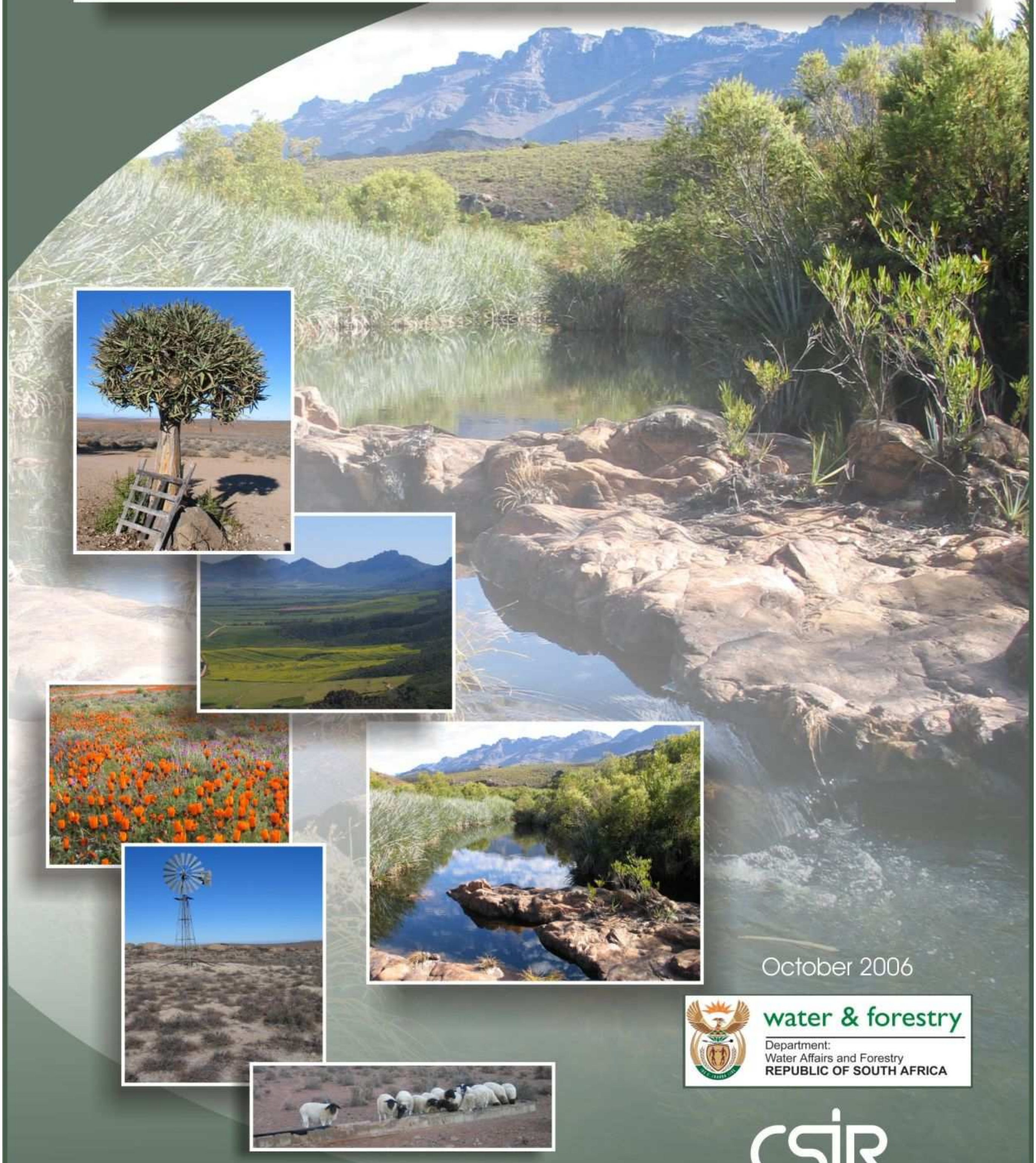
Conservation Assessment of Freshwater Biodiversity in the Olifants/Doorn Water management Area



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our future through science

J.L. Nel, A. Belcher, N.D. Impson, I.M. Kotze, B. Paxton, L.Y. Schonegevel and L.B. Smith-Adao

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Executive Summary

This study forms part of a broader project (DWAF project 2005-170) by the Department of Water Affairs and Forestry (DWAF) which aims to develop a planning capacity for freshwater conservation in South Africa. A conservation assessment was conducted in the Olifants/Doorn Water Management Area to identify spatial priorities for freshwater ecosystems. The study focussed on the four following objectives, as agreed in the contract between the CSIR and DWAF:

- Conserve and maintain a sample of the freshwater biodiversity and associated ecosystem processes, with a focus on biodiversity of regional significance;
- Provide systematic and strategic guidance regarding the trade-offs between conservation and development;
- Direct future conservation and development opportunities; and
- Provide strategic perspective to decision-makers at the scale of a water management area.

The technical planning approach adopted for this study is based on systematic conservation planning principles and methods (Margules and Pressey 2000; Roux *et al.* 2006). This report presents the systematic approach that was followed, its outcomes in the form of a portfolio of conservation areas, and broad management actions to promote the implementation of the suggested portfolio.

The areas included in this conservation portfolio are not intended as formal protected areas only. Rather, they reflect areas that need to be managed appropriately to conserve the full spectrum of freshwater biodiversity for both present and future generations. Identification of these areas alone is not enough to catalyse conservation action, and this study should not be seen as a completed conservation planning exercise. These spatial priorities need to be verified and then coupled to an implementation strategy developed in collaboration with the key stakeholders in the area (Driver *et al.* 2003, Knight et al. 2006). A major value of systematic assessments lies not only in the selected conservation areas they identify, but also in the **mechanism they provide for stakeholder collaboration** around conservation action. Providing such a mechanism for collaboration is immensely important in conserving freshwater ecosystems, which can be considered one of the greatest governance challenges faced by modern societies, since water affects every activity of human society and everyone needs to be part of the solutions for conserving freshwater ecosystems.

One of the most appropriate frameworks within which to implement this conservation portfolio would be the Catchment Management Agencies under the auspices of the DWAF. The Olifants/Doorn Water Management Area is a relatively well-resourced area, and there is considerable momentum towards establishing a Catchment Management Agency (DWAF 2005c), with the mobilisation of 11 catchment management forums. Strategies and plans for these forums are in the process of development, providing an excellent opportunity for incorporating aspects of this conservation plan into the strategies and business plans of these forums. Given this institutional readiness, combined with the importance of the Olifants/Doorn Water Management Area in terms of its biodiversity, it is recommended, that we capitalise on this opportunity, and develop an implementation strategy to accompany this conservation assessment as a matter of urgency.

An important step during the development of the implementation strategy is to field verify the conservation portfolio, and in turn refine the implementation strategy where necessary. This latter step is very important as many selected areas are based on best available data, some of it modelled, and each data set has its limitations. A summary of the GIS layers that were used in designing the portfolio of conservation areas is provided below (cross-referenced to the particular section of the report), along with a short description on how these were applied in the design, and the limitations to their application:

GIS layer	Description & how it was used in the conservation portfolio design	Limitations
Sub-quaternary catchments (Section 4.1)	These are catchments nested within quaternary catchments, used as planning units (units of selection) within the conservation portfolio.	The approach used to derive this GIS layer produced large catchment size variability. Future refinements should attempt to derive sub-quaternary catchments of a more uniform size.
Special features (Section 4.3)	Features of special biodiversity or scenic significance mapped by regional experts. These included intact river gorges, which serve as evolutionary barriers, zones of rejuvenation and natural barriers to alien fish invasion; rivers free of alien fish; and a large intact wetland system on the Matjies River. All special features were included as low-impact management zones in the final conservation portfolio. In addition to this, planning unit cost was "discounted" for all those sub-quaternary catchments containing special features. In instances where there are choices between two sub-quaternary catchments, this discounting has the affect of favouring selection of sub-quaternary catchments with special features.	This is an expert-based GIS layer, which is neither exhaustive, nor consistent across the landscape. It merely provides some obvious special features as a starting point for the conservation planning software. Future refinements could improve on this GIS layer by paying better attention to riparian vegetation of special significance and known wetlands.
River types (Section 4.4)	River types for 1:500 000 rivers, derived using a combination of flow variability (Hannary and Hughes 2003), ecoregions (Kleynhans 2004), and longitudinal zonation (Rowntree and Wadeson 1999). These were used as coarse-filter biodiversity surrogates, and targets were set to conserve a representative sample of all river types. All sub-quaternary catchments contributing towards targets for river types were selected as river conservation zones in the conservation portfolio. Conserving a representative sample of river types is assumed to provide representative habitat for biodiversity to persist and evolve.	River types developed for this assessment are preliminary and based on desktop data. They are still in the process of review and refinement. A potential refinement is to include biogeographical zones, e.g. primary catchments, which reflect evolutionary lineages, and therefore biodiversity. A review of the river types should include aspects such as assessing whether each river type is a true reflection of river biodiversity in the field, as well as testing the effectiveness of river types as coarse filter surrogates of biodiversity.
Wetland delineations (Section 5.1)	Mapped wetland boundaries for the study area, based on an amalgamation of four GIS layers: sensitive wetlands of the Western Cape Province; perennial and non-perennial pans from 1:50 000 topocadastral maps; beta version of the South African Wetlands Map; and polygons created by applying a 100 m GIS buffer to either side of lowland rivers.	Although this GIS layer includes many known and mapped wetlands from the first two mentioned GIS layers, the vast majority of the delineations are from the beta version of the South African Wetlands Map. This GIS layer is a predictive model which maps where water is most likely to accumulate on the landscape, using remote-sensing and other landscape characteristics. The resultant map therefore represents potential wetlands rather than actual wetlands. Therefore this GIS layer should be verified in the field. A priority point of departure would be to verify the sub-quaternary catchments selected in the conservation portfolio as containing important wetlands.

GIS layer	Description & how it was used in the conservation portfolio design	Limitations
Wetland types (Section 5.2)	Wetland types derived using the hydro-geomorphological typing framework proposed by the National Wetland Inventory project (Ewart-Smith 2006). This is a hierarchical typing framework that enables wetlands to be characterised according to the functions they perform, and the goods and services they are likely to provide. This GIS layer was applied in the conservation portfolio in two ways. Firstly, targets were set to conserve a representative sample of all wetland types. All sub-quaternary catchments contributing towards targets for wetland types were selected as wetland conservation zones in the conservation portfolio. Conserving a representative sample of wetland types is assumed to provide representative wetland habitat for biodiversity to persist and evolve. The second way in which this GIS layer was applied was to recognise the functional importance of wetlands. All wetland delineations were included in the conservation portfolio as either low- or moderate-impact management zones, the level of management being based on the functional importance and sensitivity of the different wetland types.	Typing wetlands to the level of the Functional Unit provides only a broad-scale list of the diversity of different wetland types in the study area. Finer levels of detail will need to be added using field trips and aerial photography. Wetland typing was undertaken on wetland delineations that are mainly potential wetlands, rather than actual wetlands. Therefore, a priority point of departure would be to verify the sub-quaternary catchments selected as containing important wetland types in the conservation porfolio.
Combined fish sanctuaries (Section 6)	A GIS layer that combines the sub-quaternary catchments designated as fish sanctuaries for the endemic and indigenous freshwater fishes of the study area. This GIS layer was applied in two ways in the conservation portfolio. Firstly, sub-quaternary catchments containing rivers selected as fish sanctuaries were incorporated into the conservation portfolio as river conservation zones. Secondly, any sub-quaternary catchment deemed important for fish migration was selected as a moderate-impact management zone in the conservation portfolio (if it had not already been selected as a river conservation zone).	Designation of spatial areas for fish species alone is not enough to maintain viable populations in the long-term. Attention also needs to be given to controlling alien invasive fish species, and over-abstraction. Fish species in the Olifants/Doorn Water Management Area are highly sensitive to altered water quality and water quantity, and an effort to maintain ecological water requirements throughout the Olifants-Doring and Sandveld primary catchments is essential.

GIS layer	Description & how it was used in the conservation portfolio design	Limitations
River ecological integrity (Section 7.1)	Ecological integrity of quaternary catchment main rivers used a combination of • Present ecological status (Water Situation Assessment Model data; Kleynhans 2000); • River Health Programme monitoring sites; and • Habitat integrity data at 5 km stretches along the Doring, Groot, Olifants and Rondegat rivers. Ecological integrity of the remaining 1:500 000 rivers (termed "tributaries') was modelled using National Land Cover 2000 GIS data. Modelled tributary integrity was based on a threshold of minimum percentage natural vegetation, and erosion, within the sub-quaternary catchment and riparian buffer. Only rivers that were currently of high ecological integrity were able to contribute toward achieving targets in the conservation portfolio. Selecting rivers of high integrity incorporates many small-scale biodiversity processes and maximizes conservation benefits from functioning ecosystem components that are already in place. Where targets for river types could not be achieved in rivers of high ecological integrity, an assessment of rehabilitation potential was undertaken.	The modelled tributary ecological integrity data are preliminary and need to be refined to consider the cumulative upstream impacts of dams. These refinements should then be field verified.
Wetland ecological integrity (Section 7.2)	Modelled ecological integrity of wetlands based on National Land Cover 2000 GIS data. The integrity was derived using a threshold of minimum percentage natural vegetation within the sub-quaternary catchment, as well as within a radius of 50 and 100 m of a wetland. Only wetlands that were deemed of high ecological integrity were able to contribute toward achieving targets in the conservation portfolio. Selecting wetlands of high integrity incorporates many small-scale biodiversity processes and maximizes conservation benefits from functioning ecosystem components that are already in place.	This GIS layer is likely to be an under-estimation of the extent to which wetlands have been impacted. The wetland integrity data therefore need to be field verified. Results are likely to be over-optimistic regarding the state of wetlands, due to several limitations: • Differences in scale may under-estimate intense and highly localised impacts that are smaller than the minimum mapping unit of the National Land Cover 2000 GIS layer. • Extent of land degradation under-estimated by National Land Cover 2000 leads to under-estimation of impacts, since wetlands are particularly sensitive to trampling and grazing. • Deleterious land use practices are not always mapped.

GIS layer	Description & how it was used in the conservation portfolio design	Limitations
Significant groundwater discharge areas (Section 8.3.1)	Areas where there is a medium to high prediction of groundwater to surface water interaction. These were modelled using a combination of six GIS layers (groundwater response units, groundwater levels, springs, geological faults, aquifer dependent ecosystems and groundwater contribution to baseflow). In areas of significant groundwater discharge, groundwater is thought to play a particularly important role in the ecological functioning of surface waters, maintaining river pools that serve as crucial refugia in the summer low flow months, sustaining river baseflows, and maintaining wetlands and riparian vegetation. These areas were thus included in the conservation portfolio as moderate-impact management zones.	The resulting map of groundwater-surface water interaction is a predictive model based on relatively coarse-scale desktop GIS data and expert interpretation. These data should therefore be confirmed in the field.
Significant groundwater recharge areas (Section 8.3.2)	Areas that have significant groundwater recharge (> 30 mm/yr), based on the Chloride Mass Balance (Lerner *et al.* 1990; DWAF 2005b). Deleterious activities in areas that have significant recharge can have a keystone effect on the functioning of groundwater dependent ecosystems, which can be in the immediate vicinity, or far removed from the recharge area. Identifying areas of significant groundwater recharge allows for pro-active management of activities that may lower the groundwater quantity or quality in their vicinity. Areas that have significant recharge were included in the conservation portfolio as moderate-impact management zones.	Groundwater recharge is based on a national assessment, and is an interpolated surface of 1 x 1 km cells. The scale is quite coarse, although expert knowledge of the area confirms the areas that have been highlighted as significant are a true reflection of reality.
Significant water yield areas (Section 10.3)	Areas that contribute significantly to the water supply of the Olifants/Doorn Water Management Area are delineated by proclaimed Mountain Catchment Areas. These areas were included in the conservation portfolio as moderate-impact management zones to ensure that land and water use activities do not have a major impact on water quality and quantity, which in turn would have a domino effect on the functioning of many dependent ecosystems.	Future refinements should examine improved methods to measure high water yield areas, such as using mean annual precipitation in combination with evapotranspiration.
Rehabilitation potential (Section 12.1)	Sub-quaternary catchments that are feasible to rehabilitate to help conserve examples of river types that currently cannot achieve conservation targets in intact rivers. Sub-quaternary catchments deemed feasible for rehabilitation were incorporated explicitly into the conservation portfolio as river rehabilitation zones.	Trade-offs between ecological, economic and social impacts have not been fully taken into account in this assessment of rehabilitation potential.

GIS layer	Description & how it was used in the conservation portfolio design	Limitations
Conservation portfolio (Section 12)	Selected areas for conservation, highlighting river and wetland conservation zones, low- and moderate-impact management zones, and river rehabilitation zones (see below this table for broad management implications of each of these zones). The purpose of this conservation portfolio is to: • Propose areas that will conserve and maintain a sample of the freshwater biodiversity and associated ecosystem processes; • Provide systematic and strategic guidance regarding the trade-offs between conservation and development; • Direct future conservations and development opportunities; and • Provide strategic perspective to decision-makers at the scale of a Water Management Area.	The spatial scale of the portfolio is detailed enough to provide a strategic perspective to sub-national decision-makers on what should be done to conserve biodiversity of freshwater systems. The outputs, however, are not fine enough to provide management guidelines at a local scale, e.g. detailed management objectives of a specific river reach habitat, or of a particular wetland. This finer level of detail will need to be addressed through the development of management plans for each selected *AND field verified* area in the conservation portfolio. These management plans should outline the most appropriate strategies to employ for each selected area, depending on criteria such as the characteristics of the biodiversity features requiring conservation, the main land use pressures and threats in the area, the socio-economic opportunities and constraints, and specific financial and institutional arrangements. The biodiversity features in each selected area, as well as some key management interventions, are provided in Appendix 6 to guide the development of these management plans.
"Targets + REC Configuration" (Section 13.1)	Desired ecological integrity class for rivers, to serve as a catchment configuration scenario in the development and testing of the National Water Resources Classification System.	The National Water Resources Classification System was only able to apply the "Targets + REC Configuration" to *main rivers of quaternary catchments*. Moreover, the desired class of all rivers within a quaternary catchment was generalised to the condition required at the *outlet* of that catchment. This implies that any tributary selected as a river conservation zone within a quaternary catchment that has a C-category desired at its outlet will also be classified as a category C, rather than A or B, within the National Water Resources Classification System. Using only main river recommendations to classify water resources has profound implications from a biodiversity perspective. Main rivers in South Africa are heavily utilised and regulated to provide water security for socio-economic demands. Tributaries are often less impacted than main rivers and therefore play a critical role in conserving the freshwater biodiversity of South Africa.

Using these layers along with explicit conservation targets produced a conservation portfolio containing the following zones:

1. _River and wetland conservation zone_: These are sub-quaternary catchments required for achievement of wetland and/or river targets. Any intact wetland or river selected should maintain a present ecological integrity class of A or B.

2. _River rehabilitation zone_: These are sub-quaternary catchments that require rehabilitation of their rivers to an A or B ecological integrity class to help achieve conservation targets.

3. _Low-impact management zone_: Only low impact activities should be allowed in these areas, to maintain the integrity of one or more of the following biodiversity features: special feature and/or wetland function.

4. _Moderate-impact management zone_: Only moderate impact activities should be allowed in these areas, to maintain the integrity one or more of the following biodiversity features: wetland function, fish migratory corridor, upstream management area, significant water yield area, significant groundwater recharge area, and/or significant groundwater discharge area.

Generic management actions within these zones include:

- Retaining natural flow regime (both in terms of magnitude and variability). Flow is one of the most effective management tools available to flush out invasive alien fish and plants, as well as accumulated sediment in rivers, thereby increasing the quantity and quality of spawning habitat for fish, and providing cues for migration and spawning. Management actions to maintain natural flow regime should include:
  - Existing abstractions should be more focussed towards winter (May to September on the Olifants River system; June to September on the Sandveld, Doring and Knervlakte systems).
  - Water release from the Clanwilliam Dam should take note of the ecological requirements of the Olifants-Doring River system (Brown et al. 2004). This includes at least one winter release (preferably August), even if the dam is not full.
  - Optimal use should be made of existing abstractions through demand-management measures.
  - Controlling groundwater abstractions, particularly in the Sandveld and Koue Bokkeveld sub-areas.
  - No further building of instream dams and weirs (not only do these restrict movement, but it has also become common practise in the area to ignore the requirement of allowing summer water releases).
- Prohibiting the stocking of farm dams (even off-stream dams) with alien fish.
- Regular spear-fishing and netting of alien fish as a rehabilitation or control measure.
- No further granting of licenses for extensive agriculture. The catchment as a whole is only just in water balance (water demand equals water availability).
- Enforcing the 35 m riparian buffer zone. This applies to crops, since rivers and their associated biota are highly susceptible to crop pesticides. It also applies to excluding livestock, which cause considerable bank erosion, with subsequent degradation of water quality.

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List of Acronyms

CAPE	Cape Action for People and the Environment
DWAF	Department of Water Affairs and Forestry
FCG	Freshwater Consulting Group
GEOSS	Geohydrological and Spatial Solutions International
UCT	University of Cape Town
WWF	Worldwide Fund for Nature

1 INTRODUCTION

1.1 The freshwater biodiversity crisis

Freshwater ecosystems[1] and the biodiversity they support comprise a valuable natural resource. They are a source of aesthetic, spiritual, cultural and recreational value, and provide direct and indirect goods and services on which human societies depend (Information Box 1). Their conservation is therefore critical to all humankind.

Yet this valuable resource is in crisis. Increasing evidence suggests that freshwater ecosystems may well be the most endangered in the world (Ricciardi and Rasmussen 1999; Sala *et al.* 2000; Jenkins 2003; WWF 2004; Driver *et al.* 2005; Revenga *et al.* 2005; Dudgeon *et al.* 2006). The rate and extent of freshwater biodiversity loss is confounded by lack of data, but where data exist the estimates are bleak. Over 20 % of the global freshwater fish species have gone extinct, or become threatened or endangered (Moyle and Leidy 1992) - including 31 % threatened in South Africa (Bills and Skelton 2001). The global index of freshwater species shows a decline of 50 % between 1970 and 2000, a decline more rapid than that recorded for equivalent terrestrial and marine indices (WWF 2004). Extinction rates for North American freshwater fauna are projected to be five times higher than for terrestrial fauna, at a rate equal to that of tropical forests (Ricciardi and Rasmussen 1999). Similar downward trends are documented for freshwater habitats. For example, Nel *et al.* (in press) found that over 50 % of the freshwater ecosystems associated with main rivers in South Africa are critically threatened, a proportion much higher than those reported for the country's terrestrial ecosystems.

1.2 New approaches to freshwater biodiversity conservation are required

The freshwater biodiversity crisis is largely a consequence of the challenges inherent to conserving freshwater ecosystems, notably:

- Freshwater systems tend to lie at the lowest point in the landscape, and thus act as "receivers" of wastes, sediments and pollutants in runoff from the surrounding landscape. Managing entire catchments, which are often vast stretches of land, is therefore required.
- Because of the "openness" or fluidity of freshwater systems, they are subject to upstream, upland, and downstream impacts. Paying attention to connectivity becomes paramount, which also requires whole-catchment management.
- There is often fierce competition between multiple stakeholders for utilisation of water resources. Strong cooperative governance, which seeks to balance human and ecological needs within whole catchments, is therefore essential to manage resources sustainably and conserve freshwater biodiversity.

[1] This report uses the international term "Freshwater ecosystems" to refer to any inland water ecosystem. Thus, saline water ecosystems are also incorporated into this term.

It is clear from these challenges that conserving freshwater ecosystems depends on whole-catchment management, where land and water is managed in an integrated way that aims to achieve ecological as well as socio-economic sustainability. This will inevitably require trade-offs between catchments which are allocated to high protection (restricted utilisation) and those allocated to socio-economic development (high utilisation). Assessing the impact of these trade-offs for conservation can be addressed within the relatively new discipline of **freshwater conservation planning**, which offers a proactive and systematic means of identifying those catchments that are essential for conserving biodiversity, and those that are not.

This concept also aligns well with the proposed **national water resources classification** process, to be implemented by DWAF as a requirement under the National Water Act (Act No. 36 of 1998). The proposed national water resources classification process provides a mechanism for balancing protection and utilisation by assessing and managing aquatic resources in terms of a selected management class, which prescribes certain ecological states (Roux 1999, Roux 2001, DWAF 2006). Each of the proposed classes has specific implications regarding the manner and extent to which the resource can be utilised, as well as the types of services that can be provided by the resource on a sustainable basis (Table 1). Using catchments identified through the freshwater conservation planning process can help identify those catchments that should be afforded high protection in terms of national water resources classification. The system for undertaking national water resources classification is currently under development, using the Olifants/Doring primary catchment as a testing area.

Information Box 1: Human dependence on biodiversity

It can be argued that biodiversity has intrinsic value in and of itself. The intrinsic value of biodiversity and the need for its conservation is a component that is recognised by the United Nations Convention on Biological Diversity, to which South Africa is a signatory, as well as our National Environmental Management: Biodiversity Act (Act No. 10 of 2004). Both of these instruments strive to conserve a representative sample of biodiversity as a natural heritage for current and future generations.

More recently, sound arguments have also been made for the need to recognize that biodiversity is fundamental for current and future social and economic livelihoods (Scholes and Biggs 2004; Millennium Ecosystem Assessment 2005). Our individual and collective dependence on biodiversity is absolute; without it, humans would not be able to survive. Apart from the direct benefits of biodiversity such as food and water, humans also derive benefit from its influence on climate regulation, water purification, soil formation, flood prevention and nutrient cycling; while the aesthetic and cultural impact of biodiversity is obvious (Daily 1997; Balmford *et al*. 2002). All of these benefits to people fall into the broad category of "ecosystem services", and can be summarised into provisioning, regulating and cultural services that affect people directly, as well as indirect supporting services that maintain the other services. In combination, these services benefit human well-being through impacting on security, quality of life, health and social relations, all of which influence the degree of freedom and the choices that are available to people. When ecosystem services are impaired this inevitably leads to a narrowing of livelihood choices and an increase in the vulnerability of the poor. Loss of biodiversity leads to ecosystem degradation and subsequent loss of important ecosystem services (Holmlund and Hammer 1999; Duraiappah *et al*. 2005). Moreover, this loss tends to harm poor rural communities more directly, since they have limited assets and infrastructure and are more directly dependent on common property resources for their livelihoods. Our path towards sustainable development, poverty alleviation and enhanced human well-being for all, is therefore completely dependent on how effectively we are able to manage and protect biodiversity.

Table 1: The River Health and the National Water Resources Classification System
The relationship is shown between the categories used by the River Health Programme and the classes proposed by the National Water Resources Classification System

River health categories (Roux 2004)		**National Water Resources Classification System (DWAF 2006)**	
Category	**Description**	**Proposed management class**	**Description**
A or B (Natural or good)	Ecosystem essentially in good state; biodiversity of in-stream and riparian habitats largely intact.	Class I: Minimally used	The configuration of water resources within a catchment results in an overall water resource condition that is minimally altered from its pre-development condition. Human activity has caused no or minimal changes to the historically natural structure and functioning of biological communities, hydrological characteristics, chemical concentrations and the bed, banks and channel of the resource.
C (Fair)	Ecosystem essentially in good state; biodiversity largely intact, although sensitive species may be lost, with tolerant or opportunistic species dominating	Class II: Moderately used	The configuration of water resources within a catchment results in an overall water resource condition that is moderately altered from its pre-development condition.
D (Poor)	Mainly tolerant species present or alien species invasion; disrupted population dynamics; species are often diseased.	Class III: Heavily used	The configuration of water resources within a catchment results in an overall water resource condition that is significantly altered from its pre-development condition.
E or F (Poor)	Mainly tolerant species present or alien species invasion; disrupted population dynamics; species are often diseased.	Unacceptably degraded resources	Due to over-exploitation, these rivers are already in a state that is ecologically unsustainable, and need to be rehabilitated to a sustainability baseline of Class III

1.3 Objectives and scope of this study

This study has been undertaken for the Olifants/Doorn Water Management Area. It makes use of on an extensive amount of existing information for the area, both in terms of data and expert knowledge, and has two main objectives:

(i) To develop a spatial biodiversity assessment, which systematically identifies catchments and features important for conserving freshwater ecosystems and their associated biodiversity in the study area

This spatial assessment can inform business and management strategies of a variety of implementing agencies. It provides systematic and strategic guidance regarding the trade-offs between conservation and development, and can be used to provide strategic perspective to decision-makers at the scale of a water management area. It should therefore be used to further develop an implementation plan in conjunction with multiple stakeholders, including implementing agencies responsible conserving freshwater biodiversity, and sectors whose activities impact on biodiversity. The development and adoption of this implementation plan is fundamental to carrying out the recommendations stemming from the spatial biodiversity assessment, but is beyond the scope of this project.

(ii) To test how spatial assessments would interface with the National Water Resources Classification System in determining the desired management class of rivers from a freshwater biodiversity perspective

The system for undertaking national water resources classification is currently under development, using the Olifants/Doring primary catchment as a testing area. This study therefore presented an ideal opportunity for testing how the outputs of spatial biodiversity assessments can be made suitable for incorporation into the national water resources classification process.

1.4 Approach and stakeholder consultation to date

The approach to this study was guided by recommendations emanating from the national cross-sectoral policy process on conserving freshwater ecosystems and their associated biodiversity (Roux *et al.* 2006). This process collated operational policy objectives and guiding principles to advance the practical conservation of freshwater biodiversity across multiple sectors and spheres of government. The objectives and guidelines are a culmination of analysis, consultation and deliberation amongst the primary agencies responsible for conservation of freshwater biodiversity in South Africa. A summary of the objectives and guiding principles, is provided for convenience in Appendix 1, and can be summarized as follows:

- Objective 1: Set and entrench quantitative conservation targets for freshwater biodiversity
- Objective 2: Plan for representation of freshwater biodiversity
- Objective 3: Plan for persistence of freshwater biodiversity
- Objective 4: Establish a portfolio of freshwater conservation areas
- Objective 5: Enable effective implementation

Objectives 1-4 are addressed completely in this study, whilst objective 5 (enabling effective implementation) is only partially addressed. Objective 5 should be regarded as an ongoing process that is initiated at the outset of the approach. Thus, although the development of an implementation strategy falls beyond the scope of this study, key implementing agencies were consulted in the development and review of the spatial biodiversity assessment (Table 2).

Table 2: Consultation process to date
Dates, purpose of each workshop and participants (in alphabetical order of surname) are provided. The affiliation of each participant is provided in brackets after their name.

Date	**Purpose**	**Participants**
Feb 2006	Information sharing with the team responsible for developing the National Water Resources Classification System	Cate Brown (Southern Waters) Evan Dollar (CSIR) Justine Ewart-Smith (FSG) Tony Turton (CSIR) Alison Joubert (UCT) Jeanne Nel (CSIR) Jane Turpie (UCT)
13 Mar 2006	Developing a common understanding about how conservation planning approaches could be applied to the ecological component of National Water Resources Classification System	Justine Ewart-Smith (FSG) Jeanne Nel (CSIR)
25 Apr 2006	Initial information sharing with regional DWAF managers	Toni Belcher (Regional DWAF) Dana Grobler (Blue Skies) Jeanne Nel (CSIR)
12 May 2006	River typing to devise river nodes for the National Water Resources Classification System	Cate Brown (Southern Waters) Justine Ewart-Smith (FSG) Jeanne Nel (CSIR) Lindie Smith-Adao (CSIR)
27 Jun 2006	Discussions on the opportunities for developing an implementation strategy to accompany the spatial biodiversity assessment	Toni Belcher (Regional DWAF) Rodney February (WWF) Nancy Job (FSG) Jeanne Nel (CSIR) Deon Nel (WWF) Lindie Smith-Adao (CSIR)
18 Jul 2006	Information sharing with DWAF Catchment Manager for the Olifants/Doorn Water Management Area	Jeanne Nel (CSIR) Abdulla Parker (Regional DWAF)
24 Jul 2006	Information sharing with regional CapeNature managers	Johan Burger (CapeNature) Dean Impson (CapeNature) Pierre de Villiers (CapeNature) Jeanne Nel (CSIR) Rika du Plessis (CapeNature) Charl du Plessis (CapeNature), Sean Ranger (CapeNature) Jaco Venter(CapeNature)

Continued on next page……………

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Date	Purpose	Participants
3 Aug 2006	Towards developing GIS layers to depict river types, river integrity and fish sanctuaries	Toni Belcher (Regional DWAF) Willie Enright (Regional DWAF) Rodney February (WWF) Dean Impson (CapeNature) Inge Kotze (CSIR) Deon Nel (WWF) Jeanne Nel (CSIR) Bruce Paxton (UCT) Lindie Smith-Adao (CSIR)
15 Aug 2006	Devising an approach for incorporating groundwater into the spatial biodiversity assessment	Julian Conrad (GEOSS) Inge Kotze (CSIR) David Le Maitre (CSIR) Jeanne Nel (CSIR)
16 Aug 2006	Devising an approach for incorporating wetlands into the spatial biodiversity assessment	Liz Day (FSG) Inge Kotze (CSIR) Jeanne Nel (CSIR)
21 Sep 2006	Review collated GIS layers of river types, river integrity and fish sanctuaries	Toni Belcher (Regional DWAF) Dean Impson (CapeNature) Jeanne Nel (CSIR)
28 Sep 2006	Lessons learnt in testing how to incorporate spatial biodiversity assessment outputs into the National Water Resources Classification System	Cate Brown (Southern Waters) Jeanne Nel (CSIR)

2 DESCRIPTION OF THE STUDY AREA

The Olifants/Doorn Water Management Area is one of the most diverse water management areas in the country with respect to its natural characteristics and water resources, and is also the least populated water management area in the country. A summary of the general characteristics of the area is provided below. For a more detailed description, the reader is referred to DWAF (2005a).

