, the percentage share of GVA has decreased by 26% in the mining and quarrying sector and whereas the Electricity, gas and water sector and trade, catering and accommodation services sectors have almost doubled (Table 4-2). GVA has also increased for transport and storage services, financial services and the community, social and government services sector. The agricultural and manufacturing sectors have remained relatively stable since 2009.

The City of Cape Town and Winelands socio-economic zones had the highest percentage contribution to total GVA of 73.6% and 19.7% respectively (Figure 4.4, Figure 4.5). The Lower Berg and Tulbagh Fruit Area contributed the least to overall GVA in the study area (Figure 4.5).

GVA in the agriculture, forestry and fisheries sector and associated manufacturing sector was highest in the Lower Berg and Tulbagh Fruit Area socio-economic zones (Figure 4.6). The financial services sector and wholesale trade, catering and accommodation sector were important contributors to GVA in all socio-economic zones (Figure 4.6).

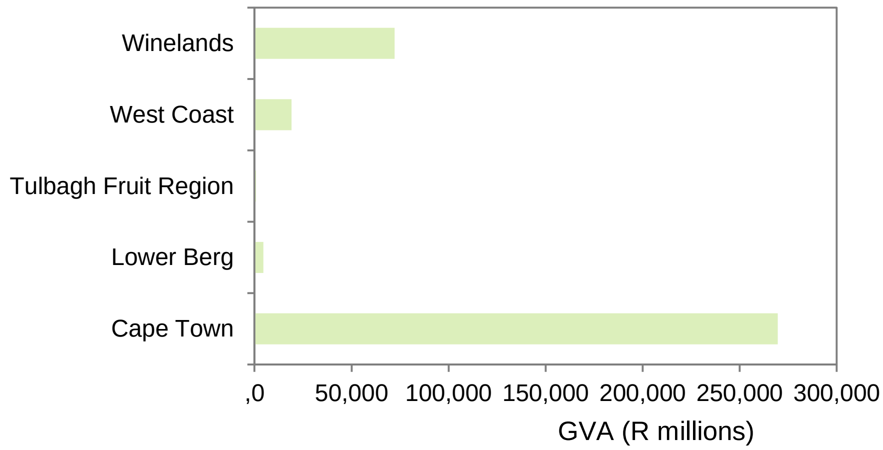


Figure 4.5. GVA (R millions) for each socio-economic zone in 2015 (Source: GAP 2011, WCG 2014a, and StatsSA 2016).

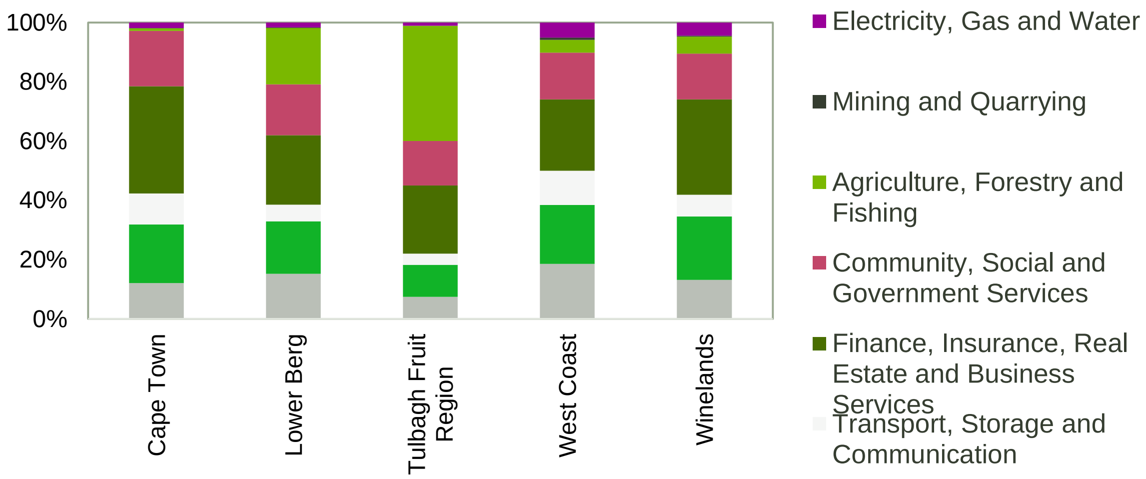


Figure 4.6. Percentage contribution of different sectors to total GVA in each socio-economic zone in 2015 (Source: GAP 2011, WCG 2014a, and StatsSA 2016).

Table 4-2. Total GVA (nominal 2015 prices) and percentage per sector contribution to GVA for each socio-economic zone in 2009 and 2015 (Source: GAP 2011, WCG 2014a, and StatsSA 2016).

Socio-economic zone	Agriculture, Forestry and Fishing		Mining and Quarrying		Manufacturing		Electricity, Gas and Water		Wholesale and Retail Trade, Catering and Accommodation		Transport, Storage and Communication		Finance, Insurance, Real Estate and Business Services		Community, Social and Government Services	
Total (R millions)	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**
Cape Town	2 103	2 379	444	349	26 265	32 547	1 796	4 806	24 296	53 485	18 065	28 226	57 391	97 332	28 539	50 477
Lower Berg	844	869	17	10	1 111	697	64	71	458	809	354	255	810	1 074	603	787
Tulbagh Fruit Region	285	280	-	-	63	54	9	7	57	78	34	27	201	166	91	108
West Coast	831	829	229	149	3 625	3 532	547	952	3 306	3 783	1 839	2 191	3 734	4 579	2 583	2 988
Winelands	4 066	4 133	362	272	10 971	9 501	2 279	3 159	11 380	15 469	4 785	5 267	24 007	23 278	8 686	11 122
Total	**8 129**	**8 491**	**1 051**	**780**	**42 035**	**46 331**	**4 695**	**8 995**	**39 498**	**73 624**	**25 077**	**35 967**	**86 143**	**126 429**	**40 502**	**65 482**
Percentage	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**
Cape Town	1%	1%	0%	0%	17%	12%	1%	2%	15%	20%	11%	10%	36%	36%	18%	19%
Lower Berg	20%	19%	0%	0%	26%	15%	1%	2%	11%	18%	8%	6%	19%	23%	14%	17%
Tulbagh Fruit Region	39%	39%	0%	0%	9%	7%	1%	1%	8%	11%	5%	4%	27%	23%	12%	15%
West Coast	5%	4%	1%	1%	22%	19%	3%	5%	20%	20%	11%	12%	22%	24%	15%	16%
Winelands	6%	6%	1%	0%	16%	13%	3%	4%	17%	21%	7%	7%	36%	32%	13%	15%
Total	**3%**	**2%**	**0%**	**0%**	**17%**	**13%**	**2%**	**2%**	**16%**	**20%**	**10%**	**10%**	**35%**	**35%**	**16%**	**18%**

It was estimated that the agriculture, forestry and fisheries sector contributed R8.5 billion to total GVA in the study area in 2015. Outputs are highest in the Winelands as well as parts of Cape Town, while most of the Lower Berg has very low values (Figure 4.7).

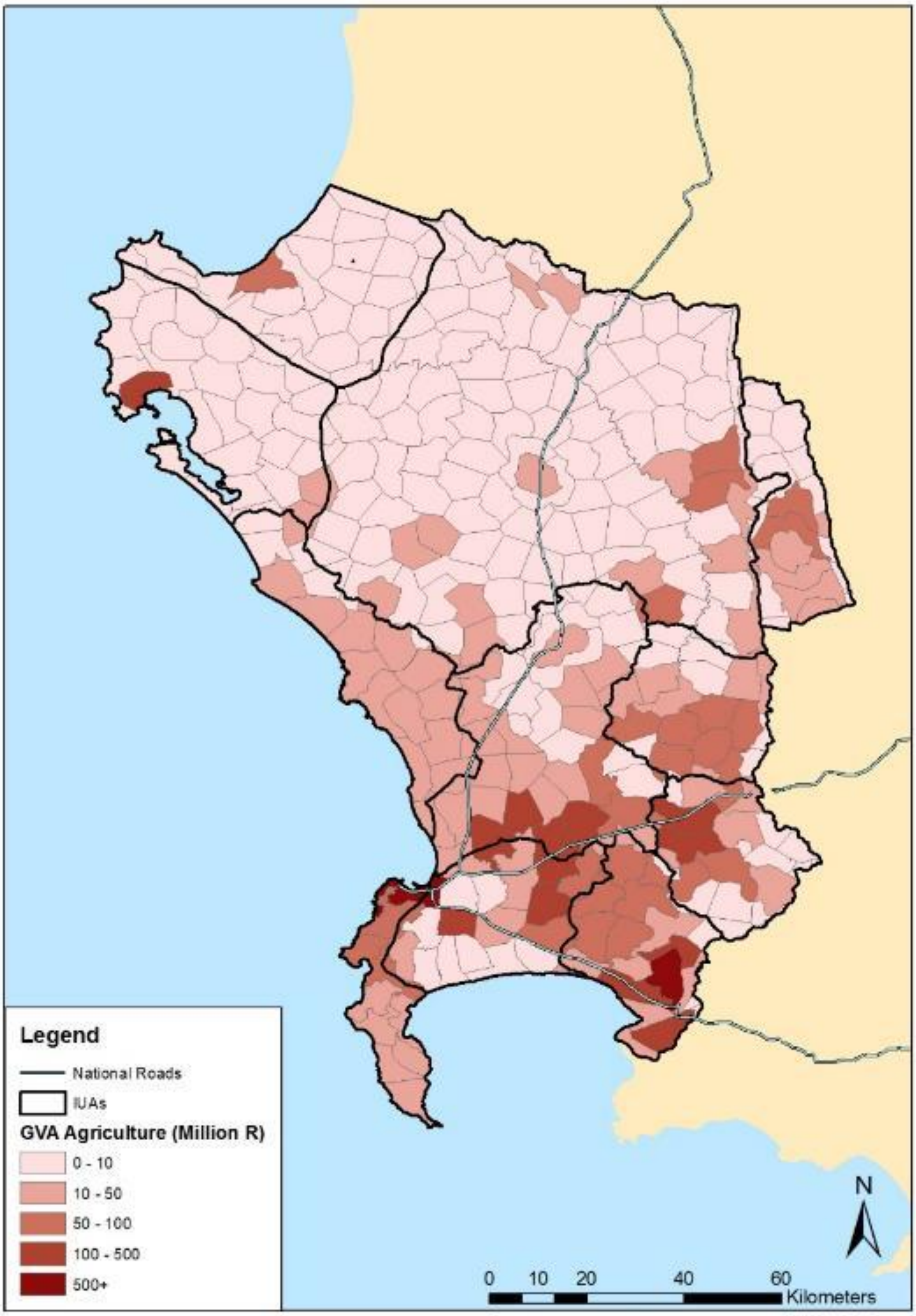


Figure 4.7. Agriculture GVA (R millions) in 2015 per mesozone (Source: GAP 2011, WCG 2014a, and StatsSA 2016).

4.2.2 Employment by sector

The community, social and government services employs the highest number of people in the study area, followed by the wholesale trade, catering and accommodation sector and the financial and business services sector (Figure 4.8, Table 4-3). However, since 2009, the percentage of people employed in the community, social and government services has decreased by 2% and also by 3% in the manufacturing sector (Figure 4.8). Percentage employment in the wholesale trade, catering and accommodation sector has seen the highest increase in percentage employment of 4%. The transport, storage and communication services sector also saw an increase in percentage employment from 2009 to 2015 (Figure 4.8).

Percentage employment per sector for each socio-economic zone is shown in Figure 4.9. Percentage employment in the agriculture, forestry and fisheries sector is highest in the Lower Berg and Tulbagh Fruit Area socio-economic zones (Figure 4.9). The wholesale trade, catering and accommodation sector as well as the community, social and government services sector employed a significant number of people across all socio-economic zones.

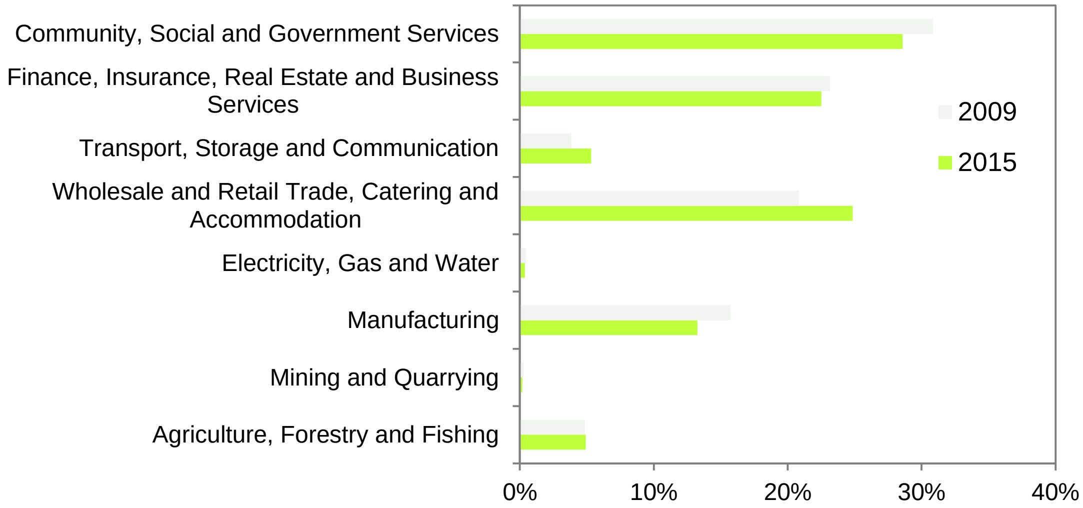


Figure 4.8. Percentage employment in each sector in the study area in 2009 and in 2015 (Source: GAP 2011, WCG 2014a, and StatsSA 2016).

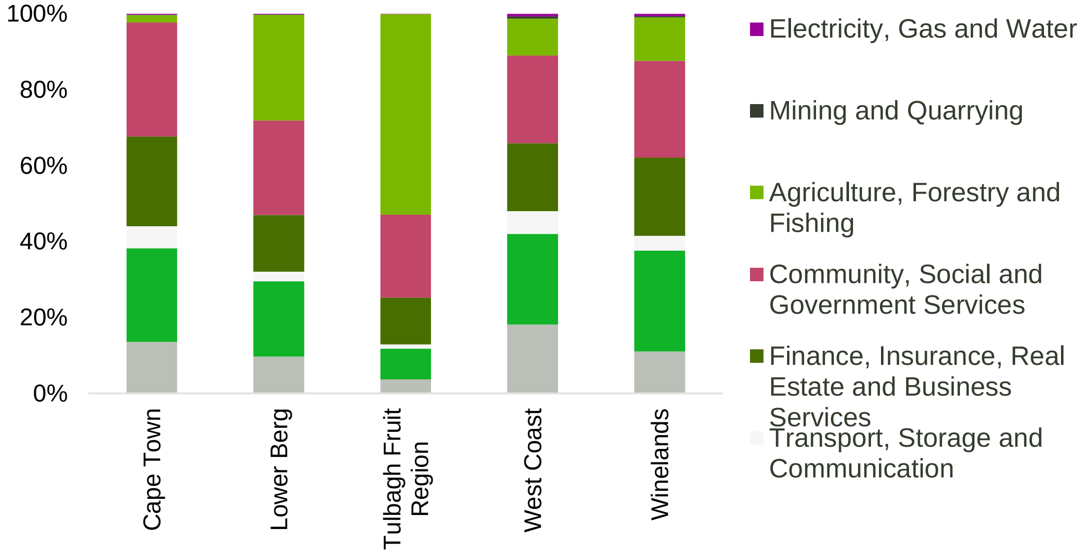


Figure 4.9. Percentage employment in each sector for each socio-economic zone in 2015 (Source: GAP 2011, WCG 2014a, and StatsSA 2016).

Table 4-3. Total number of individuals and percentage contribution to employment within each sector of the economy and for each socio-economic zone in 2009 and 2015 (Source: GAP 2011, WCG 2014a, and StatsSA 2016).

Socio-economic zone	Agriculture, Forestry and Fishing		Mining and Quarrying		Manufacturing		Electricity, Gas and Water		Wholesale and Retail Trade, Catering and Accommodation		Transport, Storage and Communication		Finance, Insurance, Real Estate and Business Services		Community, Social and Government Services	
Total individuals	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**
Cape Town	14 523	18 341	1 258	1 043	116 741	130 500	1 933	2 675	140 047	236 383	30 473	55 281	169 247	226 887	238 225	288 103
Lower Berg	4 902	6 397	41	26	4 301	2 238	81	47	3 286	4 548	642	590	3 120	3 416	6 079	5 715
Tulbagh Fruit Region	2 069	2 393	-	-	230	169	15	6	342	365	56	50	816	559	1 131	989
West Coast	6 029	7 444	728	487	15 967	13 960	600	537	20 133	18 362	3 316	4 567	13 397	13 746	22 002	17 754
Winelands	26 341	30 838	1 065	842	38 191	29 799	2 546	1 796	68 096	71 441	8 146	10 331	71 245	55 364	76 086	68 356
Total	**53 863**	**65 412**	**3 092**	**2 398**	**175 431**	**176 666**	**5 175**	**5 060**	**231 904**	**331 099**	**42 632**	**70 820**	**257 826**	**299 971**	**343 523**	**380 917**
Percentage	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**	**2009**	**2015**
Cape Town	2%	2%	0%	0%	16%	14%	0%	0%	20%	25%	4%	6%	24%	24%	33%	30%
Lower Berg	22%	28%	0%	0%	19%	10%	0%	0%	15%	20%	3%	3%	14%	15%	27%	25%
Tulbagh Fruit Region	44%	53%	0%	0%	5%	4%	0%	0%	7%	8%	1%	1%	18%	12%	24%	22%
West Coast	7%	10%	1%	1%	19%	18%	1%	1%	25%	24%	4%	6%	16%	18%	27%	23%
Winelands	9%	11%	0%	0%	13%	11%	1%	1%	23%	27%	3%	4%	24%	21%	26%	25%
Total	**5%**	**5%**	**0%**	**0%**	**16%**	**13%**	**0%**	**0%**	**21%**	**25%**	**4%**	**5%**	**23%**	**23%**	**31%**	**29%**

4.3 Status quo assessment

4.3.1 Economic activities depending on water

4.3.1.1 Overview of water use in the study area.

A consolidation of both sectoral and total present-day demands from surface water and groundwater sources was performed, including demands from local sources outside the WCWSS shown in Table 4-4.

Table 4-4. IUA present-day water demands per primary sector (million m^3/a).

IUA	Urban / Industrial	Irrigation	Afforestation & Alien Plants	Total
Upper Berg	24	52	12	88
Middle Berg	9	73	3	85
Lower Berg	10	55	1	65
Berg Tributaries		15	5	20
Eerste	7	68	5	80
Sir Lowry's	18	19	7	44
Cape Flats	229	14	2	245
Peninsula	27		2	29
Diep		67	1	68
West Coast	6		1	7
Langebaan	18		1	19
Total Demand	**348**	**363**	**40[#]**	**750**

[#] *Including about 15 million m^3/a surface and groundwater use by invasive alien plants*

4.3.1.2 Agriculture

The extent of agricultural crop production in the study was assessed based on information collated from the Crop Census conducted by the Department of Agriculture in 2013. Details about the types and area of different irrigated and dryland crops were available and these were used to determine the overall agricultural outputs for the study area. Detailed information relating to the extent of non-irrigated and irrigated agriculture in each IUA is given in Appendix F.

There are a total of almost 430 000 hectares of dryland crops and almost 73 000 hectares of irrigated crops within the study area (Figure 4.10Figure 4.10, Table 4-5). Just more than 60% of the dryland crops are located within the Lower Berg socio-economic zone (Figure 4.10,Table 4-5). Planted pasture represents 36% and grains 55% of dryland crops in the study area. Natural grazing and fallow land covered just almost 60 000 ha within the study area, with 48% of this being located in the Lower Berg and 37% within the West Coast socio-economic zones (Table 4-5).

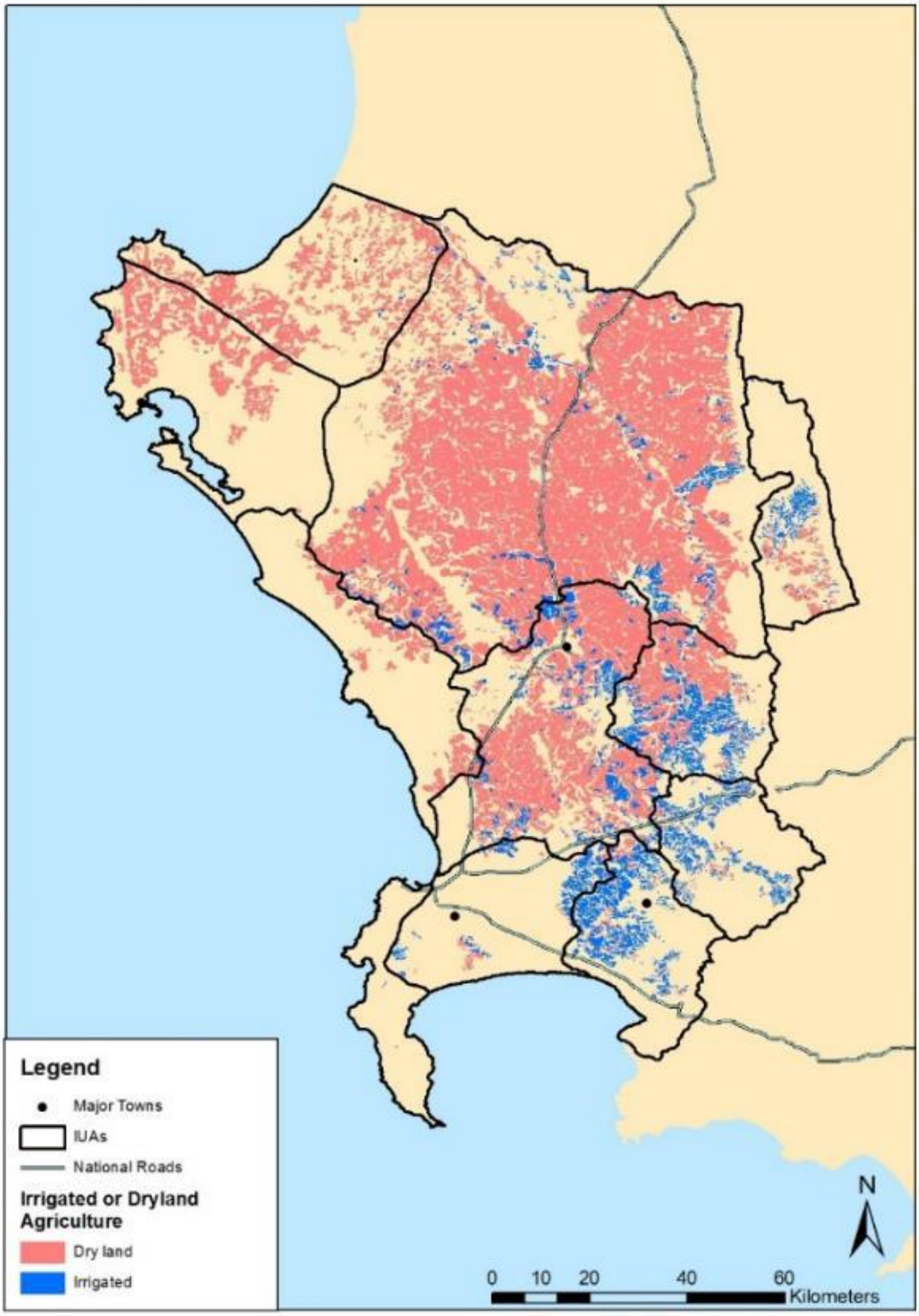


Figure 4.10. Extent of dryland crops and irrigated crops (Source: Western Cape DoA Crop Census 2013).

Table 4-5. Estimated total hectares of irrigated agricultural area and dryland agricultural area, excluding fallow area, in each socio-economic zone (Source: Western Cape DoA Crop Census 2013).

Socio-economic zone	Dryland Crops	Irrigated Crops
Cape Town	1 434	5 068
Lower Berg	266 773	15 830
Tulbagh Fruit Area	5 159	3 299
West Coast	65 727	917
Winelands	88 148	47 625
Grand Total	**427 242**	**72 739**

Of the irrigated crops, 65% were found within the Winelands socio-economic zone. Wine grapes cover the largest area in the study area accounting for 71% of the total irrigated crop area, followed by stone fruit (10%) and table grapes (6%; Table 4-6).

Table 4-6. Total area of irrigated and dryland crops, excluding fallow area (Data source: Western Cape DoA Crop Census 2013).

Crop Type	Irrigated (ha)	Dryland (ha)
Grapes - Wine	51 365	9
Pome Fruit (apples and pears)	1 491	-
Planted Pasture	810	152 212
Stone Fruit	7 034	-
Grapes - Table	4 576	22
Grains	2 624	236 853
Citrus / sub-tropical Fruit	1 593	-
Other fruit crops	1 707	-
Vegetables	1 507	1 143
Nuts & oil seeds	47	13 642
Lupines	-	22 097
Flowers	9	778
Other crops	6	539
Total	**72 768**	**427 296**

Irrigation agriculture plays a very important role not only in direct exports of fresh produce but in underpinning a number of agro-processing industries in the Western Cape, many of which are important export industries (Figure 4.11).

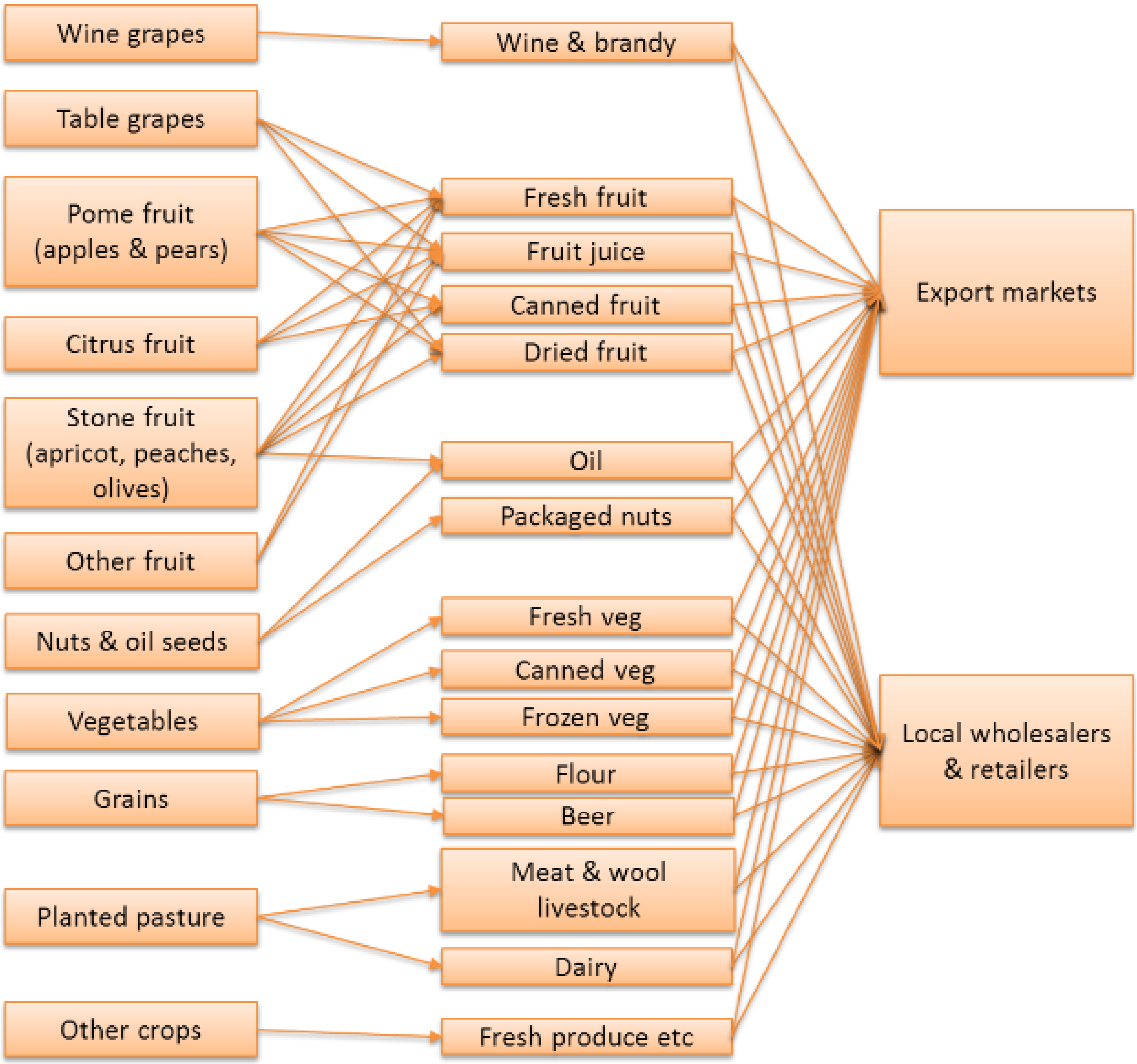


Figure 4.11. Summary of irrigated crops in the study area and their products.

Economic outputs and employment associated with irrigated agriculture in the study area were estimated using information collated from the industry-specific reports from the relevant farming association websites (see

Table 4-7), summary crop statistics for 2015 from the Department of Agriculture, Forestry and Fisheries website, the 'Trends in the Agricultural Sector' 2016 Report and the 'Abstract of Agricultural Statistics' 2016 Report.

Total production for each irrigated crop type was calculated by multiplying the average production per hectare by the total area of crops within the study area. This was then multiplied by the average price per tonne to determine average gross output per crop in 2015 Rands. Western Cape multipliers disaggregated by agricultural subsectors and crop types (Conningarth 2016, updated to 2014) were used to estimate direct, indirect and total value added as well as total employment for each irrigated agricultural activity.

Table 4-7. A list of the associations and their websites for the main agricultural crops in the study area.

Irrigated Crop Type	Association and report references
Pome Fruit (apples and pears)	SA Apple and Pear Producers Association (SAAPPA) www.hortgro.co.za/ Hortgro (2016)
Stone Fruit	SA Stone Fruit Producers Association (SASPA) www.hortgro.co.za/ Hortgro (2016)
Grapes - Wine	SA Wine Industry Information & Systems (SAWIS) www.sawis.co.za/ SAWIS (2016)
Grapes - Table	SA Table Grape Industry www.satgi.co.za/ SATI (2016)
Nuts & oil seeds	Oil and Protein Seeds Development Trust (OPDT) www.opot.co.za/ DAFF (2016a, 2016b)
Citrus / Sub-tropical fruit	Citrus Growers Association (CGA) www.cga.co.za/ SA Subtropical Growers Association (Subtrop) www.subtrop.co.za/ DAFF (2016a, 2016b)
Berries	SA Berry Producers Association(SABPA) www.saberries.co.za/ DAFF (2016a, 2016b)
Grains	Grain SA www.grainsa.co.za/ DAFF (2016a, 2016b)

The gross output for all irrigated crop types and the number of people employed are given in Table 4-8.

The gross output for all irrigated crops was estimated to be R6.9 billion. Wine grapes and stone fruits contributed the most to the overall output. Berries, tree fruits such as figs, pomegranates and guavas, and table grapes had the highest average price per tonne. Direct value added amounted to R2.4 billion, indirect and induced value added was R2.3 billion and total value added was estimated to be R4.8 billion in 2015.

It is estimated that over 20 000 people are employed in irrigated farming in the study area. Total employment includes direct, indirect and induced employment effects and includes all labourers employed within each activity, which are either skilled, semi-skilled or unskilled. Employment was highest in wine grape farming, the most economically productive crop within the study area, with over 9 000 labourers employed. This was followed by table grapes and stone fruit farming.

Table 4-8. Total gross output, direct and total value added and total employment for the main irrigated crop types in the study area (2015 Rands, Western Cape 2014 multipliers).

Irrigated Crop Type	Average production per ha (tons/a)	Average price per tonne (R, 2015/16)	Gross output	Direct value added	Total value added	Total employment
Grapes - Wine	17	3 245	2 914	1 292	2 214	9 039
Grapes - Table	15	12 989	892	313	705	3 736
Pome Fruit	36	6 880	369	96	254	1 283
Stone Fruit	21	10 653	1 574	402	906	3 629
Citrus / sub-tropical Fruit	43	4 592	314	127	221	989
Tree Fruit Other	25	13 731	466	101	282	1 140
Berries	23	16 022	117	30	61	229
Grains	3	3 487	30	11	20	88
Planted Pasture	22.5	1 853	34	12	23	103
Vegetables	30	3 988	182	76	137	526
Nuts & oil seeds	1.14	6 628	0	0	0	1
Total			**6 892**	**2 461**	**4 823**	**20 762**

4.3.1.3 Forestry

About 7% of South Africa is under commercial forestry. In 2012/13 there were a total of 54 361 ha of plantation forests in the Western Cape, representing 4.3% of the national total (Forestry South Africa 2015). This is lower than the approximately 64 000 ha indicated by the 2013/14 land cover map. Of these plantations, 96% are softwood, mainly pines and gums. This yielded a sawlog production of 4.5 million m^3 in 2012/13 (Forestry South Africa 2015). Based on land cover data, 16% of the Western Cape's plantation forestry area is within the study area (Figure 4.12). Most of this is found within the Winelands socio-economic zone (55%) with only 14%, 14%, 12% and 5% found in the Tulbagh, Lower Berg, Cape Town and West Coast socioeconomic zones respectively (Figure 4.12).

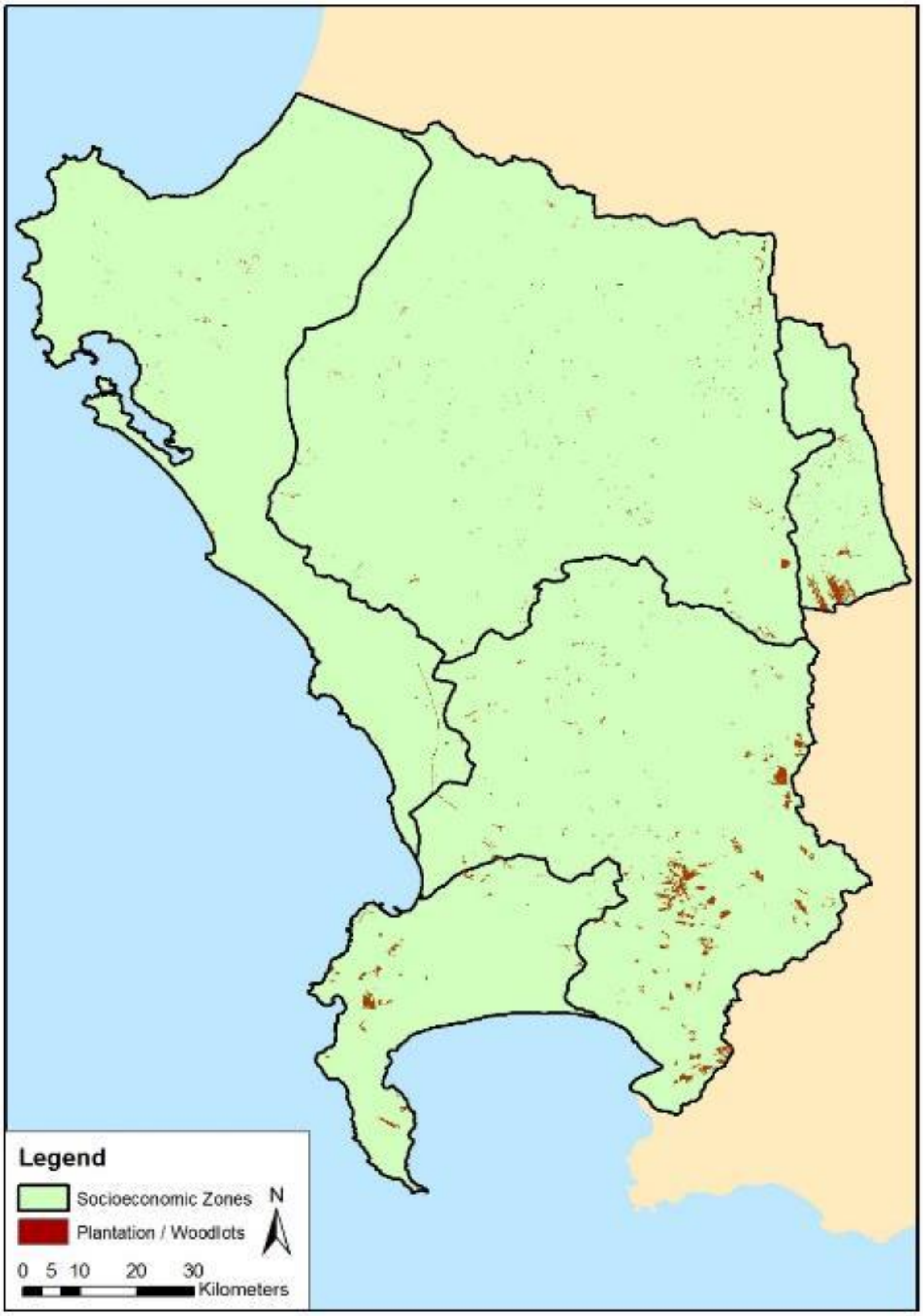


Figure 4.12.Extent of forestry plantations and woodlots (Source: DEA, National Land Cover 2013/14).

