ATLAS OF FRESHWATER ECOSYSTEM PRIORITY AREAS IN SOUTH AFRICA

MAPS TO SUPPORT SUSTAINABLE DEVELOPMENT OF WATER RESOURCES

Front Cover: Clanwilliam and Fiery redfins in the Rondegat River of Cederberg, South Africa

The Rondegat River is a Freshwater Ecosystem Priority Area in the Olifants/Doorn Water Management Area and an extremely important fish sanctuary. It is home to five threatened fish species, including the Clanwilliam redfin and fiery redfin, both of which are endangered and found only in South Africa. Both species are highly vulnerable to predation by alien bass and bluegill sunfish, as well as water abstraction. Both species depend on the delivery of the correct amounts of water at the correct times of year for the adults to spawn and feed and for their young to develop and grow. The Rondegat River runs through the Cederberg Wilderness Area which is managed by CapeNature.

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ATLAS
of
FRESHWATER ECOSYSTEM PRIORITY AREAS
in South Africa:
Maps to support sustainable development of water resources

Report to the

Water Research Commission

by

JL Nel, A Driver, WF Strydom, A Maherry, C Petersen, L Hill, DJ Roux, S Nienaber, H van Deventer, E Swartz and LB Smith-Adao

Obtainable from

Water Research Commission
Private Bag X03
GEZINA, 0031
South Africa

orders@wrc.org.za

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The content presented in this atlas summarises the data and on-the-ground knowledge of the freshwater ecological community in South Africa, and represents over 1000 person years of experience.

The development of this atlas was a collaborative effort between the CSIR, South African National Biodiversity Institute (SANBI), Water Research Commission, Department of Environmental Affairs, Department of Water Affairs, Worldwide Fund for Nature (WWF), South African Institute for Aquatic Biodiversity (SAIAB) and South African National Parks (SANParks).

The content presented in this atlas summarises the data and on-the-ground knowledge of the freshwater ecology community in South Africa, and represents over 1000 person years of experience. Input data that informed the identification of priority areas were collated and reviewed in a series of five regional expert workshops in May and June 2009. Resulting draft priority areas were reviewed in a national stakeholder workshop in July 2010. Without exception those involved shared their data, knowledge and experience freely, making the products showcased in this atlas not only a consolidation of the best available science in freshwater biodiversity planning in South Africa but also an exceptional example of collaboration between scientists, managers and other users. Over 100 experts participated in the input and review workshops, representing a range of stakeholders including: national departments of Water Affairs and Environmental Affairs, provincial conservation authorities, regional officials and catchment managers for the Department of Water Affairs, scientific councils, several non-governmental organisations (NGOs) and private consultants. Thanks to all these workshop participants (full list of participants provided in Appendix A and B of the technical report).

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Dirk Roux


Dirk Roux


Dirk Roux


Dirk Roux

National workshop photographs


Dirk Roux


Dirk Roux


Pontso Pakkies

Foreword

Water is the lifeblood of South Africa and influences every part of the economy and the aspirations of our people. The availability of freshwater is a key enabler, and its unavailability a major constraint, to the economic development of our country and the well-being of our citizens. And, while most people think of water as coming simply from a tap, or from a dam, the quantity, quality and timing of flows of these precious water resources are in fact shaped and controlled by the health of the ecosystems through which they have passed. These ecosystems – our rivers, wetlands, lakes and pans – constitute irreplaceable natural infrastructure for water resource management, and havens for our rich biodiversity.

This atlas provides the first comprehensive assessment of our Freshwater Ecosystem Priority Areas, or, in short, those areas of the country that are most important for sustaining the integrity and continued functioning of our freshwater ecosystems.

There is no doubt that South Africa's freshwater ecosystems are under increasing pressure. The recently completed National Biodiversity Assessment highlighted that 65% of wetland ecosystem types and 57% of river ecosystem types are already threatened. However, there are also examples of these ecosystems that are still in good condition, often the smaller tributaries. These healthy ecosystems are the lifeblood that replenishes and sustains the hard-working and heavily impacted larger rivers that underpin all our economic activities.

The mandate for taking care of our freshwater ecosystems is shared between the Department of Water Affairs and the Department of Environment Affairs, as well as their provincial and regional counterparts. Water is also important to a number of sister departments including the Department of Agriculture, Forestry and Fisheries, and the Department of Mineral Resources. It is therefore essential that water is dealt with in an integrated and cooperative manner across these key departments. This atlas provides us with a unified product that will help to underpin such cooperative governance.

The maps presented here, together with the Implementation Manual for Freshwater Ecosystem Priority Areas, will help greatly to ensure that healthy freshwater ecosystems continue to form the cornerstone of the implementation of our water resource classification system and the development of catchment management strategies throughout the country. They also inform planning and decisions about land use and the expansion of the protected area network. By highlighting which ecosystems should remain in a healthy and well-functioning state, the maps provide a tool to guide our choices for the strategic development of water resources and to support sustainable development.

The atlas is also a remarkable, globally innovative product that all South Africans can be proud of, drawing together the knowledge of our freshwater science community, as well as practitioners and water resource managers, whose collaboration forms the foundation for the work presented here. For the first time this wealth of knowledge has been consolidated into a single document, which helps to make excellent science accessible to policymakers, managers and the public.

I encourage you to use these maps in your work, and to work with all sectors of government to ensure that our priority rivers and wetlands are maintained in a healthy state, so that they can continue to support the health and well-being of our people.

Mrs Bomo Edith Edna Molewa
Minister of Water and Environmental Affairs
Republic of South Africa

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Background

South Africa's freshwater ecosystems are diverse, ranging from sub-tropical in the north-eastern part of the country, to semi-arid and arid in the interior, to the cool and temperate rivers of the fynbos. Freshwater ecosystems refer to all inland water bodies whether fresh or saline, including rivers, lakes, wetlands, sub-surface waters and estuaries. Consistent with global trends, high levels of threat have been reported for freshwater ecosystems, with over half of the country's river and wetland ecosystem types considered threatened in the National Biodiversity Assessment 2011 (Nel et al. 2011). South Africa's freshwater fauna also display high levels of threat with at least one third of freshwater fish indigenous to South Africa reported as threatened, and a recent southern African study on the conservation status of major freshwater-dependent taxonomic groups (fishes, molluscs, dragonflies, crabs and vascular plants) reported far higher levels of threat in South Africa than in the rest of the region (Darwall et al. 2009).

Urgent attention is needed to ensure that we conserve some natural examples of the different ecosystems that make up the natural heritage of this country for current and future generations. The National Freshwater Ecosystem Priority Areas project (NFEPA) responds to this need, providing strategic spatial priorities for conserving South Africa's freshwater ecosystems and supporting sustainable use of water resources.

NFEPA provides guidance on how many rivers, wetlands and estuaries, and which ones, should remain in a natural or near-natural condition. It supports the implementation of the National Water Act, the Biodiversity Act and the Protected Areas Act.

Who should use these maps?

Intended users of NFEPA products include: the national departments of Water Affairs and Environmental Affairs, Catchment Management Agencies and their associated stakeholders, SANBI, SANParks, bioregional programmes, provincial conservation authorities, provincial environmental affairs departments, national and provincial departments of agriculture, the Department of Mineral Resources, municipalities, NGOs, conservancies and environmental consultants.

SANBI's Freshwater Programme is involved in ongoing support to provinces, municipalities and other stakeholders to ensure that NFEPA products are available and incorporated meaningfully into their respective policies, programmes and decisions. Data and products are available through SANBI's Biodiversity GIS website (http://bgis.sanbi.org), which serves spatial biodiversity information freely to the public. Alternatively, contact SANBI's Freshwater Programme at freshwater@sanbi.org.za.

The National Freshwater Ecosystem Priority Areas project

The maps presented in this atlas are a culmination of the National Freshwater Ecosystem Priority Areas project (NFEPA), a three-year partnership project between the South African National Biodiversity Institute (SANBI), CSIR, Water Research Commission (WRC), Department of Environmental Affairs (DEA), Department of Water Affairs (DWA), Worldwide Fund for Nature (WWF), South African Institute of Aquatic Biodiversity (SAIAB) and South African National Parks (SANParks). NFEPA maps provide strategic spatial priorities for conserving South Africa's freshwater ecosystems and supporting sustainable use of water resources. These strategic spatial priorities are known as Freshwater Ecosystem Priority Areas, or 'FEPAs'. NFEPA maps were developed using the principles of systematic biodiversity planning, also known as systematic conservation planning (Margules and Pressey 2000). Systematic biodiversity planning is a well-established field of science in which South Africa is considered a world leader (Balmford 2003).

The NFEPA maps and supporting information form part of a comprehensive approach to sustainable and equitable development of South Africa's scarce water resources. For integrated water resources planning, NFEPA provides guidance on how many rivers, wetlands and estuaries, and which ones, should remain in a natural or near-natural condition to support the water resource protection goals of the National Water Act (Act 36 of 1998). NFEPA products are therefore directly applicable to the National Water Act, feeding into Catchment Management Strategies, water resource classification, reserve determination, and the setting and monitoring of resource quality objectives. NFEPA products are also directly relevant to the National Environmental Management: Biodiversity Act (Act 10 of 2004), informing both the listing of threatened freshwater ecosystems and the process of bioregional planning provided for by this Act. NFEPA products support the implementation of the National Environmental Management: Protected Areas Act (Act 57 of 2003) by informing the expansion of the protected area network.

Freshwater ecosystems refer to all inland water bodies whether fresh or saline, including rivers, lakes, wetlands, sub-surface waters and estuaries.

Andrew Brown

Andrew Brown

Peter Chadwick/WWF-SA

Other products of the National Freshwater Ecosystem Priority Areas project

This Atlas is one of a suite of NFEPA products. The accompanying DVD includes the full range of NFEPA products listed below:

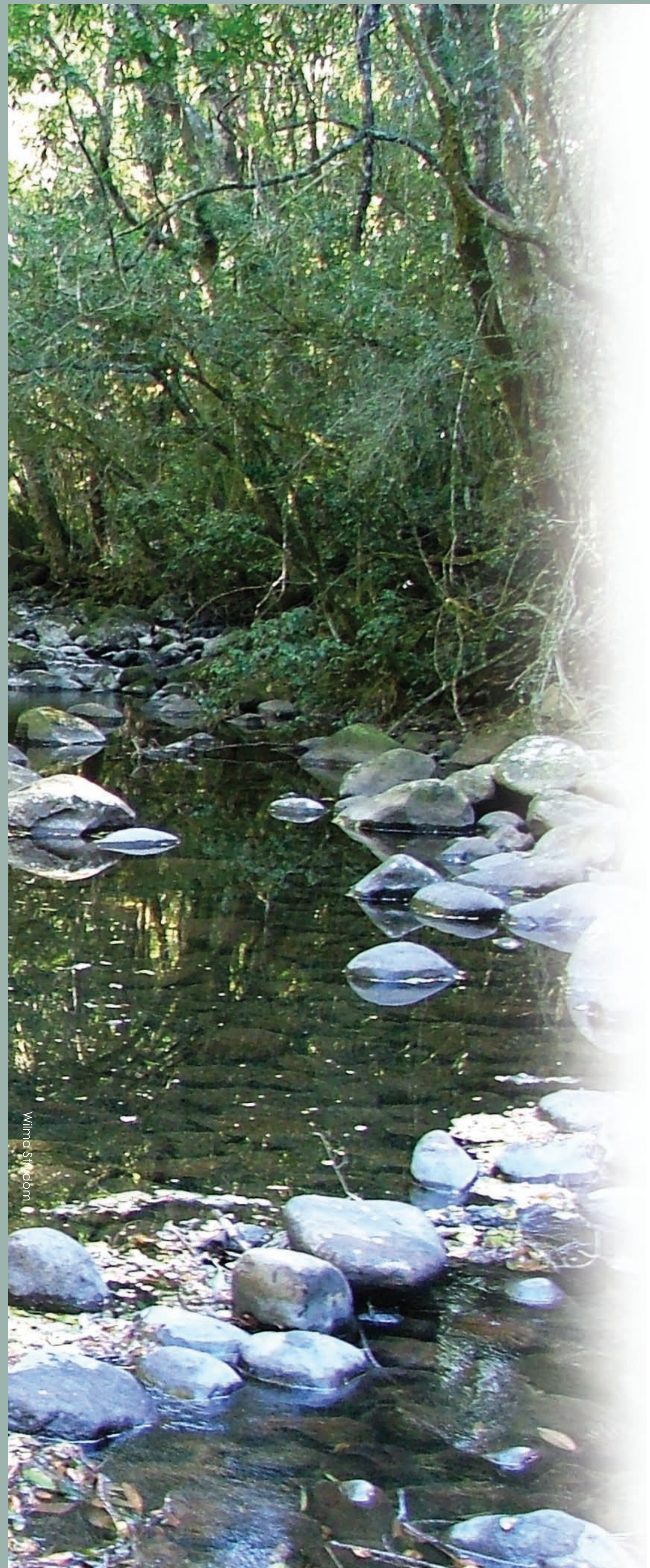
- An ***open source map viewer*** provides non-technical users with a user-friendly and easy-to-install interface that can be used to select different data layers for viewing, with the ability to zoom in and out of different regions.
- ***GIS data*** used in the atlas are provided for technical users in shapefile format together with associated metadata.
- ***Look-up table*** that lists the ecosystem types, species, biophysical processes and special features recorded within each river FEPA and Fish Support Area, according to unique sub-quaternary catchment codes shown on the FEPA maps in Part 2 of this atlas.
- ***PDFs of FEPA maps*** presented in Part 2 of this atlas that can be printed by users.
- An ***implementation manual*** describes how NFEPA products can be used in planning and decision-making processes by a range of sectors to support sustainable management of freshwater ecosystems. It also answers frequently asked questions regarding the project and its outputs, and provides freshwater ecosystem management guidelines for the key FEPA map categories.
- A ***technical report*** explains the scientific methods and stakeholder engagement process used to create the map products and the analysis of legal and institutional mechanisms available for implementing NFEPA products. It also reflects on insights gained from case study applications.
- ***Slide presentations*** of NFEPA are given in abridged and unabridged versions, with the former targeting a policy and implementation audience, and the latter a more scientific audience.

Alida Britz

Part 1: Introduction

This section describes:

1.1 The importance of healthy ecosystems, emphasising the need for sustainable development of water resources
1.2 Guiding principles that should direct the management of freshwater ecosystems in support of sustainable development
1.3 Major pressures on freshwater ecosystems
1.4 Systematic biodiversity planning: how it originated in terrestrial settings and has evolved to become applicable to freshwater settings, and how the approach was applied to identify Freshwater Ecosystem Priority Areas
1.4 History of freshwater biodiversity planning in South Africa: acknowledging the body of work and foundation on which the NFEPA project builds
1.5 Planning at different scales: resulting in a nested system of broad-scale and fine-scale plans



1.1 The importance of healthy ecosystems

Water affects every activity and aspiration of human society and sustains all ecosystems. Rivers, wetlands, lakes and estuaries have long inspired artists and musicians, enriching the human spirit with their beauty. Freshwater ecosystems provide for many of our fundamental needs: water for drinking and irrigation, food such as fish and waterbirds, and reeds for craftsmanship. Healthy ecosystems also provide important regulating ecosystem services, such as preventing floods and easing the impacts of droughts. A healthy ecosystem supports functional communities of plants and animals that are able to remove excess nutrients and toxic substances from water, keeping it cleaner for drinking, irrigation and recreation. Healthy rivers, wetlands and groundwater systems also maintain water supply and buffer the effects of storms, reducing the loss of life and property to floods. Healthy river banks with natural vegetation help to trap sediments, stabilise river banks and break down pollutants draining from the surrounding land. Estuaries provide nursery areas for marine and estuarine animals, and supply fresh water and nutrients to the sea, which drive marine food webs and maintain important fisheries (Lamberth et al. 2009).

Freshwater ecosystems provide for many of our fundamental needs: water for drinking and irrigation, food such as fish and waterbirds, and reeds for craftsmanship. Healthy ecosystems also provide important regulating ecosystem services, such as preventing floods and easing the impacts of droughts.

Water is also one of South Africa's most limited resources, constraining our future social and economic development. Its wise use is critical to the sustainable development of our emerging economy and the well-being of all our citizens, particularly the poorest, who depend directly on the health of natural resources for their livelihoods (Millennium Assessment 2003). Yet this valuable national asset is in crisis. Pressures arising from social and economic needs have resulted in widespread degradation of freshwater ecosystems. In many regions of the country water demand outstrips supply, and water quality has declined due to increased pollution from industry, urban expansion, mining, power generation, agriculture, forestry and inadequate sewage treatment. The National Biodiversity Assessment 2011 revealed that over half of our river, wetland and estuary ecosystem types in South Africa are threatened (Nel et al. 2011). Such widespread degradation of freshwater ecosystems inevitably compromises ecosystem service delivery and results in more costly management interventions and the loss of resilience to changing circumstances. This current situation is even more alarming when future pressures on water resources are considered – the demand for water is predicted to escalate dramatically (DWAF 2004) and many parts of the country are expected to become drier as a result of climate change, threatening our water supplies (Schulze 2005).

A focus on sustainable development becomes crucial given these current and future pressures on water resources. It is widely accepted that economic, social and ecological systems are inextricably bound (Figure 1.1). Protection and utilisation of natural resources therefore need to work hand-in-hand to achieve sustainable development. In the context of water resources management, this means that catchments can be designed to support multiple levels of use, with natural rivers and wetlands that are minimally-used supporting the sustainability of hard-working rivers that often form the economic hub of the catchment. This concept is firmly embedded in the National Water Act, and forms the foundation of the water resources classification system (Dollar et al. 2010). Keeping some rivers and wetlands in the catchment in a natural or good condition serves a dual purpose of conserving South Africa's freshwater biodiversity and promoting the sustainable use of water resources in the catchment. This is particularly important if we are to meet government objectives for both sustainable water resources development and freshwater biodiversity conservation. The question remains: which rivers and wetlands, and how many, should be maintained in a natural condition to support these two goals?

Healthy freshwater ecosystems support human needs – without them, social and economic development is not possible. South Africa's freshwater ecosystems are under enormous pressure and have already been substantially degraded, with more than half of our river and wetland ecosystem types classified as threatened.

The NFEPA maps presented in this atlas represent a joint effort between the water and biodiversity sectors to incorporate freshwater ecosystem goals into water resource planning and management.

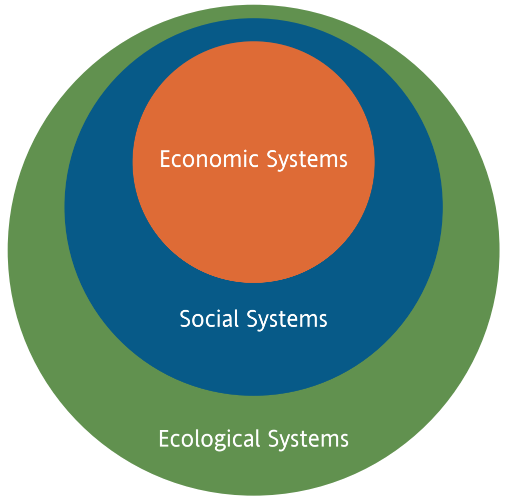


Figure 1.1: Economic, social and ecological systems are inextricably bound. The health of our ecological systems and associated natural capital underpins social and economic growth.

The NFEPA project addresses this question by synthesising data and existing knowledge to identify strategic Freshwater Ecosystem Priority Areas, or FEPAs, for promoting sustainable water resource use and achieving the freshwater ecosystem goals of the country (Roux et al. 2006). The resulting maps and supporting information represent a joint effort between the water and biodiversity sectors to incorporate freshwater ecosystem goals into integrated water resource planning and management in terms of the National Water Act. These map products should be used in conjunction with the Implementation Manual for Freshwater Ecosystem Priority Areas, which can be found on the accompanying DVD (see page 1 of this atlas for the full suite of NFEPA products).

1.2 Guiding principles for managing freshwater ecosystems

Below are eight principles that should guide the management of freshwater ecosystems in support of sustainable development. These principles informed the identification of FEPAs.

Principle 1: Fresh water flowing out to sea is not wasted

Freshwater inputs to estuaries and the sea are necessary to maintain important ecological processes that keep our marine resources healthy. For example, fresh water provides an important environmental cue that helps fish and other marine animals find their way to estuary mouths to breed. Nutrients in fresh water also form the foundation of marine food webs. These ecological processes are vital for maintaining commercial and recreational fish stocks, as well as for providing a source of food to poor coastal communities that depend directly on marine resources for food. A certain amount of water is also required to flush and scour the mouth of most estuaries. Without the scouring effect, sediments build up at the mouth and the risk of back-flooding during storms increases. Artificial breaching of an estuary mouth to minimise this risk is expensive and damages estuarine ecosystems. Apart from the scouring effect, fresh water helps to flush estuaries of organic matter and other pollutants, which otherwise smell unpleasant. If too much water is taken out of a river along its length, not enough fresh water reaches the estuary and the sea to maintain these vital ecological processes.

Principle 2: Freshwater ecosystems are connected systems that require a source-to-sea approach

No single ecosystem component can be meaningfully managed in isolation from its connected aquatic ecosystems – be they rivers, wetlands, groundwater, estuaries or marine ecosystems. What happens upstream or in the surrounding landscape affects downstream ecosystems and their ability to provide ecosystem services. The now commonly acknowledged whole-catchment approach should be taken further to become a source-to-sea approach, because freshwater inputs impact significantly on estuarine and marine environments, and the ecosystem services they deliver.

Principle 3: Healthy tributaries and wetlands support the sustainability of hard-working rivers

Freshwater ecosystems in a catchment can be designed to support different levels of use, with natural rivers and wetlands that are minimally-used supporting the sustainability of heavily-used rivers and wetlands that often form the economic hub of the catchment. In many catchments, the desired condition of the estuary (as agreed on through negotiations between stakeholders) will be a determining factor in the management of upstream water resources connected to the estuary. To ensure that some tributaries and wetlands stay healthy, a catchment can be zoned for varying degrees of use and impact. For example, FEPAs should be zoned for low impact activities; surrounding secondary zones can allow moderate impact activities; and heavily impacting activities such as high-intensity agriculture, plantation forestry and mining, can be restricted to high impact zones. In addition, buffers of natural vegetation around all freshwater ecosystems support the maintenance of healthy freshwater ecosystems (see principle 4).

Principle 4: Healthy riparian, wetland and estuary buffers reduce the impact of land-based activities

Freshwater ecosystems are generally the lowest point in the landscape, making them the receivers of wastes, sediment and pollutants in runoff. This, combined with the strong connectivity of freshwater ecosystems, means that they are highly susceptible to upstream, downstream and upland impacts. Managing land-based impacts is therefore essential. While it is seldom feasible for entire catchments to be 'locked away' from human use, catchments can be designed to incorporate varying levels of use and impacts on freshwater ecosystems as discussed in principle 3. Buffers of natural vegetation around all freshwater ecosystems, even heavily-used ones, go a long way to reducing the effects of damaging land-use practices (such as agricultural activities close to river banks). The effective width of the buffer should be determined on a site-specific basis. The Implementation Manual for FEPAs (available on the NFEPA DVD) provides some recommendations for delineating management buffers.

Principle 5: Groundwater sustains river flows, particularly in dry seasons

Groundwater abstracted from boreholes in or close to rivers, streams or wetlands has a very direct influence on river flow, and should be not be viewed as an additional water resource. Such groundwater plays an important role in sustaining river flows ('base flows') and supporting refuge pools in the dry season. Apart from the human benefits of maintaining river flows in the dry season, refuge pools in seasonal rivers support water-dependent animals that would otherwise not survive when the rivers dry up. Healthy riparian zones (river banks and their surrounds), which filter pollutants that drain from the land, are also often maintained by groundwater. When groundwater has very weak links to surface water (such as in deep, confined aquifers) it may be possible to abstract it without significantly impacting on freshwater ecosystems; however, long term impacts are not well understood.

Principle 6: Rivers provide ecological corridors in an increasingly fragmented landscape

Rivers form important ecological corridors from water source areas all the way down to the sea. These river corridors support land and water-based ecosystem processes and biodiversity that depend on connectivity. The loss of connectivity between different parts of a catchment fundamentally alters ecosystem processes and associated services, and negatively affects biodiversity. Such landscape connectivity provides social and ecological resilience, especially within a changing climate. This contributes to ecosystem-based adaptation to climate change.

Principle 7: Managing freshwater ecosystems requires strong cooperation across multiple sectors

The effective protection of freshwater ecosystems requires close coordination and cooperation among the sectors responsible for protection and management of water resources, biodiversity conservation, land-use management (including agricultural resources), and integrated development planning. Coordination and cooperation can be greatly enhanced through a skilled facilitating organisation that can play an intermediary role between the water user, science and policy domains. SANBI, provincial conservation authorities and Catchment Management Agencies are well-placed to play such a role in freshwater ecosystem conservation.

Principle 8: A strategic and systematic approach to conserving freshwater ecosystems is needed

The intensity of the pressures on freshwater ecosystems means that we cannot manage impacts just on a river-by-river or wetland-by-wetland basis. A strategic approach to planning and setting priorities is essential, to focus conservation efforts where they will have the greatest impact. Systematic biodiversity planning provides a spatial planning tool for achieving this. With its overarching goal of planning for the long-term persistence of biodiversity, systematic biodiversity planning identifies those areas that are essential for conserving biodiversity. Spatial priorities are based on achieving representation of the full spectrum of freshwater ecosystems and associated biodiversity within the region of concern. A systematic biodiversity planning approach was used in the development of the NFEPA maps (see Section 1.4 below).

1.3 Major pressures on freshwater ecosystems

Many pressures contribute to the degradation of freshwater ecosystems, and it is often difficult to isolate a single cause.

1.3.1 Flow alteration

Flows can be altered either by removing water from a freshwater ecosystem or adding more water through return flows or water transfer schemes. Altering the flow regime (e.g. timing, frequency, speed or volume of flow) changes river channel characteristics and habitats. This alters the functioning of freshwater ecosystems and has a profound and often negative effect on freshwater plants and animals. Flow alteration ranges from large-scale projects such as the building of large dams and water transfer schemes, to local alterations that are individually small but have significant cumulative impacts. In South Africa, most large rivers are heavily utilised and regulated to improve water security, and large dams can store up to two thirds of the country's total annual runoff. Water transfer schemes are also widespread across the country to cater for areas where water demand exceeds the natural supply of water. There is growing concern around the cumulative impact of small farm dams which have been shown to have substantial impact on the quality and quantity of waters in South African rivers (Mantel et al. 2010), and threaten the sustainability and longevity of large dams within the associated catchments (Boardman et al. 2009).

The single biggest pressure on South Africa's freshwater ecosystems is alteration of flow, for example through building dams or transferring water between catchments.

Lindie Smith-Adao

1.3.2 Water pollution

Pollution threatens freshwater ecosystems and available water resources, posing health risks to South African society. Pollution sources include industrial and mining effluent, agricultural pesticides and fertilizers, and domestic effluent including sewage.

Pollution of water is a very serious and growing problem in South Africa, especially as failing water treatment infrastructure battles to treat the increasing domestic and industrial effluent from towns and cities. Many industrial processes produce waste containing harmful chemicals that are sometimes discharged directly into sewers, rivers or wetlands. Pollution from agricultural pesticides and fertilizers washing into rivers or leaching into groundwater is a major problem, exacerbated by decreased dilution capacities that result from over-abstraction of water. These problems can increase the salinity and nutrient loads of water resources, processes that are respectively known as 'salinisation' and 'eutrofication'. Salinisation and eutrophication impact human health, the utility of water resources for agriculture and industry, and the structure and functioning of freshwater ecosystems.

Wilda Basson

Acid mine drainage

Peter Chadwick/WWF-SA

Eutrophication

1.3.3 Destruction or degradation of natural habitat

Habitat destruction or degradation includes direct impacts (such as bulldozing and planting of crops in wetlands or river channels) and indirect impacts (such as clearing natural vegetation in the surrounding catchment, resulting in increased sediment loads and erosion). Wetland ecosystems have been particularly hard hit: in agricultural areas they have been predominantly dammed or drained for cultivation, and in urban areas they are frequently completely transformed by infrastructure development. The widespread destruction and modification of river banks is a major problem as this reduces the filtering capacity that healthy buffers of natural vegetation provide and destroys freshwater plant and animal habitat (see principle 4 in Section 1.2).

Destruction of river banks and wetlands, for example by ploughing or building infrastructure, results in often irreversible damage to freshwater ecosystems and their ability to provide ecosystem services.

Alien vegetation

Roxanne Klein

1.3.4 Invasive alien species

Invasive alien plant species have a substantial impact on riverine habitat and water yield, consuming an estimated 7% of South Africa's total annual runoff. The Working for Water programme in South Africa has created considerable awareness of the problems associated with invasive alien plant water use.

Invasive alien plants impact on river habitat and water yield. Invasive alien fish such as bass and trout, often introduced for aquaculture or recreational fishing, disrupt ecosystem functioning and are the number one threat to indigenous fish species.

Less awareness exists around the threats posed to freshwater ecosystems by invasive alien fish, such as trout, bass and carp. These species are often introduced to river systems for aquaculture and recreational fishing. Even when invasive alien fish are not directly introduced in rivers, they often escape from farm dams in which they are stocked (e.g. when the dam wall is breached in floods). Invasive alien fish now occur extensively in most large rivers in South Africa, and impact on indigenous freshwater plants and animals through altering habitats, competing for resources and eating indigenous plants and animals. Invasive alien fish present a grave threat to indigenous fish species and have led to local extinctions in some river systems. Invasive alien fish have also been associated with loss of invertebrates such as dragonflies. Un-invaded streams (often the smaller tributaries of large rivers) frequently serve as the last remaining refuges for indigenous freshwater species. Preventing invasions of alien fish in un-invaded streams is crucial, as controlling or eradicating invasive alien fish is difficult and expensive. Weirs can be useful for preventing upstream invasions, although an assessment of the environmental impact of the weir to the entire freshwater ecosystem should be done prior to construction.

Obstructing river flow

Ernst Swartz

1.3.5 Climate change

Predicted changes in rainfall and temperature will impact on water resources. These changes are likely to have a disproportionately large impact on runoff and river flow (Schulze 2005), with implications for future planning and management of water resources, especially around extreme events such as droughts and floods. For example, keeping rivers and wetlands healthy will help to regulate flow and reduce the risk of flooding. Climate change is also likely to impact on freshwater species. Animals may need to move to rivers at higher altitude with cooler stream temperatures, and barriers in the river channel (such as dams) could restrict such movement.

Changes in rainfall and temperature as a result of climate change are likely to have a large impact on river flows. Keeping freshwater ecosystems healthy will help them adapt to these changes with least disruption to ecosystem services.

Habitat destruction

Ernst Swartz

1.4 Systematic biodiversity planning

Systematic biodiversity plans identify geographic priority areas that need to stay in a natural or near-natural condition to support sustainable development. The systematic approach is embedded in policy and practice in South Africa, and represents the best available science in this field.

Systematic biodiversity planning is a strategic and scientific approach to identifying those areas that are the most important for biodiversity conservation. The key objectives of systematic biodiversity planning are to ensure that all ecosystems and species are represented, that key ecological processes are kept intact, and that this is achieved in the smallest, most efficient area possible (Margules and Sarkar 2007).

Systematic biodiversity planning in South Africa is firmly embedded in both policy and practice. The National Biodiversity Framework requires provinces to develop provincial biodiversity plans. The National Protected Area Expansion Strategy is founded on systematic biodiversity planning principles, providing the strategy to guide national and provincial authorities in the expansion of the country's protected areas over the next 20 years. Bioregional plans published in terms of the Biodiversity Act must use a systematic biodiversity planning approach to identify Critical Biodiversity Areas and Ecological Support Areas, and must integrate priorities for terrestrial and freshwater ecosystems. Examples of such maps can be found on SANBI's Biodiversity GIS website (http://bgis.sanbi.org). NFEPA can be used as the freshwater input into an integrated systematic biodiversity planning exercise to develop Critical Biodiversity Areas and Ecological Support Areas for provincial biodiversity plans and bioregional plans in terms of the Biodiversity Act. For recommendations on how to accomplish this, the reader is referred to the NFEPA technical report available on the NFEPA DVD or on SANBI's Biodiversity GIS website (http://bgis.sanbi.org).

Systematic biodiversity plans focus on ecosystems, species, ecological processes and connectivity. Freshwater biodiversity plans use sub-catchments as planning units, reflecting the need to manage not just the water resource itself but also the surrounding land.

1.4.1 History of systematic biodiversity planning

Systematic biodiversity planning has had almost three decades of research and practice in the terrestrial realm, but has only recently been applied to freshwater settings. The evolution of systematic biodiversity planning has led to a greater applicability of the science to freshwater ecosystems, with much of the new ground being pioneered in South Africa (Balmford 2003; Roux et al. 2002; Nel et al. 2009a).

Systematic biodiversity planning emerged as a field of science in response to the realisation that *ad hoc* approaches to conservation, where areas were protected for reasons unrelated to their biodiversity, were not delivering the best bang for the conservation buck (Figure 1.2). The first strategic attempts at identifying priority areas were focused largely on identifying lists of sites that freshwater scientists knew were of conservation importance based on their experience in the field. This approach was further advanced by developing scoring systems for comparing the relative importance of different sites, based on attributes such as habitat diversity, naturalness, representativeness, rarity, species richness and special features (Figure 1.2). Using scoring approaches to prioritise conservation action can be problematic. Choosing high scoring areas over low scoring ones has a tendency to undermine representation even if representativeness is a criterion that is scored and heavily weighted. Early efforts in systematic biodiversity planning focused very much on addressing the issue of representation through setting explicit biodiversity targets for representation, and achieving these targets in an efficient manner by choosing areas that complement, rather than duplicate, their biodiversity features.

The first systematic biodiversity plans focused on representation of terrestrial biodiversity in an efficient set of protected areas (Figure 1.2). By the late 1990s, the scope had expanded to include planning for the persistence of biodiversity, recognising that many natural processes responsible for maintaining biodiversity will not persist if they are not explicitly incorporated into the identification of spatial priority areas. The focus on protected areas was also broadened to incorporate planning within multi-functional landscapes with the outputs of biodiversity plans aimed not only at directing the expansion of the protected area network, but also at informing land-use planning and day-to-day decisions made about land use throughout the landscape (Cadman et al. 2010). In response to the many calls for science to have more impact on the ground, the trend of the 2000s is to plan for implementation of the biodiversity planning outputs, embedding the entire exercise in a stakeholder-driven implementation process, and designing maps and accompanying guidelines that are tailored to meet user needs (Figure 1.2). An even more recent advance in systematic biodiversity planning is to use it in planning for ecosystem-based adaptation to climate change, by incorporating biophysical features that provide climate change resilience into the identification of spatial priority areas (e.g. altitudinal gradients).

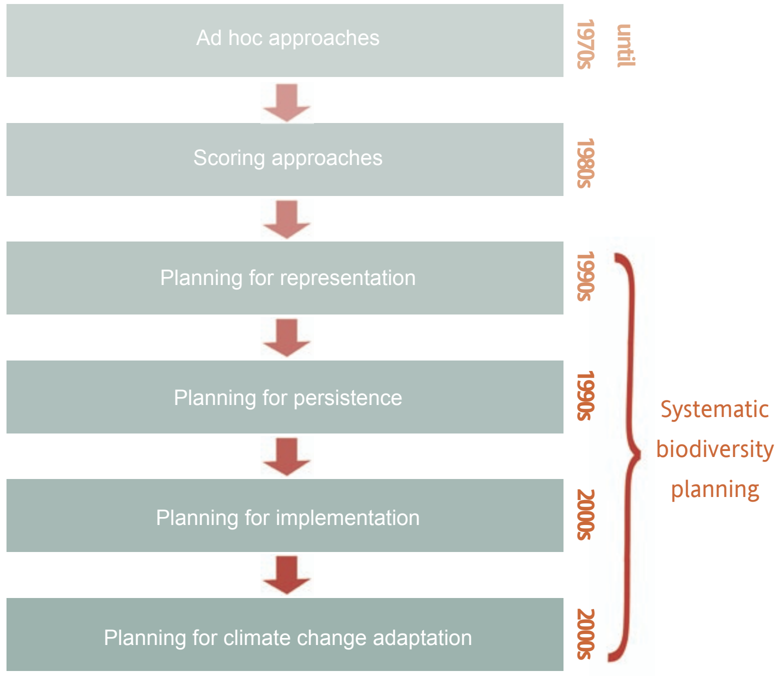


Figure 1.2: Evolution of systematic biodiversity planning approaches in South Africa

Planning for persistence as well as representation, and planning with a view to informing a range of land uses rather than just the location of protected areas, were important advances in the applicability of systematic biodiversity planning to freshwater ecosystems. Given the connectivity of freshwater ecosystems, a focus on representing biodiversity in isolated areas, without regard for upstream, downstream or upland areas, is conceptually flawed. It is also seldom feasible to declare whole catchments as protected areas, and therefore varying levels of protection, ranging from high to low use-restrictions, are needed. The mid-2000s were characterised by a growing momentum in systematic biodiversity planning for freshwater ecosystems, with several important advances (Nel et al. 2009a; Linke et al. 2011). All freshwater biodiversity plans use sub-catchments as planning units, thereby incorporating the need to manage the water resource of concern as well as the surrounding land (Lehner et al. 2006; Thieme et al. 2007). Many include the development of a river tree-network that can be used to assess upstream-downstream linkages (Moilanen et al. 2008). Most plans also consider some form of multiple-use zonation in which different levels of protection are recommended depending on the role that sub-catchment fulfils in achieving biodiversity goals (Abell et al. 2007; Thieme et al. 2007). For example, the maps of Freshwater Ecosystem Priority Areas in this Atlas show categories that are broadly based on diminishing use restrictions: *Freshwater Ecosystem Priority Areas ('FEPAs')* focus on representing natural or near-natural examples of freshwater ecosystems, and management is therefore fairly restrictive; Fish Support Areas need to be maintained in a condition that supports the fish populations they contain – this need not be a natural or near-natural condition; Upstream Management Areas require management only to ensure that human activities do not degrade the condition of FEPAs and Fish Support Areas that occur downstream.