The Olifants/Doorn Water Management Area is one of 19 water management areas in South Africa, deriving its name from the main river that drains the area, the Olifants River. The word "Doorn", an ancient form of Doring, was added to distinguish it from the many other Olifants rivers in the country, and because the Doring River is the main tributary of the Olifants River. The water management area is situated on the west coast of South Africa occurring mainly in the Western Cape Province of South Africa, with a smaller portion in the north-east occurring in the Northern Cape Province (Figure 1). It incorporates the entire E-primary catchment, as well as portions of the F- and G-primary catchments, respectively north and south of the Olifants River estuary. The major river in the water management area is the Olifants River, of which the Doring and Sout rivers are main tributaries. Almost all the surface flow originates from the small, high-rainfall area around the Cederberg and is carried to the ocean by the Olifants and Doring rivers. Six sub-areas within the water management area form the management units used by the Regional Office of DWAF, namely: Upper and Lower Olifants, Koue Bokkeveld, Doring, Knersvlakte, and the Sandveld (Figure 1).

There are three distinct types of topography in the area. Rolling hills and sand dunes are located in the west along a coastal strip, and provide a significant groundwater resource; rugged mountains with peaks rising to almost 2 000 m above sea level occur in the south; and plains and rocky hills characteristic of the western Karoo are found in the north-eastern portion of the water management area. Prominent topographic features are the Cederberg and Groot Winterhoek mountain ranges, and the narrow Olifants River valley. There is a large variation in rainfall, with the highest mean annual rainfall (up to 1 500 mm) recorded in the Cederberg mountains in the south-west, which diminishes to less than 100 mm per year in the north, and a harsh and arid climate prevails over most of the water management area. The diverse soil types and variance in rainfall gives rise to a variety of vegetation types, including Karoo and karroid types, false Karoo types, temperate and transitional forest types, scrub types, and fynbos.

The Olifants/Doorn Water Management Area is the most notable endemic fish hotspot in southern Africa (Skelton *et al.* 1995). Nine out of the twelve indigenous fish species are endemic to the system, and all are threatened. The Olifants River estuary is one of only three permanently-open estuaries on the west coast of South Africa and therefore represents a critical habitat for estuarine-associated fauna. It is ranked as the third most important estuary for conservation in South Africa (Turpie 2004) and is considered to be one of the top ten important bird areas (DWAF 2005a). The Verlorevlei in the Sandveld sub-area is one of the largest natural wetlands on the west coast of southern Africa. It is a proclaimed RAMSAR site in recognition of its international importance as a feeding ground for several rare and threatened bird species, and the presence of many rare and threatened species, for example rare and threatened freshwater fish (the

Verlorevlei redfin, *Galaxias zebratus*), and rare and threatened mammals such as the Cape clawless otter (*Aonyx capensis*). Verlorevlei, and many other coastal wetlands in the Olifants/Doorn Water Management Area, are highly vulnerable due to pressure from over-utilisation of groundwater. The Doring River is one of the few large rivers in the country with no major instream dam on its mainstem, and it supports a high number of endemic fish. It is also important for the maintaining the functioning of the Olifants River estuary, as it improves water quality and quantity of the Olifants River below the confluence. Other important conservation areas include the Cederberg Wilderness Area, the Groot Winterhoek Wilderness Area and the Tankwa Karoo National Park. The Cape Action for People for the Environment (CAPE) programme is an initiative which seeks to protect the rich biological heritage of the Cape Floristic Region. It has a number of conservation projects underway in the area, such as the Greater Cederberg Biodiversity Corridor initiative which aims to conserve the biodiversity of the Cederberg region, and numerous alien fish control projects.

There are no major towns or urban areas in the Olifants/Doorn Water Management Area, and it is the least populated water management area in the country, containing less than 1 % of the national population. Approximately 65 % of this population is located in the Koue Bokkeveld, the Upper and Lower Olifants, and the Sandveld sub-areas. Most of the land in the water management area (about 95 %) is used as grazing for livestock, predominantly for sheep and goats. Land cover over much of the area is therefore largely natural, although there is evidence of degradation, particularly along water courses where sheet erosion and dongas develop (Figure 2). Although the area of irrigated land is small (Figure 2), irrigated agriculture is the economic mainstay of the water management area, with 95 % of total water use allocated to irrigation. Intensive production of deciduous fruits, citrus and grapes occurs in the Koue Bokkeveld and along the Olifants River, whilst large quantities of groundwater are abstracted for irrigation of potatoes in the Sandveld area. Tourism is an important and growing sector of the economy in the water management area, and coastal towns suffer from water shortages over the summer tourist season due to peak demand. Economic development is likely to be modest and will depend mainly on further irrigation development and the development of tourism.

The Olifants River is regulated by the Clanwilliam and Bulshoek dams. There are no large dams on the Doring River, although the upper Doring River also receives a water transfer from the Breede Water Management Area for irrigation purposes. The ecological impact of this transfer appears to be highly localised, impacting only the portion of the Doring River flowing through the Koue Bokkeveld. Numerous farm dams have also been constructed throughout the upper Olifants and Doring catchments. Water use and availability are generally in balance over most of the water management area. Exceptions are in the Olifants River valley upstream of Clanwilliam Dam, where irrigation requirements have exceeded availability, and in the Sandveld area where over-exploitation of groundwater is known to occur.

Future growth for towns, industry and mining is expected to be low, however there is a demand for ongoing expansion of existing irrigation in the Upper Olifants, Koue Bokkeveld and the Sandveld sub-areas. Currently, restrictions have been placed on the issuing of further water licences in all sub-areas except the Knersvlakte, until more information becomes available regarding the feasibility of identified development options and the implications of the Reserve.

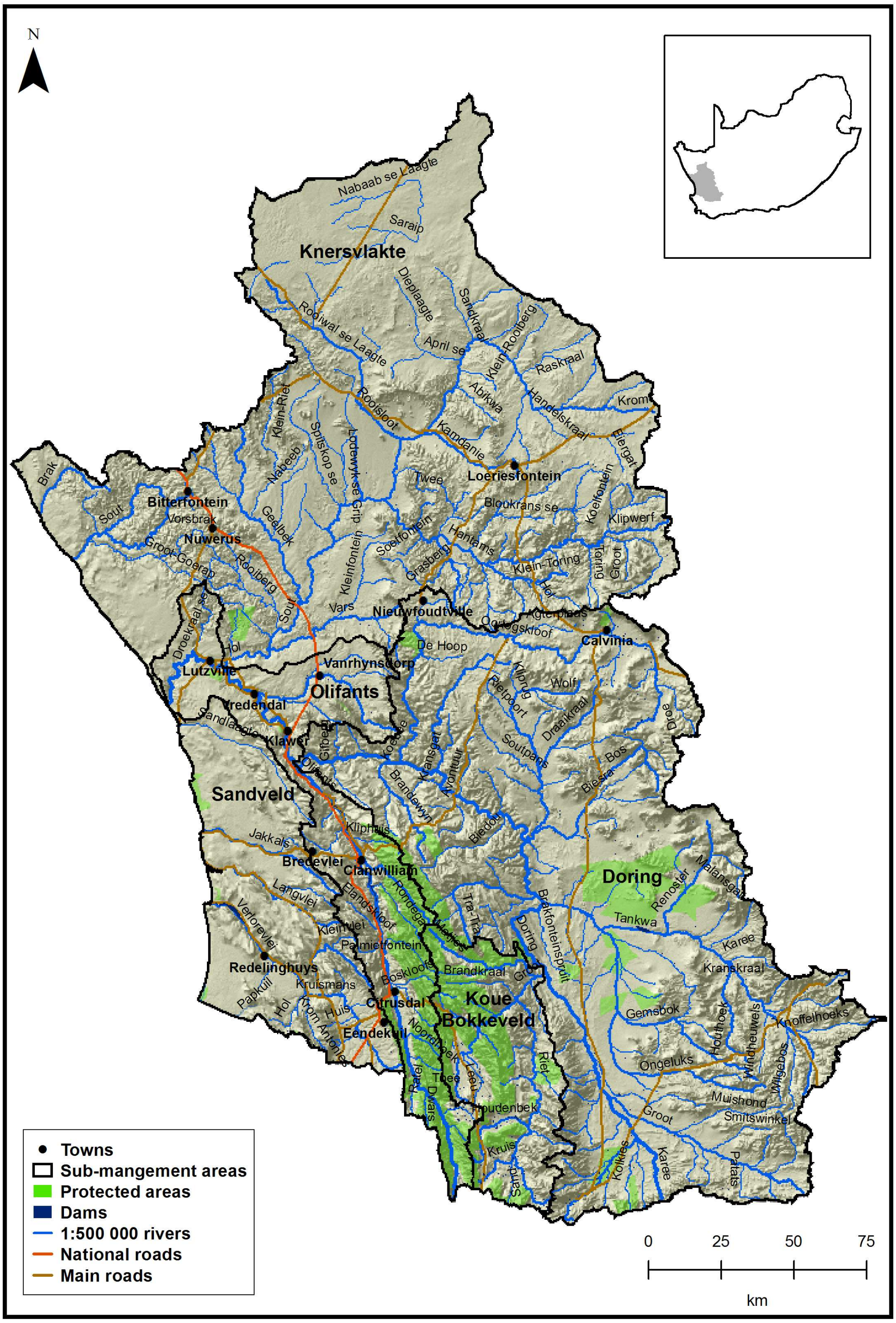

Figure 1: Map of the Olifants/Doorn Water Management Area
The location in South Africa is shown in the inset. The main map shows 1:500 000 rivers, sub-water management areas, and the major towns and roads.

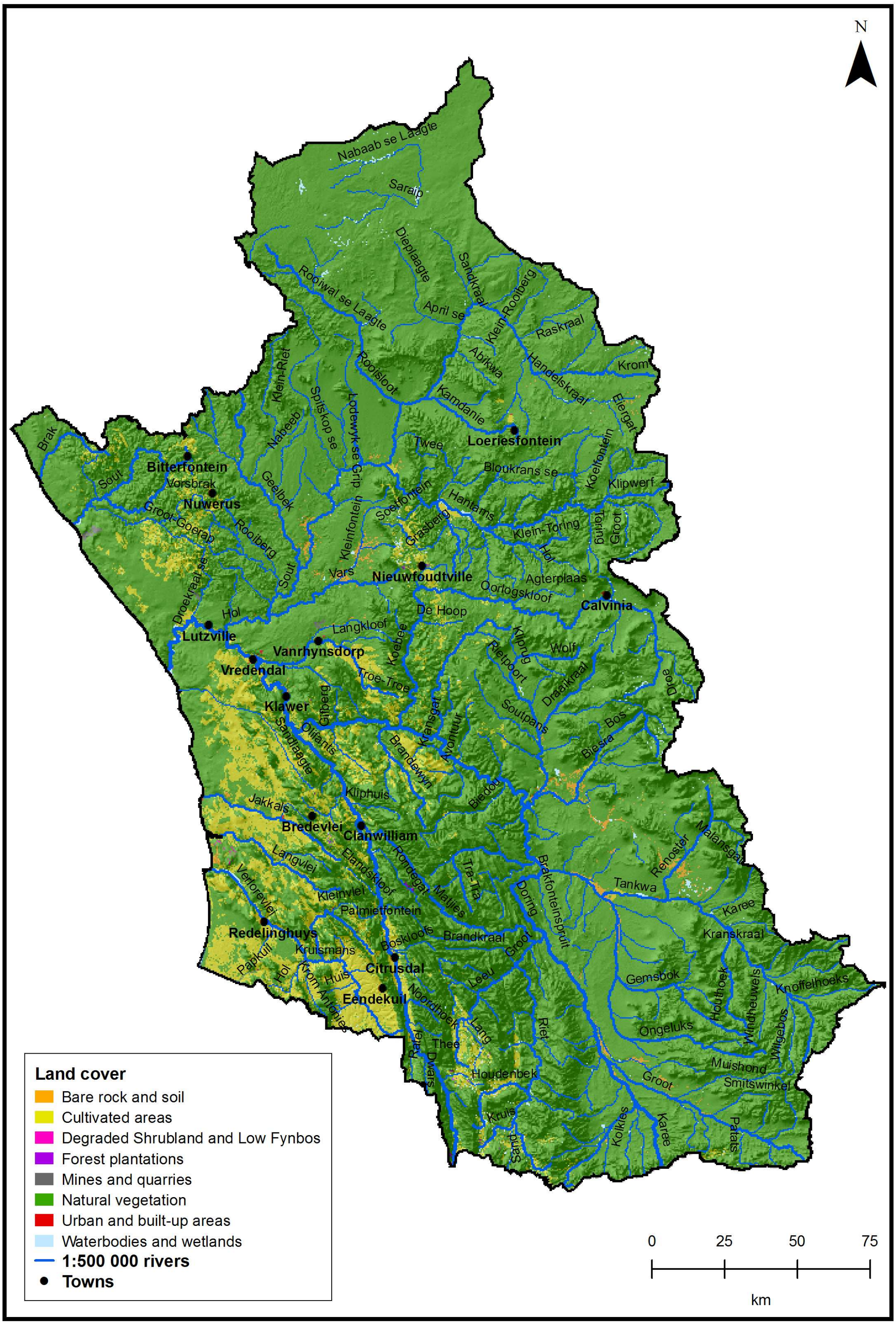

Figure 2: Land cover in the Olifants/Doorn Water Management Area.

3 SETTING QUANTITATIVE CONSERVATION TARGETS

A first step in promoting the systematic and purposeful conservation of freshwater biodiversity is to incorporate a clear and explicit conservation vision into the strategies and business plans of those implementing agencies responsible for managing freshwater ecosystems. This vision should then be translated into quantitative conservation targets. Conservation targets (also referred to as biodiversity targets) set minimum, quantitative requirements for biodiversity conservation in order to: allow an evaluation of whether or not existing conservation efforts adequately represent the biodiversity of a region; provide guidance for planners who are balancing a number of competing demands for natural resources in a region, and provide water resource management and biodiversity conservation agencies with common quantitative measures for which to aim (Groves 2003).

Conservation targets reflect scientific best judgement, and the adoption and implementation of these targets is a reflection of societal norms and values. There is no correct way of setting targets because of the uncertainty around requirements of structural, compositional and functional elements of biodiversity. Therefore, the setting and adoption of conservation targets should be informed through evolving understanding of the effect of anthropogenic activities on biodiversity. A conservation target should thus be subject to review over time.

The conservation vision and targets emanating from the national cross-sector policy process (Roux *et al*. 2006) were used to guide the vision and conservation targets adopted for the Olifants/Doorn Water Management Area. The vision encompasses all water resources (both surface and sub-surface waters), and not just rivers.

Conservation Vision for the Olifants/Doorn Water Management Area

To conserve a sample of the full variety or diversity of freshwater ecosystems that occur in the Olifants/Doorn Water Management Area, including all species as well as the habitats, landscapes, rivers and other water bodies in which they occur, together with the ecosystem processes responsible for generating and maintaining this diversity, for both present and future generations.

The following guidelines from Roux *et al.* (2006) were considered in setting conservation targets:

(i) At least 20 % of each freshwater ecosystem type should be maintained in an A or B integrity category, where A or B refers to the highest level of protection afforded by the National Water Resources Classification System of DWAF (i.e. Management Class I; see Table 1). This recommendation stems from the World Conservation Union's Caring for the Earth strategy (IUCN 1989), which stipulates that a minimum of 20 % of a country's natural aquatic assets require protection - dropping below this threshold (i.e. failing to meet a minimum conservation target of 20 %) implies that the ecosystem is inadequately represented in the country, and has become critically endangered.

(ii) In order to maintain freshwater ecosystem functioning, whole river systems rather than isolated reaches should, wherever possible, be selected for contributing towards the national conservation target. Where this is not attainable, river ecosystems that are designated for conservation should, where relevant, be connected through river systems that are in a state that supports ecological connectivity - for example allowing migration of a key species. River systems that provide connectivity should be considered part of an overall conservation portfolio design for freshwater conservation, i.e. maintenance of their ecological state will be necessary for achievement of the overall conservation target. However, where connecting rivers are in less than an A or B integrity category, they should not contribute towards satisfying the 20 % conservation target.

(iii) Where a particular freshwater ecosystem that has been identified as important for achieving targets, but through past or current over-utilisation has been modified to a state that does not conform to conservation objectives, restoration or rehabilitation should be undertaken subject to feasibility. Rehabilitation efforts should strive to return the chemical, physical and biological attributes of a water resource to that associated with a defined (not necessarily pristine) ecological state.

Translating these recommendations to the Olifants/Doorn Water Management Area, quantitative conservation targets were calculated for river types, fish species, and wetland types.

3.1 Conservation targets for river types

The conservation target was calculated as 20 % of the total length of each Level 3 river type. These targets should only be achieved within river reaches that have an ecological integrity category of A or B - any river reach lower than an A- or B-category, included in the plan for maintaining longitudinal connectivity, did not contribute towards achieving this 20 % target.

For those river types that cannot meet their conservation target, i.e. where the length in A or B categories has dropped below 20 % of the total length of that river type, the feasibility of rehabilitating examples of these river types was investigate, within the context of the potential opportunity for conserving these river types elsewhere in the country. Quantitative conservation targets derived for each Level 3 river type are shown in Appendix 2, together with an assessment of the ability to achieve this target in the water management area.

3.2 Conservation targets for fish species

Explicit and quantitative conservation targets were set for all ten indigenous freshwater fish species. No explicit conservation targets were set for estuarine fish species, but the estuary itself was selected as an important conservation feature.

For the eight endemic freshwater fish species, a targets was set to select a "viable" population *at least twice*, preferably in different secondary catchments (which translate roughly to different sub-areas). For example, select one population in the Olifants and one in the Doring; or one in the Olifants and one in the Sandveld. "Viable" was defined broadly to mean a self-maintaining, recruiting population of fish. "Species" were defined as evolutionary significant units (*sensu* Moritz 1994) – thus, in cases where recent taxonomic studies suggest a genetic separation between populations, these populations were treated as distinct units. For the indigenous freshwater fish species that are not endemic to the area, only one viable population was selected.

Additional considerations included ensuring an adequate mix of tributary habitat, and habitat in the mainstem rivers of the Olifants, Doring, Koebee or Groot rivers for migratory species. The rationale for this is that tributaries provide refugia free of alien fish, so that smaller fish can escape predation; whilst mainstem rivers provide critical habitat for larger adult fish, because the rivers support greater numbers of larger fish, being more productive and offering more living space. Rivers free of alien fish were also favoured for selection in the conservation portfolio (Section 11.1.2).

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3.3 Conservation targets for wetland types

The conservation target for *representation* of wetland types was calculated as 20 % of the total area of each Level 3 wetland type. These targets should only be achieved within wetland types whose modelled ecological integrity is natural. Those wetlands selected to achieve representation targets need to be in their near-pristine condition to maintain the full range of structural, compositional and functional biodiversity (i.e. their habitats and associated biota, as well as their functions). These wetlands should be awarded the highest level of protection. For those wetland types that cannot meet their conservation target for representation, i.e. where the area of near-pristine wetland type has dropped below 20 % of the total area of that wetland type, the feasibility of rehabilitating examples should be investigate. Quantitative conservation targets for representation of wetland types are shown in Appendix 3, together with an assessment of the ability to achieve this target in the water management area.

In addition to those wetlands required in a near-pristine state for representation, a target was set to prevent further degradation to the functioning of all mapped wetlands. The rationale for this is that wetlands are important for ecological functioning and ecosystem services, such as stream flow regulation and flood reduction, erosion control and water quality improvement. Thus, all potential wetlands were flagged to achieve this target; however, not all these wetlands need to be maintained in a near-pristine condition, and a level of protection was assigned to different functional wetland types based on their functional importance and sensitivity to anthropogenic impacts (Section 10.1).

3.4 Free-flowing rivers

The length of a river is characterised by certain ecological gradients, e.g. temperature, nutrient and sediment/substrate gradients, along which biota are predictably structured. Anthropogenic disturbances such as excessive water abstraction or the construction of a dam creates discontinuities, and discontinuous segments of a river cannot support the same ecological processes or provide the same services that are associated with free-flowing rivers. These services include the transportation of sediment that are essential for maintaining estuaries and coastal wetlands and controlling pollution through effectively transporting excess contaminants and nutrients.

A free-flowing river is a river that flows undisturbed from its source to its mouth, at either the confluence with a larger river or the sea (WWF 2006). The size of a free-flowing river can potentially be characterised based on total length from source to mouth, the size of the watershed drained by the stream or the average discharge at the mouth. A conservation target of one free-flowing river of at least 100 km in length was set for the purposes of incorporating this pronicple into the Olifants/Doorn conservation portfolio. A further criterion in prioritisation of the conservation value of free-flowing rivers is that these rivers include as many longitudinal zones as possible.

4 PLANNING FOR REPRESENTATION: RIVERS

4.1 Delineating sub-quaternary catchments

In order to select areas to achieve conservation targets, the units of selection, or planning units, need to be defined at the appropriate scale. Using catchments as planning units has the advantage of highlighting that conservation of freshwater ecosystems depends on appropriate management of both land and water in a drainage basin. However, primary drainage areas are too large to provide sufficient detail required at the water management area level. Indeed, it has been found in previous freshwater conservation planning exercises (van Niewenhuizen 1998; Nel *et al.* 2006) that even the smaller quaternary catchments are too large a spatial scale to provide information in sufficient level of detail to use at a water management area level. For this reason, sub-quaternary catchments were modelled to use as planning units in this study. Focussing on sub-quaternary catchments as the units of selection also has the benefit of incorporating lateral connectivity (across aquatic-terrestrial gradients) and vertical connectivity (interactions with groundwater).

Sub-quaternary catchments were modelled using a combination of digital elevation data (US SRTM 90m)[2] and the DWAF 1:500 000 rivers[3]. Catchment boundaries were delineated around each river segment, defined as the stretch of river between confluences. This resulted in 528 sub-quaternary catchments, which are approximately nested within the 313 quaternary catchments (Figure 3). The size of the sub-quaternary catchments is variable, ranging from 0.2-853 km^2, with an average size of 107 km^2.

4.2 Selecting rivers for analysis

The 1:500 000 rivers GIS layer (DWAF 2004) was used for the analyses in this study. This GIS layer is based on 1:500 000 topographical maps, however, it has been refined to include alignment of the rivers to within 50 m of the 1:50 000 topographical maps. This GIS layer was supplemented by four additional rivers, added from the 1:50 000 rivers GIS layer. Three of these rivers were added because they contained river health monitoring sites, and include two un-named streams (corresponding to sub-quaternary catchments 390 and 529) and the Noordhoek River (corresponding to sub-quaternary catchment 527). The fourth river, the Krom River, was added because regional river experts felt that it was a large enough stream, situated in the Greater Cederberg Wilderness Area, and of conservation value in terms of fish species.

[2] available from the website: http://www.personal.psu.edu/users/j/z/jzs169/Project3.htm
[3] available on DWAF website: http://www.dwaf.gov.za/iwqs/gis_data/river/All.htm

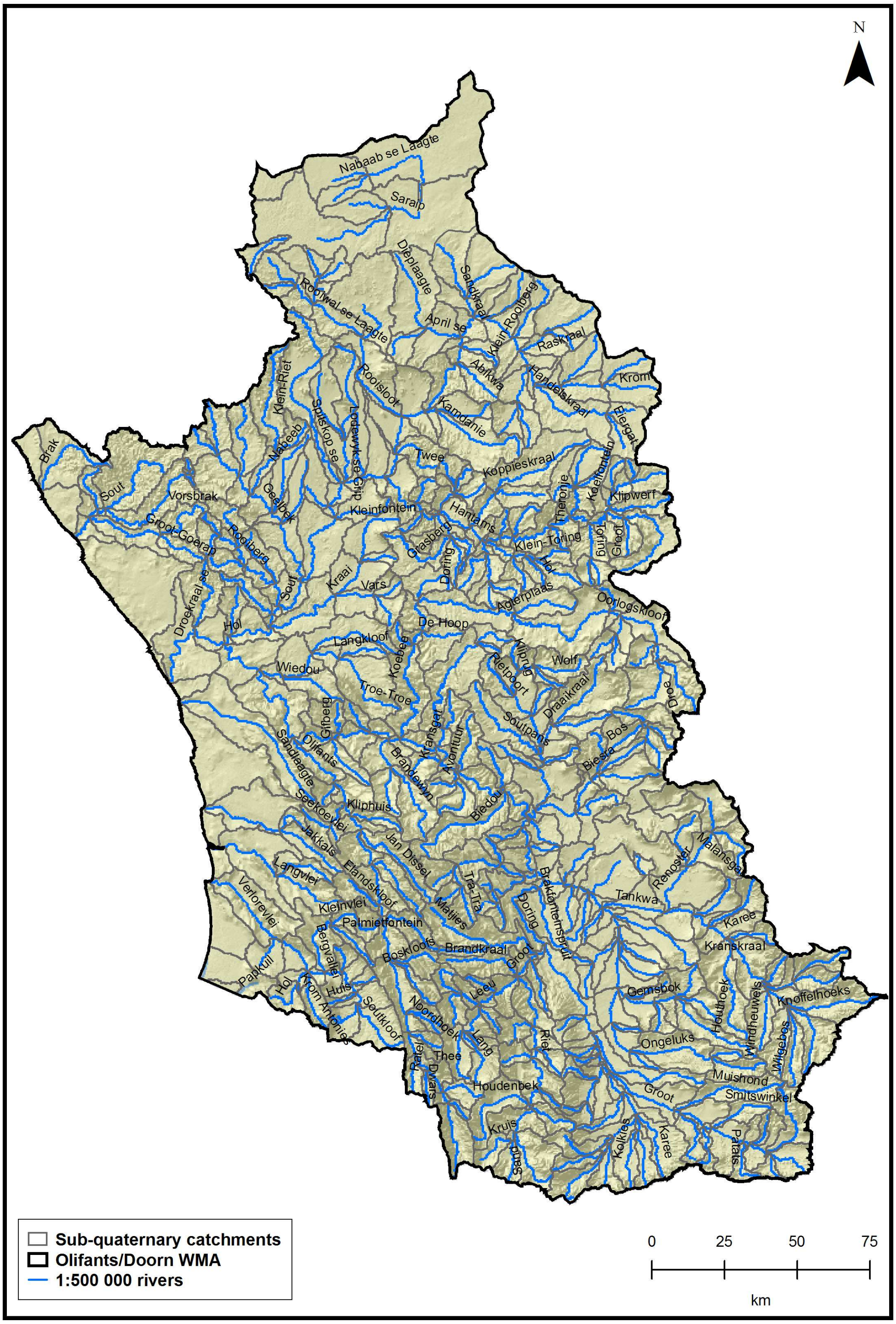

Figure 3: Sub-quaternary catchments
Sub-quaternary catchments (n=528) were used as planning units.

4.3 Mapping special features

Several experts in the Olifants/Doorn Water Management Area helped to identify biodiversity features in the landscape which had special value for biodiversity, and which may not be picked up by representation of river types, wetland types or fish species. These special features included:

- Intact river gorges, which serve as evolutionary barriers, zones of rejuvenation and natural barriers to alien fish invasion;
- Rivers free of alien fish; and
- A large intact wetland system on the Matjies River.

Eighteen special features were mapped (Table 3, Figure 4). These were included in the conservation portfolio by mapping the actual delineation for on-site conservation, rather than including the entire sub-quaternary catchments within which it fell. Sub-quaternary catchments containing special features were also discounted in planning unit cost used by the conservation planning software (MARXAN/CLUZ, see Section 11.1.2). This discounting encourages MARXAN/CLUZ to select the sub-quaternary catchments containing the special feature, where there are choices between two sub-quaternary catchments with similar biodiversity features (see Section 11.1.2, Information Box 2).

Table 3: Special features mapped using regional experts
ID is a unique identifier associated with each mapped feature (see Figure 4).

ID	Description
1	Biedou River gorge. This is a potholed gorge containing a waterfall with a sheer bedrock drop of about 10 m. Note that ID 18 identifies the entire Biedou River as a special feature because it is free of alien fish. However, it is important to single out the waterfall.
2	Olifants River gorge. This is the only place left on Olifants and Doring rivers where indigenous fish are not invaded. It contains the last remaining mainstem population of the Clanwilliam sawfin, *Barbus serra* (where Olifants, Doring, Koebee, Groot are defined as fish mainstems). This area is of outstanding scenic beauty. Water quality is also very good and it the area serves as a River Health Programme reference site for the Olifants River. Vegetation is still very intact, although there is a slight invasion of black wattle at the downstream end of the gorge.
3	Three waterfalls on the Twee River, and one on the Middledeur River that are of outstanding scenic value. The TweeRiver redfin, *Barbus erubescens*, is endemic to the Twee River. Clanwillian yellowfish, *Labeobarbus capensis,* which was introduced above the waterfall, is impacting these redfins, and this should be monitored and controlled.
4	Area on Twee River above the weir. This is the site that CapeNature has identified as an alien fish eradication project. The plan is to eradicate Cape kurper and prove a sanctuary area for the Twee River redfin, *Barbus erubescens*.

Continued on next page……………

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ID	Description
5	Matjies River wetlands. Large area with pristine vegetation, containing important plant species. This is also an important water source area. It supports the following fish populations: Doring Fiery redfin (*Pseudobarbus phlegethon)*, Clanwillian yellowfish (*Labeobarbus capensis*) and Clanwilliam sawfin (*Barbus serra)*.
6	Koebee River gorge. This is a near-pristine gorge located in the northernmost extension of fynbos vegetation. It contains potentially many ecotones with Fynbos and Succulent Karoo vegetation types. It also contains a reproducing population of Clanwilliam sandfish, *Labeo seeberi* (there are only two such populations on the Doring system, and this one is the best).
7	The cascades on the Olifants River, about 10-15 km below Bulshoek Dam. This is a degraded part of the Olifants River, and maintenance of this special feature in a natural A or B integrity category is not feasible. However, this area should be managed in a C-category. For this, there needs to be a water release plan from the dam that provides some flooding.
8	The Doring River. Apart from Elandsvlei and Doringbos rivers, and the confluence of the Biedou River, the entire Doring River could be considered a gorge. This is one of the reasons why the Doring River is still in a largely natural B-category (it is difficult to farm in this area). The Doring River is also one of the few remaining large rivers that has no large dam on its mainstem. There is thus an immense opportunity to conserve this large river system, particularly given its importance in maintaining endemic fish species and maintaining ecological functioning of the ecologically and economically important Olifants River estuary.
9	Olifants River estuary. The Olifants River estuary is one of only three permanently-open estuaries on the west coast of South Africa and therefore represents a critical habitat for estuarine-associated fauna. It is ranked as the third most important estuary for conservation in South Africa and is considered to be one of the top ten important bird areas.
10	Verlorevlei wetland. The Verlorevlei is one of the largest natural wetlands on the west coast of southern Africa. It is a proclaimed RAMSAR site in recognition of its international importance as a feeding ground for several rare and threatened bird species, and the presence of rare and threatened freshwater fish (the Verlorevlei redfin, *Galaxias zebratus*), and rare and threatened mammals such as the Cape clawless otter (*Aonyx capensis*). Verlorevlei, and many other coastal wetlands, are highly vulnerable due to pressure from over-utilisation of groundwater.
11	Ratel River. Alien fish free river on the Olifants River system.
12	Thee River. Alien fish free river on the Olifants River system.
13	Noordhoek River. Alien fish free river on the Olifants River system.
14	Boskloof River at Citrusdal. Alien fish free river on the Olifants River system.
15	Rondegat River. Alien fish free river on the Olifants River system.
16	Gif River. Alien fish free river on the Doring River system.
17	Brandkraal River. Alien fish free river on the Doring River system.
18	Biedou River. Alien fish free river on the Doring River system.Note that ID 1 identifies the Biedou River gorge as a special feature because of its waterfall.