Forestry production was estimated based on data collated from the Abstract of South African Forestry Facts for the year 2012/13. The value per m^3 for sawlogs was calculated using the gross value of outputs and the total volume of roundwood sales for the Western Cape. Roundwood production of $11m^3$ per ha was determined using provincial roundwood production estimates. The gross output per ha per year was then calculated using these two estimates. The total gross output for the study area was then determined by multiplying the output per ha by the total plantation area within the study area. Values were then updated to 2015 Rands.

Estimated plantation production statistics are summarised in Table 4-9. In 2015 the total output for plantation forestry in the study area was estimated to be R116 million, with the Winelands socio-economic zone contributing R63 million to this. Direct value added was estimated to be R34 million and total value added at R77 million. It was estimated that 280 people were employed in the forestry sector within the study area in 2015 with 137 of these jobs being in the Winelands socio-economic zone.

Table 4-9. Total gross output, direct and total value added and total employment in 2015 for plantation forestry in the study area.

Socio-economic zone	Gross output (R million)	Direct value added (R million)	Total value added (R million)	Total employment
Winelands	63	19	38	137
Tulbagh	16	5	11	39
Lower Berg	16	4	10	37
All other zones	20	6	13	49
Total	**116**	**34**	**77**	**280**

4.3.2 Tourism

Tourism is an integral and significant part of the Western Cape economy. The study area includes some of South Africa's and the Western Cape's major attractions for overseas tourists. The study area is also an important domestic tourism area, particularly for people living in major urban centres of Cape Town and Port Elizabeth. Tourism activities are centred on a wide range of attractions, many of which are or are linked to natural environments, in which aquatic ecosystems are often a significant feature. In addition, wine tasting is an important feature of tourism in the Western Cape, which is in turn an additional benefit of irrigation agriculture. Thus choices regarding water allocation and RQOs may impact on the value of tourism in the study area, with knock-on effects within and beyond this area.

The types of tourism and recreation that are potentially affected include:

- river-based adventure tourism, through impacts on water flows suitable for the activities;
- freshwater, estuary and shore angling, through impacts on fish stocks;
- general nature-based tourism, through impacts on landscapes, biodiversity, water levels for swimming etc. and suitability for human recreational contact; and
- wine-tourism, through impacts on the extent of viticulture.

Available information on some of these activities is described briefly below. However, information is patchy, and it is difficult to estimate the tourism value of any of these activities in the absence of reliable and comprehensive information on the numbers of participants and their expenditure. Therefore in the sections that follow, we have taken the approach of estimating the value of wine- and nature-based tourism in each of the socio-economic zones and IUAs from provincial and regional data, using mapping techniques.

4.3.2.1 Information on water-related tourism activities

Adventure activities

There are a number of companies offering river-based adventure activities within the study area, including Langebaan Lagoon for kayaking as well as kloofing in the Groot Winterhoek Mountains and the Steenbras

River Gorge. The main companies offering these activities were contacted for information on pricing and approximate annual number of participants in these water-associated activities (Table 4-10). The annual turnover of the major companies offering activities in aquatic systems was approximately R416 000. These data came from approximately two-thirds of the main companies operating in the area who were willing to participate in providing information, and overall turnover for these kinds of aquatic activities would be likely to exceed R550 000.

While some people do undertake these activities on their own, the information on commercial activities gives an indication of the economic contribution of these activities. Most of these activities are seasonal, relying mainly on higher demand during summer months, apart from white water rafting during winter.

Table 4-10. Companies offering recreational activities in rivers and estuaries within the study area along with data on approximate participation and turnover supplied by companies.

Company	Area	Activity	Approximate participation (ppl/yr)
Gravity Adventure Group	Langebaan Lagoon	Paddling	500
Abseil Africa	Steenbrass River Gorge	Kloofing	160
TOTAL			**660**

Most of these activities are sensitive to both the quantity and quality of water flowing through these systems. During low flow or drought periods a number of these operations become unsafe to operate such as kloofing experiences. Poor water quality would also be expected to negatively impact the participation in these activities.

Freshwater angling

Freshwater angling in the study area is dominated by trout and bass fishing. Trout were introduced into Cape streams over 100 years ago and have since survived as wild populations. Rainbow trout are most common, although brown trout occur in some streams. The study area falls outside of the main trout fishing areas of the Western Cape that are controlled by the Cape Piscatorial Society (CPS) on behalf of Cape Nature. However, trout fishing occurs on a number of private farms in the Franschhoek Valley, as well as in the Voelvlei and Misverstand dams.

The vulnerable endemic Berg-Breede whitefish or witvis was also a recreational fishing species within the upper Berg system, however it has now become extinct within the catchment and only exists within the upper Breede system. While various studies exist on the value of freshwater angling in other parts of the country, there are no estimates for the Western Cape.

Estuary angling and recreation

Many of the estuaries along the coast are popular for recreational angling as well as a host of other recreational activities. It is difficult to separate these values. Lamberth & Turpie (2003) estimated the value of estuary-based angling at the national scale to be in the order of R428.5 million (1997 Rands), with the West and South Coasts together making up 41% of this value (R469 million in 2015 Rands). Based on their estimates of relative catches in each estuary, this puts the angling value of estuaries in the study area at about **R20 million** per annum. This excludes Langebaan Lagoon, the value of which would exceed that of the Berg estuary

Inshore marine angling

Shore and boat-based angling along the coast targets many species that use estuaries at some stage in their life cycle (see Box 4.2 on estuary nursery function as an ecosystem service). These species are sensitive to estuarine hydrodynamics and water quality, and their abundance is related to environmental flows. McGrath et al. (1997) found that the economic impact of recreational angling was far more significant than the value added by inshore commercial fisheries. Lamberth & Turpie (2003) estimated the estuary contribution to shore angling for the whole country. Based on the relative size and functionality of the estuaries along the West and South coasts, the current contribution of the estuaries in the study area to marine recreational fisheries was estimated to be in the order of **R17.5 million** in 2015 Rands, with two of these estuaries, the Berg and Sand, together accounting for 90% of this value. Note, however, that more recent studies have found a decrease in recreational fishing effort in recent years (e.g. Dunlop & Mann 2012, 2013 for KwaZulu-Natal), and these estimates need to be updated with further research. Again, the Lamberth & Turpie (2003) study did not estimate the nursery value of Langebaan Lagoon, which could be significant.

Nature-based tourism in general

Nature-based tourism encompasses a wide range of activities including taking scenic drives, hiking, visiting nature reserves (e.g. West Coast National Park), staying in attractive locations such as along rivers or at estuary mouths (e.g. Velddrif), going to the beach, etc., including the adventure and angling activities described above. As with the above, the value of nature based tourism can be estimated using statistics of user numbers and expenditure. These are usually derived from data records (e.g. hotel statistics), surveys and/or observations. Few studies have been carried out on the value of nature-based tourism in the study area or surrounding areas. Turpie et al. (2003) estimated the value of ecotourism for the Cape Floral Kingdom based on scant available data at the time. Based on studies of individual estuaries in the Western Cape as well as expert input, Turpie & Clark (2007) estimated the tourism values of each of the estuaries in the Cape. These estimates suggest that the tourism value of estuaries in the study area (excluding Langebaan) would be in the region of **R18.5 million per annum** in 2015 Rands (Table 4-11), which is almost ten times the value estimated above for angling alone. More recently, Turpie et al. (2012) estimated the combined value of visitor expenditure to the Berg estuary to be R18 million per year, which is similar to the R16 million estimated through the above method.

Table 4-11. Ballpark estimates of tourism value of selected estuaries within the study area, updated from Turpie & Clark (2007) using CPI index.

Socioeconomic Zone	Estuary	Tourism value (Rands/yr)
West Coast	Berg	16 100 000
Winelands	Rietvlei/Diep	1 207 500
Cape Town	Wildevoëlvlei	64 400
Cape Town	Sand	1 127 000
Winelands	Eerste	16 100
Winelands	Lourens	8 050
TOTAL		**18 523 050**

4.3.2.2 Estimate of tourism values using a spatial approach

Overall value of tourism in the Western Cape

Tourism in the Western Cape makes a significant contribution to both the regional and national economy. Much of this tourism value is linked to natural attractions, as well as to the wine industry. Indeed, in 2015, visiting the winelands ranked fifth for tourists visiting South Africa, after Cape Town city, V&A waterfront, Table Mountain Cableway and Cape Point.

Total foreign direct spend (TFDS) in the Western Cape was estimated to be R14.9 billion in 2015; some 21.8% of the national TFDS (Wesgro 2015). 51.5% of the 1.324 million foreign visitors in 2015 were on holiday, and 20.8 were on business trips (Tourism SA 2016). The proportion visiting on holiday is much higher for the Western Cape than in the rest of the country. The remainder were mostly visiting friends and relatives. International visitors spent 16.25 million bed nights in the province. Domestic visitor expenditure in the Western Cape during the same period was estimated to be R2 124 million (Tourism SA 2016). This was spent on 2.2 million day trips and 2.8 million overnight trips. Thus total tourism expenditure during 2015 was in the order of R17 billion.

The majority of overseas visitors were visiting friends and relatives, whereas the majority of domestic visitors were on holiday. Holiday tourism accounts for the highest proportion of expenditure (Table 4-12).

Table 4-12. Percentage contribution of different types of visitors to total number of visits and total expenditure for overseas and domestic tourists to the Western Cape during 2015. Source: Tourism SA (2016), Wesgro (2015) and own calculations.

Origin	Main purpose of visit	% visits[1]	% spend[1]	Total spend (R millions)	% visiting tourist offices[2]	Estimated spend relating to attractions (R millions)
Overseas	Holiday	30.0	52.5	9 352.1	95.0	9 352.1
	Business	13.0	17.3	3 599.8	1.7	157.1
	VFR	54.0	29.3	946.8	0.5	14.5
	Other	3.0	0.8	1 015.8	2.8	154.6
	Subtotal			**14 914.6**		**9 678.4**
Domestic	Holiday	51.5	62.8	1 115.6	87	1 115.6
	Business	20.8	24.2	368.2	9	89.9
	VFR	17.7	6.4	622.2	4	16.2
	Other	10	6.8	18.0	0	0
	Subtotal			**2 124.0**		**1 221.8**
Overall	**Total**			**17 038.6**		**10 900.2**

1. Tourism SA (2016). 2. Wesgro (2015, multiple regional reports)

4.3.2.3 The contribution of the Western Cape's attractions

In this study, the main interest is in the value of tourism relating to attractions that may be affected by water allocation. As a first step, this requires estimating how much of tourism expenditure can be attributed to attractions generally, such as going to enjoy beaches, nature, wine routes etc., as opposed to spending that is not related to attractions, such as going to conferences, medical treatments, etc. Expenditure on attractions cannot simply be estimated as the expenditure by holiday tourists, as it is often also the case that tourists visiting for another primary reason such as business, also take some time to enjoy local attractions. This is evident from the tourism statistics are also gathered by tourism offices within each of the Western Cape's tourism regions (Table 4-12; Figure 4.13).

According to these data, almost all visitors to tourism offices in the different regions are holiday visitors, but the mix also includes visitors of other types. These statistics were used to derive the estimated expenditure by overseas and domestic visitors that could be attributed to visiting tourism attractions in the Western Cape. Overall it was estimated that 65% of overseas visitor expenditure and 58% of domestic visitor expenditure in 2015 was on attractions, with a total of R10.9 billion, accounting for 64% of total tourism expenditure. Most of this (R9.7 billion) was by overseas tourists.

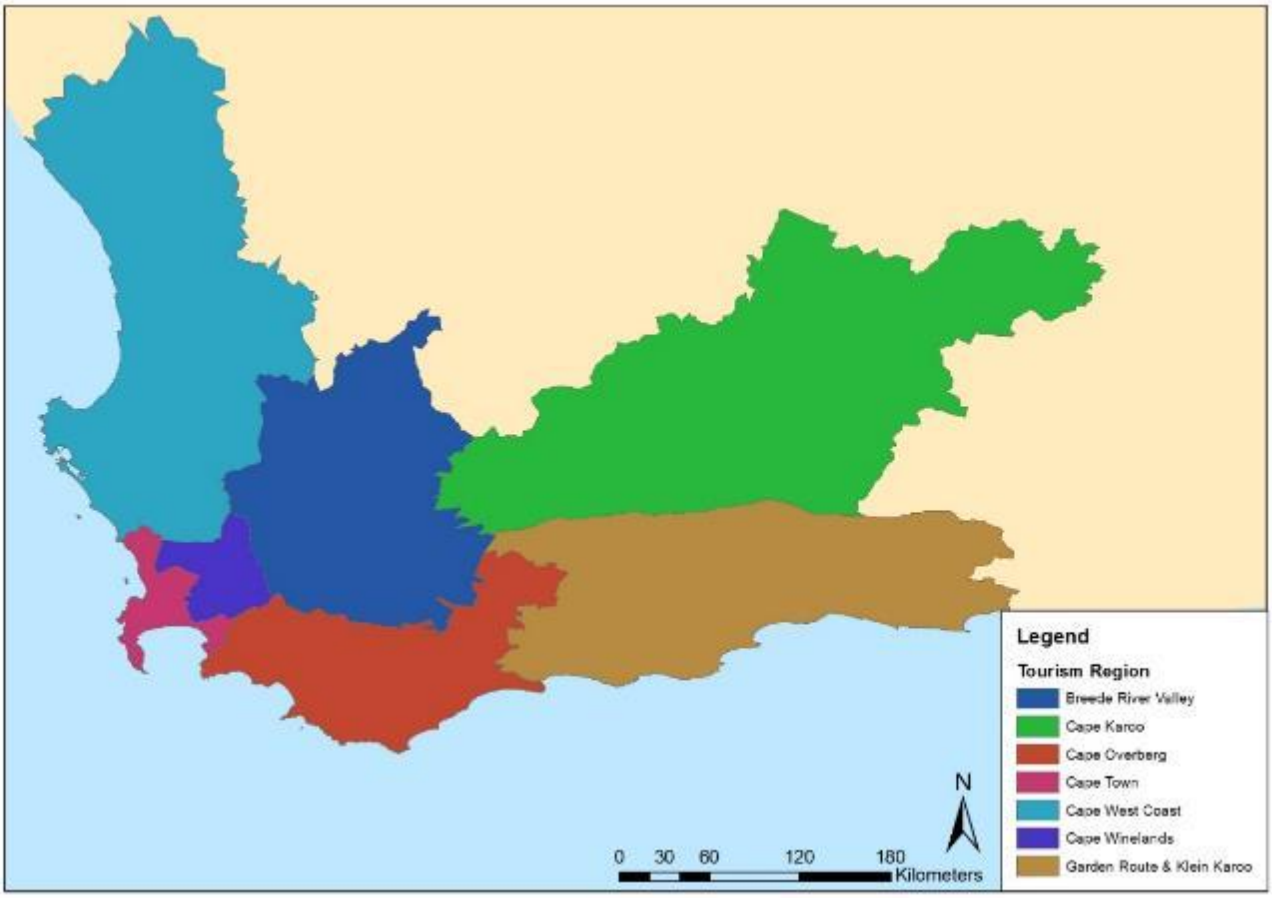


Figure 4.13. Tourism regions of the Western Cape.

4.3.2.4 Variation among the tourism regions

The statistics collected in the regional offices also provide more spatial resolution on types of visitors and their activities in the different areas. Domestic visitors dominate in all the regions, but foreign tourists make up a relatively high proportion of visitors in Cape Town, the Overberg, the Winelands and the Garden Route/Klein Karoo (Figure 4.14). Reasons for visiting these different regions also differ widely (Table 4-13), but frequently include natural attractions and wine tasting as well as a host of cultural and other attractions.

Based on the percentage of beds in each of the regions (Cornelissen 2005) and the percentage frequency of different types of attractions, the tourism expenditure generated by different types of attractions in the different regions of the Western Cape are shown in Figure 4.15. The remaining tourism expenditure is shown as other expenditure, assuming that 50% of expenditure is in Cape Town (our estimates require a more conservative than that of Grant Thornton 2009 ~ 65%). Overall, the results suggest that nature-based tourism in the Western Cape generated a total expenditure of about R4 490 million in 2015.

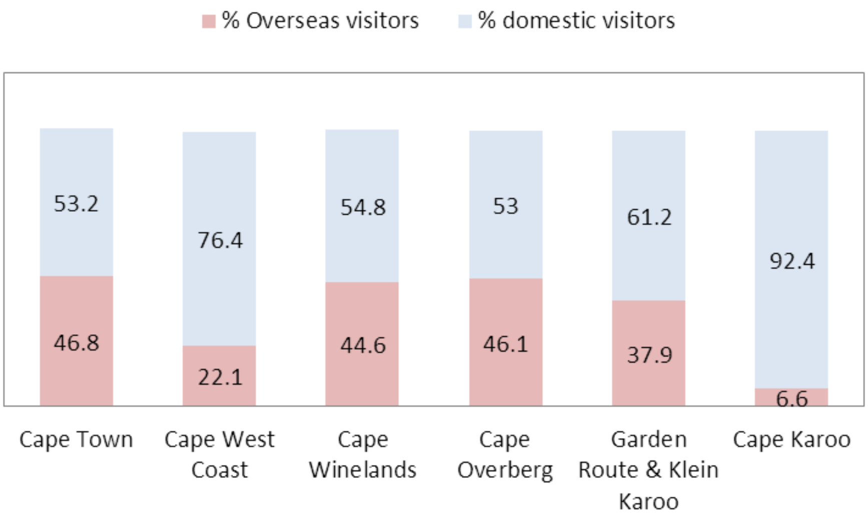


Figure 4.14. Proportion of overseas versus domestic tourists visiting the Western Cape.

Table 4-13. Percentage frequency of main attractions based on stated top 3 activities listed by overseas and domestic visitors to tourism offices in the different tourism regions (Wesgro reports), and weighted by % overseas vs. domestic. These are summarised into broad categories below. Blank cells are where categories were not listed as an option or did not feature in the top 3.

Main Attraction	Cape Town	Cape West Coast	Cape Winelands	Cape Overberg	Cape Karoo	Cape Garden Route & Klein Karoo
Wine tasting	11.0	2.7	19.6	2.2		9.2
Outdoor activities	20.7	11.6	13.6	2.5		12.8
Scenic drives		29.0	13.2	26.5	12.0	21.3
National Parks			4.2		4.2	2.5
Adventure	7.0	2.0	2.6		1.3	2.2
Beaches	12.1			4.4		5.3
Fishing		4.0		4.7		
Whale watching				7.4		
Ostrich farms						1.2
Golf		4.2		5.7		1.1
Culture/heritage	19.9	11.7	13.6	13.4	53.7	11.6
Gourmet restaurants	16.3	14.9	11.1	12.0	4.2	9.1
Shopping						2.8
Crafts/food markets			3.7	4.2	1.9	5.7
Nightlife/clubbing	2.5					
Expos/exhibitions		3.8	4.4			
Meetings/incentives		4.6	4.4		2.7	
Summary:						
Wine tasting	**11.0**	**2.7**	**19.6**	**2.2**	**-**	**9.2**
Nature-based attractions	**39.8**	**46.6**	**33.7**	**45.5**	**17.5**	**44.1**
Cultural & other attractions	**49.2**	**50.7**	**46.7**	**52.3**	**82.5**	**46.7**

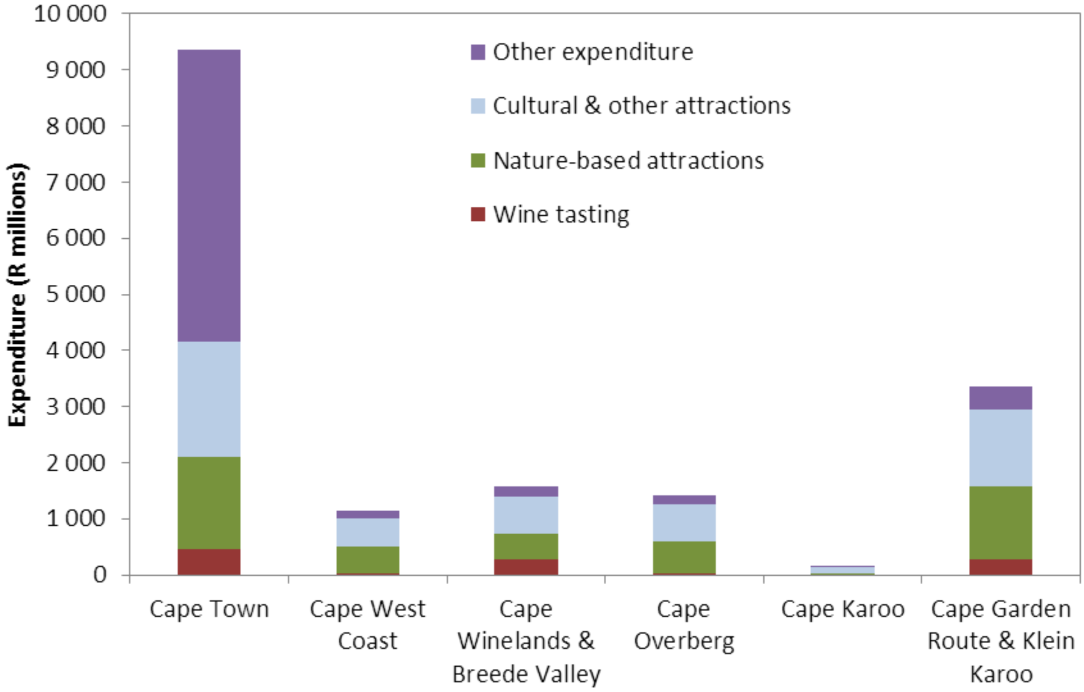


Figure 4.15. Estimated expenditure attributed to different types of attractions in different tourism regions of the Western Cape (this study).

4.3.2.5 Finer-scale geographic variation in value

In order to estimate the value of tourism in the socio-economic zones and IUAs, and potentially specific aquatic ecosystems, it would be necessary to estimate how these values are distributed at a higher level of spatial resolution than the tourism regions described above.

The spatial distribution of tourism visitation across the study area was assessed using Google Earth Panoramio photos. Panoramio hosts photographs from all over the globe, focusing on images of landscapes, natural features and animals in their natural environment. Images that focus on people, interiors, paintings, logos and events are excluded from the website (Panoramio 2015). Geo-tagged imagery can provide information about the places depicted in the photographs, as well as the interests, behaviours and mobility of the people who took them (Andrienko *et al.* 2009).

The pattern of these photographs represents where people value natural attractions. Panormaio photos were gridded to a 0.025 Decimal degree grid across the country. In the Western Cape, the numbers of photographs uploaded per tourism region were strongly correlated with the number of beds, which indicates that photo densities are a reasonable indicator of relative tourism value (Figure 4.16).

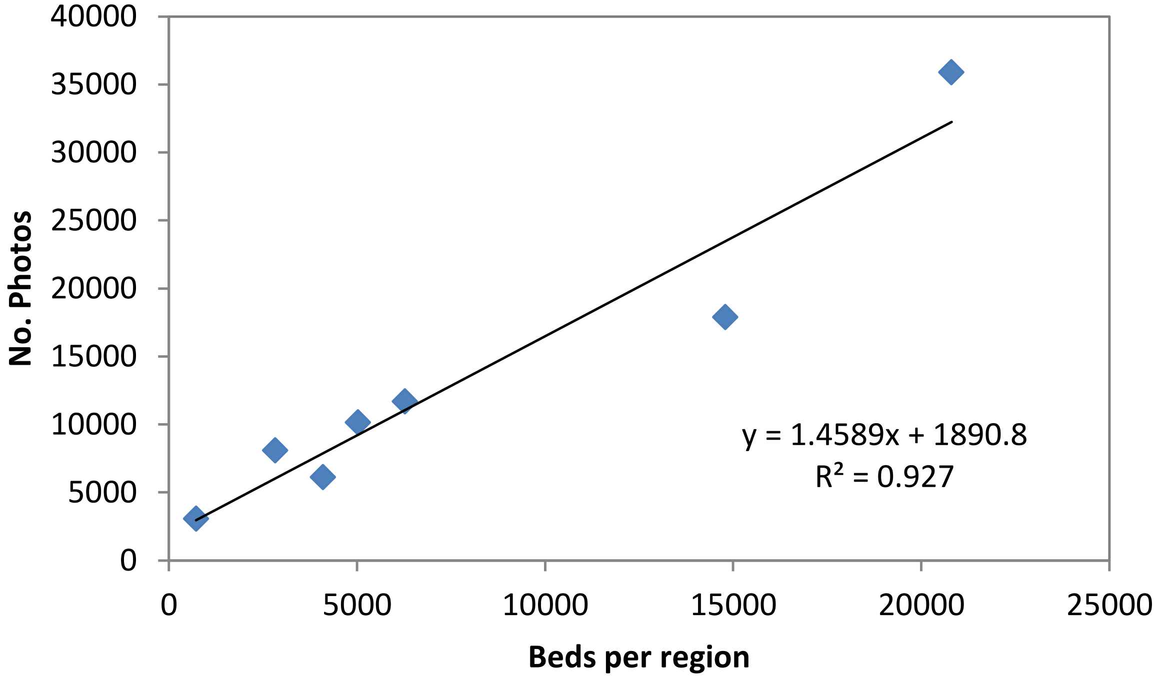


Figure 4.16. Distribution of photos uploaded to Panoramio across the Western Cape.

Of the Panoramio photographs uploaded within the Western Cape, 53% fell within the study area. Applying this percentage to the value to the estimated expenditure attributed to attractions within the entire Western Cape in 2015 gives a value of R6 489 million.

The geographic pattern of photo density is shown in Figure 4.17. Within the study area, the main tourism areas are concentrated along the coast, around the Cape Peninsula (Figure 4.17). Other centres of tourism activity concentrated around Langebaan lagoon as well as throughout the southern Winelands.

Total photograph uploads per zone were used to estimate the value of tourism attractions in each socio-economic zone (Table 4-14). Of these, the attractions in and around Cape Town had the highest number of photos and therefore value, followed by the Winelands. Details of the IUAs within each zone are provided in the zonal summaries below.

In order to estimate the contribution of rivers and estuaries to this tourism value, the number of photos occurring close to streams, rivers and estuaries was assessed. Rivers were buffered according to their stream order with 100 m buffers for 1st order streams, 200 m for 2nd order streams and so on up to 500 m for 5th order streams. Estuaries were also buffered between 100 - 500 m according to the stream order of the main inflowing river. The number of photos occurring in grid cells that intersected these buffered areas was then summed according to the socio-economic zones into which they fell and used to estimate the gross output of rivers and estuaries to tourism (Table 4-14).

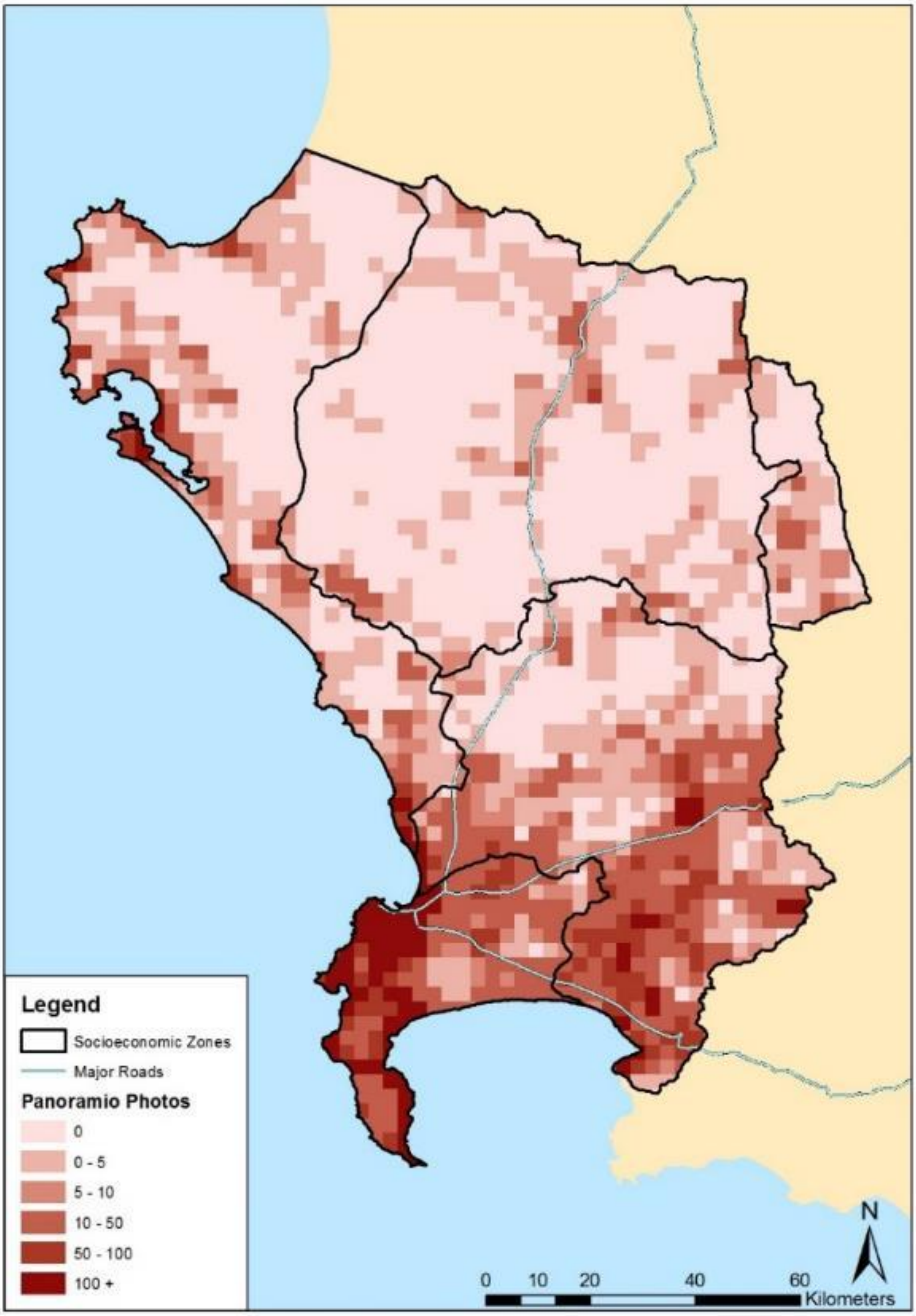


Figure 4.17. Distribution of photos uploaded to Panoramio across the study area.

Unlike the distribution of attractions overall, the output relating to the rivers and estuaries was greatest in the Winelands and the Lower Berg (Table 4-14). Conversely, Cape Town had relatively few photos associated with rivers and estuaries.

Table 4-14. Estimated value of tourism attractions within each socio-economic zone.

Socio-economic zone	Gross Output (R million per year)	Percentage at or near rivers and estuaries	Estimated contribution of rivers and estuaries (R million per year)
West Coast	706.1	45%	316.5
Lower Berg	147.9	50%	73.8
Tulbagh Fruit Area	45.7	43%	19.8
Winelands	1 609.3	61%	977.0
Cape Town	3 980.5	31%	1 214.2
Total	**6 489.4**		**2 601.3**

4.3.3 Property

While natural attributes may generate revenues through domestic and international tourism, they can also manifest in property values, leading to value added in the associated services and financial sectors. People not only visit pleasant environments, they may also pay a premium to live near them. This reflects additional amenity value that is not reflected in tourism expenditure. In the study area, this is particularly true for coastal areas (e.g. Turpie & de Wet 2009a, b), and estuaries (van Zyl & Leiman 2001, Turpie & Clark 2007). Very little empirical work has been undertaken to estimate these premiums in the study area, but Turpie & Clark (2007) estimated the property premium associated with estuaries on the basis of property counts and interviews with estate agents. The property premium was expressed as an annual value as direct income (value added) generated in the real estate sector, based on annual rates of property over and estimated percentage fees to agents.

Values for the estuaries within the study area from this study were used and inflated to 2015 prices using the CPI Index as well as adjusting to the growth in the numbers of properties surrounding each estuary using Google Earth imagery. The combined property value of the estuaries was in the order of R52 million (Table 4-15). This value came from only five of the estuaries, three of which were within the Cape Town socioeconomic zone. The Rietvlei/Diep estuary held the highest value, making up 62% of the total value. The value for the Berg Estuary through the above method was also similar to that found in another study conducted which estimated a property value attributable to the estuary at 8.2 million (when updated to 2015 Rands), however this value does not taken into account any increase in property numbers since the study was conducted, so is likely an underestimate (Turpie et al. 2012b).

Table 4-15. Value generated in the financial sector through property markets that can be attributed to estuaries within the study area. Numbers based on Turpie & Clark (2007) updated using CPI index and growth in the number of houses around estuaries.

Socioeconomic Zone	Estuary	Annual value (Rands/yr)
West Coast	Berg	10 988 200
Winelands	Rietvlei/Diep	32 708 750
Cape Town	Houtbaai	0
Cape Town	Wildevoëlvlei	1 932 000
Cape Town	Bokramspruit	0
Cape Town	Schuster	0
Cape Town	Krom	0
Cape Town	Silvermine	2 173 500
Cape Town	Sand	4 738 200
Winelands	Eerste	0
Winelands	Lourens	0
Winelands	Sir Lowry's Pass	0
Winelands	Steenbras	0
TOTAL		**52 540 750**

4.3.4 Commercial fisheries

Of the commercial fisheries operating off the coast, the traditional boat-based line fishery is the only one influenced by environmental flows through their influence on the supply of ecosystem services in the form of estuarine fish nursery areas (see Box 4.2 on estuary nursery function).

This fishery dates back to the 1500s (Thompson 1913). It is a boat-based fishery in which fish are caught on lines with no more than 10 baited hooks per line. The fishery thus operates inshore where fish are accessible on day or short overnight trips and in water shallow enough to be caught using manual labour with hand lines or rods and reels. By the late 1980s, the majority of vessels were highly mobile, trailable ski-boats that could follow aggregations of shoaling species such as yellowtail, snoek, geelbek and kob. When these aggregations occur far from the fishers' base, the boats are driven up to launch sites closer to the fishing grounds. By the end of the 1990s there were approximately 3 000 fishing boats ranging from 3 m dinghies to 15 m deck boats carrying a total of around 3 000 crew were involved in the commercial line fishery (Griffiths 2000, Mann 2000). This multispecies fishery landed about 250 species, although only about 20 were commercially important (Lamberth & Joubert 1999). Griffiths (2000) analysed fishery data over a 100-year period, and found that in spite of technological advances over this period, declines in catch rate were indicative of severe overexploitation (i.e. 75-99%).

The Minister of Environmental affairs and Tourism declared an environmental emergency in the traditional line fishery in December 2000, and restricted the number of vessels and fishers in the commercial fishery, as well as bag and size limits for commercial and recreational line fishers. The commercial line fishery was split into three regional management zones, restricting the movement of vessels from one region to the next within the 2006-2013 long-term rights allocation (MCM 2006). Since 1985, all commercial line fish permit holders have had to submit catch returns to the National Marine Linefish System (NMLS) database.