Key steps in the systematic biodiversity planning framework are shown in Figure 1.3, along with examples of supporting information that were used in NFEPA to implement this stepwise planning framework.

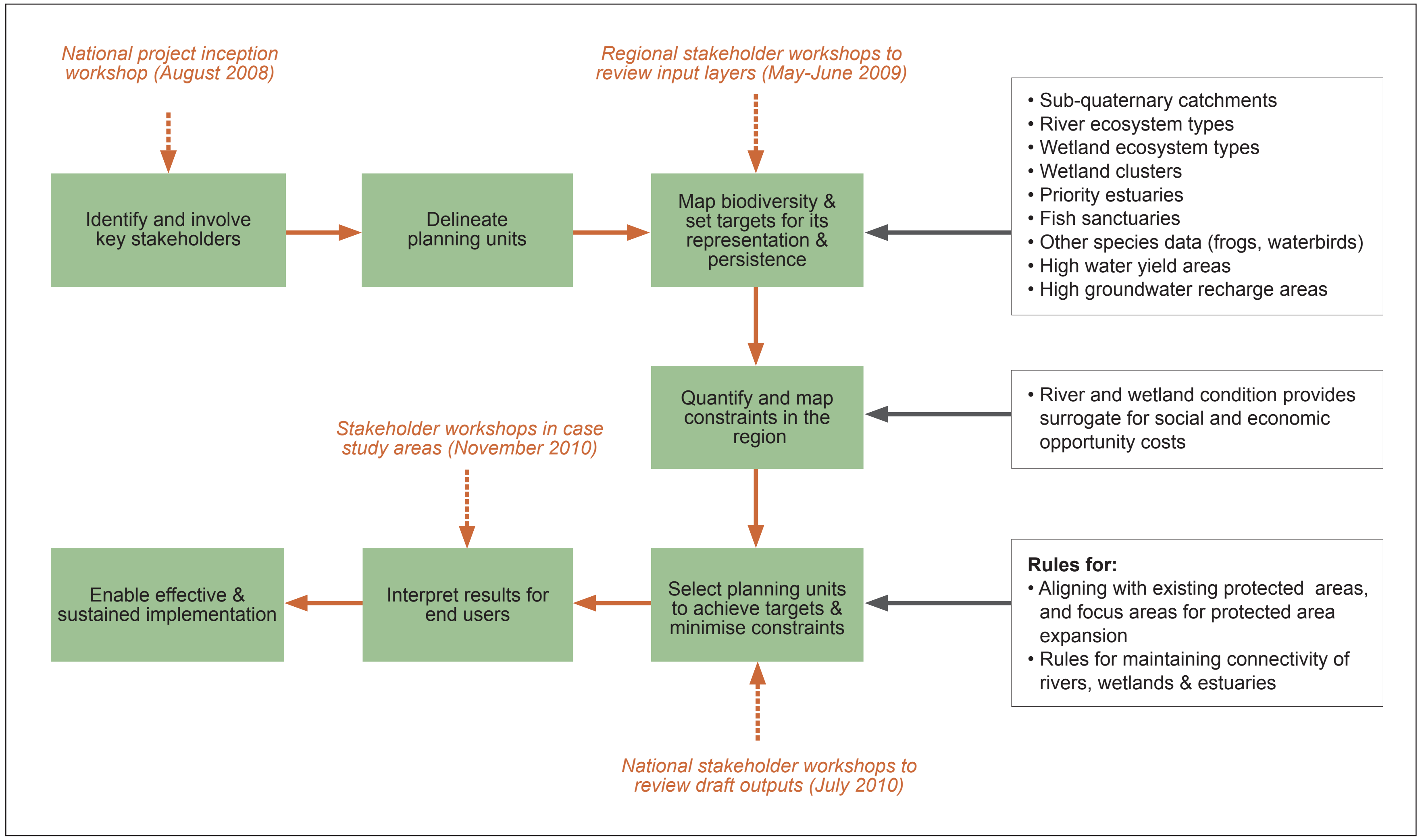


Figure 1.3: The stepwise biodiversity planning framework (green boxes) that guided the NFEPA approach, including the data (white boxes) that were used in each step, and stakeholder workshops that were held

1.5 History of freshwater biodiversity planning in South Africa

Biodiversity planning is not new in South African freshwater science. Some three decades ago, our freshwater ecologists had already recognised the need to make strategic use of limited conservation resources. Since the 1970s and at about 10-year intervals, four planning exercises have been undertaken for different aspects of South Africa's freshwater biodiversity, identifying strategic priority areas using advancing approaches to biodiversity planning (Figure 1.2).

In the 1970s, Graham Noble evaluated the conservation status of 40 aquatic biotopes and made recommendations for the conservation of 25 sites, recommending formal conservation within protected areas (Figure 1.4a: Noble 1974). These biotopes were descriptive but not spatially explicit and the sites that were recommended for conservation were relatively well known by experts rather than chosen in a systematic way. In the 1980s, 144 "sites of outstanding conservation importance", were spatially identified across the country as a starting point for conservation action (Figure 1.4b: O'Keeffe 1986). These were based on expert opinion of importance rather than a systematic analysis of river ecosystem types and species, recognising that "until we can classify our rivers and river zones in detail, management of different priorities will at best be haphazard" (O'Keeffe et al. 1989). In the 1990s, a spatially explicit and systematic biodiversity plan was developed for freshwater fish species in South Africa (Skelton et al. 1995). Twenty quarter degree squares (15' x 15') of "maximum importance" were identified as the minimum set of sites that would together protect each species at least once (Figure 1.4c).

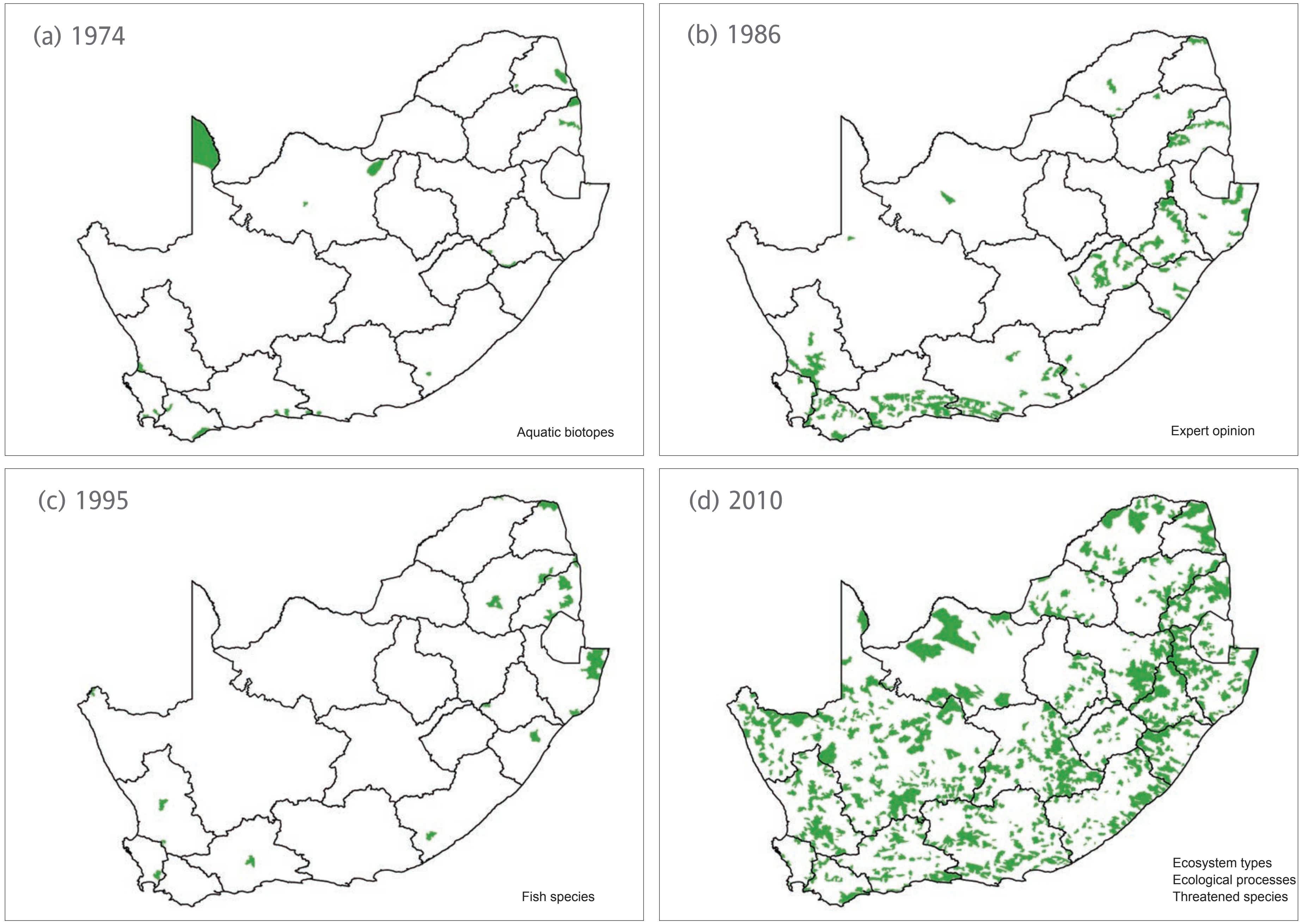


Figure 1.4: Strategic priority areas that have been identified since the 1970s using advancing approaches to systematic biodiversity planning

Several sub-national freshwater biodiversity plans undertaken in the mid-2000s, together with the development of key national GIS layers over the last decade, provided an effective basis for undertaking a national systematic biodiversity plan for freshwater ecosystems.

As discussed in Section 1.4, the 1990s signified a giant leap forward in South Africa's ability to identify priority areas using systematic biodiversity planning approaches, and today the country is at the forefront in this field (Balmford 2003). As early as 1999, aquatic ecologists were exploring the potential use of systematic biodiversity planning for freshwater ecosystems of the Cape Floristic Region of South Africa (Van Nieuwenhuizen and Day 2000). The first ever published application of systematic biodiversity planning to freshwater ecosystems arose from a South African project addressing the strategic expansion of the Greater Addo Elephant National Park (Roux et al. 2002). These methods and data were developed, refined and piloted for six of South Africa's 19 Water Management Areas in 2006, namely the Fish-to-Tsitsikamma, Inkomati, Olifants, Usutu-Mhlathuze, Crocodile (West) and Marico, and Olifants-Doorn (Kotze et al. 2006; Nel et al. 2006a; Nel et al. 2006b; Smith-Adao et al. 2006). Development of these methods was greatly facilitated by advances in available GIS data such as river ecoregions (Kleynhans et al. 2005), geomorphic provinces (Partridge et al. 2010), longitudinal zonation of rivers (Rowntree and Wadeson 1999), estimated ecological condition for major river systems (Kleynhans 2000), and availability of national land cover at a 30 metre resolution (Van Den Berg et al. 2008).

The technical advances in freshwater biodiversity planning were also supported by a concurrent cross-sectoral policy process between several national government departments and national agencies (Roux et al. 2006). This policy process played an important role in providing a politically accepted national biodiversity target for South Africa's freshwater ecosystems: participating departments and organisations agreed to maintain at least 20% of each major freshwater ecosystem type in South Africa in a good condition. This 20% target should be refined as new scientific knowledge arises.

The work outlined above built the scientific competence necessary to undertake systematic biodiversity planning for freshwater ecosystems at a national level. It also promoted broad institutional support for the products of such an exercise. The NFEPA project embarked on this ambitious venture in August 2008, synthesising current knowledge and identifying national priority areas for freshwater ecosystems (Figure 1.4d). It is intended that this project too will be updated, most likely on a ten-year cycle.

1.6 Biodiversity planning at different scales

Biodiversity planning can be done at a range of spatial scales from broad global assessments, to regional, national, catchment and sub-catchment assessments (Figure 1.5). The most appropriate scale depends on the types of questions that need to be addressed and how the resulting maps are to be used. The spatial scale at which planning is undertaken should determine the resolution of the input data, such as the detail of the river network used and the resolution of the data used to classify freshwater ecosystems and their ecological condition. The finer the scale of interest, the finer the resolution of data required. Importantly, finer scale planning is not necessarily required across the entire landscape; with limited resources it makes sense to focus fine-scale planning initiatives on priority areas that have been identified in a broader scale systematic biodiversity plan such as NFEPA. This results in a nested system of broad-scale and fine-scale plans.

NFEPA provides a national assessment that is at a fine enough scale to be used meaningfully in Water Management Areas and provinces, identifying priorities at sub-quaternary catchment scale.

FEPAs have been identified at the sub-quaternary catchment scale (Figure 1.6). Sub-quaternary catchments are watersheds that are approximately nested in the Department of Water Affairs quaternary catchments (Midgley et al. 1994). The watershed of a sub-quaternary catchment is delineated around each river reach, where a river reach is defined as the portion of river between river confluences on the Department of Water Affairs 1:500 000 river network GIS layer. The maps of FEPAs (Part 2 of this atlas) are at a resolution suitable for planning at the level of a Water Management Area, for processes such as catchment visioning, water use scenario planning and water resource classification.

Each FEPA needs a management plan that identifies the key wetland and river habitats for which it was selected, delineates management buffers around these, and addresses specific pressures that may impact on its conservation. In some instances it may be sensible to develop management plans for groups of FEPAs, Fish Support Areas and Upstream Management Areas. A look-up table is provided on the accompanying DVD that lists the ecosystem types, species, biophysical processes and special features recorded within each river FEPA and Fish Support Area, according to unique sub-quaternary catchment codes as shown in Part 2 of this atlas.

FEPAs have also been summarised to a coarser level of resolution, providing maps of the density of Freshwater Ecosystem Priority Areas per Water Management Area (Section 3.1) and sub-Water Management Area (Section 3.2). These maps are intended to initiate a dialogue on policy mechanisms that are needed to support the implementation of national freshwater ecosystem goals, recognising that responsibility for achieving these is spread unevenly across the country.

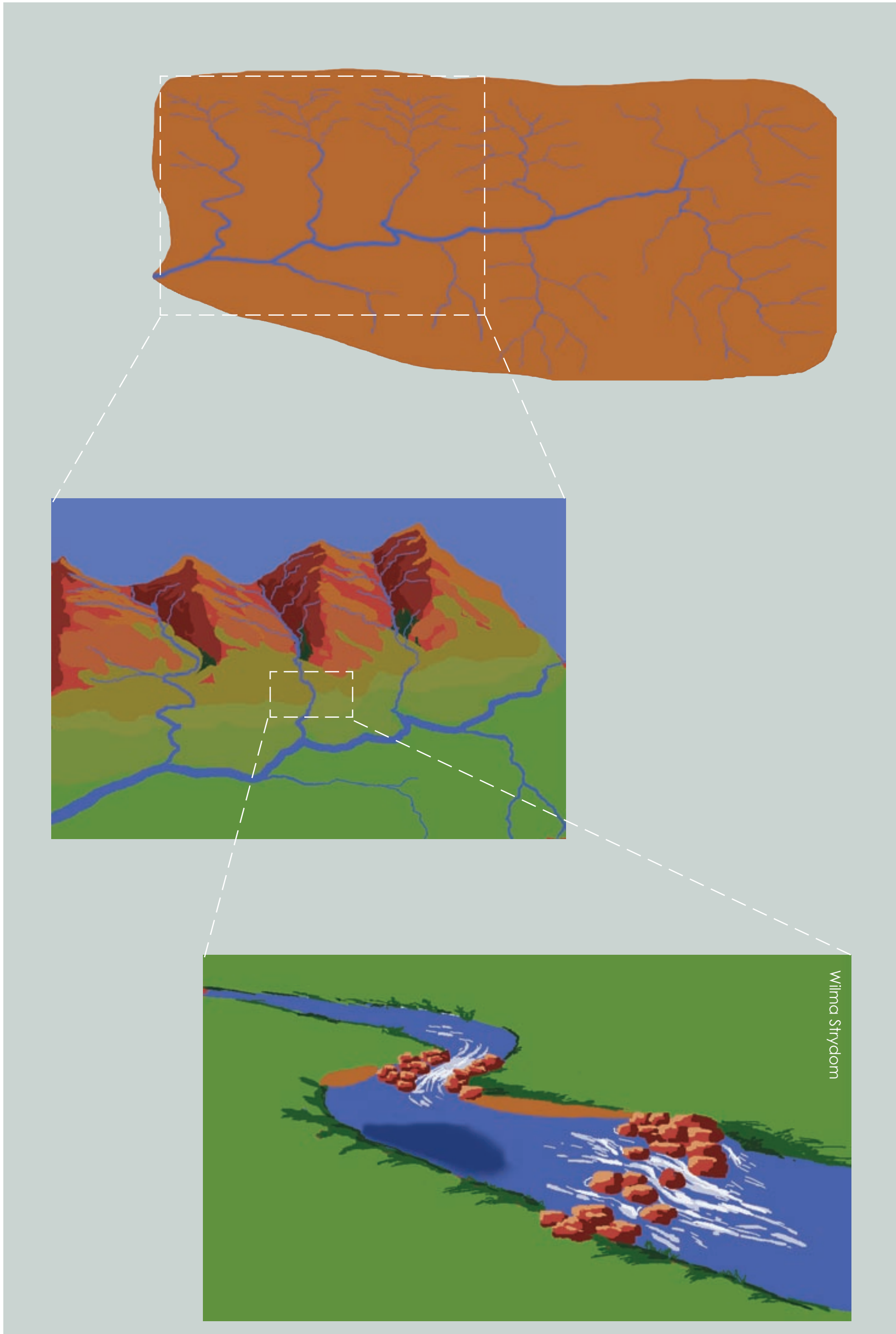


Figure 1.5: Planning for freshwater ecosystem conservation and management should take place at a hierarchy of spatial scales. Broad-scale plans inform the focus of finer levels of biodiversity planning and management, from identifying the relative importance of large primary catchments all the way through to managing priority river reaches and their component priority habitats such as pools and riffles.

At a finer scale of planning, FEPAs and Fish Support Areas can be used as the basis for identifying Critical Biodiversity Areas and Ecological Support Areas used in provincial biodiversity plans and bioregional plans. These plans integrate priority areas for freshwater ecosystems with those for terrestrial ecosystems. Critical Biodiversity Areas are similar to FEPAs and need to remain in a natural or near-natural condition to conserve biodiversity and ecological functioning. Ecological Support Areas are similar to Fish Support Areas and Upstream Management Areas, and need to be managed to prevent degradation of Critical Biodiversity Areas. Using FEPA maps as a basis for identifying Critical Biodiversity Areas and Ecological Support Areas requires, at a minimum, setting a rule for generating variable-width buffers around FEPAs, and assigning Ecological Support Areas to the smaller stream network within sub-quaternary catchments containing river FEPAs (using the 1:50 000 river GIS layer). For recommendations on how to accomplish this, the reader is referred to the NFEPA technical report available on the NFEPA DVD or on SANBI's Biodiversity GIS website (http://bgis.sanbi.org).

Provincial biodiversity plans and district-level bioregional plans integrate priority areas for freshwater and terrestrial ecosystems. FEPA maps will feed into the identification of Critical Biodiversity Areas and Ecological Support Areas in these plans.

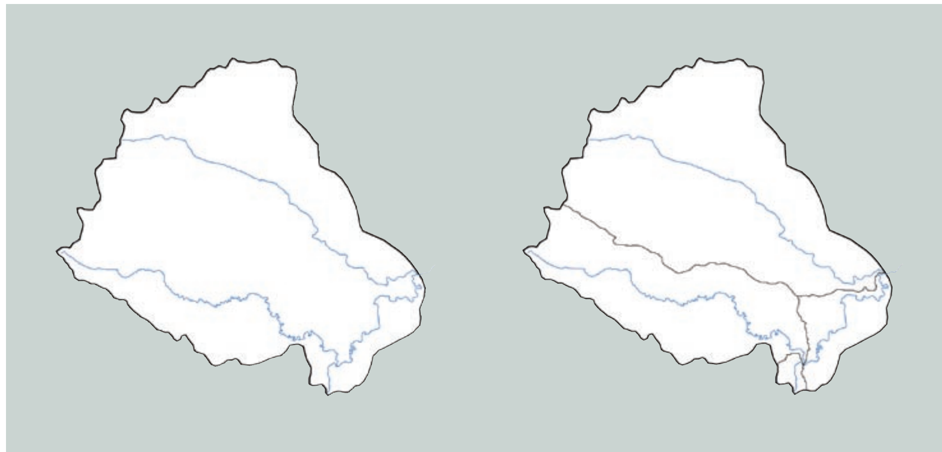


Figure 1.6: Quaternary catchments of South Africa were split into sub-quaternary catchments using the Water Affairs 1:500 000 river network. Sub-quaternary catchments are on average six times smaller than quaternary catchments.

Part 2: Freshwater Ecosystem Priority Area maps for Water Management Areas

This section includes:

FEPA maps show Freshwater Ecosystem Priority Areas, Fish Support Areas and Upstream Management Areas. A range of criteria were used to identify FEPAs, including criteria dealing with ecosystems, ecosystem services and species.

This section of the atlas provides a map for each Water Management Area showing Freshwater Ecosystem Priority Areas (FEPAs), as well as Fish Support Areas and Upstream Management Areas.

South Africa has 19 Water Management Areas used as administrative and management units for implementing water policy and legislation. Catchment Management Agencies are in the process of being established for Water Management Areas or groups of Water Management Areas. Water Management Areas are delineated using catchment boundaries and do not match provincial or municipal boundaries (Figure 2.1).

FEPA maps provide the basis for the biodiversity sector's input into Catchment Management Strategies, water resource classification, reserve determination, and resource quality objectives, all undertaken in terms of the National Water Act.

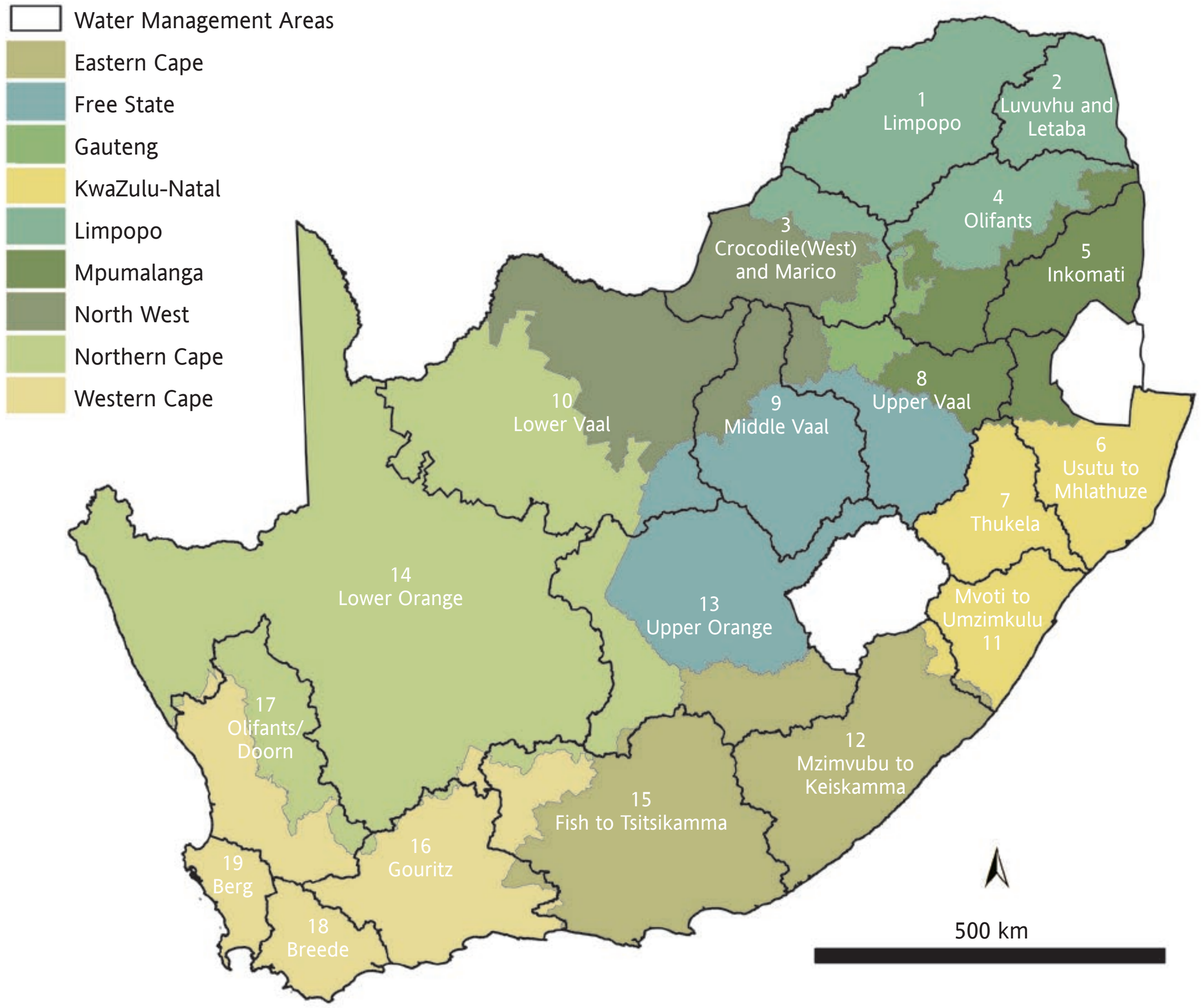


Figure 2.1: Map of South Africa showing Water Management Area and provincial boundaries

2.1 Introduction to Freshwater Ecosystem Priority Area maps

FEPA maps show rivers, wetlands and estuaries that need to stay in a good condition in order to conserve freshwater ecosystems and protect water resources for human use. River FEPAs are often tributaries that support hard-working mainstem rivers, and are an essential part of an equitable and sustainable water resource strategy. This does not mean that FEPAs need to be fenced off from human use, but rather that they should be supported by good planning, decision-making and management to ensure that human use does not impact on the condition of the ecosystem. The current and recommended condition for all river FEPAs is A or B ecological category (see Table 2.1 for a summary of ecological categories and Table 4.1 for more detailed descriptions of the categories). Wetland FEPAs that are considered in less than a good condition should be rehabilitated to the best attainable ecological condition.

River FEPAs should remain in good condition (A or B ecological category) and wetland FEPAs should remain in good condition or be rehabilitated to their best attainable ecological condition. Upstream Management Areas need to be managed to prevent degradation of downstream FEPAs.

Table 2.1: Present ecological state categories used to describe the current and desired future condition of South African rivers (after Kleynhans 2000). For NFEPA, rivers in an A or B category were regarded as being in good condition.

Ecological category	Description
A	Unmodified, natural
B	Largely natural
C	Moderately modified
D	Largely modified
E	Seriously modified
F	Critically/Extremely modified

Each sub-quaternary catchment has a unique code, which can be used to look up further information about the river FEPAs and Fish Support Areas in that sub-quaternary catchment, using the look-up table on the NFEPA DVD.

FEPA maps support several policy processes in terms of the National Water Act, the Biodiversity Act and the Protected Areas Act (Box 2.1). They provide the basis for the biodiversity sector's input into policy processes provided under the National Water Act, such as the development of Catchment Management Strategies, water resource classification, reserve determination, and the setting and monitoring of resource quality objectives. FEPA maps also support the listing of threatened ecosystems, and the development of provincial biodiversity plans, bioregional plans and biodiversity management plans in terms of the Biodiversity Act. In addition, FEPA maps should inform the implementation of protected area expansion in terms of the Protected Areas Act, including through biodiversity stewardship programmes. The Implementation Manual for FEPAs (available on the NFEPA DVD or at http://bgis.sanbi.org) provides further detail on how to use FEPAs in policy processes that support the management and conservation of freshwater ecosystems.

Peter Chadwick/WWF-SA

Box 2.1. Policy mechanisms supported by Freshwater Ecosystem Priority Area maps

This box summarises some of the key policy mechanisms for managing and conserving freshwater ecosystems, which should be informed by FEPA maps. For more detail see the Implementation Manual for FEPAs (available on the NFEPA DVD or at http://bgis.sanbi.org).

National Water Act

- ***Catchment Management Strategies:***
  FEPA maps form the core of the biodiversity sector inputs into a Catchment Management Strategy, including the biophysical situation assessment, catchment visioning, water resource protection strategy, and scenario planning, as set out in the Guidelines for the Development of Catchment Management Strategies (DWAF 2007).

- ***Water resource classification:***
  River, wetland and estuary FEPAs should be regarded as significant water resources. The location of FEPAs should be used to prioritise the allocation of resource unit nodes, which should be sited immediately downstream of FEPAs. Water-use scenarios should include at least one scenario that achieves the desired condition for FEPAs (i.e. A or B ecological category). Preferably this should be the ecologically sustainable base configuration scenario.

- ***Reserve determination:***
  FEPAs should be used in identifying priority water resources for reserve determination and should be afforded a higher confidence reserve determination than desktop or rapid approaches. FEPAs should be taken into account when allocating resource units for assessment and monitoring, prioritising the allocation of resource nodes immediately downstream of FEPAs.

- ***Setting and monitoring of resource quality objectives:***
  FEPAs should be used to prioritise the allocation of resource unit monitoring nodes, which should be sited immediately downstream of the FEPA. The ecological requirements for setting resource quality objectives (as outlined in the Department of Water Affairs' guidelines for resource quality objectives) should be prioritised for FEPAs.

- ***Water use licensing:***
  FEPAs should be regarded as ecologically important and as generally sensitive to changes in water quality and quantity. The impact of a license application on the ecological condition of a FEPA should be thoroughly assessed. If a licence application is approved in a FEPA, stringent conditions should be attached to the licence to prevent degradation of the ecological condition of the FEPA.

Biodiversity Act

- ***Listing of threatened ecosystems:***
  The data and analysis undertaken to produce FEPA maps (especially river ecosystem types and river condition, Sections 4.1 and 4.2) provide key information for the development of a list of threatened river ecosystems for publication in terms of the Biodiversity Act. River ecosystems for which it is no longer possible to meet the biodiversity target should be listed as Critically Endangered ecosystems.

- ***Development of provincial biodiversity plans and bioregional plans:***
  FEPAs should be favoured in the identification of Critical Biodiversity Areas and Ecological Support Areas. All river and wetland FEPAs should at least be considered to be Ecological Support Areas.

- ***Development of Biodiversity Management Plans for ecosystems and species:***
  FEPAs, fish sanctuaries (Section 3.4), high water yield areas (Section 3.5) and high groundwater yield areas (Section 3.6) should be considered in identifying ecosystems and species of special concern for which biodiversity management plans will be developed.

Protected Areas Act

- ***Expansion and management of the protected area network:***
  FEPAs should be considered in decision-making about expanding the protected area network. This includes the expansion of state-owned protected areas, as well as the activities of provincial biodiversity stewardship programmes which work with private and communal landowners to develop contractual protected areas. FEPAs should also be considered in the development of protected area management plans, which should ensure that FEPAs remain in a good condition.

FEPAs were identified based on:

- Representing ecosystem types and flagship free-flowing rivers (Sections 3.3, 4.1, 4.3, and 4.7),
- Maintaining water supply areas in areas with high water yield (Sections 3.5),
- Identifying connected ecosystems,
- Representing threatened and near-threatened fish species and associated migration corridors (Section 3.4),
- Preferentially identifying FEPAs that overlapped with:
  - Any free-flowing river (Section 3.3),
  - Priority estuaries identified in the National Biodiversity Assessment 2011 (Section 4.7),
  - Existing protected areas and focus areas for protected area expansion identified in the National Protected Area Expansion Strategy.

Although areas with high groundwater recharge were identified (Section 3.6), they did not influence the identification of FEPAs. Future refinement of FEPAs should seek to include groundwater considerations more explicitly.

Richard Bugan

2.2 Categories on the Freshwater Ecosystem Priority Area maps

Different categories are shown on the FEPA maps, each with different management implications. A sub-quaternary catchment code is also provided on the FEPA maps. This code can be used to look up further information about the river FEPAs and Fish Support Areas in each sub-quaternary catchment. This additional information is useful for developing site specific management plans, and is available in the look-up table on the NFEPA DVD or on SANBI's Biodiversity GIS website (http://bgis.sanbi.org).

- ***River FEPA and associated sub-quaternary catchment:***
  River FEPAs achieve biodiversity targets for river ecosystems and threatened/near threatened fish species, and were identified in rivers that are currently in a good condition (A or B ecological category). Their FEPA status indicates that they should remain in a good condition in order to contribute to national biodiversity goals and support sustainable use of water resources.

  For river FEPAs the *whole sub-quaternary catchment is shown in dark green*, although FEPA status applies to the actual river reach within such a sub-quaternary catchment. The shading of the whole sub-quaternary catchment indicates that the surrounding land and smaller stream network need to be managed in a way that maintains the good condition (A or B ecological category) of the river reach.

  It is important to note that river FEPAs currently in an A or B ecological category may still require some rehabilitation effort, e.g. clearing of invasive alien plants and/or rehabilitation of river banks. From a biodiversity point of view, rehabilitation programmes should therefore focus on securing the ecological structure and functioning of FEPAs before embarking on rehabilitation programmes in Phase 2 FEPAs or other areas (see below).

- ***Wetland or estuary FEPA:***
  For wetland and estuary FEPAs, *only the actual mapped wetland or estuarine functional zone is shown on the map as a FEPA, indicated by a turquoise outline* *around the wetland or estuary*. The associated sub-quaternary catchment is not shown in dark green (unless it contains a river FEPA). Connected freshwater ecosystems and surrounding land that need to be managed in order to maintain wetland and estuary FEPAs in good condition need to be identified at a finer scale and in management plans for individual wetland or estuary FEPAs. In some cases it may be the whole sub-quaternary catchment and in others it may be a smaller area.

  Wetland FEPAs were identified using ranks that were based on a combination of special features and modelled wetland condition. Special features included expert knowledge on features of conservation importance (e.g. Ramsar wetland status, extensive intact peat wetlands, presence of rare plants and animals) as well as available spatial data on the occurrence of threatened frogs and wetland-dependent birds. Wetland condition was modelled using the presence of artificial water bodies as well as by quantifying the amount of natural vegetation in and around the wetland (within 50 m, 100 m and 500 m of the wetland). Based on these factors, wetlands were ranked in terms of their biodiversity importance. Biodiversity targets for wetland ecosystems were met first in high-ranked wetlands, proceeding to lower ranked wetlands only if necessary.

  Although wetland condition was a factor in selection of wetland FEPAs, wetlands did not have to be in a good condition to be chosen as a FEPA. Wetland FEPAs currently in a good ecological condition should be managed to maintain this condition.Those currently in a condition lower than good should be rehabilitated to the best attainable ecological condition.

  Estuary FEPAs are the national priority estuaries identified in the National Biodiversity Assessment 2011 (Van Niekerk and Turpie 2011). The functional zone for each estuary is shown on the map, which includes the main channel or open water as well as the zone to which the estuary may expand during flood (guided largely by the 5 m coastal contour line). Estuary FEPAs are shown on the map in the same way as wetland FEPAs, with turquoise outlines. The recommended ecological category for priority estuaries is listed in Van Niekerk and Turpie (2011).

- ***Wetland cluster:***
  Wetland clusters are groups of wetlands embedded in a relatively natural landscape. This allows for important ecological processes such as migration of frogs and insects between wetlands. In many areas of the country, wetland clusters no longer exist because the surrounding land has become too fragmented by human impacts.

  An orange outline *is shown around groups of wetlands that belong to a wetland cluster.* Wetlands do not have to have FEPA status to belong to a wetland cluster (although clusters with a high proportion of wetland FEPAs were favoured in identifying wetland clusters).

- ***Fish sanctuary and associated sub-quaternary catchment:***
  Fish sanctuaries are rivers that are essential for protecting threatened and near threatened freshwater fish that are indigenous to South Africa. The associated sub-quaternary catchment is *marked with a red* *or black fish symbol* *on the map.* A red fish indicates that there is at least one population of a critically endangered or endangered fish species within that sub-quaternary catchment. A black fish indicates the presence of vulnerable and near threatened fish populations. Some fish sanctuaries are FEPAs, with their associated sub-quaternary catchments shown in dark green; others are Fish Support Areas, with their associated sub-quaternary catchments shown in medium green (see explanation of Fish Support Areas below).