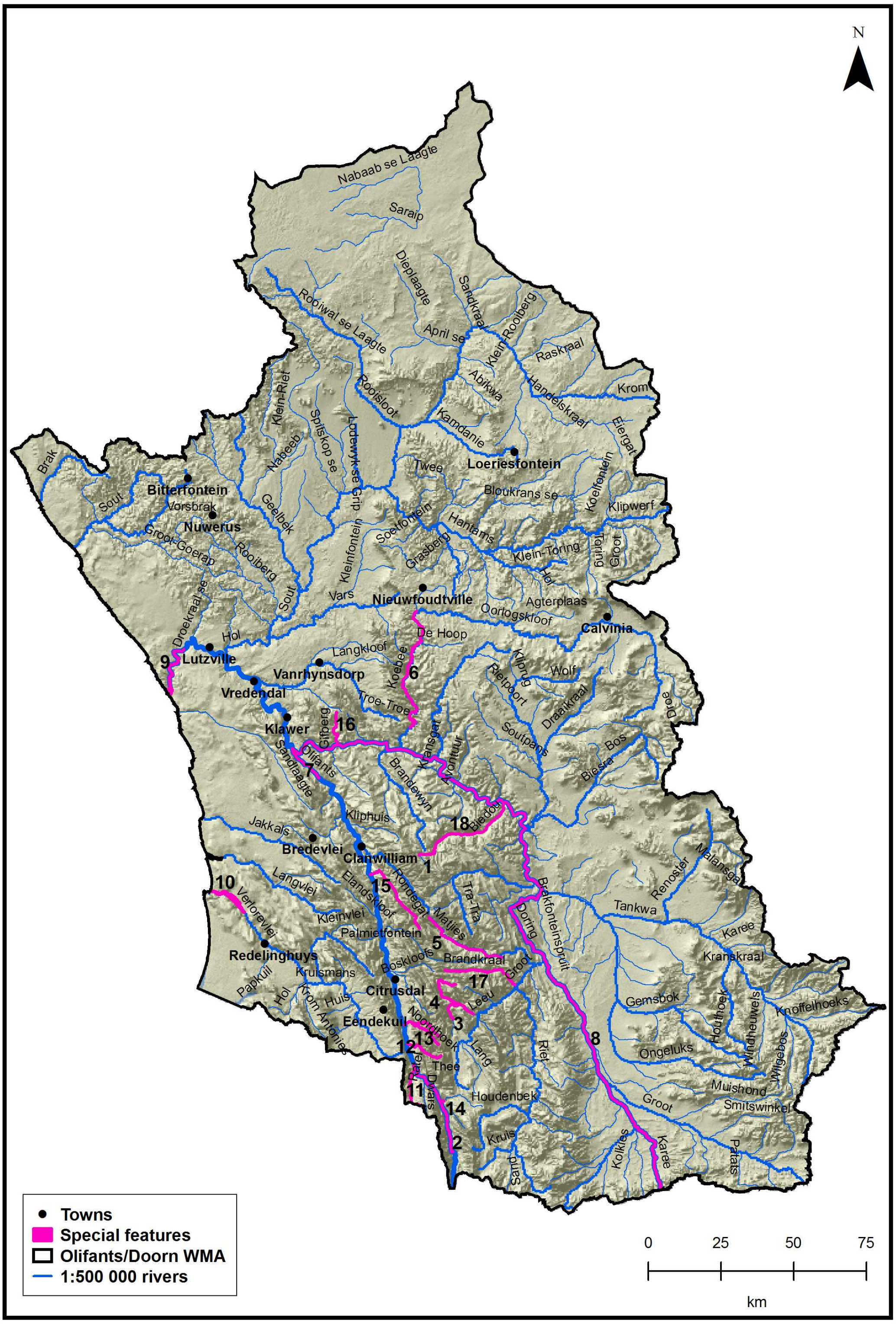

Figure 4: Special features identified in the study area

Refer to Table 3 for a detailed description of the special feature, corresponding to the ID provided.

4.4 River typing

A hierarchical system, which classifies rivers according to three levels, was used to type the rivers selected for this study (Section 4.2). At the level of the landscape, rivers were classified according to landscape characteristics and flow variability to produce landscape-level river types (or Level 2 river types). These Level 2 river types were supplemented with a characterisation of geomorphologic (longitudinal) zones at the level of individual streams to produce Level 3 river types. This longitudinal zonation serves as a surrogate for characterising the ability of a river reach to store or transport sediment, each zone representing a different physical template available for biotic habitation. Using this stream-level descriptor in conjunction with the Level 2 landscape characterisation provides a surrogate of the biotopes expected within the river reach, which in turn can be used as a surrogate for biodiversity pattern within river ecosystems. An overview of the three levels used to type rivers in the Olifants/Doorn Water Management Area is provided below.

4.4.1 Level 1: Freshwater ecoregions

Level 2 river ecoregions (Kleynhans *et al.* 2005) were used to characterise the landscape through which the river flows. These ecoregions represent areas within which ecological characteristics are similar; therefore, rivers in the same ecoregion will be more similar to one another than rivers in different ecoregions. Ecoregion boundaries in Kleynhans *et al.* (2005) were delineated by regional experts from various parts of the country. Delineation of Level 1 ecoregions involved evaluating maps of geographic phenomena such as climate, soils and geology, natural vegetation and physiography. These ecoregions were then used as a basis for the more detailed Level 2 ecoregion delineations, using the same information, but in more detail. For example, the physiographic aspects were described in terms of their terrain morphology, relief, altitude and slope in Level 2 delineations.

Six of the 31 Level 1 ecoregions in South Africa occur in the Olifants/Doorn Water Management Area (Table 4). These are further divided into 15 Level 2 ecoregions in the study area (Figure 5), which have yet to be described.

Table 4: Description of the Level 1 ecoregions that occur in the study area (after Kleynhans et al. *2005)*

Name	Level 1 ecoregion	Level 2 ecoregions	Description
Great Karoo	21	21.1, 21.2, 21.3	Characterised by plains with low to moderate relief, although significant areas contain closed hills and mountains with moderate to high relief. Vegetation consists of a diversity of Nama Karoo, Succulent Karoo, Renosterveld and thicket types. The Tankwa and Hantam rivers, both tributaries of the Doring River, are the main rivers in this ecoregion, respectively located in the Doring and Knersvlakte sub-areas.
Western Folded Mountains	23	23.1, 23.2, 23.3, 23.4	Closed hills and mountains with moderate to high relief are distinctive in this area, although tablelands and plains are present. Prominent escarpments occur along the east and north west of the region. Mountain fynbos is the dominant vegetation type. The Olifants River has its source in this region, as does the Groot River, a main tributary of the Doring River.
South Western Coastal Belt	24	24.1, 24.2, 24.4	Plains with a moderate to low relief are characteristic of the region, with altitude varying from sea level to 900 m.a.m.s.l. The dominant vegetation type is West Coast Renosterveld, although significant areas of fynbos, succulent Karoo and thicket are also found in this region. This region is located mainly in the Sandveld sub-area, containing the headwaters of the Verlorevlei, Langvlei and Jakkals rivers.
Western Coastal Belt	25	25.1, 25.2	Plains with low and moderate relief are typical of this region, with altitude varying from sea level to 700 m.a.m.s.l. Vegetation types consist of succulent Karoo types. The lower Olifants River, and the Doring and Sout rivers traverse this region.
Nama Karoo	26	26.2, 26.4	Topography is diverse, but plains with a moderate to high relief and lowlands, hills and mountains with moderate to high relief are dominant. Vegetation consists almost exclusively of Nama Karoo types. This ecoregion is extensive outside the Olifants/Doorn Water Management Area, and rivers with the study area in the Nama Karoo are ephemeral.
Namaqua Highlands	27	27.1	Closed hills and mountains with moderate to high relief are distinctive in this region. Dominant vegetation types consist of Succulent Karoo types and Renosterveld. This ecoregion is extensive outside the Olifants/Doorn Water Management Area, and rivers with the study area in the Namaqua Highlands are ephemeral.

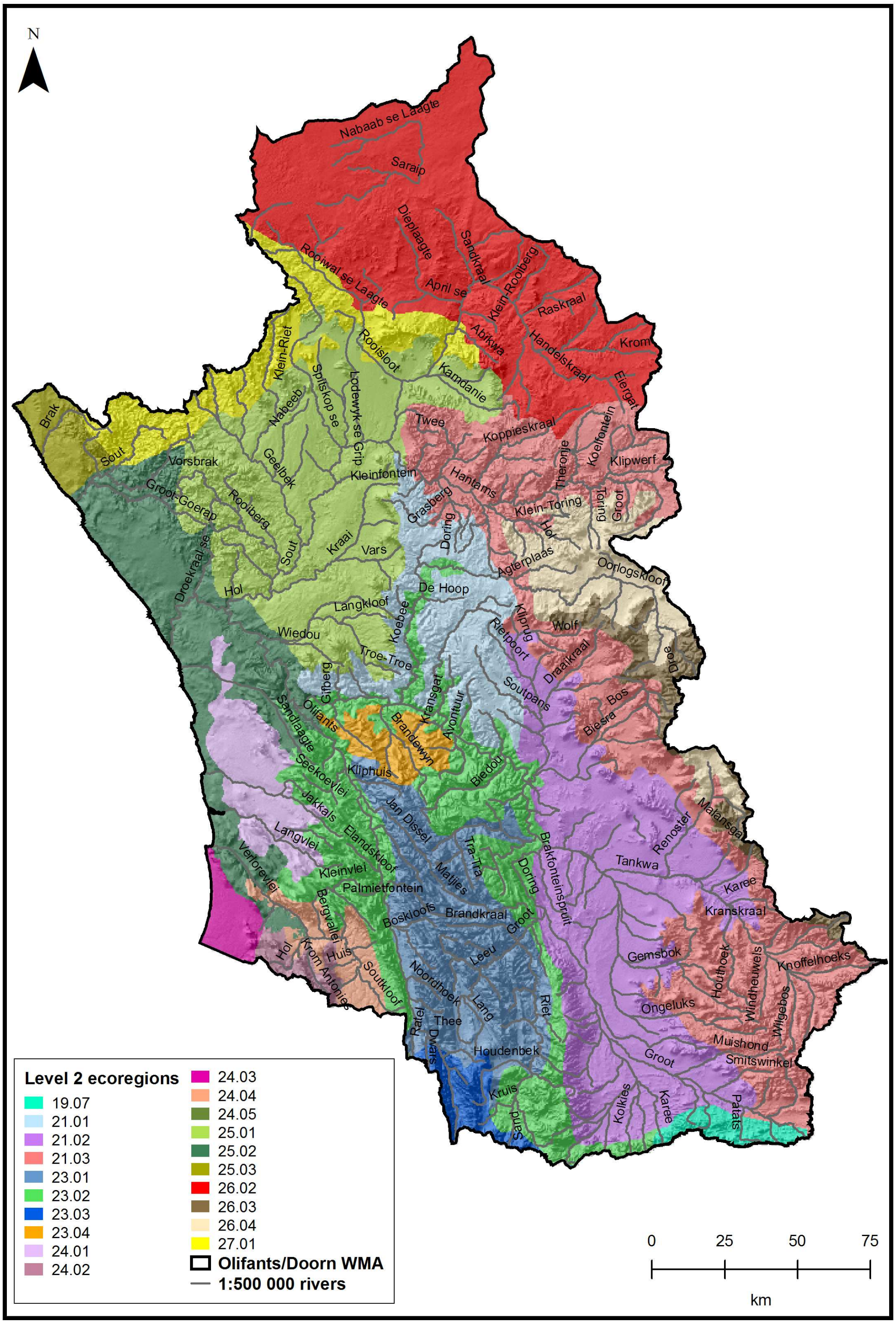

Figure 5: Level 2 ecoregions used as the first level of the river typing hierarchy
Level 1 ecoregions are described in Table 4; Level 2 ecoregions have not yet been described.

4.4.2 Level 2: Freshwater ecoregions combined with flow variation

Spatial and temporal distribution patterns of biota in South African rivers are strongly determined by flow variability. Thus, flow variability was explicitly incorporated into the river typing hierarchy by characterising rivers according to three broad categories:

- Permanent – those rivers that flow all year round;
- Seasonal – those rivers that flow annually but not permanently; and
- Ephemeral – those rivers that can go for several years without a flood event.

The hydrological index (Hannart and Hughes 2003) was used to characterise hydrological variability, measured as a ratio of flow variability to base flow in a river. For South African rivers, a hydrological index value of close to 1 will be found for regions of low variability (commonly referred to as perennial-type rivers) and a value of > 50 would indicate semi-arid regions of high variability (periodic- or ephemeral-type rivers). Hydrological index values for all 1986 quaternary catchments in South Africa were grouped into nine statistical classes (Table 5) using an automated version of the Worsley Likelihood Ratio test (Worsley 1979; Dollar *et al.* submitted). For the purposes of this study, and based on expert evaluation of the nine classes, rivers in quaternary catchments with a hydrological index class of 1-4 were assumed permanent, those in class 5 were considered seasonal, and those in classes 6-7 were considered ephemeral (Figure 6).

Table 5: Nine statistical classes of hydrological index

Classes were derived by Dollar et al. *(submitted) using the hydrological indices of Hannart and Hughes (2003). These indices were lumped into three descriptions of flow variability for the purposes of this study.*

Class	**Hydrological index (HI) thresholds**	**Flow variability descriptors used in this study**
1	HI ≤ 4.394	Permanent
2	4.394 < HI ≤ 7.535	
3	7.535 < HI ≤ 13.745	
4	13.745 < HI ≤ 16.110	
5	16.110 < HI ≤ 37.819	Seasonal
6	37.819 < HI ≤ 64.169	Ephemeral
7	64.169 < HI ≤ 92.705	
8	92.705 < HI ≤ 98.124	
9	98.124 < HI	

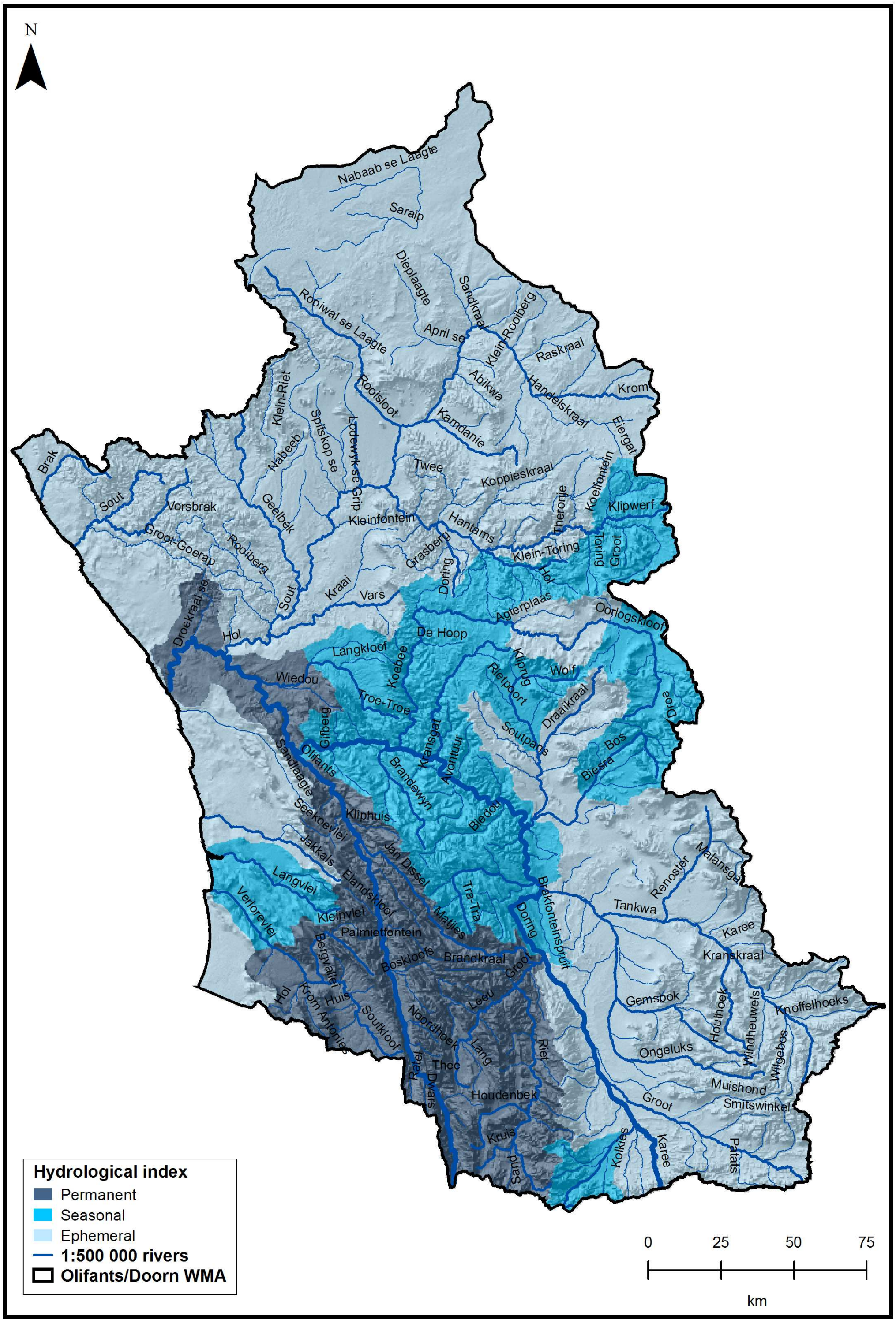

Figure 6: Flow variability of rivers in the study area
Flow variability is based on the hydrological index developed by Hannart and Hughes (2003), and was used, in combination with Level 2 ecoregions, to derive Level 2 river types.

Ecoregions (forming the first level of the river typing hierarchy) were spatially combined with the three flow variability classes to produce 27 Level 2 river types (Figure 7). Of these 27 Level 2 river types, 13 have their range completely within the study area, and a further 5 have over 80 % of their range within the Olifants/Doorn Water Management Area. Thus, Level 2 river types in the Olifants/Doorn Water Management Area exhibit a high degree of endemicity, with 18 (67 %) types considered to be unique, or endemic, to the area (Table 6).

Table 6: Level 2 river types for the Olifants/Doorn Water Management Area
The first part of the Level 2 river type describes the flow variability, the second part describes the Level 1 ecoregion, and the last part is a number describing the Level 2 ecoregion. % WMA length is the length of the river type expressed as a percentage of the total river length within the water management area; % National length is the length of each river type expressed as a percentage of its total length in South Africa.

Level 2 river type	Length in WMA (km)	% WMA length	% National length
Permanent-South Western Coastal Belt-2	44	1	92
Permanent-South Western Coastal Belt-4	142	2	33
Permanent-Western Coastal Belt-1	39	< 1	91
Permanent-Western Coastal Belt-2	173	2	100
Permanent-Western Folded Mountains-1	586	7	100
Permanent-Western Folded Mountains-2	426	5	88
Permanent-Western Folded Mountains-3	99	1	16
Seasonal-Great Karoo-1	241	3	100
Seasonal-Great Karoo-2	193	2	100
Seasonal-Great Karoo-3	386	5	100
Seasonal-Nama Karoo-4	248	3	100
Seasonal-South Western Coastal Belt-1	50	1	100
Seasonal-Western Coastal Belt-1	100	1	100
Seasonal-Western Coastal Belt-2	55	1	100
Seasonal-Western Folded Mountains-1	91	1	97
Seasonal-Western Folded Mountains-2	535	6	96
Seasonal-Western Folded Mountains-4	79	1	57
Ephemeral-Great Karoo-1	110	1	58
Ephemeral-Great Karoo-2	1079	13	100
Ephemeral-Great Karoo-3	1060	13	39
Ephemeral-Nama Karoo-2	739	9	16
Ephemeral-Nama Karoo-4	129	2	3
Ephemeral-Namaqua Highlands-1	301	4	11
Ephemeral-South Western Coastal Belt-1	50	1	100
Ephemeral-Western Coastal Belt-1	979	12	100
Ephemeral-Western Coastal Belt-2	244	3	100
Ephemeral-Western Folded Mountains-2	108	1	62

4.4.3 Level 3: Level 2 river types combined with longitudinal zones

River ecosystems are essentially a manifestation of the landscapes that they drain. They are the result of the natural flow regime which drives the system, as well as the sediment which is transported or deposited in the system. Generally, a river's longitudinal profile shows a downstream decrease in the slope gradient which leads to a decrease in stream velocity. This in turn, results in changes in the types of sediments found in the river channel. Larger, more coarse sediments are typically associated with the steeper headwater rivers whereas finer, while siltier sediments occurs in the lowland rivers (Rowntree and Wadeson 1999; Roux *et al.* 2002). The combination of the longitudinal zones and Level 2 river types can therefore be used to describe the different physical habitat templates available for biotic habitation (Nel *et al*. 2006).

Longitudinal zones were derived for all rivers using techniques from Rowntree and Wadeson (1999) and a semi-automated procedure developed at the Directorate: Resource Quality Services, DWAF. For the purposes of depicting biodiversity at the scale appropriate for conservation planning in the Olifants/Doorn Water Management Area, the resulting longitudinal zones were combined into four zones (Table 7). The lumped longitudinal zones were combined spatially with the Level 2 river types to derive 78 combinations, which can be considered Level 3 river types (Appendix 2, Figure 7). These were used as the final river types in the conservation portfolio.

Table 7: Longitudinal zones used in the Olifants/Doorn conservation portfolio
The corresponding longitudinal zones described by Rowntree and Wadeson (1999) are also provided. Note: Source zones as described by Rowntree and Wadeson (1999) were not identified in this area.

Lumped longitudinal zone	**Rowntree and Wadeson (1999) zones**
Mountain stream	Mountain headwater streams, mountain streams
Upper foothills	Transitional zones and upper foothills
Lower foothills	Lower foothills
Lowland river	Lowland river

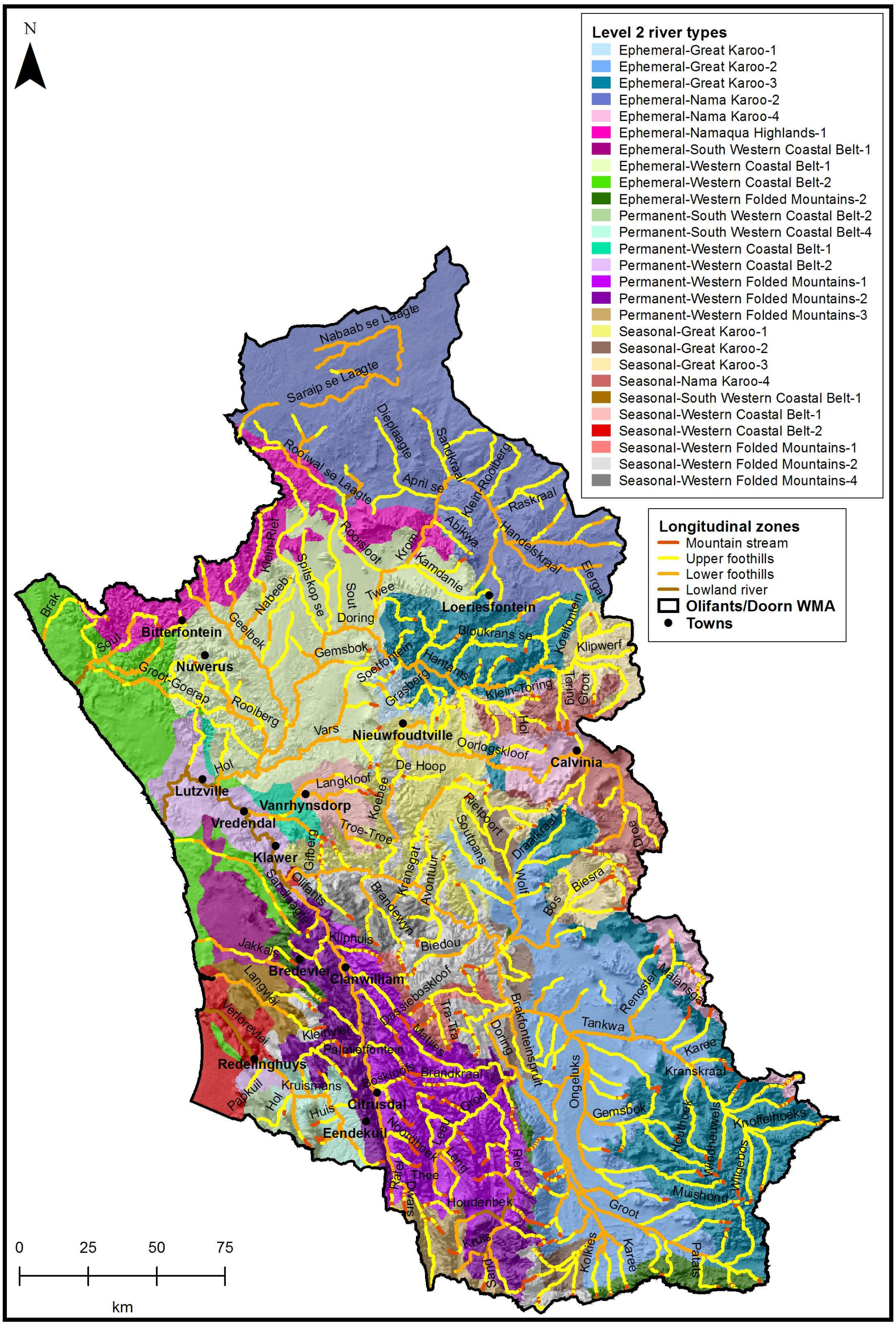

Figure 7: Level 2 and 3 river types for the Olifants/Doorn Water Management Area
Shaded areas represent the 27 unique Level 2 river types. The first part of the Level 2 river type describes the flow variability, the second part describes the Level 1 ecoregion, and the last part is a number describing the Level 2 ecoregion. The Level 2 river types were classified further at the level of individual streams using longitudinal zones, as depicted by the line colours.

5 PLANNING FOR REPRESENTATION: WETLANDS

Wetlands occur in areas where soils are saturated or inundated with water for varying lengths of time and at different frequencies. For this report, a wetland is defined as ***any inland water environment excluding rivers, and including areas of marine water, the depth of which at low tides does not exceed ten metres***. This is similar to the definition applied in the recent national wetland inventory project (Ewart-Smith 2006) which adapted the RAMSAR definition (Davis 1994) to South African conditions; with the exception that rivers are included in the Ewart-Smith (2006) definition.

Wetlands are ecologically, socially and economically valuable resources. They support a wide diversity of fish, amphibians, water birds and plants, and deliver important ecosystem services, such as water storage, reduced surface water flow and erosion control, reduced impact of flash floods, sustained stream flow, increased groundwater recharge, and water purification. This conservation assessment acknowledges the need for representing pristine or near-pristine examples of each wetland type, as well as the need to maintain all wetlands for the ecological functions and services they provide (see Section 10.1). In order to conserve wetlands, it is necessary to map localities of wetlands, and classify them into different wetland types. The section below provides an overview of the mapping and typing procedures followed in this conservation assessment.

5.1 Mapping potential wetlands

Although there are existing GIS layers of wetland boundaries for the Western Cape, these are by no means comprehensive, representing only a fraction of the actual wetlands that occur in the study area. To overcome this problem, existing GIS layers of known wetlands were combined with a GIS layer that delineates potential wetland boundaries. It is important to note that the resulting GIS layer of wetlands for the Olifants/Doorn Water Management Area is comprised mainly of *potential* wetlands and not actual wetlands. These delineations have yet to be confirmed using interpretation of aerial photography and field verification.

Four GIS layers, described below, were combined to map the wetland boundaries of the Olifants/Doorn Water Management Area (Figure 8):

(i) *Sensitive wetlands of the Western Cape Province*
This GIS layer is available from CapeNature (Shaw and de Villiers 2001), and contains boundaries of known and sampled sensitive wetlands.

(ii) *Perennial and non-perennial pans from 1:50 000 topocadastral maps*
These were sourced from the Surveyor General (from topocadastral maps) and combined with the sensitive wetlands GIS layer.

(iii) *Beta Version of the South African Wetlands Map*[4]

This comprises potential wetlands (which still need field verification). The GIS layer was derived as part of the National Land Cover 2000 project, using mapping and modelling techniques that enhanced wetland detection. These mapping techniques are described in detail in Thompson *et al.* (2002). Basically, spectral data that indicate "greenness" and "wetness" are derived from two satellite overpasses taken in different seasons. These are used, together with terrain-based hydrological modelling (including elevation, flow accumulation, sinks and topographic position), to generate an index of "landscape wetness potential", which predicts on a scale of one to five those areas in the landscape where water is most likely to accumulate (Ewart-Smith *et al.* 2006). Do all 1-5 in the beta version

(iv) *Polygons created by applying a GIS buffer to lowland rivers*

All longitudinal zones classified as "Lowland river" (Section 4.4.3) were buffered in GIS by 100 m on either side. These buffered areas were then combined with the above three GIS layers, retaining the maximum outer polygon edge as the delineation of the lowland floodplain, i.e. if a wetland derived from layers (i), (ii) or (iii) extended more than 100 m from the river, that boundary was applied.

5.2 Wetland typing

Numerous typing systems have been developed for wetlands in South Africa (e.g. Dini and Cowan 2000; Jones and Day 2003; Farinha *et al.* 2005; Kotze *et al.* 2005). These were recently reviewed by wetland specialists at a national workshop to produce a hierarchical typing system for South Africa (Ewart-Smith *et al.* 2006). This system is based primarily on hydrological and geomorphic criteria, which are considered to provide more robust and consistent outcomes than criteria based primarily on biotic measures (Finlayson *et al.* 2002). In terms of wetlands (as defined by this study, which excludes rivers), the hierarchy outlined in Ewart-Smith *et al.* (2006) proceeds from describing wetlands as Functional Units at a broad level of detail (Table 8), to describing Structural and Habitat Units at increasingly finer levels of detail. Each level in the hierarchy is based on one or more "discriminators" that distinguish one wetland type from another, such that:

- Primary discriminators based on drainage and landform (shape and/or setting) distinguish Functional Units;
- Secondary discriminators based on dominant cover type distinguish Structural Units; and
- Tertiary discriminators based on dominant life form characteristics and vegetation types distinguish Habitat Units.

This study used the primary discriminators in Ewart-Smith (2006) as a guide to describing wetlands as Functional Units. It further distinguished broad Structural Units, although this level of the hierarchy is incomplete and would need further describing as field information becomes available. The approach to typing wetlands into Functional Units and broad Structural Units is described below. It should be noted that this approach was based purely on existing desktop GIS data, and should be verified in the field.

[4] Available on the BGIS website: http://bgis.sanbi.org . Click the National Wetlands Inventory link on the BGIS homepage which will redirect you to the National Wetlands Inventory homepage.