After 2003 the number of licensed vessels in the commercial fleet was diminished to about a tenth of the former numbers. However, effective effort has not diminished to the same degree, since the ski boats have since became larger, with longer travel ranges, and have the ability to handle rougher weather. They are also now mostly operated and crewed by full time professional line fishers. Along with these changes, operating costs (particularly fuel and bait) have increased dramatically since 2003 (Turpie et al. 2012a).

A total of 455 long-term traditional line fish rights were issued in South Africa for 2006 to 2013, in three zones[4]. Then 215 were allocated for the subsequent period in a controversial process that led to 567 appeals from this fishery and is still not fully resolved. Each of these rights represents a boat with an average of 8 crew.

Effort and catch data were drawn from the National Marine Linefish System (NMLS) database for the period 2006 to 2011. Data from before 2006 do not provide a good reflection of the fishery as it is at present, as those catches included handline hake. Post 2006 data is also better since the first long term rights allocation in 2006 impacted the fishery. Spatial mapping of effort and catches in the line fishery is less accurate than in other sectors, because of the logbook method employed by fishers, which is to describe location in relation to numbered sections along the coast and estimated distance offshore. No bearings are given, and no GPS data are recorded by the fishers with which to calibrate these estimates. This means that in plotting the data, estimates of the bearings have to be made. These are done very coarsely as due east, south or southeast of the coast (for the coast east of Cape Agulhas). Nevertheless this allows estimation of the proportion of catches taking place in the study area.

[4] ZONE A: Port Nolloth to Cape Infanta; ZONE B: Cape Infanta to Port St Johns; and ZONE C: KwaZulu-Natal

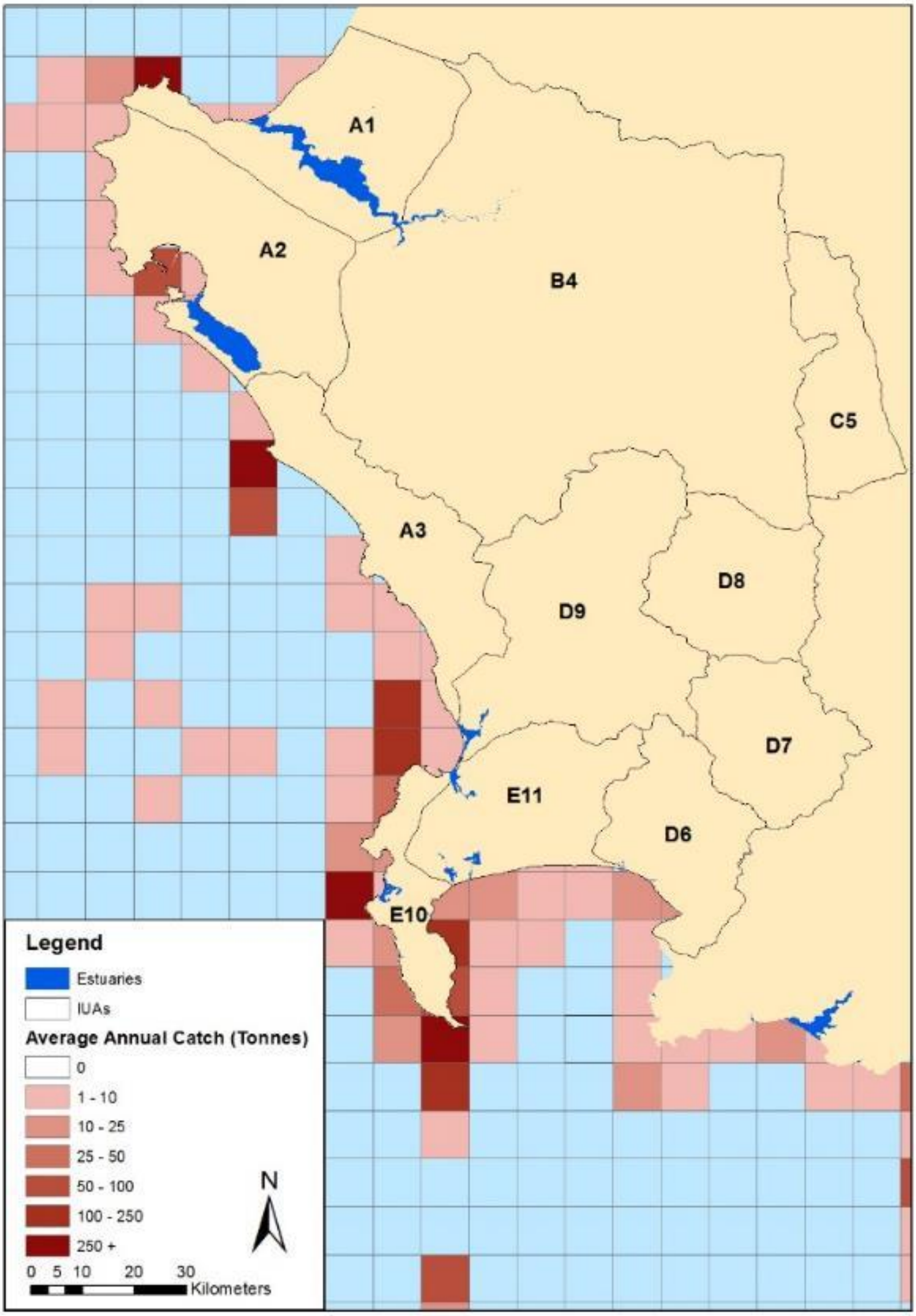


Figure 4.18.Distribution of average annual line fishery catches across the coast of the study area in relation to IUAs and estuaries.

The South African line fishery is valued in excess of R2.2 billion per annum (Department of Agriculture, Forestry and Fisheries 2014). The sum of average annual catches in each of the grid blocks off the coastline of the study area was 4 261 Tonnes/yr which equates to approximately 60% of the value for the whole country. This suggests that the gross output value of the traditional line fishery within the study area is approximately **R1.3 billion/year**, provided the resource is managed sustainably.

Box 4.2. Nursery value of estuaries

Estuaries play an important role as nursery areas for many fish and invertebrate species that spend the rest of their life cycle in marine or freshwater habitats, including many species that are harvested for recreational or commercial purposes (Whitfield 1994; Beck *et al.* 2001). The quantity and quality of freshwater inflows to estuaries as well as management of habitats within them affect their capacity to function as nursery areas.

Fish species that use estuaries have been classified according to their relationships with estuaries. Of particular importance in terms of nursery value are the fish species in category I and II, for which the management of estuaries plates a crucial role in fisheries (Lamberth & Turpie 2003). Most estuary-dependent fish species enter estuaries as larvae or post larvae (Whitfield & Marais 1999) and once the estuarine dependent phase is complete, they leave the estuaries for the marine environment where they become available to marine fisheries, and upon maturity contribute to the spawning stock (Wallace 1975a,b).

The five major categories and subcategories of fish that utilize South African estuaries (Whitfield 1994).

Category	Description
I	Estuarine species that breed in southern African estuaries:
	Ia. Resident species, no record of spawning in marine or freshwater environments
	Ib. Resident species that do have marine and freshwater breeding populations
II	Euryhaline marine species that normally breed at sea, with juveniles showing varying degrees of dependence on southern African estuaries:
	IIa. Juveniles dependent on estuaries as nursery areas
	IIb. Juveniles occur mainly in estuaries, but are also found at sea
	IIc. Juveniles occur in estuaries, but are usually more abundant at sea.
III	Marine species that occur in estuaries in small numbers, but are not dependent on these systems
IV	Freshwater species, whose penetration into estuaries is determined mainly by salinity tolerance
V	Catadromous species that use estuaries as transit routes between marine and freshwater environments, but may also occupy estuaries in some regions
	Va. Obligate catadromous species that require freshwater in their development

	Vb. Facultative catadromous species that do not require a freshwater phase in their development

Fish diversity and abundance differs between estuaries of different sizes and types, with higher species richness associated with larger and permanently open systems (Lamberth & Turpie 2003), such as Knysna estuary and the Breede Estuary. However, estuary health, in particular, the quality of water and quantity of water entering an estuary can impact fish abundance and diversity significantly. Within the study area there are a number of estuaries that have become severely degraded as a result of significant flow modifications, very poor water quality, habitat destruction and reduced food availability (Van Niekerk & Turpie 2012). The condition of each estuary needs to be taken into consideration when determining its contribution to nursery value.

Estimates of nursery value have been made for all South African estuaries, based on inshore fishery catches and the level of dependence of each species on estuaries (Lamberth & Turpie, 2003). Based on this 2003 study, it was estimated that the 50 or so estuaries in the Western Cape contribute about R250 million to the value of inshore fisheries (in 2013 Rands). However, many of the Western Cape's estuaries have become degraded as nursery habitats because of freshwater starvation and mouth manipulation. Furthermore, the fish stocks themselves have also been depleted through overfishing, both legal and illegal. Based on the scores given in a recent evaluation of the current health of fish stocks in each of South Africa's temperate estuaries (WRC and CSIR, unpublished data), in conjunction with information on estuary volumes, it is estimated that the nursery outputs from estuaries in the Western Cape are now only about 27% of their original capacity, suggesting that we have lost services to the value of R675 million (Turpie et al. 2014). This is because some of the most important nursery areas that account for much of the overall capacity have been severely degraded. Based on the above data, the most important systems to focus on in order to recover much of this value are the Olifants, Verlorenvlei, Berg, Bot/Kleinmond and Breede estuaries.

4.3.5 Other economic contributions of aquatic ecosystems

The above sections include the outputs of economic sectors for which are based on activities occurring at or in aquatic ecosystems, in the case of tourism and *in situ* recreational activities, or activities which are based on production from aquatic ecosystems in the case of marine fisheries. Even if not well quantified, these relationships are intuitively understood. In addition, aquatic ecosystems may contribute to the economy in more subtle ways, in that the absence of these services would lead to increased costs to government or the private sector, effectively resulting in lower value added. These cost-savings can therefore be thought of as economic benefits.

In the case of aquatic ecosystems, such benefits are associated with the regulation of **hydrology-associated processes**, such as flood attenuation, sediment retention and water quality amelioration, as well as **climate-associated processes**, such as carbon sequestration. In the latter case, this is considered to be negligible for aquatic ecosystems in the study area and is not dealt with further. The hydrological functions and their value are briefly reviewed and assessed below, based on available information.

4.3.5.1 Flood attenuation

Wetlands are widely believed to be important for flow regulation, through flood attenuation, groundwater recharge and the maintenance of base flows. Rivers will also perform these roles to some extent, but the bulk of research has focussed on wetlands. Flood attenuation occurs when wetlands ameliorate the potential impacts of flood events by absorbing the flood peaks and lengthening the flood period at a lower level, thereby reducing the risk of damage caused by flooding downstream. This occurs due to the detention storage and vegetative resistance to flow through an area (Ogawa & Male 1986, Smithers & Schulze 1993). A wetland that attenuates a flood effectively will have a broader flatter peak on the flood hydrograph. Flood attenuation results in reduced flow rates downstream, and hence a reduction in bank and streambed erosion (Vellidis *et al.* 2003), as well as reduced risk of flooding of downstream areas. The benefits of this may be in reduced damages and/or avoided expenditure on flood protection infrastructure. This service can also have significant benefits for the insurance industry.

The capacity for a wetland to attenuate flows is influenced by its holding capacity (available surface water volume and soil porosity) and resistance due to habitat ‘roughness’ (Krasnostein & Oldham 2004, Jothiyangkoon *et al.* 2001) as well as its degree of saturation or inundation (Potter 1994). It also depends on its location in the catchment (Kotze & Breen 1994) and season (Krasnostein & Oldham 2004).

Methods to assess the extent to which wetlands provide flow regulation functions range from low-cost rapid methods to expensive, issue specific and data intensive modelling approaches (Kusler 2004, Thiesing 2001). Rapid methods are generally not designed to provide quantitative measurements of functional performance and use the presence or absence of selected wetland characteristics as predictors of wetland functions (Thiesing 2001). There has been relatively little quantitative description of the hydrological functions performed by wetlands (Smakhtin & Batchelor 2005), particularly in South Africa.

Flood attenuation can be quantitatively assessed through the application of hydrological models that simulate catchment rainfall-runoff processes and wetland and river channel hydraulics (e.g. Kleynhans *et al.* 2009). Very little work has been carried out on the flood attenuation capacity of wetlands in the study area. In the Olifants, uMkomati and Usutu to Umhlatuze WMAs, Turpie et al. (2010) estimated flood attenuation by wetlands at a quaternary catchment scale. 1:20 year flood peaks, flood volumes and durations were derived at the outlets of all quaternaries in the study area, for the total catchment upstream of the outlet (i.e. including all quaternaries upstream of the quaternary under consideration). The flood hydrograph was then routed through a lumped storage representing an “effective” storage volume of all main stem wetlands in the quaternary under consideration. Attenuation storage volumes (i.e. the maximum volume of water in storage during passage of the flood – which could be less than the total available storage in the wetland) were then determined. These volumes were used as proxies for the flood attenuation capacity of the main stem wetlands. In this study, however, none of the scenarios are expected to have an impact on the storage capacity of wetlands in the WMA. Therefore it was not considered essential to quantify this function. Nevertheless, it is possible to generate a ball-park estimate of the potential value of these systems using a simplified version of the above approach (without hydrological modelling).

Approximate estimates of wetland volumes were derived by assuming typical shapes and maximum surface water depths for each wetland type, and taking effective soil moisture storage depth into account. Soil moisture storage depths were estimated for individual wetlands by intersecting wetlands with the South African Atlas of Climatology and Agrohydrology layers (Schulze& Horan 2007) to determine topsoil and subsoil depths and porosities, while maximum surface water depths were assumed to be constant for each wetland type. The volume equations that were used were:

Valley bottom: $V = 1/3 \times (d_{water} + d_{soil}) \times area$ (triangular prism), $d_{water} = 0.5$ m

Floodplain: $V = (d_{water} + d_{soil}) \times area$ (disc), $d_{water} = 0.8$ m

Pans: $V = 2/3 \times (d_{water} + d_{soil}) \times area$ (bowl), $d_{water} = 0.8$ m

Seeps and Flats: $V = (d_{water} + d_{soil}) \times area$ (disc), $d_{water} = 0$ m

Seasonal variations of water stored in wetlands play a determining role in flood attenuation capacity. Large recurrence interval floods typically occur after days, or even weeks of wet conditions when catchments are saturated. Under these conditions, wetland storage available for flood attenuation could be limited. In addition, and unlike artificial impoundments that can be drawn down prior to a flood event, outflows from natural wetlands are unregulated. For these reasons, it was conservatively assumed that a maximum of 30% of total wetland volume is available for flood attenuation storage.

Flood attenuation generates value through reducing the risk of flood damage. The most practical way to value this function is using the replacement cost method. In this case the engineering solution to replace the service would be the construction of dams of equivalent attenuation capacity. The cost of doing this was estimated based on data from DWAF on the capital replacement costs of dams. Assuming that the service if fully demanded, the replacement cost method yields an estimated value of R80.9 million (capital, not annual, value). As a lower bound estimate, the costs per quaternary were modified using an index of demand for flood attenuation. Demand for the service was assessed based on GIS data of land use and infrastructure in the downstream quaternary catchment. If urban areas or mines occurred within 100 m of rivers then the service was considered fully demanded, if irrigated agriculture was present, the service was considered 50% demanded and if neither occurred then the service was considered not demanded. This yielded an estimated value of 34 million m^3 in terms of flood attenuation storage with an estimated value of R47 million (Table 4-16). The true value is likely to lie somewhere in between, as the benefits of wetlands may be felt within their own quaternary (including in coastal quaternaries) and also in quaternaries beyond the next downstream quaternary. This value was highest in the Lower Berg area which has upper catchments that provide the services to the towns and irrigated areas below (Table 4-16).

As expected, the value of flood retention by wetlands was not very high in the areas adjacent to the coast, as there are not as many downstream beneficiaries to benefit of any service offered.

Table 4-16. Natural wetland areas, estimated effective storage values and approximate value of flood retention value within the study area.

Socio-economic zone	Wetland area km^2	Effective storage capacity Million m^3	Approximate lower bound value Million R	Approximate upper bound value Million R
West Coast	46.2	7.4	0	17.6
Lower Berg	75.5	19.9	41.3	47.3
Tulbagh Fruit Area	20.3	1.4	1.7	3.4
Winelands	15.3	3.8	3.8	8.9
Cape Town	14.2	1.6	0.6	3.8
TOTAL	**171.4**	**34.1**	**47.4**	**80.9**

4.3.5.2 Sediment retention

Sediment yield from catchment areas is accelerated by land disturbance, elevating the sediment loads carried by rivers. Wetlands can trap some of these extra sediments, thus reducing the potential damage caused by elevated sediment loads downstream. These damages would include the costs associated with increased turbidity of aquatic systems, siltation of aquatic habitats and siltation of water supply infrastructure and monitoring weirs. Higher silt loads in rivers may decrease light penetration and thus primary productivity, which in turn affects fisheries. Silt deposition within rivers decreases habitat and hence biodiversity in these systems. Siltation of dams and weirs reduces their capacity and lifespan, incurring costs through increased maintenance and/or augmentation schemes.

The ability of wetlands to remove excess sediment loads is related to their ability to reduce water velocity, and is thus closely related to a wetlands flow regulation capacity. Slope of the wetland is obviously a key factor (Novitzki 1979), as well as the roughness and holding capacity of the wetland. As the water slows down, the energy required to keep sediments in suspension is lost, and deposition occurs (Vellidis *et al.* 2003).

The value of sediment retention can be measured using the replacement cost method or a damage costs avoided method. Damage costs of sedimentation are difficult to estimate in the absence of detailed studies, though preliminary estimates have been made in the international literature.

The ability of wetlands to remove excess sediment loads is related to their ability to reduce water velocity, and is thus closely related to a wetlands flow regulation capacity. Therefore the value of the sediment retention service is at least partly captured when valuing the flood attenuation service of wetlands.

4.3.5.3 Water quality amelioration

Water entering wetlands from developed catchments generally has elevated amounts of sediments, nutrients and pollutants from catchment activities, industrial effluents, treated and untreated sewage and other wastes. Excess phosphorous tends to stimulate algal growth in freshwater ecosystems and dams, while excess nitrogen would have this effect in estuarine and marine systems. This leads to deterioration in ecosystem health and capacity to deliver ecosystem services. Toxic algal blooms, heavy metals and pathogens pose a risk to human health. Thus the services provided by wetlands can save on water treatment costs and/or human health costs, as well as avoiding losses in fisheries, tourism and other ecosystem values described in the preceding sections (see Box 4.3).

A number of studies have been carried out on the waste treatment function in natural and created aquatic habitats (e.g. Peltier *et al.* 2003, Thullen *et al.* 2005, Batty *et al.* 2005), but most research has been carried out in treatment wetlands. In South Africa there are data on the capacity of artificial wetlands to treat wastewater (e.g. Rogers *et al.* 1985), but little data exists on natural systems, which are generally less efficient. In natural systems, landscape processes also need to be taken into account, as waste uptake does not only occur within aquatic ecosystems, but also occurs during the drainage process, as waste-water runs through various habitats *en route* to streams and rivers.

Turpie et al. (2010) undertook a preliminary study on the role of wetlands in determining water quality in a selection of 100 sub-catchments in the Western Cape, including in the study area (Figure 4.19). Wetlands in these catchments were found to play a significant role in the reduction of nitrates, nitrites, and ammonium, but not dissolved phosphorus or suspended solids (which carry most of the phosphorous), probably due to the temporal nature of the study. Estimated removal rates ranged from 307 to 9 505 kg N/ha/y, with an average of 1 594 ± 1 375 kg N/ha/y. Further research is required to understand this service and its value.

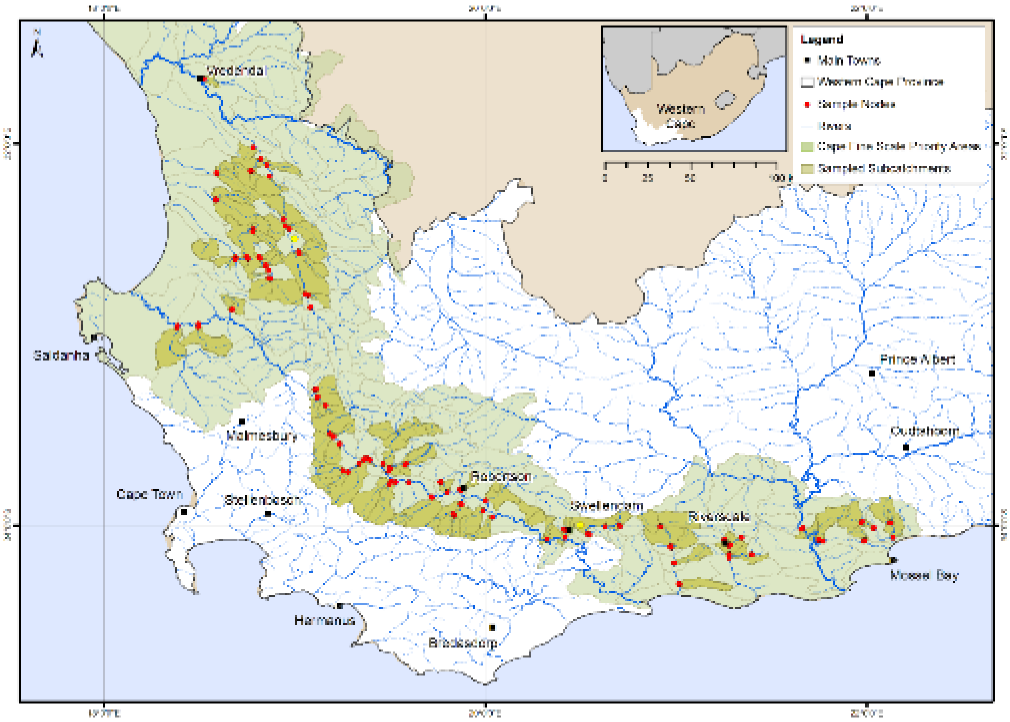


Figure 4.19. **Sampling localities used by Turpie et al. 2010 (red dots) and their subcatchment areas (dark green shading), within the area of the Western Cape Province that has been mapped at a fine scale (light green shading).**

Box 4.3. Water quality amelioration by wetlands

There are a number of different process through which wetlands remove sediments, nutrients and pollutants from the inflowing water (Figure 4.20). Nutrients that are introduced in dissolved form can be taken up directly by plants and incorporated into plant tissue as they grow. Most of the phosphorous that is introduced to wetlands is attached to sediment and settles to the bottom, where it can remain inactive (Brinson 2000). However, if sediments are stirred up then some of this phosphorous can go back into solution and become available for use by plants. The uptake of dissolved phosphorous will continue as long as there is room for further plant growth (in terms of space, oxygen or plant size limits), after which the system will reach some kind of equilibrium in which the uptake is balanced by the senescence, death and rotting of plant material which reintroduces nutrients into the water column (remineralisation). At this point there would be no further net uptake of nutrients by the wetland unless nutrients are being exported out of the system (e.g. by harvesting plants or dredging and removal of sediments), or unless there is a natural process of peat formation.

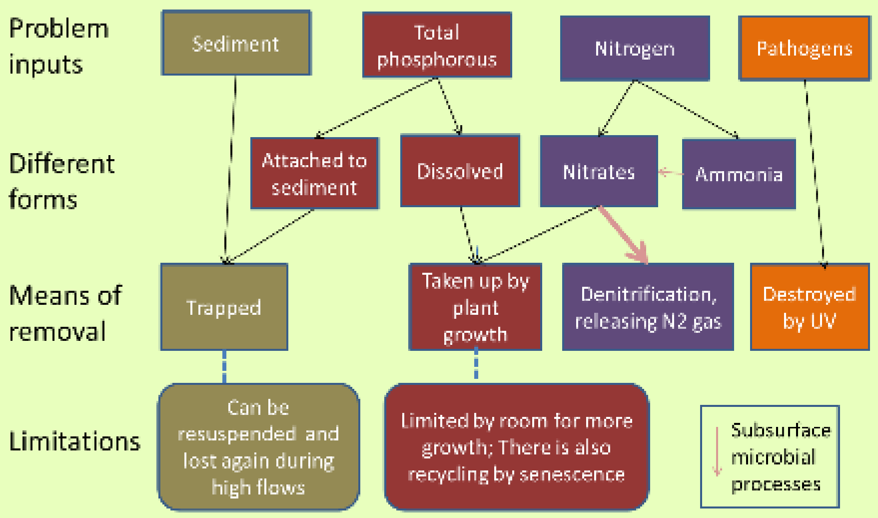


Figure 4.20. Summary of water quality amelioration services by natural systems (Source: Turpie 2015)

Nitrogen is removed in wetlands mainly by the nitrification–denitrification process (Saunders & Kalff 2001). Nitrification is the microbially-mediated oxidation of ammonium (NH4) to nitrite (NO2) and then nitrate (NO3). This process consumes oxygen and thus occurs in aerobic areas of the wetland. Nitrate then diffuses to anaerobic areas of the wetland where it may be denitrified. This is the rate-limiting step in the removal of nitrogen from flooded systems. In the denitrification process nitrate (NO_3) is reduced to gaseous nitrous oxide (N_2O) and nitrogen gas (N_2), which are then released to the atmosphere (Mitsch & Gosselink 1993). This occurs mainly in sediments with abundant organic matter that provides a carbon source for denitrifying bacteria. Bacteria concentrations are reduced in wetlands by exposure to UV-light. The degree to which this occurs is linked to the duration of water retention within the system.

The ability of wetlands to perform water quality amelioration services depends on their area and type of vegetation as well as to their overall health and management. Hydraulic efficiency, which is the degree to which a wetland disperses inflow over its area, is also important (Jordan *et al.* 2003). This maximizes contact area and it can be assumed that it serves to increase detention time as well. There is an upper limit to the amount of pollution that a wetland can remove, as well as to the amount of pollution that can be added to a wetland without having a significant impact on its functioning and biodiversity. At high phosphorus loading rates wetlands may eventually become a phosphorus source rather than a sink (Tilton & Kadlec 1979, Forbes *et al.* 2004). This also varies seasonally. Wetlands are thought to be better at removing total suspended solids, phosphorus and ammonia during high flow periods (when sediment loads entering the wetland increase), but better at removing nitrates during low flow periods (Johnston *et al.* 1990, McKee *et al*. 2000).

4.3.6 Population, income and living conditions

4.3.6.1 Population

A total of 4.4 million people lived within the study area in 2011 (Figure 4.21). The population has grown significantly since 1996, with a 13% increase between 1996 and 2011, and a 30% increase between 2001 and 2011 (Figure 4.21).

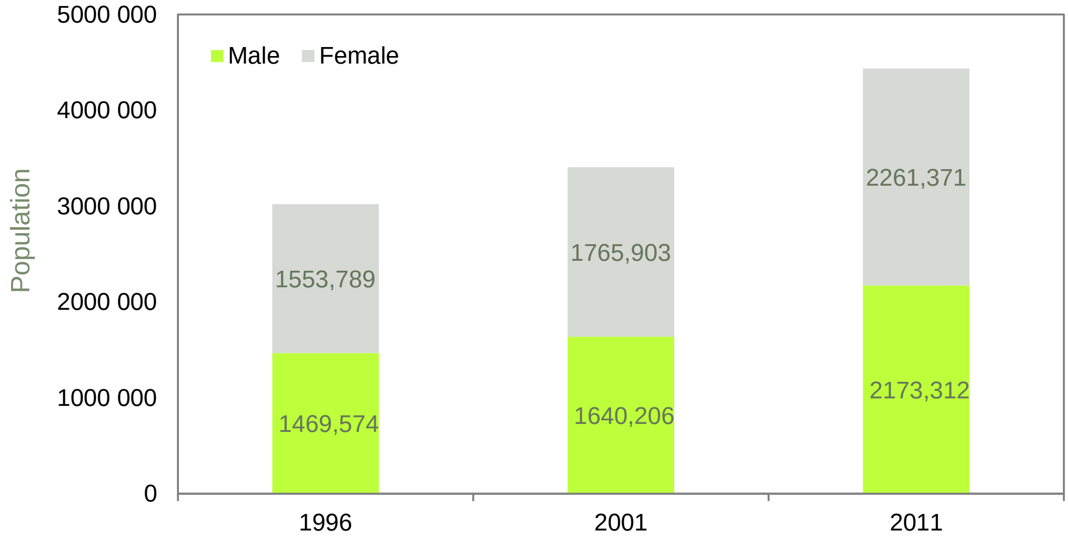


Figure 4.21. Population statistics for the study area in 1996, 2001 and 2011 (Source: StepSA 2015 based on StatsSA Census data).

Population growth was fairly even across the socio-economic zones between 1996 and 2001 with increases of between 10% in the Tulbagh Fruit Region and 21% in the West Coast (Figure 4.22). Population growth was higher between 2001 and 2011 with increases between 25% in Cape Town and ranging up to 48% in the West Coast socio-economic zone.

By far the most populated socio-economic zone was Cape Town, followed by the Winelands. Together these two zones accounted for over 90% of the total population in the study area in all years (Figure 4.22 and Table 4-17). There were just under 1 250 000 households in the study area, with an average household size of 3.6 in 2011 (Table 4-17). The Tulbagh Fruit Area has an average household size of 4.1, the highest in the study area, and the West Coast has the lowest household size of 3.3 (Table 4-17).

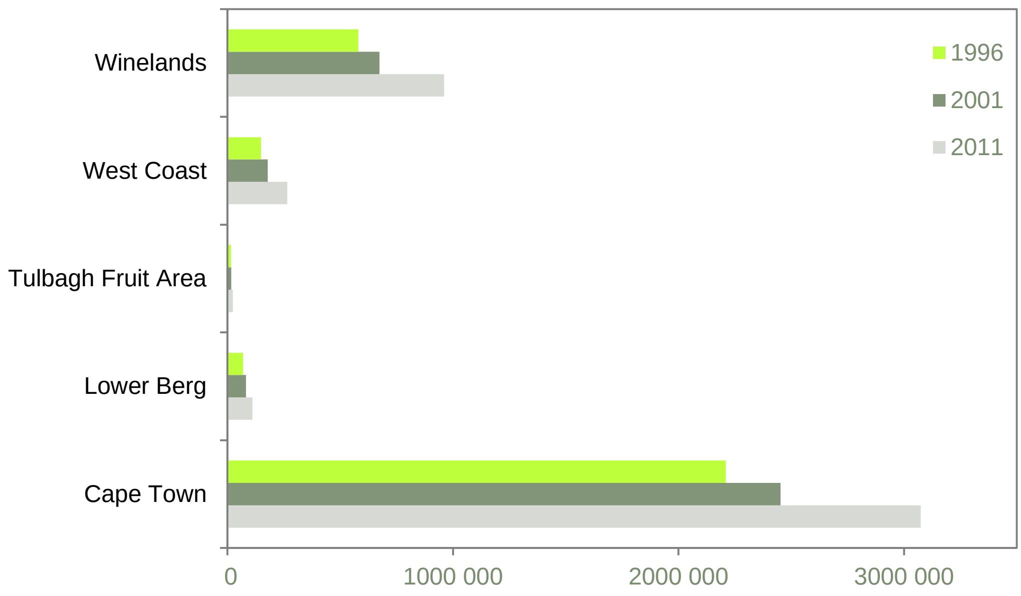


Figure 4.22. Population in each socio-economic zone in the study area in 1996, 2001 and 2011 (Source: StepSA 2015 based on StatsSA Census data).

Table 4-17. Total population, number of households and average household in each socio-economic zone in 2011 (Source: StepSA 2015 based on StatsSA 2011 Census data).

Socio-economic zone	Population 2011	Number of households	Average household size
Cape Town	3 073 703	848 936	3.6
Lower Berg	110 058	27 861	4.0
Tulbagh Fruit Area	24 264	5 927	4.1
West Coast	265 988	80 258	3.3
Winelands	960 670	286 223	3.4
Total	**4 434 683**	**1 249 205**	**3.6**

Within the study area there are two large metropolitan areas, namely Cape Town and Stellenbosch. Around 70% of the population resides within the Cape Town socioeconomic zone alone. The highest densities of people within the study area are found on the cape flats with densities reaching over 10 000 people/km^2. Outside of these metropolitan areas, especially within the Lower Berg socio-economic zone, densities are much lower, often below 10 people/km^2 (Figure 4.23).

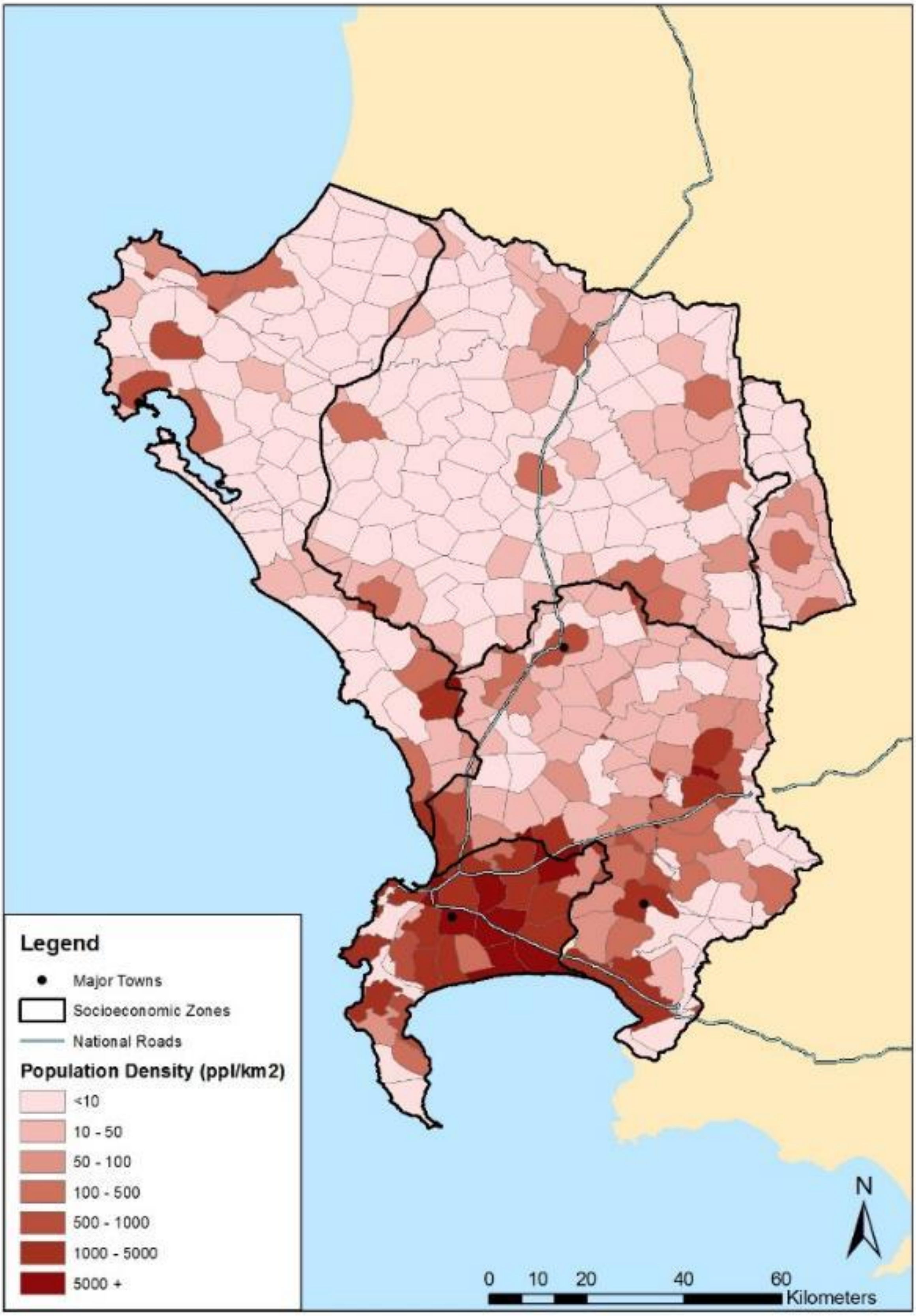


Figure 4.23. Population density by mesozone. (Source: StepSA 2015 based on StatsSA Census data).