  A goal of NFEPA is to keep further freshwater species from becoming threatened and to prevent those fish species that are already threatened or near threatened from going extinct. In order to achieve this, there should be no further deterioration in river condition in fish sanctuaries and no new permits should be issued for stocking invasive alien fish in farm dams in the associated sub-quaternary catchment. Fish management plans need to be developed for all fish sanctuaries to protect the fish they contain, with priority given to those fish sanctuaries containing critically endangered or endangered fish species (indicated by the red fish symbol on the map). These plans should address issues such as management of a particular stretch of river habitat within the sub-quaternary catchment, the construction of weirs to keep invasive alien fish species to a minimum (following an environmental impact assessment), and managing aquaculture and angling to ensure no further introduction of invasive alien fish species.

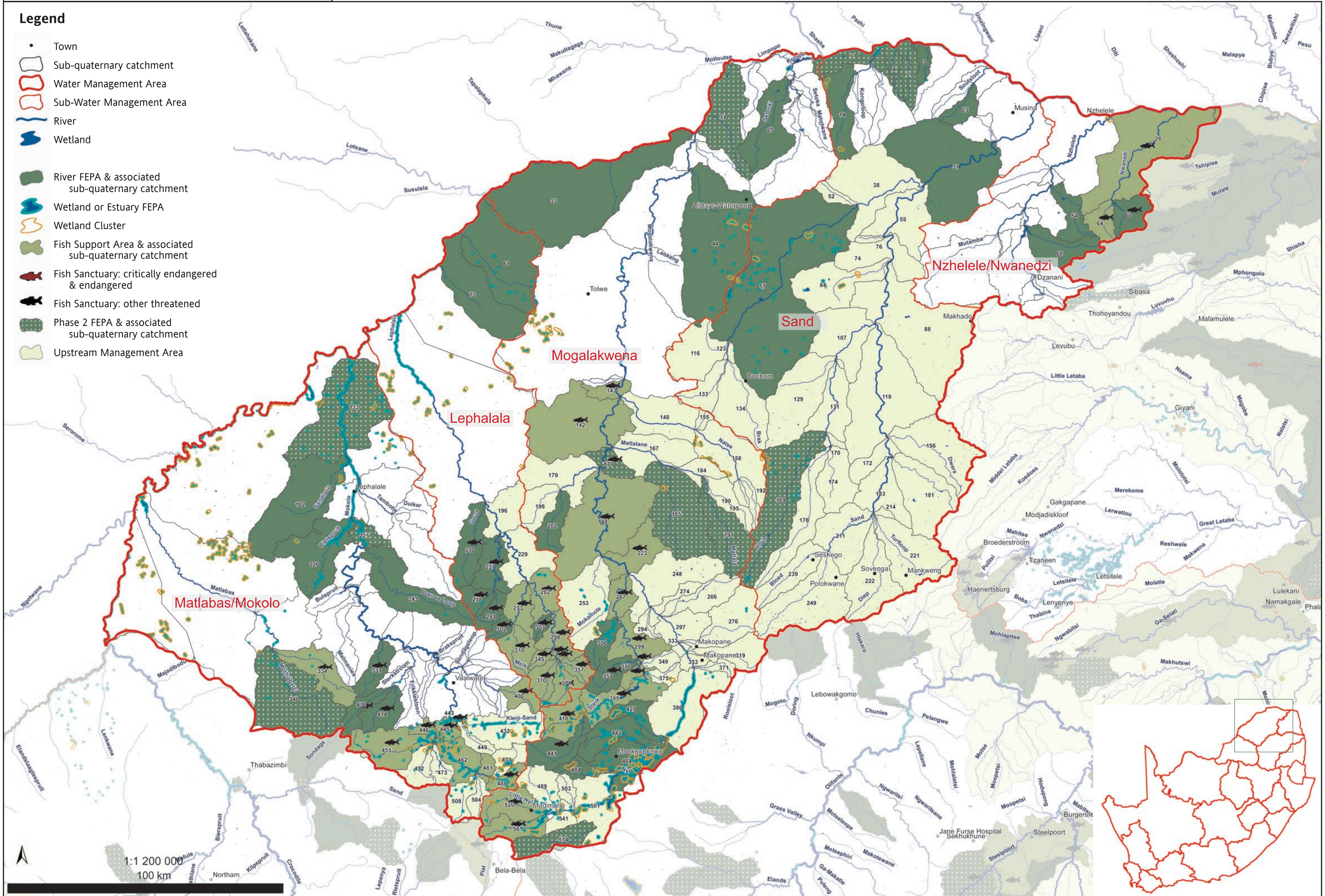
- ***Fish Support Area and associated sub-quaternary catchment:***
  Fish sanctuaries in a good condition (A or B ecological category) were identified as FEPAs, and the whole associated sub-quaternary catchment is shown in dark green. The remaining fish sanctuaries in lower than an A or B ecological condition were identified as Fish Support Areas, and the associated sub-quaternary catchment is *shown in medium green.* Fish Support Areas also include sub-quaternary catchments that are important for migration of threatened or near threatened fish species – these are not marked with a fish symbol.

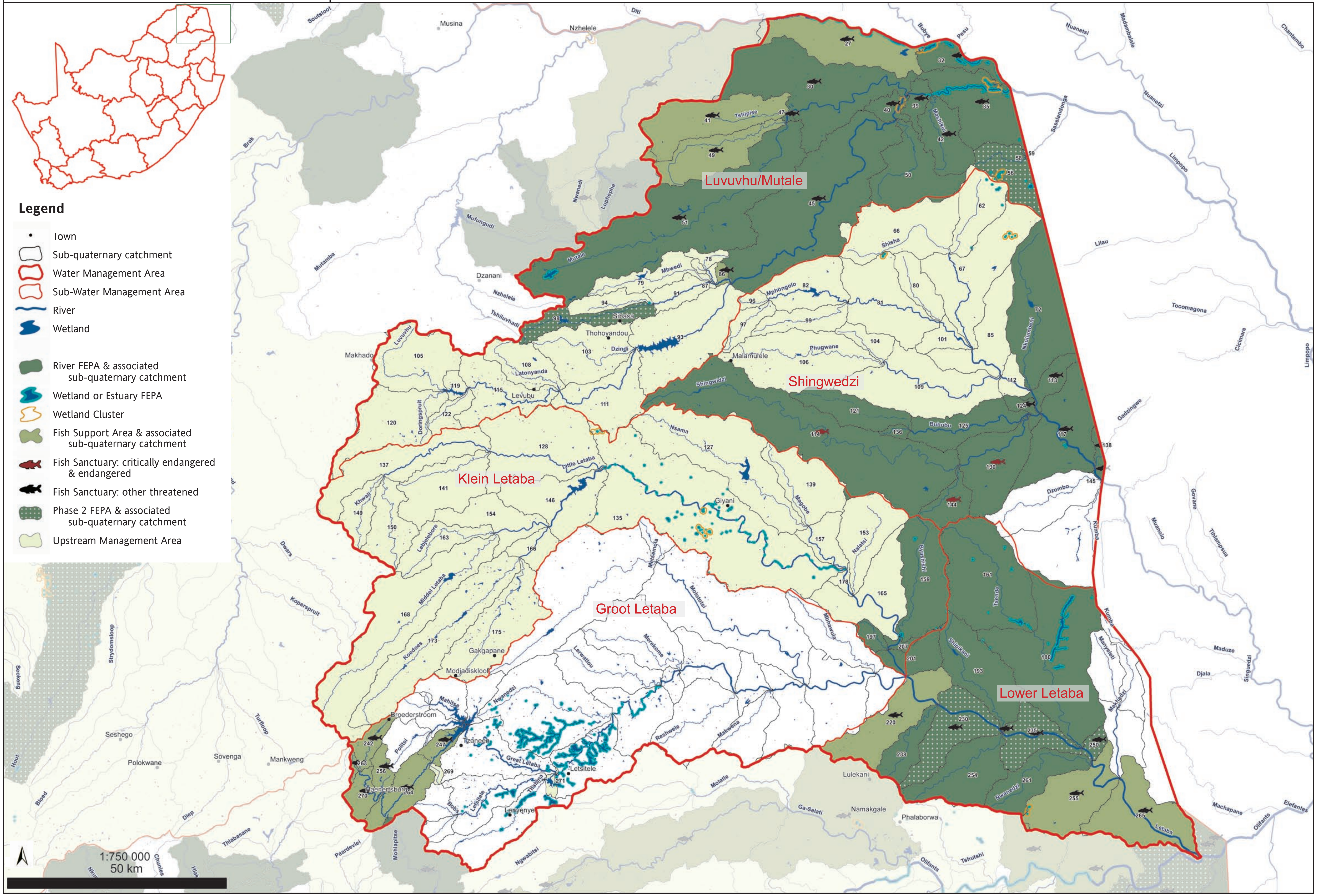
- ***Upstream Management Area:***
  Upstream Management Areas, *shown in very pale green*, are sub-quaternary catchments in which human activities need to be managed to prevent degradation of downstream river FEPAs and Fish Support Areas. Upstream Management Areas do not include management areas for wetland FEPAs, which need to be determined at a finer scale.

- ***Phase 2 FEPA:***
  Phase 2 FEPAs were identified in moderately modified rivers (C ecological category), only in cases where it was not possible to meet biodiversity targets for river ecosystems in rivers that were still in good condition (A or B ecological category). River condition of these Phase 2 FEPAs should not be degraded further, as they may in future be considered for rehabilitation once FEPAs in good condition (A or B ecological category) are considered fully rehabilitated and well managed. Phase 2 FEPAs and their associated sub-quaternary catchments are *shown in dark green with white dots.*

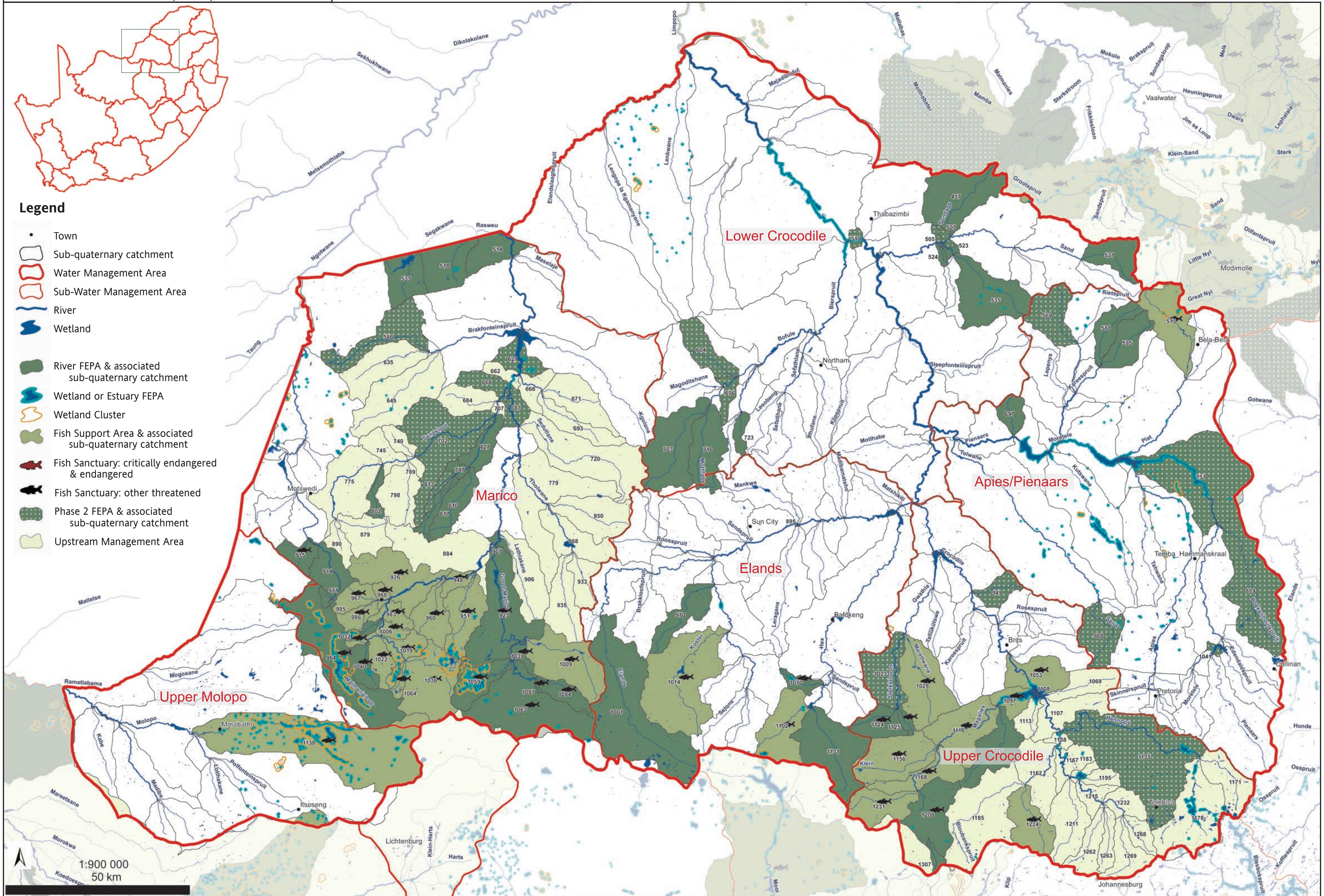
- ***Free-flowing river:***
  Free-flowing rivers are rivers without dams. These rivers flow undisturbed from their source to the confluence with a larger river or to the sea. Dams prevent water from flowing down the river and disrupt ecological functioning with serious knock-on effects for the downstream river reaches and users. Free-flowing rivers are a rare feature in the South African landscape and part of our natural heritage.

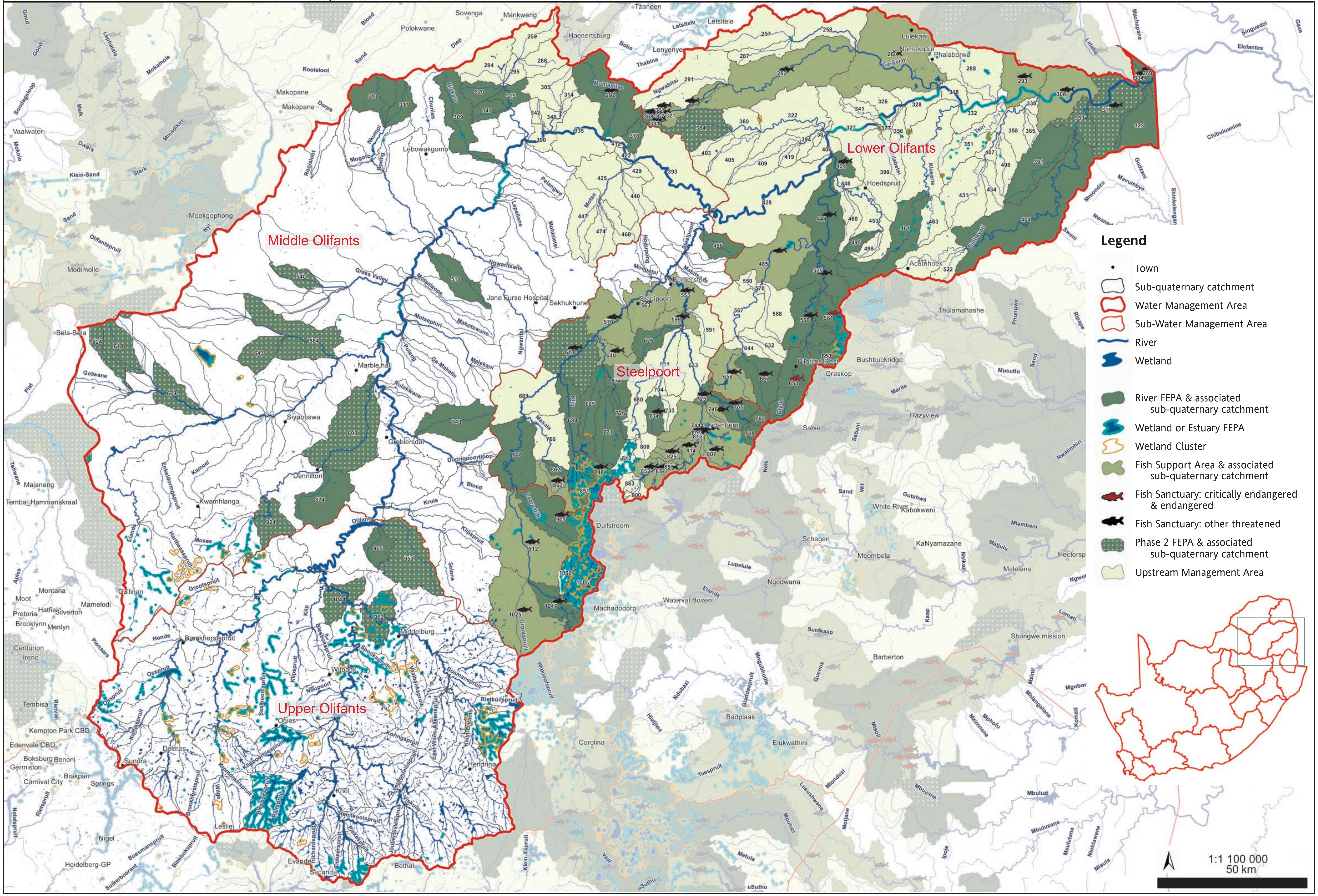
  Free-flowing rivers are not shown on the FEPA maps, but are mapped separately (see Figure 3.3 in Section 3.3). Nineteen flagship free-flowing rivers were identified based on their representativeness of free-flowing rivers across the country, as well as their importance for ecosystem processes and biodiversity value. These flagship rivers should receive top priority for retaining their free-flowing character. Flagship free-flowing rivers are listed in Table 3.1, and coded in the river shapefile on the NFEPA DVD.

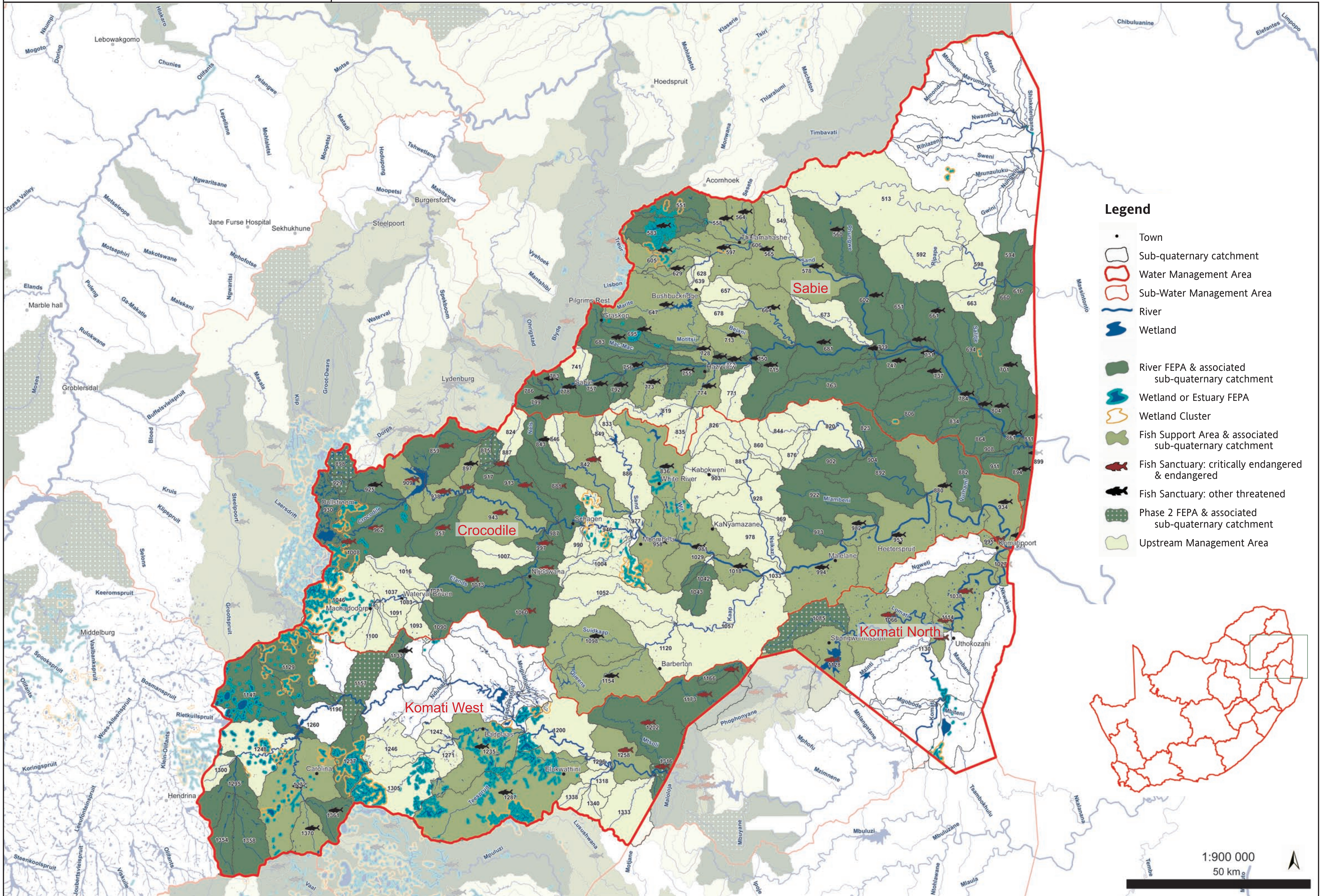

Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
Nzhelele/Nwanedzi
Sand
Mogalakwena
Lephalala
Matlabas/Mokolo
1:1 200 000
100 km

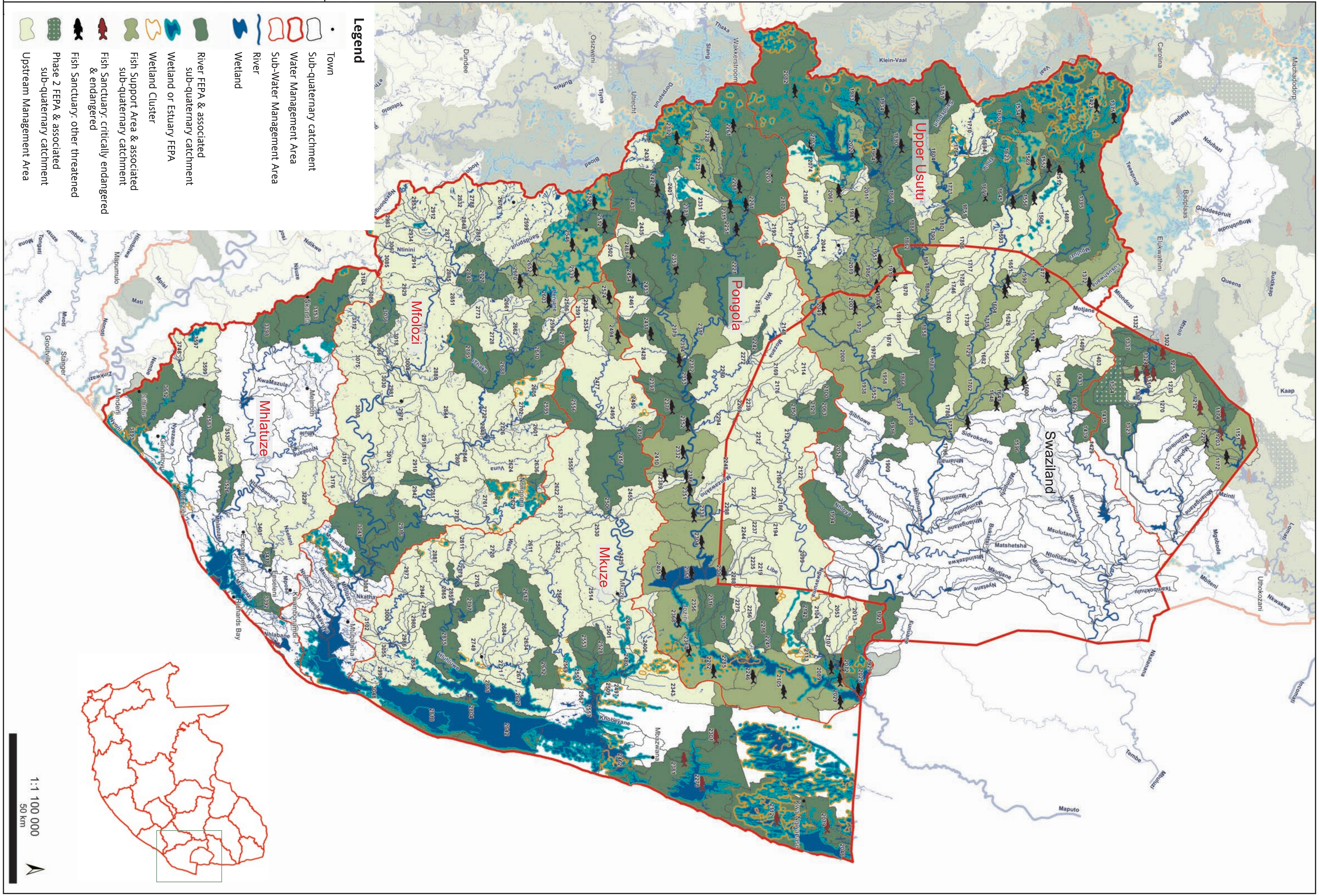

Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
Luvuvhu/Mutale
Shingwedzi
Klein Letaba
Groot Letaba
Lower Letaba
Musina
Nzhelele
Dzanani
Thohoyandou
Sibasa
Makhado
Malamulele
Giyani
Gakgapane
Modjadjiskloof
Broederstroom
Tzaneen
Haenertsburg
Letsitele
Lenyenye
Lulekani
Namakgale
Phalaborwa
Polokwane
Seshego
Sovenga
Mankweng
1:750 000
50 km

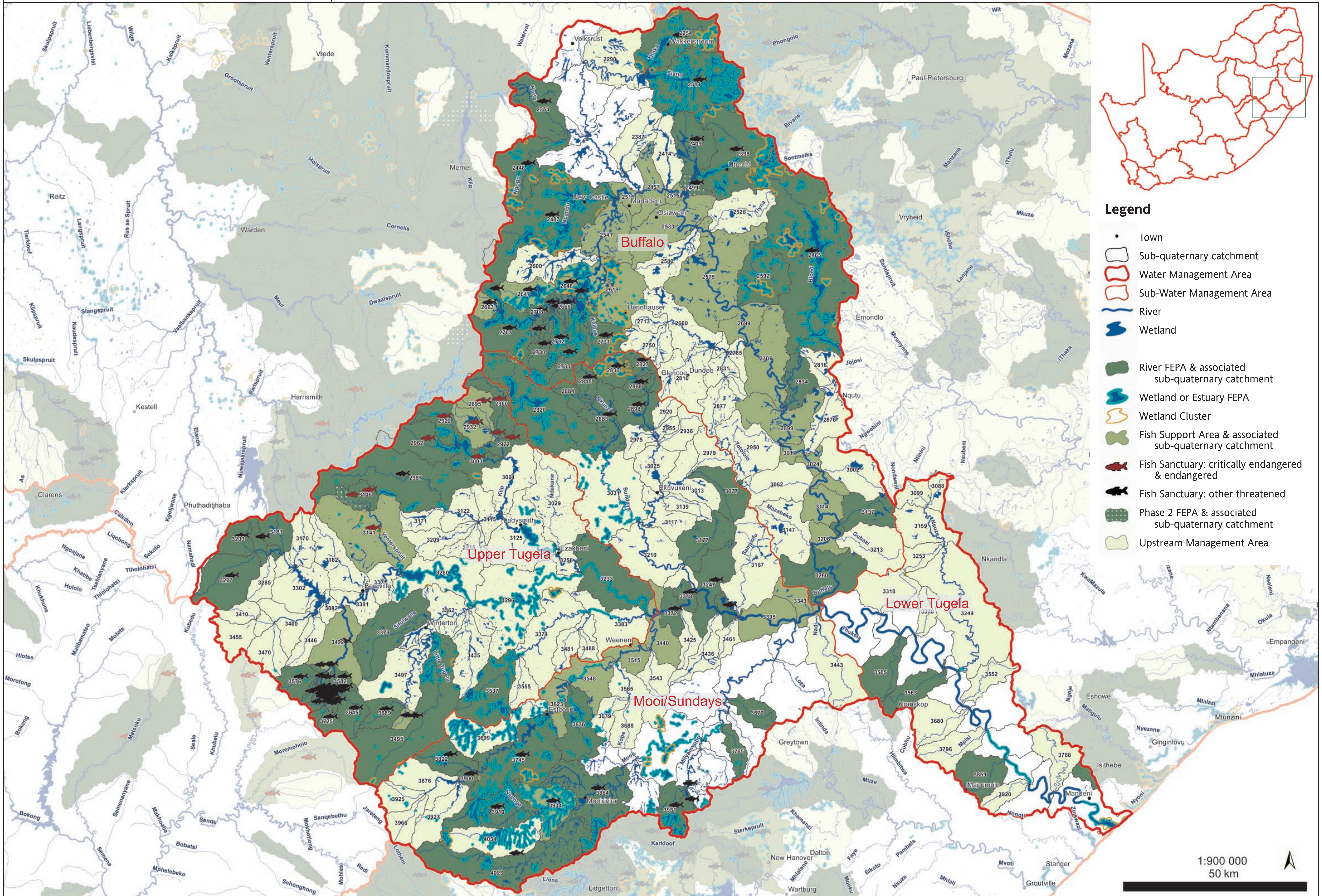
WMA 3 CROCODILE(WEST) AND MARICO

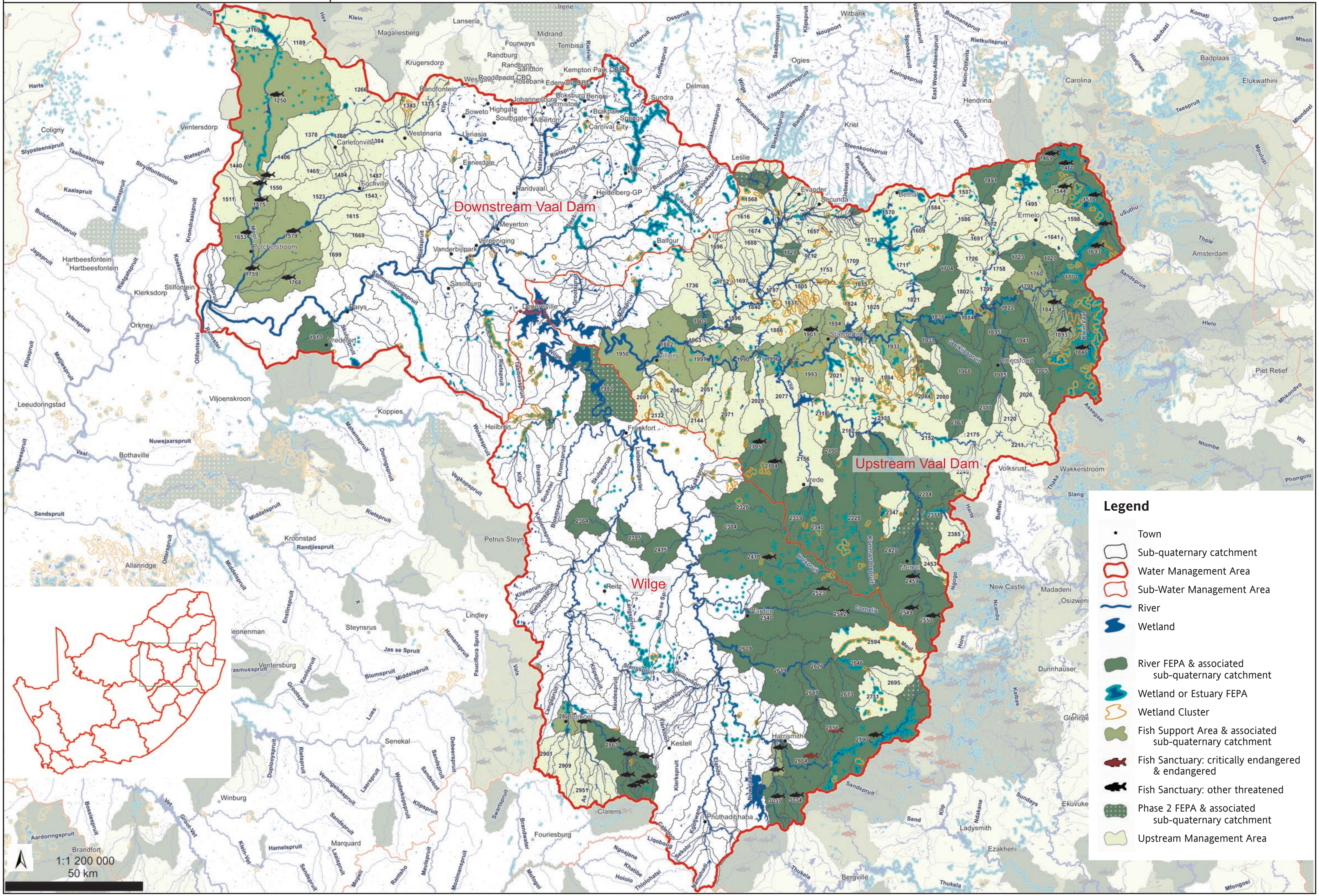


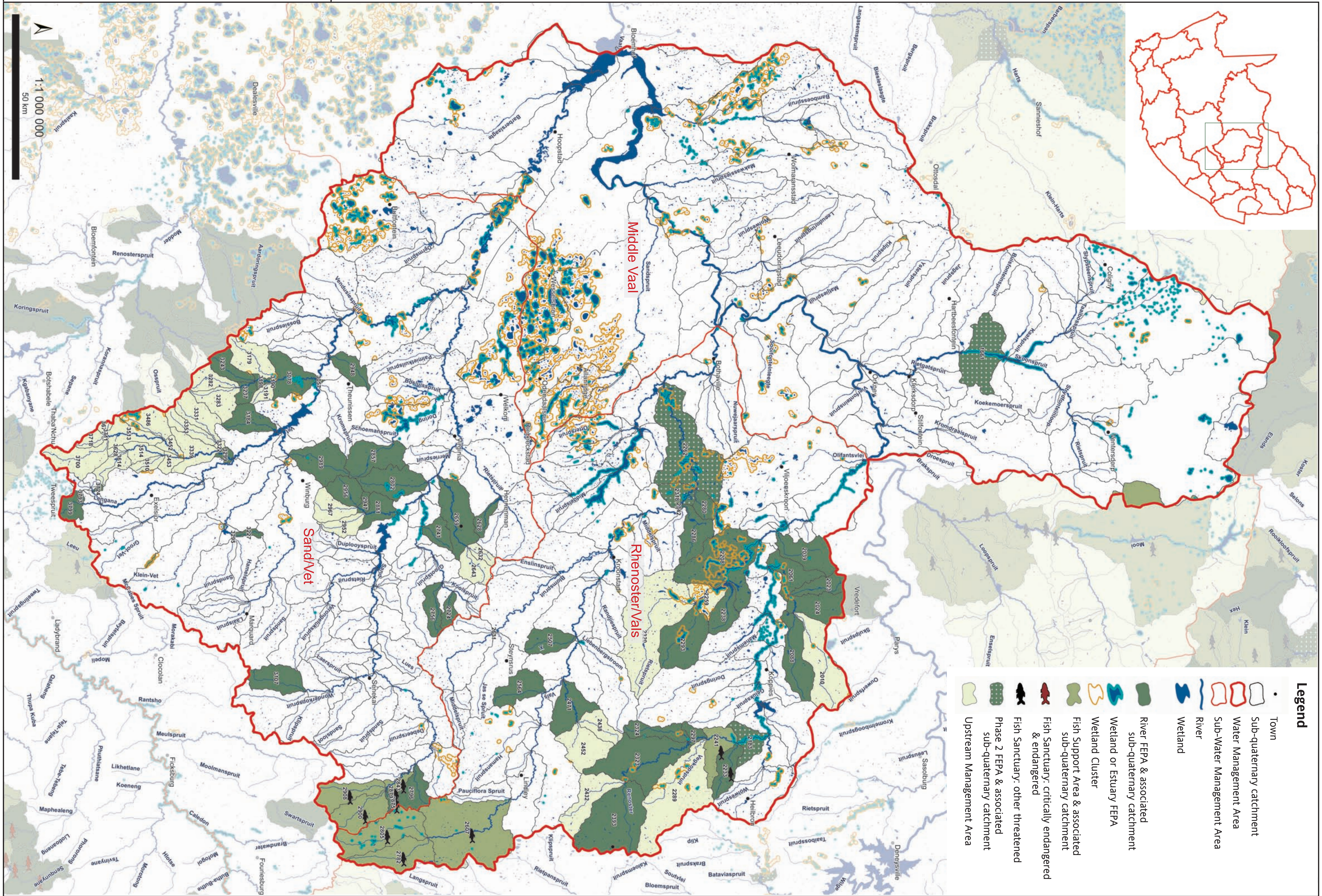

Lower Olifants
Middle Olifants
Steelpoort
Upper Olifants
Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
1:1 100 000
50 km