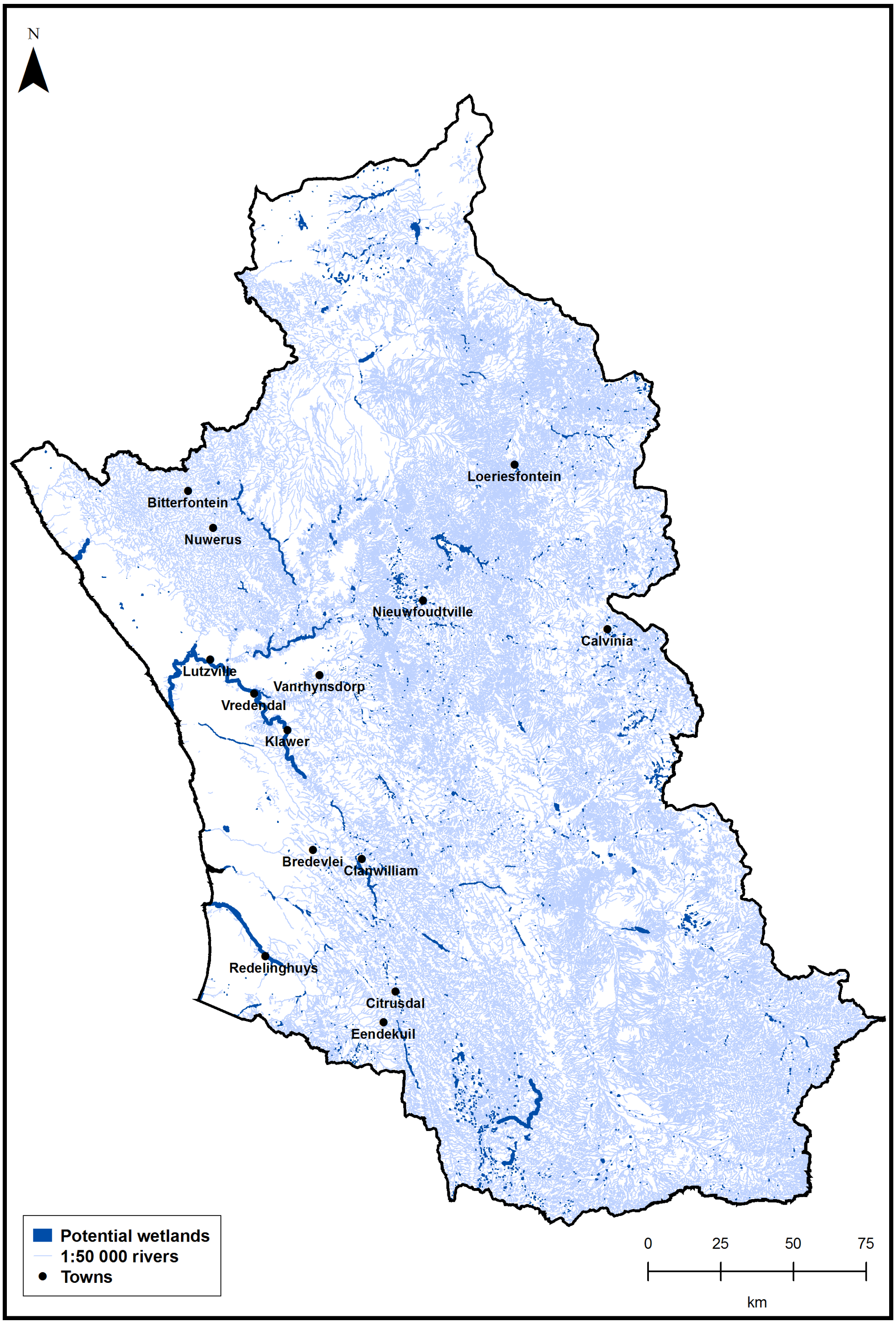

Figure 8: Wetland delineations in the Olifants/Doorn Water Management Area

Table 8: Proposed national system for typing wetlands according to Functional Units (after Ewart-Smith et al. 2006)

Drainage	Landform (shape and/or setting)
Channelled	Valley bottom
	Floodplain
	Depression linked to channel
	Seep linked to channel
Unchannelled	Depression not linked to a channel
	Seep not linked to a channel

5.2.1 Drainage

This primary discriminator distinguishes between wetlands that are channelled (i.e. connected to the river channel) and those that are unchannelled. The 1:50 000 rivers GIS layer, available from DWAF, was buffered in GIS by 100 m on either side. Any mapped wetland falling partially or completely within this buffer was considered channelled (i.e. linked to the river channel); whilst any wetland falling outside this buffered area was considered unchannelled. The majority of wetlands in the study area (90 %) are linked to a river channel (Table 9).

It should be noted that the spatial scale of these analyses may lead to over-estimating the number of unchannelled wetlands, since any wetland that is connected to surface drainage through a stream that is finer scale than 1:50 000 will be coded incorrectly as an unchannelled wetland.

Table 9: Drainage categories and proportion of wetlands within each category Criteria used to derive drainage categories are also provided

Drainage	Criteria used	% Area
Channelled	Falls completely or partially within a 100 m GIS buffer applied to 1:50 000 rivers	90
Unchannelled	Falls outside a 100 m GIS buffer applied to 1:50 000 rivers	10

5.2.2 Landform (shape and/or setting)

Five categories of landform were defined (Table 10). These were identified using the following three steps, in order of appearance:

(i) Code the perennial and non-perennial pans obtained from the 1:50 000 topocadastral maps (see Section 5.1) as "Perennial depression" or "Non-perennial depression".

(ii) Code the buffered lowland floodplain wetlands mapped in Section 5.1 as "Floodplain".

(iii) For the remaining wetlands, code "Valley bottom" and "Seep" wetlands using a combination of slope[5] and soil depth[6], as follows:
- "Seep" wetlands are those situated on steep slopes (>2.4°) with shallow soils (< 450 mm);
- "Valley bottom" wetlands are those situated on mid-slopes and foot-slopes (0-2.4°), with moderately-deep to deep soils (>450 mm).

Floodplain wetlands have the greatest area in this landform (44 %), followed by valley bottom wetlands and seeps (Table 10). Depressions comprise less than 10 % of the wetland area, with only one perennial depression in the area.

Table 10: Landform categories and proportion of wetlands within each category Criteria used to derive drainage categories are also provided

Landform	Criteria used	% Area
Floodplain	Wetlands intersecting a 100 m GIS buffer around lowland river reaches	44
Valley bottom	Wetlands occurring on slopes of 0-2.4° and soils < 450 m that are not "Depression" or Floodplain"	24
Depression (perennial)	Perennial pans from the 1:50 000 Surveyor General topocadastral maps	< 1
Depression (non-perennial)	Non-perennial pans from the 1:50 000 Surveyor General topocadastral maps	7
Seep	Wetlands occurring on slopes of > 2.4° and soils > 450 mm that are not "Depression" or Floodplain"	24

[5] generated from the United States 90 m digital elevation data; available from the website: http://www.personal.psu.edu/users/j/z/jzs169/Project3.htm

[6] generated from the General Soils Pattern Map of South Africa as part of the National Land Type Survey, which provides soil and terrain information at a 1:250 000 scale. Available from the Agricultural Research Council, Agricultural Geo-referenced-Information System (AGIS) website: www.agis.agric.za.

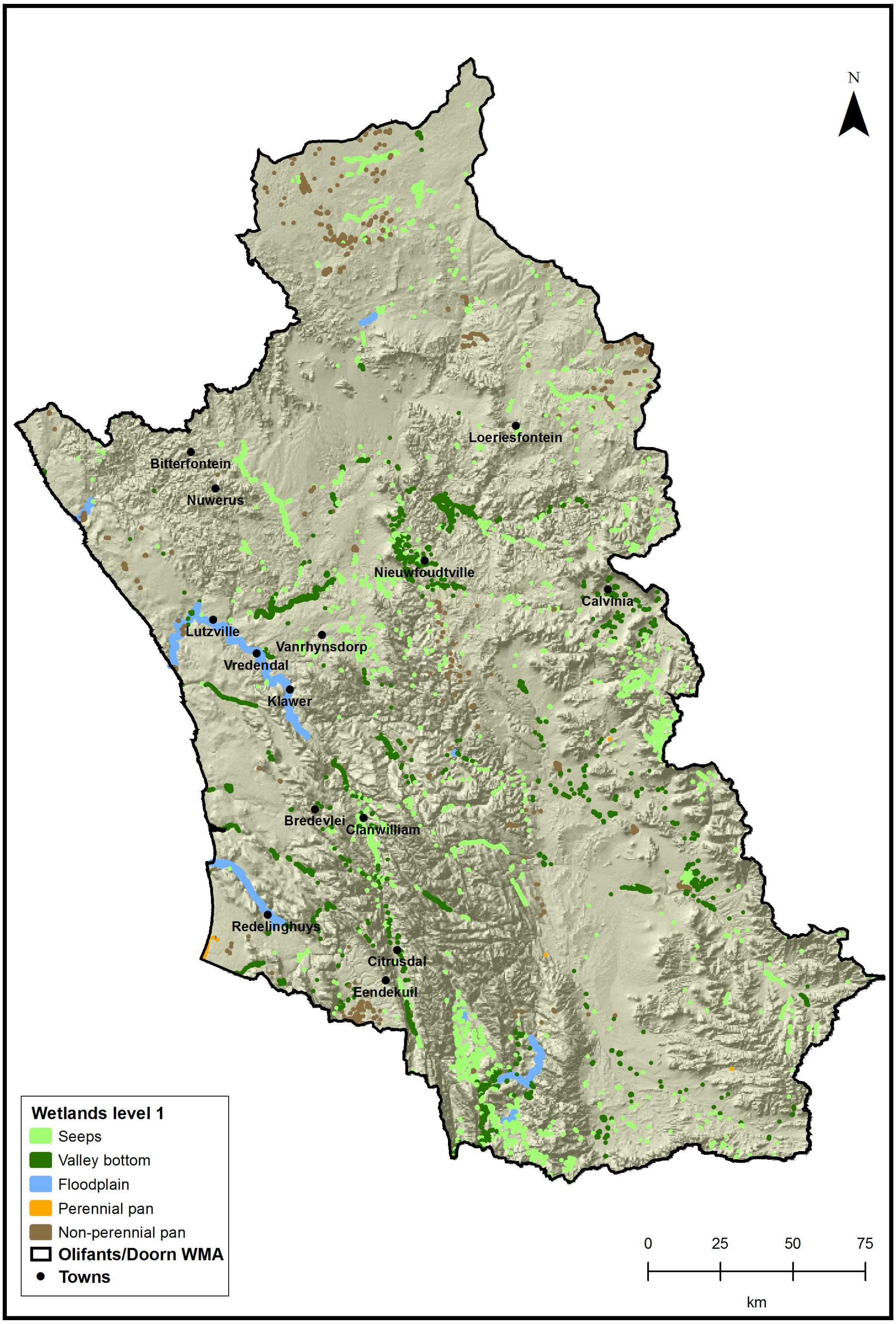

Figure 9: Wetlands and their associated landform (shape and/or setting)
Boundaries of the wetlands have been accentuated to facilitate viewing.

5.2.3 Vegetation group

Vegetation groups from the 1:250 000 vegetation map the South Africa, Lesotho and Swaziland (Mucina and Rutherford 2004) were used to further characterise wetlands on the premise that wetlands in a particular vegetation group will be more similar to one another than to wetlands in other vegetation groups. Broad vegetation groupings reflect differences in geology, soils and climate, and were considered a better surrogate for typing wetlands than Level 2 ecoregions Kleynhans *et al.* 2005) developed specifically for river channels. There are nine vegetation groups in the Olifants/Doorn Water Management Area (Table 11).

Table 11: Vegetation groups in the Olifants/Doorn Water Management Area (after Mucina and Rutherford 2004)

Vegetation group	**% Area**
Alluvial	39
Dune Strandveld	1
Fynbos	14
Nama Karoo	1
Renosterveld	4
Salt Marsh	1
Salt Pans	1
Sand and Dune Fynbos	15
Succulent Karoo	24

5.2.4 Final wetland types

Combining the descriptions of drainage, landform and vegetation group for each wetland produced 45 different wetland types (Appendix 3), which were used as the final wetland types in the conservation assessment. In terms of total wetland area, the Channelled Alluvial floodplain wetlands are the most extensive, comprising 25 % of the wetland area in the Olifants/Doorn Water Management Area (Appendix 3). Channelled Succulent Karoo seeps are also relatively extensive, forming more than 10 % of the total wetland area. Seeps are characteristically less extensive in terms of area, but occur in high numbers.

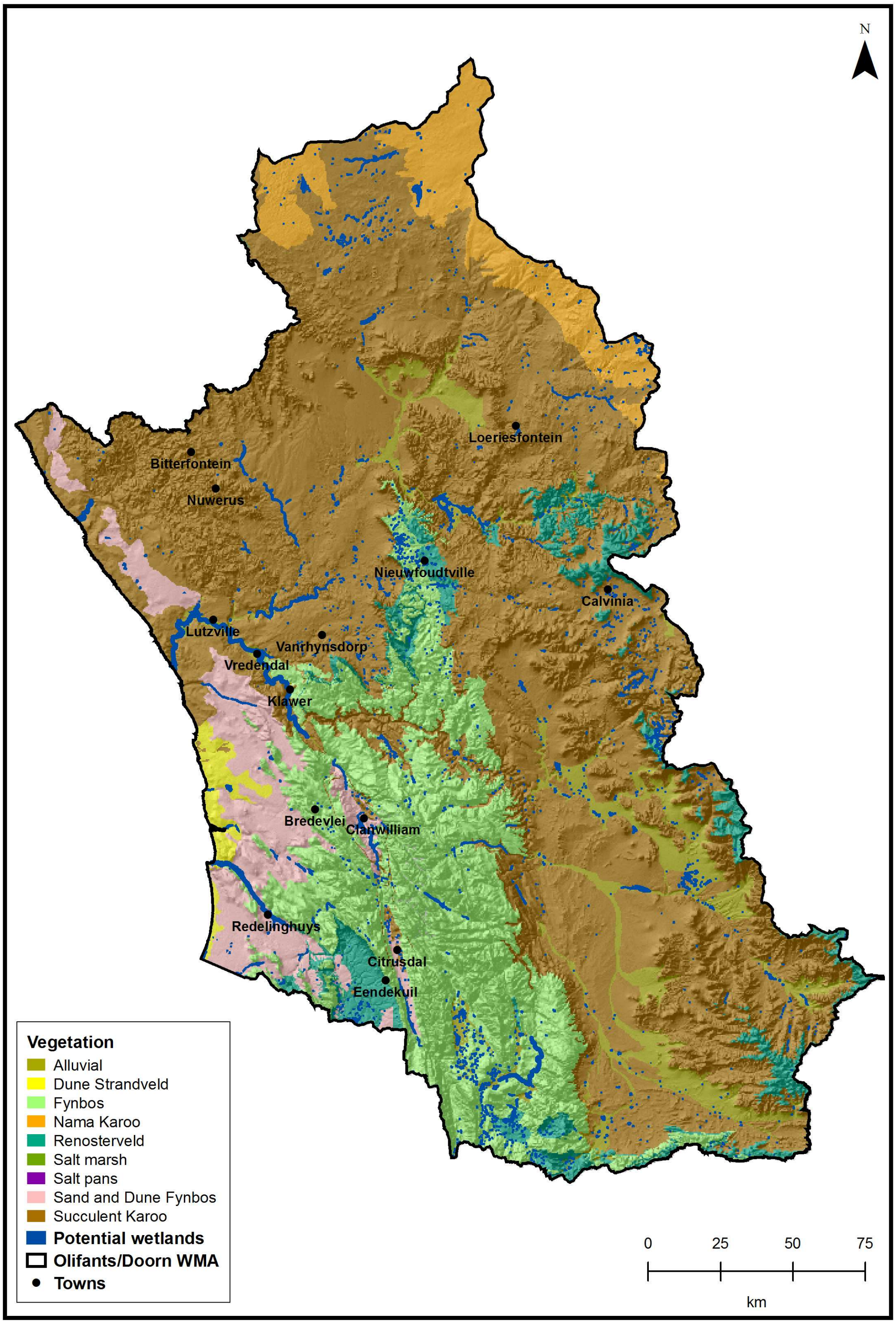

Figure 10: Wetlands and their associated vegetation group
Boundaries of the wetlands have been accentuated to facilitate viewing.

6 PLANNING FOR REPRESENTATION: FISH

The Olifants/Doorn Water Management Area is undoubtedly one of the most important in the country in terms of its freshwater fish fauna, containing the highest number of endemic freshwater fishes, which are all threatened by invasive alien fish species, unsustainable water abstraction and habitat degradation. There are nine endemic fish species (Table 12), of which at least one (Fiery redfin, *Pseudobarbus phlegethon*) may be split into several species. An additional three indigenous fish species also occur in the water management area, of which at least one (Cape galaxias, *Galaxias zebratus*) may well be split into five species.

Table 12: Freshwater fishes of the Olifants/Doorn Water Management Area
The IUCN conservation status reflects the 2006 updates.

Common name	Scientific name	Endemic/ Indigenous	IUCN Conservation status
Verlorevlei redfin	*Pseudobarbus burgi*	endemic	Endangered
Fiery redfin	*Pseudobarbus phlegethon*	endemic	Critically endangered
Clanwilliam redfin	*Barbus calidus*	endemic	Vulnerable
Twee River redfin	*Barbus erubescens*	endemic	Critically endangered
Clanwilliam sawfin	*Barbus serra*	endemic	Endangered
Clanwilliam yellowfish	*Labeobarbus capensis*	endemic	Vulnerable
Clanwilliam sandfish	*Labeo seeberi*	endemic	Endangered
Spotted rock catfish	*Austroglanis barnardi*	endemic	Endangered
Clanwilliam rock catfish	*Austroglanis gilli*	endemic	Vulnerable
Chubbyhead barb	*Barbus anoplus*	indigenous	Data deficient
Cape galaxias	*Galaxias zebratus*	indigenous	Data deficient
Cape kurper	*Sandelia capensis*	indigenous	Data deficient

Several existing initiatives have recognised the importance of the freshwater fishes in this area. The CAPE programme has a dedicated alien fish control project underway, focussing on the Rondegat, Krom and Suurvlei rivers. CapeNature has also identified several rivers for freshwater fish conservation, including the Biedou, Boskloof, Breekkrans, Matjies/Driehoeks, Doring, Groot, Jan Dissels, Noordhoek, Olifants River gorge, Koebee/Oorlogskloof, Ratel, Rondegat, Thee and Twee rivers. These rivers contain moderate to high numbers of indigenous fish, as well as good habitat, flow and water quality. Many of these rivers have also been selected as fish sanctuaries in this conservation assessment (Table 13).

To conserve this biodiversity of global and national importance, fish sanctuaries urgently need to be established and managed. Quantitative conservation targets were set for each fish species (Section 3.2) and used to guide the delineation of fish sanctuaries in the Olifants/Doorn conservation assessment. Using expert knowledge of the area, river reaches containing viable[7]

[7] "Viable" was defined broadly to mean a self-maintaining, recruiting population of fish.

populations of each species were identified. In the few instances where options existed for placement of sanctuaries (i.e. where several viable populations could be chosen to satisfy conservation targets), factors such as existing conservation initiatives, land use and complementarity were taken into account.

Sections 6.1-6.12 provide a more detailed account of the fish sanctuaries delineated for each of the 12 freshwater fish species. These were combined to provide a summary map of the fish sanctuaries required to achieve conservation targets for the freshwater fish of the Olifants/Doorn Water Management Area (Figure 11). A total of 34 sub-quaternary catchments were selected as fish sanctuary areas, representing 680 km of river and approximately 4 050 km^2 of land. These catchments should be managed to maintain at least a B-category river ecological integrity. An additional 15 sub-quaternary catchments were selected for maintaining longitudinal connectivity between tributaries and the mainstems of the Olifants and Doring rivers. Some of these "connecting" rivers may be able to withstand moderate impacts, but should be managed in at least a C-category ecological integrity. For some species, maintaining this longitudinal connectivity is important for allowing re-colonization events and genetic exchange between tributaries, and providing sufficient habitat for recruitment and spawning. However, maintaining longitudinal connectivity is not always desirable between tributary and mainstem populations where this will facilitate invasion or re-invasion by alien species; this was taken into account in designating connecting rivers.

Table 13: Rivers selected as fish sanctuaries in the Olifants/Doorn conservation portfolio Catchments selected for maintaining longitudinal connectivity between the tributaries and the mainstems of the Olifants and Doring rivers are not included. Note: Some rivers are split into more than one sub-quaternary catchment, which is why there are not 34 rivers listed.

Single species sanctuary	**Sanctuary for two species**	**Sanctuary for three species**
Lower Koebee	Middle Koebee-Oorlogskloof	Rondegat
Doring	Krom	Biedou
Heks	Twee	Matjies
Thee	Noordhoeks	Verlorevlei
Ratel	Olifants gorge	
Dwars		
Langvlei		

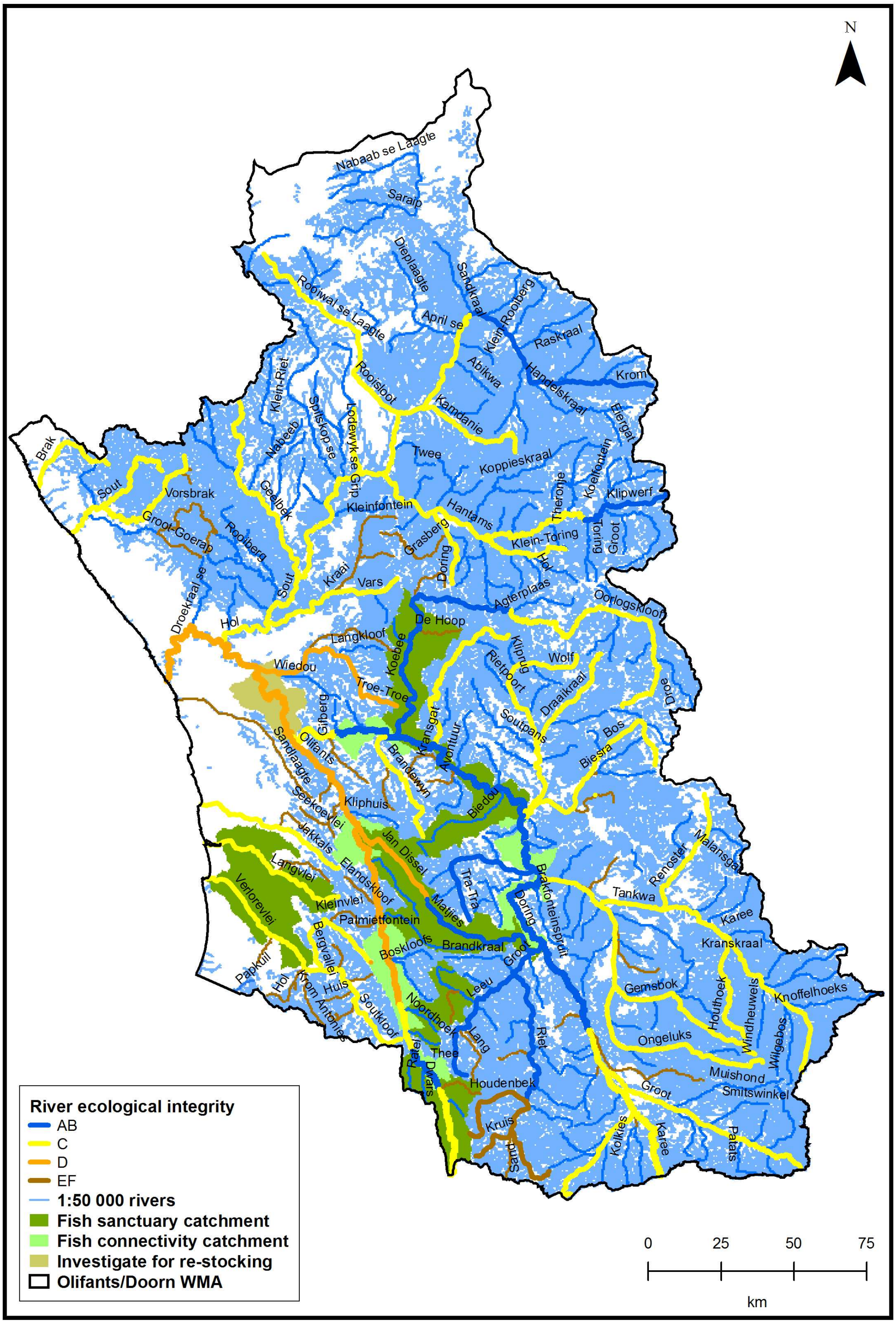

Figure 11: Fish sanctuaries required to achieve conservation targets for freshwater fishes Separate maps for each species are provided in Sections 6.1-6.12.

6.1 Verlorevlei redfin

Scientific name:	*Pseudobarbus burgi*
Family:	Cyprinidae
Conservation status:	Endangered
Ecological significance:	Endemic to the Olifants/Doorn and Berg WMAs
Social significance:	Scientific and conservation value

Taxonomy
Studies suggest a genetic separation between the Verlorevlei and Berg River populations of Berg River redfin. Thus, for the purposes of this conservation assessment, the Olifants/Doorn population was treated as an endemic species.

Habitat requirements
This redfin is found in a wide range of habitats from clear mountain streams to deep, still, vegetated pools of lowland rivers. It is quite a tolerant Karoo-type species, both in terms of water quality and flow, but becomes sensitive to flow in spring for spawning and migration. It feeds mainly from the bottom on invertebrates, algae and detritus.

Main pressures
This species is associated with agricultural areas and is therefore very vulnerable to land use pressures. It is severely threatened by habitat loss and degradation, and predation by alien fish.

Recommended sanctuaries based on conservation targets
Two populations have been selected in the G-primary catchment (Sandveld catchment): one on the Verlorevlei River and one on the Langvlei River. The Sandveld area is an important biodiversity hotspot for both terrestrial and aquatic ecosystems, and Verlorevlei is a declared RAMSAR site.

Management actions
These Sandveld systems are under immense agricultural pressure and ecological integrity places both selected sanctuary rivers in a C-category. It is vitally important that the current rate of degradation in the area be halted and even reversed. This is recognised by many conservation initiatives in the area, such as the Department of Agriculture’s LandCare programme, CapeNature’s Greater Cederberg Biodiversity Corridor initiative, and CAPE’s fine-scale conservation planning initiative.

Removal of alien plants from the Verlorevlei River is likely to improve the ecological integrity of this system to a low B-category. To prevent additional degradation of this system, no further abstraction of surface or ground-water should be permitted, as it is critical to maintain refuge pools in summer low-flow periods, both in terms of a reasonable quality and depth. It is not possible to rehabilitate the Langveli system to even a low B-category. This species could possibly tolerate a C-category, but to prevent additional degradation of this system, no further abstraction of surface or ground-water should be permitted.

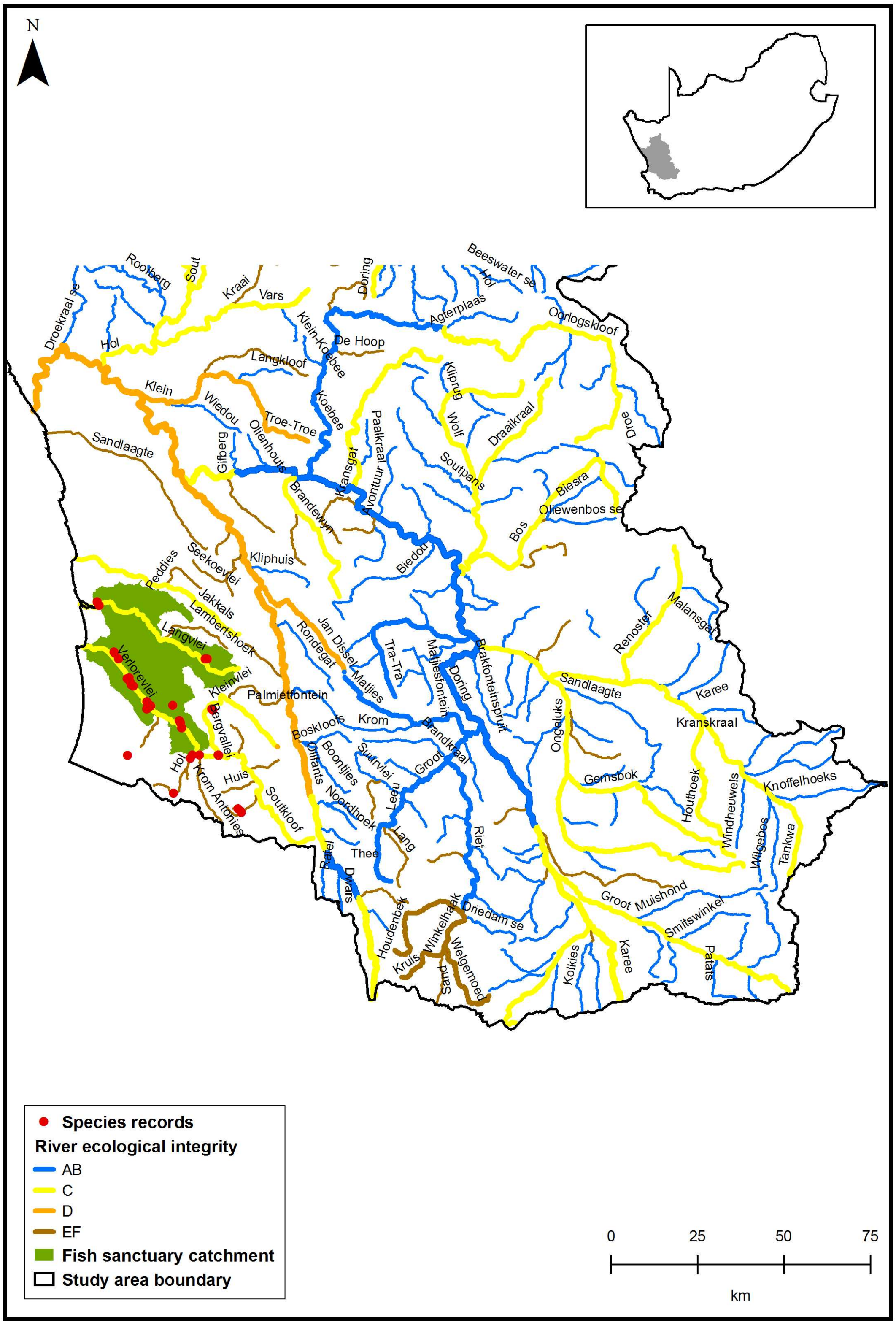

Figure 12: Sanctuary areas for the Verlorevlei redfin

6.2 Fiery redfin

Scientific name:	*Pseudobarbus phlegethon*
Family:	Cyprinidae
Conservation status:	Endangered
Ecological significance:	Endemic to the Olifants/Doorn and Berg WMAs Studies suggest separation into several species
Social significance:	Scientific and conservation value

Taxonomy
Latest genetic evidence suggests that the populations on the Olifants and Doring rivers are distinct species, or Evolutionarily Significant Units (*sensu* Moritz 1994). For the purposes of the conservation assessment, the populations were therefore treated as distinct species: the Olifants fiery redfin and the Doring fiery redfin.

Habitat requirements
The Fiery redfin is a habitat generalist, being equally abundant in slow-deep and shallow-fast habitats. It is predominantly a benthic omnivore, indicating robustness to low flows. Adults breed between October and December, and to facilitate spawning it is essential that environmental flow recommendations be implemented in targeted systems.

Main pressures
The Fiery redfin is extremely vulnerable to predation by alien bass. It is also associated with lower reaches of rivers, which are frequently heavily impacted by agriculture. Hence, habitat destruction is also a key threat to the Fiery redfin. This species is in danger of extinction, and it is also recommended that a population be re-established in the Krom River. There is also a need to assess the Breekkrans River population as a possible target, since the Driehoek River population is very vulnerable due to presence of alien fish.

Recommended sanctuaries based on conservation targets
The Rondegat and Thee rivers were chosen as sanctuary rivers for the Olifants fiery redfin; the Matjies/Driehoek system was chosen for the Doring fiery redfin, along with a recommendation to re-establish the population in the Krom River. The entire length the Thee River is free of alien fish, as well as the upper reaches of all the other selected sanctuary rivers. Retaining connectivity with the Olifants and Doring rivers is not necessary within the recommended sanctuary system, as the Fiery redfin cannot escape predation by the alien bass in these systems.

Management actions
The fiery redfin is very sensitive to modifications in water quality and quantity. General management actions include no building of instream dams, no summer abstraction, no stocking of off-stream dams with alien fish, and enforcement of the 35 m riparian buffer, including no access by livestock. Enforcement of the 35 m riparian buffer is a particular issue within the Thee catchment, as well as allowing summer flow through preventing abstraction of water in summer. The Rondegat and Krom rivers are the focus of a CAPE alien fish control project, which includes a re-establishment programme on the Krom River. The key management intervention on the Matjies River is to remove alien fish from off-stream dams. On the Krom River management should address the problems created by livestock, where run-off from paddocks results in eutrophication, creating a serious water quality problem immediately downstream of the farm.