4.3.6.2 Income, poverty and unemployment

The average household income for the study area was R205 797 in 2011 (Table 4-18). The Tulbagh Fruit Area and had the lowest average household income, less than half that of the average for the study area. Cape Town and wine lands had the highest average incomes (Table 4-18).

Table 4-18. Number of households, average household income and percentage of poor households in each socio-economic zone in 2011 (Source: StepSA 2015 based on StatsSA 2011 Census data).

Socio-economic zone	Number of households	Average household income (R)	% of poor households
Cape Town	848 936	291 544	17.8%
Lower Berg	27 861	125 786	8.0%
Tulbagh Fruit Area	5 927	90 160	10.0%
West Coast	80 258	230 619	13.9%
Winelands	286 223	290 874	16.1%
Total	**1 249 205**	**205 797**	**16.9%**

Of the 1 249 205 households in the study area, just over 210 000 were considered to be poor[5], or living in poverty, in 2011 (Table 4-18, Figure 4.26). The number of poor households in the study area has increased from 8% in 1996 to 15% in 2001 and 16.9% in 2011 (Figure 4.26).

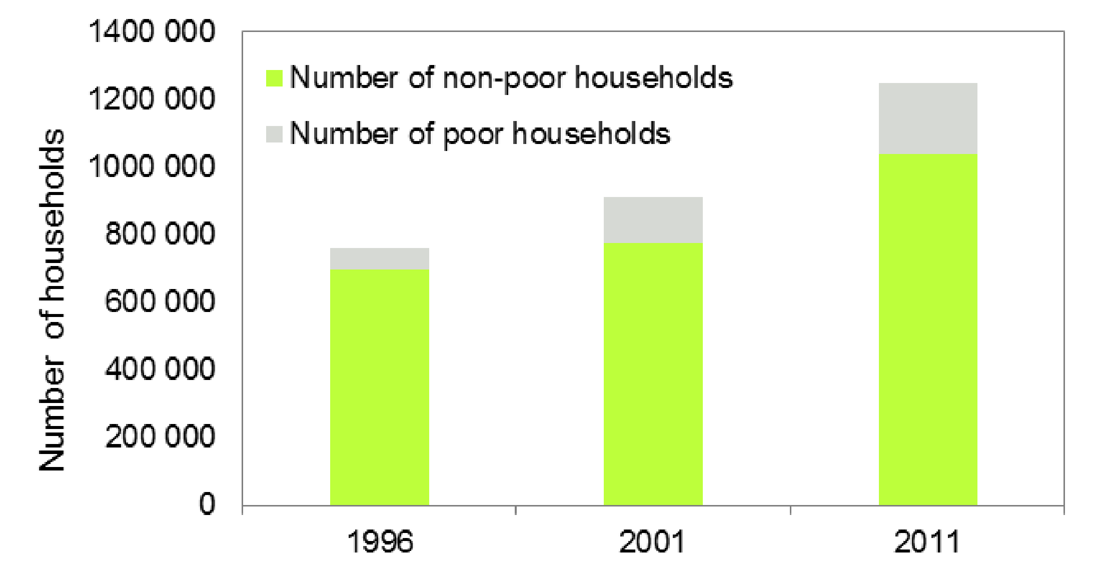


Figure 4.24. The number of non-poor households and the number of poor households within the study area in 1996, 2001 and 2011 (Source: StepSA 2015 based on StatsSA Census data).

[5] Determining the proportion of poor households in the study area was based on household income and expenditure patterns in South Africa, developed by the Bureau of Market Research (BMR 2013). The 'poor' income category (R0 – R54 344 per household per annum) as defined by the BMR was used to establish the proportion of households living in poverty (StepsSA 2015). As this income category did not align directly with the 'poor' income category in the StatsSA Census data of R0 – R48 000, a proportional number of households from the R48,000 - R96,000 category were added together to bring this in line with the BMR cut off of R54,355 (StepsSA 2015). To calculate this for 1996 and 2001 years, the CPI was used to inflate 1996 and 2001 prices to establish the equivalent income category cut off for the census data in these years.

Cape Town and the Winelands have the highest percentage of poor households in the study area in 2011 at over 15% (Figure 4.25). The winelands has the highest rate of increase in the percentage of poor households since 1996, increasing by 222%, while Cape Town was the lowest, only increasing by 88% (Figure 4.26). For most socioeconomic zones, there were greater increases in the percentage of poor households between 1996 and 2001 than between 2001 and 2011 (Figure 4.25). The Tulbagh Fruit Area was the only socio-economic zone which saw a decrease in the percentage of poor households between any two census years (Figure 4.26). Unemployment across the study area has increased on average by 2% between 1996 and 2011. Socio-economic zones with the highest proportion of households living in poverty also had the highest increase in unemployment rates between 1996 and 2011

The Winelands, West Coast ad Cape Town have all experienced increases in unemployment since 1996. Whilst the Lower Berg has shown little change and the Tulbagh Fruit Area has had a decrease in the percentage unemployment (Figure 4.28). Unemployment was lowest in 2011 in the Tulbagh Fruit Region and Lower Berg at 8% and 9% respectively.

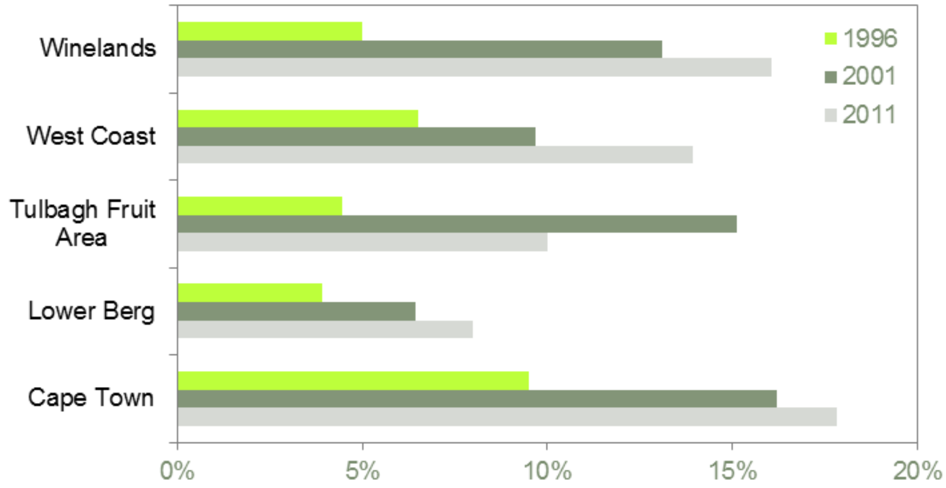


Figure 4.25. **The number of poor households in each mesozone (Source: StepSA 2015 based on StatsSA Census data).**

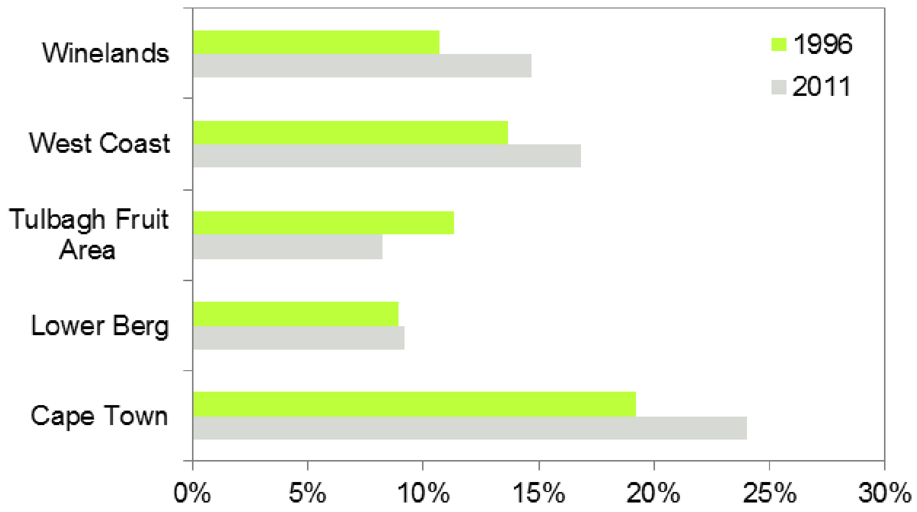


Figure 4.26. **Percentage of poor households in each socio-economic zone in 1996, 2001 and 2011 (Source: StepSA 2015 based on StatsSA Census data).**

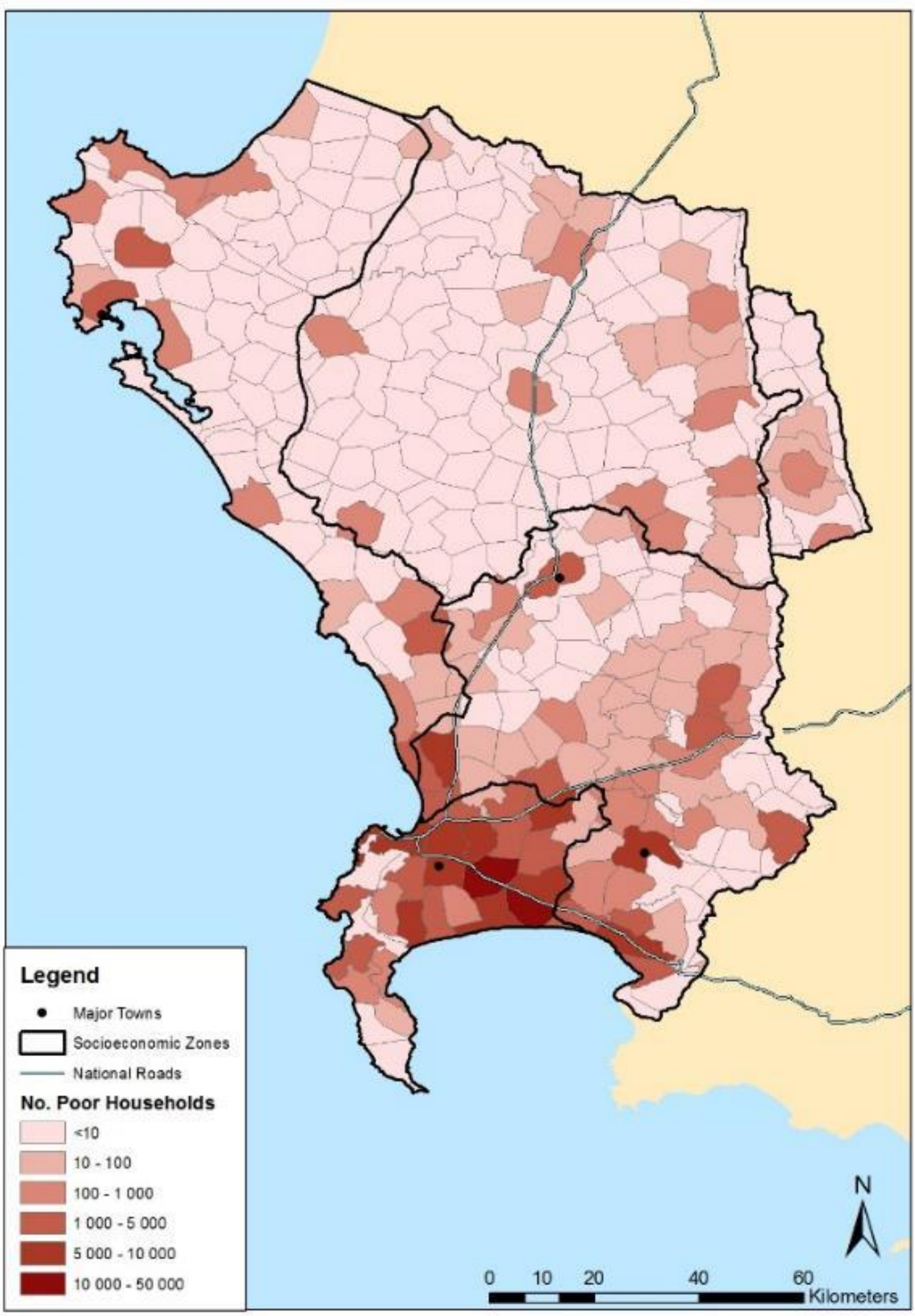


Figure 4.27. Percentage unemployment in each socio-economic zone in 1996 and 2011 (Source: StepSA 2015 based on StatsSA Census data).

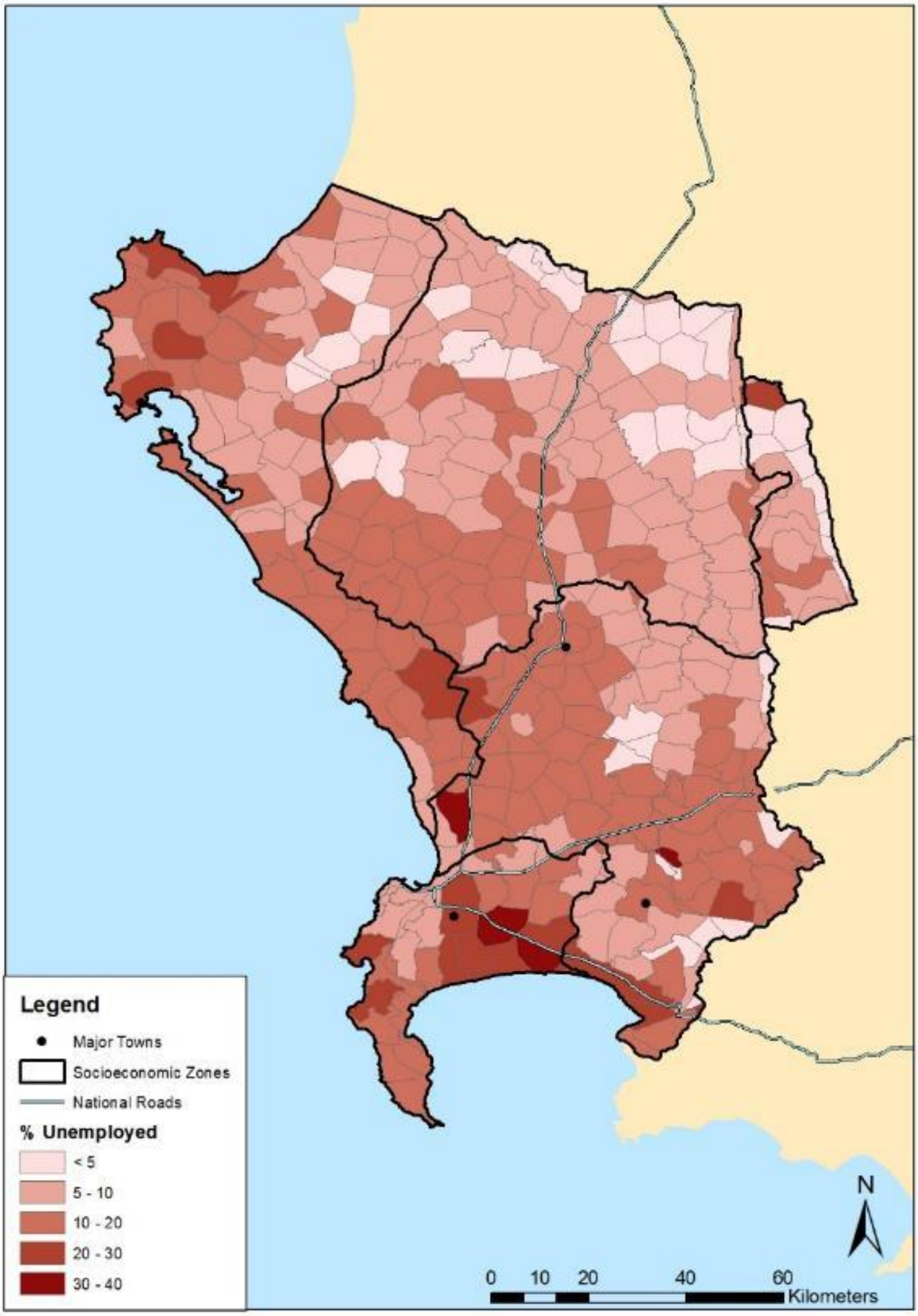


Figure 4.28. Percentage unemployment in 2011 in each mesozone (Source: StepSA 2015 based on StatsSA Census data).

4.3.6.3 Access to electricity

In 2011 96% of households in the study area were using electricity as their main source of energy for lighting, compared to 93% of households in 2001 and 91% of households in 1996. The use of other forms of lighting, such as candles, gas and paraffin are highest in the Tulbagh Fruit Area (11%), whereas all other socio-economic zones had less than 5% using other forms of lighting (Figure 4.29).

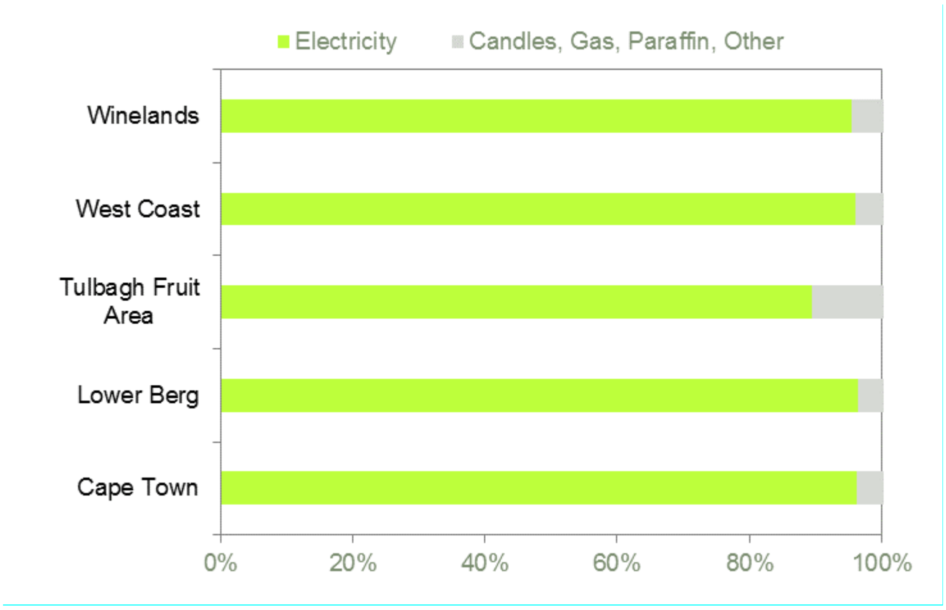


Figure 4.29. Percentage of households using electricity as a main source of lighting, compared to other sources (Source: StepSA 2015 based on StatsSA Census data).

4.3.6.4 Water and sanitation

The number of households in the study area with access to piped water has increased significantly over the period 1996 to 2011 (Figure 4.30). Between 1996 and 2011 the percentage of households with access to piped water in the dwelling had increased by 50%.

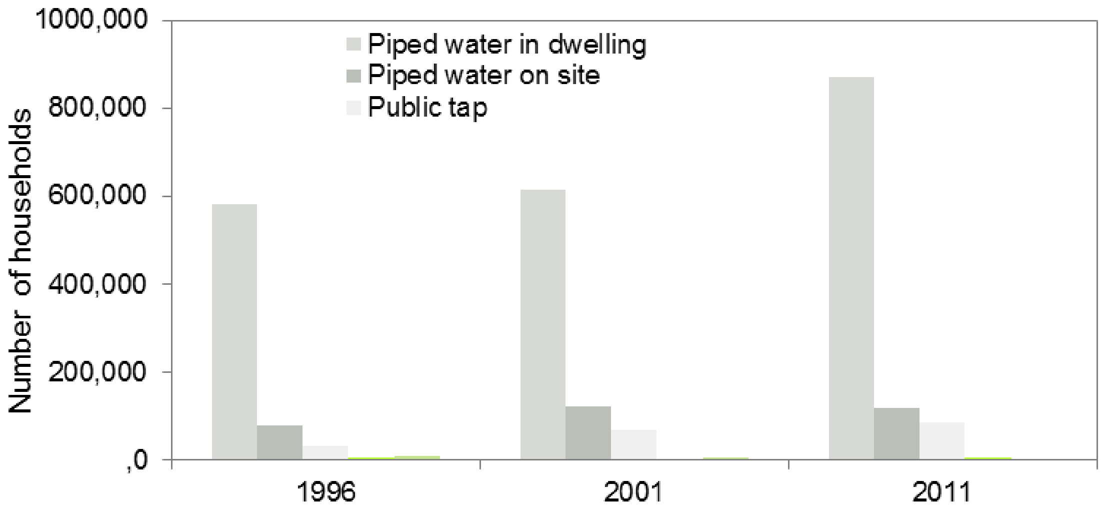


Figure 4.30. The number of households with different sources of water supply in 1996, 2001 and 2011 (Source: StepSA 2015 based on StatsSA Census data).

Access to water is variable across the study area (Figure 4.31). Poor access to water is most prevalent in the Tulbagh Fruit Area, affecting almost 14% of households (Figure 4.31). This figure is lowest in the Lower Berg (2.4%) and the West Coast (3.8%).

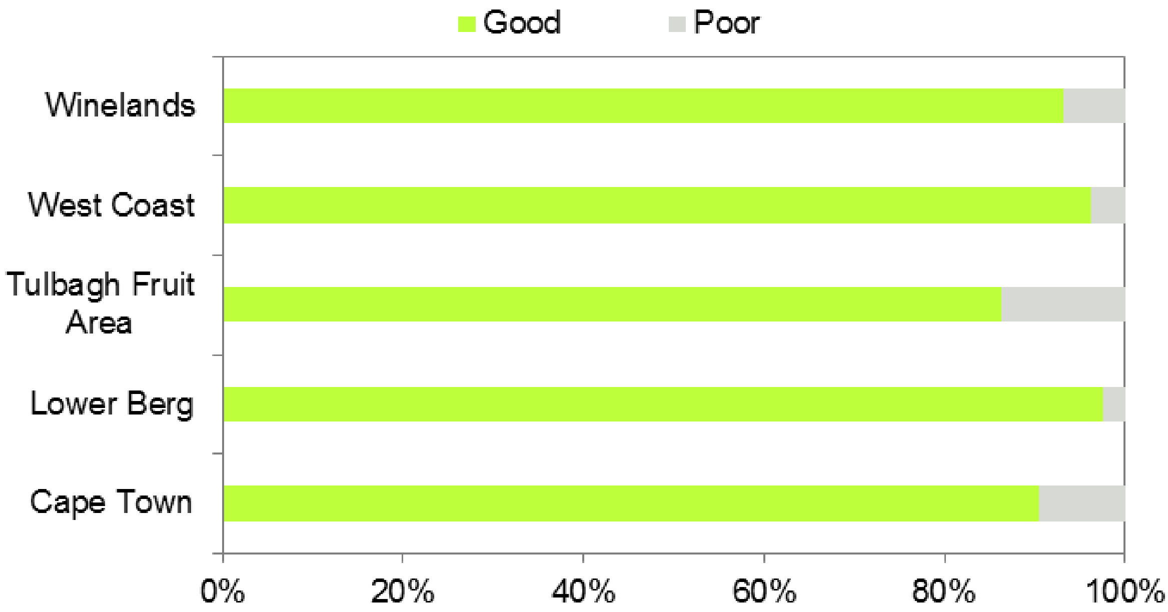


Figure 4.31. Percentage of households with good access or poor access to water in 2011. Good access = Piped water into the dwelling or on dwelling site. Poor access = either no access to piped water, use of a communal tap or other (Source: StepSA 2015 based on StatsSA Census data).

The percentage of households with poor access to water increased in all the socio-economic zones between 1996 and 2001 (Figure 4.32). However, in most socioeconomic zones, the percentage then decreased between 2001 and 2011 (Figure 4.32). Exceptions to this were within the Tulbagh Fruit Area which also saw an increase in poor access to water between 2001 and 2011 and Cape Town, which saw little changeover the same period. The Tulbagh Fruit Area, Cape Town and the Winelands had the highest percentages with poor access to water in 2011 at 14%, 10% and 8% respectively (Figure 4.32). The lowest percentages were within the Lower Berg and West Coast socio-economic zones with 2% and 4% respectively.

In 1996, less than 1% of households in the study area had no access to piped water, this figure declined slightly in 2001 but in 2011 was similar levels to 1996 (Table 4-19). While in 1996 there were some large differences in the percentage with no access to piped water between socioeconomic zones, in 2011 most zones were similar (Table 4-19). All socio-economic zones with the exception of Cape Town have seen improvements in access to piped water between 1996 and 2011.

The total number of households with flush toilets has increased over the period 1996 – 2011, however the percentage of households has remained relatively similar (Figure 4.33). In 2011 94% of households in the study area had flush toilets[6], similar to the 93% in 1996 and 2001 (Figure 4.33).

[6] Flush toilets include the use of chemical toilets which made up only 1% of the total

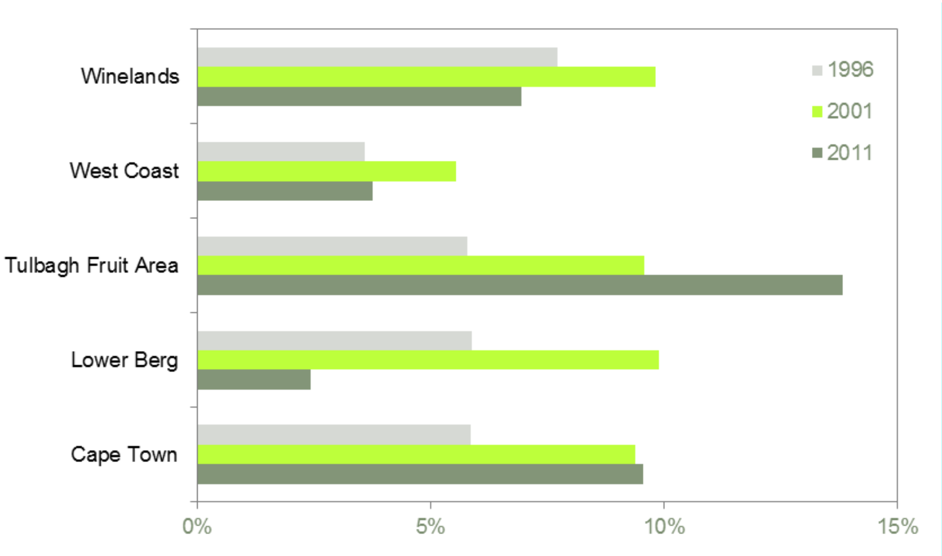


Figure 4.32. Percentage of households with poor access to water in 1996, 2001 and 2011 (Source: StepSA 2015 based on StatsSA Census data).

Table 4-19. Percentage of households with no access to piped water in each socio-economic zone in 1996, 2001 and 2011 (Source: StepSA 2015 based on StatsSA Census data).

Socio-economic zone	2011	2001	1996
Cape Town	0.6%	0.2%	0.2%
Lower Berg	0.6%	1.3%	2.9%
Tulbagh Fruit Area	0.5%	0.5%	5.2%
West Coast	0.6%	0.5%	1.0%
Winelands	0.6%	0.4%	2.0%
Total	**0.6%**	**0.3%**	**0.7%**

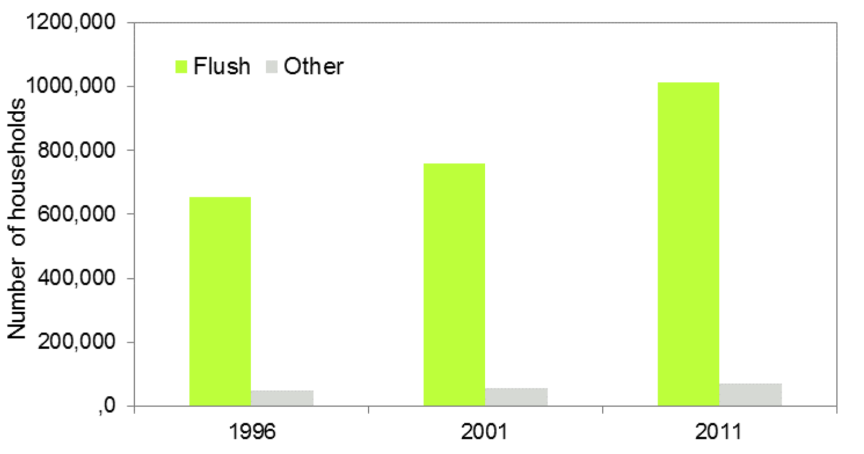


Figure 4.33. Number of households with a flush toilet compared to households using other types of toilets in 1996, 2001, 2011 (Source: StepSA 2015 based on StatsSA Census data).

The households in the Tulbagh Fruit Area and the Lower Berg have the highest percentage usage of other types of sanitation, with 11% and 9% of all households not having a flush toilet, respectively (Figure 4.34). This figure was lowest in the West Coast and the Winelands, with only 5% of households in these regions not having a flush toilet.

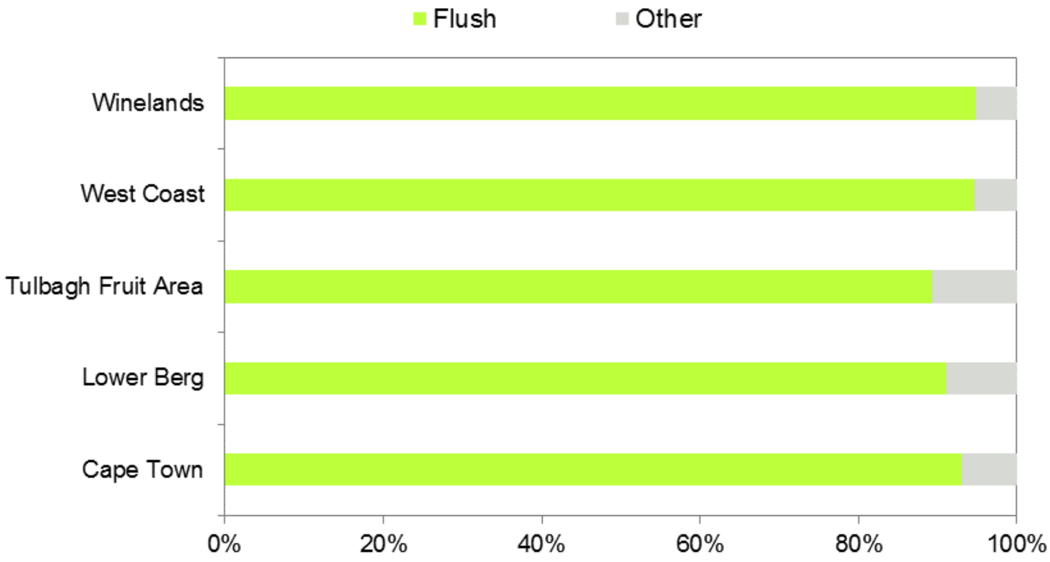


Figure 4.34. Percentage of households with a flush toilet and the percentage of households using other types of toilets in 2011 (Source: StepSA 2015 based on StatsSA Census 2011).

In 2011 95% of households in the study area had access to good refuse removal, which includes the weekly or monthly collection of refuse by local authority. Poor refuse removal includes no refuse disposal or the use of a communal or private dump. There was a slight improvement overall between 1996 and 2011 in access to good refuse collection. In 2011 more than 15% of households in the Tulbagh Fruit Area and the Lower Berg had poor refuse collection whereas the other three zones had less than 10% (Figure 4.35).

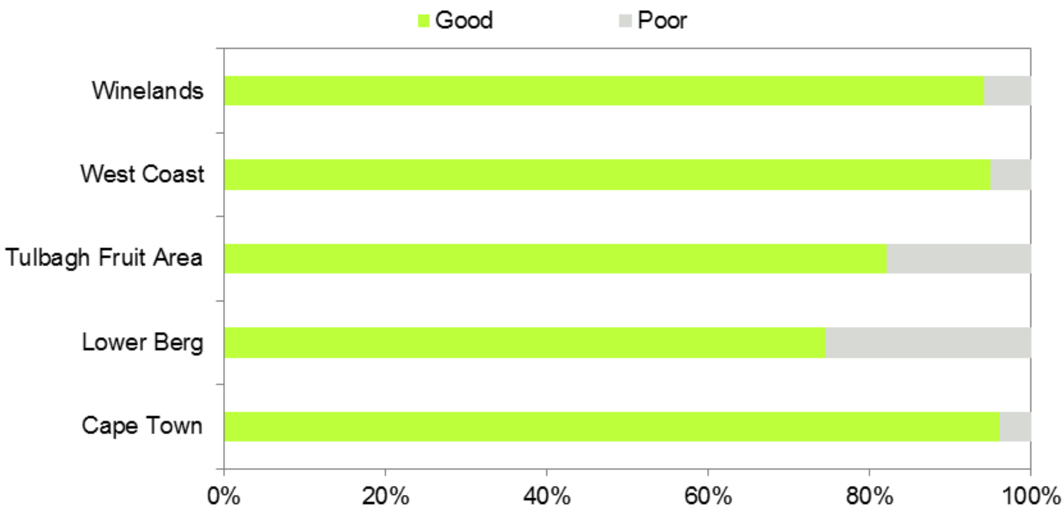


Figure 4.35. Percentage of households with poor refuse removal and good refuse removal in 2011 (Source: StepSA 2015 based on StatsSA Census data).

4.3.6.5 Reliance on aquatic natural resources

In many parts of the country, rivers, estuaries and wetlands play a significant role in supporting livelihoods. This is mostly associated with people living in traditional households within former homeland areas (DWAF 2010), where poverty levels tend to be highest. Use of natural resources can also be important for poor households living in peri-urban areas (Lannas & Turpie 2009). There are no former homelands within the Berg Water Management Area. Nevertheless, there are numerous poor communities living within farms, around farming towns, and larger urban areas, that are reliant to some extent on natural resources. Thus it is expected that there is some level of collection of plant and fish resources, and collection of river water for domestic use. In the latter, case, it is necessary to determine the amount required to meet Basic Human Needs, as per the National Water Act (Act 36 of 1998).

4.3.6.6 Water for Basic Human Needs

It was estimated that in 2011 a total of 4 819 households in the study area were reliant on rivers and streams as their main source of domestic water (Table 4-20). This equates to 0.4% of all households in the study area. The Lower Berg and Tulbagh Fruit Area had the highest percentage of households reliant on river water (Table 4-20). All other zones had less than 1% of households collecting river water.

Based on 2011 data, and the requirement of 25 litres per person per day for households depending on river flows as their source of domestic water, the Basic Human Needs requirement is in the order of 492 m3 per day, which amounts to an annual allocation of about 180 000 m3 for the study area as a whole. It is assumed that numbers of households relying on rivers for basic human needs will diminish, rather than grow, over time.

Table 4-20. The number and percentage of households within each socio-economic zone that are collecting water from rivers and streams (Source: StatsSA Census 2011).

Socio-economic zone	IUA	No. HH relying on river water	Average Household size	Minimum daily flow required to meet Basic Human Needs (m^3/day)
West Coast	Berg Estuary	237	4.05	24
	Langebaan	48	3.33	4
	West Coast	61	4.83	7
Lower Berg	Lower Berg	1 784	4.32	193
Tulbagh	Berg Tributaries	346	4.64	40
Winelands	Eerste and Sir Lowry's	593	3.82	57
	Upper Berg	217	4.48	24
	Middle Berg	613	4.61	71
	Diep	354	4.10	36
Cape Town	Peninsula	17	2.96	1
	Cape Flats	548	3.81	52
Total		**4 819**	**4.09**	**492**

4.3.6.7 Other river and wetland resources

The majority of inland freshwater fisheries across South Africa are recreational (McCafferty et al 2012). However, since the 1990s there has been an increase in the utilisation of freshwater aquatic resources for providing food security; although this has been mainly concentrated in impoundments like large dams (McCafferty et al. 2012). Estimates of the value of subsistence fisheries along rivers in the Olifants, Inkomati and Usutu to Mhlatuze WMAs ranged from <R2 000 – R28 000/km/year which was based on household survey data and % traditional land use. Even in these traditional rural areas, fishing was a marginal activity with only 4% of households participating the in previous year (DWA 2010). While the participation in the inland subsistence fishery is likely under-reported, there is very little information on subsistence inland aquatic resources across the country (e.g. Weyl et al. 2007, Andrew et al. 2000, Rouhani 2003), and only two from the study area (Turpie et al. 2001, Lannas & Turpie 2009).