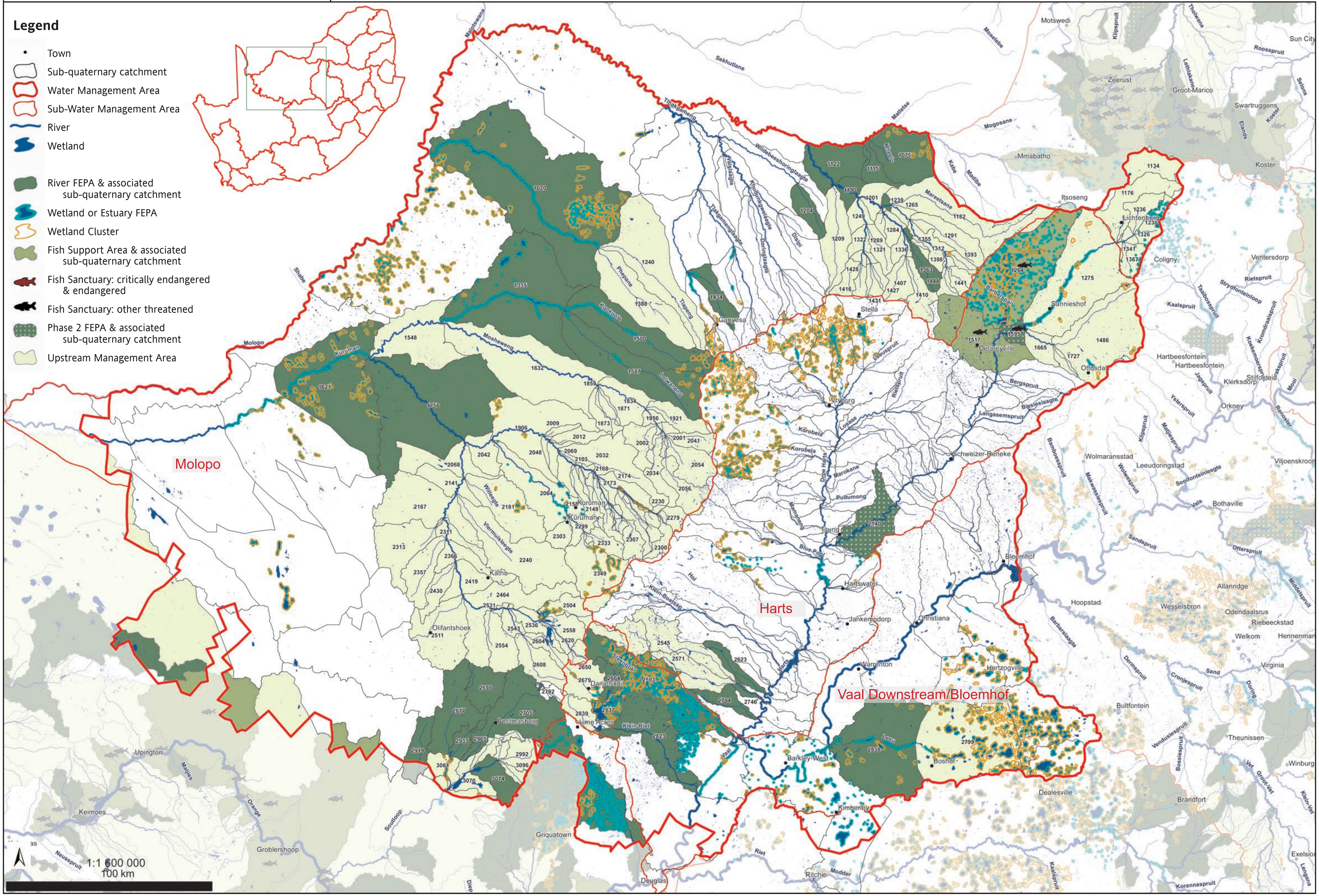

Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
Sabie
Crocodile
Komati North
Komati West
Hoedspruit
Acornhoek
Thulamahashe
Bushbuckridge
Graskop
Pilgrims Rest
Sabie
Hazyview
Lydenburg
Kabokweni
White River
KaNyamazane
Mbombela
Schagen
Ngodwana
Waterval Boven
Machadodorp
Dullstroom
Malelane
Hectorspruit
Komatipoort
Barberton
Shongwe mission
Uthokozani
Badplaas
Carolina
Elukwatini
Middelburg
Hendrina
Lebowakgomo
Burgersfort
Steelpoort
Sekhukhune
Jane Furse Hospital
Marble hall
Groblersdal
1:900 000
50 km

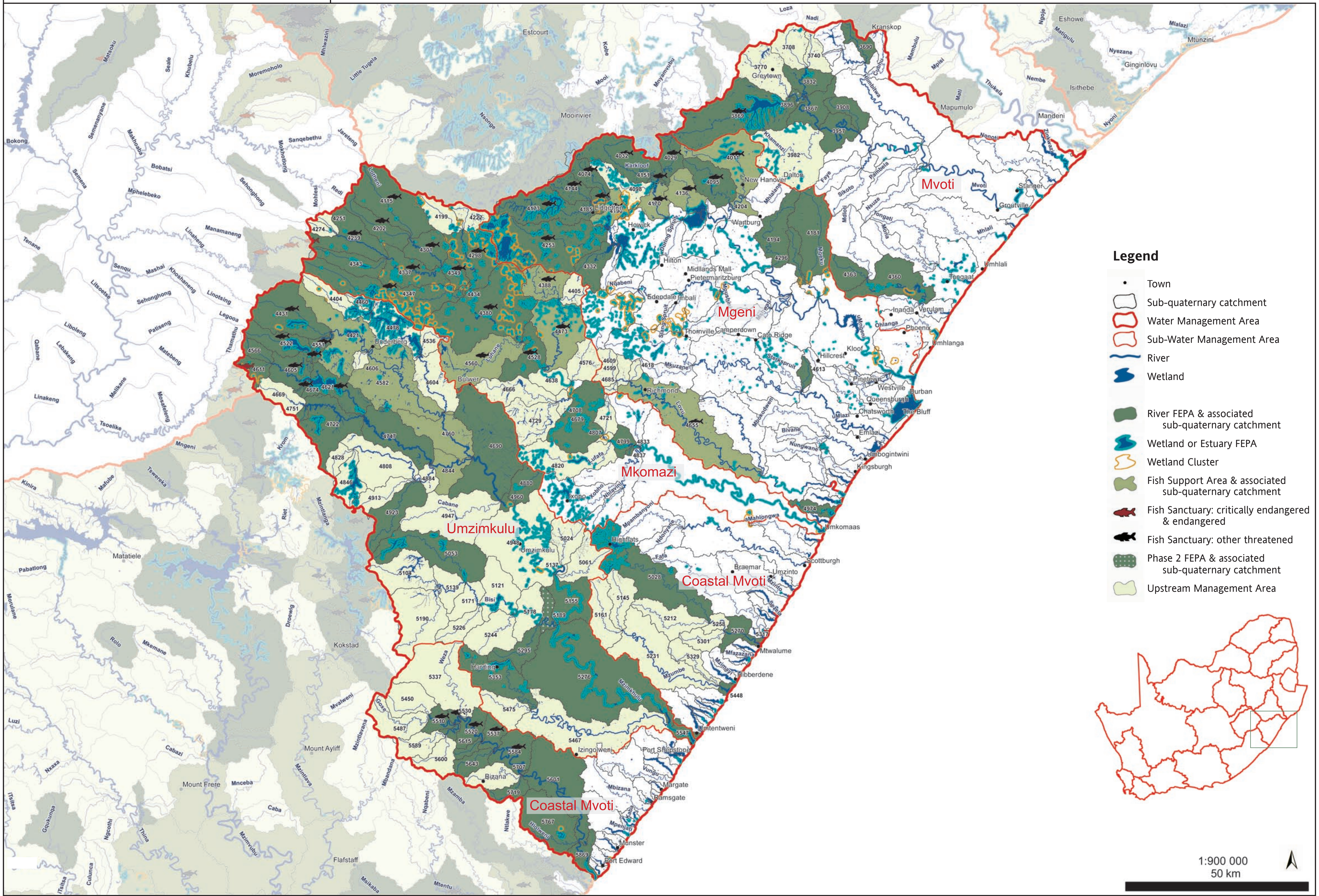

Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
Upper Usutu
Pongola
Mfolozi
Mkuze
Mhlatuze
Swaziland
1:1 100 000
50 km

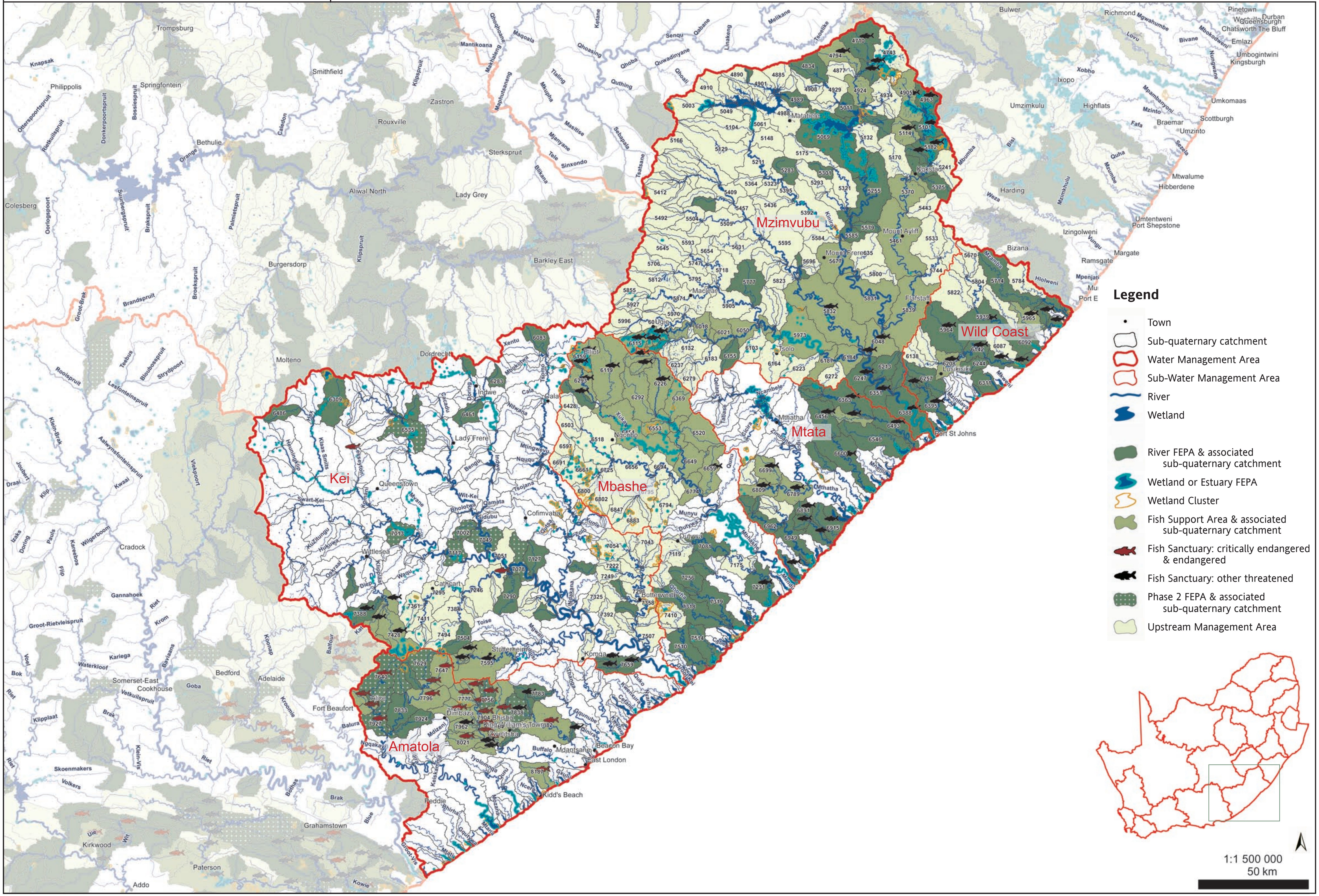

Buffalo
Upper Tugela
Lower Tugela
Mooi/Sundays
Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
1:900 000
50 km


Downstream Vaal Dam
Upstream Vaal Dam
Wilge
Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
1:1 200 000
50 km

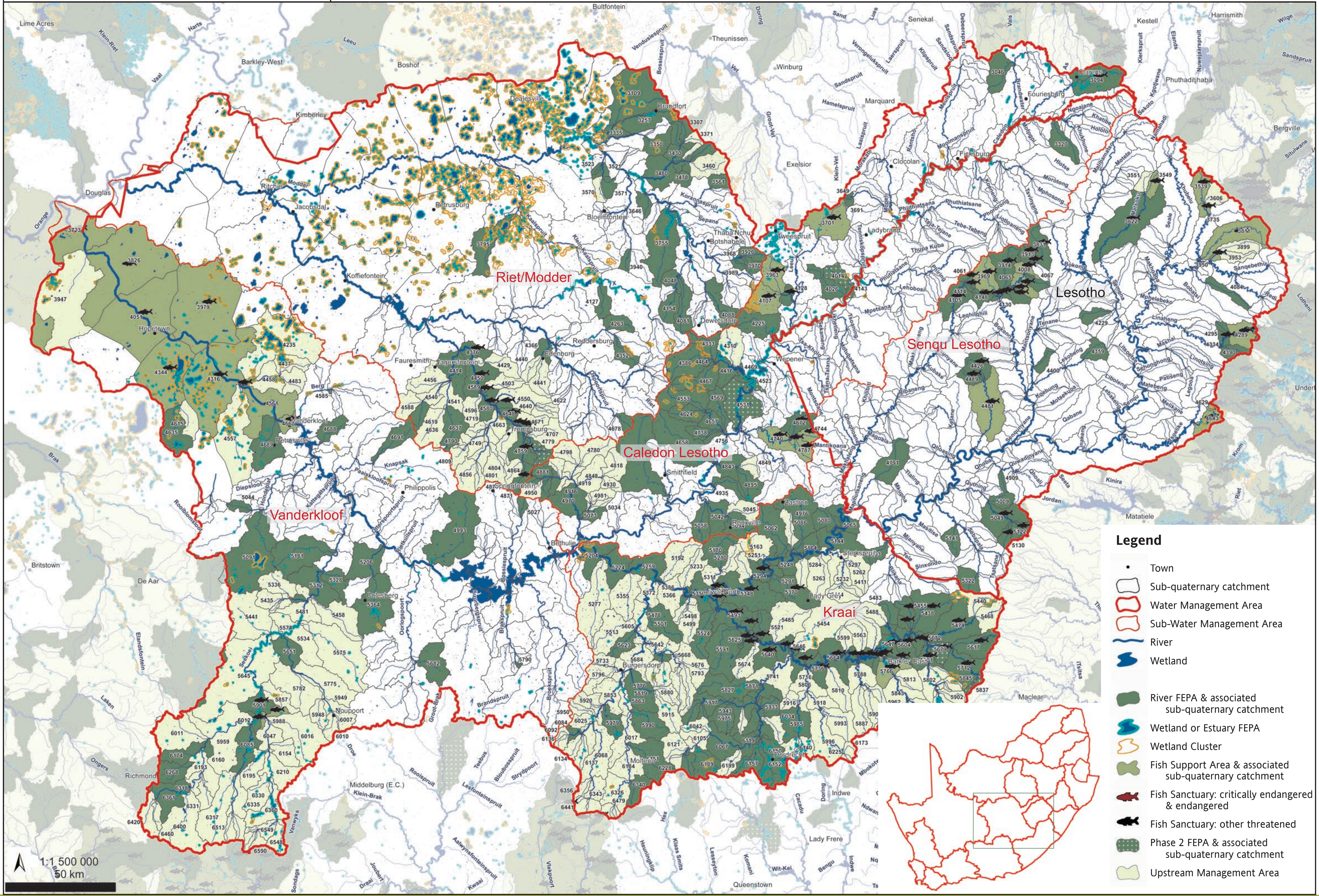

1:1 000 000
50 km
Middle Vaal
Sand/Vet
Rhenoster/Vals
Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area

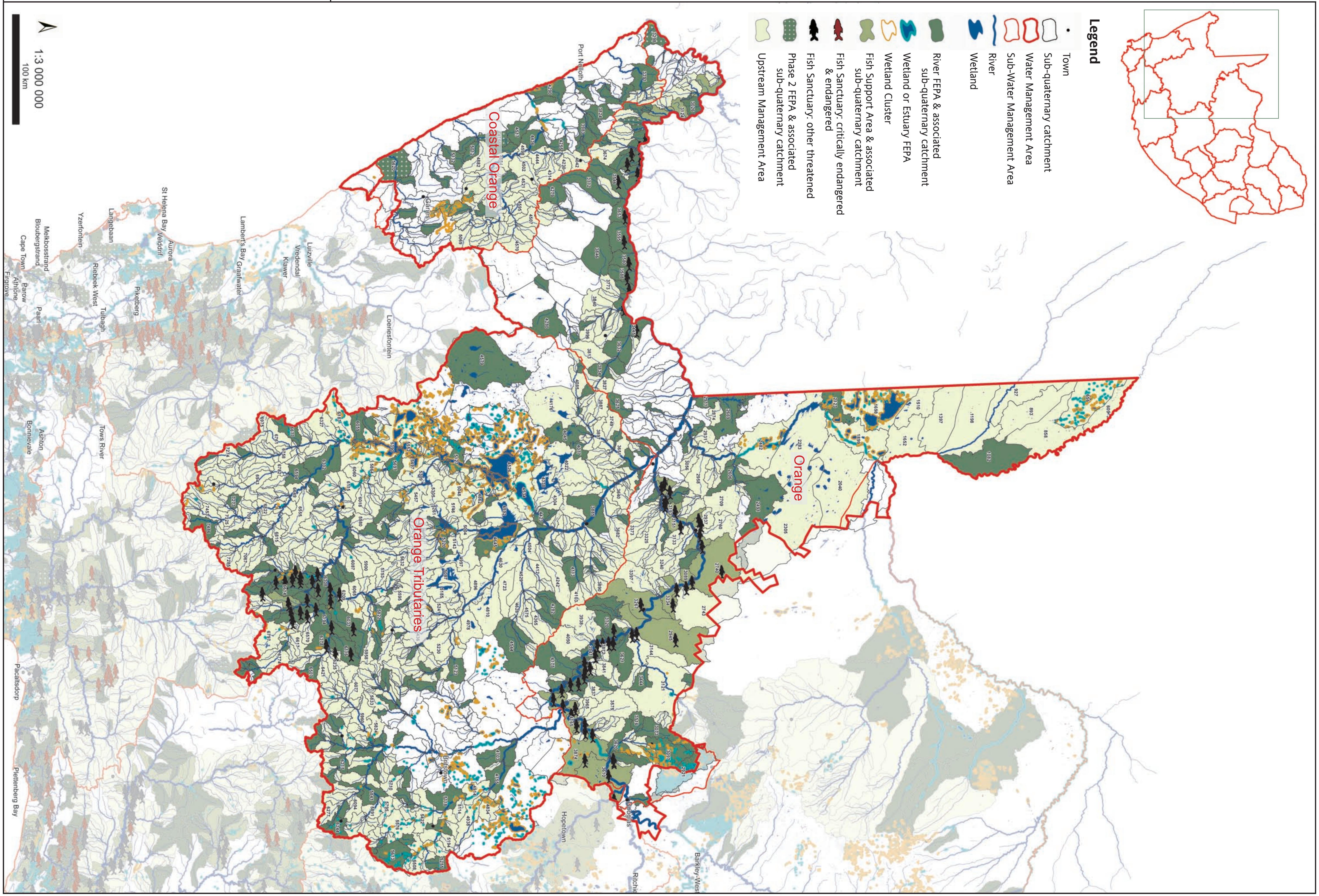

Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
Molopo
Harts
Vaal Downstream/Bloemhof
1:1 600 000
100 km

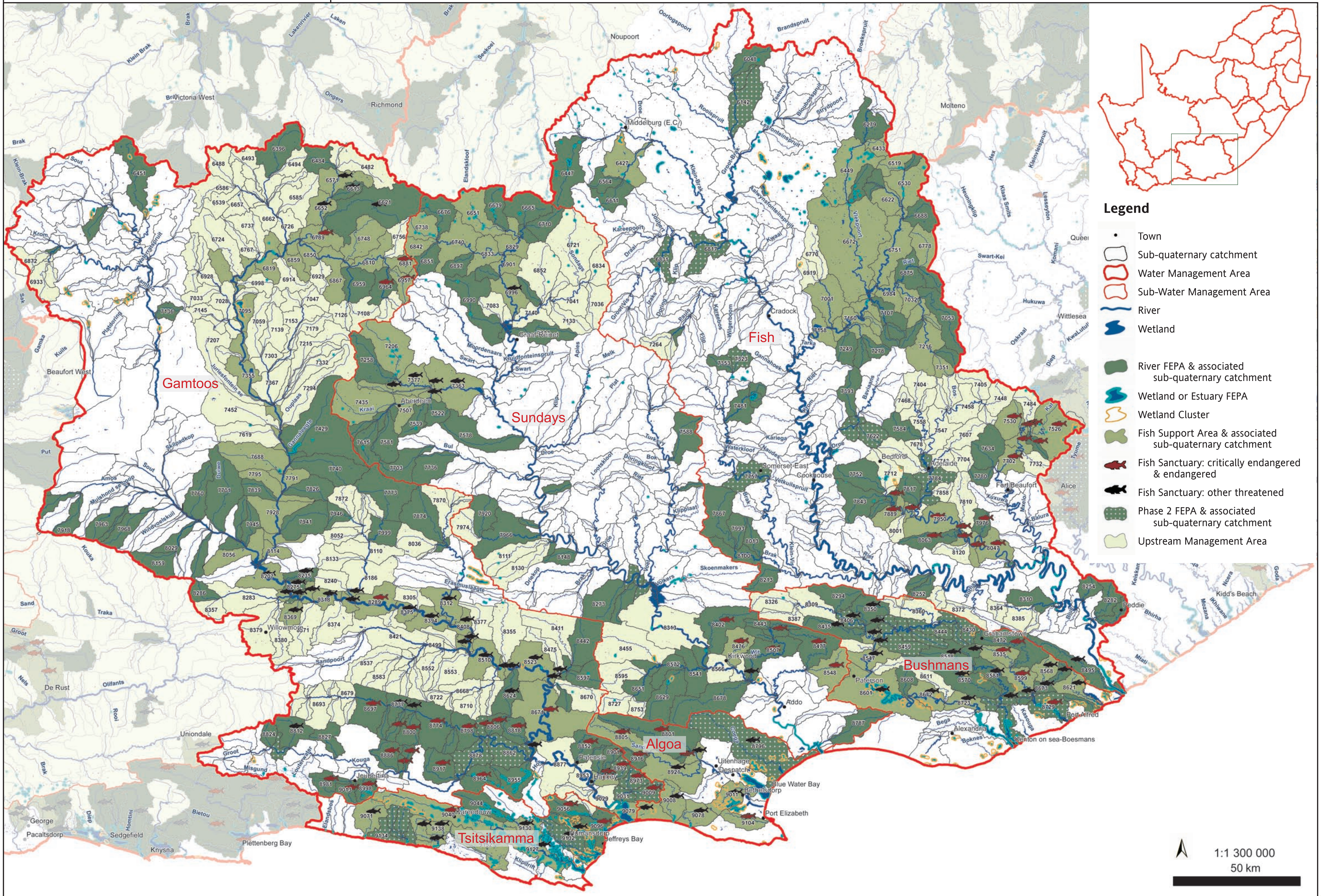

Mvoti
Mgeni
Mkomazi
Umzimkulu
Coastal Mvoti
Coastal Mvoti
Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
1:900 000
50 km

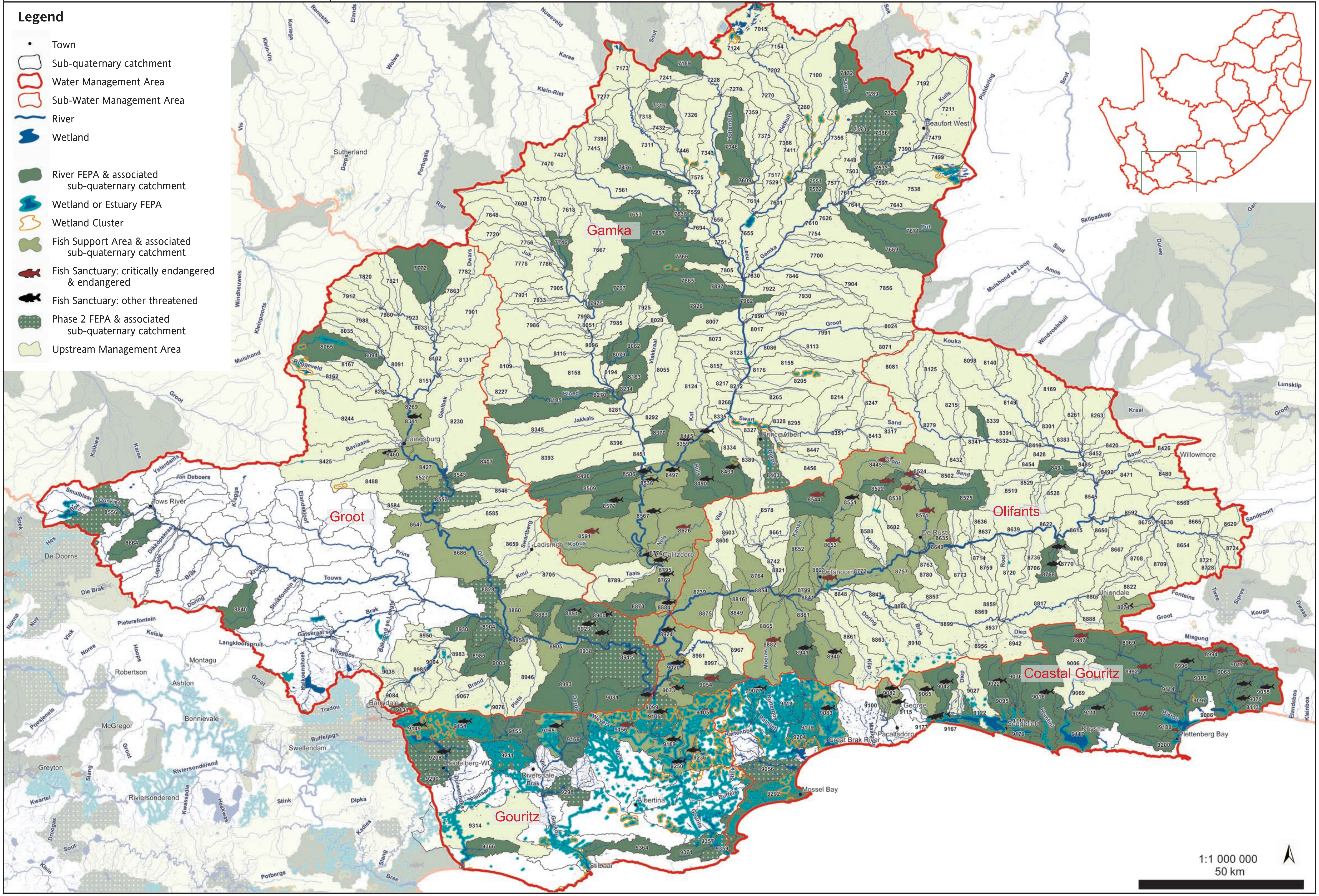

Mzimvubu
Wild Coast
Mtata
Mbashe
Kei
Amatola
Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
1:1 500 000
50 km

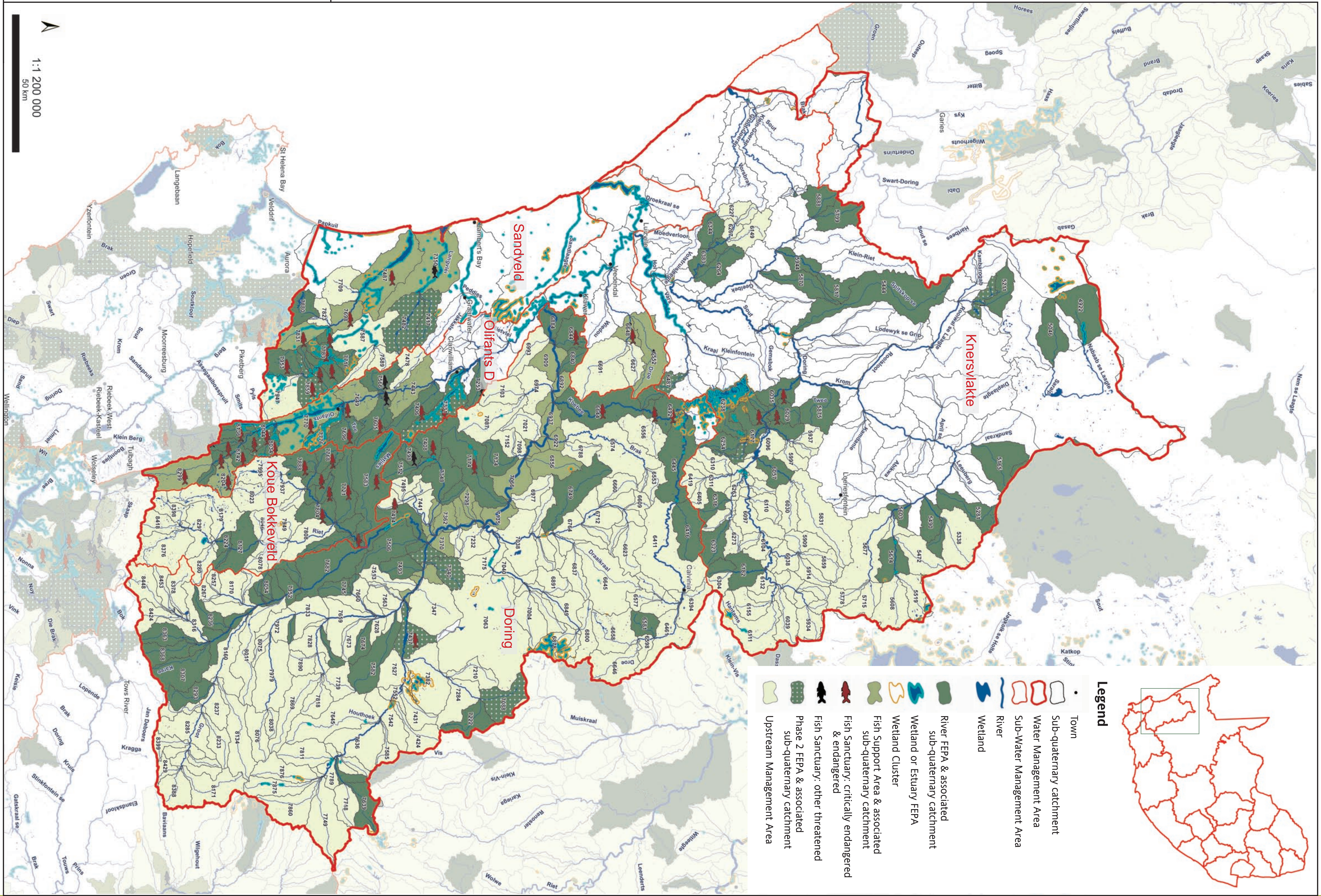
WMA 13 UPPER ORANGE



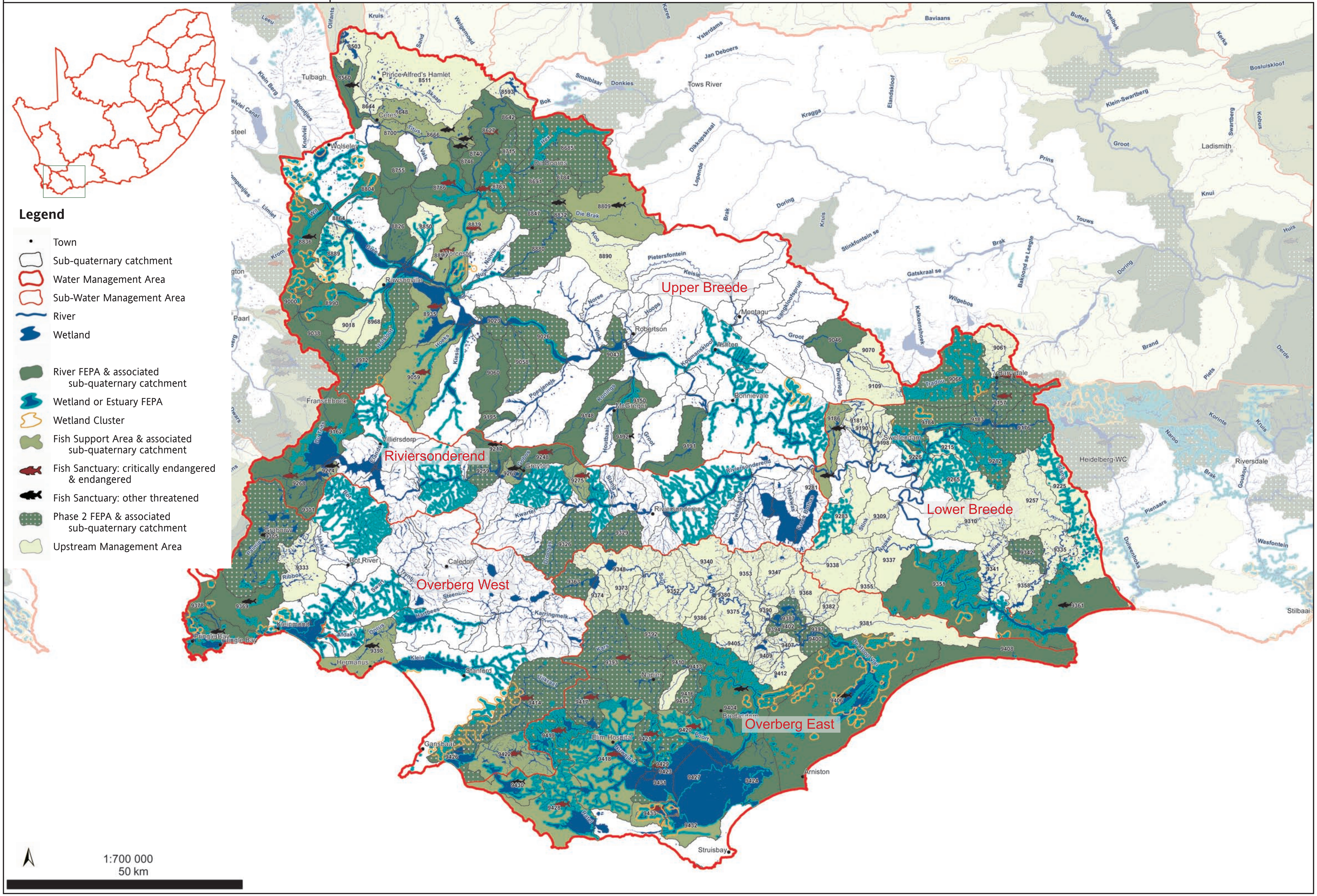

Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
1:3 000 000
100 km
Coastal Orange
Orange
Orange Tributaries
Port Nolloth
Lambert's Bay
Graafwater
Lutzville
Vredendal
Klawer
Loeriesfontein
Hopetown
Douglas
Barkley-West
Pacaltsdorp
Plettenberg Bay
Tows River
Piketberg
Tulbagh
Paarl
Cape Town

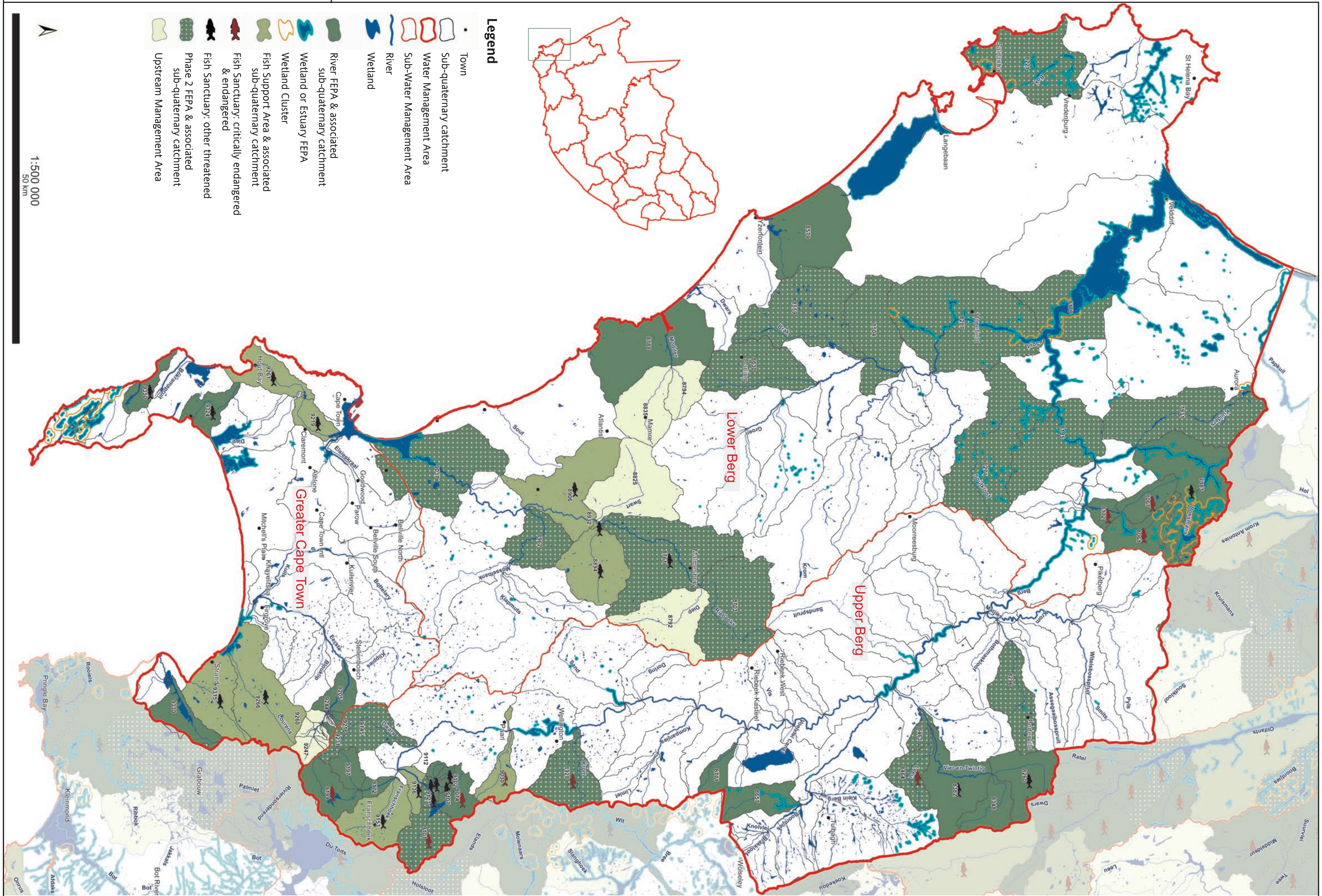

Gamtoos
Sundays
Fish
Bushmans
Algoa
Tsitsikamma
Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
1:1 300 000
50 km
Noupoort
Middelburg (E.C)
Richmond
Victoria West
Beaufort West
Graaff-Reinet
Aberdeen
Cradock
Somerset East
Cookhouse
Bedford
Adelaide
Fort Beaufort
Alice
Molteno
Queenstown
Grahamstown
Peddie
Port Alfred
Kenton on sea-Boesmans
Alexandria
Paterson
Addo
Uitenhage
Despatch
Port Elizabeth
Blue Water Bay
Jeffreys Bay
Humansdorp
Hankey
Patensie
Kareedouw
Joubertina
Willowmore
Uniondale
De Rust
George
Pacaltsdorp
Sedgefield
Knysna
Plettenberg Bay
Kidd's Beach


Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
Gamka
Groot
Olifants
Coastal Gouritz
Gouritz
Beaufort West
Laingsburg
Prince Albert
Ladismith
Calitzdorp
Oudtshoorn
De Rust
Uniondale
George
Knysna
Plettenberg Bay
Mossel Bay
Riversdale
Heidelberg-WC
Albertina
Stilbaai
Barrydale
Great Brak River
Pacaltsdorp
Hartenbos
Sedgefield
Touws River
Sutherland
Willowmore
Montagu
Robertson
Ashton
McGregor
Bonnievale
Swellendam
Greyton
Riviersonderend
De Doorns
1:1 000 000
50 km


1:1 200 000
50 km
Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
Sandveld
Olifants D
Koue Bokkeveld
Doring
Knersvlakte

WMA 18 BREEDE




Legend
Town
Sub-quaternary catchment
Water Management Area
Sub-Water Management Area
River
Wetland
River FEPA & associated sub-quaternary catchment
Wetland or Estuary FEPA
Wetland Cluster
Fish Support Area & associated sub-quaternary catchment
Fish Sanctuary: critically endangered & endangered
Fish Sanctuary: other threatened
Phase 2 FEPA & associated sub-quaternary catchment
Upstream Management Area
1:500 000
50 km
Lower Berg
Upper Berg
Greater Cape Town
St Helena Bay
Vredenburg
Saldanha
Langebaan
Velddrif
Aurora
Yzerfontein
Atlantis
Mamre
Cape Town
Claremont
Athlone
Goodwood
Parow
Bellville
Mitchell's Plain
Khayelitsha
Kuilsrivier
Stellenbosch
Strand
Wellington
Paarl
Malmesbury
Moorreesburg
Piketberg
Riebeek-Kasteel
Riebeek West
Tulbagh
Porterville
Hopefield
Franschhoek
Wolseley

Part 3: National map products

This part of the atlas presents six national maps that show:

3.1 ***Density of FEPAs per Water Management Area*** calculated as the percentage of the total area of that Water Management Area that has been identified as a FEPA or associated sub-quaternary catchment

3.2 ***Density of FEPAs per sub-Water Management Area*** calculated as the percentage of the total area of that sub-Water Management Area that has been identified as a FEPA or associated sub-quaternary catchment

3.3 ***Free-flowing rivers*** of South Africa, or rivers without dams that flow undisturbed from their source to the confluence with a larger river or to the sea

3.4 ***Fish sanctuaries*** for threatened and near threatened fish species indigenous to South Africa

3.5 ***High water yield areas***, which are sub-quaternary catchments where mean annual runoff is at least three times more than the average for the related primary catchment

3.6 ***High groundwater recharge areas***, which are sub-quaternary catchments where groundwater recharge is at least three times more than the average for the related primary catchment

3.1 Density of Freshwater Ecosystem Priority Areas per Water Management Area

Freshwater biodiversity is not evenly distributed across the country; some Water Management Areas have a higher density of FEPAs than others, and thus more responsibility for meeting national freshwater ecosystem goals.