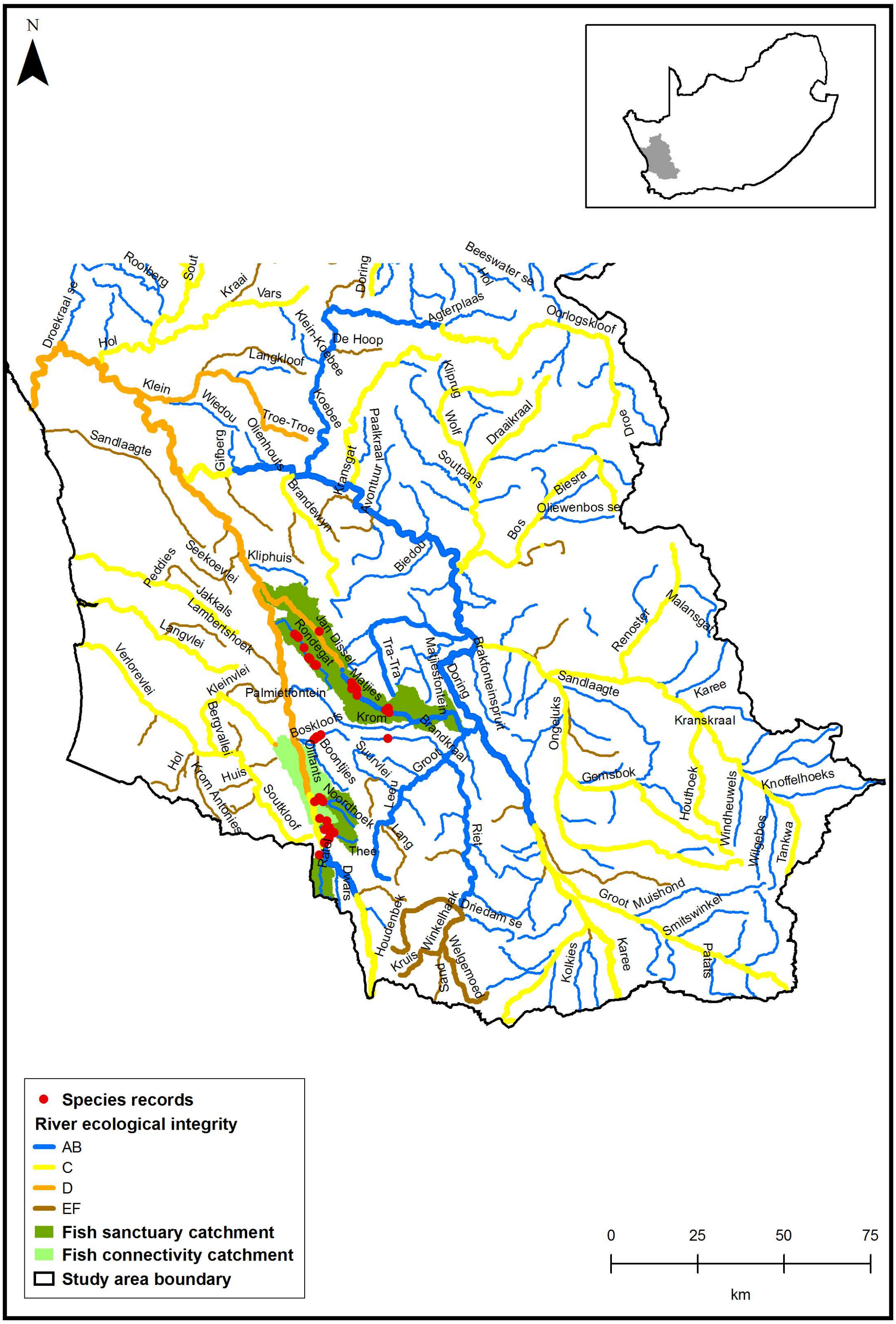

Figure 13: Sanctuary areas for the Fiery redfin

6.3 Clanwilliam redfin

Scientific name:	*Barbus calidus*
Family:	Cyprinidae
Conservation status:	Endangered
Ecological significance:	Endemic to Olifants/Doorn WMA
Social significance:	Scientific and conservation value

Habitat requirements

This species exhibits a strong preference for slow-deep habitat, with the vast majority being recorded in large pools. Its feeding ecology suggests feeding on drift in October, just prior to the commencement of spawning, possibly to aid gonadal maturation. This species is therefore very sensitive to modifications in flow, and requires a near-natural flow to be maintained in all habitats (including riffles) throughout the river, so that natural invertebrate drift is not affected. By ensuring connectivity of the river all year round, natural invertebrate drift will not become a limiting factor to this fish's survival. To facilitate spawning, it is suggested that sufficient base-flows be maintained from October through to December to indirectly aid the breeding success of these fish.

Main pressures

This species is very sensitive to over-abstraction and damage to the riparian zone. It is also highly vulnerable to predation by introduced alien bass, which has lead to population reductions and extirpations.

Recommended sanctuaries based on conservation targets

The Rondegat River on the Olifants system; and the upper Biedou River on the Doring system were selected as sanctuary rivers for this species. The lower reaches of the Biedou River are strongly seasonal with no known refuge pools, thus only the uppermost reaches of this river would serve as sanctuary. Retaining connectivity with the Olifants and Doring rivers is not necessary within the recommended sanctuary system, as this species cannot escape predation by the alien bass in these systems.

Management actions

This species is highly sensitive to changes in flow and water quality. Therefore, both the ecological integrity of the Rondegat and Biedou rivers must be maintained in at least a B-category. Maintaining the present ecological state in these river systems will require that no further weirs or instream dams are built. Existing abstractions should be more focussed towards winter (May to September on Olifants; June to September on Doring).

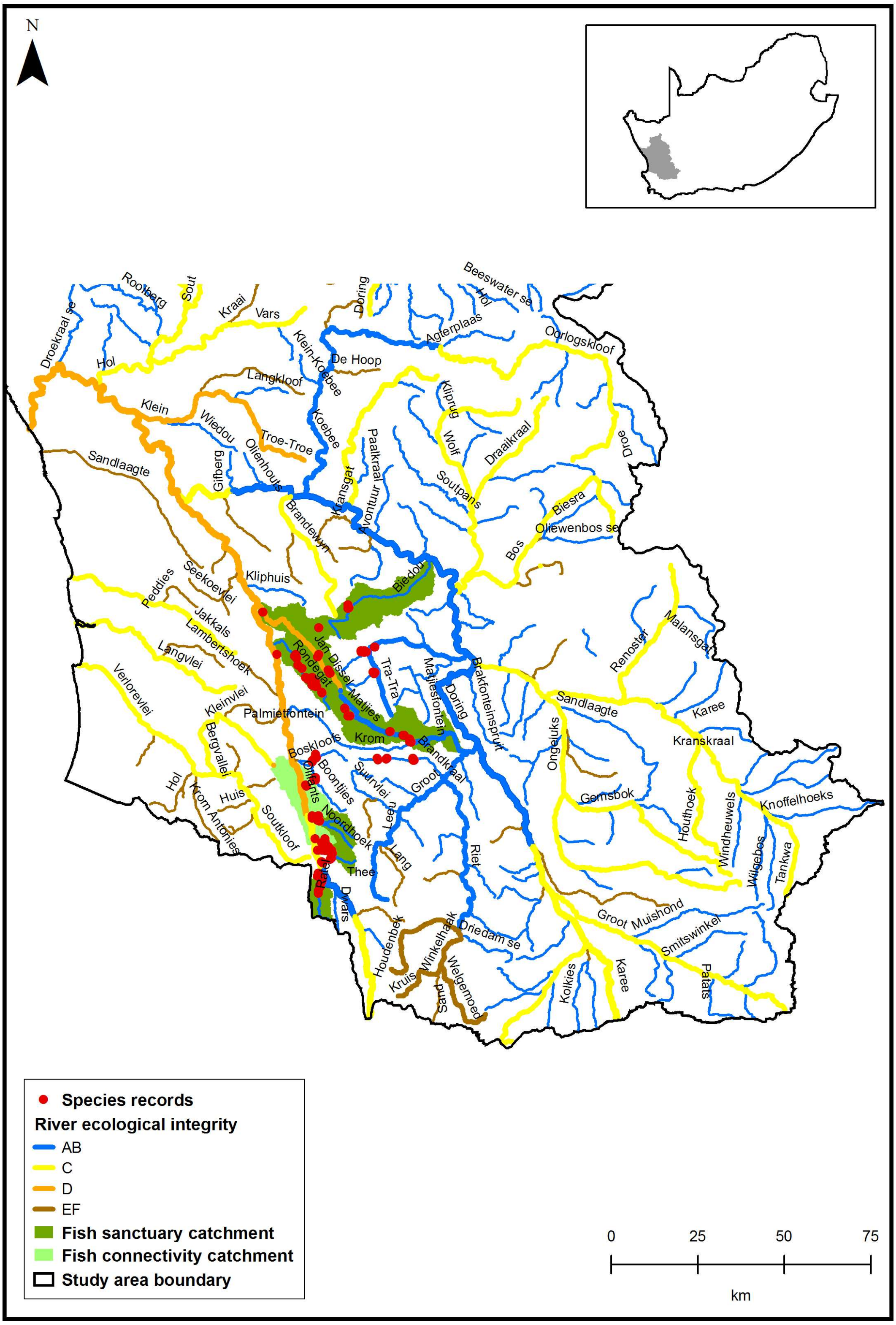

Figure 14: Sanctuary areas for the Clanwilliam redfin

6.4 Twee River redfin

Scientific name:	*Barbus erubescens*
Family:	Cyprinidae
Conservation status:	Critically endangered
Ecological significance:	Endemic to Twee River tributary of the Doring River
Social significance:	Scientific and conservation value

Habitat requirements

Natural downstream waterfalls form barriers and have given rise to the evolution of this highly localised endemic. It is found in pools and deeper flowing stretches of the Twee River system, and forms schools containing similar-sized individuals. The juveniles are often found in mixed schools with Cape galaxias (*Galaxias zebratus*). This species feeds on aquatic and other insects from surface- and mid-waters. It breeds during summer, requiring flowing water in the summer low flow months.

Main pressures

The Twee River redfin is threatened by over-abstraction of water and agricultural pollution. Predation by two species of introduced fish has also depleted populations - the Cape kurper (*Sandelia capensis*), an invasive alien fish species that was introduced above the waterfall barrier for mosquito control; and the Clanwilliam yellowfish (*Labeobarbus capensis*), indigenous in the Olifants/Doorn WMA, was mistakenly introduced here as an early conservation initiative.

Recommended sanctuaries based on conservation targets

This species is naturally confined to the Twee River, a tributary of the Doring River, owing to a waterfall that serves as a natural downstream barrier to migration of this species. The Twee River systems is therefore the only selected sanctuary area for this species, and retaining connectivity with the Doring River is irrelevant.

Management actions

The Twee River system must be maintained in at least a B ecological integrity category, and rehabilitated where necessary. The Heks River, a tributary of the Twee River, is the only tributary free of introduced fish. It therefore represents a pristine population of Twee River redfin and should not be dammed. The Seevlei River tributary of the Twee system is a proposed site for a CAPE alien fish control project, focussing on eradicating the Cape kurper (*S. capensis*). The Twee River is under pressure from commercial agriculture. Enforcement of the 35 m riparian buffer zone is essential here as several citrus and pear orchards have already been established right up to the river banks - crop spraying is therefore likely to lead to considerable agricultural pollution. Alien plant invaders should be removed from the riparian zones. It is also recommended that this species be investigated for re-stocking into off-stream dams. The success of stocking this species in off-stream dams depends on its breeding ecology: if it requires flowing water for spawning and egg incubation, this measure will not be successful.

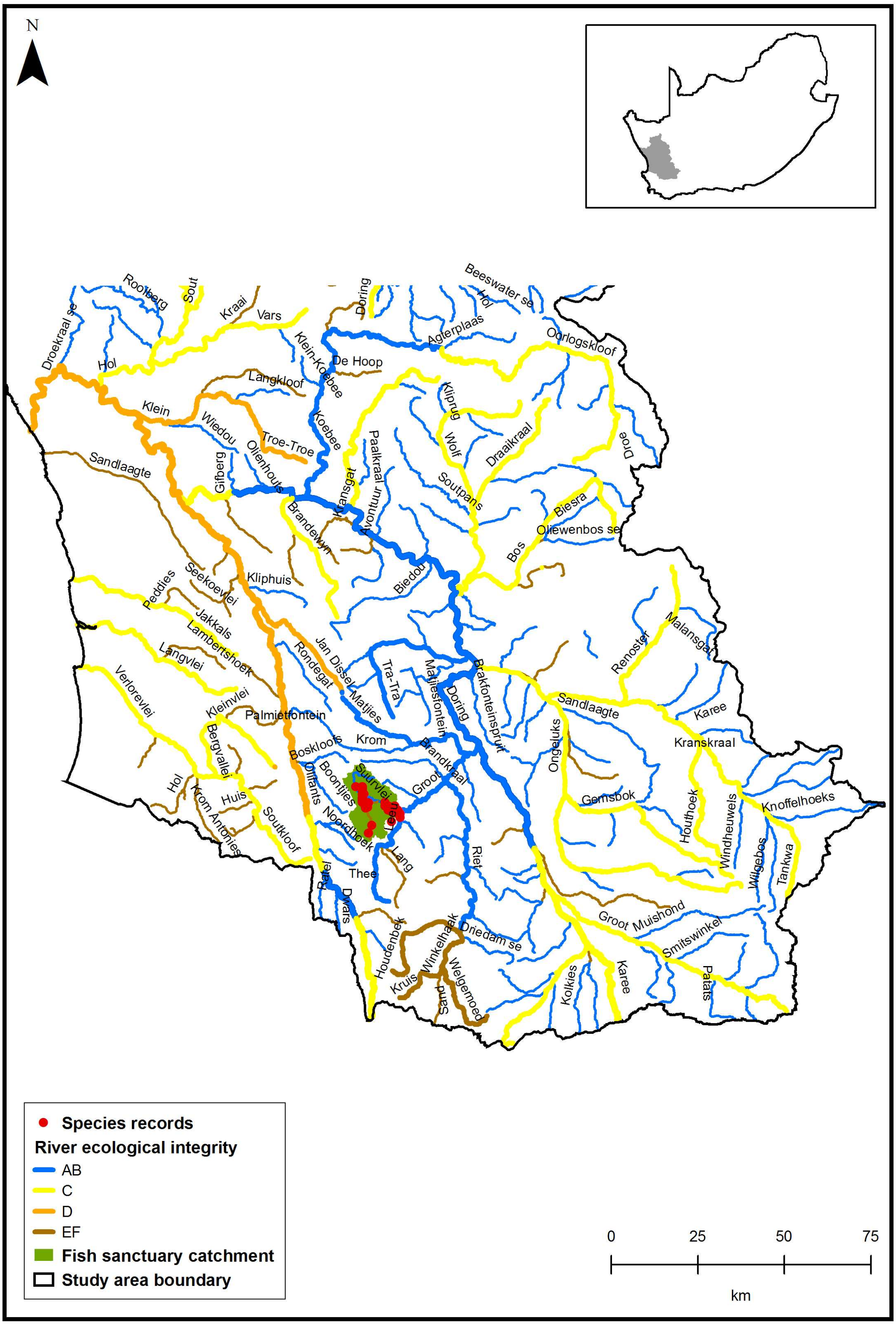

Figure 15: Sanctuary areas for the Twee River redfin

6.5 Clanwilliam sawfin

Scientific name:	*Barbus serra*
Family:	Cyprinidae
Conservation status:	Endangered
Ecological significance:	Endemic to the Olifants/Doorn WMA
Social significance:	Gamefish; Scientific and conservation value

Habitat requirements
This is a migratory fish. Conserving mainstem and tributary habitat is important for this species, since mainstem fish tend to be larger, more numerous and more fecund, whereas tributary populations provide refuge from predation by invasive alien fish. The species breeds in summer, between October and December, spawning in fast-shallow riffle and rapid habitat types with large clean cobbles. Larvae are carried out of this high-flow riffle habitat and into low-flow backwaters and slack-waters where they develop into juvenile fish. During this period they are vulnerable to predation, and select very shallow marginal areas (<0.15 m depth) in velocities $<0.01\ m.s^{-1}$.

Main pressures
Extension and intensification of the summer low flow period (October to April) in the Doring River is threatening this species, as low flow limits available spawning habitat and favours proliferation of alien fish. These conditions are due primarily to heavy surface and groundwater abstraction in the Kouebokkeveld region, as well as climate change. Instream dams also prevent migration of this species, serve as refuges for alien fish and degrade both upstream and downstream habitat.

Recommended sanctuaries based on conservation targets
Two headwater tributaries of the Olifants River, and the Olifants River gorge provide the variety of habitat required by this species on the Olifants system. A further 18 km of the Olifants River has been selected as connecting this sanctuary population to the Ratel River population. The Matjies River is the recommended sanctuary on the Doring system, including 163 km of the Doring River between the Groot and Gif river confluences.

Management actions
This species is sensitive to flow, particularly in spring for spawning, and in autumn as individuals begin migrating. They rely heavily on refuge pools in the summer low-flow period, particularly in the naturally seasonal Doring River. Management of groundwater to sustain summer flow is therefore essential on both the Olifants and Doring river systems. Although the ecological integrity of the Olifants River gorge is in a B-category, the river immediately upstream of the gorge, around the Agterwitzenberg plateau is in a C-category. To ensure that this area does not further degrade the integrity of the gorge, it should be managed as a conservancy, focussing management actions on optimal use of existing abstractions, preventing further abstractions, removal of alien plants in the riparian zone, and enforcement of the 35 m riparian zone (which should include no access by livestock). It is crucial that alien fish are eliminated from dams in the Agterwitzenberg region and the Ratel River, and to prohibited re-stocking with alien fish. With appropriate management, the integrity of the river in this area could be improved to a low B-category. Management activities for the Matjies River sanctuary should focus on controlling alien fish invasion through education and awareness, as well as spear-fishing and netting, enforcing the 35 m riparian zone buffer, removing alien plants from the riparian zone, and using existing abstractions optimally whilst preventing further building of in-stream dams and abstractions.

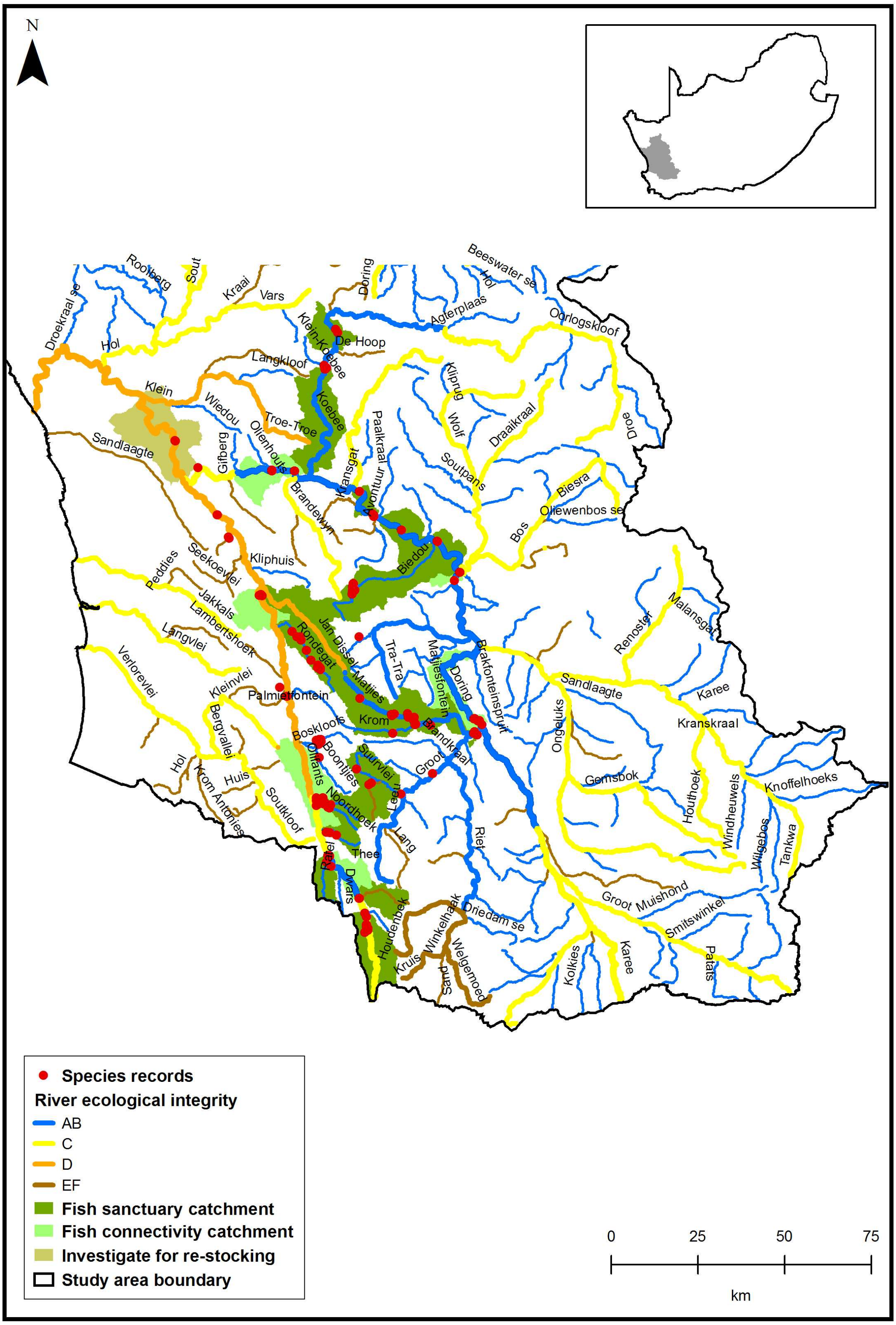

Figure 16: Sanctuary areas for the Clanwilliam sawfin

6.6 Clanwilliam yellowfish

Scientific name:	*Labeobarbus capensis*
Family:	Cyprinidae
Conservation status:	Vulnerable
Ecological significance:	Endemic to the Olifants/Doorn WMA
Social significance:	Gamefish; Scientific and conservation value

Habitat requirements
This is a migratory fish. Conserving both mainstem and tributary habitats is important since mainstem fish tend to be larger, more numerous and more fecund, whereas tributary populations provide refuge from predation by invasive alien fish. This species breeds in summer, between October and December, migrating upstream to spawn in shallow-fast riffles over clean gravel and cobble beds.

Main pressures
Extension and intensification of the summer low flow period (October to April) in the Doring River is threatening this species, as low flow limits available spawning habitat and favours proliferation of alien fish. These conditions are due primarily to heavy surface and groundwater abstraction in the Kouebokkeveld region, as well as climate change. Instream dams also prevent migration of this species, serve as refuges for alien fish and degrade both upstream and downstream habitat.

Recommended sanctuaries based on conservation targets
The sanctuary rivers include the two headwater tributaries of the Olifants River, the Olifants River gorge, and the Dwars and Ratel tributaries of the Olifants River further downstream. The Biedou River has been selected as the recommended sanctuary on the Doring system, including the 163 km of the Doring River between the Groot to Gif confluences, for linkage and exchange.

Management actions
This species is very sensitive to flow, particulary over the migration and breeding season between October and December and relies on refuge pools in the summer low-flow period, particularly on the naturally seasonal Doring River. Management of groundwater to sustain summer flow is therefore essential on both the Olifants and Doring river systems.

Although the ecological integrity of the Olifants River gorge is in an acceptable B-category, the river immediately upstream of the gorge, around the Agterwitzenberg plateau, is in a C-category. To prevent downstream degradation of the gorge, the Agterwitzenberg plateau should be managed as a conservancy. Management actions within this conservancy should focus on optimal use of existing abstractions, allowing no further abstractions, removal of alien plants in the riparian zone, and enforcement of the 35 m riparian zone (which should include no access by livestock). It is crucial that bass be eliminated from dams in the Agterwitzenberg region and the Ratel River, and that re-stocking with bass or trout are prohibited. With appropriate management the ecological integrity of the river in this area could be improved to a low B-category. Management activities for the Biedou River sanctuary should focus on enforcing the 35 m riparian zone buffer (particularly targeting livestock, such as read goats, which are causing major erosion and water quality degradation), removing alien plants from the riparian zone, using existing abstractions optimally whilst allowing no further building of in-stream dams and abstractions, and prevention of any further alien fish invasion through education and awareness.

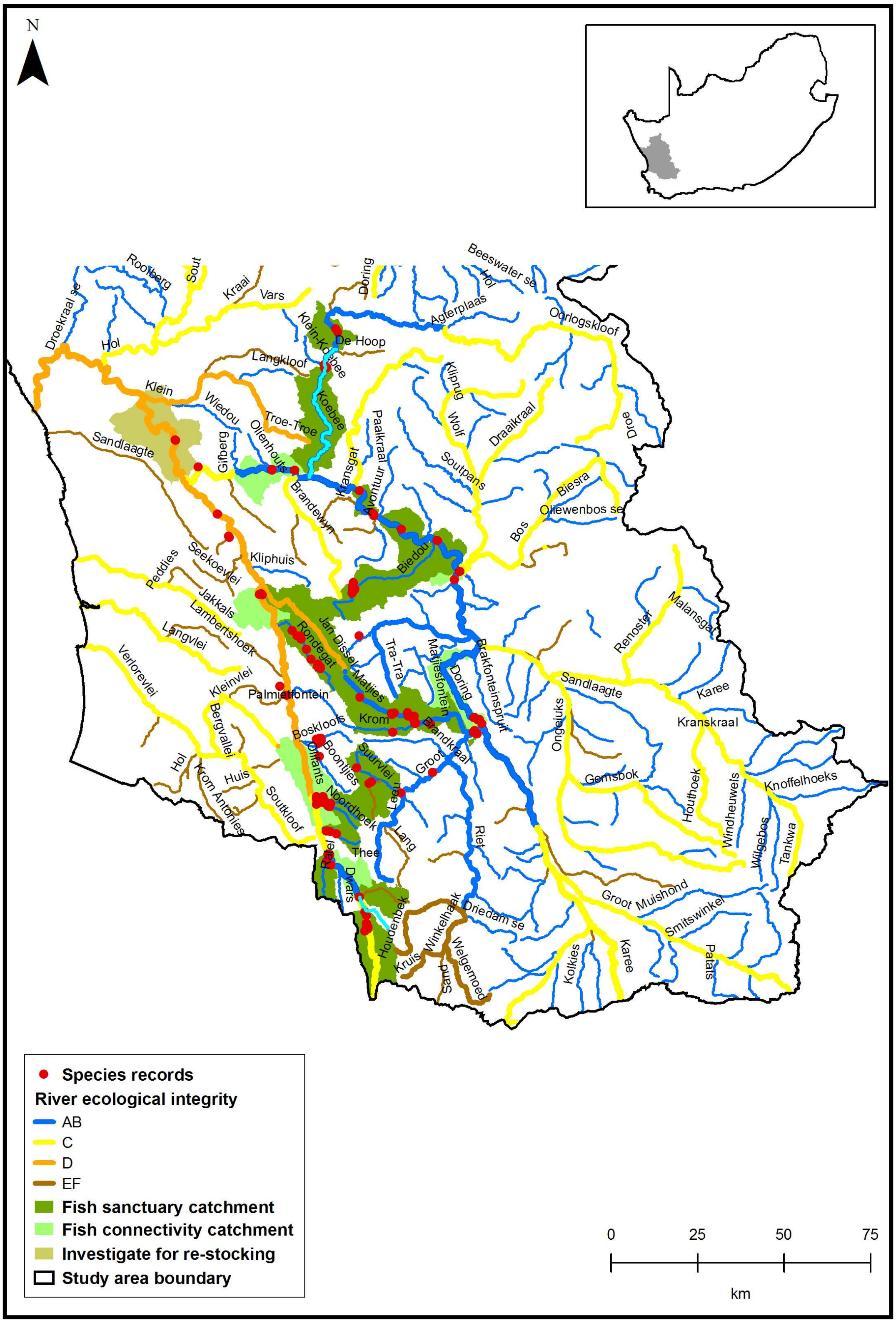

Figure 17: Sanctuary areas for the Clanwilliam yellowfish

6.7 Clanwilliam sandfish

Scientific name:	*Labeo seeberi*
Family:	Cyprinidae
Conservation status:	Critically endangered
Ecological significance:	Endemic to the Olifants/Doorn WMA Benthivore, may limit build-up of algae
Social significance:	Gamefish; Scientific and conservation value

Habitat requirements

This is a migratory fish. Conserving both mainstem and tributary habitats is important since mainstem fish tend to be larger, more numerous and more fecund, whereas tributary populations provide refuge from predation by invasive alien fish. The species was once widespread through the Olifants and Doring Rivers, but now only occurs in the Doring River. High density in the middle reaches of the Doring River and the Oorlogskloof-Koebee Rivers system suggest that this species favours the wide slow-flowing pools with fine mud and sand substrata which occur here. Adults migrate upstream in masses to spawn during October and November. High flows improve spawning, and further release predation pressure by flushing the alien bass.

Main pressures

Extension and intensification of the summer low flow period (October to April) in the Doring River is threatening this species, as low flow limits available spawning habitat and favours proliferation of alien fish. These conditions are due primarily to heavy surface and groundwater abstraction in the Kouebokkeveld region, as well as climate change. Instream dams also prevent migration of this species, serve as refuges for alien fish and degrade both upstream and downstream habitat.

Recommended sanctuaries based on conservation targets

This species is highly threatened and has been extirpated on the Olifants River system, due to impacts of the Bulshoek and Clanwilliam Dam. The sanctuary area selected for this species includes the Koebee and Biedou rivers on the Doring system, which contains the recruiting sandfish populations within the Oorlogskloof Nature Reserve, as well as 25 km of the Doring River between the two confluences. This maintains connectivity between the sanctuary populations and a population in the Gif River, which is known to be a good spawning and recruitment area. It is further recommended that sub-quaternary catchments 222 (the Olifants River between the confluence of the Doring and Troe-Troe rivers) and 218 (the lower reaches of the Troe-Troe River) be investigated for rehabilitation and re-stocking of the Clanwilliam sandfish.

Management actions

Management activities for the Koebee, Biedou and Doring rivers should focus Management activities for the Koebee, Biedou and Doring rivers should focus primarily on using natural flow regimes (both magnitude and variability) as a tool to flush out invasive alien fish and plants, as well as accumulated sediment in spawning riffles, thereby increasing the quantity and quality of spawning habitat and providing cues for migration and spawning. Other management interventions include enforcement of the 35 m riparian zone buffer, removal of alien plants from the riparian zone, optimal use of existing abstractions and prevention of further in-stream dams.

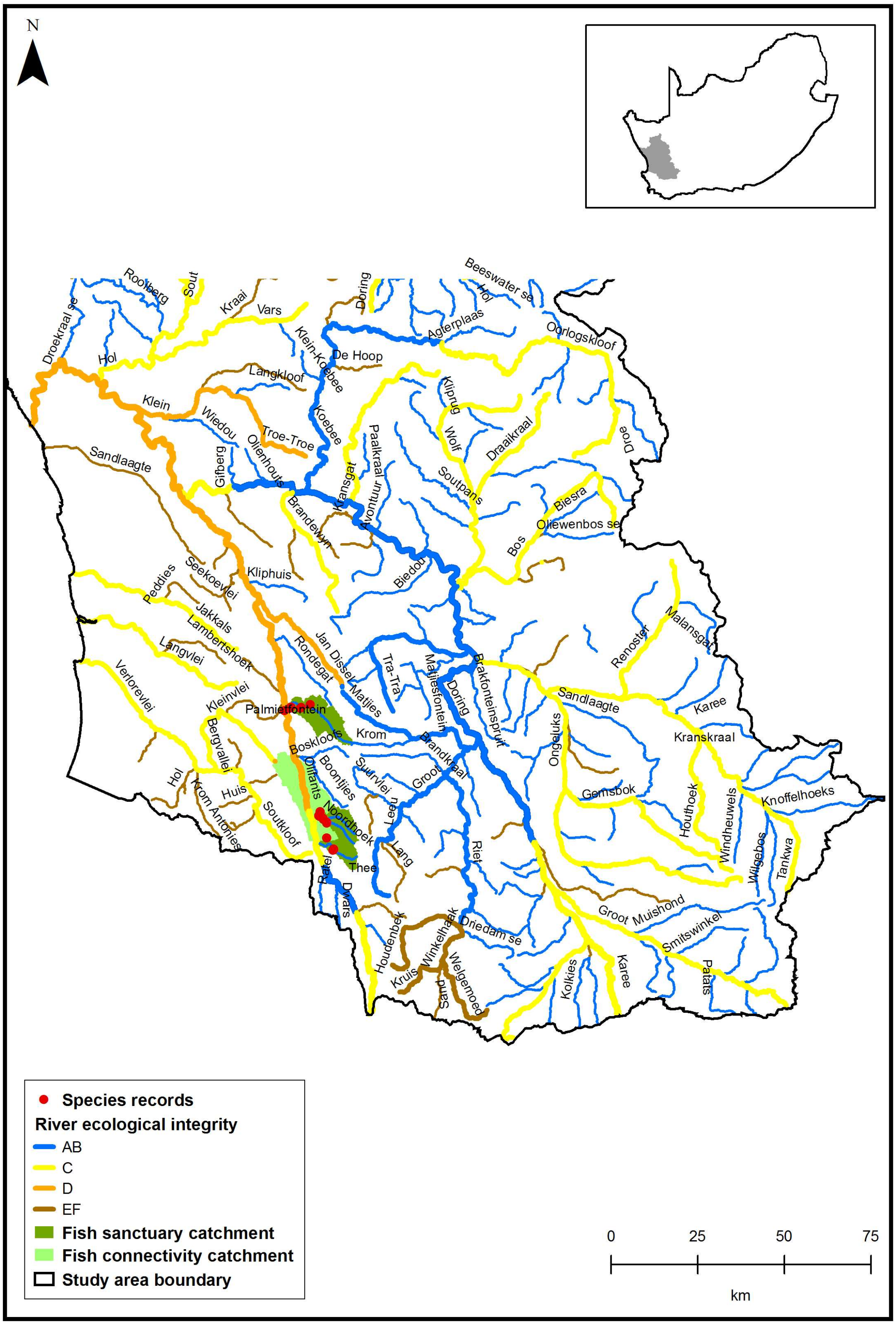

Figure 18: Sanctuary areas for the Clanwilliam sandfish

6.8 Spotted rock catfish

Scientific name:	*Austroglanis barnardi*
Family:	Austroglanididae
Conservation status:	Critically endangered
Ecological significance:	Endemic to the Clanwilliam Olifants River system
Social significance:	Scientific and conservation value

Habitat requirements
This species is very sensitive to flow and water quality, requiring riffles of both a good depth and flow. Benthic cover from cobble substrate appears to be the most important component of its habitat preferences, and this may be directly affected by flows - lowered flows in pool habitats causes heavy sedimentation, drastically decreasing benthic cover. Thus, abstraction over the low flow period decreases available wetted area, whereas curtailed intra- and inter-annual floods reduce the quality and quantity of benthic cover. Minimum ecological water requirements (see Brown *et al.*, 2004) should therefore be maintained in riffles all year round, with low-flows in riffles maintained during early summer, when recruitment is most likely. No information exists on the breeding requirements of spotted rock catfish, but adults probably breed over cobble substrata in running water, and riffles are likely to provide an important habitat for early life-history stages.