Within the study area most of the rivers and wetlands are only accessible through private or state land. Because of this, the value of inland subsistence fishing is likely to be lower than that reported elsewhere in the country. A small survey of households from the Cape Flats (Khayalitsha and Kuils River), found that no more than 10% of households used the Kuils River wetlands for any one of the following activities: collecting reeds, flowers, medicinal plants, fishing and grazing livestock (Turpie et al. 2001).

In another more recent study examining natural resource use in the Cape Flats informal settlement area of Mfuleni, some 7% of households practiced agriculture within the Mfuleni wetlands and 8.6% of household owned livestock, of which almost 90% grazed their animals on the wetland (Lannas & Turpie 2009). Lannas & Turpie (2009) estimated that the total value added of this grazing and agriculture provisioning service was in the order of (R6 million in 2015 Rands). A few households also indicated that they used the wetlands for fishing, and 1% hunted for waterfowl and small mammals within the wetlands (Lannas & Turpie 2009).

4.3.6.8 Estuary resources

Estuaries provide a value resource to both subsistence and recreational fishers. Subsistence fishers are considered to be those who fish or collect bait personally, use low technology gear, live near to the resource and either use the catches to meet basic food requirements or sell the catches locally to gain income to allow them to meet basic food requirements. The subsistence fishery consists primarily of bait collection as well as well as fishing. The predominant species that make up bait collection is the mudprawn *Upogebia africana* which made up 94.6% of subsistence bait catches in Knysna estuary (Napier et al. 2009). In the same study, subsistence fish catches were also dominated by a few species, namely Cape stumpnose *Rhabdosargus holubi* and strepie *Sarpa salpa*, while other larger species like spotted grunter *Pomadasys commersonnii* were also heavily targeted.

Subsistence fishing and bait collection does not, however, occur in all estuaries along the coast and is related to the size of the estuary as well as its degree of accessibility and enforcement of conservation within protected areas. Turpie & Clark (2007) estimated the annual catches and values for subsistence fisheries in South African estuaries using data collected as part of the Subsistence Fisheries Task Group assessment (Clark et al. 2002) and interpolating using expert knowledge for estuaries for which no data were available. Turpie & Clark (2007) estimated that only approximately 50 subsistence fishers were operating within the estuaries in the study area on a day-to-day basis.

In addition, Langebaan Lagoon supports small-scale fishing. The boat based, non-recreational fishery is regulated by the number of boats permitted to harvest within the area. While commercial fishing is not normally permitted within estuaries, it is permitted in Langebaan Lagoon. A small-scale net-fishery operates within regulated areas of the lagoon. The number of permit holders for this fishery are low and come from either the Churchhaven or Langebaan communities. Gill-net permits holders targeting harder landed an estimated 590 tonnes per annum, valued at approximately R1.8 million during 1998-1999 (Hutchings & Lamberth 2002). Recent data on catches are not available, however if catches remained similar, the value of this small-scale fishery would be almost 12.5 million in 2015 Rands.

These data for estuaries, including Langebaan lagoon, were updated to 2015 Rands and are presented in Table 4-21. This suggests that the total subsistence value for the coastline could be in the region of **R13.6 million per year**.

Table 4-21. Estimates of the value of the subsistence and small scale fisheries within significant estuaries. Values are from Turpie & Clark (2007) and Hutchings & Lamberth 2002 and are updated to 2015 Rands using the CPI index. * Estuaries with 'poor' health ratings according to NBA 2012 indicating possible overexploitation of resources.

Socioeconomic Zone	Estuary	Harvest value R/year
West Coast	Berg	966 000
West Coast	Langebaan	12 493 879
Winelands	Rietvlei/ Diep*	78 246
Cape Town	Wildevoël vlei*	4 015
Cape Town	Sand	19 723
Cape Town	Zeekoevlei	-
Winelands	Eerste*	29 882
Winelands	Lourens	4 015
Total		**13 595 760**

The majority of the estuaries fall into the Cape Town socio-economic zone, however the majority of the value is derived from Langebaan and the Berg Estuary within the West Coast socio-economic zone (Table 4-21). Almost all the other estuaries with significant value are considered in poor health according to the National Biodiversity Estuary Assessment (Van niekerk & Turpie 2012).

Note that the estimates of values for subsistence fishing do not necessarily represent the sustainable yield that can be harvested without causing detriment to the ecosystem. There are however, not many good estimates on what the sustainable yield is for the species targeted by subsistence fishers along this coastline. The bulk of subsistence catches of estuary fish are species like mullet, with a significant bycatch of estuary dependent line fish. While the catches of mullet might be sustainable, the latter are thought to be unsustainable in many cases, and affect the nursery value of these habitats.

5 STATUS QUO SUMMARY OF INDIVIUDAL IUAs

The approach we followed in the provisional delineation of the IUAs is described in the companion document to this Status Quo Report, namely the *Resource Unit and Integrated Units of Analysis Delineation Report* (DWS, 2016). The final delineation of 12 IUAs for the study area is presented in Table 5-1.

Table 5-1. Composition of 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
		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

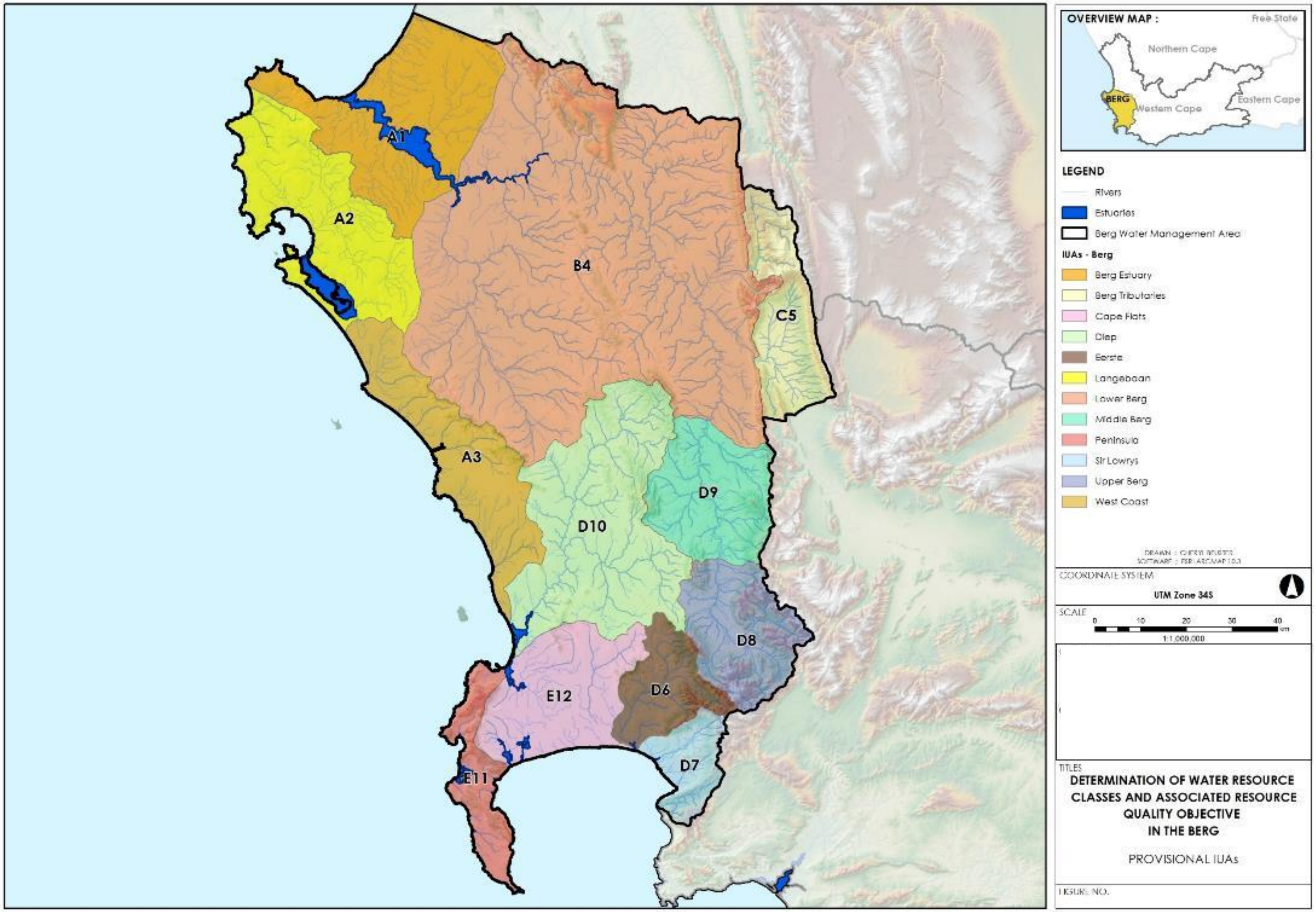


Figure 5.1. Locations of IUAs delineated for the study area.

5.1 IUA A1: Berg Estuary

Socio-economics and ecosystem services

There are just over 31 000 ha of irrigated and dryland crops in the Berg Estuary IUA with grains and planted pasture being the principal crops. Gross economic output of water affected activities was estimated to be R436 million in 2015 with inshore fisheries representing almost 80% of this. The population of the IUA is close to 27 000 people and 8 000 households of which 2.7% are dependent upon river water.

Water resources

IUA A1, A2 and a portion of A3 and B4 occur within the West Coast GRU. The West Coast region is formed by basement Malmesbury Group overlain by the Sandveld Group. Surface water is limited in the region, related to low rainfall, subdued topography and highly permeable sand-dominated geology. The Sandveld Group aquifers are a significant resource for the region. Aurora relies solely on groundwater, and according to the trend analysis for the Aurora-Hopefield water use cluster water is predominantly used for irrigation and is of a good quality.

Water quality in the Berg estuary is affected by seawater intrusion and tidal effects, therefore TDS, EC, chloride concentrations are high and the water unsuitable for irrigation agriculture. There is a salinity gradient with salt concentrations being highest near the river mouth (near seawater quality) and declining in an upstream direction up to the inflow into the estuary where the salinity approaches that of the lower Berg River. The DWS as well as the Western Cape Province are monitoring water quality in the estuary.

Table 5-2. Present day "fitness for use" categories for selected water quality variables at selected water quality sampling points in the Berg Estuary IUA (A1).

		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	**IUA**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**
G1H023Q01	A1	Red	Red	Yellow	Yellow	Red	Red	Blue	Blue	Blue	Green	Blue	Yellow	Blue	Blue
G1HO24Q01	A1	Red	Red	Red	Red	Red	Red	Blue	Blue	Blue	Green	Green	Yellow	Red	Red
BERG R27	A1					Red	Red	Blue	Blue	Blue	Yellow	Yellow	Red		
BE-05 KER	A1							Blue	Blue	Blue	Blue	Yellow	Yellow		
BE-01 LAA	A1							Blue	Blue	Blue	Blue	Yellow	Yellow		

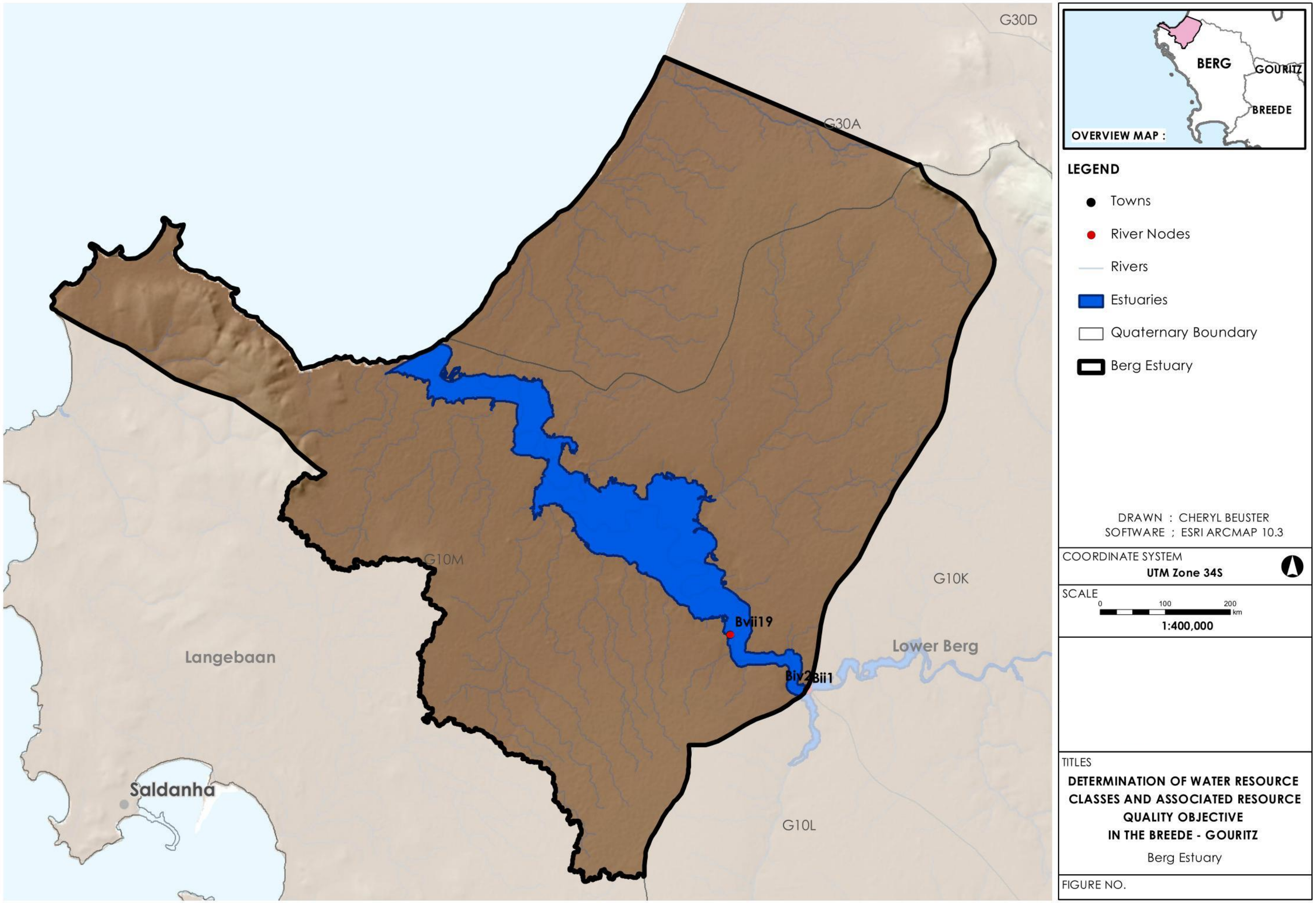
Note: 50 = median or 50th percentile, 95 = 95th percentile. Categories: Blue = Ideal, Green = Acceptable, Yellow = Tolerable, and Red = Unacceptable, Blank = No data

Ecology

There is one node on the perennial Berg River in the Berg Estuary IUA that is located in the Southern Coastal Belt. This low-lying Lowland is situated just upstream of the influence of the estuary, the Ecological Importance and Sensitivity was not assessed for this reason. The condition of this last stretch of the Berg River was determined to be moderately modified (C-category) 2014, the same as at 1999 due to few small farm dams, no impacts on high flows, high impact on low flows; fair water quality, some agricultural return flows; moderate infilling where cultivation occurs; and some removal of riparian vegetation, some exotic plants where cultivation occurs. This last reach of the Berg River is targeted as a Phase2 FEPA.

This IUA contains the large, permanently open Berg estuary that comprises about half of the estuarine functional area found within the study area. The Berg estuary is in a fair state of ecological health with water quality and physical habitat being the two components rated as poor in the 2010 RDM study. The Berg estuary has RAMSAR status but no formal protection.

The Berg River has alluvial floodplain wetlands which are characterised by wide river valleys, where periodic inundation of the floodplain sustains wetland habitat. These wetlands are highly threatened by water abstraction, which threatens the seasonal inundation of the floodplain, the persistence of floodplain vegetation and wetlands (Job et al., 2008).



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.2 IUA A2: Langebaan

Socio-economics and ecosystem services

There are just close to 24 000 ha of irrigated and dryland crops in the Langebaan IUA with grains and planted pasture being the principal crops. Gross economic output of water affected activities was estimated to be R355 million in 2015 with tourism representing more than 85% of this. The population of the IUA is approximately 80 000 people and 24 000 households of which less than 1% are dependent upon river water.

Water resources

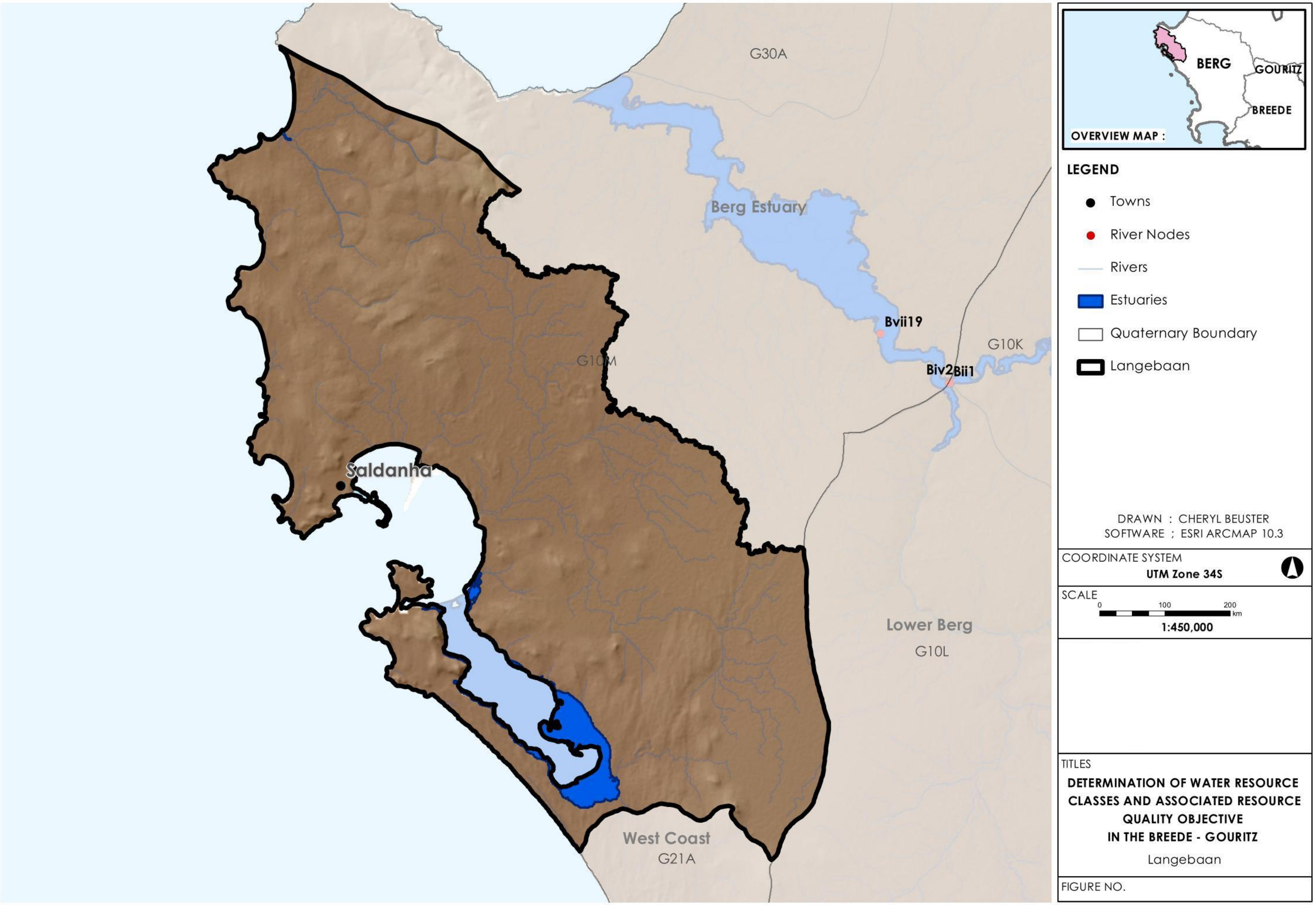
IUA A1, A2 and a portion of A3 and B4 occur within the West Coast GRU. Langebaan Road Wellfield provides 17% of the supply of the towns of Langebaan, Langebaanweg and Saldanha. According to the trend analysis for the Langebaan water use cluster water levels and water quality is variable.

Ecology

There are no river nodes in the Langebaan IUA. The Bok River is targeted as a Phase2 FEPA.

This IUA contains Langebaan, the only estuarine bay within the study area. Langebaan incorporates the largest estuarine channel area within the study area, but it is largely a marine dominated system and is fed by groundwater (volumes to be determined) rather than surface flows. Langebaan is in a good state of ecological health and is wholly protected within the West Coast National Park.

Strandveld valley bottom wetlands are located almost exclusively in the Saldanha Peninsula. They are seasonal wetlands, tend to be saline and occur on neutral to alkaline sands or granite-derived soils (Job et al., 2008). As opposed to Langebaan these wetlands are generally fed by hillslope seeps lying on higher ground and are not particularly groundwater dependent (Job et al., 2008). Threats to these wetlands are both cultivation and urban expansion, with changes to the flow regime being of particular concern.



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.3 IUA A3: West Coast

Socio-economics and ecosystem services

There are just over 11 000 ha of irrigated and dryland crops in the West Coast IUA with grains and planted pasture being the principal crops. Gross economic output of water affected activities was estimated to be R669 million in 2015 with tourism and fisheries representing over 90% of this. The population of the IUA is approximately 160 000 people and 50 000 households of which less than 1% are dependent upon river water.

Water resources

The West Coast GRU extends to just past Grotto Bay in IUA A3. Grootwater Aquifer occurs around Yzerfontein. The rest of the IUA occurs within the Atlantis GRU, which is an area of subdued topography where thick Sandveld Group deposits outcrop, overlying basement rock and forming a significant aquifer. Basement outcrops in the higher lying areas to the east are where the Sout River originates. Minor wetlands in coastal dunes are sustained by groundwater. Major groundwater abstraction occurs for Atlantis water supply via the Atlantis Water Supply Scheme.

Most of the DWS water quality sampling points in this IUA are located at salt pans (G201/01A1, G201/02B1, and G201/08C1) or near the sea where the quality can be affected by tidal influences. Sampling points G201/07A1 is located at the Witsand Aquifer Recharge Basin which receives treated wastewater from the Atlantis (De Fleur) WWTW. The quality here is moderately saline but high in phosphates.

Table 5-3. Present day "fitness for use" categories for selected water quality variables at selected water quality sampling points in the Dwars Mosselbank IUA (A3).

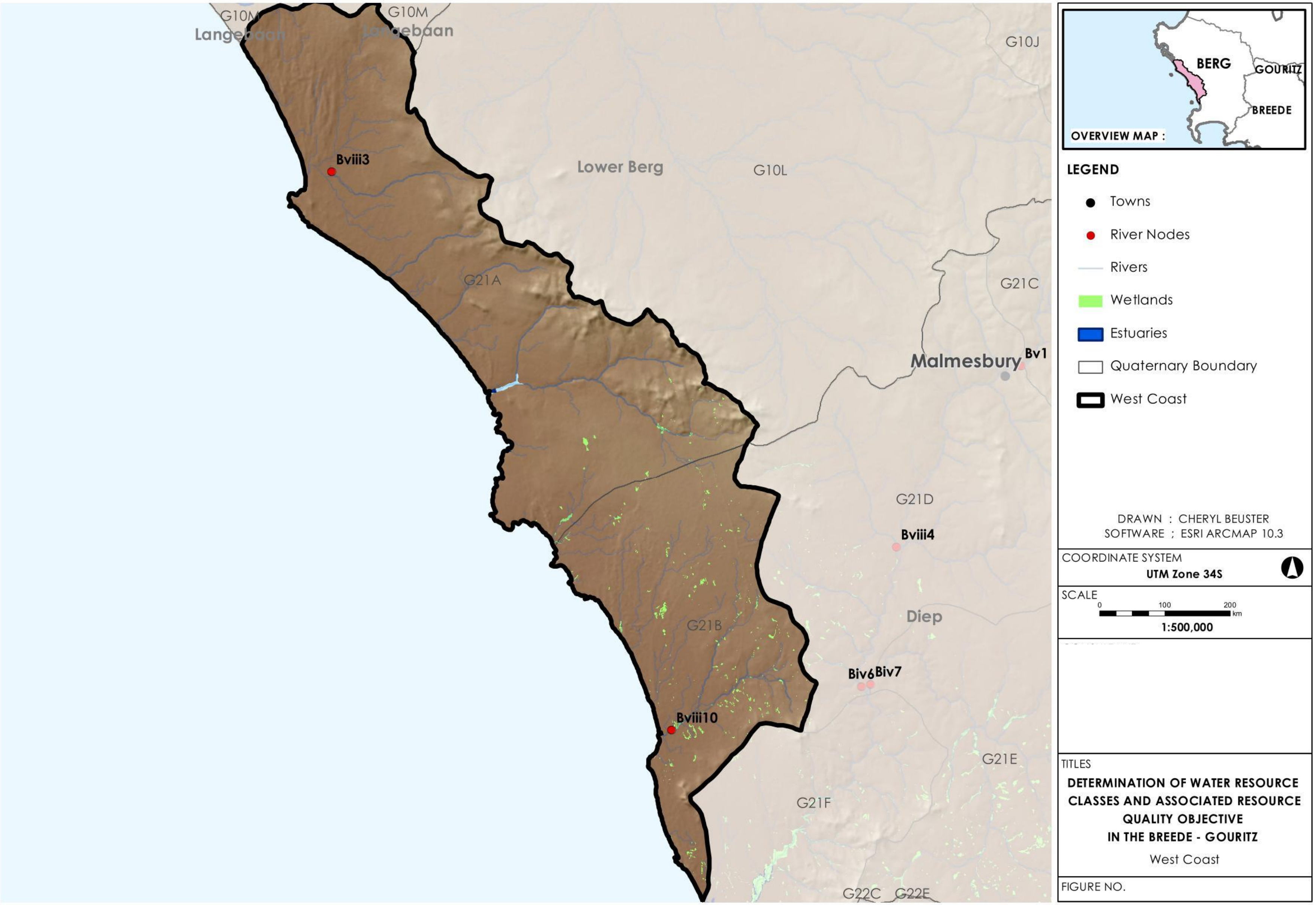
		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	**IUA**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**
G201/01A1	A3														
G201/02B1	A3														
G201/08C1	A3														
G201/04B1	A3														
G201/06A1	A3														
G201/07A1	A3														

Note: 50 = median or 50th percentile, 95 = 95th percentile. Categories: Blue = Ideal, Green = Acceptable, Yellow = Tolerable, and Red = Unacceptable, Blank = No data

Ecology

Some of the coastal rivers in the West Coast IUA flow perennially, others like the inflow into the Yzerfontein salt pan are non-perennial. The rivers are small and may be steep or low-lying, comprising Upper and Lower Foothills, which are considered to be of High Ecological Importance and Sensitivity. The ecological condition of these rivers has degraded since 1999, now being largely or severely modified (D and E-category). The reasons for the condition assessment include moderate abstraction and flow changes, a few small farm dams with minimal impact on high flows; pollution from agricultural runoff; some channel manipulation, with modified bed and banks, habitat diversity reduced by cultivation along channels; and clearing of riparian vegetation and presence of exotic woody plants. There are two FEPAs, the one on the Silverstroom River being supported by a conservation area Upstream.

Yzerfontein salt pan, a saline depression wetland, is currently being mined for gypsum. Alien invasive vegetation in the area and deepening of the main pan due to dredging activities may have contributed to the loss of wetland area (Malan et al., 2015). The wetland has a PES of B, with a degrading trajectory due to mining, and an EIS of 6.1, due to employment provided by mining and the habitat provided for water birds (Malan et al., 2015). The wetland provides habitat for important water birds and water amelioration benefits, and it has an overall EIS of 5.2 (Malan et al., 2015).



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.4 IUA B4: Lower Berg

Socio-economics and ecosystem services

There are just over 282 000 ha of irrigated and dryland crops in the Lower Berg IUA with grains and planted pasture being the principal dryland crops with wine grapes making up a large proportion of the irrigated land.. Gross economic output of water affected activities was estimated to be R1 938 million in 2015 with irrigated fruit representing the majority of this. The population of the IUA is approximately 110 000 people and 28 000 households of which over 4% are dependent upon river water.

Water resources

The Lower Berg IUA occurs within the Picketberg, 24 Rivers and West Coast GRUs. To the north of the IUA the mountainous area is dominated by the Table Mountain Group, which is highly faulted causing the Piekenierskloof and Peninsula Formations to be contact in places. Registered groundwater use is largely restricted to the TMG in this area. The Hopefield/Aurora water use cluster has boreholes in Quaternary Deposits showing seasonal fluctuations in water level and good water quality, with Hopefield itself having a wellfield providing 30% water supply. The 24 Rivers GRU occurs to the west of the Lower Berg IUA. The TMG aquifers are significant in this GRU, with high recharge and discharge to surface water. The perennial flow of the Groot-Kliphius River being evidence of this. Picketberg and Porterville have up to a quarter groundwater supply. There is little registered water use in this GRU.

Salinity in the Lower Water Berg River increases in a downstream direction; compare G1H013Q01 at Drieheuwels to the downstream G1H031 at Misverstand Weir. This increase is as a result of irrigation return flows and naturally saline tributaries such as the Matjies River (G1H035Q01) and Moreesburgspruit (G1H034Q01). The Leeu River (G1H029Q01) that drains from the Great Winterhoek Mountains has very good water quality and is one of the sources of high flow transfers into the off-channel storage dam, Voëlvlei Dam which is a water source to the City of Cape Town and towns in the Swartland. Elevated phosphate concentrations occur in the Lower Berg IUA.

Table 5-4. Present day "fitness for use" categories for selected water quality variables at selected water quality sampling points in the Lower Berg IUA (B4).

		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4		
Station	**IUA**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	
G1H013Q01	B4															
G1H029Q01	B4															
G1H031Q01	B4															
G1H034Q01	B4															
G1H035Q01	B4															
G1H040Q01	B4															
G1H043Q01	B4															
G1R001Q01	B4															
G1R003Q01	B4															
DIE BOORD	B4															
SARON	B4															
GROEN R307	B4															
SOUT R307	B4															
SOUT TRIB	B4															
SOUT R45	B4															
BOESMANS	B4															
G103/01A1	B4															
G103/02A1	B4															
G103/03A1	B4															

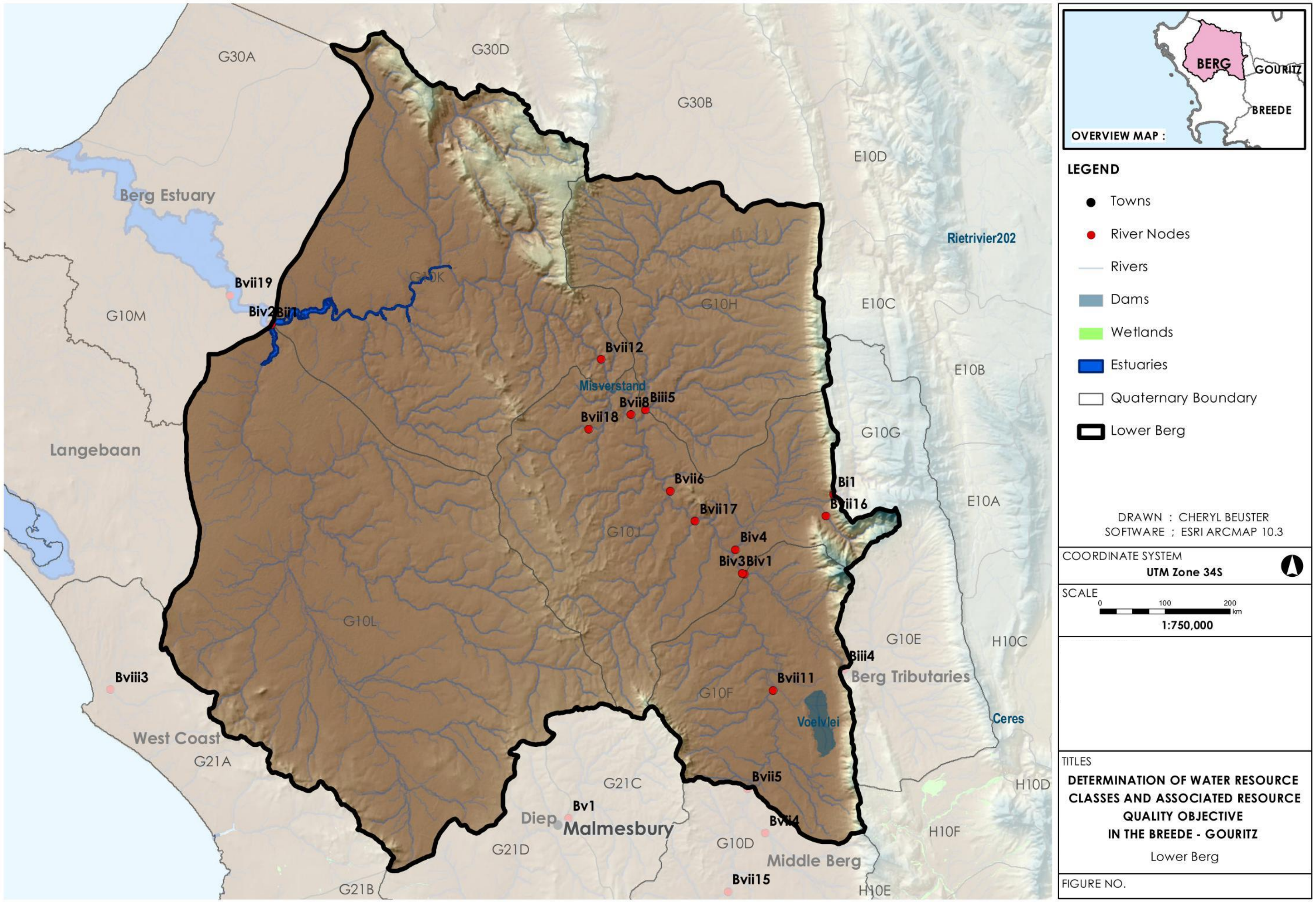
Note: 50 = median or 50th percentile, 95 = 95th percentile. Categories: Blue = Ideal, Green = Acceptable, Yellow = Tolerable, and Red = Unacceptable, Blank = No data

Ecology

All the rivers in the Lower Berg IUA are situated in the Southern Coastal Belt and apart from two tributaries, the Leeu and Sout, flow perennially. The Leeu River is the only steep Upper Foothill, the other tributaries are low-lying Lower Foothills, while the Berg River is a low-lying Lowland. The Ecological Importance and Sensitivity of these rivers varies from Moderate to Very High. For the most part the ecological condition of the rivers has remained the same 1999-2014; there were two drops in condition at the Mooresburg Spruit and a section of the Berg River at Misverstand Weir, from a D to an E-category and a C to a D-category respectively (largely to severely and moderately to largely modified respectively). The reasons for the condition assessment include high abstraction and small farm dams with moderate to high impacts on flows; water quality poor, pollution impacts from agricultural and urban return flows , WWTW; infilling of wetlands and floodplains where cultivation occurs, rivers channelized through towns, banks bulldozed in places, berms created along cultivated fields; and removal of riparian vegetation, some exotic plants where cultivation occurs, some patches of intact indigenous vegetation elsewhere, livestock trampling, much *Eucalyptus.* There are six FEPAs on some higher lying tributaries and there are a number of Phase2 FEPAs elsewhere. Examples of the kinds of rivers in the Middle Berg are shown in Figure 5.2.

Two depression wetlands occur on a tributary of the Berg River to the north of Darling. The Koekispan and Kiekoesvlei occur within agricultural lands and are host to a variety of water birds. Koekispan is a saline pan which still bears a berm from salt mining. It has a low EIS of 2.8 (Malan et al., 2015), due to the remaining impacts of the wetland modifications and high nutrient levels within the wetland. Kiekoesvlei is a freshwater pan within pasture lands. It has an EIS of 4.9 due to the occurrence of red data birds (flamingos) and *Oxalis disticia,* but the wetland is also under the effects of elevated nutrients (Malan et al., 2015).

Figure 5.2. Rivers typical of Middle Berg; Mooreesburg Spruit G10J-8322 (left) and Sandspruit G10J-8487 (right).