Figure 3.1 shows the proportion of each Water Management Area identified as a FEPA, calculated as the percentage of the total area of that Water Management Area that has been identified as a FEPA or associated sub-quaternary catchment. This map shows that some Water Management Areas (those that are darker in colour) have more FEPAs to look after than others. However, lighter coloured Water Management Areas still have FEPAs to prioritise, just not as many. An important policy question is how we can support Water Management Areas with a high proportion of FEPAs in achieving our national freshwater ecosystem goals.

The proportion of each Water Management Area made up of FEPAs varies from 10% in the Berg Water Management Area to 38% in the Thukela. This variability is a consequence of river and wetland ecosystem heterogeneity and fish species distribution. For example, the Inkomati and Usutu to Mhlathuze Water Management Areas have high river ecosystem heterogeneity, and therefore a high proportion of FEPAs (32 and 33% respectively).

The proportion of FEPAs in each Water Management Area is also influenced by river condition, because only rivers that are still in good condition (A or B ecological category) can be chosen as FEPAs. For example, the Crocodile (West) and Marico and Olifants Water Management Areas have high river ecosystem heterogeneity, but there are no longer sufficient rivers in a good condition to meet biodiversity targets for river ecosystems, reducing the number of FEPAs identified. The small proportion of FEPAs identified in these Water Management Areas are generally the only ones left in a good condition. This means that FEPAs in low density Water Management Areas are no less important than those in high density areas. In fact, in cases where low density of FEPAs results from poor condition of rivers and wetlands, the FEPAs that have been identified are arguably more important.

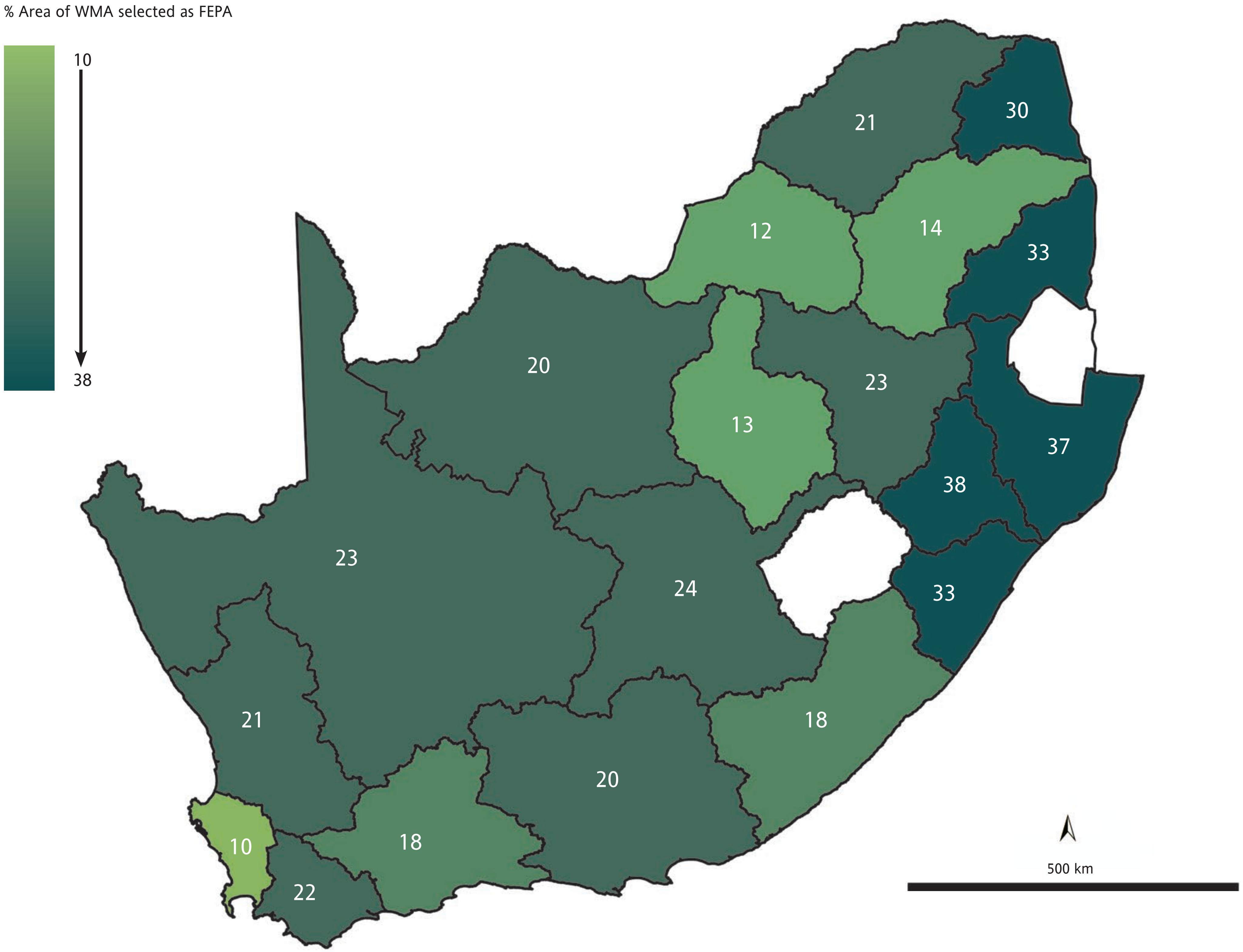


Figure 3.1: Density of Freshwater Ecosystem Priority Areas per Water Management Area

3.2 Density of Freshwater Ecosystem Priority Areas per sub-Water Management Area

Each Water Management Area is divided into several sub-Water Management Areas broadly based on the catchments of large tributaries within the Water Management Area. Figure 3.2 shows the proportion of each sub-Water Management Area identified as a FEPA, calculated as the percentage of the total area of that sub-Water Management Area identified as a FEPA or associated sub-quaternary catchment.

The map shows that even within Water Management Areas, freshwater biodiversity is not evenly distributed. This has important implications for the development of Catchment Management Strategies, which often use sub-Water Management Areas in the catchment visioning process, and are often managed and implemented at sub-Water Management Area level. Sub-Water Management Areas are also often the level at which water user forums operate.

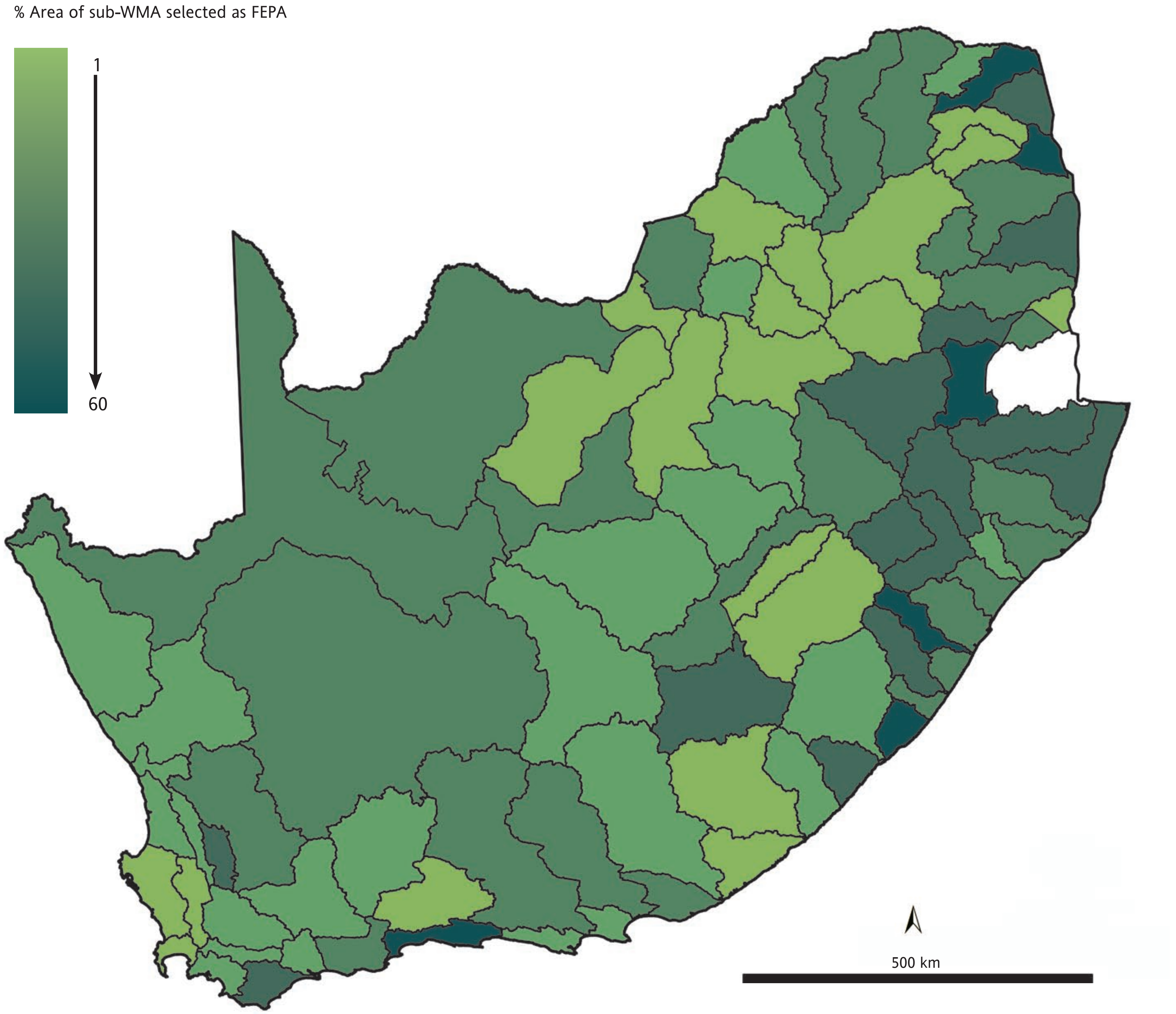


Figure 3.2: Density of Freshwater Ecosystem Priority Areas per sub-Water Management Area

3.3 Free-flowing rivers

A free-flowing river is a long stretch of river that has not been dammed. A free-flowing river flows undisturbed from its source to the confluence with another large river or to the sea. Today there are very few large rivers that remain undammed, or 'free flowing'. Free-flowing rivers are rare features in our landscape and an important part of our natural heritage. They offer considerable social, economic and conservation value, supporting the livelihoods of people in the catchment. Poor rural populations with close livelihood links to the river are likely to be impacted most and benefit least from dams. As discussed in Section 1.2, water flowing out to sea is not wasted but plays an important role in securing a range of estuarine and marine ecosystem services.

Opportunities for conserving free-flowing rivers are fast disappearing with the growing demand for development of water resources. While acknowledging the importance of developing water resources, there is also an urgent need to identify some free-flowing rivers that can serve as a representative set of our country's last remaining free-flowing rivers, and to maintain their free-flowing character.

Free-flowing rivers are rivers without dams – a rare feature in the South African landscape. Dams prevent water from flowing down the river and disrupt ecological functioning with serious knock-on effects for the downstream river reaches and users. Nineteen flagship free-flowing rivers have been identified. Their free-flowing character should be maintained and they should remain in a good condition in order to conserve a representative sample of our heritage.

River reaches satisfying all of the following requirements were selected as free-flowing rivers:

- Permanent or seasonally flowing rivers. Rivers that do not flow every year (ephemeral rivers) were not considered.
- Rivers in good condition (A or B ecological category).
- No dam in the channel throughout its length. This assessment used 1:50 000 farm dams (Department of Land Affairs: Chief Directorate Surveys and Mapping 2005-2007). Data constraints prevented consideration of farm dams built after 2005, as well as weirs. The Upper Vaal and Upper Marico rivers were special cases where the long stretch of river flowing freely from source to dam was considered free flowing.
- Length $\geq$ 50 km for inland rivers, with no length threshold for coastal rivers.

Table 3.1: Free-flowing rivers of South Africa. River names in blue are flagship free-flowing rivers that are top priorities for retaining their free-flowing character. Rivers are listed from west to east.

Eastern Cape
Riet
Kap
Mpekweni
Mgwalana
Kobonqaba
iNxaxo
Qhorha & tributaries*
Shixini
Nqabarha*
Ntlonyane
Xora*
Mncwasa
Mdumbi
Mtakatye*
Mnenu
Sinangwana
Mngazana
Mntafufu
Mzintlava
Mkozi
Msikaba*
Mtentu*
Sikombe
Mpahlane
Mzamba*
Mtamvuna & tributaries*
Kraai & tributaries*

KwaZulu-Natal
Mzimkhulu*
Mzumbe
Mpambanyoni*
aMahlongwa
aMahlongwana
Mkomazi & tributaries*
Nsuze* (tributary of Thukela)
Matigulu & tributaries*
Black Mfolozi & tributaries*
Nsonge
Nondweni
Ngogo
Mfule*
Nyalazi*
Mkuze & tributaries*

Mpumalanga
Ntombe (tributary of Phongolo)
Hlelo*
Upper Vaal*
Elands*
Mbyamiti
Nwanedzi-Sweni*

Limpopo
Mutale-Luvuvhu*
Mohlapitse

Northern Cape
Upper Sak, Klein-Sak & tributaries*

NorthWest
Upper Groot-Marico

Western Cape
Doring & tributaries*
Klaas Jaagers
Rooiels
Touws
Karatara-Hoekraal
Homtini
Knysna
Bietou-Palmiet
Groot
Bloukrans

* Free-flowing rivers longer than 100 km

There are 62 free-flowing rivers in South Africa, of which only 25 are longer than 100 km (Figure 3.3; Table 3.1). This constitutes only 4% of the length on the 1:500 000 river network GIS layer. Acknowledging that not all of these are likely to remain free flowing in the light of development needs and objectives, 19 of the 62 free-flowing rivers have been identified as flagship free-flowing rivers. These flagships were identified based on their representativeness of free-flowing rivers across the country, as well as their importance for ecosystem processes and biodiversity value. These flagship rivers should receive top priority for retaining their free-flowing character. See pages 37-41 for stories of selected flagship free-flowing rivers.

The upper Groot Marico River in the North West province is the only free-flowing river representative of the entire north-western region of the country. The Eastern Cape and KwaZulu-Natal have the highest numbers of free-flowing rivers, several of which are short coastal rivers.

The Eastern Cape and KwaZulu-Natal provinces have the highest number of free-flowing rivers in the country (Table 3.1). Many of these rivers will undoubtedly lose their free-flowing status as these provinces urgently require development of water resources to improve water supply to households and agriculture. Flagship free-flowing rivers should receive top priority for maintaining their dam-free status. The provinces of Gauteng and Free State have no remaining free-flowing rivers. Rivers of the Free State tend to be dry rivers that can go for years without flowing; thus, the lack of free-flowing rivers for this region is natural. The lack of free-flowing rivers in the Gauteng province is indicative of rivers working hard to meet the demands of the largest economic hub of the country – representation of freshwater ecosystems within this region often needs to be sought outside Gauteng in the North West province. This emphasises the immense importance of the upper Groot-Marico River, which is the only free-flowing river representative of the entire north-western region of the country (see narrative on the Groot-Marico River on page 40 below).

Where free-flowing rivers have to be dammed, there are some simple measures that can be put in place to mitigate the worst effects of the dams. These include:

- undertaking comprehensive environmental flow assessments prior to dam construction to understand and mitigate the consequences of the dam on the social, economic and ecological environments;
- designing dams that allow for environmental flow releases; and
- constructing passages for fish to by-pass the dam wall.

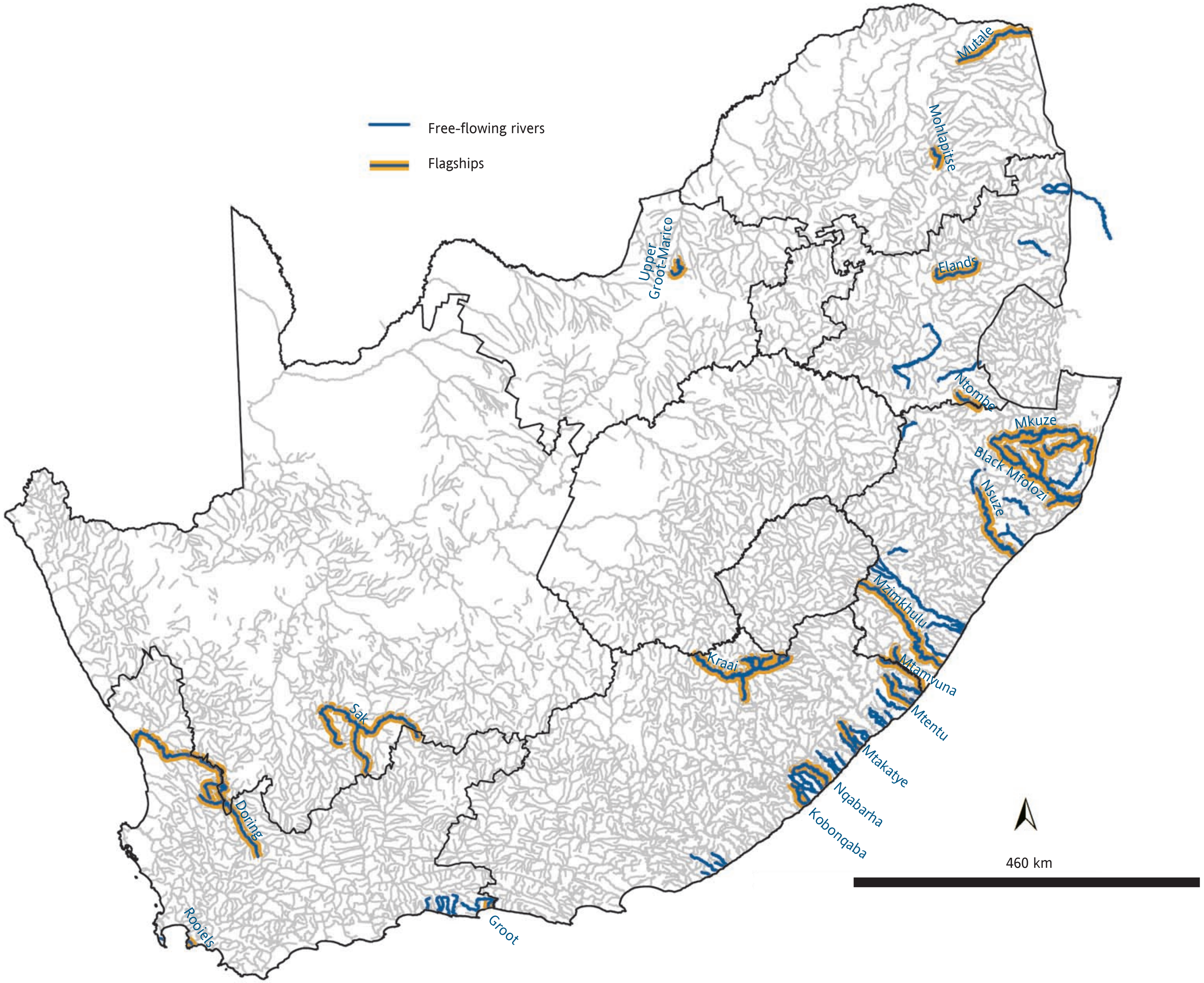


Figure 3.3: Free-flowing rivers of South Africa. River names are given for the flagship free-flowing rivers. Stories of selected flagship free-flowing rivers are provided on pages 37-41.

The Mtentu River: An ecotourism asset

The Amadiba community of the Mtentu River on the Wild Coast in the Eastern Cape Province are well known for protecting and valuing their free-flowing river, the water it provides and the surrounding environment.

The natural beauty of the Mtentu landscape makes it an attraction to tourists who are trying to escape the hustle of cities or more heavily populated tourist areas. Self-catering accommodation, campsites, and guest houses offer tourists a base to experience nature, canoeing, other water sports, hiking, horse riding, and bird and animal watching at its best. The Mkambati Nature Reserve is an 8 000 ha coastal reserve flanked by the forested ravines of the Msikaba and Mtentu rivers. For plant lovers, this place is special as it is the only one in the world where the Pondo Coconut is naturally found. Nearby is the Mkambati Marine Protected Area, which extends six nautical miles seawards between the eastern bank of the mouth of the Mtentu River and the western bank of the mouth of the Msikaba River. This protected area is alive with fish, otters, sharks and other marine life. It is also special for bird lovers, as the endangered Cape Griffon vultures have important nesting sites on the cliffs of the Mtentu and Msikaba gorges.

An interesting aspect of many of the tourism initiatives in the area is that they are intentionally geared towards being ecologically sensitive, and community based. This implies including local communities in the development, management and running of the tourism initiatives of the area and ensuring that direct economic benefit is guaranteed for the communities. Ecotourism projects that offer hiking, horse-riding, canoeing and communal living are examples of this sort of pro-poor, eco-friendly tourism opportunity in the area.

The free-flowing Mtentu River is a node of ecotourism activity on the Wild Coast. Pro-poor, eco-friendly tourism opportunities in the area offer long term prospects for social and economic development, so needed in the Eastern Cape Province.

The beauty of the Mtentu River and its surrounds should not be taken for granted. Since 2007 the area has been faced with several controversial prospecting and mining applications for heavy minerals. The mining companies and Department of Mineral Resources have argued in favour of mining in the area, suggesting that it will bring greater economic revenue and jobs to the communities of the Mtentu. There has been a powerful community level and civil society reaction to these claims. A variety of coalitions including the Sustaining the Wild Coast Campaign, the Amadiba Crisis Committee, a group of Wild Coast sangomas, human rights attorney Richard Spoor, and others have publicly opposed the mining. They argue that the number of jobs created will be small, and that mining will destroy the eco-tourism industry in the area, damage the rich biodiversity of the Mtentu and surrounds, uproot communities from their homes and livelihoods, and reduce longer term economic prospects, which are closely dependent on and tied to the relatively pristine environment.

Cleary the people of the Mtentu river and its surrounds are well aware of the precious piece of environment that they inhabit. With this awareness in place the community should have the will to respond to new challenges emerging in the area.

The Doring River: Keeping farmers in business

From its origins in the majestic Hex River Mountains, the Doring River winds its way through the Cederberg and joins the heavily utilised Olifants River at Klawer in the Western Cape. The Doring is currently free flowing for 200 km, making it the second longest free-flowing river in the country.

Maintaining the free-flowing nature of the Doring is critical for various reasons. To start with, a free-flowing and relatively pristine Doring River enables greater economic productivity for the Olifants River. Currently the Olifants River is heavily used for activities such as fruit farming, herding of goats and sheep, rooibos farming, and salt panning. In order to increase the economic productivity of this river, the Olifants Dam wall needs to be raised by 15 m to increase its storage capacity. Such development comes with severe ecological impacts and reduction of stream flow, particularly impacting on the area downstream of the dam where there are numerous grape farms. However, if the Doring River is kept healthy and free flowing, its natural flow and sediment actually replenishes the health of the Olifants River below the dam, thus keeping downstream farmers in business and the sensitive Olifants River estuary in an acceptable state of health.

If the Doring River is kept healthy and free-flowing, its natural flow and sediment replenishes the health of the Olifants River, thus keeping downstream farmers in business

The Doring River is abuzz with tourist activities, ranging from guest houses, to hiking trails, to river rafting, to nature reserves which boast sights like the spectacular Nieuwoudtville Falls. Wouter Groenewald, the director of a prominent rafting company on the river, says that he has been taking groups of people down the river for the last 22 years. During this time tourists navigate the river by day, sleep on its banks by night, drink from the river and experience magnificent nature at its best. Tours are only run during the winter rainy season. Groenewald says that any upstream damming severely impacts on the flow of the water in the lower part of the river where they operate. It is also critical to his business that the river is clean, in order to ensure the health of his customers.

Over and above the economic benefits that the Doring has, it is also a critical water source for specific communities and families. These people depend on the seasonal winter flows of the river to sustain subsistence farms which exist in the otherwise harsh climate of the Doring River valley. It also forms part of a southern African fish "hotspot" – all indigenous fish are unique to the region and, according to global standards, are highly threatened.

Riko du Plessis

Doring River

The upper Groot Marico River: the last remaining free-flowing river in the north-western regions of the country

The communities of the Upper Groot Marico River in the North West Province know the worth of their river. In what is otherwise a semi-arid region, this river is literally the life source for the communities of the area. Over and above providing clean drinking water, the river supports a variety of activities including traditional rituals, full-time farming, weekend farming, nature reserves, tourism activities, and private weekend getaways. However, the Marico meets more than just practical needs of its communities. It is a source of the region's spirituality, identity and sense of community. Peter Phefo, a Koffiekraal municipal representative and community member, says "We call our river Madikeweni", which means the coming together of different groups of people. Similarly, Daan van der Merwe, chair of the Marico Catchment Conservation Association says, "The Groot Marico River is our 'lewensaar' (our main artery). It binds us all together as communities."

In response to concerns about ongoing nickel mining applications in the Marico area, along with a growing body of science illustrating the importance of keeping this biologically unique river in a healthy state, communities and landowners have gathered together to form various activist groups and associations.

One such group, called MMutlwa wa Noko (thorn of the porcupine), works to oppose mining applications which it believes will damage the river and surrounds. It is made up of a diverse group of community members from the Marico town and downstream rural areas such as Koffiekraal. The group's coordinator, Brian Sheer, points out that the name 'thorn of the porcupine' has been chosen to symbolise that the threat posed by mining applications is "not a black or white issue, but a black and white issue," just like the porcupine quill itself. Collaboration between all communities of the Groot Marico River is essential in tackling this issue.

The upper Groot Marico River is the last remaining free-flowing river in the semi-arid north-western regions of the country. Diverse communities dependent on the river have been brought together in response to mining applications that threaten water quality and quantity.

The Marico Catchment Conservation Association is another group formed to protect the river. Currently there are 70 landowners who are part of this group which spans an area of approximately 25 000 ha upstream of the Marico Bosveld Dam. All members of the association have applied for conservancy status for their land and many are in the process of applying for protected environment or nature reserve status too. In the longer term it could be incorporated into a transfrontier conservation area with Botswana, given the dependence that Gabarone has on the river for water. The Marico Catchment Conservation Association aims to conserve the natural, cultural and historical assets of the Groot Marico. Their objectives are to conserve the river, promote sustainable development and encourage research on their river system and its related environment, given the unique ecological nature of the river and its relatively pristine state.

Chair of the association, Daan van der Merwe, says that the people of the Marico are rallying to protect their river because "it is morally and ethically the right thing to do. We are moving away from being just consumers to also being preservers of our river".

The Mutale River: At the heart of the VhaVenda people's livelihoods and spirituality

The Mutale River valley rests within the former 'homeland' of VhaVenda, in the far north of Limpopo Province. The VhaVenda people depend directly on the rivers and lakes for their daily water supply due to minimal water infrastructure being available in the area. Even where there are taps or boreholes, community members complain of the water being too salty or the taps being unreliable and thus still resort to fetching water directly from the river. Clearly, given the direct dependence of these communities on the water supply, the health and quality of the water directly impacts on the well-being of the Venda people.

The main form of land use in the Mutale river valley is subsistence farming. There is also a modest tourism industry around the river providing accommodation *en route* to the Kruger Park via the Punda Maria or Pafuri gates. Also Makuya Park, on communally-owned land, is now linked to the Kruger National Park.

The Mutale River supports one of only a handful of natural freshwater lakes in South Africa, Lake Fundudzi. The Lake is a sacred site believed to be the dwelling place of the ancestral spirits. Local communities protect the sacred rites of the lake.

To the Venda people, water is more than a practicality; it is also intrinsically tied to the spiritual life of some of the communities. One of the most significant sacred sites is Lake Fundudzi, which lies on the Mutale River. There are many rituals connected with Lake Fundudzi, one of only a handful of natural freshwater lakes in South Africa. There is a legend that a python god lives in the lake and cares for the crops. In order to please the python, the community pours sacrificial beer, which is brewed by the chief's sister, onto the water. The lake is also believed to be the dwelling place of the ancestral spirits of the Vhatavhatsindi people. The guardian of the lake is Chief Netshiavha. He discourages all foreigners from going to the lake unless accompanied by a local who knows the proper formalities for approaching the lake. Terrible things are believed to happen to those who do not respect the sacred rites of the lake.

Keeping the Mutale River free flowing and in a good ecological condition helps supply good quality water to dependent local communities, and supports the conservation of our cultural heritage.

Mutale River

The Elands River: A unique biodiversity haven and a life line for its people

The Elands River arises on the grassland plateau of the Drakensberg mountains near Machadodorp, flows downstream until it reaches the Crocodile River in Mpumalanga Province, which links with the Inkomati River that flows across the Mozambican border and eventually meets the Indian Ocean.

Here we have a river that both South Africa and Mozambique are dependent on to ensure that water quality and quantity needs are met for drinking and other uses. For example, the Crocodile River, into which the Elands River flows, is a major supplier of drinking water to the town of Nelspruit. The good water quality and quantity of the Elands River helps to dilute pollutants in the more heavily used Crocodile River.

The Elands River is also a haven for biodiversity in South Africa. Concerned landowners, registered water users, aquatic biologists from the University of Johannesburg and the University of the North, local and national public organisations such as Mpumalanga Tourism and Parks Agency, the Free State Nature Reserve, and CapeNature, as well as the Resource Quality Service specialists from the Department of Water Affairs, are all well aware of the special nature of this river. This is illustrated by the formation of the Elands River Conservancy which includes a number of landowners. More recently, in 2004, the Elands River Yellowfish Conservation Area (ERYCA) was also established.

The Elands River helps to provide good quality drinking water to downstream towns and users, for example in Nelspruit and even in Mozambique. With a beautiful waterfall at each end, it is a refuge for many threatened fish which could become a major draw card for angling if their populations are restored.

ERYCA is an active conservation initiative which aims to conserve a 60 km segment of the Elands River which is isolated between two waterfalls – the Waterval-Boven and Lindenau Falls. These falls act as natural barriers which have caused a unique array of aquatic organisms to evolve here alone. The particular conservation focus is on Bushveld small-scale yellowfish which are found only in this river. If this unique population of fish can be restored to 1980s levels, it would become a major draw card for angling, one of the largest sporting industries in South Africa. ERYCA also has the potential to support the re-introduction of the highly threatened Inkomati rock-catlet to the area.

Managing the environment of Mpumalanga presents complex challenges. The upper part of the Elands River, for example, has been noted for its rich coal deposits. Mining in this ecologically sensitive area would have huge impacts on water quality and quantity in the area. Having an active and aware community, working together with other stakeholders, will help promote good planning and decision-making to ensure that the Elands River maintains its free-flowing character, and continues to support water quality and quantity needs in the region.

The Mzimkulu River: Valued from source to sea

This free-flowing river of KwaZulu-Natal arises in the Drakensberg Mountains and flows downstream to meet the ocean at Port Shepstone. Mzimkulu means “home of all rivers” and considering the rich cultural history surrounding the river it is clearly also “home to all people” such as the early Khoi and San, the Nguni, and the Zulu people; the English, German and Norwegian settlers; and more recently a range of landowners, rural communities and tourists.

The water quality of the Mzimkulu, from its source in the mountains to the sea is excellent, with the primary impact on the river being the reduction of water quantity for farming and other activities. Much of the activity along this river depends on its natural state.

The Mzimkulu River, from its source in the mountains to the sea, is in excellent condition. Much of the activity along this river depends on its natural state, including dairy farming, tourism and the fastest growing canoe race in the country.

At its source the Mzimkulu lies within the uKhahlamba-Drakensberg Park, which is a World Heritage Site. The area owes this prestigious status to its rare rock paintings, the natural beauty of its basaltic buttresses, sandstone ramparts, high-altitude grasslands, pristine river valleys and gorges, and the resultant habitats which provide a home for numerous endemic and globally threatened species of birds and plants.