Main pressures
This species faces habitat destruction from stream channelling, over-abstraction of water and sedimentation. Although it is threatened by introduced bass, it tends to be more resilient to predation than some of the other freshwater fish, by being night active and hiding under cobble.

Recommended sanctuaries based on conservation targets
The spotted rock catfish has no natural population on the Doring River system. Two populations were selected on the Olifants River system to fulfil conservation targets: one on the Noordhoek River and one on the Heks River. This includes a 41 km section of the Olifants River between the Heks and Thee River confluences, to allow for recolonization and genetic exchange. However, the legitimacy of the proposed connecting river on the Olifants needs to be assessed in future studies for two reasons: (i) connectivity between the Noordhoeks and Olifants rivers may not be desirable, considering the possibility of invasion by alien fish (a study would need to confirm if this is the case or not); and (ii) the portion of the Olifants River chosen as the “connector” has become unnaturally seasonal, blocking any migration that could potentially take place, due to over-utilisation of summer base-flows. Thus a connectivity sanctuary may be a little over-optimistic.

Management actions
The ecological integrity of the Noordhoek and Heks rivers should be maintained in at least a B-category. No further in-stream dams should be built within the sanctuary system (they prevent movement), stocking off-stream dams with alien fish should not be permitted, and there should be no further granting of extensive agriculture. The 35 m riparian buffer should also be enforced within these catchments (which should include no access by livestock). The ecological integrity of the Olifants River, which connects the Noordhoeks and Heks populations, is currently in a D-category, but good rainfall helps it to recover to a low B-category in the winter, providing the opportunity for the spotted rock catfish to recolonize other tributaries. Further degradation of the Olifants River should be prevented by focussing on winter abstraction only, i.e. no summer abstraction should be permitted.

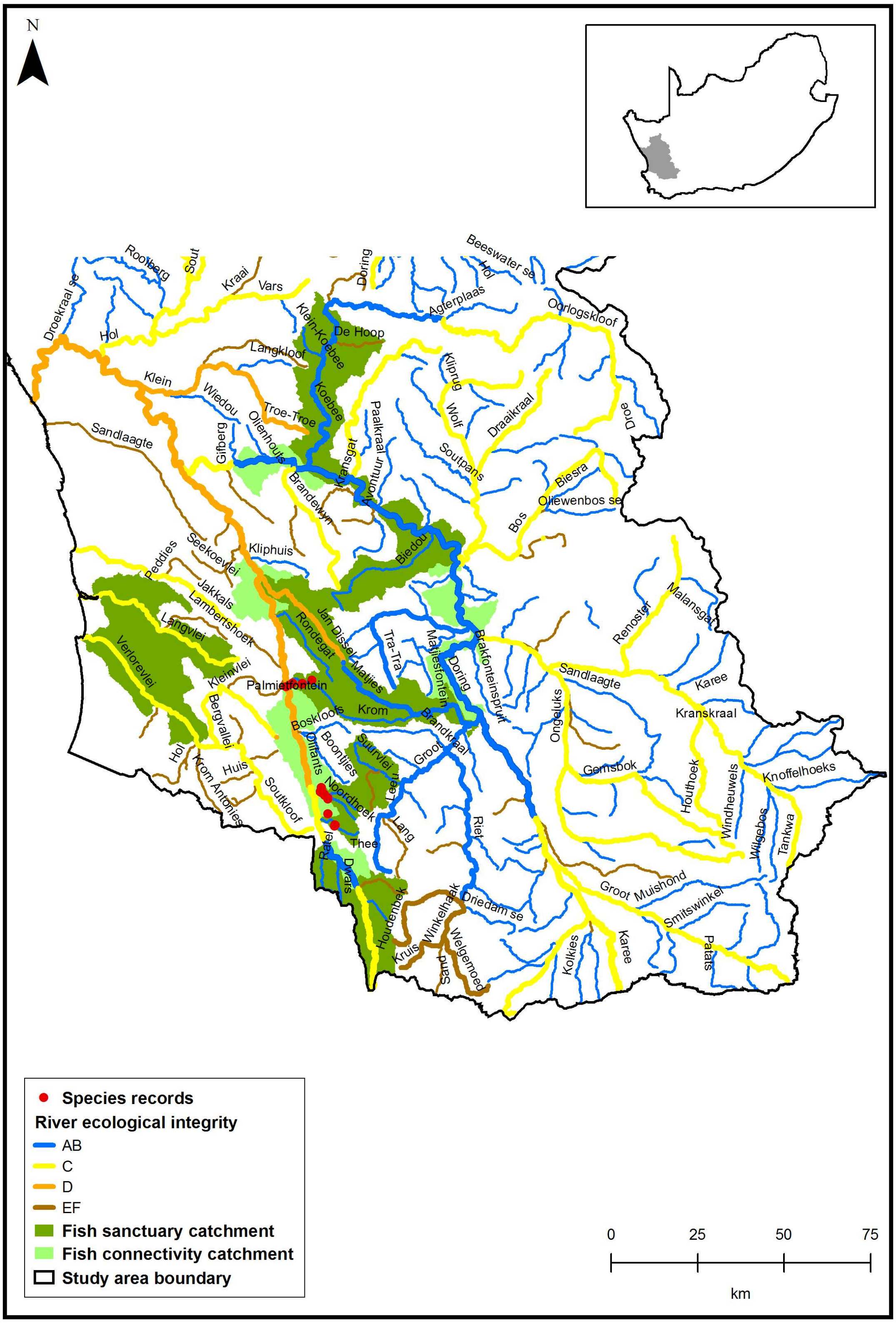

Figure 19: Sanctuary areas for the Spotted rock catfish

6.9 Clanwilliam rock catfish

Scientific name:	*Austroglanis gilli*
Family:	Austroglanididae
Conservation status:	Vulnerable
Ecological significance:	Endemic to Olifants/Door WMA
Social significance:	Scientific and conservation value

Habitat requirements
This species lives among rocks and cobbles and under banks, requiring riffles of both a good depth and flow. Like the spotted rock catfish (*A. barnardi*), this species is sensitive to flow and water quality, with lowered flows reducing the essential cobble habitat through heavy sedimentation. Minimum ecological water requirements (see Brown *et al.*, 2004) should therefore be maintained in riffles all year round, with low-flows in riffles maintained during early summer, when recruitment is likely. Adults probably breed over cobble in running water, and riffles are likely to provide an important habitat for early life-history stages.

Main pressures
Pressures include habitat destruction from stream channelling, water over-abstraction and sedimentation. Introduced bass are a threat, but it can escape predation by hiding under cobble.

Recommended sanctuaries based on conservation targets
The Jan Dissel River was selected as the sanctuary on the Olifants system, including 21 km of the Olifants River between the Kliphuis and Rondegat confluences. The Krom River was selected on the Doring system, which includes the entire Matjies River system. Retaining connectivity with the Doring River is irrelevant, as this species is flow-dependent and the Doring River is a naturally seasonal river, which ceases to flow in summer.

Management actions
The ecological integrity of the Jan Dissel River is currently in a C-category, caused by introduced bass, alien invasive plants in the riparian zone and poor water quality in the lower reaches. It should be rehabilitated to at least a low B-category. Existing alien plant control operations in this catchment should continue, with a strong focus on including rehabilitation of the associated riparian habitat. Improvement of the waste water treatment in the lower reaches of the Jan Dissel River is necessary, as this is responsible for lowered water quality, which also impacts water quality of the Olifants River. Key management actions to aid connectivity between the Jan Dissel and Olifants rivers include release of at least one winter flood from the Clanwilliam Dam (preferably in August), clearing of alien trees in the riparian zone, and preventing farmers in this area from building well points and sandbars in the river. These management activities would likely improve the integrity of the Olifants River between the Clanwilliam and Bulshoek dams to a low B-category, which could conceivably support this species. The Krom River on the Doring system has been selected as a priority river for the CAPE alien fish control project. No further in-stream dams should be built on this river, stocking off-stream dams with alien fish should not be permitted, and there should be no further granting of extensive agriculture. The 35 m riparian buffer should also be enforced in this catchment (which should include no access by livestock).

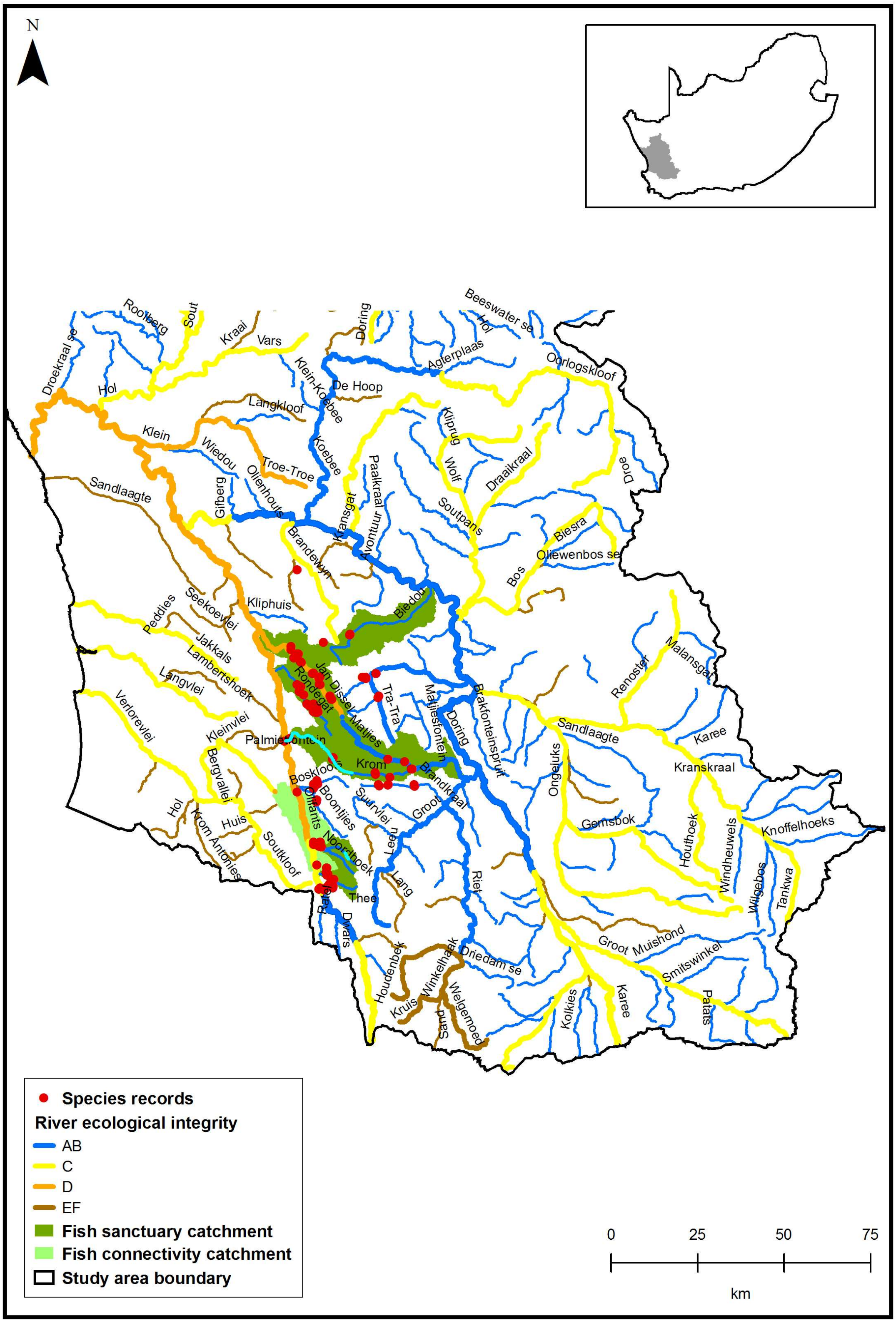

Figure 20: Sanctuary areas for the Clanwilliam rock catfish

6.10 Chubbyhead barb

Scientific name:	Barbus anoplus
Family:	Cyprinidae
Conservation status:	Not Threatened
Ecological significance:	Indigenous
Social significance:	Suitable for cool-water aquariums and garden ponds; Scientific and conservation value

Habitat requirements

This species was probably quite common at one stage in the Olifants and Doring rivers, giving rise to the wide distribution now prevalent only in their tributaries. Although this species is widespread in the rest of the country, genetic studies suggest that it may be separated into several distinct species. Additionally, the opportunity is high for conserving this species in the Olifants/Doorn WMA, relative to other parts of the country. The Chubbyhead barb occurs in a wide variety of habitats from small streams to large rivers and lakes. It breeds in summer, and larvae reach maturity after a year. It is omnivorous and feeds on insects, zooplankton, seeds, green algae and diatoms.

Main pressures

Introduced alien fish have isolated populations of this species into tributaries. Habitat destruction from agricultural development, including in-stream dams and abstraction, has also caused decline in population numbers.

Recommended sanctuaries based on conservation targets

The population on Koebee-Oorlogskloof system has been selected as the recommended sanctuary area. There are also small populations which are conservation worthy in the Kliphuis, Brandkraal, Palmietfontein (Marcuskraal), although these have not been selected.

Management actions

The ecological integrity of the Koebee-Oorlogskloof system should be maintained in its current B-category. To ensure that this is so, no further in-stream dams should be built (they prevent movement), stocking off-stream dams with alien fish should not be permitted, and there should be no further granting of extensive agriculture. The 35 m riparian buffer should also be enforced (which should include no access by livestock).

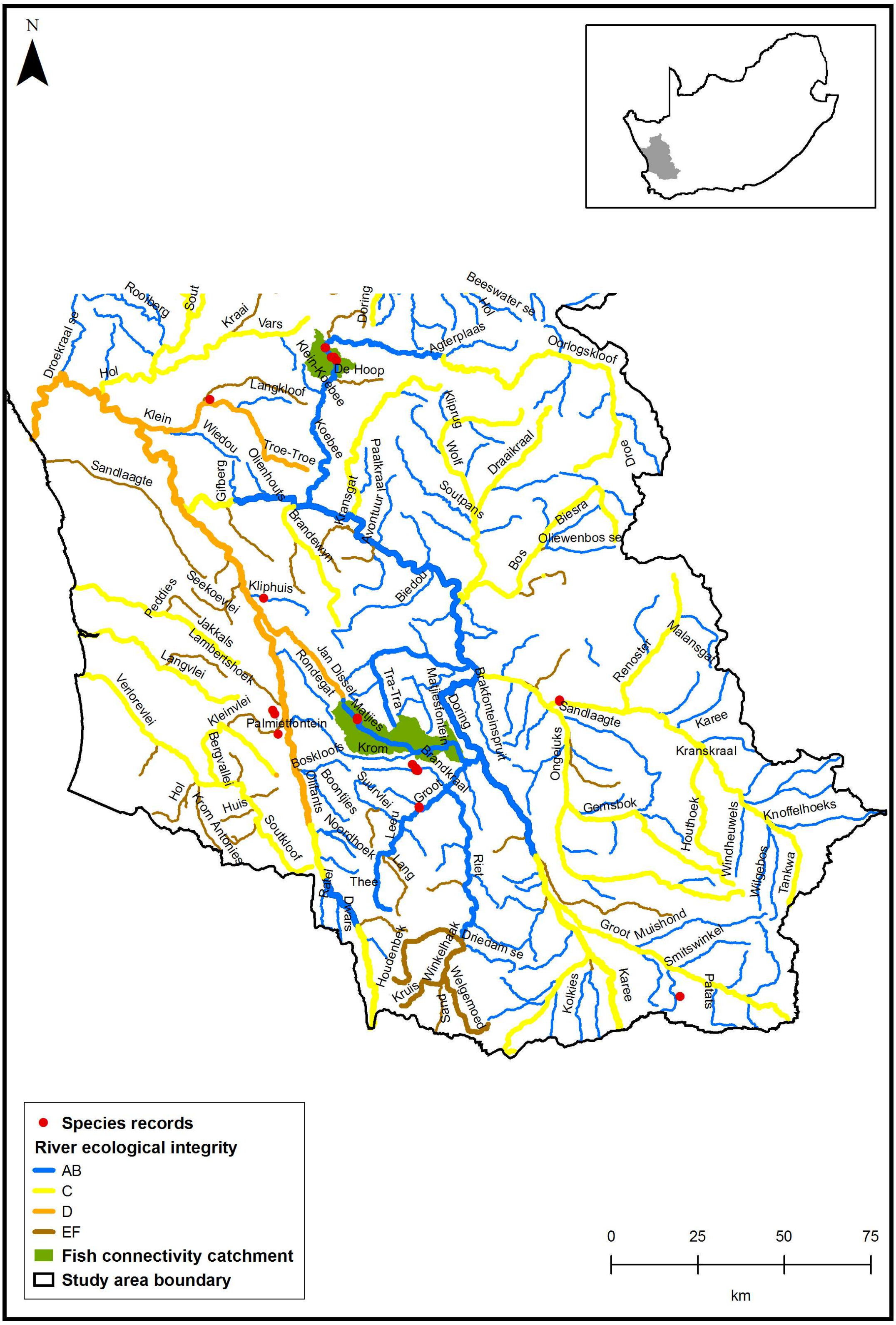

Figure 21: Sanctuary areas for the Chubbyhead barb

6.11 Cape galaxias

Scientific name:	*Galaxias zebratus*
Family:	Galaxiidae
Conservation status:	Near threatened
Ecological significance:	Indigenous; Potential genetic separation into five species
Social significance:	Suited to cool-water aquariums; Valuable fodder fish for trout; Scientific and conservation value

Taxonomy
Genetic evidence suggests separation into at least five species, possibly endemic to the Olifants/Doorn WMA. These are represented by populations on the Driehoek, Rondegat, Noordhoek, Middledeur (tributary of the Twee) and Verlorevlei rivers. The upper and lowland Verlorevlei population could be further separated into two species. The five populations mentioned above were treated as distinct species in this study. Field surveys and taxonomic studies should be undertaken to identify further sub-species.

Habitat requirements
Genetic variations seem to have differential preferences, but in general they occur in cooler flowing or standing waters, favouring gentle currents in the shelter of banks near the head of pools. They frequently associate with cover or shelter such as marginal vegetation. Although small, this is an extremely hardy fish, known to tolerate changes in water quality and flow. Its small size and cryptic colour also enables it to shelter from predation by alien fish. The species feeds on small drifting invertebrates, and breeds in summer.

Main threats
Excessive water abstraction in tributaries raises water temperatures to lethal limits in summer. Invasive alien plants in the riparian zone also destroy habitat for this species, which needs the shelter and cover provided by the natural riparian vegetation (e.g. Palmiet). Clearing of riparian zones for agricultural development also destroys habitat.

Recommended sanctuaries based on conservation targets
Driehoek, Rondegat, Noordhoek, Middledeur (tributary of the Twee) and Verlorevlei rivers.

Management actions
The ecological integrity category of the Driehoek, Rondegat, Noordhoek and Middledeur rivers should be maintained in the present B-category. To ensure that this is so, no further in-stream dams should be built and the 35 m riparian buffer should be enforced. The Verlorevlei is under immense agricultural pressure, with a C-category present ecological integrity. It is vitally important that the current rate of degradation here be halted and even reversed. This is the subject of conservation initiatives in the area, such as the Department of Agriculture's LandCare programme and the Greater Cederberg Biodiversity Corridor initiative. Removal of alien plants from the Verlorevlei River is likely to improve the ecological integrity of this system to a low B-category. To prevent additional degradation of this system, no further abstraction of surface or ground-water should be permitted, as it is critical to maintain refuge pools in summer low-flow periods.

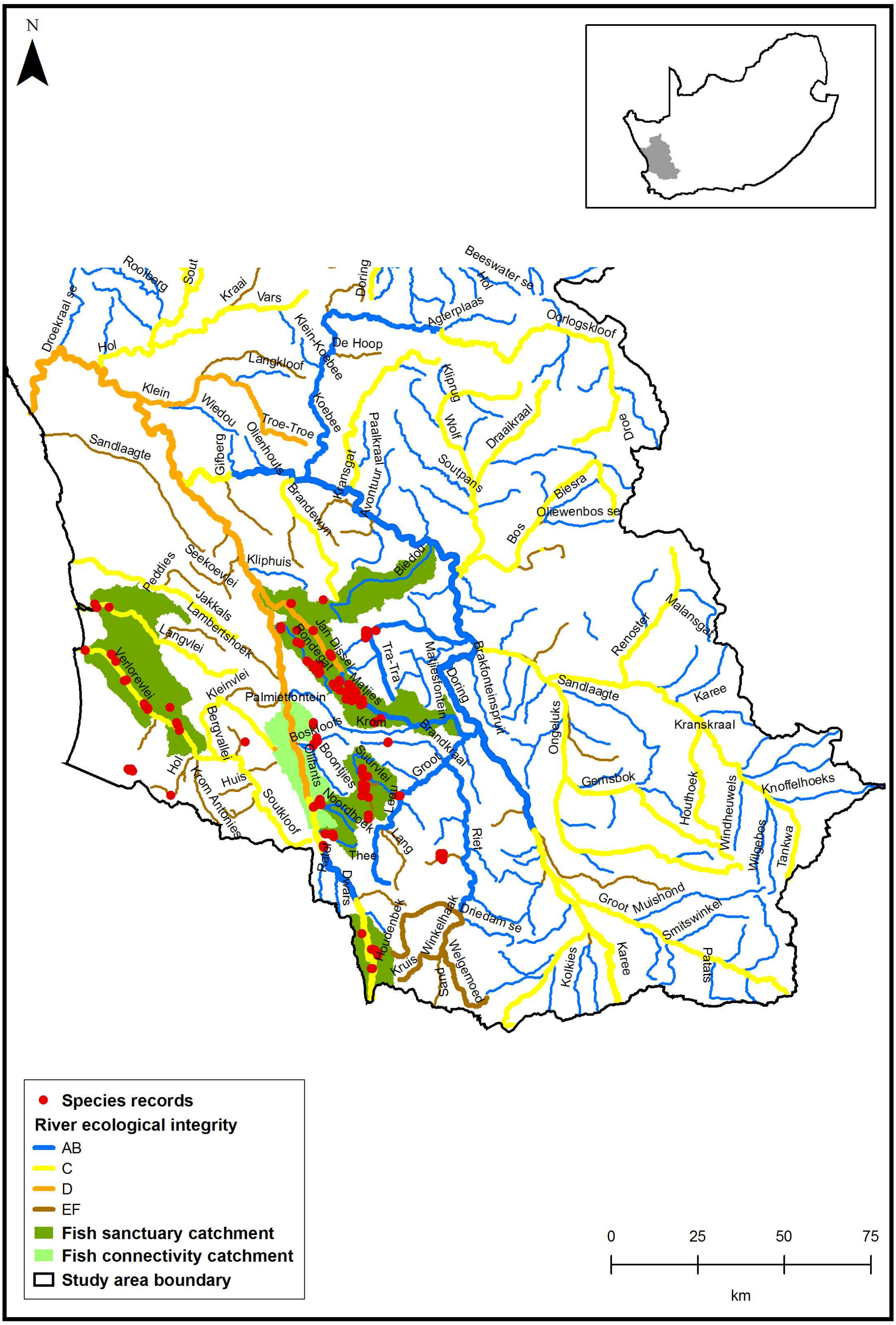

Figure 22: Sanctuary areas for the Cape galaxias

6.12 Cape kurper

Scientific name:	*Sandelia capensis*
Family:	Anabantidae
Conservation status:	Near threatened
Ecological significance:	Indigenous
Social significance:	Aquarium species; Scientific and conservation value

Habitat requirements

This species occurs naturally in the G-primary catchment (Sandveld catchment). It was also mistakenly introduced above the waterfall barrier on the Twee River system, where it has become invasive. It is a hardy species that lives in a wide variety of habitats, favouring quiet or slow-flowing water, with plant or root cover. It feeds on invertebrates and small fish, and breeds in summer.

Main threats

The species is threatened by habitat destruction and predation from introduced bass.

Recommended sanctuaries based on conservation targets

The Verlorenvlei River up to Hol River confluence has been selected as the sanctuary for this fish.

Management actions

This Verlorevlei River is under immense agricultural pressure and currently the ecological integrity of this sanctuary river is a C-category. It is vitally important that the current rate of degradation in the area be halted and even reversed. This is recognised by many conservation initiatives in the area, such as the Department of Agriculture's LandCare programme, CapeNature's Greater Cederberg Biodiversity Corridor initiative, and CAPE's fine-scale conservation planning initiative. Removal of alien plants from the Verlorevlei River is likely to improve the ecological integrity of this system to a low B-category. To prevent additional degradation of this system, no further abstraction of surface or ground-water should be permitted, as it is critical to maintain refuge pools in summer low-flow periods, both in terms of a reasonable quality and depth. It is recommended that intensive surveys and taxonomic studies be undertaken as a research priority to identify further sub-species.

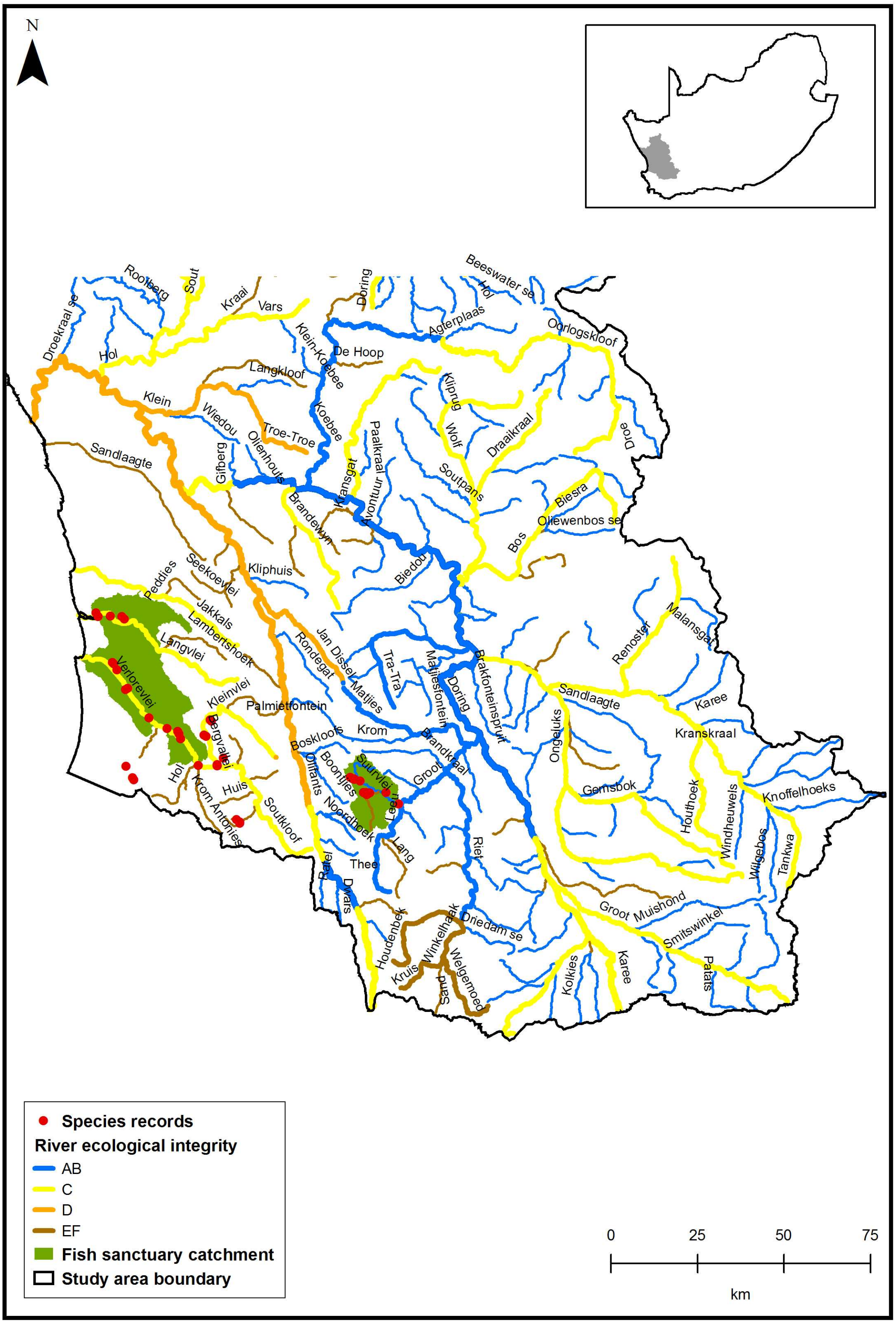

Figure 23: Sanctuary areas for the Cape kurper

7 ENSURING PERSISTENT CONSERVATION: ECOLOGICAL INTEGRITY

Ideally, those ecosystems that are currently considered to be of high integrity should be selected for the purposes of conserving biodiversity, since these are the ones that accurately represent the biodiversity of the region, and in which ecological and evolutionary processes operate within their natural ranges. For example, the flow regime is often considered to be a "master variable" of freshwater ecosystems, vital in shaping aquatic and riparian communities, and the physical characteristics of river-floodplain ecosystems in both time and space (Rowntree and Wadeson 1999; Richter and Richter 2000; Richter *et. al.* 2003). Conservation portfolios should give preference to selecting freshwater ecosystems where there is a realistic chance of maintaining or restoring natural flow regimes. This often translates to selecting freshwater ecosystems of high ecological integrity first, since these are the ones most likely to have natural or near-natural flow regimes.

From a practical point of view, selecting ecosystems that are currently of high integrity also: (i) facilitates operational management since ecosystems operating close to natural conditions tend to be more self-sustaining, and require less conservation management; and (ii) improves the cost efficiency of conservation management as no rehabilitation is required.

Explicit consideration was given to mapping the current ecological integrity of both rivers and wetlands. Ecological integrity for rivers was based on actual data wherever possible, and supplemented with data modelled from natural land cover. Wetland ecological integrity was based entirely on natural land cover.

7.1 River ecological integrity

7.1.1 Main rivers

Existing ecological integrity data tend to focus on main rivers. For example, national present ecological status (Kleynhans 2000) derived for the Water Situation Assessment Model provide integrity data for main rivers within each quaternary catchment. Here, main rivers are defined as rivers that pass through a quaternary catchment into a neighbouring quaternary catchment. In situations where no river passes through the quaternary catchment, the longest river system is chosen as the main river. This definition was adopted for the purposes of the ecological integrity analyses.

River ecological integrity categories used for main rivers were based on the present ecological status categories, which range from A (natural) to F (critically modified). For the purposes of this assessment, rivers with an overall present ecological status category of natural or largely natural (Category A or B respectively) was considered "intact" and suitable for contributing towards achievement of quantitative conservation targets. Ecological integrity was mapped using a combination of three existing data sets for main rivers:

- Present ecological status (Water Situation Assessment Model data; Kleynhans 2000);
- River Health Programme monitoring sites; and
- Habitat integrity data at 5 km stretches along the Doring, Groot, Olifants and Rondegat rivers.

The present ecological status was used as the base GIS layer, and was updated according to the latter two data sets. In instances where the condition of the river at the level of the landscape was better than that at the site level (from River Health data), experts were asked to review whether the differences were a result of localised impacts, or differences that should be picked up at the landscape scale. The present ecological status category was only updated if the difference was significant at a landscape scale (

Only 20 % of main rivers in the Olifants/Doorn Water Management Area are considered intact and able to contribute toward achieving conservation targets (Figure 25). The majority of main rivers (67 %) are moderately modified, i.e. in a C ecological integrity category. This is similar to the national trend (Nel *et al.* in press), although there are considerably fewer largely modified rivers (D, E or F ecological integrity categories) in the Olifants/Doorn Water Management Area (Figure 25). Main rivers in South Africa are heavily utilised and regulated to improve water security for socio-economic use, and there are widespread water transfer schemes across the country to cater for areas where water requirements exceed the natural water availability (Braune 1985; O'Keeffe 1989; DWAF 2004b). Smaller tributaries are often less regulated and therefore are frequently in a better condition than main rivers. Thus, tributaries have a crucial role to play in meeting conservation targets, and are important to include in the assessment.