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.5 IUA C5: Berg Tributaries

Socio-economics and ecosystem services

There are just over 8 000 ha of irrigated and dryland crops in the Berg Tributaries IUA with grains, planted pasture and stone fruit being the principal crops. Gross economic output of water affected activities was estimated to be R633 million in 2015 with irrigated crops representing almost 90% of this. The population of the IUA is approximately 24 000 people and 6 000 households of which over 3% are dependent upon river water.

Water resources

The Berg Tributaries IUA occurs within the 24 Rivers GRU to the north and Tulbagh Valley GRU to the south. The Berg River drains the centre of the 24 Rivers GRU and can be assumed to receive baseflow from the Malmesbury basement aquifer. The Tulbagh Valley GRU is predominantly underlain by Malmesbury Group with thin and discontinuous Cenozoic cover. Tulbach uses minor amounts of groundwater for domestic supply. Seasonal fluctuations of the borehole water levels within the Tulbach water use cluster are likely related to changes in rainfall, hence recharge.

Overall water quality in the Berg River tributaries is good except in the upper reaches of the Boontjies River G1H009Q01 and G1H010Q01 which could be affected by irrigation return flow, as well as fruit processing facilities to the north of the Wolseley area. Elevated phosphate concentrations in some of the effluent stream sampling points are high. However, in the quality of water that is transferred from the Klein Berg River (G1H008Q01) is slightly impacted. Concerns have been expressed about agrochemicals in the Klein Berg River because its catchment is an intensive fruit growing region.

Table 5-5. Present day "fitness for use" categories for selected water quality variables at selected water quality sampling points in the Berg Tributaries IUA (C5).

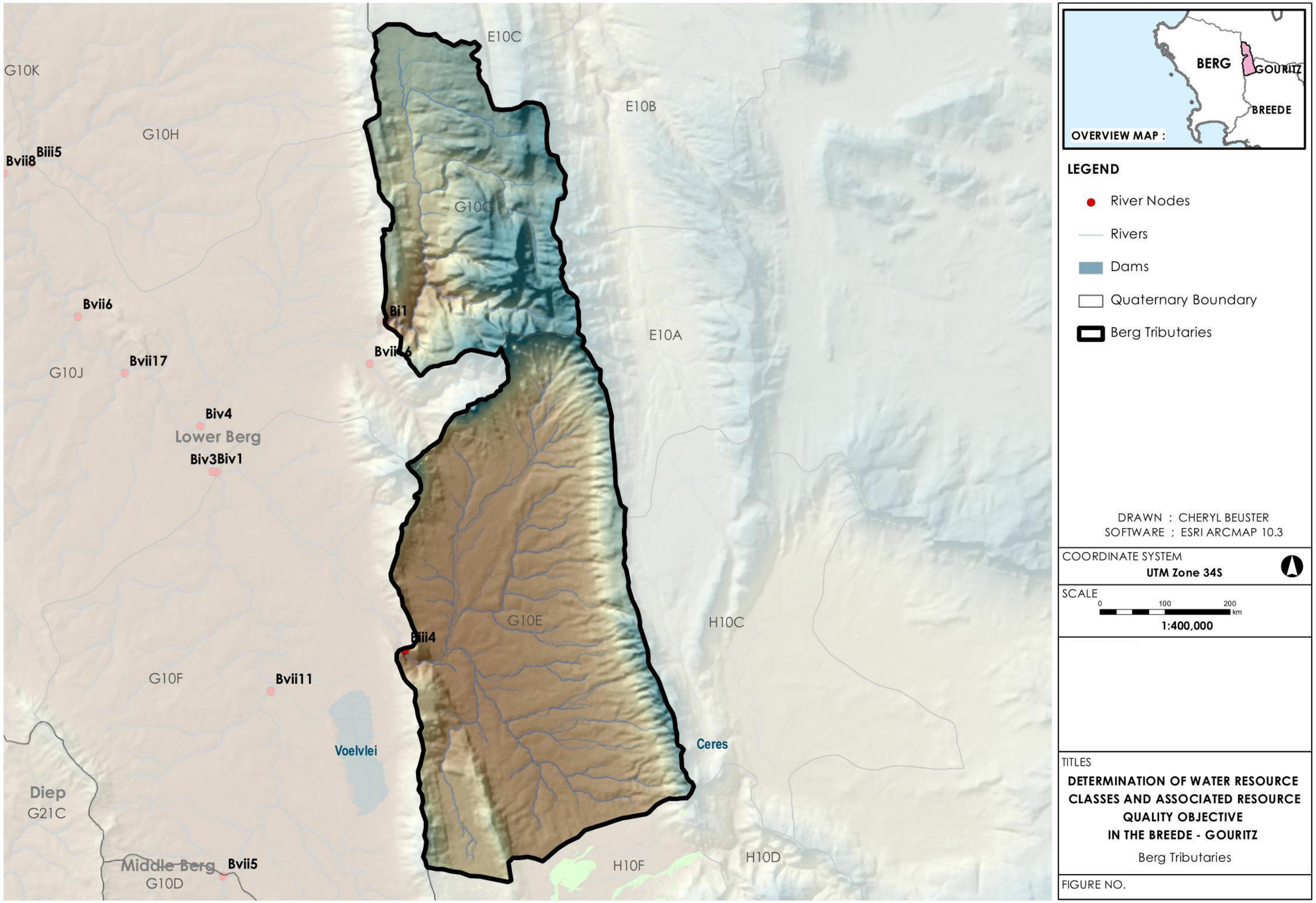
		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	**IUA**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**
G1H008Q01	C5														
G1H009Q01	C5														
G1H010Q01	C5														
G1H012Q01	C5														
G1H021Q01	C5														
G1H028Q01	C5														
KBERG TULBAGH	C5														
EDELWEIZZ	C5														
LA PLAISA	C5														
RIOOL RIV	C5														
EILANDPLA	C5														
OEWERBRUG	C5														
RIOOLPLAA	C5														

Note: 50 = median or 50th percentile, 95 = 95th percentile. Categories: Blue = Ideal, Green = Acceptable, Yellow = Tolerable, and Red = Unacceptable, Blank = No data

Ecology

All the rivers of the Berg Tributaries IUA are located in the Southern Coastal Belt and flow perennially. The small rivers may be steep Transitional or lower-lying Lower Foothills that are of Very High Ecological Importance and Sensitivity. The ecological condition of the Klein Berg River has remained the same 1999-2014, being moderately modified (C-category), while the upper reaches of the Vier-en-Twintig River have improved from being slightly to un-modified (B to an A-category). The reasons for the condition assessment include varied river condition, some in relatively good condition, others highly modified; where poor, many small farm dams with minimal impact on high flows, moderate impacts on low flows; poor water quality (odour), agricultural return flows, high iron content; rivers channelized where cultivation occurs, some deeply incised; and wholesale removal of riparian vegetation, exotic plants present. There are two FEPAs, one on the upper Vier-en-Twintig River and tributaries, and another on the Watervals River. Examples of the kinds of rivers in the Middle Berg are shown in Figure 5.3.

Figure 5.3. Rivers typical of Middle Berg; Klein-Berg G10E-8457 (left) and Boontjies G10E-8616 (right).



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.6 IUA D6: Eerste

Socio-economics and ecosystem services

There are just under 14 000 ha of irrigated and dryland crops in the Eerste IUA with wine grapes being the principal crop. Gross economic output of water-affected activities was estimated to be R1 234 million in 2015 with irrigated fruit and tourism accounting for most of this. The population is approximately 135 000 people and 36 000 households of which less than 0.1% are dependent upon river water

Water resources

The Eerste IUA is underlain predominantly by Malmesbury Group and Cape Granite Suite plutons. Rocks of the TMG suite outcrop to the west and form mountains in the east. The Peninsula Aquifer is unconfined and due to its geological setting stored groundwater volumes are low and recharge decants as mountain streams. There are no long term water level or water quality monitoring locations within this GRU.

Water quality in the upper reaches of the Eerste River is good but it deteriorates in a downstream direction as a result of runoff from formal housing and high density settlements in Stellenbosch area as well as agricultural impacts. Concerns have been expressed about the impacts of agrochemicals on affected streams. Microbial pollution has also been identified as a major concern in areas where dense settlements are located. Britz et al, (2013) found the microbial quality in the Plankenburg and Eerste Rivers to be unacceptable and not meeting WHO and DWA guidelines for safe irrigation. Monitoring indicated especially high concentrations of faecal indicator organisms in the Plankenburg, and to a lesser extent, the Eerste River. There was is consumed without further processing. They concluded that the sources of continuously high level of microbial contamination to be faecal matter from poorly serviced informal settlements. These conclusions confirm the research undertaken by Barnes and Taylor (2004) on microbial contamination of surface waters for irrigation around the Stellenbosch area. Thomas et al. (2010) modelled non-point source pollution from different land-uses in the Kuils and Eerste River and concluded that vineyards contributed over 40% of the entire pollution load followed by industrial areas, residential areas, and open barren lands.

Table 5-6. Present day "fitness for use" categories for selected water quality variables at selected water quality sampling points in the Lourens Eerste IUA (D6).

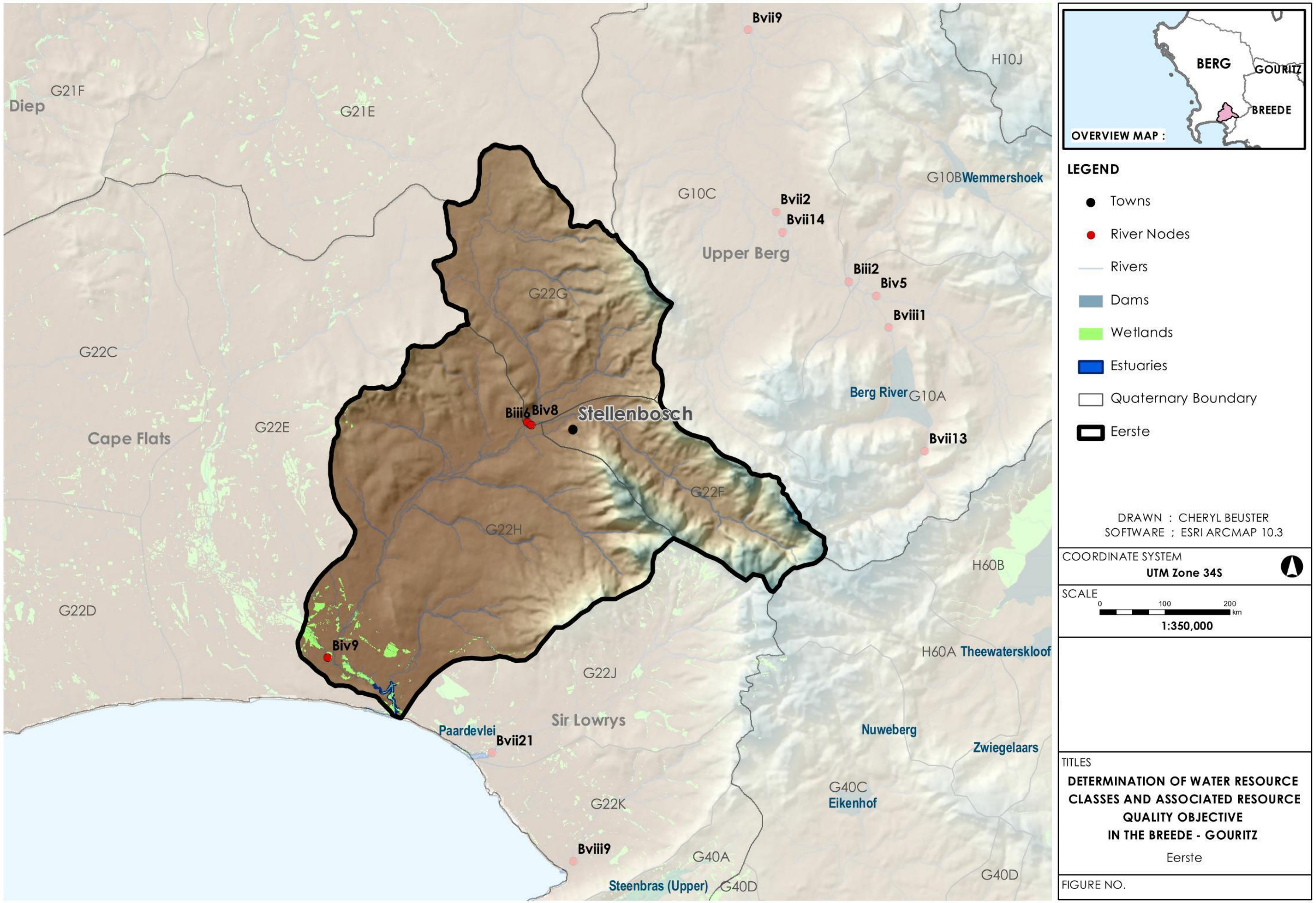
			Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	**IUA**		**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**
G2H015Q01	D6															
G2H020Q01	D6															
G2H038Q01	D6															
G2H039Q01	D6															
G4R001Q01	D6															
G2H037Q01	D6															
ZANDVLIET	D6															
UNDER KAY	D6															
ER720B2	D6															
B0720A1	D6															
B0720B1	D6															
LOURENS	D6															
SLOWRY	D6															
KR720A	D6															
KR720A1	D6															
KR720B	D6															
PR720A	D6															
PR720B	D6															

			Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	**IUA**		**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**
PR720C	D6															
VR720A	D6															
VR720B	D6															
VR720C	D6															
ER720A1	D6															
ER720B	D6															
ER720D	D6															
ER720E	D6															
ER720F	D6															
DIEP ODP	D6															
BL720A	D6															

Note: 50 = median or 50^{th} percentile, 95 = 95^{th} percentile. Categories: Blue = Ideal, Green = Acceptable, Yellow = Tolerable, and Red = Unacceptable, Blank = No data

Ecology

The rivers in the Eerste IUA are located in the Southern Coastal Belt and flow perennially. The rivers are of varying slope, there being, Mountain Streams, Upper and Lower Foothills, which are of High or Very High Ecological Importance and Sensitivity. The Ecological Condition 2014 has either stayed the same or dropped one category since 1999, most of the rivers being largely modified (D-category). The reasons for the condition assessment include numerous small farm dams and flow regulation by large dams upstream; urban and agricultural runoff, sewage effluent; clearing for fields, channel manipulation, re-routing of rivers, infilling of channels and riparian wetlands, canalisation and channelization; and cultivation along river banks, livestock, extensive removal of riparian vegetation, invasion by woody exotic plants. There is a FEPA, along the Jonkershoek River, supported by an Upstream conservation area.



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.7 IUA D7: Sir Lowry's

Socio-economics and ecosystem services

There are just over 1 500 ha of irrigated and dryland crops in the Sir Lowry's IUA with wine grapes being the principal crop. Gross economic output of water-affected activities was estimated to be R493 million in 2015 with irrigated fruit and tourism accounting for most of this. The population is approximately 189 000 people and 66 000 households of which less than 1% are dependent upon river water.

Water resources

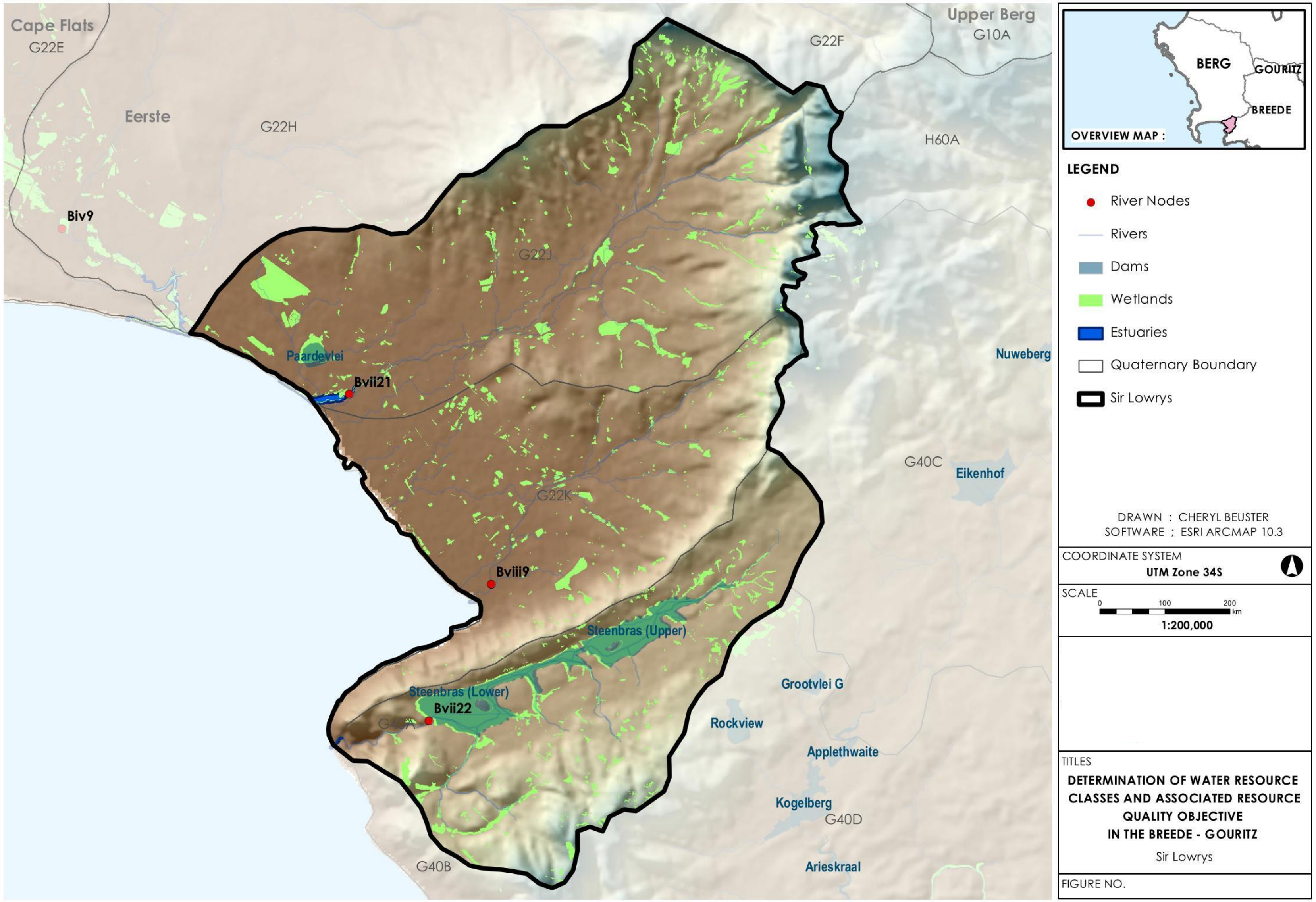
The Sir Lowry's IUA is underlain predominantly by Malmesbury Group and Cape Granite Suite plutons. Rocks of the TMG suite form Stellenbosch and Jonkershoek mountains in the east. The Peninsula Aquifer is unconfined and due to its geological setting stored groundwater volumes are low and recharge decants as mountain streams. In particular the Lourens River originates in the Peninsula formation. In the basement formations, groundwater flow is mainly restricted to weathered zones or granite scree slopes. There are no long term water level or water quality monitoring locations within this GRU.

Water quality in the upper reaches of the Lourens River is good but it deteriorates in a downstream direction as a result of runoff from formal housing and high density settlements in Somerset West, Strand, Gordons Bay, and Sir Lowry's Pass village. High salt and phosphate concentrations in some of the urban streams. The region also sees intensive viticulture and fruit cultivation and concerns have been expressed about the impacts of agrochemicals from affected streams. Bacterial monitoring by the City of Cape Town found that between 2011 and 2013 the quality in the Lourens was consistently high and that about 81% to 83% of the samples complied with intermediate contact recreation (Haskins, 2013). Bacterial quality is excellent in the upper reaches but gradually declines through the urban areas down towards the sea. Day and Clark (2012) concluded that although there was some deterioration in water quality with distance downstream in the Lourens River, there was an improvement in water quality with time. They stated that water quality in the Lourens River appeared to be less impacted than in many of the other urban rivers in the Cape Town metropole. Day and Clark (2012) found that the Sir Lowry's River was moderately impaired in the upper reaches as a result of agricultural impacts. However, downstream of Sir Lowry's Pass Village polluted runoff from poorly serviced formal and informal residential areas had a major impact on water quality. Impacts include high levels of accumulation of litter and sediment in the channels and bank and bed erosion. At the Gordon's Bay WWTW the river is diverted through the WWTW after which the water and treated effluent is conveyed to the sea within a concrete lined canal.

Apart from the Steenbras River, situated in the Cape Fold Mountains, all the rivers in the Sir Lowry's IUA are located in the Southern Coastal Belt and flow perennially. The rivers are of varying slope, there being, Mountain Streams, Upper and Lower Foothills, which are of High or Very High Ecological Importance and Sensitivity. The ecological condition 2014 has either stayed the same or dropped one category since 1999, most of the rivers being largely modified (D-category). The reasons for the condition assessment include numerous small farm dams and flow regulation by large dams upstream; urban and agricultural runoff, sewage effluent; clearing for fields, channel manipulation, re-routing of rivers, infilling of channels and riparian wetlands, canalisation and channelization; and cultivation along river banks, livestock, extensive removal of riparian vegetation, invasion by woody exotic plants.

There is a FEPA along the Steenbras River. There are also two Fish Support Areas, along the Lourens and Sir Lowry's Pass Rivers.

Paardevlei lies on the site of a natural, shallow, seasonal vlei. It lies within the Southern Folded Mountains WRU4 and has been impacted by various changes in use over the years, particularly related to fishing. In recent years it has had several rehabilitation efforts aimed at reinstating indigenous biota (Brown and Magoba, 2009). The surrounding area has been identified for significant mixed use developments.



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.8 IUA D8: Upper Berg

Socio-economics and ecosystem services

There are almost 10 000 ha of irrigated and dryland crops in the Upper Berg IUA with stone fruit and wine grapes being the principal crops. Gross economic output of water affected activities was estimated to be R1 347 million in 2015 with irrigated fruit representing more than half of this. The population of the IUA is approximately 24 000 people and 7 000 households of which less than 1% are dependent upon river water.

Water resources

The Table Mountain Group outcrops in this area, with younger Cenzoic sediments infilling valleys. Rainfall and direct recharge is high in the mountainous areas, with the TMG being dominated by outcrop of Peninsula Formation, forming unconfined aquifer overlying basement. The TMG generates discharge to mountain streams and rivers and several perennial rivers (including the Berg River) have their source in the Drakenstein and Franschhoek Mountains south of Franschhoek. Alluvial sediments of the Sandveld Group are well developed around the berg River as far as Paarl, and are likely to receive recharge from TMG when in connection and discharge to the Berg River. Groundwater makes up 13% of the total water supply to Franschhoek & Groendal, La Motte, Wemmershoek, and Roberstvlei.

Water quality in the upper Berg IUA is good although some concerns have been expressed by water quality in the Franschhoek River (G1H003Q01) which is situated downstream of the Franschhoek WWTW, some informal settlements and Stiebeuel River which is affected by runoff from dense settlements at Franschhoek (Petersen et al., 2008). The Franschhoek WWTW has been decommissioned and does not affect the river anymore. Wastewater is now treated at the new Wemmershoek WWTW which would only impact the Berg River if there is a plant failure. The Berg River Improvement Plan (Western Cape Government, 2012) was developed in 2012 which included upgrading the Langrug and Klein Mooiwater informal settlements to reduce E coli and waste loads to receiving rivers. Anecdotal information is that initial upgrades is having a positive impact on water quality in the Franschhoek River.

Table 5-7. Present day "fitness for use" categories for selected water quality variables at selected water quality sampling points in the Upper Berg IUA (D8).

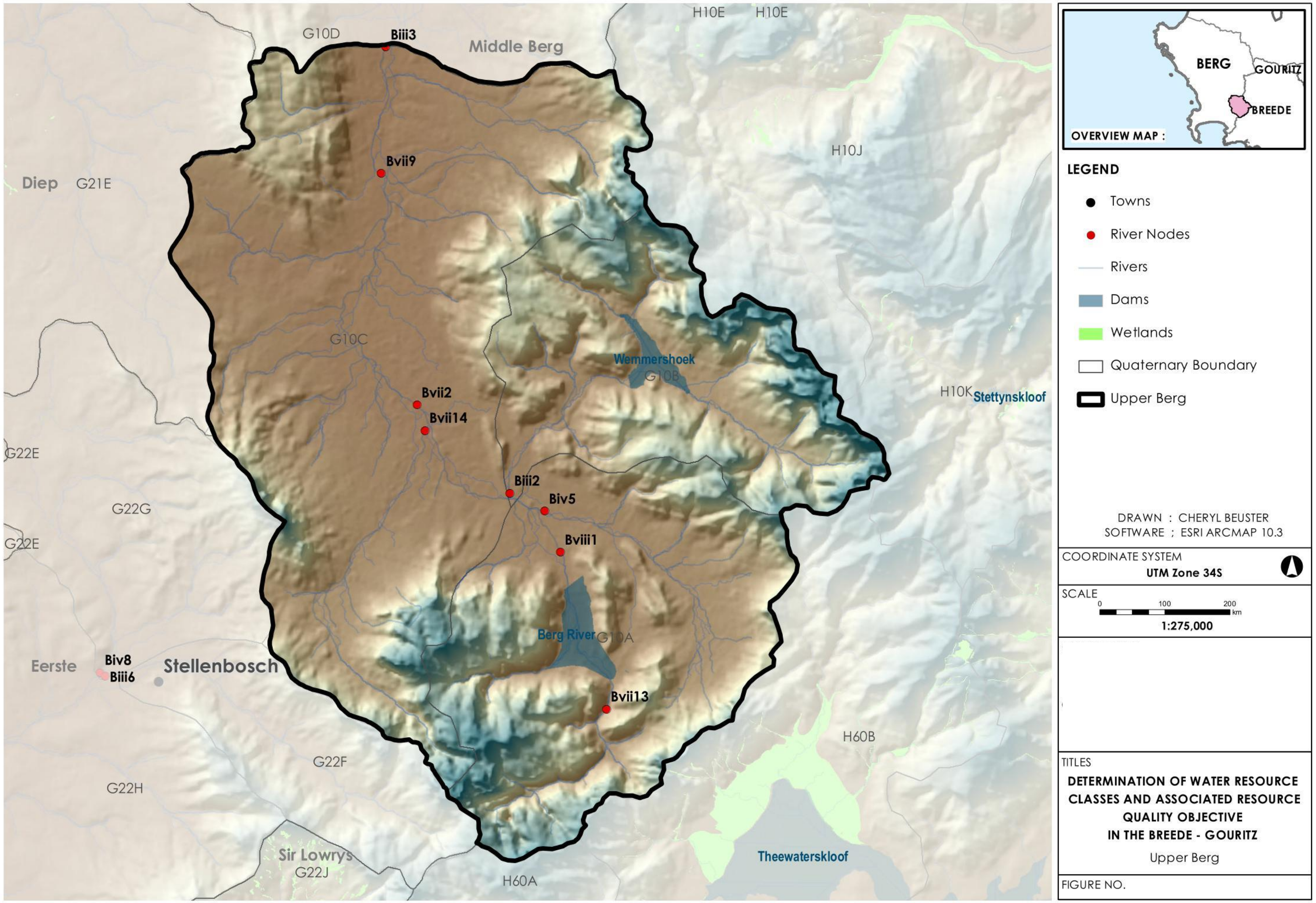
		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	**IUA**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**
G1H003Q01	D7	Blue	Green	Blue	Blue	Blue	Green	Blue	Yellow	Blue	Green	Red	Red	Blue	Blue
G1H004Q01	D7	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green	Blue	Blue
G1H019Q01	D7	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
G1H020Q01	D7	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green	Blue	Blue
G1H038Q01	D7	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
G1H064Q01	D7	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green	Blue	Blue
G1R002Q01	D7	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
FRANSCHHOEK	D7									Blue	Blue				
DIEP ODPB	D7									Blue	Blue				

Note: 50 = median or 50th percentile, 95 = 95th percentile. Categories: Blue = Ideal, Green = Acceptable, Yellow = Tolerable, and Red = Unacceptable, Blank = No data

Ecology

Apart from the Berg River, upstream of the Berg River dam located in the Cape Fold Mountains, all the rivers in the Upper Berg IUA are located in the Southern Coastal Belt and flow perennially. The small rivers are generally steep, comprising Upper and Lower Foothills of Very High or High Ecological Importance and Sensitivity. The 2014 ecological condition of most rivers is the same as at 1999, being largely modified, but there have been some improvements, probably due to clearing of exotic woody plants, on the reaches of the Upper Berg River and on the Dwars River, now moderately modified (C-category). The reasons for the condition assessment include varied in condition, upstream of the Berg River dam the Berg River is natural, downstream and elsewhere on tributaries conditions are worse; several farm dams, severe impacts on low flows by several large dams, moderate impacts on high flows; pollution impacts from urban and agricultural runoff, WWTW, salinity a problem in lower reaches, organic pollution a problem downstream of Paarl and Wellington; extensive infilling of channels, levees in places, urban construction, erosion and incision of channel banks, channel manipulation; and cultivation along river banks, wholesale removal of riparian vegetation, presence of exotic woody vegetation. The Upper Berg, up to EWR site 1 just downstream of the Berg River dam, is a FEPA, while the Franschhoek, Wemmershoek and Hugos Rivers are Fish Support Areas. The Olifants and Dwars Rivers are targets for Phase2 FEPAs. Examples of the kinds of rivers in the Upper Berg are shown in Figure 5.4.

Figure 5.4. Rivers typical of Upper Berg; Franschhoek G10A-9153 (left) and Berg G10A-9172 (right).



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.9 IUA D9: Middle Berg

Socio-economics and ecosystem services

There are just over 34 000 ha of irrigated and dryland crops in the Middle Berg IUA with grains, planted pasture, wine grapes and stone fruit being the principal crops. Gross economic output of water affected activities was estimated to be R1 499 million in 2015 with irrigated crops representing most of this. The population of the IUA is approximately 211 000 people and 50 000 households of which less than 1% are dependent upon river water.

Water resources

The middle Berg comprises sequences of basements rocks dominating outcrop in the undulating areas. The groundwater flow is focused in weathered zones and little regional flow can be expected. Several tributaries to the Berg River traverse the basement outcrops, and the groundwater will discharge to these.

Water quality in the middle Berg River is affected by effluent discharges from Paarl WWTW and Wellington WWTW, Drakenstein Prison, Paardeberg Prison and smaller treatment works at Bienne Donne and Pearl Valley. There are a number of diffuse sources which affect the quality of middle Berg River. These include urban stormwater runoff at Paarl and Wellington, as well as runoff from dense settlements associated with these two towns. Water quality is also affected by agricultural return flow (salinity) and agrochemical associated with it, as well as runoff from piggeries and feedlots in the IUA. The overall result is that water quality deteriorates in a downstream direction although by the time it reaches Hermon (G1H036Q01) only high phosphate concentrations are evident.

Microbial water quality is a particular concern in the middle Berg River especially in the Drakenstein municipal area where a clear spatial trend in was observed in E. coli counts (Drakenstein Municipality, 2004, Rossouw and Versveld, 2009, Rossouw, 2011). The counts were fairly low up to about the middle of Paarl after which there was a large increase in the E. coli counts. It appeared that the Mbekweni area was a key source of bacterial pollution. The bacterial quality in the Mbekweni and Wellington area was high but it appeared that the quality was not deteriorating further because control measures were starting to have an effect (Rossouw & Versveld, 2009). The main sources of contamination was grey water disposal into the stormwater network in high density settlements (Drakenstein Municipality, 2004). Pollution hotspots downstream of Wellington contribute from time to time to poor microbial quality in the middle Berg IUA (Rossouw, 2014).

Jackson et al. (2007) investigated metal contamination of the Berg River downstream of Paarl and found elevated concentrations of especially Al and Fe which they ascribed to leaching of metals into the river from waste and household products associated with the informal settlement and the subsequent settling on sediment. Al and Fe were consistently above the recommended guidelines as stipulated by the Department of Water and Sanitation.

Suspended sediment concentrations are not routinely monitored by DWS. During the 2-year Berg River Baseline Monitoring Programme that was undertaken prior to the construction of Berg River Dam (Ractliffe, 2007), suspended sediment data was collected during the winter months of 2003/04. This data indicated an increase in TSS concentrations from a median of 14 upstream of Paarl, to 13.8 mg/l in Paarl, to 24.8 mg/l at Hermon, to 53.4 mg/l at Drie Heuwels. TSS was strongly correlated to flow, as flow increase so does the TSS load (Ractliffe, 2007).

Table 5-8. Present day "fitness for use" categories for selected water quality variables at selected river water quality sampling points in the Middle Berg IUA (D9).

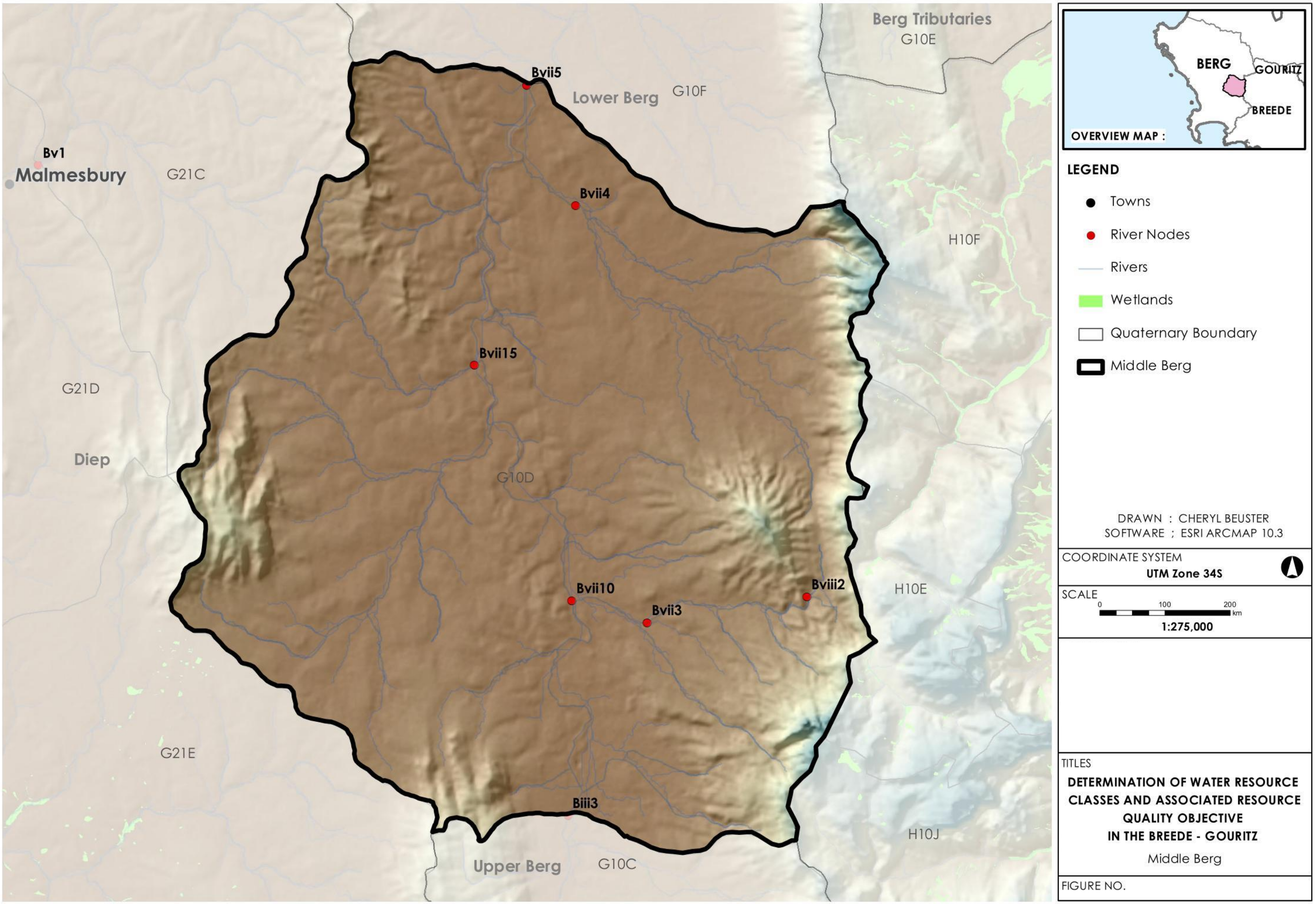
		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	**IUA**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**
BERG KERSF	D8	Blue	Blue	Blue	Blue	Red	Red	Blue	Blue	Blue	Red	Green	Red	Blue	Blue
G1H007Q01	D8	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
G1H036Q01	D8	Blue	Green	Blue	Blue	Blue	Green	Blue	Blue	Blue	Blue	Yellow	Red	Blue	Blue
G1H039Q01	D8	Red	Red	Red	Red	Red	Red	Blue	Green	Green	Yellow	Yellow	Red	Green	Red
G1H041Q01	D8	Green	Green	Blue	Blue	Blue	Green	Blue	Blue	Blue	Blue	Blue	Red	Blue	Blue
BERG DS PWWTW	D8									Blue	Blue				
BERG WWWTW	D8									Blue	Blue				
BERG IMBEQ	D8									Blue	Blue				

Note: 50 = median or 50th percentile, 95 = 95th percentile. Categories: Blue = Ideal, Green = Acceptable, Yellow = Tolerable, and Red = Unacceptable, Blank = No data

Ecology

Apart from the Kromme River, situated in the Cape Fold Mountains, all the rivers in the Middle Berg IUA are located in the Southern Coastal Belt and flow perennially. The small tributaries are steep or low-lying being either Upper or Lower Foothills, while the Berg River is a low-lying Lower Foothill or Lowland; all are of Very High or High Ecological Importance and Sensitivity. The ecological condition of the rivers 2014 has not changed since 1999 being largely modified (D-category). The reasons for the condition assessment include high abstraction for large dams, moderate impacts on high flows, very high impacts on low flows; pollution impacts from agricultural return flows, WWTW, livestock access; berms created along channels, significant infilling of floodplains, creation of levees, some parts channelized; and few indigenous riparian vegetation, clearing of channel banks for cultivation, woody exotic plants present. The only FEPA is the Kromme River, targeted as a Phase2 FEPA. Examples of the kinds of rivers in the Middle Berg are shown in Figure 5.5.