The upper to middle part of the river is used for irrigation and dairy farming, both of which benefit from the good quality of the water. In the lower reaches of the river many communities depend on the water for subsistence farming livelihoods. At Port Shepstone, the Mzimkulu reaches the ocean in a relatively natural state making it one of the few healthy freshwater systems meeting the ocean along this coastline.

All along the river there is vibrant tourist activity. From hikers drinking pure mountain water to multiple secluded riverside resorts, bed and breakfasts and retreats. The river draws hoards of people who use it for swimming, canoeing, boating, fishing and skiing. For canoeing enthusiasts this river is home for the fastest growing race in the country. The “Drakensberg Challenge”, with a Zulu slogan “Abanganlovalu” (not for the faint-hearted), runs on this river because of its natural state, and the fact that it is unhindered by dams.

By keeping the Mzimkulu in a free-flowing, natural state the river remains able to offer this broad basket of opportunities to the communities and farmers of the Mzimkulu. This also provides a natural reference site to use for studying the ecology of South African rivers.


Brian Colloty

Mtamvuna River

3.4 Fish sanctuaries

Fish sanctuaries are rivers and associated sub-quaternary catchments that are important for protecting threatened and near threatened fish species indigenous to South Africa. At least one third of South Africa's indigenous freshwater fish species are threatened. The Inkomati and Olifants/ Doorn Water Management Areas are 'hotspots' of threatened fish species.

Fish sanctuaries are rivers and their associated sub-quaternary catchments that are essential for protecting threatened and near threatened freshwater fish that are indigenous to South Africa (Table 3.2). These include large angling species like yellowfish as well as small fish like redfins.

Figure 3.4 shows the number of threatened and near threatened fish species within each fish sanctuary, ranging from one to as many as seven species. A goal of NFEPA is to keep further freshwater species from becoming threatened and to prevent those fish species that are already threatened from going extinct. In order to achieve this, there should be no further deterioration in river condition in fish sanctuaries and no new permits should be issued for stocking invasive alien fish in farm dams in the associated sub-quaternary catchments. Fish management plans need to be developed in all fish sanctuaries to protect the fish they contain. These plans should address issues such as management of a particular stretch of the river habitat within the sub-quaternary catchment, the construction of weirs to keep invasive alien fish species to a minimum (following an environmental impact assessment), and managing aquaculture and angling to ensure no further introduction of invasive alien fish species.

Invasive alien fish such as trout and bass should not be introduced or stocked in sub-quaternary catchments that have been identified as fish sanctuaries, whether for angling or aquaculture.

The IUCN Red List of threatened fish species (http://www.iucnredlist.org/initiatives/freshwater) was used as a starting point for identifying threatened and near threatened fish species in South Africa, which included those that are critically endangered, endangered, vulnerable and near threatened (Table 3.2). Those species classified by the IUCN as data deficient but deemed by South African fish biologists to be threatened, were also included. In addition, some species contain several distinct lineages and require taxonomic updating that will split them into several species, e.g. *Galaxias zebratus* may well be split into ten species. These were considered as separate lineages and each lineage was treated similarly to threatened species.

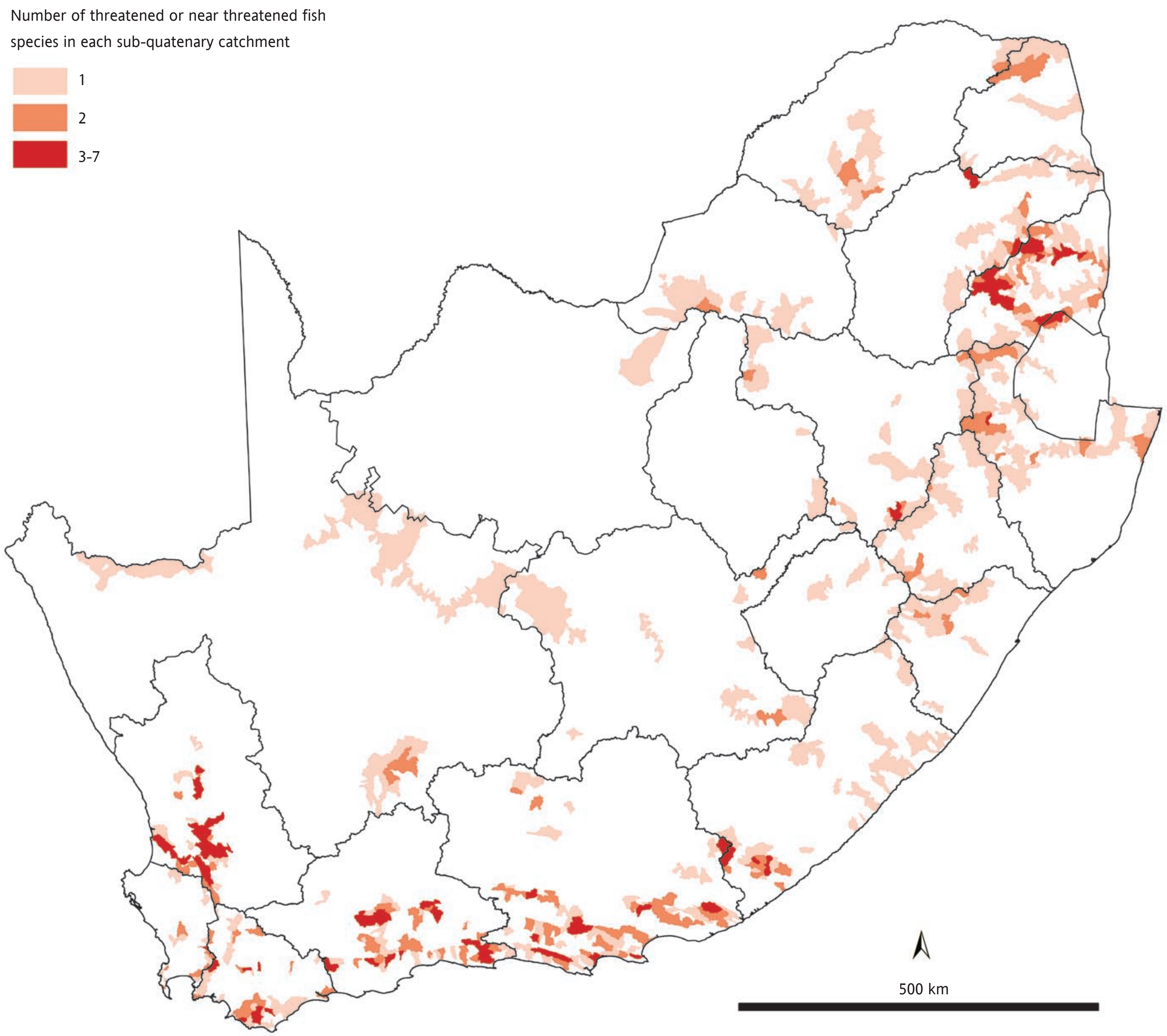


Figure 3.4: Fish sanctuaries for threatened and near threatened freshwater fish species indigenous to South Africa

Critically endangered redfin

For species and species lineages considered critically endangered or endangered, a target of 100% of all confirmed existing populations was set. For vulnerable and near threatened species and species lineages, a target of ten populations was set (or maximum confirmed populations if fewer than ten exist), coinciding wherever possible with sub-quaternary catchments selected for critically endangered and endangered species, and species lineages. The target of ten populations was derived from the IUCN criteria for conservation status which specify that as soon as a species drops below ten populations it becomes endangered (IUCN 2001).

Fish point locality data from SAIAB and the Albany Museum were used to guide selection of rivers and associated sub-quaternary catchments that would serve as fish sanctuaries for each species. This database was supplemented with expert knowledge from experienced fish biologists in different regions of the country. Historical records that are no longer valid (owing to local extinctions) were excluded from consideration. Fish sanctuary maps were identified for each species, with three possible categories:

- **Fish sanctuaries:** These are rivers and associated sub-quaternary catchments required to meet threatened and near threatened fish population targets. Fish sanctuaries in a good condition (A or B ecological category) were selected as FEPAs, and the remaining ones became Fish Support Areas. Fish sanctuaries are shown on the FEPA maps with a fish symbol (see Part 2 of this atlas). A red fish denotes a fish sanctuary that contains at least one critically endangered or endangered population; the remaining fish sanctuaries are shown with a black fish.
- **Fish migration areas:** These cater for large migratory fish that require connectivity between certain habitats, usually between mainstem and tributary habitat. Fish migration areas are shown as Fish Support Areas on the FEPA maps, but differ from fish sanctuaries in that they do not contain a fish symbol (see Part 2 of this atlas).
- **Fish upstream management areas:** These are rivers and associated sub-quaternary catchments in which human activities need to be managed to prevent degradation of downstream fish sanctuaries and fish migration areas. All fish upstream management areas are identified on the FEPA maps either as Upstream Management Areas, or in some cases as FEPAs if they were also required for representing river ecosystem types.

Fish sanctuaries for every threatened and near threatened species were combined and the number of threatened fish populations within each sub-quaternary catchment was calculated to derive Figure 3.4. A list of threatened and near threatened fish that occur within any particular fish sanctuary can be obtained from the NFEPA DVD, either by querying the fish sanctuary shapefile, or by using the unique sub-quaternary code shown on the FEPA maps (Part 2 of the atlas) to consult the look-up table on the DVD.

Table 3.2: Freshwater fish species for which fish sanctuaries were explicitly identified. Species marked with an asterisk require taxonomic updating as recent research shows that they contain several distinct lin□
refined by regional fish biologists to□
critically endangered (CR), endangered (EN) and vulnerable (VU) – were included. Species classified as data deficient (DD) by IUCN, but which contain several distinct lineages that are considered threatened were also included, as well as near threatened species (NT).

Genus	**Species**	**Common name**	IUCN Status
Amphilius	*natalensis**	Natal mountain catfish	DD
Austroglanis	*barnardi*	Spotted rock catfish	EN
Austroglanis	*gilli*	Clanwilliam rock catfish	VU
Austroglanis	*sclateri*	Rock catfish	LC
Barbus	*amatolicus*	Amatole barb	VU
Barbus	*andrewi*	Witvis	EN
Barbus	*anoplus**	Chubbyhead barb	DD
Barbus	*brevipinnis*	Shortfin barb	NT
Barbus	*calidus*	Clanwilliam redfin	VU
Barbus	*erubescens*	Twee River redfin	CR
Barbus	*hospes*	Namakwa barb	LC
Barbus	*lineomaculatus*	Line-spotted barb	VU
Barbus	*motebensis*	Marico barb	VU
Barbus	*pallidus**	Goldie barb	DD
Barbus	*serra*	Sawfin	EN
Barbus	*sp. "Banhine"*	Banhine barb	CR
Barbus	*sp. "Ohrigstad"*	Ohrigstad barb	DD
Barbus	*sp. "Waterberg"*	Waterberg barb	NT
Barbus	*treurensis*	Treur River barb	EN
Barbus	*trevelyani*	Border barb	EN
Chetia	*brevis*	Orange-fringed river bream	EN
Chiloglanis	*bifurcus*	Incomati suckermouth	EN

Genus	**Species**	**Common name**	IUCN Status
Clarias	*theodorae*	Snake catfish	LC
Galaxias	*zebratus**	Cape Galaxias	DD
Hydrocynus	*vittatus*	Tigerfish	LC
Kneria	*auriculata*	Southern kneria	CR
Labeo	*seeberi*	Clanwilliam sandfish	EN
Labeo	*umbratus*	Moggel	LC
Labeobarbus	*capensis*	Clanwillliam yellowfish	VU
Opsaridium	*peringueyi*	Southern barred minnow	LC
Oreochromis	*mossambicus*	Mozambique tilapia	NT
Pseudobarbus	*afer**	Eastern Cape redfin	NT
Pseudobarbus	*asper*	Smallscale redfin	EN
Pseudobarbus	*burchelli**	Burchell's redfin	CR
Pseudobarbus	*burgi**	Berg River redfin	EN
Pseudobarbus	*phlegeton**	Fiery redfin	CR
Pseudobarbus	*quathlambae**	Maloti redfin	EN
Pseudobarbus	*tenuis**	Slender redfin	NT
Sandelia	*bainsii*	Eastern Cape rocky	EN
Sandelia	*capensis**	Cape kurper	DD
Serranochromis	*meridianus*	Lowveld largemouth	EN
Silhouetta	*sibaya*	Sibayi goby	EN
Varicorhinus	*nelspruitensis*	Incomati chiselmouth	NT

Description of IUCN categories

CR	Critically Endangered	Facing an extremely high risk of extinction in the wild
EN	Endangered	Facing a very high risk of extinction in the wild
VU	Vulnerable	Facing a high risk of extinction in the wild
NT	Near Threatened	Likely to qualify as CR, EN or VU in the near future
DD	Data Deficient	Inadequate information to make an assessment of its risk of extinction
LC	Least Concern	Not threatened

3.5 High water yield areas

Figure 3.5 shows those sub-quaternary catchments where mean annual run-off (mm per year) is at least three times more than the average for the related primary catchment. Mean annual run-off is the amount of water on the surface of the land that can be utilised in a year, which is calculated as an average (or mean) over several years.

High water yield areas are important because they contribute significantly to the overall water supply of the country. They can be regarded as our water factories, supporting growth and development needs that are often a far distance away. Deterioration of water quantity and quality in these high water yield areas can have a disproportionately large adverse effect on the functioning of downstream ecosystems and the overall sustainability of growth and development in the regions they support. High water yield areas should therefore be maintained in a good condition (A or B ecological category). This requires minimising land use activities that reduce stream flow in these areas (e.g. plantation forestry), as well as any activity that would affect water quality (e.g. timber mills, mining, over-grazing). Wetlands also play an important role in these areas, regulating stream flow and preventing erosion. Additionally, clearing of invasive alien plants in these areas would deliver large water yield benefits relative to clearing in other parts of the catchment.

High water yield areas are our water factories, supporting growth and development needs that are often a long distance away. Land uses that reduce stream flow or affect water quality (e.g. mining, plantations, overgrazing) should be avoided in these areas, wetlands should be kept in good condition or rehabilitated, and invasive alien plants should be cleared.

The Mountain Catchment Areas Act (Act 63 of 1970) recognises the need to manage high water yield areas wisely for the benefit of both people and ecosystems. It enables mechanisms for prevention of soil erosion, protection of the natural vegetation, clearing of invasive alien plants, and implementation of fire protection plans. As early as 1959, Mountain Catchment Areas of South Africa had been delineated by hand (Figure 3.5). These correspond well with the high water yield areas identified by NFEPA (Figure 3.6).

Unfortunately only a few Mountain Catchment Areas have been declared in terms of the Mountain Catchment Areas Act. These declared Mountain Catchment Areas make a relatively large contribution to freshwater ecosystem conservation and management relative to other protected area systems (Nel et al. 2009b). Ideally, all high water yield areas should be declared in terms of the Mountain Catchment Areas Act, as the Act provides mechanisms and incentives for appropriate land management in these areas. Revitalising the Mountain Catchment Areas Act and declaring further Mountain Catchment Areas in high water yield areas, with a view to protecting the country's water resources, is a strong recommendation of the NFEPA project.

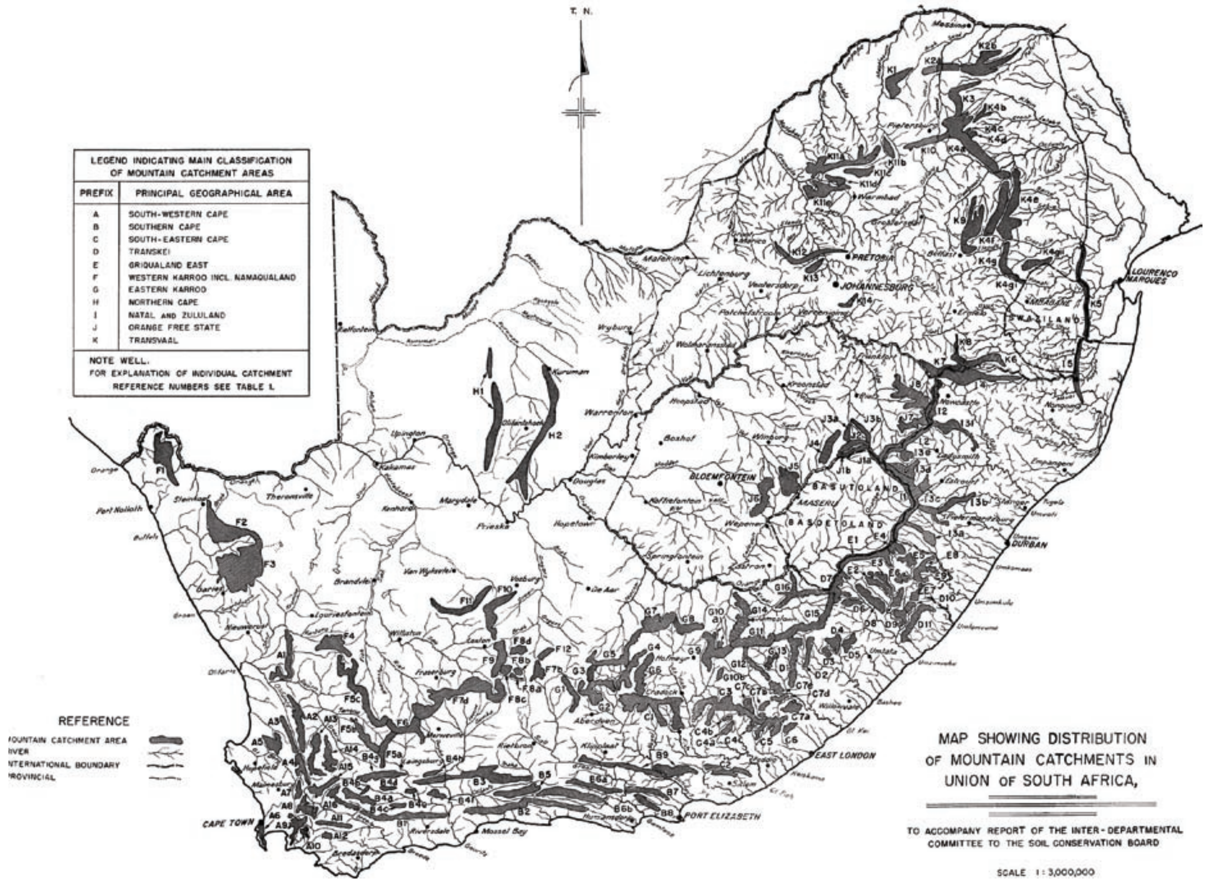


Figure 3.5: Mountain Catchment Areas, delineated by hand in 1959 (Department of Agricultural Technical Services. 1961)

Revitalising the Mountain Catchment Areas Act and declaring additional Mountain Catchment Areas could make a significant contribution to protecting South Africa's water resources.

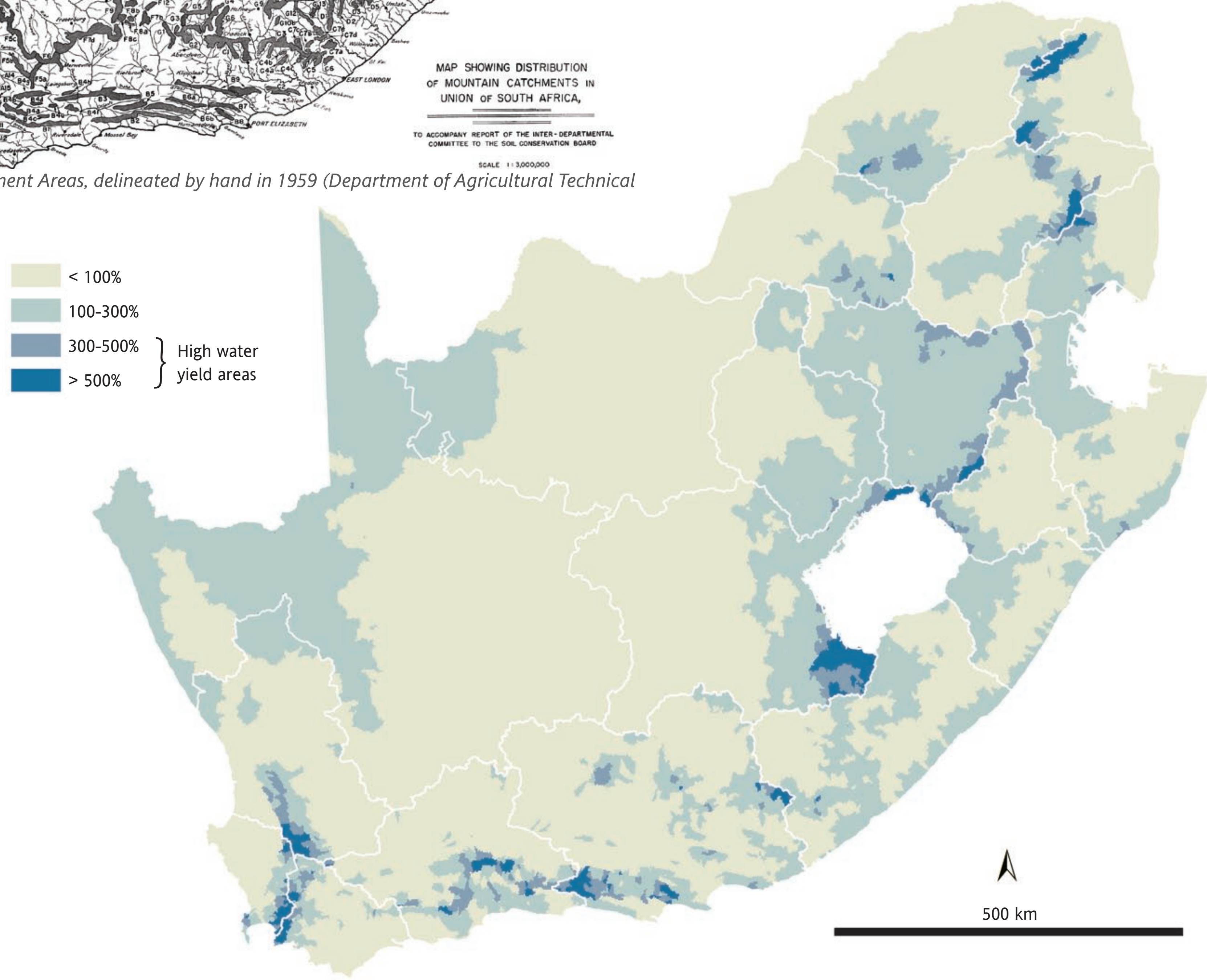


Figure 3.6: H□ at least three times more than the average for the related primary catchment

The map of high water yield areas was derived using mean annual rainfall data at a 1 x 1 minute resolution for the entire country. This was converted into mean annual runoff using the rainfall-runoff relationships established in South Africa's 1990 Water Resource Assessment (Midgley et al. 1994). Mean annual runoff for each sub-quaternary catchment was expressed as a percentage of the mean annual runoff for that primary catchment to identify areas where mean annual runoff is at least three times more than that of the primary catchment.

3.6 High groundwater recharge areas

Groundwater is critical for sustaining river flows, especially in the dry season (Figure 3.7). Groundwater recharge, the process by which rainwater seeps into groundwater systems, is crucial for sustaining groundwater resources and is calculated as an average over several years. Groundwater recharge is dependent mainly on rainfall and geological permeability, and different areas vary in their ability to recharge groundwater. Figure 3.8 shows those sub-quaternary catchments where groundwater recharge is at least three times more than the average for the related primary catchment.

High groundwater recharge areas can be considered as the recharge hotspots of the region. Keeping natural vegetation in these areas intact and healthy is critical to the functioning of groundwater dependent ecosystems, which can be in the immediate vicinity or far removed from the recharge area. For example, recharge in the Groot Winterhoek Mountains of the Olifants/Doorn Water Management Area is believed to sustain coastal aquifers over 100 km away, which in turn support high value crops (potatoes). Activities that should be prevented or controlled in these areas include groundwater abstraction, loss of natural vegetation cover, and invasion by alien plants.

High groundwater recharge areas are crucial for sustaining groundwater resources, which may be far away from the recharge area. Groundwater abstraction and loss of natural vegetation should be avoided in these areas, and invasive alien plants should be cleared.

The map of high groundwater recharge areas was derived using the 2005 groundwater resource assessment data, available at a resolution of 1 km x 1 km (DWAF 2005). Groundwater recharge (mm per year) for each 1 km x 1 km cell was expressed as a percentage of the mean annual rainfall (mm per year) for that cell. This gives a relative idea of where the proportionally highest recharge areas are in the country, compared to using absolute numbers (mm per year). Percentage recharge for each sub-quaternary catchment was expressed as the percentage recharge for the relevant primary catchment to identify areas where groundwater recharge is at least three times more than that of the primary catchment.

Figure 3.7: Groundwater sustains river flows and connected ecosystems

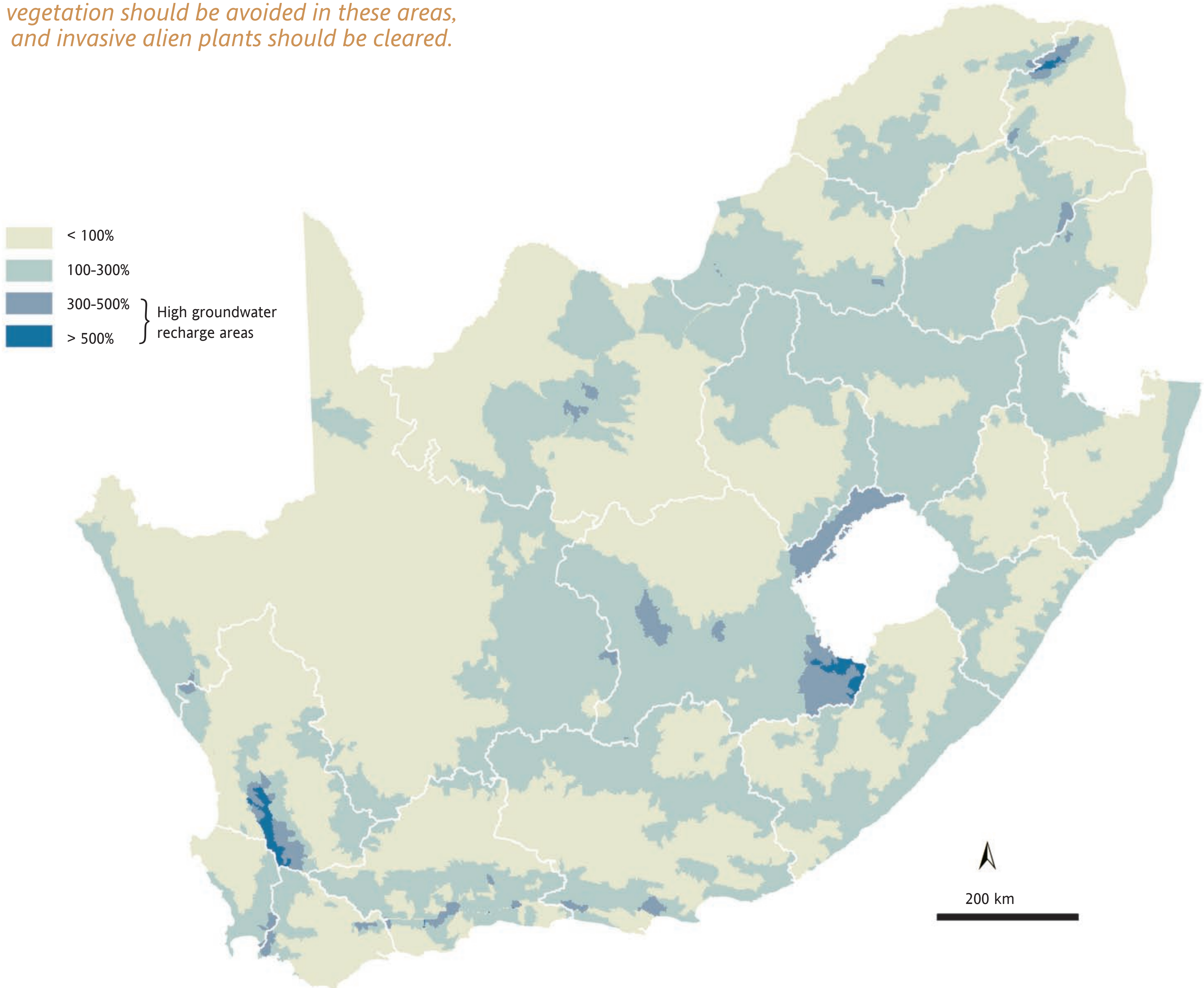


Figure 3.8: High g□
three times more than the average for the related primary catchment

Part 4: Data layers used for identifying FEPAs

The input data layers used in the development of the FEPA maps and national maps are shown here. These include:

Jeanne Nel

Input data that inform the identification of FEPAs were collated and reviewed through five regional expert workshops around the country during May and June 2009. Over 100 experts participated in these workshops and meetings, representing government, private and civil society.

This part of the atlas shows the input data layers that were used in the development of the FEPA maps and national maps presented in Parts 2 and 3. The input data layers shown here are:

- ***River ecosystem types*** comprising unique combinations of landscape features, flow variability and channel slope. River ecosystem types were used for representing natural examples of the diversity of river ecosystems across the country.
- ***River condition*** that combines data on present ecological state of rivers (Kleynhans 2000 and available updates), river health data, reserve determination data, expert knowledge and natural land cover data. Rivers had to be in a good condition (A or B ecological category) to be chosen as FEPAs.
- ***Wetland ecosystem types*** consisting of unique combinations of landforms (benches, slopes, valley floors and plains) and vegetation types. Wetland ecosystem types were used for representing the diversity of wetland ecosystems across the country.
- ***Wetland condition*** modelled using the proportion of natural vegetation in and around the wetland as an indicator of condition. Wetland condition was used to favour the selection of wetlands in good condition as FEPAs, although wetlands did not have to be in a good condition to be chosen as a FEPA.
- ***Landforms*** that categorise the country's landscape into benches, slopes, valley floors and plains. Landforms were used in identifying wetland ecosystem types.
- ***Wetland vegetation groups*** that are based on groupings of national vegetation types expected to have wetlands with similar characteristics. Wetland vegetation groups were used in combination with the landform map to identify wetland ecosystem types.
- ***Priority estuaries*** as identified in the National Biodiversity Assessment 2011 based on a systematic biodiversity planning approach. Priority estuaries became FEPAs and were also used to favour the selection of associated river and wetland ecosystems as FEPAs.

4.1 River ecosystem types

River ecosystem types were used for representing natural examples of the diversity of river ecosystems across the country. South Africa is a geologically, geomorphologically and climatically complex country, giving rise to many different types of river ecosystems and associated biodiversity. For example, a foothill river in the Highveld is very different from one in the Eastern Coastal Belt. Similarly, Highveld mountain streams, foothill rivers and lowland rivers have different physical characteristics, which determine the types of plants and animals that they support.

River ecosystem types are river reaches with similar physical features (such as climate, flow and geomorphology). Under natural conditions, rivers with the same ecosystem type are expected to share similar biological response potential. River ecosystem types can therefore be used as coarse-filter surrogates for river biodiversity, advancing freshwater conservation beyond dealing only with species, to also conserving habitats and ecosystems on a systematic basis. As explained in Section 1.5, the biodiversity target for freshwater ecosystems in South Africa is 20%, which means that we should keep at least 20% of each river ecosystem type in a good condition (A or B ecological category). This serves to conserve many common species and communities, and the habitats in which they evolve. These coarse-filter surrogates were supplemented with data on threatened and near threatened fish species (Section 3.4).

South Africa has had a national map of vegetation types for some time, which provide coarse-filter surrogates for terrestrial biodiversity. However, there has not been an agreed map of river ecosystem types, which are more or less the freshwater equivalent of vegetation types. The need to identify different river ecosystem types, in order to compare information between rivers and to allocate priority uses to different rivers, has long been recognised in South Africa (Harrison 1959; Noble 1970; O'Keefe et al. 1989). Early mapping efforts focused on defining relatively coarse regions across the country that shared similar characteristics: Harrison (1959) mapped 12 hydrobiological regions in South Africa based on water chemistry and aquatic biota; Eekhout et al. (1997) defined ten biogeographic regions based on cluster analysis of 645 species of riverine plants, fish and macro-invertebrates; and 6 regions were defined by Dallas et al.(1995) based on water chemistry. Advances in GIS and increasing availability of spatial data now permit the identification of the finer-scale river ecosystem types used here.

NFEPA used spatial information on the ecoregions of South Africa (Kleynhans et al. 2005), broad flow variability, and slope category of river channels (Rowntree and Wadeson 1999) to identify 223 river ecosystem types across South Africa. Figure 4.1 shows the number of river ecosystem types in each Water Management Area. The Usutu to Mhlathuze, Olifants and Limpopo Water Management Areas display the highest diversity, with over 20% of the total number of river ecosystem types occurring in each of these areas, while the Breede Water Management Area has a relatively low river ecosystem diversity (7%). The low river ecosystem diversity in the Breede Water Management Area is typical of the Western Cape rivers, which generally have lower species richness but high levels of endemism and threat.

In future, descriptions and lists of dominant species should be developed for each river ecosystem type, and river ecosystem types could be published in a similar manner to the vegetation map of South Africa, Lesotho and Swaziland (Mucina and Rutherford 2006).

The Department of Water Affairs 1:500 000 river network GIS layer was used as a basis for identifying national river ecosystem types for NFEPA (http://www.dwaf.gov.za/iwqs/gis_data/river/rivs500k.html). A further 97 coastal rivers were added from the 1:50 000 river network GIS layer (Department of Land Affairs: Chief Directorate Surveys and Mapping 2005-2007) based on the addition of several missing South African estuaries along the coastline (the estuary layer was also updated in the process). The ecoregion (Section 4.1.1), flow description (Section 4.1.2) and slope category (Section 4.1.3) for each river was combined to produce 223 distinct river ecosystem types for South Africa.