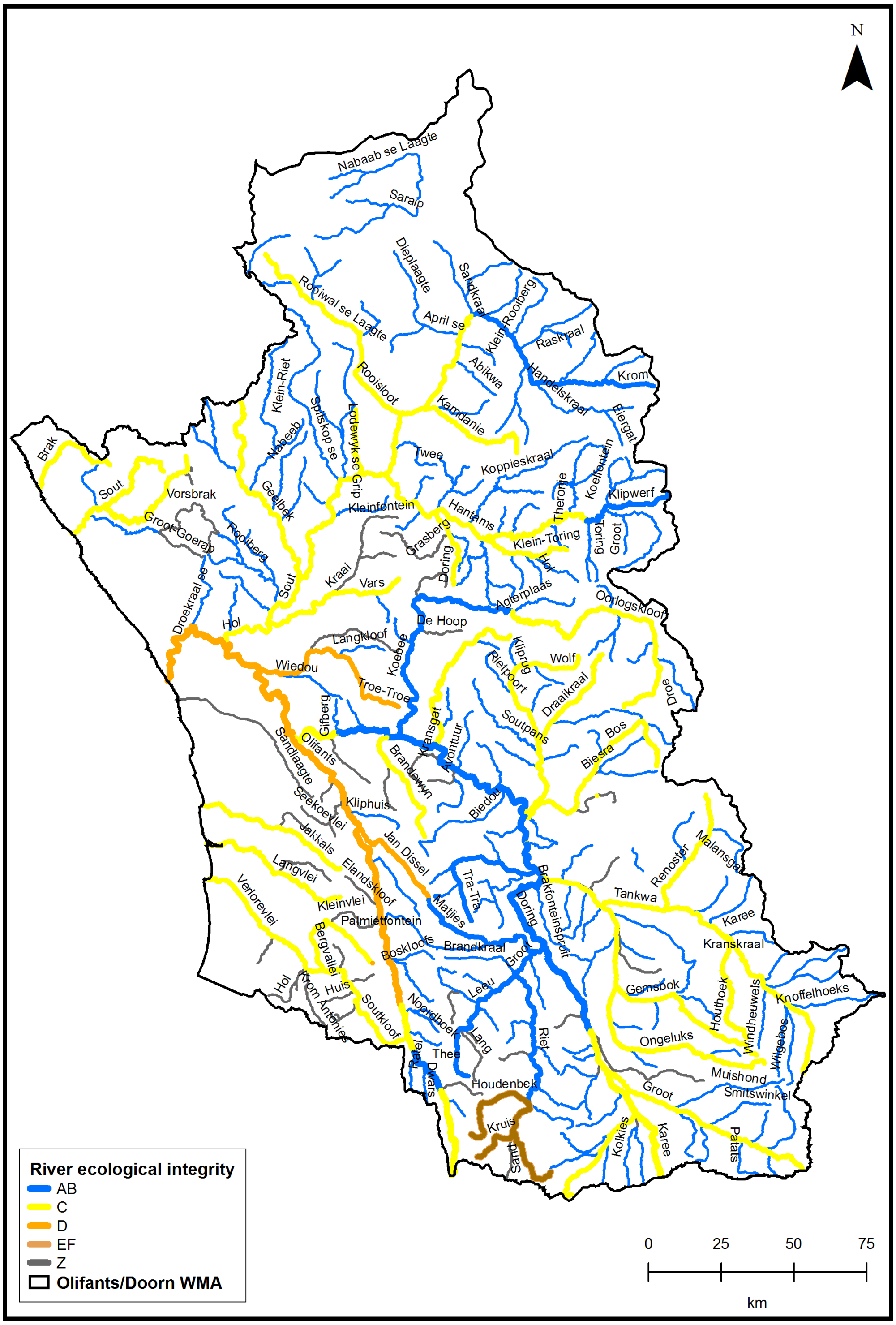

Figure 24: River ecological integrity

Ecological integrity for main rivers are based on existing data, whilst that for tributaries is based on data modeled from the National Land Cover 2000. See text for details.

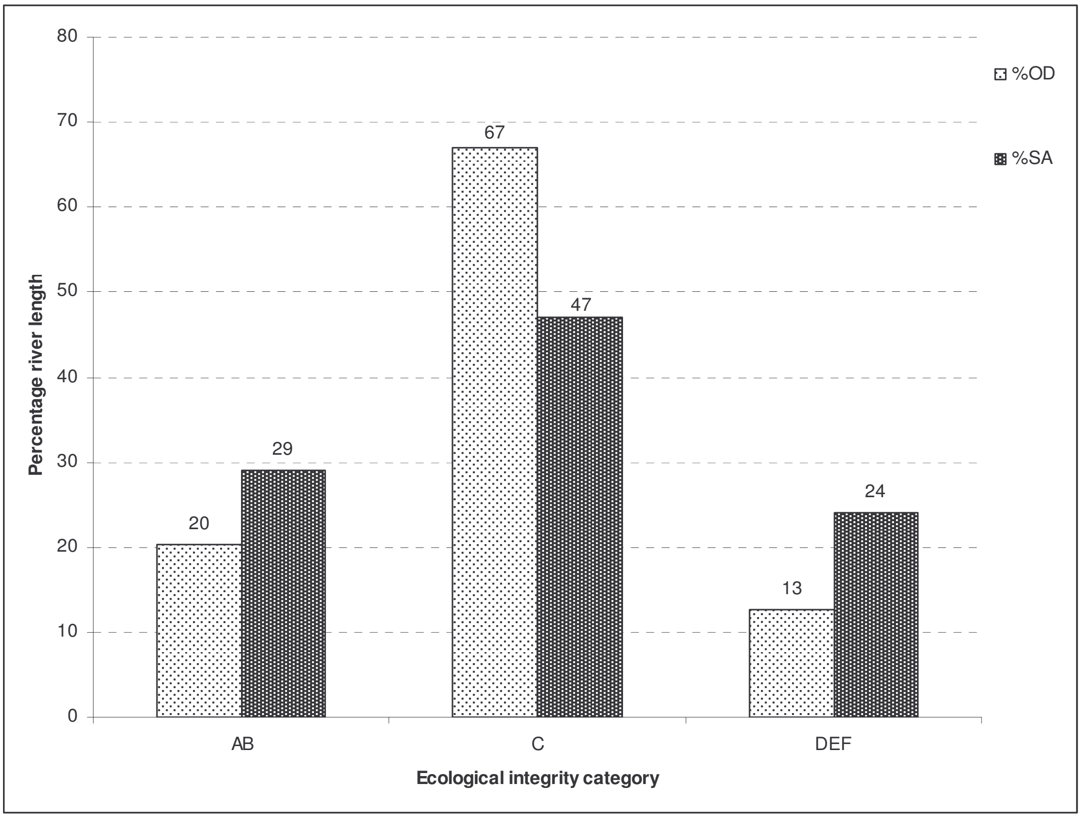

Figure 25: Main river integrity in the Olifants/Doorn Water Management Area and South Africa National data after Nel et al. *(in press). Percentage river length was calculated by summating the length of main river reaches in each present ecological status category and expressing this as a percentage of the total length of main rivers in the Olifants/Doorn Water Management Area or South Africa.*

7.1.2 Tributaries

"Tributaries" were defined as any 1:500 000 river that is not a quaternary main river. Ecological integrity for tributaries was derived using the percentage of natural land cover as a proxy, based on the study by Amis *et al.* (in press) which found that where no other data exist, the % natural vegetation serves as the best proxy. The National Land Cover 2000 GIS layer was used to distinguish natural and transformed land cover classes (Appendix 4). The "Waterbodies" land cover class contains both natural and man-made waterbodies. To differentiate between natural and man-made waterbodies, the 1:50 000 farm dams were overlayed with the National Land Cover 2000 GIS layer; waterbodies coinciding with farm dams were thus coded as transformed.

One of the major limitations in applying the National Land Cover 2000 GIS layer in these analyses is the inaccuracy associated with detecting degraded land. This is particularly pronounced in the drier areas of the country, where subsistence grazing can lead to large areas of degraded land. Grazing animals often cause a disproportionate degradation to rivers altering the riparian vegetation and causing bank erosion. For example, the presence of erosion along water courses in the drier ecoregions of the Tankwa Karoo and Namaqua Highlands is an indicator that the land around these areas is degraded, even though the National Land Cover 2000 shows this area as largely natural. To account for this inaccuracy, the presence of erosion patches as an indicator of land degradation was used in conjunction with proportion of natural land cover to calculate the ecological integrity of tributaries.

Two categories of integrity were assigned to tributaries: "Intact" (equated to the A or B ecological integrity categories of main rivers), or "Not intact" (assigned a category of "Z"). The following steps were used to calculate these categories for each river reach:

(i) Calculate three disturbance indices:
- Catchment disturbance index (% natural vegetation within each sub-quaternary catchment)
- Riparian disturbance index (% natural vegetation within a 500 m GIS buffer of a river)
- Macro-channel disturbance index (% natural vegetation within a 100 m GIS buffer of a river)

(ii) Assign the minimum of these three indices to each reach.

(iii) Assume any river reach with a minimum natural vegetation of ≥ 80 % to be "intact", or in a Category A or B, and able to contribute towards achieving river conservation targets. Assign a Category Z, or "not intact", to any river reach below this threshold.

(iv) Downgrade any AB tributaries if the % erosion within a 500 m GIS buffer of the river reach is > 3 %.

Modelled ecological integrity for tributaries supports the notion that tributaries are less impacted than main rivers, with 57 % of the river length in the Olifants/Doorn Water Management Area being in an intact state, as opposed to just 23 % when considering main rivers alone (Figure 26). This highlights the importance of tributaries for conserving biodiversity, in which conserved tributaries could be viewed as refugia for river biodiversity, replenishing other parts of the river system from time to time. For this replenishment to occur, however, it is important that the longitudinal connectivity between the tributaries and its main river be maintained. An exception to this rule, where longitudinal connectivity may not be desirable, may be in instances where connectivity increases the likelihood of invasion by alien fish. This was an important factor that was considered in designing fish sanctuaries (Section 6).

The modelled tributary ecological integrity data are preliminary and need to be refined to consider the cumulative upstream impacts of dams and water transfer schemes. These refinements should then be field verified. Although cumulative upstream impacts of dams and water transfer schemes were integrated into the present ecological status for main rivers, the modelled tributary data do not take this into account (although tributaries are generally less subject to large upstream impacts than main rivers).

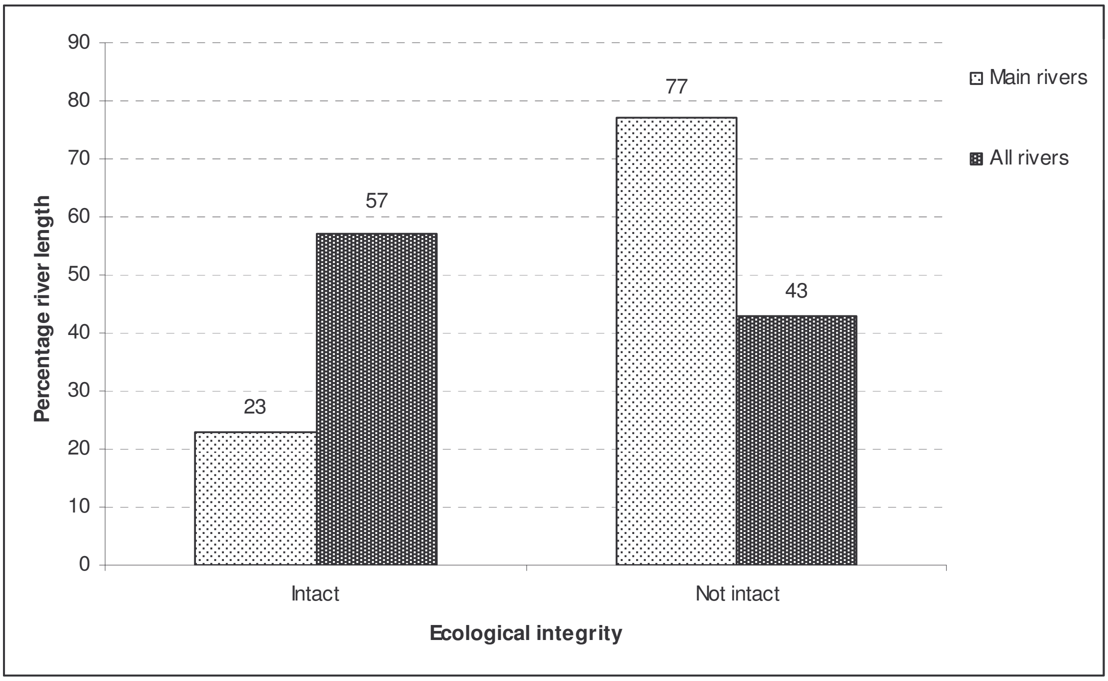

Figure 26: Ecological integrity of main rivers compared to main rivers and tributaries

7.2 Wetland ecological integrity

There are many field approaches to assessing wetland condition. However, in the absence of field data, we used a desktop modelling approach, based only on % natural land cover (similar to the approach used for deriving ecological integrity of tributaries in Section 7.1). The National Land Cover 2000 land cover classes were coded as natural or transformed (Appendix 4). The "Waterbodies" land cover class contains both natural and man-made waterbodies. To differentiate between natural and man-made waterbodies, the 1:50 000 farm dams were overlayed with the National Land Cover 2000 GIS layer; waterbodies coinciding with farm dams were thus coded as transformed.

Two categories of integrity were assigned to wetlands: "Intact", or "Not intact". The following steps were used to calculate these categories for each wetland:

(i) Calculate three disturbance indices:
- Catchment disturbance index (% natural vegetation within each sub-quaternary catchment)
- Buffered core disturbance index (% natural vegetation within a 100 m GIS buffer of a wetland)
- Core disturbance index (% natural vegetation within a 50 m GIS buffer of a wetland)

(ii) Assign the minimum of these three indices to each wetland.

(iii) Assume any wetland with a minimum natural vegetation of ≥ 90 % to be "Intact" and able to contribute towards achieving river conservation targets. Assign a category of "Not intact" to all other wetlands below this threshold.

(iv) For the ten wetland types that cannot meet their conservation targets in "Intact" wetlands, lower the minimum natural vegetation threshold to 80 %. This step attempts to lower the number of wetland types that cannot meet targets using a less conservative threshold. Using an 80 % threshold for these wetland types enabled achievement of two more wetland types (i.e. the final plan could not achieve targets for eight wetland types, and not ten).

Only 43 % of the potential wetland area is predicted to still be in an intact state and suitable for contributing towards representation targets (Appendix 3). Floodplain and valley bottom wetlands are most seriously impacted, with only 22 % and 46 % remaining intact respectively (Table 14). Depressions are predicted to be the most intact type of wetland, with 93 % of the area still intact. However, this is likely to be a gross under-estimation of the extent of impact, since the National Land Cover GIS layer does not adequately address degradation and deleterious land use practices. The wetland integrity data therefore need to be field verified. In general, results are likely to be over-optimistic regarding the state of wetlands, owing to several limitations of the data used, including:

- Differences in scale – this may result in under-estimation of intense and highly localised impacts that are smaller than the minimum mapping unit of the National Land Cover 2000 GIS layer.
- Extent of land degradation under-estimated – the National Land Cover 2000 GIS layer does not accurately detect land degradation. This leads to under-estimating the extent of impact on wetlands, since wetlands are particularly sensitive to trampling and grazing.
- Deleterious land practices are not always mapped – A common land use practice on pans in the Sandveld sub-area is to dig up pieces of turf and drain the waters, which are then left to dry into salt (Kate Snaddon *pers. comm.*). These sorts of land practices have a large impact, but will not be picked up using the National Land Cover 2000 GIS layer.

Table 14: Proportion of different landform wetland types still intact
% Intact was measured as the area of potential wetland intact expressed as a proportion of the total potential wetland area for each landform.

Landform	**% Intact**
Floodplain	22
Valley bottom	46
Depression (perennial)	100
Depression (non-perennial)	93
Seep	60

8 ENSURING PERSISTENT CONSERVATION: CONNECTIVITY

Most freshwater ecosystem functions are, directly or indirectly, maintained through connectivity. Thus, identifying areas that are important for conserving biodiversity pattern needs to be augmented with management zones aimed at controlling impacts in systems that are connected to conservation zones. Longitudinal connectivity requires managing upstream and downstream catchment impacts; vertical connectivity requires managing impacts that affect interactions between relevant surface and sub-surface waters; and lateral connectivity involves managing impacts from the surrounding landscape. The following section describes how longitudinal, vertical and lateral connectivity have been incorporated in this conservation assessment.

8.1 Longitudinal connectivity

Longitudinal connectivity should be maintained in both space (through a connected river network) and time (through maintenance of the natural hydrological regime). Ideally, whole river systems should be selected; however, it is seldom possible to find whole river systems in a consistently high ecological state (where the river is Category A or B throughout its entire tertiary or primary length). Therefore, rivers that were selected for conservation in an intact category (Categories A or B) were connected through rivers that were only moderately impacted (Category C). These connecting rivers were incorporated explicitly into the final conservation portfolio, with the recommendation that they should be maintained in an integrity category that promotes longitudinal connectivity for its associated biodiversity. For example, fish may require certain flow velocities to spawn; in these instances, maintaining longitudinal connectivity in a moderately modified system will involve determining and implementing the minimum ecological water requirements, as per Brown *et al.* (2004).

8.2 Lateral connectivity

Lateral connectivity refers to the interconnectedness that exists across an environmental gradient between aquatic, riparian and terrestrial ecosystems. As a result of this lateral connectivity, the ecological integrity of the whole catchment needs to be managed appropriately in order to conserve riverine and wetland biodiversity. The need for lateral connectivity was incorporated into the Olifants/Doorn conservation portfolio by including entire sub-quaternary catchments (Section 4.1) within which selected river reaches or wetlands occurred, highlighting that these sub-quaternary catchments will require appropriate land use practices in order to meet the level of protection awarded to the water resource.

8.3 Vertical connectivity: Groundwater

Rivers and wetlands, as well as several terrestrial ecosystems, are dependent on groundwater to varying degrees (Vegter 1995, Hatton and Evans 1998, Colvin *et al.* 2003). The persistence of healthy, functioning rivers and wetlands therefore relies on maintaining their hydrological linkages with groundwater. This is particularly true in the Olifants/Doorn Water Management Area, where groundwater sustains river flow and refuge pools in the summer low flow periods. Table 15 shows the different types of habitats that could be associated with different aquifers in the Olifants/Doorn Water Management Area. For example, springs and seeps are known to be associated with dykes and sills, as well as the fractured meta-sediments of the Table Mountain Group; whilst alluvial and coastal plain aquifers support a wider range of groundwater dependent ecosystems.

Table 15: Groundwater dependent ecosystems and their association with different aquifer types Based on the national typesettings for aquifer dependent ecosystems (Colvin et al. *2006). Different aquifer types and habitat types are listed, with an indication of the probability of occurrence. The probability is defined as: Known = there are known occurrences of these ecosystem types in this setting; Probable = these types are likely to occur there but no data are available to confirm that; and Unlikely = these ecosystem types are unlikely to occur there.*

Habitat types	***Secondary Aquifer types***		***Primary Aquifer types***	
	Dykes & Sills	***Fractured Meta-sediments***	***Alluvial***	***Coastal plain***
In-aquifer	Unlikely	Unlikely	Probable	Probable
Spring	Known	Known	Known	Probable
Riverine aquatic	Probable	Probable	Known	Known
Riparian	Probable	Probable	Known	Known
Wetland/seep	Known	Known	Known	Known
Terrestrial	Probable	Probable	Probable	Known
Estuarine/coastal	Unlikely	Known	Known	Known

Known	*Probable*	*Unlikely*

Two aspects of groundwater were mapped in order to identify areas where it is particularly important to manage and monitor groundwater to maintain ecological processes:

(i) Significant areas of groundwater-surface water discharge
(ii) Significant areas of groundwater recharge

The resulting areas were used in compiling management recommendations in this report, to highlight selected sub-quaternary catchments where groundwater should be managed and monitored. The section below provides a brief description of the rationale and derivation of the groundwater GIS layers. The reader is referred to Conrad and Münch (2006) for a more detailed methodology.

8.3.1 Significant areas of groundwater-surface water discharge

Rationale for mapping these areas
In areas indicated to have a high probability of groundwater-surface water interaction, groundwater plays a particularly important role in the ecological functioning of surface waters, maintaining river pools that serve as crucial refugia in the summer low flow months, sustaining river baseflows, and maintaining wetlands and riparian vegetation. It is therefore particularly important to manage the groundwater resource in these areas. Management activities would include controlling, or preventing, groundwater abstraction, maintaining natural vegetation cover, and clearing alien invasive plants.

Methodology
The probability of groundwater-surface water interaction was mapped using six GIS layers. These data are listed in Table 16, together with a brief description and rationale for their use. Each GIS layer was rated on a scale of one to three (except for groundwater contribution to baseflow, which was rated on a scale of one to four), and then a weight (Table 16) was applied to each, depending on the importance or significance of that layer for the particular area. Rated and weighted GIS layers were then superimposed to derive a summated score for all combined areas. Probability of groundwater-surface water interaction (high, medium or low) was assigned to these areas using the summated score (Figure 27, Appendix 4). It is important to note that the resulting map of groundwater-surface water interaction is a predictive model based on desktop GIS data and expert interpretation. These data should therefore be confirmed in the field.

A further useful refinement of these analyses was to assign groundwater nodes to the 1:500 000 rivers GIS layer for monitoring and management purposes (Figure 27). These nodes are intended as monitoring sites only, and should not be misinterpreted as the highest (or only!) areas of significant groundwater discharge. In terms of conservation planning, the probability map for groundwater-surface water interaction (Figure 27) is therefore a more meaningful map, as it is more inclusive of all areas that are likely to have a medium or high probability of groundwater-surface water interaction, highlighting both riverine and wetland areas.

Groundwater monitoring nodes were assigned using the following rules:

- Where more than 5 km of the river length is in a high or medium probability category.

- Where river length in the high or medium category extends for more than 30 km.
- Where the probability of interaction decreases downstream, a node is place approximately 1 km upstream of this change. This distance upstream was assigned to eliminate boundary effects brought about by changes in probability that could influence monitoring results.
- Where a high or medium category river passes into a new groundwater response unit (Figure 28), a node is place approximately 1 km upstream of the boundary. The distance upstream was assigned to eliminate boundary effects brought about by changes in probability that could influence monitoring results.

Significant features and management recommendations

Groundwater plays a key role in the ecological functioning of aquatic ecosystems in the Sandveld, Doring and Knervlakte sub-areas (Figure 27 and Figure 28). Permanent pools in these areas are crucial for maintaining biota in the dry season, and these pools are likely a function of alluvial storage with slow release. The Doring River is seasonal, and groundwater is also particularly important for sustaining river pools in the summer dry season, which are crucial to the survival of many endemic fishes and other aquatic biota. Groundwater can also help to sustain adequate river baseflows in the Doring River in the rainfall months. This is essential, since many of the endemic and indigenous fish depend on adequate flow velocity in the Doring River, both for habitat and spawning. It is also critical that attention be given to responsible groundwater management and monitoring in the Sandveld and Koue Bokkeveld areas, where irrigated agriculture is extensive. The over-abstraction of groundwater in the Sandveld is a major concern, as many ecosystems (terrestrial and aquatic) are dependent on groundwater in this area, including Verlorevlei which is a RAMSAR site.

Table 16: GIS data layers used to map probability of groundwater-surface water interaction
For a more detailed account of the methodology and ratings used refer to Conrad and Münch (2006).

GIS layer	Description	Rationale for use	Weight
Groundwater response units	Units that have similar hydrogeological characteristics. Based on 1:1 000 000 geology.	These units identify boundaries between aquifer and non-aquifer geological formations. A significant change in permeability at these interfaces may result in groundwater discharging to the surface. A high weighting was assigned to this GIS layer, since geology plays a key role in groundwater characteristics.	3
Groundwater levels	Interpolated surface of depth to groundwater (m), based on borehole data.	Groundwater-surface water interaction is likely to be highest in areas where groundwater levels are shallow (i.e. close to the surface). A low weighting was assigned to this GIS layer because of the high uncertainty in the data.	1
Springs	The position of known springs in the study area (not potential springs).	Points of known groundwater discharge. Springs in this area are important, therefore this GIS layer received a high weighting.	3
Geological faults	The position of geological faults in the landscape. Based on 1:250 000 geological structures.	Faults are often favourable flow paths for groundwater, although there are many faults that are weathered and essentially sealed, with no associated groundwater presence or movement. For this study, it was assumed that all faults are water bearing and a high weighting was assigned.	3
Aquifer dependent ecosystems	Probability of occurrence of aquifer dependent ecosystems. Based on 1:250 000 vegetation groupings.	Management of groundwater in the immediate vicinity of these ecosystems is crucial. A moderate weighting was applied to this GIS layer due to its coarse national scale.	2
Groundwater contribution to baseflow	Based on monthly flow data at the scale of a quaternary catchment.	This GIS layer is the most commonly used national indicator of groundwater surface water interactions. For much of the study area, however, these data indicate no groundwater-fed baseflow, yet field experience indicates groundwater is an important contributor to maintaining these systems during the dry season (*pers. comm.*, C. Brown 2006). The GIS layer was consequently assigned a low weighting.	1

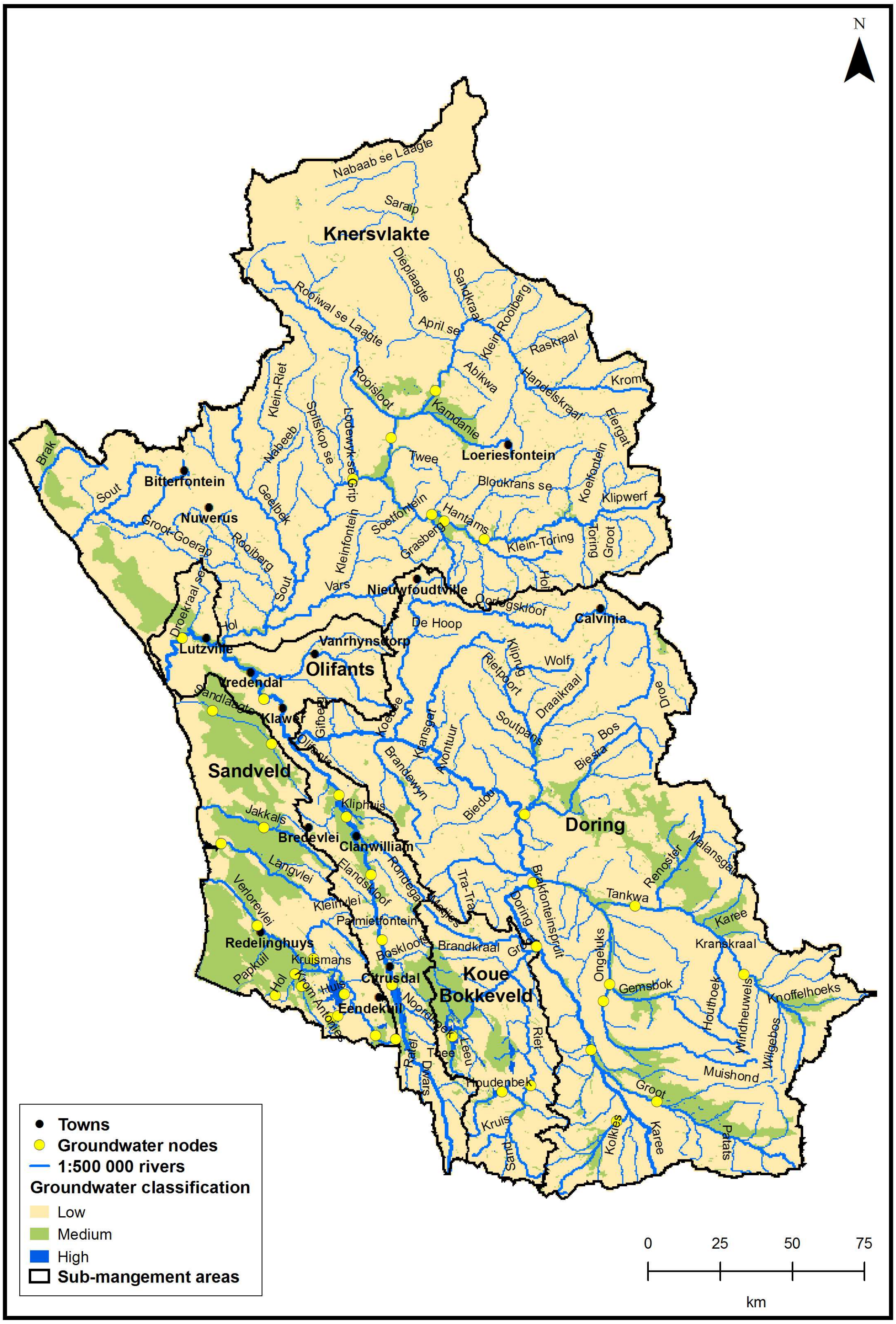

Figure 27: Probability of groundwater-surface water interaction and groundwater nodes After Conrad and Münch (2006). Based on a combination of six GIS layers listed in Table 16.

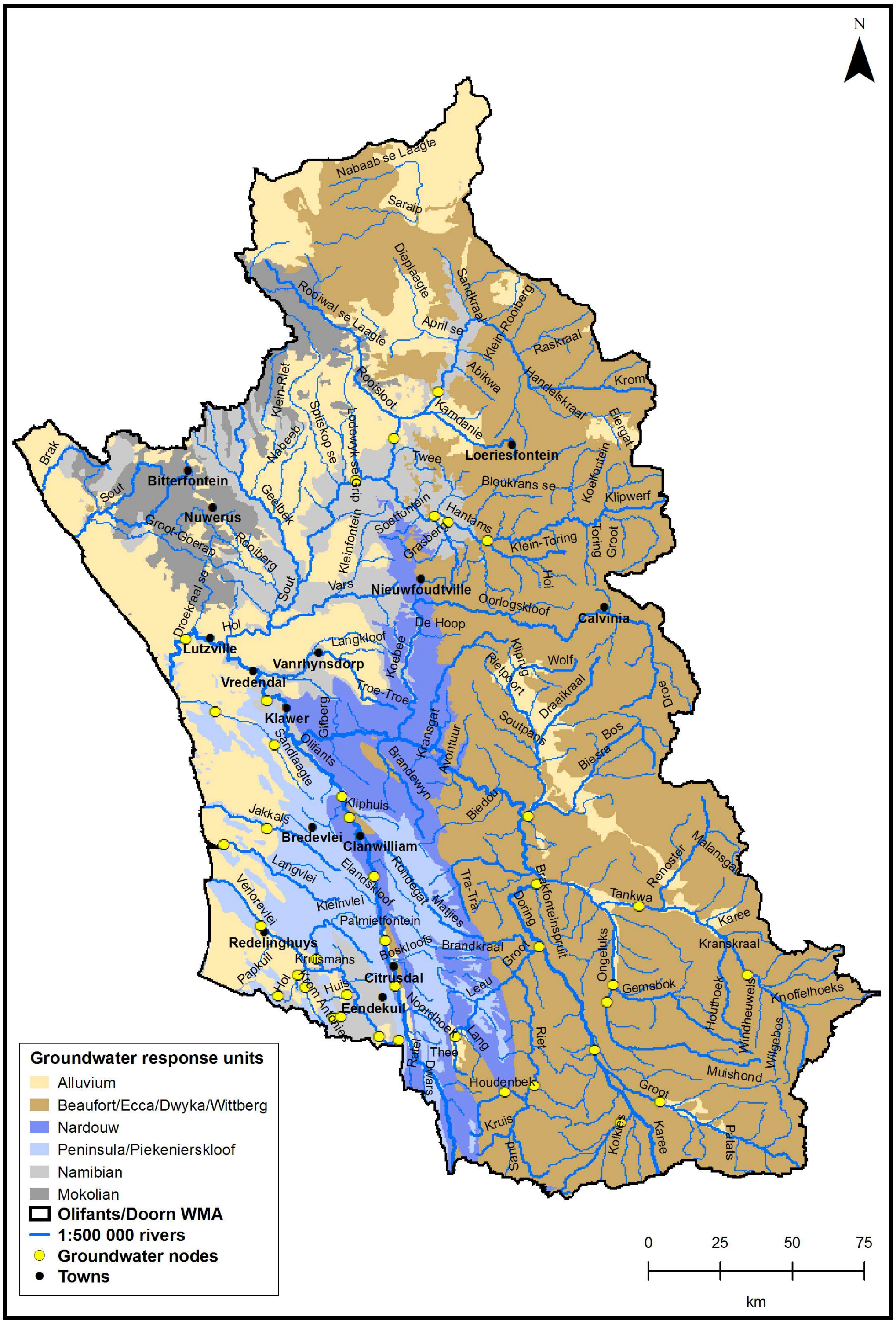

Figure 28: Groundwater response units

A significant change in permeability at these interfaces may result in groundwater discharging to the surface.