Figure 5.5. Rivers typical of Middle Berg; Kompanjies G10D-8803 (left) and Kromme G10D-9828 (right).



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.10 IUA D10: Diep

Socio-economics and ecosystem services

There are just over 76 000 ha of irrigated and dryland crops in the Diep IUA with grains, planted pasture and wine grapes being the principal crops. Gross economic output of water affected activities was estimated to be R1 332 million in 2015 with irrigated fruit representing more than half of this. The population of the IUA is approximately 402 000 people and 131 000 households of which less than 1% are dependent upon river water.

Water resources

The IUA is underlain predominantly by Malmesbury Group intruded by Cape Granite Suite plutons. Groundwater flow is mainly restricted to weathered zones or granite scree slopes. Extensive use of the basement aquifers and the existence of the Malmesbury Hot Spring that deep facture systems exist and are capable of reasonable yields. Malmesbury and Abbotsdale receive a minor portion of supply (1%) from groundwater. Groundwater use is sporadic, with the exception of the Dassenberg area where a concentration of registered boreholes are noted.

Elevated salinity is a concern in the Diep River and high concentrations are evident at Malmesbury (G2H012Q01) as well as further downstream at Adderley (upstream of the N7 Bridge) at G2H042Q01. The elevated salinity is partly due to the saline nature of the geological formations (Malmesbury shales) and agricultural activities which mobilise salts from the soils. Monitoring by the City of Cape Town in the upper reaches of the Diep River confirms that the Mosselbank and Diep Rivers are naturally brackish (Day & Clark, 2012). High phosphate concentrations also occur in the IUA, especially in the Diep River where effluent discharges are often the only flow during the low flow, dry season. Discharges from the Kraaifontein and Fisantekraal WWTWs into the Mosselbank, and Malmesbury and Potsdam WWTW into the Diep River contribute to the elevated nutrient concentrations (Day & Clark, 2012).

The Maastricht Canal was plagued by inflows of polluted water with sources likely to include seepage from agricultural areas as well as inflows from leaking sewage and runoff from poorly serviced informal settlements and backyard dwellings in formal settlements such as Fisantekraal (Day and Clark, 2012). Water quality in the Diep River downstream of the Mosselbank confluence is affected by agricultural inputs, including runoff from numerous poultry and other livestock production units, Concerns have been expressed about elevated bacterial counts in the lower Diep River (downstream of the N7 Bridge). Monitoring between 2011 and 2013 indicated that the quality deteriorated over time with 59% of samples complying with the intermediate contact water quality guidelines in 2011 compared to only 36% in 2013 (Haskins, 2012, Haskins, 2015b). Improved operations at the Potsdam WWTW have resulted in an improving nutrient concentrations downstream of the WWTW and the Milnerton Lagoon (Haskins, 2015b).

Table 5-9. Present day "fitness for use" categories for selected water quality variables at selected river water quality sampling points in the Diep IUA (D10).

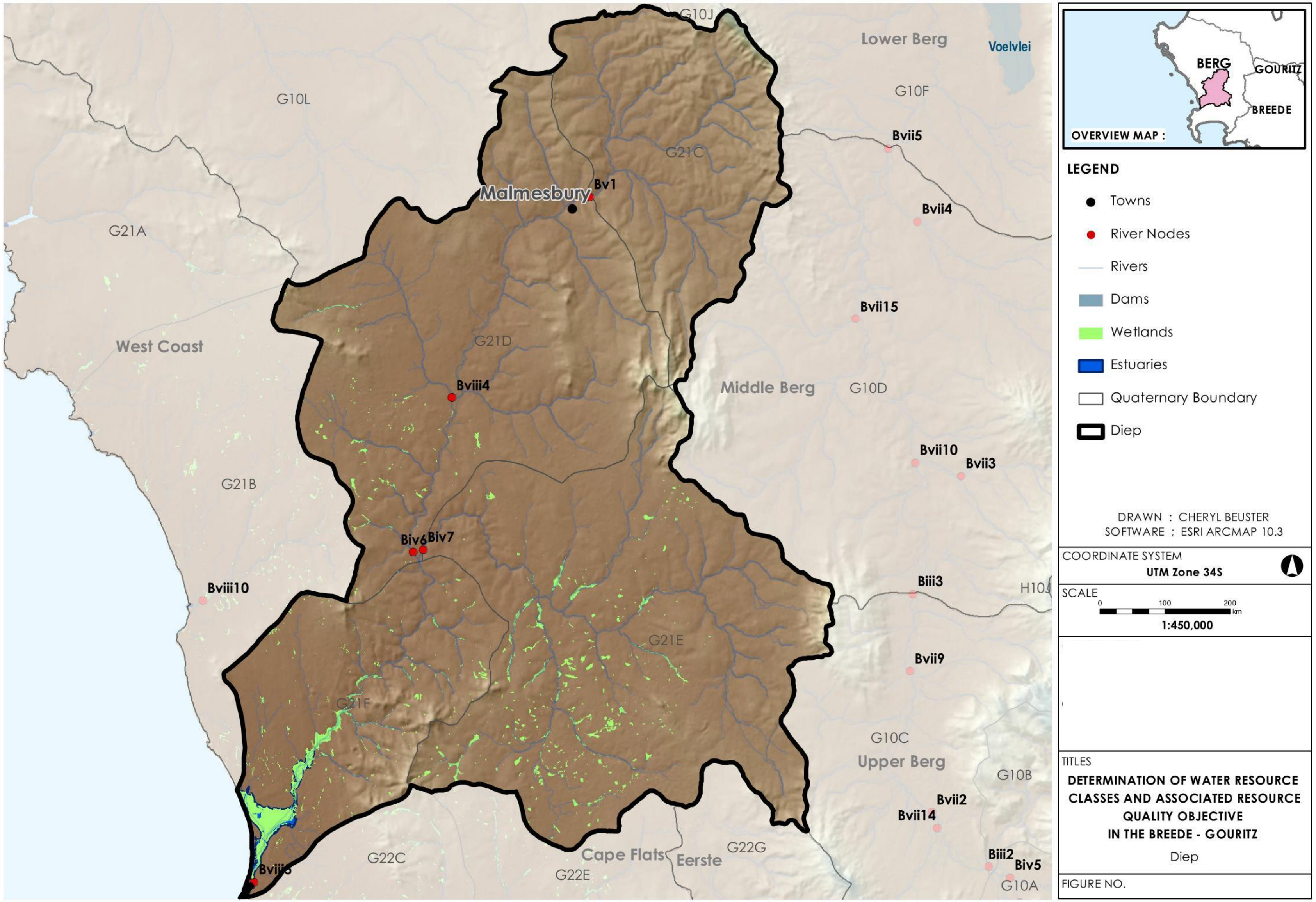
		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	**IUA**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**
G2H042Q01	D9	Red	Red	Red	Red	Red	Red	Blue	Green	Green	Green	Red	Red	Green	Green
G2H012Q01	D9	Red	Red	Red	Red	Red	Red	Blue	Green	Green	Yellow	Green	Red	Green	Green
DIEP DS MWWTW	D9									Blue	Blue				
MR720A	D9					Yellow	Red	Blue	Blue	Blue	Green	Red	Red		
MR720B	D9					Red	Red	Blue	Green	Blue	Red	Red	Red		
MR720D	D9					Red	Red	Blue	Green	Blue	Red	Red	Red		
MR720G	D9					Red	Red	Blue	Blue	Blue	Green	Red	Red		
MR720H	D9					Red	Red	Blue	Blue	Blue	Green	Red	Red		
MR720L	D9					Yellow	Red	Blue	Blue	Blue	Green	Red	Red		
DIEP PBERG	D9					Red	Red	Blue	Blue	Green	Green	Red	Red		
DIEP US MAL	D9					Red	Red	Blue	Green	Green	Yellow	Red	Red		
DIEP IN MAL	D9					Red	Red	Blue	Green	Green	Green	Red	Red		
DIEP ABBOT	D9					Red	Red	Blue	Yellow	Blue	Red	Red	Red		
DIEP KALBAS	D9					Red	Red	Blue	Blue	Blue	Green	Red	Red		
DIEP MBANK	D9					Red	Red	Blue	Blue	Blue	Blue	Red	Red		
DIEP GOED	D9					Red	Red	Blue	Blue	Blue	Green	Red	Red		
DIEP N7	D9					Red	Red	Blue	Blue	Blue	Green	Red	Red		
SWART GROEN	D9					Red	Red	Blue	Blue	Blue	Green	Blue	Yellow		
DIEP TRIB	D9					Red	Red	Blue	Blue	Blue	Green	Red	Red		
DIEP TABVIEW	D9					Red	Red	Blue	Blue	Blue	Red	Red	Red		

Note: 50 = median or 50th percentile, 95 = 95th percentile. Categories: Blue = Ideal, Green = Acceptable, Yellow = Tolerable, and Red = Unacceptable, Blank = No data

Ecology

All the rivers in the Diep IUA are located in the Southern Coastal Belt, and flow perennially. The small rivers are low-lying, comprising Lower Foothills and Lowlands, which are considered to be of High Ecological Importance and Sensitivity. The EC 2014 is much the same as at 1999 being generally poor and largely modified (D-category). The reasons for the condition assessment include high abstraction, particularly in the summer months, and many small farm dams, with low impacts on high flows and high impacts on low flows; poor water quality due to urban and agricultural return flows, discharge from WWTW; infilling of channels and large scale manipulation of riparian wetlands, highly modified bed and banks, some canalisation; and habitat diversity reduced by cultivation and urban spread. Despite the poor condition of the rivers there are a few Phase2 FEPAs, supported by Upstream conservation areas and Fish Support Areas.

This IUA contains the Rietvlei-Diep estuary, a medium-large, temporarily open estuary that includes Rietvlei, and adjacent seasonal wetlands and pans within the estuary functional zone. Present day flows are dominated by treated waste water and there are challenges experienced with runoff from low coast housing and informal settlements which is often contaminated with untreated sewage. The lower portion of the estuary (Milnerton Lagoon area) is in a degraded state of health despite lying within the Table Bay Nature Reserve. Other portions of the estuary e.g. the deep water lake and seasonal plans of Rietvlei and Flamingovlei are however in better condition.



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.11 IUA E11: Peninsula

Socio-economics and ecosystem services

There are just over 50 ha of irrigated and dryland crops in the Peninsula IUA which mainly consist of wine grapes. Gross economic output of water affected activities was estimated to be R3 375 million in 2015 with tourism representing the vast majority of this. The population of the IUA is approximately 110 000 people and 36 000 households of which less than 1% are dependent upon river water.

Water resources

The Cape Peninsula is dominated by the presence of the Table Mountain Group which generates rugged areas mostly within the Table Mountain National Park. Recharge is mainly from rainfall, but may occur from cloud moisture. Although recharge on the Peninsula is significantly higher than surroundings its geological setting means that aquifer storage is low and recharge leads to discharge within a short time frame as the aquifer decants as streams cascading off steep cliffs. Some of these are permanent seeps, other mountain steams and wetlands may be localized groundwater flow systems. Various springs emanating from scree aquifers cumulatively discharge over 100L/s to the City Bowl and Newlands area combined (GEOSS, 2015). Cenzoic sands in the Fish Hoek Valley have high water tables supporting wetlands and streams around Fish Hoek and Noordhoek.

Water quality in the Peninsula streams are good in the headwaters of streams but the middle and lower reaches are highly impacted by urban stormwater runoff and runoff from dense settlements. This is often characterised by elevated salinity, elevated phosphate concentrations, and high bacterial counts. Coastal streams are often affected by treated wastewater effluents. Water quality in the upper reaches of the Disa River is good but in the lower reaches there are concerns about dumping and vandalism of low-flow diversion structures designed to divert polluted stormwater from Imizamo Yethu into the sewage works (City of Cape Town, 2015). The result is a significant deterioration in quality over the past two decades, (Day and Clark, 2012). In the Noordhoek catchments significant impacts were recorded to water quality in Wildevoelvlei indicating critical changes in water quality at this site, when compared to natural conditions. Wildevoelvlei was subject to a sustained blue-green algal bloom as a result of phosphorus-enriched effluent discharges from the WWTW being assumed to be the major contributor to poor water quality (Day and Clark, 1012).

Table 5-10. Present day "fitness for use" categories for selected water quality variables at selected river water quality sampling points in the Peninsula IUA (E11).

		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	**IUA**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**
G203/12A2	E10	Red	Red	Red	Red	Red	Red	Blue	Blue	Yellow	Yellow	Red	Red	Green	Green
G203/13A	E10	Green	Green	Green	Green	Green	Green	Blue	Blue	Blue	Blue	Blue	Blue	Green	Green
G203/18A1	E10	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
G203/19A1	E10	Green	Green	Green	Green	Green	Green	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
G203/01A1	E10	Yellow	Yellow	Green	Green	Yellow	Yellow	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
G203/04A1	E10	Red	Red	Blue	Blue	Red	Red	Blue	Blue	Blue	Blue	Blue	Blue	Green	Green
G203/05A1	E10	Yellow	Yellow	Green	Green	Yellow	Yellow	Blue	Blue	Blue	Blue	Red	Red	Blue	Blue
ELSE	E10					Yellow	Red	Blue	Blue	Blue	Green	Blue	Blue		
SILVERM	E10					Green	Red	Blue	Blue	Blue	Blue	Blue	Red		
HOUTBAY	E10					Green	Yellow	Blue	Blue	Blue	Blue	Red	Red		

Note: 50 = median or 50th percentile, 95 = 95th percentile. Categories: Blue = Ideal, Green = Acceptable, Yellow = Tolerable, and Red = Unacceptable, Blank = No data

Ecology

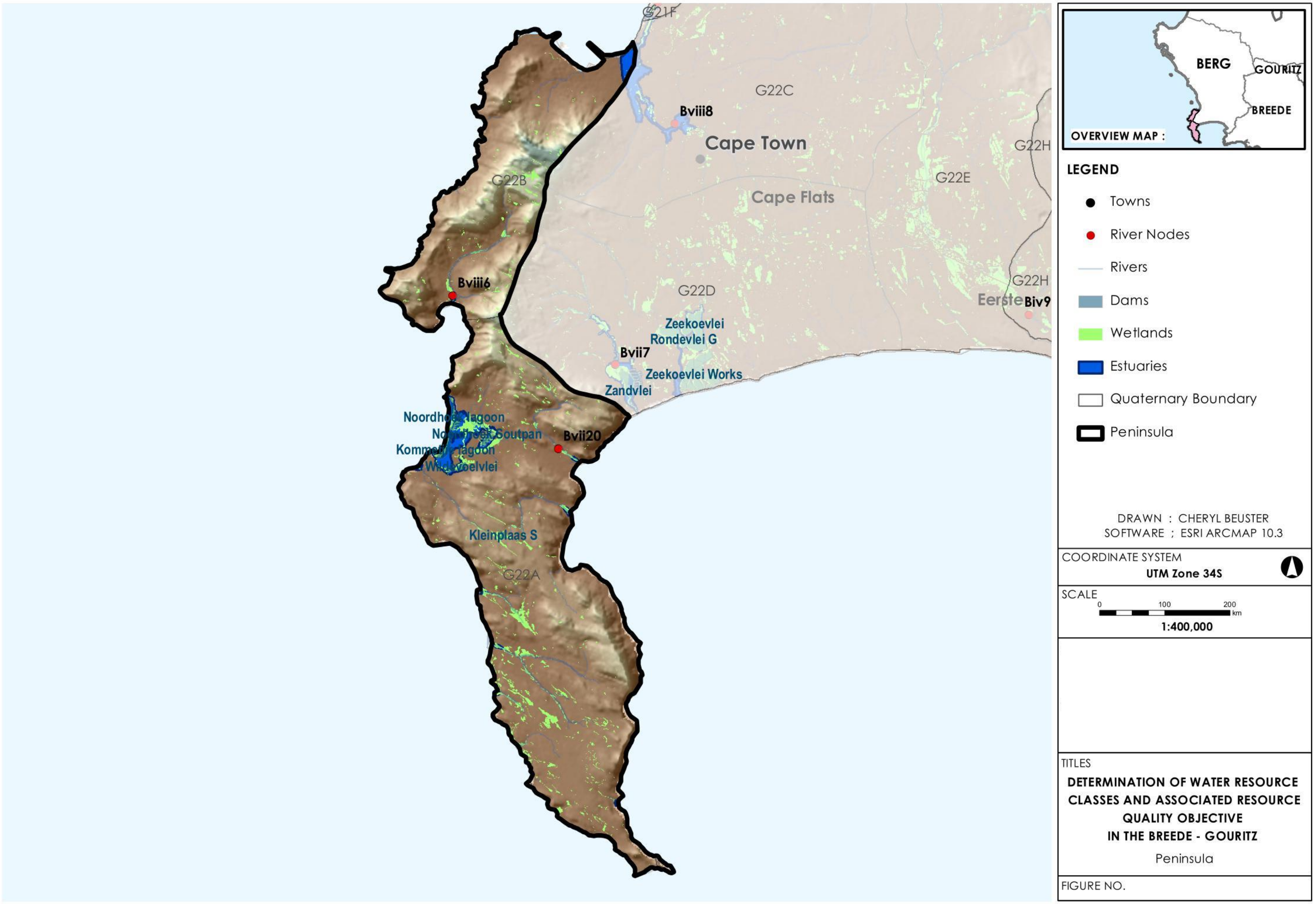
All the rivers in the Peninsula IUA are located in the Cape Fold Mountains, some flow perennially, others are non-perennial. The small rivers are generally steep, comprising Upper and Lower Foothills that are of

High Ecological Importance and Sensitivity. The ecological condition 2014 is much the same as at 1999 being moderately or largely modified (C and D-category). The reasons for the condition assessment include moderate abstraction, some large dams in the mountains which are part of the local water treatment and supply scheme for areas such as Simonstown, Scarborough, Hout Bay, low impacts on high flows, moderate impacts on low flows; fair water quality, some urban runoff; some infilling, bed and banks mostly good, some canalisation; and previously invaded areas are now cleared of exotic woody vegetation. There are two FEPAs, the Silvermine and another un-named coastal river adjacent to the Klaasjagers River, both in good condition and protected by being located in the conservation areas of the Table Mountain National Park. The Hout Bay River is a Fish Support Area, with good condition upper reaches.

This IUA contains Wildevoelvlei, a medium sized temporarily open estuary that is not fed by a river, but rather drains several seasonal wetlands and pans in the Fish Hoek-Noordhoek valley. Present day flows during summer months are almost entirely treated effluent from the WWTW that discharges into the upper Wildevoelvlei. The present ecological health of this estuary is assessed as moderately modified.

Noodhoek Valley consists of many wetlands scattered about between the developed part of the catchment and the beach. Three permanent waterbodies occur in this area: Lake Michelle (developed from former salt pans) and the Wildevoelvleis. These wetlands are of great conservation importance as they provide refuge to various rare plant and animal species. The Noordhoek Salt Pan (Lake Michelle) has an EIS of 5.9 according to Malan et al., (2015).

Along the Southern Peninsula towards Cape Point there are numerous seasonal vleis, seeps and streams, which mostly dry up in Summer (Brown and Magoba, 2009). The waters of this area are usually dark brown and acidic due to the leaching fynbos vegetation. Silvermine River emerges from the Silvermine Valley into the Fish Hoek plain whereby it joins the sea at the Silvermine Estuary. The area at upstream of the Silvermine Dam has a high EIS (5.9) due to the occurrence of rare plant species and amphibians and the area at the lower Silvermine River floodplain has an even higher EIS (7.3) due to the occurrence of red data species (otters) and as it improves water quality amelioration and reduces flooding (Malan et al., 2015). It also has important recreational value.



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

5.12 IUA E12: Cape Flats

Socio-economics and ecosystem services

There are just over 6 500 ha of irrigated and dryland crops in the Cape Flats IUA with wine grapes being the principal crop. Gross economic output of water affected activities was estimated to be R1 520 million in 2015 with tourism representing more than 75% of this. The population of the IUA is approximately 2.9 million people and 813 000 households of which less than 1% are dependent upon river water.

Water resources

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, with surface water and groundwater being considered to be in hydraulic connection (various wetlands across the Cape Flats are likely expressions of the high water table). The effects of urbanisation has significantly altered the Cape Flats aquifer, with runoff being concentrated into modified natural drainage lines and groundwater quality being affected by various sources. Domestic water supply is imported from elsewhere and registered groundwater use is focused on the Philippi agricultural area.

Water quality in the Cape Flats IUA tends to be poor with elevated salinities and nutrient concentrations. The middle and lower reaches of rivers and streams are highly impacted by urban stormwater runoff and runoff from dense settlements. This is often characterised by elevated salinity and elevated phosphate concentrations. Coastal streams are often affected by treated wastewater effluents from a number of WWTW located in the Cape Flats. The Kuils River is also highly affected by effluent discharges from the Bellville WWTW, Scottsdene, Zandvliet and Macassar WWTWs, as well as contaminated urban stormwater runoff and agricultural runoff and associated agrochemicals. Bacterial monitoring by the City of Cape Town found that between 2011 and 2013 only 53% to 35% of samples complied with intermediate contact recreation guidelines posing a health risk to children swimming in the river (Haskins, 2014). Bacterial counts in the Lotus River are very high and exceed the recreational guidelines (Haskins, 2015). The reason was contamination of rivers and stormwater canals with, inter alia, overflows from the sewage reticulation network as a result of blockages and/or the ingress of rainwater during the wet season. In informal areas the disposal of night soil into stormwater drains also contribute to high bacterial counts. Both Zeekoevlei and Rondevlei exhibit symptoms of nutrient enrichment (elevated nutrient and algal concentrations) (Haskins, 2015a). The Salt River catchment is the third largest catchment in the City of Cape Town and incudes the Liesbeek, Black and Elsieskraal Rivers. Day and Clark (2012) found that water quality in the Elsieskraal River was significantly impaired throughout almost all of its reaches with elevated nutrients, low dissolved oxygen (indicative of high organic loads) and high bacterial counts. Water quality in the Black River comprises almost primarily of treated sewage effluent from the Athlone and Borchards Quarry WWTWs characterised by high nutrient concentrations, and low dissolved oxygen concentrations. Concerns have also been expressed about high bacterial counts in the middle and lower reaches of the rivers.

Table 5-11. Present day "fitness for use" categories for selected water quality variables at selected river water quality sampling points in the Cape Flats IUA (E12).

		Chloride		TDS		EC		NO3+NO2-N		pH		PO4-P		SO4	
Station	**IUA**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**	**50**	**95**
KUILS DS BWWTW	E11									Blue	Green				
G204/02A1	E11	Yellow	Yellow	Yellow	Yellow	Red	Red	Blue	Blue	Green	Green	Red	Red	Blue	Blue
SANDVLEI	E11					Red	Red	Blue	Blue	Yellow	Yellow	Red	Red		
SANDVLEI YC	E11					Red	Red	Blue	Blue	Green	Red	Yellow	Red		
SANDVLEI OV	E11					Yellow	Red	Blue	Blue	Blue	Red	Red	Red		
SAND	E11					Yellow	Red	Blue	Blue	Green	Red	Green	Red		
ZEEKO BPD	E11					Red	Red	Blue	Blue	Blue	Yellow	Red	Red		
ZEEKO OUT	E11					Red	Red	Blue	Blue	Yellow	Yellow	Red	Red		
MNANDI SW	E11					Red	Red	Green	Yellow	Blue	Yellow	Red	Red		
MONW PS	E11					Red	Red	Blue	Green	Blue	Red	Red	Red		
BLACK US	E11					Red	Red	Blue	Green	Blue	Blue	Red	Red		
SALT TB	E11					Red	Red	Blue	Green	Blue	Red	Red	Red		
LLOTUS	E11					Yellow	Red	Blue	Blue	Blue	Red	Red	Red		
BLOTUS	E11					Yellow	Red	Blue	Green	Blue	Green	Red	Red		
KEYSERS	E11					Yellow	Yellow	Blue	Blue	Blue	Green	Red	Red		

Note: 50 = median or 50th percentile, 95 = 95th percentile. Categories: Blue = Ideal, Green = Acceptable, Yellow = Tolerable, and Red = Unacceptable, Blank = No data

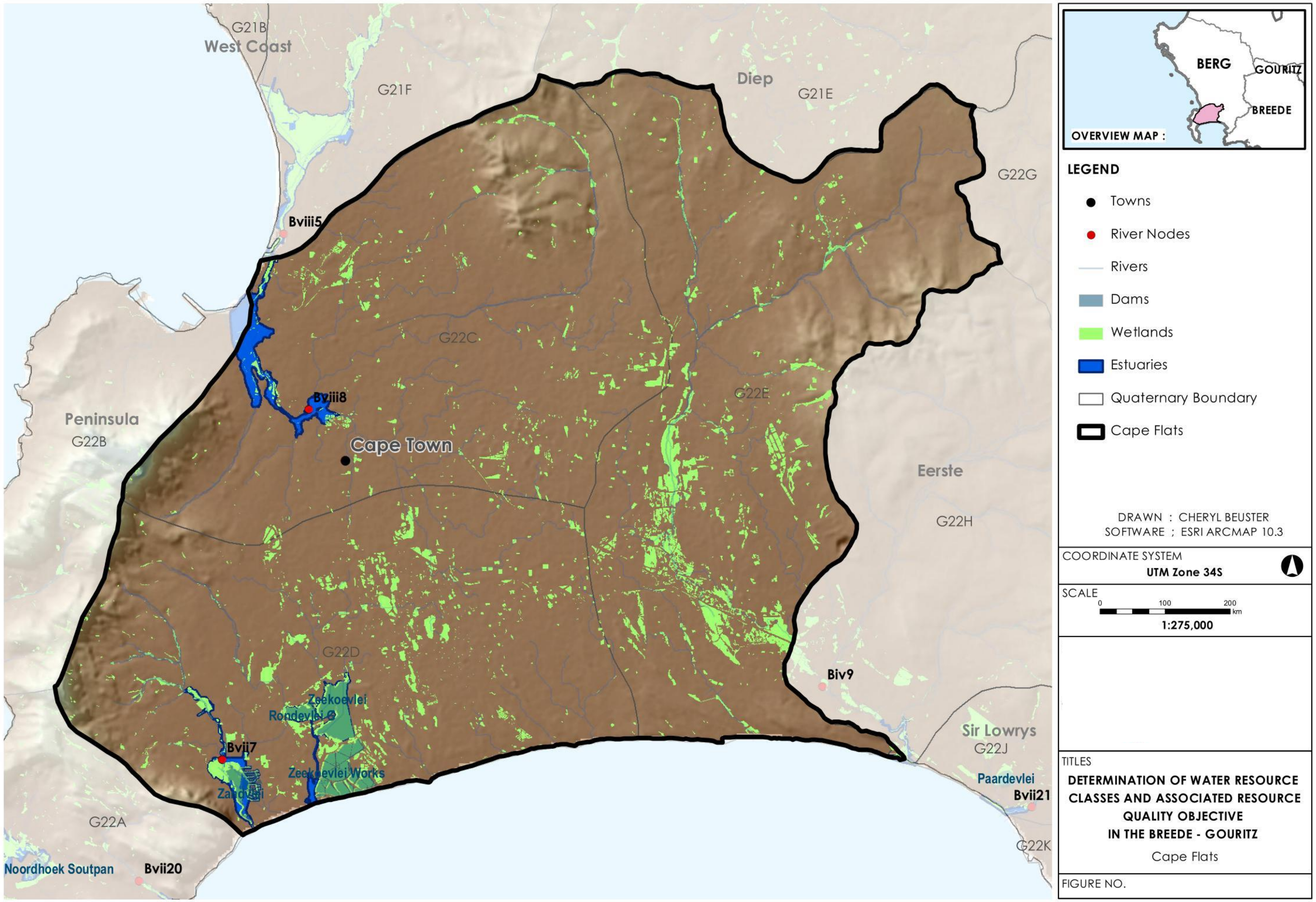
Ecology

The rivers of the Cape Flats IUA are situated in the Cape Fold Mountains or the Southern Coastal Belt, and may be perennial or non-perennial. The small rivers are generally low-lying and considered of Moderate or High Ecological Importance and Sensitivity. The ecological condition 2014 is generally poor, being largely or severely modified (D, E or F-category), the same as at 1999. The reasons for the condition assessment include dominated by an urban setting, apart from higher lying reaches; majority are canalised, have high flood flow runoff, poor dry season flows; high abstraction, very many small farm dams, low impact on high flows, high impact on low flows; high infilling and channelization of most reaches, riparian vegetation absent; and poor water quality due to urban and agricultural return flows, WWTW discharge. Due to the poor condition of the rivers there are few FEPAs, apart from the Fish Support Area of the Liesbeek River, the upper reaches of which are in very good condition.

This IUA contains the temporary open Sand (Zandvlei) and the permanently open Zeekoe estuaries. The Sand estuary is a moderately modified system that is intensively managed by the City of Cape Town and is protected in the Greater Zandvlei Estuary Nature Reserve. The Zeekoe estuary drains Zeekoevlei, although the estuary is now physically separated from the vlei by a weir and wastewater input from the Cape Flats WWTW dominates flows. The Zeekoe estuary is in a degraded state.

Zeekoeivlei is the largest of the Cape Flats wetlands, it is U-shaped with most of the present day surface inflow coming from the north basin via Big and Little Lotus “rivers” and the outflow being from the south basin through the Zeekoe Canal (Brown and Magoba, 2009). Princessvlei is a small, shallow, eutrophic freshwater coastal vlei to the north of Rondevlei (a smaller vlei next to Zeekoevlei). These wetlands (along with the Strandfontein Wastewater Treatment Works) form part of the False Bay Nature Reserve, which was proclaimed as South Africa’s 22nd Ramsar site in 2015. The importance of this area stems from the endemic vegetation type and important bird species. Most of the birds within this wetland system are concentrated at the Strandfontein Wastewater Treatment Works due to the wide range of wetland habitats present and the proximity to the ocean (Wright, 2015). Key bird species are in decline, possibly in response to changes in water level and quality (Wright, 2015). Water hyacinth has also invaded some of the settling ponds, impacting the biodiversity.

The Kuils River in its original state flowed through a flat sandy valley from source until the Cape Flats, where it meandered through a series of “kuils”. In particular the Khayelitsha wetlands have formed as the settlement expanded within the natural wetlands and a large portion of them were bulldozed and flattened (Brown and Magoba, 2009). “New” wetlands have formed as water was displaced and these wetlands form a viable habitat for aquatic animals, for water purification and for the recharge of the Cape Flats Aquifer (Brown and Magoba, 2009).



Document Path: S:\Projects\2016\G112669\mxd\A5\berg_IUA_v2_a5.mxd

6 REFERENCES

Adams, J.B., Bate, G.C. and O'Callaghan, M. 1999. Primary producers. In: Allanson BR and Baird D (eds). *Estuaries of South Africa*. Cambridge University Press, Cambridge, pp 91-117.

Adams, J. B., & Bate, G. C., 1999. Growth and photosynthetic performance of Phragmites australis in estuarine waters: a field and experimental evaluation. Aquatic Botany, 64: 359-367

Adams, J. B. 1994. The importance of freshwater to the survival of estuarine plants. PhD, University of Port Elizabeth, pages 122-134.

Adams, J.B. 2016. Distribution and status of *Zostera capensis* in South African estuaries — A review, South African Journal of Botany http://dx.doi.org/10.1016/j.sajb.2016.07.007.

Adams, J.B. and Riddin, T. 2005. Structure and Function of Intermittently Open estuaries. Part V: Macrophytes. Report submitted to South African Institute of Aquatic Biodiversity on behalf of the Water Research Commission, Project K5/1581 (Freshwater requirements of intermittently open Cape estuaries)

Alley, W. M. and Leake, S. A. 2004. The journey from safe yield to sustainability. Ground Water 42 (1) 12-16.

Anchor Environmental Consultants. 2008. Berg Estuary Management Plan - Situation Assessment Report. Report to CapeNature and the CAPE Estuary Management Programme. 85 pp.

Anchor Environmental Consultants. 2009. Berg Estuary Management Plan. Report to CapeNature and the CAPE Estuary Management Programme. 85 pp.30 pp.

Anchor Environmental Consultants. 2015. The State of Saldanha Bay and Langebaan Lagoon 2015, Technical Report. Report prepared by Anchor Environmental Consultants for the Saldanha Bay Water Quality Forum Trust.

Anchor Environmental Consultants. 2016. The State of Saldanha Bay and Langebaan Lagoon 2016, Technical Report. Report prepared by Anchor Environmental Consultants for the Saldanha Bay Water Quality Forum Trust.

Andrew, T.G., Rouhani, Q.A. and Seeti, S. 2000. Can small-scale fisheries contribute to poverty alleviation in traditionally non angling communities in South Africa? *African Journal of Aquatic Science* **25**:49-55.

Andrienko, G., Andrienko, N., Bak, P., Kisilevich, S. and Keim, D. 2009. Analysis of community-contributed space- and time-referenced data: example of Flickr photos. Proceedings of the IEEE Symposium on Visual Analytics Science and Technology (VAST 2009), Poster Paper, 2009.

Aurecon. 2011 Western Cape IWRM Action Plan: Status Quo Report Final Draft.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C. and Silliman, B. R. 2011. The value of estuarine and coastal ecosystem services. Ecological monographs, 81: 169-193

Barbier, E.B. 1994. Valuing environmental functions: tropical wetlands. *Land Economics* **70**: 155-173.

Barbier, E.B. 2011. *Capitalizing on nature: ecosystems as natural assets*. Cambridge University Press, Cambridge and New York.

Barnes, J.M. and Taylor, M.B. 2004. Health Risk Assessment in connection with the use of Microbiologically Contaminated Source Waters for Irrigation. WRC Report No: 1226/1/03, Water Research Commission.

Batty, L. C., Atkin, L. and Manning, D. A. C. 2005. Assessment of the ecological potential of mine-water treatment wetlands using a baseline survey of macroinvertebrate communities. *Environmental Pollution* **138**: 412-419.