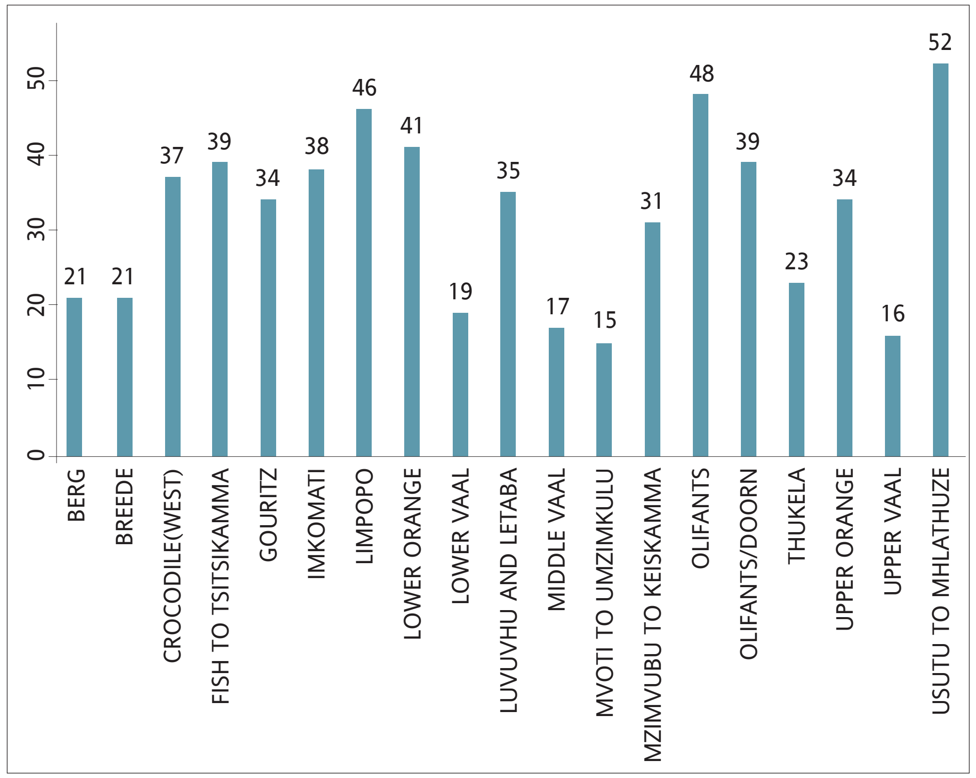


Figure 4.1: Number of river ecosystem types in each Water Management Area

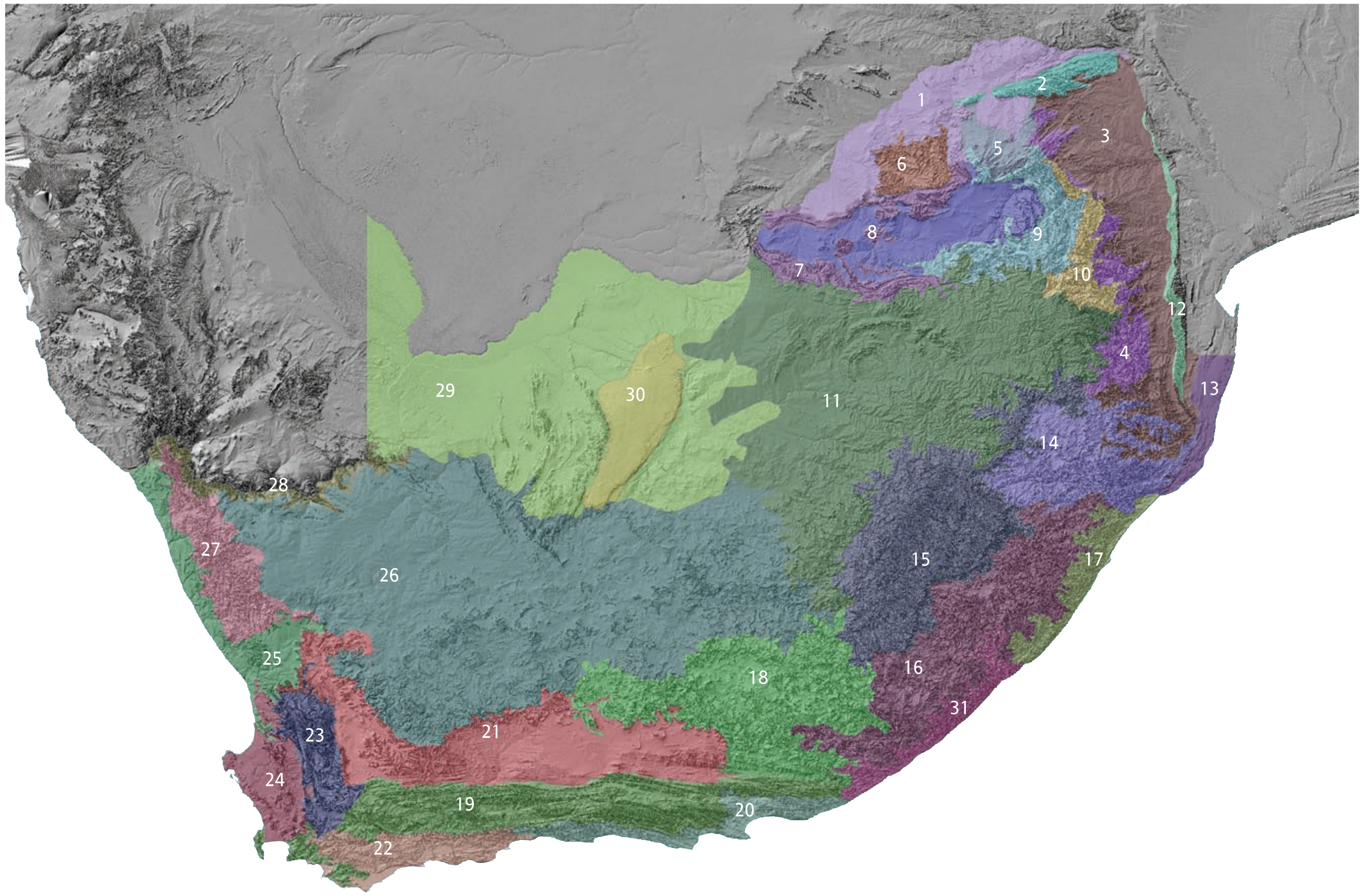
4.1.1 Level 1 ecoregions

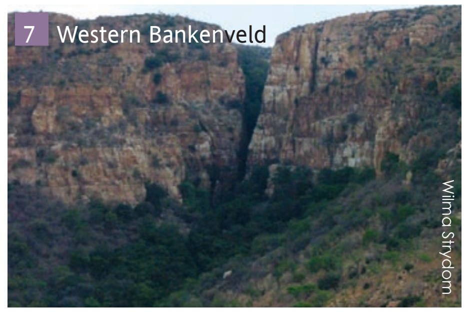
Ecoregions classify the landscape into 30 categories based on topography, altitude, slope, rainfall, temperature, geology and potential natural vegetation (Kleynhans et al. 2005). Ecoregions broadly characterise the landscape through which a river flows, such that rivers in the same ecoregion share similar broad ecological characteristics compared to those in different ecoregions. For example, the Highveld is characterised by extensive flat plains with gentle meandering rivers, compared to rivers in the Eastern Coastal Belt that are often in steeply incised and confined valleys (Figure 4.2 and accompanying photographs).

- 1 Limpopo Plain
- 2 Soutpansberg
- 3 Lowveld
- 4 North Eastern Highlands
- 5 Northern Plateau
- 8 Bushveld Basin
- 9 Eastern Bankenveld
- 10 Northern Escarpment Mountains
- 11 Highveld
- 12 Lebombo Uplands
- 13 Natal Coastal Plain
- 14 North Eastern Uplands
- 16 South Eastern Uplands
- 17 North Eastern Coastal Belt
- 22 Southern Coastal Belt
- 24 South Western Coastal Belt
- 25 Western Coastal Belt
- 31 Eastern Coastal Belt


6 Waterberg


30 Ghaap Plateau




7 Western Bankenveld


29 Southern Kalahari


15 Eastern Escarpment Mountains


28 Orange River Gorge


18 Drought Corridor

Figure 4.☐

ecosystem types.


27 Namaqua Highlands


26 Nama Karoo


23 Western Folded Mountains


21 Great Karoo


20 South Eastern Coastal Belt


19 Southern Folded Mountains

4.1.2 Flow variability categories

The 1:500 000 river network GIS layer was classified into two categories, permanent and not permanent, using flow descriptions in the Department of Water Affairs 1:500 000 rivers and the 1:50 000 rivers of the Department Land Affairs: Chief Directorate Surveys and Mapping (2005-2007). 'Permanent' includes both perennial and seasonal rivers and 'Not permanent' includes ephemeral rivers that can go for years without flowing (Figure 4.3). Rivers with different flow variability are expected to have different ecological characteristics. Ideally, flow variability for the 1:500 000 rivers should be described in more than two categories. While this is accomplished by the hydrological index developed by Hannart and Hughes (2003), it is only available for mainstem quaternary rivers. The 1:500 000 rivers require a much finer resolution than the resolution of the existing hydrological indices. Developing hydrological indices for the 1:500 000 rivers should be a future focus for improving the description of river ecosystem types.

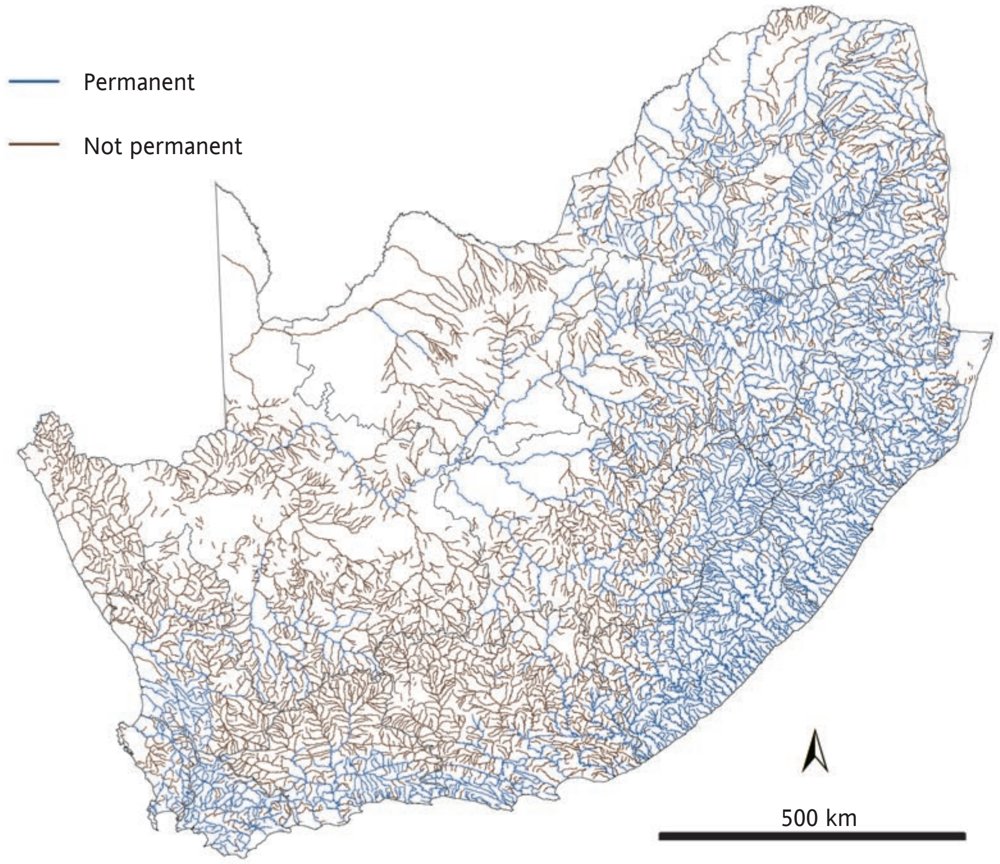


Figure 4.3: Flow descriptions for the 1:500 000 river network GIS layer. 'Permanent' refers to rivers that flow for at least some time every year; 'Not permanent' refers to ephemeral rivers that do not flow every year. This GIS layer was one of the three used to derive river ecosystem types.

Permanent river

Wilma Strydom

Not permanent river

Kevin Murray

4.1.3 Slope categories

Slope categories are based on geomorphological zonation work by Rowntree and Wadeson (1999). Geomorphological river zones characterise the ability of river reaches to store or transport sediment, with each zone representing a different physical template available for the biota. Moolman et al. (2002) used GIS slope profiles to stratify the 1:500 000 rivers according to the slope categories proposed by Rowntree and Wadeson (1999). For NFEPA, these were grouped into four classes for depicting ecological characteristics at a national level: mountain streams, upper foothills, lower foothills and lowland rivers (Figure 4.4). These zones have different physical and hydrological characteristics and are expected to have distinct biota (Figure 4.5). For example the macro-invertebrate functional feeding groups shift from shredders and collectors in mountain streams, to grazers and collectors in foothill streams, to collectors in lowland rivers. Fish tend to occur in lower foothill and lowland rivers. Mountain streams tend to be less impacted by human activities but these zones contain many endemic and specialised species that are likely to be less resilient to human impacts. Upper foothills are vulnerable zones because they often contain sensitive endemic species and present some of the best opportunities for damming. Lower foothills and lowland rivers are usually heavily impacted by agriculture and urban development. The maintenance of healthy natural vegetation along river banks is particularly important in lowland rivers as it provides filtering capacity for pollutants in runoff.

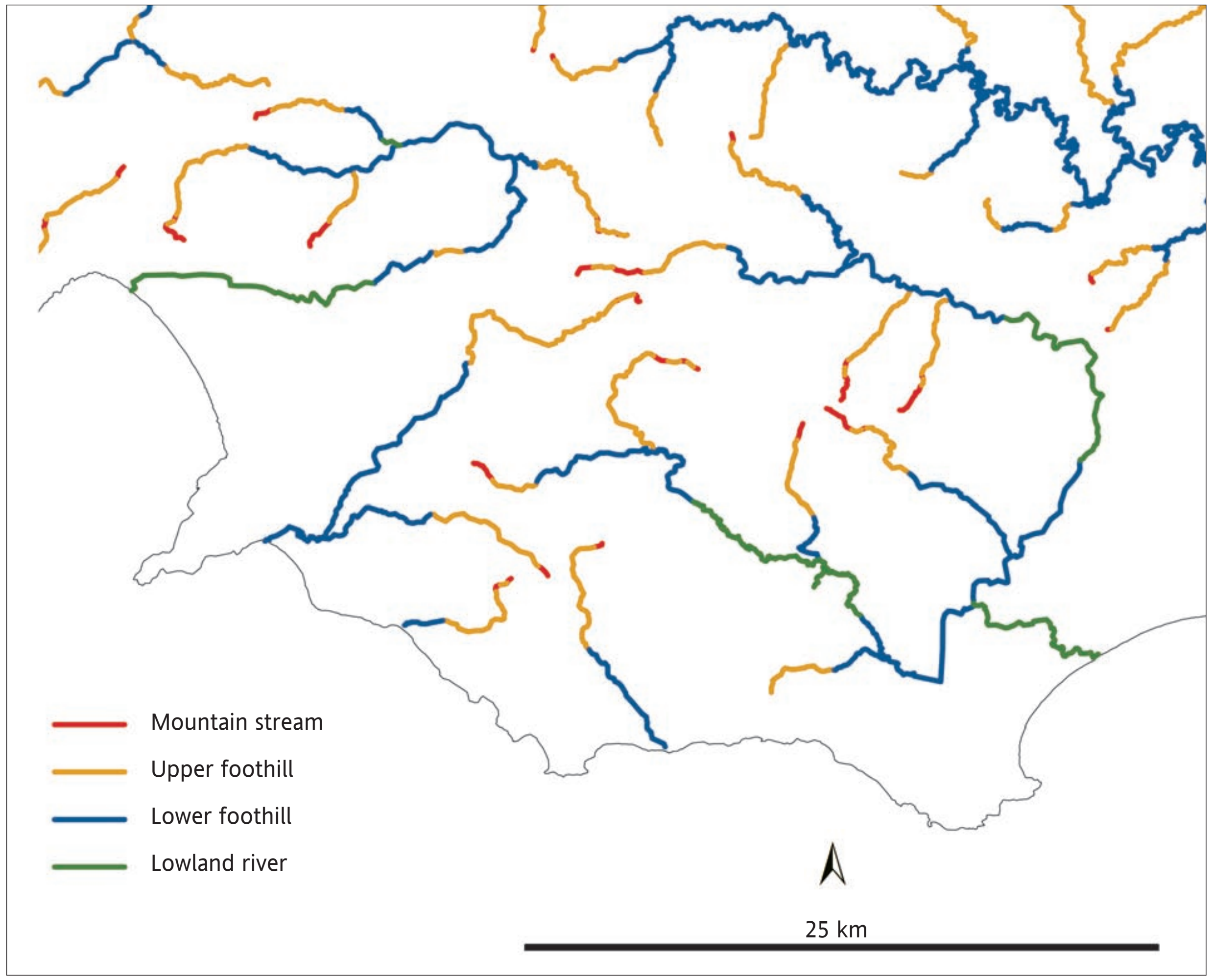


Figure 4.4: Slope categories for the 1:500 000 river network GIS layer, showing an area on the Agulhas Plain. This GIS layer was one of the three used to derive river ecosystem types.

Figure 4.5: Schematic of profiles used to derive the four slope categories which share broadly similar ecological characteristics and functioning

4.2 River condition

River condition describes the extent to which the river has been modified by human activity. In South Africa, river condition is described in six 'present ecological state' (PES) categories ranging from natural (A) to critically modified (F) (Table 4.1). Only river ecosystems in good condition (A or B ecological category) were chosen as FEPAs, because rivers in a C or lower ecological condition are considered to have lost too much of their biodiversity to be representative samples of South Africa's freshwater ecosystems. From a practical point of view, natural ecosystems tend to be more self-sustaining, thus requiring less conservation management. For example, a river with healthy natural vegetation along its banks is able to filter pollutants from the surrounding landscape and is likely to have better quality water. Rivers that are in good condition may nevertheless require some management, for example clearing of invasive alien trees and associated rehabilitation of river bank vegetation. The cost of managing rivers to keep them in good condition is lower than the cost of rehabilitating modified rivers, and the likelihood of success is greater.

Table 4.1: Present ecological state (PES) categories used to describe the current and desired future condition of South African rivers (after Kleynhans 2000). For NFEPA, rivers in an A and B category were regarded as being in good condition.

Ecological category	Description
A	Unmodified, natural.
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions have occurred.
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions are extensive.
F	Critically/Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.
Z	Rivers C-F where no data and no expert opinion is available, modelled based on percentage natural land cover.

A draft map of river condition was derived by combining the 1999 present ecological state categories for quaternary mainstem rivers (Kleynhans 2000: Table 4.1) with modelled categories for tributaries. Quaternary mainstem rivers are the 1:500 000 rivers that pass through quaternary catchments, and are hereafter referred to as 'main rivers'. The remaining 1:500 000 rivers are nested within quaternary catchments, and are referred to as 'tributaries'.

The modelled condition categories for tributaries used the percentage of natural land cover from the 30 m resolution SANBI 'Mosaic National Land Cover 2009', which updates the National Land Cover 2000 GIS layer (Van den Berg et al. 2008) with more recent and improved provincial land cover data where it exists. Tributaries were considered to be in good condition (A or B ecological category) if the percentage natural land cover within a series of buffers around each sub-quaternary river reach never dropped below 75% and the percentage erosion within 500 m of the river reach was less than 5%. The percentage natural land cover in the area surrounding a river reach is a strong indicator of the condition of the river reach. This is because loss of natural vegetation, for example as a result of urban development, cultivation or mining, together with the water use and pollutants associated with these activities, dramatically disturbs the ecological functioning of rivers in almost all cases. Erosion was used to take account of land degradation, which unlike outright loss of natural habitat is often not picked up directly in the land cover map but is a problem especially in drier regions of the country. Where erosion sheets exist they often occur along river banks, indicating severe land degradation in the surrounding area, which impacts negatively on the condition of the rivers.

Updated information on river condition for main rivers and tributaries was also collated from various sources. These additional data, combined with on-the-ground knowledge of aquatic ecologists, was used to review and update the draft river condition map in a series of regional expert workshops. Sources of updated information included:

- Updated present ecological state data for 7 of the 19 water management areas obtained from the Department of Water Affairs Resource Quality Services office;
- Desktop, rapid, intermediate and comprehensive reserve determination data from the Department of Water Affairs Surface Water Reserve Requirements database (http://www.dwa.gov.za/groundwater/gwoffices.aspx). Only 55% of the sites had coordinates and could be used, although expert input at the workshop filled in some of these gaps;
- Site-level data from the River Health Programme, obtained from the Department of Water Affairs Rivers Database (http://www.dwaf.gov.za/iwqs/rhp/naehmp.htm), State of Rivers Reports, a recent review of the River Health Programme (Strydom et al. 2006) and unpublished data from regional River Health Programme champions.

The resulting map of river condition is shown in Figure 4.7. A previous assessment showed that only a third of the length of South Africa's main rivers are in a good condition (Nel et al. 2007). This more comprehensive assessment of river condition, which included both main rivers and their 1:500 000 tributaries, shows clearly that tributaries are generally less heavily impacted than main rivers. Nearly half of the rivers are in good condition if main rivers and tributaries are considered together, compared with about a third when considering main rivers alone (Figure 4.6). This emphasises the important role that healthy tributaries play in keeping our heavily impacted main rivers functioning.

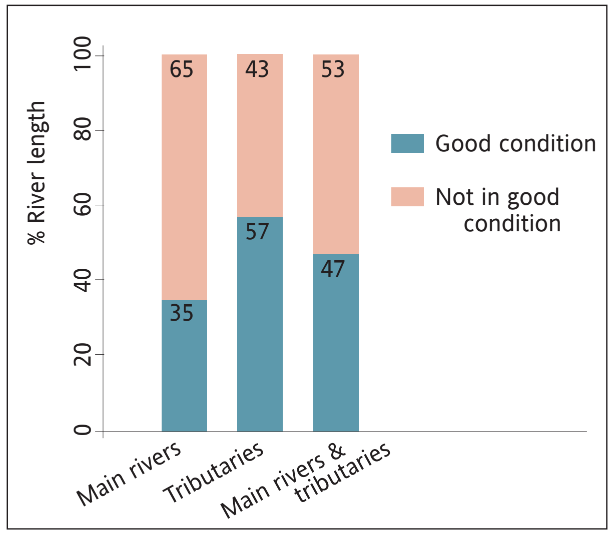


Figure 4.6: Percentage of main rivers versus tributaries in good condition. These data show that tributaries are overall in better condition than main rivers.

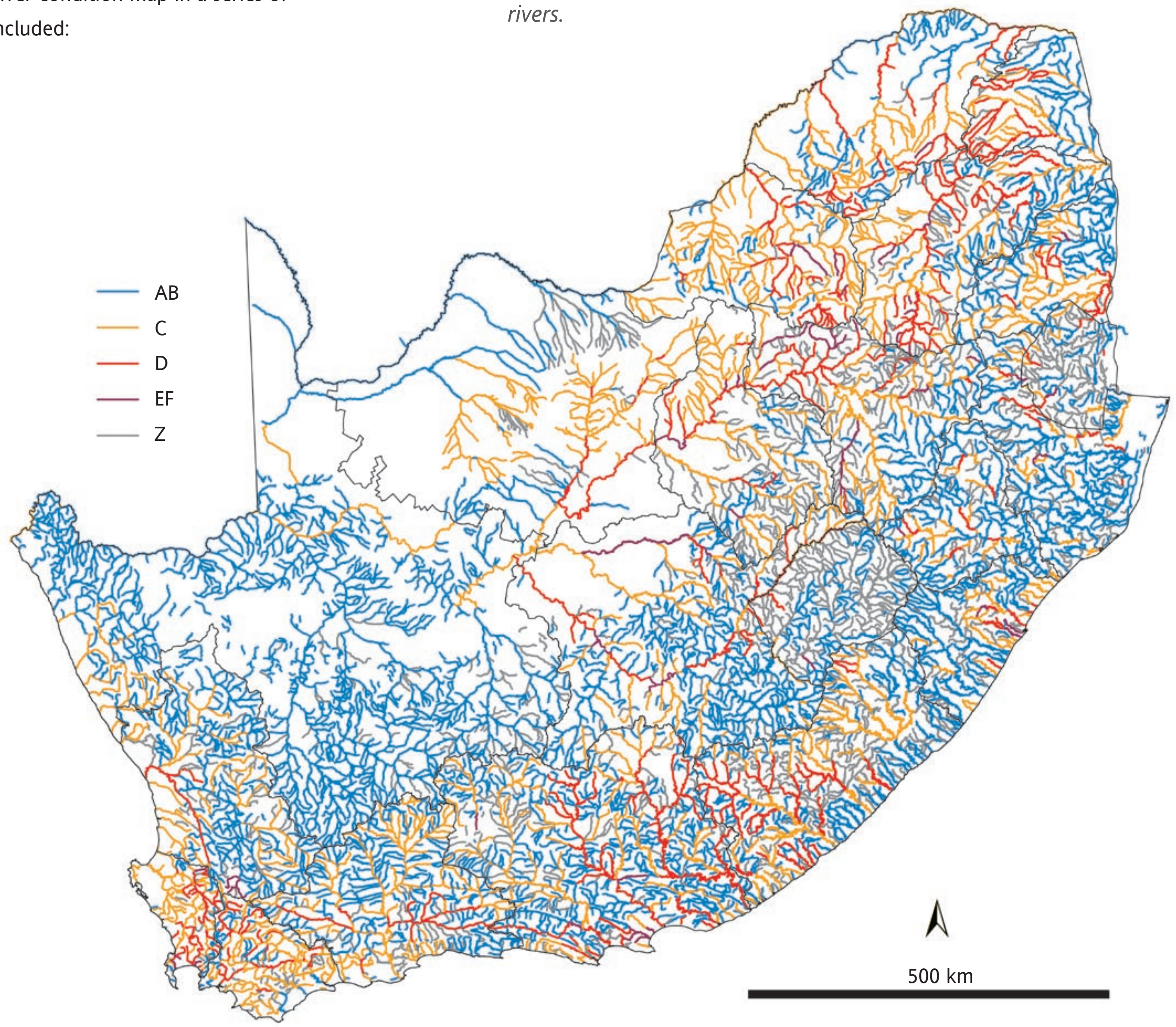


Figure 4.7: River condition in South Africa, based on a combination of empirical data and expert knowledge. River condition categories follow the present ecological state (PES) categories of Kleynhans (2000).

4.3 Wetland ecosystem types

Wetland ecosystem types were used for representing natural examples of the diversity of wetland ecosystems across the country. Wetlands of the same ecosystem type are expected to share similar functionality and ecological characteristics. For example, seeps function differently to valley-bottom wetlands; valley-bottom wetlands in the mesic highveld grassland have different characteristics to valley-bottom wetlands in sandstone fynbos. As explained in Section 1.5, the biodiversity target for freshwater ecosystems in South Africa is 20%, which means that we should keep at least 20% of each wetland ecosystem type in a natural or near-natural condition. This serves to conserve many common species and communities, and the habitats in which they evolve. The coarse-filter surrogate provided by wetland ecosystem type was supplemented with information on Ramsar status (http://ramsar.wetlands.org/), known threatened frog (http://www.adu.org.za/; http://www.adu.org.za/docs/FrogData.csv) and waterbird occurrences (http://cwac.adu.org.za/cwac_map.php?Pv=GP) and expert knowledge on biodiversity importance. These additional data sources helped in identifying wetland FEPAs (see Section 2.2 of the atlas).

Planning for wetlands at the landscape level (rather than on a site-by-site basis) is challenging. The best national information available prior to NFEPA was the SANBI National Wetland Map 3 (completed in 2009; http://bgis.sanbi.org), which maps the extent of some 100 000 wetland systems. The delineations are based largely on remotely-sensed imagery and therefore do not include historic wetlands lost through drainage, ploughing and concreting. Irreversible loss of wetlands is especially high in some areas, such as urban centres and intensively cultivated areas.

NFEPA augmented the National Wetland Map 3 with finer scale wetland maps that were available from various sub-national biodiversity planning exercises. This produced an NFEPA wetland map of almost 200 000 wetlands. Sub-national wetland data included:

- Wetlands for the entire KwaZulu-Natal Province (available from Ezemvelo KZN Wildlife);
- Cape Action for People and the Environment (C.A.P.E.) fine-scale biodiversity planning wetlands of Saldanha/Sandveld, Riversdale plain and Upper Breede River Valley (available from http://bgis.sanbi.org);
- Overberg, Niewoudtville and Kamieskroon wetlands (available from http://bgis.sanbi.org);
- Selected wetlands of conservation importance in Mpumalanga Province (available from Mpumalanga Parks and Tourism Agency).

Although there are still gaps in mapping wetlands in South Africa, enormous progress have been made over the last several years. SANBI has an ongoing wetland inventorying programme that is improving the GIS layer for national wetlands to support future planning and management.

Another important advance towards landscape-level planning for wetlands was the completion of the national wetland classification system (SANBI 2009). Levels 1 to 4 of the classification system identify broad groups of wetlands sharing similar regional context, landform and broad hydrology. Levels 5 and 6 describe site characteristics such as hydroperiod, geology, vegetation, substratum, salinity, pH and naturalness. Wetlands in the NFEPA wetland map were classified into wetland ecosystem types according to Level 4 of the national wetland classification system.

Level 4 wetland ecosystem types were derived using the landforms (Section 4.5) and wetland vegetation groups (Section 4.6). First the four landform classes (benches, slopes, plains and valley-floors) were used in conjunction with the 1:50 000 pans GIS layer (Department of Land Affairs: Chief Directorate Surveys and Mapping 2005-2007) and 1:500 000 river network GIS layer to classify each wetland into one of seven 'hydrogeomorphic types' (Figure 4.8):

- Seep
- Valleyhead seep
- Unchannelled valley-bottom
- Channelled valley-bottom
- Floodplain
- Flat
- Depression

Second, each wetland was assigned the wetland vegetation group that occupied the majority of its area, to characterise the regional context (e.g. climate, soil, geology) within which the wetland occurs. For each wetland, the hydrogeomorphic type was combined with its corresponding wetland vegetation group, producing 791 distinct wetland ecosystem types across the country. Although there are many gaps and challenges with the NFEPA wetland ecosystem types, they represent a major achievement and provide a significant new national product that can now be further refined and debated.

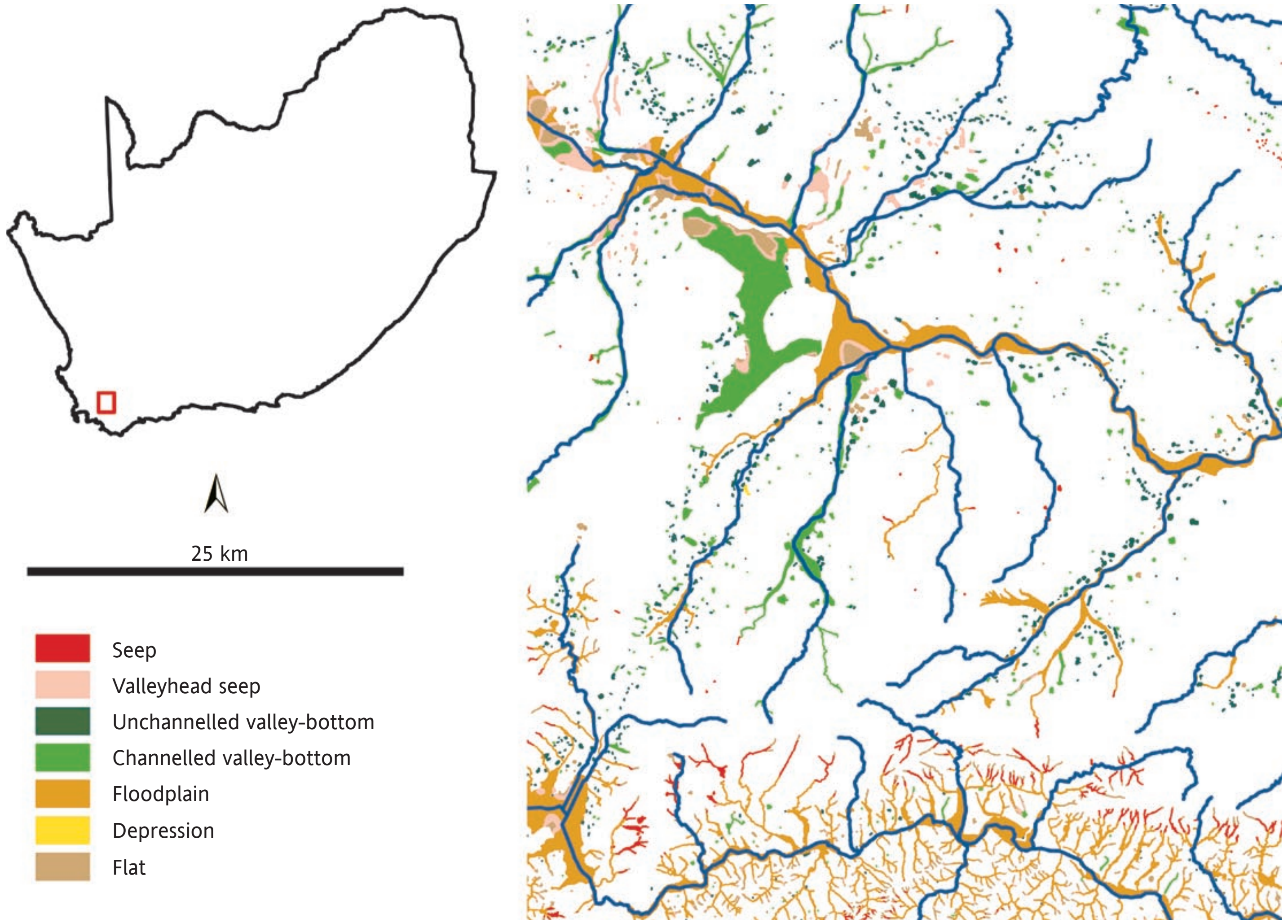
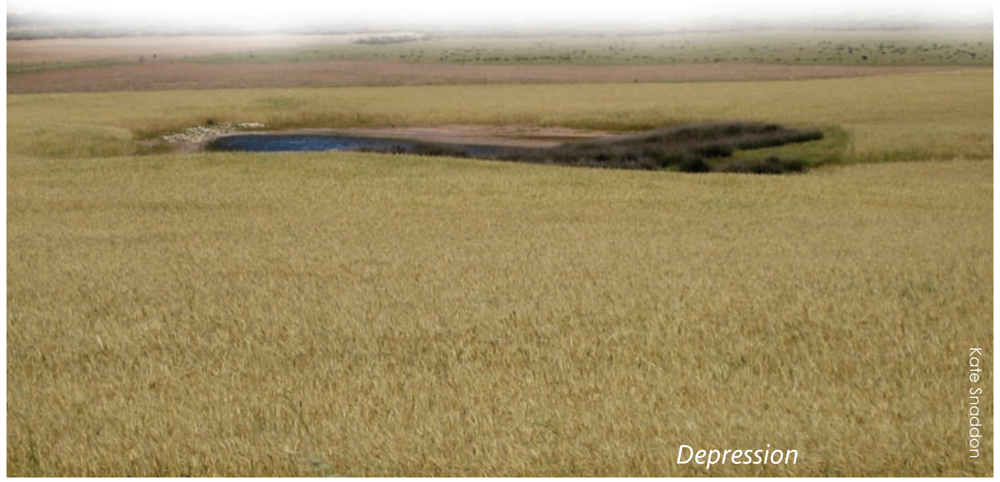


Figure 4.8: An example of the hydrogeomorphic types used to derive wetland ecosystem types in South Africa. The inset map shows the location of the area on the main map. The hydrogeomorphic type of a wetland was used together with the wetland vegetation group in which it was embedded (Section 4.6) to determine its wetland ecosystem type.



4.4 Wetland condition

Wetland condition describes the extent to which a wetland has been modified by human activity. There are many approaches to assessing wetland condition in the field. However, in the absence of field survey data for most wetlands across the country, wetland condition was modelled by NFEPA to serve as a relative measure for informing choices in selecting wetland FEPAs. As explained in Section 2.2, choices in the selection of wetland FEPAs were made using wetland ranks, which were based on a combination of special features and wetland condition. Wetlands with known special features (e.g. presence of rare plants and animals, extensive intact peat wetlands) were selected as the first choice for achieving biodiversity targets for wetland ecosystem types. Any remaining targets were achieved first in wetlands of good condition, proceeding only if necessary to wetlands of progressively modified condition (Table 4.2). Wetland FEPAs did not have to be in a good condition to be chosen as a FEPA, but those wetland FEPAs currently in less than good condition should be rehabilitated to the best attainable ecological condition.

Wetlands that had the majority of their area coinciding with 1:50 000 artificial water bodies (Department of Land Affairs: Chief Directorate Surveys and Mapping 2005-2007) were assigned a heavily- to critically-modified wetland condition (equivalent of D, E or F ecological category for rivers: Table 4.1). For the remaining wetlands, the percentage natural land cover in and around the wetland was used as a surrogate measure of wetland condition. The same land cover data as used for modelling condition of tributaries was applied (Section 4.2). Percentage natural land cover was calculated within four areas: the wetland itself, and the wetland surrounded by GIS buffers of 50 m, 100 m and 500 m from the edge of the wetland. The lowest of these four resulting percentages of natural land cover was used to guide the condition category of the wetland (Table 4.2; Figure 4.9), using the following rules:

- Non-riverine wetlands were considered to be in a good, moderately modified or heavily modified condition if the lowest percentage natural land cover in and around the wetland was 75% or more, 25-75%, or less than 25% respectively.
- This same rule was applied to riverine wetlands associated with natural or moderately modified rivers (i.e. in an A, B, or C ecological category) because in such cases the surrounding land use is more likely to be a driver of wetland ecosystem degradation than the condition of the associated river.
- Riverine wetlands associated with a largely modified, seriously modified or critically modified river (i.e. in a D, E or F ecological category) were assigned a heavily modified condition irrespective of the surrounding natural land cover.
- Several riverine wetlands are associated with rivers too small to be included on the 1:500 000 river network GIS layer – in these instances, the river condition was unknown and the wetland was assigned a condition based on the lowest percentage natural land cover.

It is very difficult to assess accurately how much of South Africa's wetland area has already been irreversibly lost. However, we know it is substantial, especially in urban areas and intensively cultivated areas. Over and above this irreversible loss that has already taken place, approximately 45% of our remaining wetland area in South Africa is in a heavily or critically modified condition, owing to human impacts such as damming, draining and bulldozing of wetlands. This is of immense concern given the important regulating ecosystem services that healthy wetlands provide, such as purifying water and regulating floods.