Beck, M.W., Heck, K.L., Able K.W., Childers, D.L., Eggleston, D.B., Gillanders, B.M., Halpern, B., Hays, C.G., Hoshino, K., Minello, T.J., Orth, R.J., Sheridan, P.F., and Weinstein. M.P. 2001. The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrates. *Bioscience* **51**: 633–641.

Bickerton, I.B. 1982. Report No. 15 Zeekoe (CSW 5). In: Heydorn, A.E.F. & Grindley, J.R. (eds), Estuaries of the Cape. Part II. Synopses of Available Information on Individual Systems. CSIR, Stellenbosch, Unpublished report No. 414: 61pp

Bredehoeft, J.D., and T.J. Durbin. 2009. Ground water development—the time to full capture problem. Ground Water 47, no. 4: 506–514.

Brinson, M.M. 2000. Changes in the functioning of wetlands along environmental gradients. *Wetlands* **13**: 65-74.

Britz, J.D., Sigge, G.O., Huisamen, H., Kikine, T., Ackermann, A., Lötter, M., Lamprecht, C., and Kidd, M. 2013. Fluctuations of indicator and index microbes as indication of pollution over three years in the Plankenburg and Eerste Rivers, Western Cape, South Africa. Water SA, 39(4): 457-466

Brown, C. and Magoba, R. eds. 2009. Rivers and wetlands of Cape Town: Caring for our rich aquatic heritage. Water Research Commission.

Brown, C, Ewart-Smith, J, Conrad, J, Rossouw, N. 2006. The development of the water resources classification system (WRCS). Volume 2. Ecological, hydrological and water quality guidelines for the 7-step classification procedure. CSIR Report No. CSIR/NEW/WR/ ER/2006/0187B/C, Department of Water Affairs and Forestry, Pretoria, 136pp.

Chapman, V. J. 1974. Salt marshes and salt deserts of the world. Ecology of halophytes. Academic press, New York. Pages 3-19.

Christie, N. D. 1981. Primary production in Langebaan Lagoon. Estuarine Ecology with Particular Reference to southern Africa. J. H. Day. Cape Town, Balkema: 101-115.

City of Cape Town. 2014. Estuary Management Plans. Available from: www.capetown.gov.za/en/EnvironmentalResourceManagement/Coastal%20Management%20Programme%202014/Chapter%2023%20-%20Estuary%20Management%20Plans.pdf Downloaded on the 2 June 2016.

City of Cape Town. 2015. Report on the Inland and Coastal Water Quality Trends for the period ending December 2015. Internal report to the Transport for Cape Town Portfolio Committee.

Clark, B. M., Hauck, M., Harris, J. M., Salo K. and Russell E. 2002 Identification of subsistence fishers, fishing areas, resource use and activities along the South African coast, *South African Journal of Marine Science* **24**:1, 425-437.

Clark, B.M, Turpie, J.K, Adams, J., Cyrus, D., and Perissonotto, R. 2014. Ecological assessment. Vol IV. In: Clark, B.M & Turpie, J.K. (eds.) Analysis of alternatives for the rehabilitation of the Lake St Lucia estuarine system. Anchor Environmental Consultants Report no. AEC/1487/4 submitted to iSimangaliso Wetland Park Authority.

Clark, B.M., Bennett, B.A. and Lamberth, S.J. 1994. A comparison of the ichthyofaunas of two estuaries and their adjacent surf zones, with an assessment of the effects of beach-seining on the nursery function of estuaries for fish. South African Journal of Marine Science 14: 121-131.

Clark, B.M., Hutchings, K. and Lamberth, S.J. 2009. Long-term variations in composition and abundance of fish in the Berg Estuary, South Africa. Transactions of the Royal Society of South Africa 64(2): 238-258.

Cliff, S. and Grindley, J.R. 1982. Report No. 17: Lourens (CSW 7). In: Heydorn, A.E.F. & Grindley, J.R. (eds), Estuaries of the Cape. Part II. Synopses of Available Information on Individual Systems. CSIR Research Report No. 416: 39 pp.

Coastal and Environmental Consulting. 2010. Estuary Management Plan for the Sand Estuary. Prepared for the C.A.P.E. Estuaries Programme. 72 pp.

Compton, J. 2004. The Rocks and Mountains of Cape Town, Published by Juta and Company Ltd, 2004, 112pp ISBN 1919930701, 9781919930701.

Conningarth Consultants. 2015. Sectoral multipliers – National and Western Cape: 2006 at 2014 prices, and 2014 at 2014 prices. Report and spreadsheet submitted to GreenCape.

Cooper, A. 1982 The effects of salinity and waterlogging on the growth and cation uptake of salt marsh plants. *New Phytol*. 90, 263-275.

Cornelissen, S. 2005. Tourism impact, distribution and development: the spatial structure of tourism in the Western Cape province of South Africa. *Development Southern Africa* **22**(2): 163-185.

Costanza, R., D'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* **387**: 253-260.

Costanza. R., de Groot, R. Sutton, P., van der Ploeg, S., Anderson, S.J., Kubiszewski, I., Farber, S., and Turner, R.K. 2014. Changes in the global value of ecosystem services. *Global Environmental Change* **26**: 152-158.

Day, E. and Clark, B. 2012. Development of a water quality index and related reporting tools and information for inland and coastal waters of the City of Cape Town. Application of the City of Cape Town Water Quality Index to historical water quality data: 1978 to 2011. Report to City of Cape Town by Anchor Environmental Consultants, Freshwater Consulting Group and 3rd Quarter. 94pp.

de Villiers, C., Hodgson, A. and Forbes, A. 1999. Studies on estuarine macroinvertebrates. In B.R. Allanson & D. Baird eds. Estuaries of South Africa. Cambridge University Press, United Kingdom. pp.167-207.

DEADP, 2011. Department of Environmental Affairs and Development Planning. Western Cape Sustainable Water Management Plan – Status Quo Assessment.

Delvin, J., and M. Sophocleous, 2005. The persistence of the water budget myth and its relationship to sustainability. Hydrogeology Journal, 13: 549–554.

Department of Agriculture, Forestry and Fisheries (DAFF). 2016a. Trends in the Agricultural Sector 2015. Department of Agriculture, Forestry and Fisheries, Pretoria South Africa.

Department of Agriculture, Forestry and Fisheries (DAFF). 2016b. Abstract of Agricultural Statistics 2016. Department of Agriculture, Forestry and Fisheries, Pretoria South Africa.

Department of Agriculture, Forestry and Fisheries (DAFF). 2014. Status of the South African marine fishery resources. Department of Agriculture, Forestry and Fisheries, Cape Town, South Africa.

Department of Water Affairs (DWA). 2010. Feasibility Study into the Potential Development of Further Surface Water Supply Schemes for the Western Cape: Comprehensive assessment of the Ecological Water Requirements for the Berg River Estuary. Report No. Pretoria.

Department of Water Affairs (DWA). 2011. The Groundwater Dictionary: A comprehensive reference of groundwater related terminology. Second Edition. Online document: https://www.dwaf.gov.za/Groundwater/GroundwaterDictionary.aspx.

Department of Water Affairs (DWA). 2010. *The nature, distribution and value of aquatic ecosystem services of the Olifants, Inkomati and Usutu to Mhlatuze Water Management Areas.* Contract Report by Anchor Environmental Consultants for Department: Water Affairs, 362pp.

Department of Water Affairs and Forestry (DWAF). 2007. Berg River Baseline Monitoring Programme Final Report - Volume 3: Estuary And Floodplain Environment. Clark, B.M and Ractliffe G. (Eds.). Report prepared for the Department of Water Affairs and Forestry, DWAF Report No. P WMA 19/G10/00/1907. Pretoria.

Department of Water Affairs and Forestry (DWAF) 2006. Groundwater Resource Assessment II: Task 3aE Recharge. Version 2.0 Final Report 2006-06-20.

Department of Water Affairs and Forestry (DWAF). 2008. The Assessment of Water Availability in the Berg Catchment (WMA 19) by Means of Water Resource Related Models: Groundwater Model Report, Volumes 1-9. Prepared by Umvoto Africa (Pty) Ltd in association with Ninham Shand (Pty) Ltd on behalf of the Directorate: National Water Resource Planning. DWAF Report No. P WMA 19/000/00/0408.

Department of Water and Sanitation (DWS). 2015. Support to the Continuation of the Water Reconciliation Strategy for the Western Cape Water Supply System: Status Report October 2015. Prepared by Umvoto Africa (Pty) Ltd in association with WorleyParsons RSA on behalf of the Directorate : National Water Resource Planning. DWS Report No.

Department of Water and Sanitation (DWS). 2016. Support to the Continuation of the Water Reconciliation Strategy for the Western Cape Water Supply System – Cape Flats Aquifer Management Strategy. Prepared by Umvoto Africa (Pty) for the Department of Water and Sanitation, South Africa. Final, May 2016.

Dollar, ESJ, Brown, CA, Turpie, JK, Joubert, AR, Nicolson, CR and Manyaka, S. 2006. The development of the Water Resources Classification System (WRCS). Volume 1. Overview and 7-step classification procedure. CSIR Report No., Department of Water Affairs and Forestry, Pretoria, 70pp.

Drakenstein Municipality (2004). Paarl: Berg River: Investigation of microbiological pollution from informal and high-density areas. Prepared by Lyners Consulting Engineers & Project Managers and Ninham Shand.

Dunlop, S.W. and Mann, B.Q. 2012. An assessment of participation, catch and effort in the KwaZulu-Natal shore- based marine linefishery, with comments on management effectiveness. African Journal of Marine *Science* **34**: 479-496.

Dunlop, S.W. and Mann, B.Q. 2013. An assessment of the offshore boat-based linefishery in KwaZulu-Natal, South Africa. *African Journal of Marine Science* **35**(1): 79-97.

Ewart-Smith, J.L., Snaddon, K., Ractliffe, S.G., Dallas, H.F., Ollis, D.J. and Ross-Gillespie, V. 2008. Revised Wetland GIS cover for the City of Cape Town. Phase 4: Cape Peninsula, City Centre, northern and eastern extremities and the complete City Wetlands Map. Report submitted to the City of Cape Town, July 2008, 33 pp.

Fielding, P.J., Damstra, K.S.J. and Branch, G.M. 1991. Benthic diatom biomass, production and sediment chlorophyll in Langebaan Lagoon, South Africa. *Estuarine Coastal Shelf Science*, 27: 413-426.

Forbes, G., Dickson, K.R., Golden, T.D., Hudak P. and Doyle, R.D. 2004. Dissolved phosphorus retention of light-weight expanded shale and masonry sand used in subsurface flow treatment wetlands. *Environmental Science Technolology* **38**: 892-898.

Forestry South Africa. 2015. Abstract of South African Forestry Facts 2012/13. Department of Agriculture, Forestry and Fisheries.

Geospatial Analysis Platform (GAP) 2011. Geospatial Analysis Platform – Version 2, based on the SA Mesoframe Version 1.1. CSIR. Available from www.gap.csir.co.za.

GEOSS (2015). Hydrogeological investigation of existing water springs in the City of Cape Town and Environs: Strategy Document. Completed by GEOSS for the City of Cape Town, Water & Sanitation; Water Demand Management & Strategy Department. GEOSS Report no.: 2014/10-08, June 2015.

Gordon, N., Adams, J.B. and Bate, G.C. 2008. Epiphytes of the St. Lucia Estuary and their response to water level and salinity changes during a severe drought. Aquatic Botany 88(1):66 – 76.

Görgens, A. H. M. and de Clercq, W. P. 2005. Research on the Berg Water Management Area: Summary of the water quality information system and soil quality studies. WRC Report No: TT 252/05. Water Research Commission.

Griffiths, M.H. 2000. Long-term trends in catch and effort of commercial linefish off South Africa's Cape Province: snapshots of the 20TH century. *South African Journal of Marine Science* **22** 81-110.

Grindley, J.R., Dudley, S.F.J. 1988. Estuaries of the Cape Part II: synopses of available information on individual systems No. 28: Rietvlei CW 24 and Diep CW 25. CSIR Research Report 427. Stellenbosch: Estuarine and Coastal Research Unit, Council for Scientific and Industrial Research. 82 pp.

Grindley, J.R. 1977. The zooplankton of Langebaan lagoon and Saldanha Bay. Transactions of the Royal Society of South Africa 42: 341-370.

Harrison, T.D. 1999. A preliminary survey of the estuaries on the south coast of South Africa, Cape Agulhas – Cape St Blaize, Mossel Bay, with particular reference to the fish fauna. Transactions of the Royal Society of South Africa 54(2): 285–310.

Harrison, T.D. 2004. Physico-chemical characteristics of South African estuaries in relation to the zoogeography of the region. Estuarine, Coastal and Shelf Science 61: 73-87.

Haskins, C. 2013. Lourens MAC – Water Quality Report. City of Cape Town.

Haskins, C. 2014. Kuils Forum – Water quality report. City of Cape Town.

Haskins, C. 2015a. False Bay Ecology Park - Water Quality Report. City of Cape Town.

Haskins, C. 2015b. Table Bay Nature Reserve – Water Quality Report. City of Cape Town.

Hortgro. 2016. Key deciduous fruit statistics 2015. Compiled by Hortgro, Paarl. Downloaded from www.hortgro.co.za. Accessed 16 September 2016.

Hughes, D.A. and Hannart, P. 2003. A desktop model used to provide an initial estimate of the ecological instream flow requirements of rivers in South Africa. Journal of Hydrology, 270, 167-181.

Hutchings K. and Lamberth SJ. 2002. Bycatch in the gillnet and beach-seine fisheries in the Western Cape, South Africa, with implications for management. *South African Journal of Marine Science* **24**: 227–241.

Hutchings, K & S. J. Lamberth 2002a. Catch and effort estimates for the gillnet and beach-seine fisheries in the Western Cape, South Africa. *South African Journal of Marine Science* 24, 205-225*.*

Hutchings, K & S. J. Lamberth 2002b. Bycatch in the gillnet and beach-seine fisheries in the Western Cape, South Africa, with implications for management. *South African Journal of Marine Science* 24, 227-241*.*

Hutchings, K., Clark, B.M., Atkinson, L.J. and Attwood, C. G. 2008 - Evidence of recovery of the linefishery in the Berg River Estuary (Western Cape, South Africa) subsequent to closure of commercial gill netting. *Afr. J. mar. Sci.* **30(3):** 507–517.

Jackson, L., Conrad, J. and Carstens, M. 2010. Situation assessment for the Zandvlei estuary. Unpublished report prepared for the CAPE Estuaries Programme, October 2008. Coastal & Environmental Consulting, Hout Bay.

Jackson L, Conrad J, De Meyer M, Cullinan C, Mahomedy L, and Dehrmann, A. 2008. Situation assessment for the Diep estuary. Unpublished report prepared for the CAPE Estuaries Programme, October 2008. Peak Practice, Hermanus.

Jackson, V.A., Paulse, A.N., van Stormbroek, T, Odendaal, J.P. and Khan, W. 2007. Investigation into metal contamination of the Berg River, Western Cape, South Africa. Water SA, 33(2): 175-182

Job, N., Snaddon, K., Day, L., Nel, J. and Smith-Adao, L., 2008. CAPE fine-scale planning project: Aquatic ecosystems of the Sandveld-Saldanha planning domain. Report submitted to CapeNature.

Johnston, C. A., Detenbeck, N. E. and Niemi, G. J. 1990. The cumulative effect of wetlands on stream water quality and quantity. A landscape approach. *Biogeochemistry* **10**: 105 -141.

Jordan, T. E., Whigham, D. F., Hofmockel, K. H. and Pittek, M. A. 2003. Wetlands and Aquatic Processes: Nutrient and Sediment Removal by a Restored Wetland Receiving Agricultural Runoff. *Journal of Environmental Quality* **32**: 1534–1547.

Jothiyangkoon, C., Sivapalan, M. and Farmer, D. L. 2001. Process controls of water balance variability in a large semi-arid catchment: downward approach to hydrological development. *Journal of Hydrology* **254**: 174-198.

Karez, R.S., Engelbert, P., Kraufvelin, M.F. Pedersen and Sommer, U. 2004. Biomass response and changes in composition of ephemeral macroalgal assemblages along an experimental gradient of nutrient enrichment. Aquatic Botany 78 103-117.

Kibirige, I. and Perissinotto, R. 2003. In situ feeding rates and grazing impact of zooplankton in a South African temporarily open estuary. Marine Biology 142: 357-367.

Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N.J. and Rowntree, K.. 2005. River EcoClassification– Manual for EcoStatus Determination. Department of Water Affairs and Forestry, Pretoria.

Kleynhans M. T., Turpie J. K., Rusinga F. & Görgens A. H. M. 2009. Quantification of the flow regulation services provided by Nylsvlei wetland, South Africa. In: Turpie, J.K. (ed) *Development of a protocol for the valuation of wetlands in South Africa. Volume II. The valuation of provisioning, regulating and cultural services provided by wetlands: case studies from South Africa and Lesotho*.

Kleynhans, CJ and Louw MD. 2007. Module A. Ecoclassification and Ecostatus determination in River Ecoclassification: Manual for Ecostatus determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report.

Kotze D. C. and Breen C. M. 1994. Agricultural land-use impacts on wetland functional values. WRC Report No 501/3/94, Water Research Commission, Pretoria.

Krasnostein, A. L. and Oldham, C. E. 2004. Predicting wetland water storage. *Water Resources Research* **40**. W10203.

Kruseman, G.P. and de Ridder, N.A. 1991. Analysis and evaluation of pumping test data Wageningen, The Netherlands. International Institute for Land Reclamation and Improvement. Second Edition (completely revised).

Kusler, J. 2004. Final Report 1: Wetland Assessment for Regulatory Purposes. Assessing Functions and Values. Association of State Wetland Managers, New York.

Lamberth SJ, Branch GM and BM Clark 2010. Estuarine refugia and fish responses to a large anoxic, hydrogen sulphide, ''blacktide'' event in the adjacent marine environment. Estuarine, Coastal and Shelf Science 86 (2010) 203–215.

Lamberth, S.J and Joubert, A.R. 1999. Priority Line fish species for research and Management: a first attempt. In: B. Q. Mann (Ed.) Proceedings of the third Marine Linefish Symposium. The South African Network for Coastal and Oceanographic Research, Occasional Report **5**: 130-137.

Lamberth, S.J. and Turpie, J.K. 2003. The role of estuaries in South African fisheries: economic importance and management implications. *African Journal of Marine Science* **25**: 131–157.

Lannas, K.S.M. and J.K. Turpie. 2009. Valuing the provisioning services of wetlands: contrasting a rural wetland in Lesotho with a peri-urban wetland in South Africa. *Ecology and Society* **14**(2): 18. [online] URL: http://www.ecologyandsociety.org/vol14/iss2/art18/

Madsen JD, Chambers PA, James WF and EW Koch 2001. The interaction between water movement, sediment dynamics and submersed macrophytes. Hydrobiologia 444: 71–84.

Malan, H., Day, J., Ramjukadh, C. and Olivier, N. 2015. Trajectories of change in wetlands of the Fynbos Biome from the late 1980s to 2014. Water Research Commission Report (K5/2183), Pretoria.

Mann, B.Q. 2000. Southern African *Marine Linefish Status Reports. Special Publication of the Oceanographic Research Institute of South Africa.* **7**: 257pp.

Mann, B.Q. 2013.Southern African Marine Linefish Species Profiles. Special Publication, Oceonographic research Institute. Durban 357p.

McCafferty, J.R.., Ellender, B.R., Weyl, O.L.F. and Britz, P.J. 2012 The use of water resources for inland fisheries in South Africa. *Water SA* **38**(2): 327-344.

Mcgrath, M.D., Horner, C.C.M., Brouwer, S.L., Lamberth, S.J., Mann, B. Q., Sauer, W.H.H. and Erasmus, C. 1997. An economic valuation of the South African linefishery. *South African Journal of Marine Science* **18**: 203–211.

McKee, L.J., Eyre, B.D. and Hossain, S. 2000. Transport and retention of nitrogen and phosphorus in the sub-tropical Richmond River estuary, Australia — a budget approach. *Biogeochemistry* **50**:241-278.

Mead, A., Carlton, J.T., Griffiths, C.L. and Rius, M. 2011. Revealing the scale of marine bioinvasions in developing regions: a South African re-assessment. *Biological Invasions* 13(9): 1991-2008.

Mielke, C.H. and de Wit, M. J. 2009. Large-Scale structural map of the Cape Fold Belt derived by remote sensing analysis. 11th SAGA Biennial Technical Meeting and Exhibition, Swaziland, 16-18 September 2009, pages 521-523.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC.

Mitsch, W.J. and Gosselink, J.G. 1993. Wetlands. 2nd Edition. John Wiley, New York.

Montoya-Maya, P.H. and Strydom, N.A. 2009b. Zooplankton composition, abundance and distribution in selected south and west coast estuaries in South Africa. African. African Journal of Aquatic Science 34(2): 147-157.

Napier, V.R., Turpie, J.K. and Clark, B.M. 2009 Value and management of the subsistence fishery at Knysna Estuary, South Africa. *African Journal of Marine Science* **31**(3): 297-310.

Nel, J.L and Driver, A. 2012. National Biodiverisity Assessment 2011: Technical Report. Volume 2: Freshwater Component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B/ Council for Scientific and Industrial Research, Stellenbosch.

Nel, J.L., Murray, K.M., Maherry, A.M., Petersen, C.P., Roux, D.J., Driver, A., Hill, L., Van Deventer, H., Funke, N., Swartz, E.R. and Smith-Adao, L.B., 2011. Technical Report for the National Freshwater Ecosystem Priority Areas project (No. K5). WRC Report.

Nondoda, S. P. 2012. Macrophyte distribution and responses to drought in the St Lucia Estuary. MSc, Nelson Mandela Metropolitan University. Page 31.

Novitzki, R. P. 1979. Hydrologic characteristics of Wisconsin's Wetlands and their influence on floods, stream flow, and sediment. In: *Wetland functions and values: the state of our understanding.* Greeson, P. E., Clark, J. R. & Clark, J.E. (Eds.). American Water Resources Association, Minneapolis.

Ogawa, H. and Male, J. W. 1986. Simulating the flood mitigation role of wetlands. *Journal of Water Resources Planning and Management* **112**: 114-128.

Panoramio website. 2015. Panoramio acceptance policy for Google Earth and Google Maps. Available: http://www.panoramio.com/help/acceptance policy. Accessed 2015 August 3.

Peltier, E. F., Webb, S. M. & Gaillard, J. F. 2003. Zinc and lead sequestration in an impacted wetland system. *Advances in Environmental Research* **8**: 103–112.

Pennings, S. C., Grant, M. and Bertness, M. D. 2005. Plant zonation in low-latitude salt marshes: disentangling the roles of flooding, salinity and competition. Journal of ecology, 93: 159-167.

Petersen, C.R., Leaner, J.J., Maherry, A., and McConkey, G. 2008. River Management Strategy for the Berg Water Management Area of the Western Cape: Scoping Report. DWAF Project No. 2006-462, Department of Water and Sanitation.

Potter, K. W. 1994. *Estimating Potential Reduction Flood Benefits of Restored Wetlands*. University of Wisconsin.

Ractliffe, G. 2007. Berg River Baseline Monitoring Programme Final Report - Volume 2: Riverine Baseline Monitoring Programme and Statement of Baseline Conditions. DWAF Report No. P WMA 19/G10/00/1807. Department of Water & Sanitation.

Rogers R. E., Rogers K. H. and Buzer J. S. 1985. *Wetlands for wastewater treatment: with special reference to municipal wastewaters*. WITS University Press, Johannesburg.

Rossouw, J.N. and Versfeld, K. 2009. Assessment of the water quality status of the Berg River in the Paarl/Wellington area: An update to 2009. Report prepared for the Drakenstein Municipality by Aurecon South Africa.

Rossouw, J.N. 2011. Assessing the environmental impacts of upgrading / extending the Wellington Waste Water Treatment Works: Assessment of the Water Quality Impacts. Report to Doug Jeffery Environmental Consultants.

Rossouw, J.N. 2014. Water quality management mapping of the Berg River: Hotspot monitoring. Berg River Water Quality Task Team, Department of Water Affairs.

Rouhani, Q.A. and Davies, M.T.T. 2003 A report on the survey to determine the potential for recreational and subsistence fisheries in the Alfred Nzo District Municipality. Rural Fisheries Programme, Department of Ichthyology and Fisheries Science, Rhodes University. 20 pp.

Saunders and Kalff 2001. Nitrogen retention in wetlands, lakes and rivers. Hydrobiologia 443: 205-212.

Schulze, R.E. and Horan, M.J.C. 2007. Soils: Hydrological Attributes. In: Schulze, R.E. (Ed). 2007. South African Atlas of Climatology and Agrohydrology. Water Research Commission, Pretoria, RSA, WRC Report 1489/1/06, Section 4.2.

Sfriso A, Pavoni B, Marcomini A and Orio, AA. 1992. Macroalgae, nutrient cycles, and pollutants in the Lagoon of Venice. Estuaries 15 (4) 517–528.

Smakhtin, V. U. and Batchelor, A. L. 2005. Evaluating wetland flow regulating functions using discharge time-series. *Hydrological processes* **19**: 1293-1305.

Smithers, J. C. and Schulze, R. E. 1993. The influence of wetlands on streamflow regulation and flood attenuation: A modelling approach. In: S. S. Y. Wang (Ed.), *Advances in Hydro-science and Engineering*. University of Mississippi, USA. 396 – 402pp.

Sophocleous, M., 2000. From safe yield to sustainable development of water resources – the Kansas experience. Journal of Hydrology 235: 27–43.

South African Table Grape Industry (SATI). 2016. Statistics Booklet 2015. Paarl, Western Cape. Downloaded from www.satgi.co.za. Accessed on 15 September 2016.

South African Wine Industry Information & Systems (SAWIS). 2016. SA Wine Industry 2015 Statistics, NR 40. Paarl, Western Cape. Downloaded from www.sawis.co.za. Accessed on 15 September 2016.

StatsSA 2011. Census. Statistics South Africa.

StatsSA 2016. Detailed GDP historical series 2010-2015. Accessed from www.statssa.gov.za

StepSA 2015. Spatial Temporal Evidence for Planning South Africa. Developed by CSIR. Available from www.stepsa.org.

Theis, C.V., 1940. The source of water derived from wells. Civil Engineering 10 (5) 277-280.

Thiesing, M. A. 2001. An evaluation of wetland assessment techniques and their applications to decision making. In: *Wetland inventory, assessment and monitoring: Practical techniques and identification of major issues*. Finlayson, C. M., Davidson, N. C. & Stevenson, N. J. (Eds.). Proceedings of Workshop 4, 2nd International Conference on Wetlands and Development, Dakar, Senegal, 8-14 November 1998, Supervising Scientist Report 161, Supervising Scientist, Darwin.

Thomas, A., Chingombe, W., Ayuk, J. and Scheepers, T. 2010. A Comprehensive Investigation of the Kuils-Eerste River Catchments Water Pollution and Development of a Catchment Sustainability Plan. WRC Report No. 1692/1/10. Water Research Commission

Thompson, W.W. 1913 - The Sea Fisheries of the Cape Colony from Van Riebeeck's days to the Eve of the Union, with a Chapter on Trout and Other Freshwater Fisheries .Cape Town; Maskew Miller: viii + 163 pp

Thullen, J. S., Sartoris, J. J. and Nelson, S. M. 2005. Managing vegetation in surface-flow wastewater-treatment wetlands for optimal treatment performance. *Ecological Engineering* **25**: 583–593.

Tilton, D.L. and Kadlec, R.H. 1979. The utilization of a fresh-water wetland for nutrient removal from secondarily treated waste water effluent. *Journal of Environmental Quality* **8**:328- 334.

Tourism, S.A. 2016 Tourism Annual Report. South African Tourism – Strategic Research Unit.

Turpie JK and Clark B (2007). The health status, conservation importance, and economic value of Temperate South African estuaries and development of a regional conservation plan. Draft Report. Anchor Environmental Consultants CC, University of Cape Town.

Turpie, J.K., Wilson, G. and Van Niekerk, L. 2012. National Biodiversity Assessment 2011: National Estuary Biodiversity Plan for South Africa. Anchor Environmental Consulting, Cape Town.

Turpie, J., Joubert, A., van Zyl, H., Harding, B. and Leiman, A. 2001. *Valuation of open space in the Cape Metropolitan Area. A pilot study to demonstrate the application of environmental and resource economics methods for the assessment of open space values in two case study areas: Metro South and Metro South-east.* Report to the City of Cape Town. 104pp.

Turpie, J., Mills, A., Kong, T. and Tacon, C. 2014. A preliminary assessment of priorities and opportunities for mobilising private sector investment in the Western Cape's natural capital. Report submitted to Western Cape Government, South Africa. 207pp.

Turpie, J.K. and de Wet, J. 2009a. The recreational value of the Garden Route Coast, South Africa, and implications of changes in management. Anchor Environmental Consultants report to World Wide Fund for Nature – South Africa.

Turpie, J.K. and de Wet, J. 2009b. The recreational value of the Kogelberg Coast, South Africa, and implications of changes in management. Anchor Environmental Consultants report to World Wide Fund for Nature – South Africa.

Turpie, J.K., Clark, B.M. and Hutchings, K. 2007. The economic value of Marine Protected Areas along the Garden Route Coast, South Africa, and implications of changes in size and management. Report to WWF-SA.

Turpie, J.K., Clark, B.M. and Wilson, G. 2012a. Appendix No. 1. Specialist report – The economic value of the Berg River Estuary. Pre-feasibility and feasibility studies for augmentation of the Western Cape water supply systems by means of further surface water developments. Report No. 1 – Volume 3. Department of Water Affairs: Directorate: Optional Analysis. Report No: P WMA 19/G10/2413/3

Turpie, J.K., Dollar, E., Goldin, J., Mullins, W. Mallory, S., Rossouw, N., and Joubert, A. 2006. *Socio-economic guidelines for the 7-step classification procedure*. Contract report to the Department of Water Affairs and Forestry. CSIR

Turpie, J.K., Heydenrych, B.J. and Lamberth, S.J. 2003. Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies. *Biological Conservation* **112**: 233-251.

Turpie, J.K., Hutchings, K., Clark, B. and Clarke, F. 2012b. Potential impact of the proposed Addo Marine Protected Area on commercial fisheries. Anchor Environmental report to SANParks.

Turpie, J.K., Smith, B.S., Emerton. L.E., and Barnes, J. 1999. *Economic value of the Zambezi Basin wetlands.* Report to IUCN-ROSA, Harare. 346pp.

Turpie, J.K.,, Day, E., Ross-Gillespie, V. and Louw, A. 2010. Estimation of the Water Quality Amelioration Value of Wetlands: A Case Study of the Western Cape, South Africa. Environment for Development Discussion Paper Series EFD DP 10-15.

University of Cape Town (UCT), 1995. Report on the phase one archaeological investigation of aspects of the site known as Die Bron in Malmesbury. Prepared for Malmesbury Transitional Council, March 1995, Prepared by Archaeology Contracts Office, Department of Archaeology, University of Cape Town.

Van Niekerk L and Turpie JK eds. 2012. South African National Biodiversity Assessment 2011: Technical Report. Volume 3: Estuary Component. CSIR Report Number CSIR/NRE/ECOS/ER/2011/0045/B. Council for Scientific and Industrial Research, Stellenbosch.

van Zyl, H. and Leiman, A. 2001. Case studies using revealed preference methods II: Estimating the property value of open space using the hedonic valuation method. Pp. 59-69. In: J Turpie, A Joubert, H Van Zyl, B Harding, & A Leiman. Valuation of open space in the Cape Metropolitan Area: A pilot study to demonstrate the application of environmental and resource economics methods for the assessment of open space values in two case study areas: Metro South and Metro South-east. City of Cape Town. Vellidis, G., Smith, M. C., Liebowitz, S. G., Ainslie, W. B. & Pruitt, B. A. 2003. Prioritizing Wetland Restoration for Sediment Yield Reduction: A Conceptual Model. *Environmental Management* **31**: 301 – 312.

VanDer Linden, S.C. 2014 *Salt marsh distribution and structure at Langebaan Lagoon*. MSC Thesis. Department of Botany, Nelson Mandela Metropolitan University 128 p.

Viskich, M., Griffiths, C.L., Erasmus, C. and Lamberth, S. 2016. Long-term physical, chemical and biological changes in a small, urban estuary. African Journal of Marine Science 1-15

Wallace, J.H. 1975a. *The estuarine fishes of the east coast of South Africa. I. Species composition and length distribution in the estuarine and marine environments. II. Seasonal abundance and migrations*. Durban, South Africa: Investigational Report, Oceanographic Research Institute, **40**: 1-72.

Wallace, J.H. 1975b. *The estuarine fishes of the east coast of South Africa. III. Reproduction.* Durban, South Africa: Investigational Report, Oceanographic Research Institute **41:** 1-51.

Water Research Commission, 2002. A Synthesis of the Hydrogeology of the Table Mountain Group. WRC Report TT 158/01. January 2002. Edited by K. Pietersen and R. Parsons.

Water Research Commission, 2003. Ecological and Environmental Impacts of Large-scale Groundwater Development in the Table Mountain Group (TMG) Aquifer System February 2003. WRC project K5/1327. By C. Brown, C. Colvin, C. Hartnady, R. Hay, D Le Maitre, K. Riemann

Water Research Commission, 2009. Groundwater Flow Conceptualization and Storage Determination of the Table Mountain Group (TMG) Aquifers. By Y Xu, L Lin and H Jia. WRC Report No. 1419/1/09. ISBN 978-1-77005-840-8

Water Research Commission, 2016a. The Capture Principle Approach to Sustainable Groundwater use: Incorporating Sustainability Indicators and a Decision Framework. Draft Final Report for project K5/2311. Compiled by H. Seyler, M. Holland and K. Witthueser, September 2016.

Water Research Commission, 2016b. Regional Water Sensitive Design Scenario Planning for Cape Town using an Urban (Geo)hydrology Model. Draft Final Report for project K5/2441. Compiled by H. Seyler, M. Bolleart and K. Witthueser, August 2016.

Wesgro. 2015. The Western Cape. Tourism Destination Performance. Wesgro, Cape Town and Western Cape Research.

West Coast District Municipality. 2009. Investigation into Alternative Water Sources for the West Coast District Municipality. Volumes 1 – 4. Compiled by Element Consulting Engineers Project Number 07076, June 2009.

Western Cape Department of Agriculture. 2013. Crop Census 2013. Available from Cape Farm Mapper, version 2.0. www.gis.elsenburg.com.

Western Cape Government. 2014a. Municipal Economic Review and Outlook 2014. Provincial Treasury, Cape Town South Africa. ISBN: 978-0-621-43100-1

Western Cape Government. 2014b. Socio-economic Profile Saldanha Bay Municipality. Working Paper. Western Cape Government Provincial Treasury.

Weyl, O.L.F., Potts, W.M., Rouhani, Q. and Britz, P.J. 2007. The need for an inland fisheries policy in South Africa: a case study on the Northwest Province. *Water SA* **33**: 497-504.

Whitfield, A.K. 1992. A characterization of southern African estuarine systems. *Southern African Journal of Aquatic Sciences* 18: 89-103.

Whitfield, A.K. 1994. An estuary-association classification for the fishes of southern Africa. South African Journal of Science 90: 411–417.

Whitfield, A. K. 1998. Biology and Ecology of Fishes in Southern African Estuaries. Ichthyological Monographs of the J.L.B. Smith Institute of Ichthyology, No. 2, 223 pp

Whitfield, A.K. and Marais, J.F.K. 1999. The ichthyofauna. In *Estuaries of South Africa* Allanson, B.R., Baird, D. (eds.). Cambridge: Cambridge University Press, pp. 209-233.

Whitfield, A.K. 1994. An estuary-association classification for the fishes of southern Africa. *South African Journal of Science* **90**: 411-417

Wooldridge, T.H. 1999. Estuarine zooplankton community structure and dynamics. In: Allanson B.R. & Baird, D. eds. Estuaries of South Africa, Cambridge University Press, United Kingdom. pp. 141-166.

Wu Yong. 2005. Groundwater recharge estimation in Table Mountain Group aquifer systems with a case study of Kammanassie area. PhD Thesis, University of the Western Cape, Bellville.