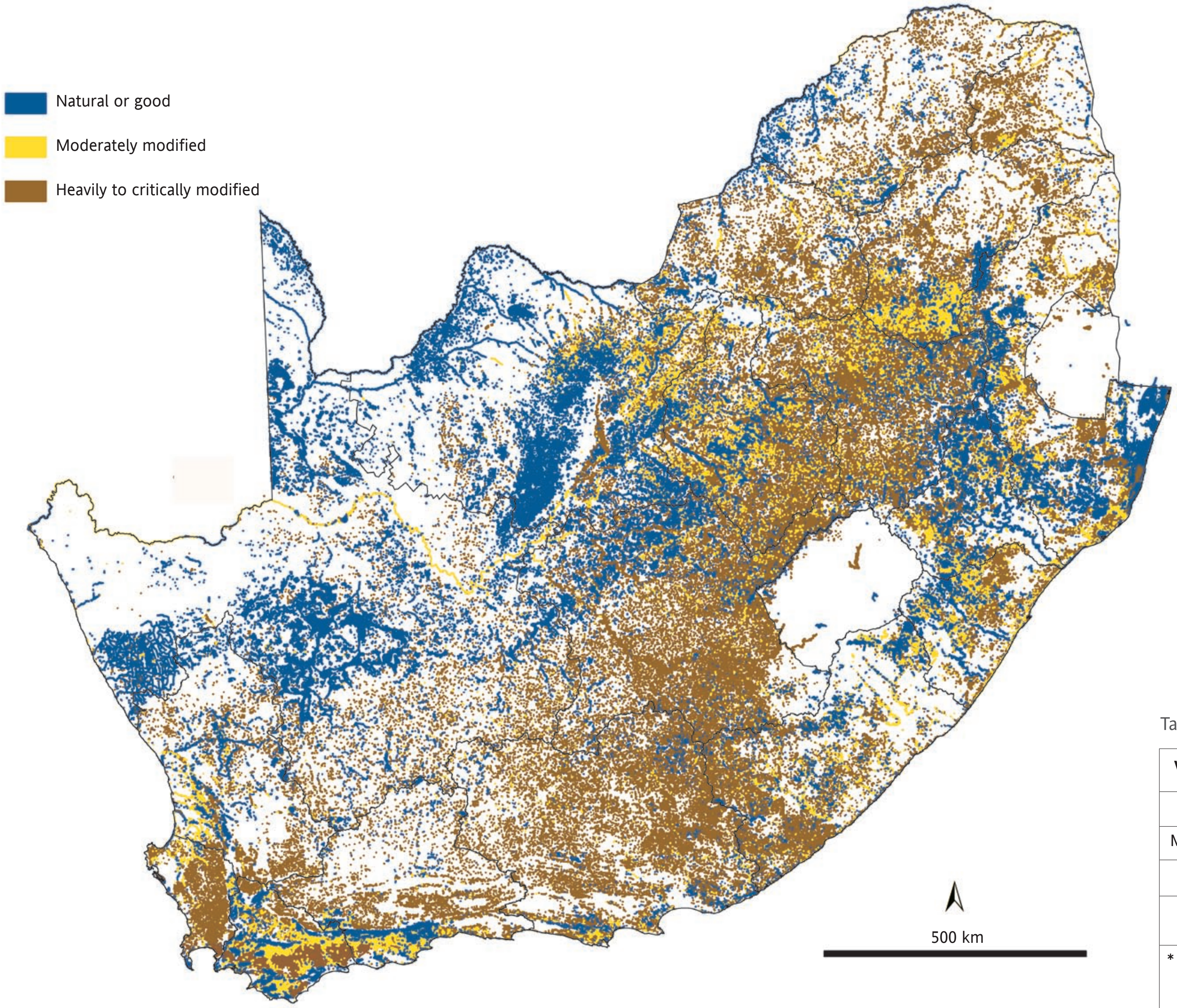


Figure 4.□

been accentuated to make them more visible.

Table 4.2: Wetland condition categories

Wetland condition	Assessment criteria *	% of total wetland area **
Good	Natural land cover ≥ 75%	44
Moderately modified	Natural land cover 25-75%	18
Heavily modified	Riverine wetland associated with a D, E, F or Z category river	9
Critically modified	Wetland where the majority of its area coincides with a 1:50 000 artificial inland water body, or where natural land cover < 25%	36

* Percentage natural land cover was calculated within four areas: the wetland itself, and the wetland surrounded by GIS buffers of 50 m, 100 m and 500 m from the edge of the wetland. The lowest of these four percentages was used.

** Note that this excludes the extent of wetlands that have already been irreversibly lost due to draining, ploughing and concreting.

4.5 Landforms

Landforms describe the topography of a land surface in the context within which it occurs, identifying a range of landform classes such as valley floors, slopes and benches. Landforms provide a framework for the role the landscape plays in processes related to geology, hydrology and ecology. Landforms were developed by NFEPA for classifying wetlands according to the landscape setting within which they fall, and provided one of the primary determinants for classifying wetland ecosystem types (Section 4.3). Four landform classes recommended by the national wetland classification system (SANBI 2009) were identified: benches, plains, slopes and valley floors (Figure 4.10).

These landform classes are useful to a wide range of planning and management applications beyond biodiversity planning, such as assessments of soil, geology, hydrology, fire and flood risk, hazard prediction, forestry, agricultural and forestry potential, climate change as well as numerous engineering and military applications.

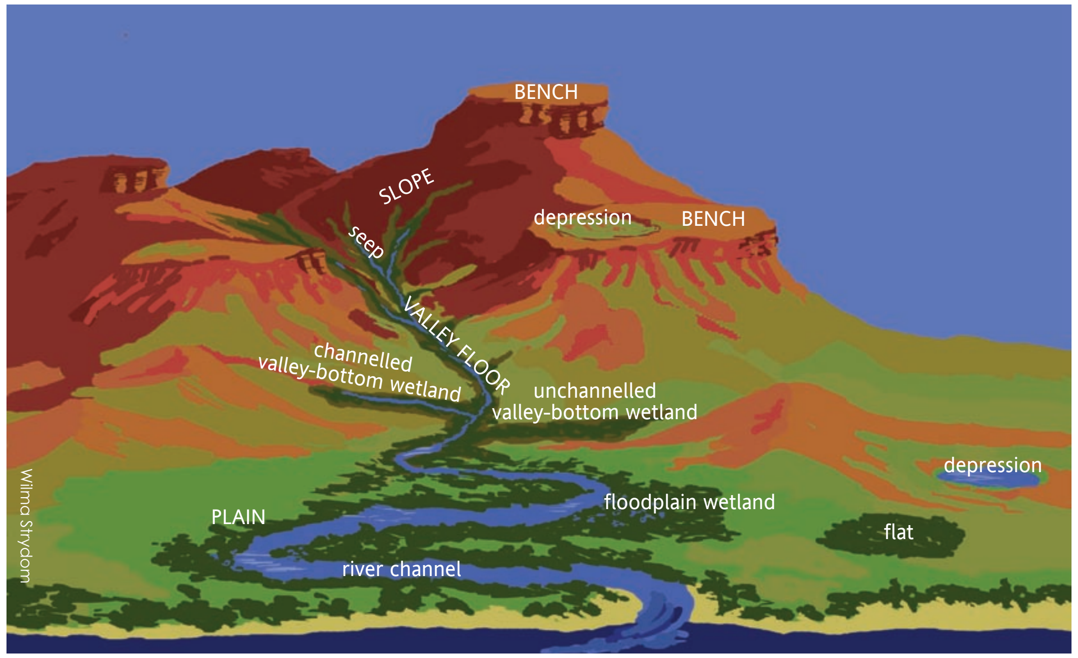


Figure 4.10: Schematic showing the different landscape settings of each landform class (after SANBI 2009), which inform classification of the different wetland ecosystem types. Landform classes are shown in upper case, and the wetland ecosystem types that they potentially contain are shown in lower case.

Landforms for the country were generated using a 50 m resolution digital elevation model generated from contours at 20 m intervals and spot height data per 1:50 000 data sheets. The ArcGIS 9.3 Landform Tool was used, which calculates the standard deviation from the average elevation in a specified search area to identify landform classes. This tool offers the option of using a small neighbourhood to consider the landform within a local context, and a large neighbourhood to reflect the regional context within which the landform occurs. The maximum valley widths per geomorphic province (as calculated by Partridge et al. 2010) were used to inform selection of the small neighbourhood across the country, and the maximum width tertiary catchments (Midgley et al. 1994) informed selection of the large neighbourhood (van Deventer et al. in review). The results (Figure 4.11) were compared to 260 random points that were classified manually using Google Earth imagery and topographical maps, and showed a 50-60% overall accuracy. The Landform Tool tended to overestimate benches and valleys, and underestimate slopes. This level of congruency suggests that this landform layer may be suitable for coarse-scale national application, but will have to be further refined for use at the local scale.

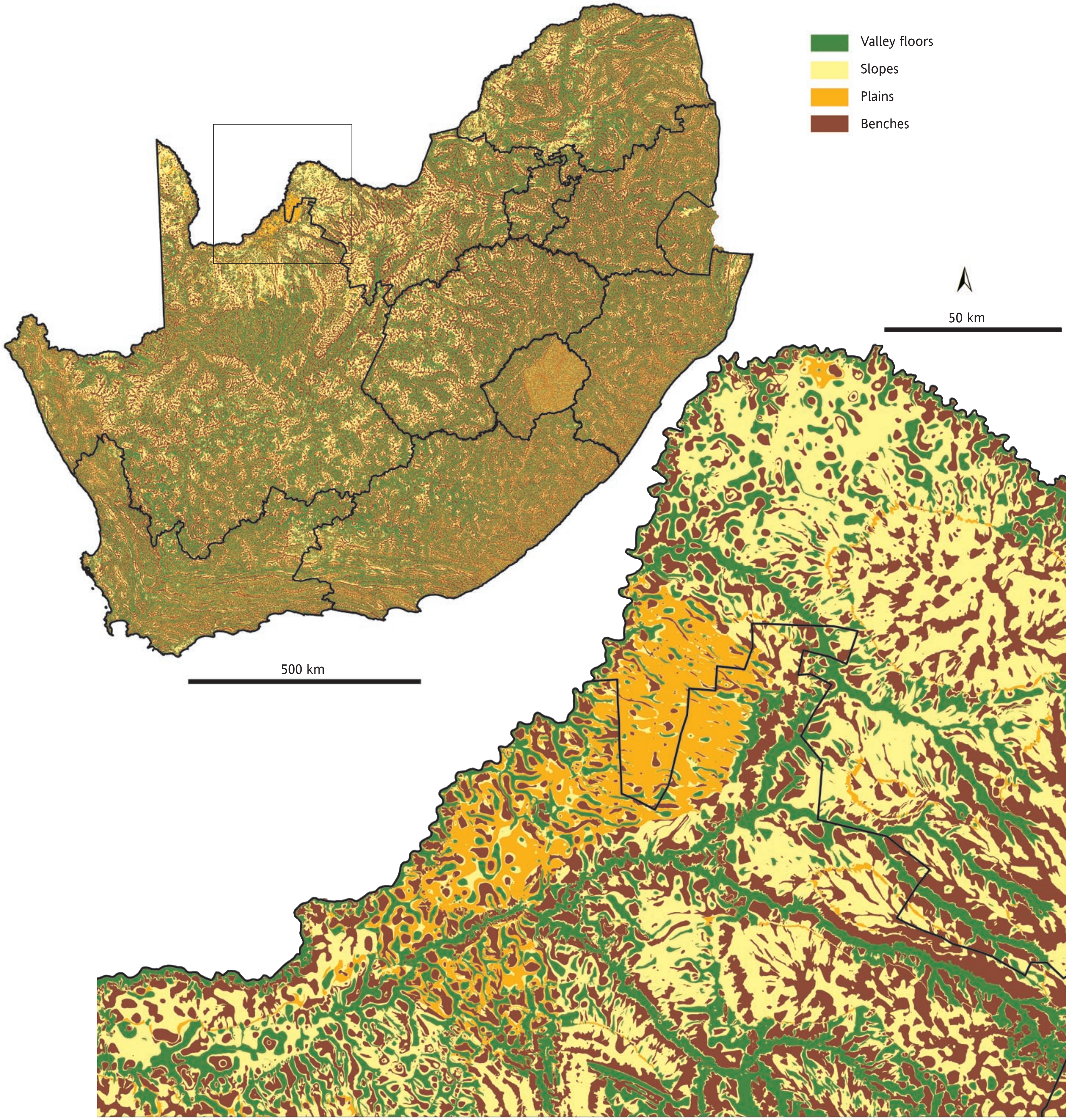


*Figure 4.11: Landforms of □
wetland vegetation groups (Section 4.6) to classify wetland ecosystem types.*

4.6 Wetland vegetation groups

Wetland vegetation groups were used to characterise the regional context within which wetlands occur based on the premise that wetlands in a particular vegetation group are likely to be more similar to one another than to wetlands in other vegetation groups. Broad vegetation groupings reflect differences in geology, soils and climate, which in turn affect the ecological characteristics and functionality of wetlands.

Wetland vegetation groups were derived by grouping the 438 vegetation types of South Africa, Lesotho and Swaziland (Mucina and Rutherford 2004) into groups thought to reflect the turnover of wetland biodiversity at a national level. The expert knowledge of regional wetland ecologists was used to do the grouping, resulting in a map of 133 wetland vegetation groups (Figure 4.12). This was then used, in combination with the landform map (Section 4.5), to classify wetland ecosystem types. Future research should focus on improving these groupings using cluster analysis of representative surveys of wetlands across the country.

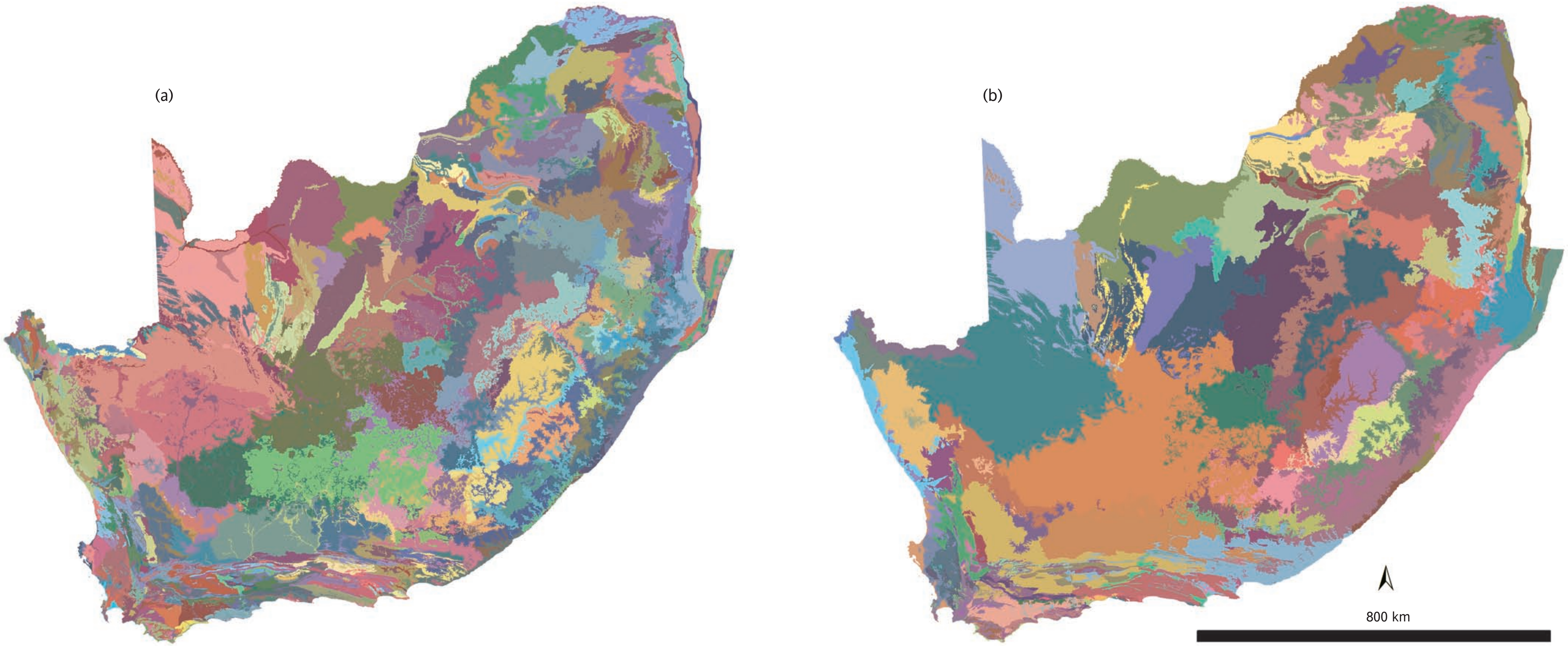


Figure 4.12: (a) Vegetation □
Wetland vegetation groups were used to characterise the regional context within which wetlands occur (after SANBI 2009).

4.7 Priority estuaries

The National Biodiversity Assessment 2011 identified priority estuaries for South Africa using systematic biodiversity planning methods (Van Niekerk and Turpie 2011). Three hundred estuaries along the South African coast were assessed. Biodiversity targets were set for estuarine ecosystem and habitat types, estuarine species, and large scale ecological processes (e.g. connectivity between estuaries). Input data included plant, fish and bird distribution data, estuarine health assessment data, and data on ecological processes (e.g. importance of estuary as a nursery area for fish). Both the input data and outputs were reviewed and evaluated by estuary ecologists and practitioners around the country. A separate report is available as part of the National Biodiversity Assessment 2011 (Van Niekerk and Turpie 2011), including the recommended ecological category for each priority estuary.

The 122 national priority estuaries are shown in dark blue in Figure 4.13. All priority estuaries became FEPAs and are shown on the FEPA maps (Part 2 of this atlas) in the same way as wetland FEPAs, with turquoise outlines. In addition, the priority estuaries were used to help identify river and wetland FEPAs. Wherever possible, river and estuary priorities were aligned. However, river condition and estuary condition do not always coincide, as some estuaries linked to rivers in poor condition are resilient and able to recover as a result of marine influences, while other estuaries linked to good condition rivers are negatively influenced by local impacts such as coastal developments. This means that in some cases an estuary is identified as a priority but the river upstream is not a FEPA, and vice versa.

Functional zones for all 300 estuaries are shown in Figure 4.13, mapped for the first time as part of the National Biodiversity Assessment 2011. The estuarine functional zone includes the open water area of the estuary as well as the zone to which the estuary may expand during flood (guided largely by the 5m coastal contour line).

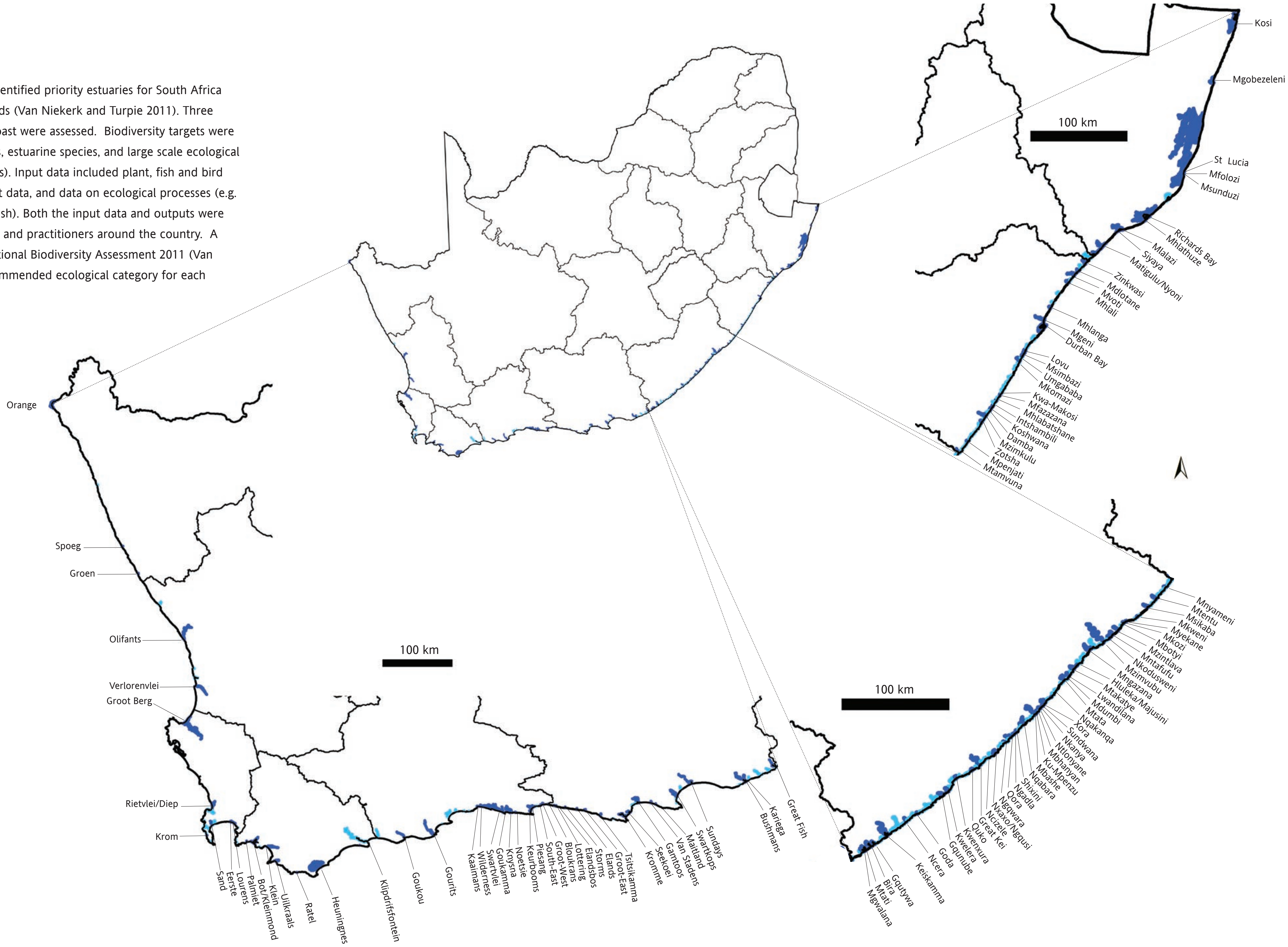


Figure 4.13: Priority estuaries from the National Biodiversity Assessment 2011, shown in dark blue (Van Niekerk & Turpie 2011). The estuarine functional zone is shown for all estuaries, but only the priority estuaries are labelled.

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Acronyms

BGIS	Biodiversity GIS Website (http://bgis.sanbi.org)
C.A.P.E.	Cape Action Plan for People and the Environment
CSIR	Council for Scientific and Industrial Research
FEPA	Freshwater Ecosystem Priority Area
GIS	Geographic Information System
KZN	KwaZulu-Natal
NFEPA	National Freshwater Ecosystem Priority Area
NGO	Non-Governmental Organisation
SAIAB	South African Institute of Aquatic Biodiversity
SANBI	South African National Biodiversity Institute
SanParks	South African National Parks
WRC	Water Research Commission
WWF	Worldwide Fund for Nature

Glossary

Bench (landform): An area of mostly level or nearly level high ground (relative to the broad surroundings), including hilltops/crests (areas at the top of a mountain or hill flanked by down-slopes in all directions), saddles (relatively high-lying areas flanked by down-slopes on two sides in one direction and up-slopes on two sides in an approximately perpendicular direction), and shelves/terraces/ledges (relatively high-lying, localised flat areas along a slope, representing a break in slope with an up-slope on one side and a down-slope on the other side in the same direction).

Best attainable ecological category: The ecological category that is most close to natural (category A) to which an ecosystem can be rehabilitated/restored. See glossary descriptions for ecological category and rehabilitation/restoration.

Biodiversity: The diversity of genes, species, ecosystems and landscapes on Earth, and the ecological and evolutionary processes that maintain this diversity.

Biodiversity feature: An element of biodiversity for which it is possible to set a quantitative biodiversity target, for example a vegetation type, a river ecosystem type, a species, or the spatial component of an ecological process.

Bioregional plan (published in terms of the Biodiversity Act): A map of biodiversity priority areas (critical biodiversity areas and ecological support areas), for a municipality or group of municipalities, accompanied by contextual information, land- and resource-use guidelines and supporting GIS information. The map must be produced using the principles and methods of systematic biodiversity planning. A bioregional plan represents the biodiversity sector's input to planning and decision-making in a range of other sectors. The development of a bioregional plan is usually led by the relevant provincial conservation authority or provincial environmental affairs department. A bioregional plan that has not yet been published in the Government Gazette in terms of the Biodiversity Act is referred to as a biodiversity sector plan.

Catchment: A catchment is the area (a geographical region) where water from rain (or snow) becomes concentrated and drains downhill into a river or lake. The term includes all land surface, streams, rivers, and lakes between the source and where the water enters the ocean.

Channelled valley-bottom wetland: A mostly flat valley-bottom wetland dissected by and typically elevated above a channel. The dominant water supply is usually from the channel, as surface flow resulting from overtopping of the channel banks, as interflow, or from adjacent valley-side slopes (as overland flow or interflow).

Condition: The ecological health or integrity of an ecosystem, assessed using categories that describe the degree of modification from natural condition. For NFEPA, condition was assessed using all available data, including present ecological state data (Kleynhans 2000), River Health Programme data, reserve determination data and modelling of land cover where no other data existed, as well as expert knowledge. (Also see ecological category and present ecological state).

Critical Biodiversity Areas: Those areas required to meet quantitative targets for biodiversity, as determined by an integrated terrestrial and aquatic systematic biodiversity plan. These areas are critical for conserving biodiversity and maintaining ecosystem functioning in the long term. These areas differ from FEPAs in that they are usually determined at a finer, sub-national scale and integrate terrestrial and aquatic priority areas.

Depression (landform): A landform with closed elevation contours that increases in depth from the perimeter to a central area of greatest depth, and within which water typically accumulates. Water supplied by precipitation, ground water discharge, interflow and (diffuse or concentrated) overland flow. Depressions may be flat-bottomed, referred to as 'pans' or round-bottomed, referred to as 'basins'. They may have any combination of inlets and outlets or lack them completely.

Ecological category: A simplified measure of the extent that an ecosystem has been altered from natural condition due to human impact. There are six ecological categories (Table 4.1) ranging from A (natural) to F (critically/extremely modified), derived using expert assessment of specific criteria. (Also see condition and present ecological state).

Ecological integrity: Used to describe the extent that ecosystems have been altered by humans from their original natural condition. (Also see condition, ecological category and present ecological state).

Ecological processes: The processes that operate to maintain and generate biodiversity and ensure the continued functioning of ecosystems. Ecosystems function because they are maintained by ecological processes such as nutrient cycling, natural disturbance regimes (e.g. flow regime), groundwater recharge, filtering of pollutants and migration of species. Systematic biodiversity plans seek to map and set targets for spatial components of these ecological processes, such as large-scale landscape corridors, groundwater recharge areas or the buffer of natural vegetation area around a wetland or river. Ecological processes often form the foundation of ecosystem service delivery for people.

Ecological Support Areas: Those areas that play a significant role in supporting ecological functioning of Critical Biodiversity Areas and/or delivering ecosystem services, as determined in a systematic biodiversity plan.

Ecoregions: Areas with relative homogeneity in ecosystems. Within an ecoregion the mosaic of ecosystem components (biotic and abiotic, as well as terrestrial and aquatic) is different to that of adjacent ecoregions.

Ecosystem: Refers to the assemblage of living organisms, the interactions between them and with their physical environment. Every ecosystem is characterised by its composition (living and non-living components of which it consists), the structure (how the components are organised in space and time) and the ecological processes (functions such as nutrient cycling) that maintain the structure and composition and so maintain the ecosystem as a functioning unit. Ecosystems can operate at different scales – from very small (a pond) to whole landscapes (an entire Water Management Area).

Ecosystem-based adaptation: Using biodiversity and ecosystem services as part of an overall strategy to help people adapt to the adverse effects of climate change. It involves maintaining ecosystems in a natural, near-natural or functioning state, or restoring ecosystems where necessary, to support human adaptation to climate change.

Ecosystem services: The benefits that people obtain from ecosystems, including provisioning services (such as food, water, reeds), regulating services (such as flood control), cultural services (such as recreational fishing), and supporting services (such as nutrient cycling, carbon storage) that maintain the conditions for life on Earth.

Endemic: A plant or animal species, or an ecosystem type, which is naturally restricted to a particular defined region (not to be confused with indigenous). For example, a fish may be endemic to South Africa in which case it occurs naturally in no other country, or endemic only to a specific river, which means it occurs naturally only in that particular river and nowhere else in the country or world.

Fish Migration Corridor: These areas cater for large migratory threatened and near threatened fish species that require connectivity between habitats, usually between the mainstem and tributary habitats.

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Fish Support Area: Fish sanctuaries are sub-quaternary catchments that are required to meet biodiversity targets for threatened and near threatened fish species indigenous to South Africa. Fish sanctuaries in sub-quaternary catchments associated with a river reach in good condition (A or B ecological category) were selected as FEPAs; the remaining fish sanctuaries became Fish Support Areas. Fish Support Areas also include sub-quaternary catchments that are important for migration of threatened and near threatened fish species. River reaches in Fish Support Areas need to be maintained in a condition that supports the associated populations of threatened fish species, which need not necessarily be an A or B ecological category.

Flat wetland: A wetland area with little or no relief or gradient, situated on a plain or a bench. Water is mainly supplied by precipitation, with the exception of coastal flats where the water may be supplied by a high water table (i.e. groundwater).

Floodplain wetland: A flat or gently sloping wetland area adjacent to and formed by a lowland or upland floodplain river. Periodic inundation by overtopping of the channel bank may occur and water and sediment input is mainly via overtopping of a major channel, although there could be some overland or subsurface flow from adjacent valley side-slopes (if present).

Freshwater Ecosystem Priority Areas (FEPAs): Strategic spatial priorities for conserving freshwater ecosystems and associated biodiversity, determined through a process of systematic biodiversity planning and identified using data on freshwater ecosystem types, species and ecological processes. FEPAs are often tributaries and wetlands that support hard-working main rivers, and are an essential part of an equitable and sustainable water resource strategy. FEPAs need to stay in a good condition to manage and conserve freshwater ecosystems, and to protect water resources for human use. This does not mean that FEPAs need to be fenced off from human use, but rather that they should be supported by good planning, decision-making and management to ensure that human use does not impact on the condition of the ecosystem. The current and recommended condition for all river FEPAs is A or B ecological category (see Table 1 for description of ecological categories). Wetland or estuary FEPAs that are currently in a condition lower than A or B should be rehabilitated to the best attainable ecological condition.

Freshwater ecosystems: All inland water bodies whether fresh or saline, including rivers, lakes, wetlands, sub-surface waters and estuaries. The incorporation of groundwater considerations into the FEPA maps was rudimentary and future refinement of FEPAs should seek to include groundwater more explicitly.

Function/functioning/functional: Used here to describe ecosystems working or operating in a healthy way (opposite to dysfunctional which means working poorly or in an unhealthy way).

Hydrogeomorphic wetland types: A framework for mapping wetland ecosystem types based on hydrological and geomorphological characteristics. This type of framework uses factors that influence how wetlands function (e.g. climate, landscape setting). For NFEPA, wetland ecosystem types were mapped using the recently completed national wetland classification system, which is a hydrogeomorphological framework. (Also see national wetland classification system).

Mountain Catchment Areas: High water yield areas that contribute significantly to the overall water supply in the country. They are located in high mountainous areas and are regarded as 'water factories', supporting growth and development needs that are located long distances away.

National Biodiversity Framework: The Biodiversity Act provides for the publication of a National Biodiversity Framework, which provides a framework to co-ordinate and align the efforts of the many organisations and individuals involved in conserving and managing South Africa's biodiversity, in support of sustainable development. The first National Biodiversity Framework, published in 2009, identifies 33 priority actions for the period 2008 to 2013, providing an agreed set of priorities to guide the work of the biodiversity sector in South Africa.

National Protected Area Expansion Strategy: Provides a strategy to guide the national and provincial conservation authorities in the expansion of the country's protected areas over the next 20 years. The spatial component of the strategy integrates priority areas for terrestrial and freshwater ecosystems and is based on systematic biodiversity planning principles. The first National Protected Area Expansion Strategy was developed in 2008, to be reviewed every five years.

National wetland classification system: A recently completed hydrogeomorphological framework , which was used to identify wetland ecosystem types for NFEPA. It is a six-tiered framework, with four spatially-nested primary levels that are applied in a hierarchical manner to distinguish between different wetland ecosystem types on the basis of 'primary discriminators' (i.e. criteria to distinguish consistently between different categories at each level of the hierarchy). NFEPA wetland ecosystem types were determined to Level 4 of the hierarchy using desktop data on freshwater ecoregions, vegetation types and position of the wetland in the landscape. (Also see hydrogeomorphic wetland types).

Plain (landform): An extensive area of low relief characterised by relatively level, gently undulating or uniformly sloping land. This includes coastal plains (bordering the coastline), interior plains (characteristic of the Karoo region), and plateaus (areas of low relief but high altitude occurring at the edge of the escarpment). Plains are differentiated from valley floors based on that they are not located in between two side-slopes (typical of mountain ranges, hills, or other uplands).

Present ecological state (PES): The present condition of a river at the time of assessment or survey, which describes the extent to which a river or wetland has been altered by humans from its original, natural condition. Present ecological state is described in six ecological categories (Table 4.1) ranging from A (natural) to F (critically/extremely modified), and is derived using expert assessment of criteria known to influence the condition of freshwater ecosystems. The ecological categories represent a simplified measure of the extent of ecological alteration as assessed by regional experts. (Also see condition and ecological category).

Priority estuary: Priority estuaries were identified for the National Biodiversity Assessment 2011 (Van Niekerk and Turpie 2011) using systematic biodiversity planning. The estuarine functional zones of all priority estuaries were identified as FEPAs (includes the main channel of the estuary as well as the zone to which the estuary may expand during floods). Priority estuaries in good condition (A or B ecological category) need to remain in this condition; those that are currently in a condition lower than A or B should be rehabilitated to the best attainable ecological condition.

Protected areas: Areas of land or sea that are formally protected by law (i.e. recognised in terms of the Protected Areas Act) and managed mainly for biodiversity conservation.

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Quaternary catchment: South Africa has a system of catchment delineations used extensively in water resources assessment, planning and management. These catchments are nested hydrological units from the primary drainage basin, through to secondary and tertiary catchments, with the smallest operational unit being the quaternary catchment (Midgley et al. 1994).

Ramsar wetland: A wetland listed under the 'Convention on Wetlands of International Importance', which gives it recognition by the international community as being of significant value, not only for the country, but for humanity as a whole (see www.ramsar.org).

Rehabilitation/restoration (Ecological restoration): The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed, which involves the repair of the natural environment to a state close to its original state. For example, this can be achieved through the removal of invasive alien plants, or the repair of eroded sites and the replanting of indigenous plants. Restoration involves not only the reparation of ecosystem processes, productivity and services, but also the re-establishment of species composition and community structure.

River condition: See condition, ecological category, ecological integrity and present ecological state.

River ecosystem types: River reaches with similar physical features, comprising unique combinations of landscape features, flow variability and channel slope. Rivers with the same ecosystem type are expected to share similar biological responses under natural conditions. For NFEPA, river ecosystem types were used to represent natural examples of the diversity of river ecosystems across the country. They were mapped using unique combinations of Level 1 ecoregions (Kleynhans et al. 2005), slope categories (Rowntree and Wadeson 1999) and permanence of flow (Department of Land Affairs: Chief Directorate Surveys and Mapping 2005-2007).

Slope (landform): An inclined stretch of ground that is not part of a valley floor, which is typically located on the side of a mountain, hill or valley.

Sub-quaternary catchment: These are sub-catchments that are broadly nested in the quaternary catchments used by Department of Water Affairs (Midgley et al. 1994). The watershed is delineated around each river reach, where a river reach is defined as the portion of river between the confluences on the 1:500 000 river network GIS layer. (Also see quaternary catchment).

Sub-Water Management Area: Areas within a Water Management Area that usually serve as management units. They are broadly based on the catchments of large tributaries within the Water Management Area.

Sustainable development: Development that serves the needs of both present and future generations equitably, involving the integration of social, economic and ecological factors into planning, implementation and decision-making.

Systematic biodiversity planning: Also known as a systematic conservation planning. A scientific method for determining spatial areas of biodiversity importance. It involves: mapping biodiversity features (such as ecosystems, species, spatial components of ecological processes); mapping a range of information related to these biodiversity features and their condition; setting quantitative targets for biodiversity features; analysing the information using software linked to GIS; and developing maps that show spatial biodiversity priorities. The configuration of priority areas is designed to be spatially efficient (i.e. to meet biodiversity targets in the smallest area possible) and to avoid conflict with other land and water resource activities where possible.

Systematic Conservation Plan: See systematic biodiversity planning.

Threatened ecosystems: Ecosystems with a high risk of undergoing significant degradation of ecological structure, function or composition as a result of human activities. In South Africa, the Biodiversity Act provides for listing of threatened ecosystems that are described in three categories with the level of threat escalating as an ecosystem moves from vulnerable to endangered to critically endangered. The purpose of listing threatened ecosystems is primarily to reduce the rate of ecosystem and species extinction. This includes preventing further degradation and loss of structure, function and composition of threatened ecosystems.

Threatened species: Species at a high risk of extinction as a result of human activities. The IUCN has developed criteria for assessing the conservation status of a species and includes different categories of escalating threat (http://www.iucnredlist.org/). In South Africa, the Biodiversity Act provides for listing of threatened species to halt further extinction of species.

Unchannelled valley-bottom wetland: Mostly flat valley-bottom wetland area without any major channels and there are no distinct channel banks or diffuse flows occurring even during and after high rainfall events. Water supply is typically from an upstream channel, as the flow becomes dispersed, from adjacent slopes (if present) or groundwater.

Upstream Management Areas: These are sub-quaternary catchments in which human activities need to be managed to prevent the degradation of downstream FEPAs and Fish Support Areas.

Valleyhead seep: A gently sloping wetland area located on a bench setting at the head of a drainage line, with water inputs mainly from subsurface flow (although there is usually also a convergence of diffuse overland water flow in these areas during and after rainfall events). Horizontal, unidirectional (down-slope) movement of water in the form of interflow and diffuse surface flow dominates within a valleyhead seep, while water exits at the downstream end as concentrated surface flow where the valleyhead seep becomes a channel.

Water Management Area: South Africa has 19 Water Management Areas used as administrative and management units for implementing water policy and legislation. Catchment Management Agencies are in the process of being established for Water Management Areas or groups of Water Management Areas. Water Management Areas are delineated using catchment boundaries and do not match provincial or municipal boundaries.

Wetland cluster: A group of wetlands within 1 km of each other that are embedded in a relatively natural landscape matrix through which dispersal between wetlands can occur (e.g. of frogs and invertebrates). This allows for important ecological processes such as migration between wetlands.


Lesa van Rooyen

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