8.3.2 Significant areas of groundwater recharge

Rationale for mapping these areas

Groundwater recharge is dependent mainly on rainfall and geological permeability, and different areas will vary in their ability to recharge groundwater. Deleterious activities in areas that have significant recharge can have a keystone effect on the functioning of groundwater dependent ecosystems, which can be in the immediate vicinity, or far removed from the recharge area. Identifying areas of significant groundwater recharge allows for pro-active management of activities that may lower the groundwater quantity or quality in their vicinity. Such management activities would include controlling, or preventing, groundwater abstraction, maintaining natural vegetation cover, and clearing alien invasive plants.

Methodology

Groundwater recharge (mm per year) has been calculated for the whole of South Africa, and is available at a 1 km x 1 km cell size (DWAF 2005b). The method of determining groundwater recharge was based on the Chloride Mass Balance (Lerner *et al.* 1990). A GIS model was then established, which replicates natural processes of direct groundwater recharge (DWAF 2005b). This model was calibrated and refined according to known recharge values at several sites across the country, as well as expert knowledge. For the purposes of this study, groundwater recharge for each 1 km x 1 km cell was divided into five categories of recharge (Table 17); those areas in the "Medium", "High" or "Very High" groundwater recharge category were flagged for management (Figure 29).

Significant features and management recommendations

Groundwater recharge is highest in the mountainous regions of the Groot Winterhoek, near Porterville (Figure 29), where the Olifants River has its origin. Rainfall in this area is high, being correlated with topography (i.e. increased rainfall with increased ground elevation). In addition, these mountainous or higher lying areas are predominantly comprised of Table Mountain Group quartzites, which are very resistant to weathering and well-fractured and jointed, permitting good infiltration of rain water, which ultimately becomes groundwater recharge. Groundwater recharge in this area is crucial to the ecological functioning of many far-removed areas in the coastal Sandveld, e.g. Verlorevlei (an important RAMSAR site).

Much of the land falling in the "Medium", "High" and "Very High" recharge categories is protected either as provincial nature reserve or under the Mountain Catchment Area Act (Figure 29). Preventing groundwater abstraction in these areas is vital. Clearing of alien invasive plants should also be a priority in these areas. In addition, only low impact land activities should be permitted to retain vertical linkages with the groundwater. Maintaining the integrity of wetlands in these areas is especially important to optimize groundwater recharge.

Table 17: Categories of groundwater recharge used for this study

Groundwater recharge (mm per year)	**Category**
< 10	Negligible
10 – 30	Low
30 – 90	Moderate
90 – 150	High
> 150	Very High

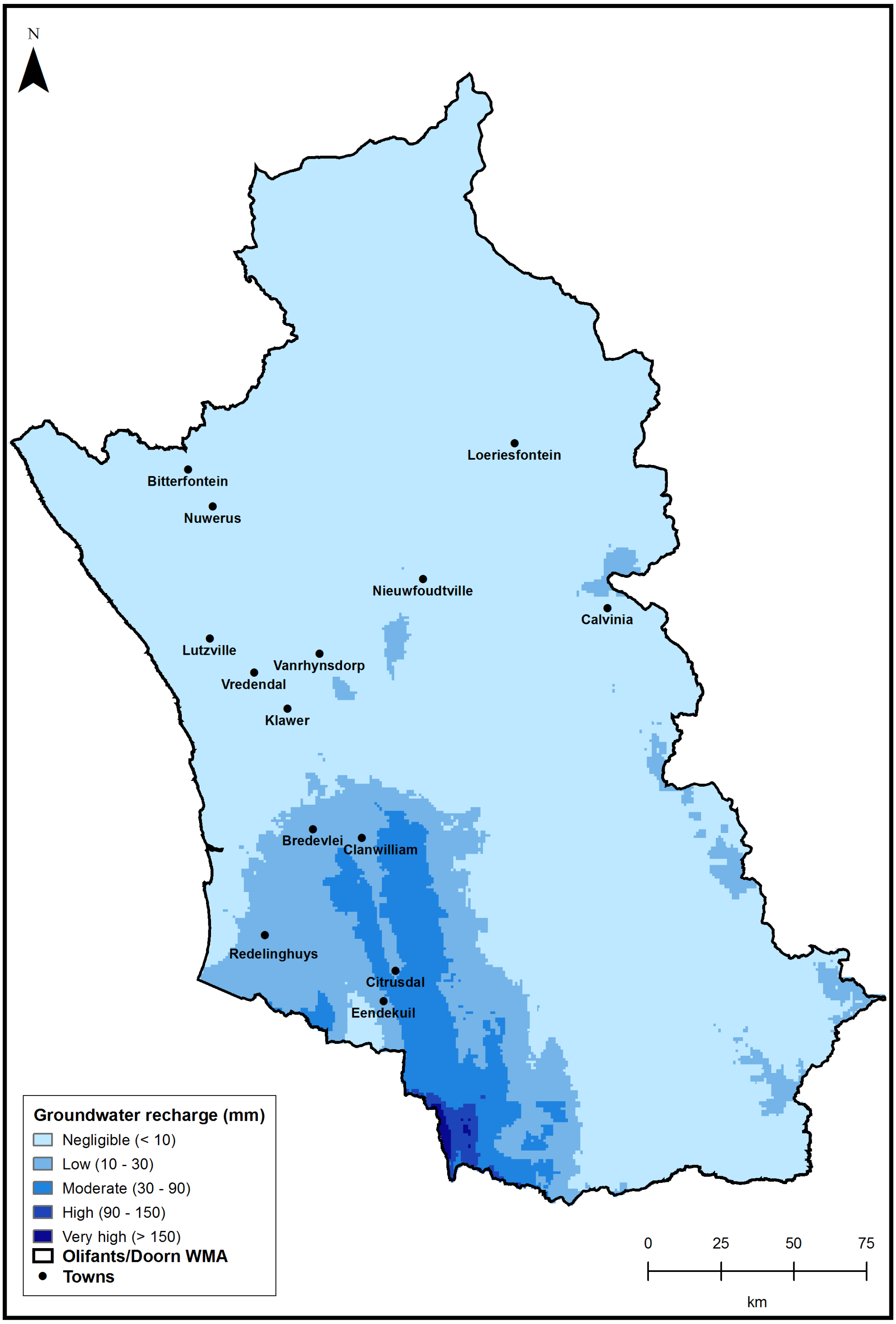

Figure 29: Significant areas of groundwater recharge
Areas in the "Moderate", "High" and "Very high" category were considered significant areas of groundwater recharge.

9 ENSURING PERSISTENT CONSERVATION: SIZE

Any area included in the conservation portfolio should be large enough to allow biodiversity features to recover from natural disturbances and have populations that reproduce sufficiently to remain viable in the long term. The actual extent of what constitutes "sufficient size" will vary between systems and what is being conserved, and should be assessed on a case-by-case basis. Size of river reaches, wetlands and fish populations was assessed prior to inclusion in the conservation portfolio.

9.1 River size

Each river reach chosen for inclusion in the Olifants/Doorn conservation portfolio was evaluated in terms of its size. In most cases, only reaches over 5 km were chosen for conservation purposes. However, there were a few instances, mainly in headwater streams, where the only option to conserve a representative stretch of river was in a reach of < 5 km, which was connected to rivers of lower integrity (Categories C-F). Because headwaters are by definition shorter rivers and can be important and viable for specific aquatic biota even with their small size, it was decided that they should be included in the conservation portfolio ***unless*** their contribution to the overall target of that river type was < 10 %.

9.2 Wetland size

Minimum size thresholds were set for representative habitat wetlands, depending on the type of landform (Table 10). For seeps, a size threshold of 3 ha was applied. This means that no seep smaller than 3 ha was considered for representation of a particular wetland type, although all seeps irrespective of size were included as important for processes (see Section 10.1). Similarly, a size threshold of 5 ha was applied to depressions, valley bottom and floodplain wetlands for representation within the conservation portfolio.

9.3 Fish population size

Only fish populations that experts deemed viable were incorporated into the conservation portfolio, where "viable" was defined broadly to mean a self-maintaining, recruiting population of fish.

10 ENSURING PERSISTENT CONSERVATION: ADDITIONAL SPATIALLY EXPLICIT PROCESSES

Many important natural processes will have been incorporated in the assessment through Sections 3 to 9. Some of these may even be spatially explicit, e.g. significant areas of groundwater recharge. This section deals with any *additional* spatially explicit processes that have not yet been incorporated. Mapping spatially explicit processes enables conservation assessments to depict critical management zones in which adverse impacts need to be particularly well-managed to maintain ecological connectivity and integrity.

10.1 Areas for maintenance of wetland functioning

In addition to representing pristine or near-pristine examples of the different wetland types, this conservation assessment recognises the importance of wetlands in maintaining ecological functioning, and providing important goods and services to humans. The hydrogeomorphic typing framework devised for wetlands (*sensu* Ewart-Smith *et al.* 2006) distinguishes Functional Units (Section 5.2), which can be used to describe the functions that each wetland type is likely to provide (Table 18).

All mapped potential wetlands were included in the conservation portfolio as areas which require management. However, not all these wetlands need to be managed in a natural or near-natural condition: we distinguished between wetlands that should be afforded a high level of protection (need to be managed in their natural or near-natural condition) and wetlands that should be afforded a moderate level of protection (those that can withstand some degree of human utilisation and impact). This level of protection was based on a scoring assessment of the functional importance of the wetland, and its sensitivity to anthropogenic impacts. Scores were assigned to functional importance and sensitivity as follows: Very high = 3, High = 2, Moderate = 1. Protection level was then assigned by summing the scores for importance and sensitivity, where wetland types with a summed score of 5 were assigned a high protection level and those with summed scores of 2-5 were assigned a moderate protection level (Table 19).

Table 18: Hydrological functions of the different Functional Units used to type wetlands (After Kotze et al. *2005). Toxicants include heavy metals and biocides. "++" refers to functions that are very likely to be present and often performed to a high level; "+" refers to functions that are likely to be present at least to some degree; and "0" refers to functions that are unlikely to be performed to any significant extent.*

				Enhancement of water quality			
Wetland type	**Flood attenuation**	**Stream flow augmentation**	**Erosion control**	**Sediment trapping**	**Phosphates**	**Nitrates**	**Toxicants**
Valley bottom (channelled)	+	0	++	+	+	+	+
Valley bottom (unchannelled)	+	+?	++	++	+	+	++
Floodplain	++	0	++	++	++	+	+
Depression	+	0	0	0	0	+	+
Seep (channelled)	+	+	++	0	0	++	++
Seep (unchannelled)	+	0	++	0	0	++	+

Table 19: Protection levels afforded to different wetland types
Based on an assessment of functional importance and sensitivity to anthropogenic impacts. Scores were assigned to functional importance and sensitivity as follows: Very high = 3, High = 2, Moderate = 1. Protection level was then assigned by summing the scores for importance and sensitivity, where wetland types with a summed score of 5 were assigned a high protection level and those with summed scores of 2-5 were assigned a moderate protection level.

Wetland type	**Functional importance**	**Sensitivity**	**Protection level**
Valley bottom (channelled)	Very high	High	High
Valley bottom (unchannelled)	High	High	Moderate
Floodplain	High	Moderate	Moderate
Depression	Moderate	Moderate	Moderate
Seep (channelled)	High	Very High	High
Seep (unchannelled)	Moderate	Very High	Moderate

Valley bottom wetlands of the Olifants/Doorn Water Management Area are functionally very important for erosion control, sediment control, water quality, and general maintenance of riverine habitats (Table 18). They are comprised mainly of *Palmiet* vegetation in their natural state. In general, valley bottom wetlands are very vulnerable to loss (more likely to lose the wetland than for it to change to another wetland). This would increase erosion and loss of habitat (e.g. sand bars), which in turn would impact biota such as fish. Thus, these wetlands are very important in maintaining habitat types for indigenous and endemic fish of the Olifants/Doorn Water Management Area. Given the sensitivity to loss of these wetlands, and the relative importance of the channelled and unchannelled valley bottom wetlands, they were assigned protection levels of high and moderate respectively (Table 19).

Floodplain wetlands function mainly to slow down sediments and facilitate spread of flow, thereby facilitating nutrient uptake and water quality improvement. These wetlands are less prone to loss than valley bottom wetlands and, if impacted, are more likely to change their structural characteristics, e.g. to change from a *Palmiet* to a *Phragmites* wetland. These slightly altered wetlands would be able to perform a similar function. Thus, from a functional perspective, floodplain wetlands are generally the most resilient of the functional types, and can be afforded a more moderate level of protection (Table 19).

Seepage wetlands are very sensitive to loss, and have a profound domino effect on the functioning of riverine ecosystems if impacted. They therefore need to be afforded a high level of protection (Table 19).

In general, channelled wetlands are functionally much more important than unchannelled wetlands (Table 18 and Table 19). However, it should be noted that the spatial scale of the analyses that differentiated between channelled and unchannelled wetlands may lead to under-estimating the number of channelled wetlands, since any wetland that is connected to surface drainage through a stream that is finer scale than 1:50 000 will be coded incorrectly as a an unchannelled wetland.

The subsequent map of appropriate protection level for maintaining wetland function is provided in (Figure 30). This GIS layer was applied in the conservation portfolio in a similar way to the significant zones of groundwater discharge (Section 8.3), by flagging areas as either low- or moderate-impact management zones, depending on the wetland's functional importance and sensitivity.

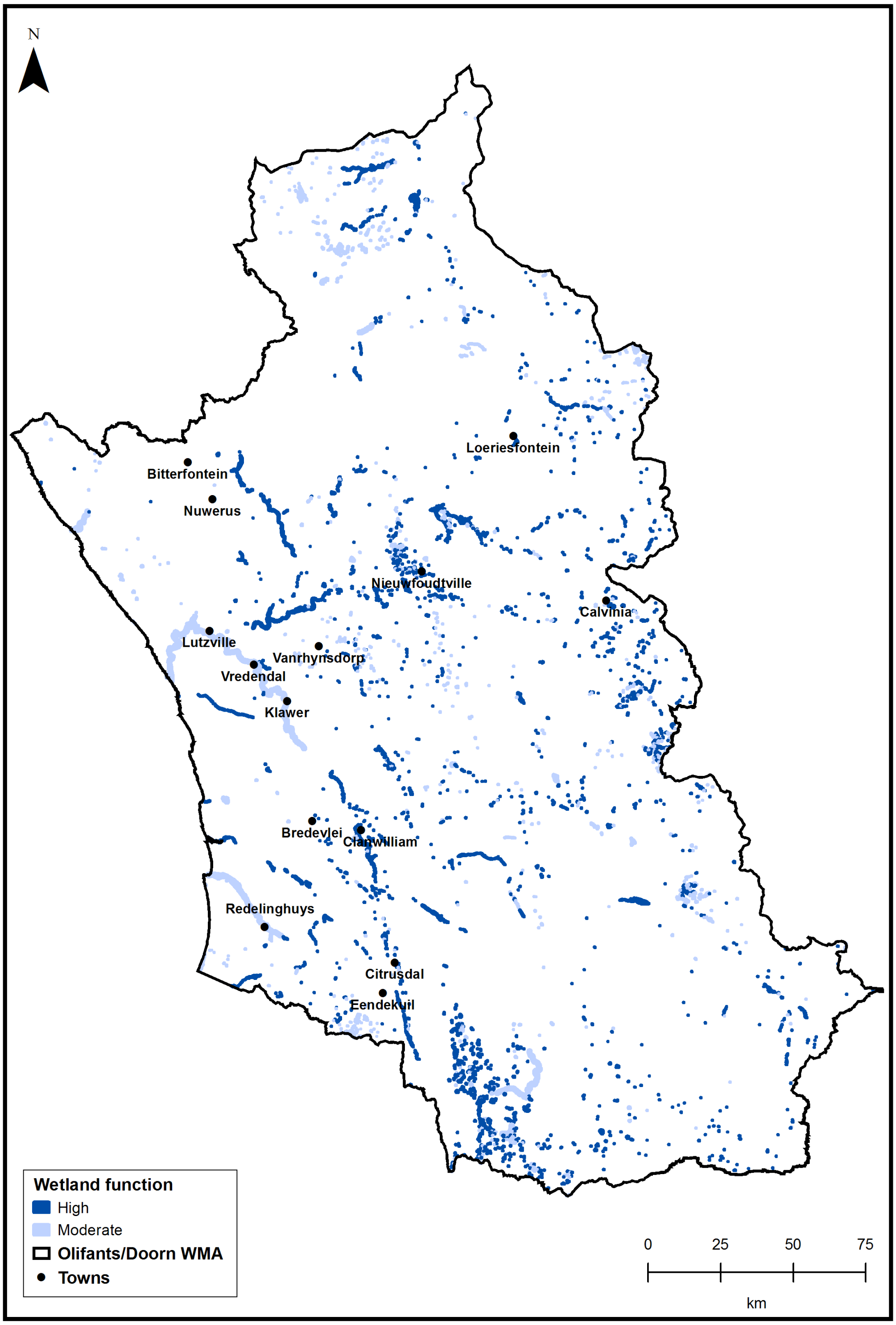

Figure 30: Areas important for maintaining wetland functioning

Wetland delineations have been accentuated for ease of viewing. Those wetlands afforded a high level of protection should be managed close to their natural state. Those wetlands afforded a moderate level of protection could withstand some human utilisation and impacts.

10.2 Migration routes

During delineation of fish sanctuaries, portions of river important for fish migration were flagged as requiring management in an ecological integrity which supports migration (Figure 11). This requires implementing ecological water requirements as per Brown *et al.* (2004), particularly in the low rainfall summer months. A total of 15 sub-quaternary catchments were identified as important for fish migration: 237, 238, 247, 286, 288, 292, 294, 299, 300, 315, 337, 354, 413, 419 and 487. These sub-quaternary catchments were included explicitly in the conservation portfolio (see Section 11.1.4).

10.3 Significant water yield areas

Sub-quaternary catchments that contribute significantly to the water supply of the area should be managed to ensure that activities do not have a major impact on water quality and quantity, which in turn would have a domino effect on the functioning of many dependent ecosystems. This is recognised by the Mountain Catchment Area Act (Act No. 63 of 1970) which delineates major mountain catchment areas that should be managed to ensure sustainable water supply. Mountain Catchment Areas have been delineated for the Olifants/Doorn Water Management Area, and these were used as the areas significant for water yield (see the boundaries of the Mountain catchment areas in Figure 29).

These are strongly correlated with mean annual precipitation, and as a result overlap to a large extent with the significant areas of groundwater recharge (Section 8.3). This GIS layer was applied in the conservation portfolio in a similar way to the significant zones of groundwater recharge, by flagging areas that require land use management that prevents stream flow reduction activities, such as plantation forestry, as well as any activity that would affect water quality.

11 DESIGNING A PORTFOLIO OF CONSERVATION AREAS

The areas included in this conservation portfolio are not intended as formal protected areas only. Rather, they reflect areas that need to be managed appropriately to conserve the full spectrum of freshwater biodiversity for both present and future generations (as per the conservation vision for the Olifants/Doorn Water Management Area; see pg 12). There exist a suite of strategies and policies that could be employed in combination to implement appropriate land and water management (e.g. formal protected area strategies, integrated water resource management strategies, extension and stewardship strategies). An important next step would therefore be to develop management plans for each *field verified* selected area. These management guidelines should outline the most appropriate strategies to employ for that area (see Section 14).

In designing a conservation portfolio, the quantitative conservation targets for representation (Section 3), as well as numerous spatial layers for biodiversity processes (Section 7) are taken into account in order to achieve the conservation vision. To maximise efficiency in achieving this vision, it makes sense to plan for all freshwater ecosystems together (e.g. representative river types, representative wetland types, fish sanctuaries), because in many places conservation targets for wetland and river type representation may be achieved simultaneously. Moreover, conserving representative wetland types will require appropriate management of the riverine habitat[8], and vice versa - conserving river types selected for representation will require appropriate management of the associated wetlands[8].

The section below outlines the selection protocol used to derive the conservation portfolio for achieving the conservation vision within the Olifants/Doorn Water Management Area. This conservation portfolio reflects the areas required to achieve *all* conservation targets, i.e. rivers, wetlands and fish together. Since one of the objectives of this study was to test how this spatial assessment would interface with the National Water Resources Classification System in determining the desired management class of *rivers* from a freshwater biodiversity perspective, a separate section is provided which considers the conservation portfolio for achieving river type targets alone (Section 13).

11.1 Selection protocol

The following steps were used, in the order listed below, to select sub-quaternary catchments and special features for inclusion in the Olifants/Doorn Water Management Area conservation portfolio:

1. Use the 528 modelled sub-quaternary catchments (Section 4.1) as the units of assessment and selection, or the planning unit for rivers and wetlands. Include all special feature delineations as part of the conservation portfolio, but not necessarily the entire sub-quaternary catchment within which they fall.

[8] Although not necessarily in a natural condition

2. Use MARXAN/CLUZ conservation planning decision support software to help with the derivation of an initial plan that takes into account the following multiple criteria:
   - Complementarity and efficiency in achieving conservation targets;
   - Building in longitudinal connectivity; and
   - Where there are choices between sub-quaternary catchments with similar biodiversity features, choose sub-quaternary catchments:
     - containing special features;
     - containing a high proportion of intact wetlands (for maintenance of river functioning);
     - containing protected areas; and/or
     - containing CapeNature stewardship priority areas.
3. Investigate removal of marginal sub-quaternary catchments, defined as sub-quaternary catchments whose cost of conservation to benefit derived through target achievement is above a certain threshold;
4. Add in additional sub-quaternary catchments needed for rehabilitation;
5. Add in additional sub-quaternary catchments needed for migration;
6. Build in large-scale connectivity where it is still needed; and
7. Add in high and moderate management zones associated with special features, areas important for maintenance of wetland function, significant water yield areas, and significant areas of groundwater recharge and discharge.

An outline of each of these steps is provided below.

11.1.1 Step 1: Defining the planning unit

Sub-quaternary catchments were used as planning units for rivers and wetlands. These have the advantage of retaining to some extent the longitudinal, vertical and lateral connectivity of selected river reaches and wetlands. Special features were found to be very land hungry in the conservation portfolio, with not as much rationale for their direct conservation as representative river types and wetlands types, and fish sanctuaries. For this reason, it was decided that special features would be included in the conservation portfolio by means of their actual delineations, as opposed to selecting the entire sub-quaternary catchment within which they fell.

11.1.2 Step 2: Using decision support software to derive initial outputs

The process of using decision support software to aid decision-making on the most efficient way of meeting multiple criteria is frequently applied in conservation planning, since conservation portfolios attempt to achieve multiple conservation targets in an efficient manner, taking into account complementarity. However, to date, most conservation planning software has been developed for terrestrial ecosystems and has limited utility in aiding decision-making for freshwater conservation plans. A recent marine conservation planning software (MARXAN/CLUZ; Ball and Possingham 2000) has been developed, which is more suited to freshwater environments because it builds connectivity into its algorithm. This is now supported by user-friendly front-face software, CLUZ (Smith 2005), that interfaces with a geographic information system (ARCVIEW ver 3.2, ESRI 1997). The MARXAN/CLUZ software was used to provide initial decision support in selecting sub-quaternary catchments for inclusion into the conservation portfolio.

MARXAN/CLUZ selects near-optimal solutions to achieving conservation targets by costing portfolios produced by simulated annealing algorithms, where effective portfolios have the lowest costs. The portfolio cost consists of three parts (see Information Box 2), which help to ensure that the issues in Step 2 of the selection protocol are addressed, namely:

- Complementarity and efficiency in achieving conservation targets;
- Building in longitudinal connectivity; and
- Where there are choices between sub-quaternary catchments with similar biodiversity features, choose sub-quaternary catchments:
    - containing special features;
    - containing a high proportion of intact wetlands;
    - containing protected areas; and/or
    - containing CapeNature stewardship priority areas.

Cost parameters are outlined briefly in Information Box 2, and a more detailed account of how planning unit cost was derived is supplied in Appendix 5. Using the cost parameters, we ran[9] MARXAN/CLUZ to determine the best possible options for achieving conservation targets for river types, wetland types and fish sanctuaries.

11.1.3 Step 3: Investigating removal of marginal sub-quaternary catchments

The cost of including each sub-quaternary catchment into the conservation portfolio was compared to the maximum percentage contribution that sub-quaternary catchment made towards achieving a conservation target. Seven sub-quaternary catchments selected by MARXAN/CLUZ contribute less than 10 % to any particular biodiversity feature (sub-quaternary catchments 102, 152, 306, 359, 399, 427 and 496). However, removal of all these sub-quaternary catchments has a large cumulative effect on overall target achievement of the conservation portfolio. Further examination found that removing all sub-quaternary catchments where the maximum contribution to targets was less than 10 %, **except for** sub-quaternary catchment 306 (required to achieve non-isolated wetlands in Sand and Dune Fynbos), had a much lower impact on overall target achievement of the conservation portfolio. Subsequent removal of these six sub-quaternary catchments brought target achievement of four seasonal or ephemeral river types in the Greater Karoo ecoregion (Appendix 2) to below 100 %, but not below 75 % (i.e. these river types still achieve a target of more than 15 %).

[9] Starting proportion 0.20, BLM 0, Clumping - default step function, Algorithm Used: Annealing and Iterative Improvement, No Heuristic used, Number of runs 500, Number of iterations 5000000, Initial temperature set adaptively, Cooling factor set adaptively, Number of temperature decreases 10000

Information Box 2: MARXAN portfolio costs and costs applied for the Olifants/Doorn conservation portfolio

MARXAN establishes an efficient conservation portfolio by cost. The portfolio cost consists of three parts, which are explained below in terms of the costs applied to the Olifants/Doorn conservation portfolio.

1) The combined planning unit cost

Each planning unit is assigned a cost value. MARXAN calculates the combined cost of all the selected planning units (i.e. those in each portfolio). The Olifants/Doorn sub-quaternary catchments were assigned a basic cost of 400. Planning untis containing (i) special features, (ii) a high proportion of intact wetlands, and (iii) protected areas **or** CapeNature stewardship priority areas were then "discounted" by 100 (i.e. maximum discount could be as large as 300 if the sub-quaternary catchment satisfies all three of these conditions). Where there are choices between two sub-quaternary catchments with similar biodiversity components, this discounting encourages MARXAN to select the more preferred sub-quaternary catchments. For a detailed methodology on setting of planning unit cost, see Appendix 5.

2) The boundary cost

The boundary cost measures the amount of edge that selected planning units in a portfolio share with unselected units. This means that a portfolio containing one connected patch of units will have a lower boundary cost than a number of scattered, unconnected units. Selecting for longitudinal connectivity can be encouraged by assigning a boundary cost to boundaries between sub-quaternary catchments that have rivers running through them into neighbouring sub-quaternary catchments. MARXAN then multiplies this value by the Boundary Length Modifier (BLM) constant, which is a user-defined number. Increasing this number increases the cost of having a fragmented portfolio.

A boundary cost of 200 was assigned to boundaries between sub-quaternary catchments that had rivers running through them into neighbouring catchments. Various scenarios of Boundary Length Modifier were investigated. In the end, it was difficult to ascertain what was being selected for target achievement and what was being selected to counteract boundary cost. Thus, the final conservation portfolio did not include a boundary cost; longitudinal connectivity was added manually in a later step.

3) Target penalty factor (or species penalty cost)

MARXAN calculates whether the target for each biodiversity feature is met by a portfolio and includes a cost for any target that has not been met. In the Olifants/Doorn conservation portfolio, the penalty cost was set at 100 000.

The total cost of a portfolio combines these three costs and is calculated as:

Combined planning unit cost + (boundary cost * BLM) + Combined species penalty factors

11.1.4 Step 4: Adding additional sub-quaternary catchments for rehabilitation

A rehabilitation assessment was conducted for river types that could not achieve their 20 % conservation targets in A- or B-category rivers (Section 12.1). Thirteen sub-quaternary catchments were identified as feasible for rehabilitating rivers in order to help achieve river type targets, namely: 131, 248, 262, 264, 341, 353, 354, 358, 362, 364, 405, 508 and 512. Four of these catchments (131, 341, 508 and 512) had already been included in the plan for conservation of representative wetland types. The remaining nine were also explicitly incorporated into the plan, and flagged as sub-quaternary catchment requiring river rehabilitation (rivers should be rehabilitated to an ecological integrity category of A or B).

11.1.5 Step 5: Adding additional sub-quaternary catchments for migration

During delineation of fish sanctuaries, sub-quaternary catchments important for fish migration were flagged as requiring an ecological integrity that supports the longitudinal connectivity required for migration. A total of 15 sub-quaternary catchments were identified as important for fish migration (237, 238, 247, 286, 288, 292, 294, 299, 300, 315, 337, 354, 413, 419 and 487). Four of these had already been selected through the above steps. The 11 remaining sub-quaternary catchment were added explicitly to the conservation portfolio, and flagged as moderate management zones, to be managed in at least a C-ecological integrity category.

11.1.6 Step 6: Building in longitudinal connectivity where it is still needed

Using MARXAN/CLUZ and the sub-quaternary catchments as planning units facilitates some degree of longitudinal connectivity within river systems. However, the connectivity is often not adequate, and needs to be fully accomplished manually. Headwater reaches were all sufficiently large (≥ 1 km) and were left as isolated. This step focused mainly on upstream connectivity. An additional 41 sub-quaternary catchments were flagged as upstream management areas, requiring moderate management. This included all the intact tributaries of the Doring River that drain the Cederberg. These tributaries are very important in achieving the ecological water requirements for the Doring River, and their management is essential to ensure the sustainability of the downstream conservation areas. All rivers within these upstream management areas were assigned to a moderate management zone, to maintain the downstream habitat.

11.1.7 Step 7: Adding in low- and moderate-impact management zones

These included:

- Special features (Section 4.3) - as low-impact management zones;
- Areas important for maintenance of wetland function (Section 10.1) – as low- or moderate-impact management zones, depending on functional importance and sensitivity;
- Significant water yield areas (Section 10.3) – as moderate-impact management zones;
- Significant areas of groundwater recharge (Section 8.3.1) – as moderate-impact management zones; and
- Significant areas of groundwater discharge (Section 8.3.2) – as moderate-impact management zones.

12 THE OLIFANTS/DOORN CONSERVATION PORTFOLIO

Separate analyses of rivers and wetlands in MARXAN/CLUZ revealed that, whilst conservation targets for both river and wetland types can be achieved simultaneously in many places, some areas required for wetland habitat representation are not necessarily required for river type representation, and vice versa. Thus, selecting representative river types will not automatically conserve of the full spectrum of wetland types, and vice versa. This is evidenced by the patterns of **irreplaceability** displayed by MARXAN/CLUZ outputs (Figure 31). Irreplaceability is a measure of the likelihood that a particular sub-quaternary catchment will be required in the conservation portfolio for achieving targets. A sub-quaternary catchment is totally irreplaceable if it contains a biodiversity feature whose targets can be achieved nowhere else in the planning domain.

Because areas required for achieving targets for fish and river types are not always congruent with those areas required for wetland types, incorporating both rivers and wetlands into the conservation portfolio produces a more land hungry portfolio than one only for rivers (see Section 13), or only for wetlands. The resulting conservation portfolio (Figure 32) was divided into four zones:

(i) River and wetland conservation zones. These are sub-quaternary catchments required for achievement of wetland and/or river targets. Any intact wetland or river selected should maintain a present ecological integrity class of A or B.

(ii) River rehabilitation zones. These are sub-quaternary catchments that require rehabilitation of their rivers to an A or B ecological integrity class to help achieve conservation targets.

(iii) Low-impact management zones. Only low impact activities should be allowed in these areas, to maintain the integrity of one or more of the following biodiversity features: special feature and/or wetland function.

(iv) Moderate-impact management zones. Only moderate impact activities should be allowed in these areas, to maintain the integrity one or more of the following biodiversity features: wetland function, fish migratory corridor, upstream management area, significant water yield area, significant groundwater recharge area, and/or significant groundwater discharge area.

An area could be allocated to a low- or moderate-impact management zones for a variety of reasons, which would affect the way in which it is managed. For example, an area allocated to a moderate-impact zone because it is a high groundwater recharge area will require management of groundwater abstraction, clearing of alien invasive plants and maintenance of natural vegetation; whereas an area assigned to a low-impact zone because of the presence of a seep may have more specific criteria. The reasons for allocating a specific area to each of the four classes above are described in Appendix 6, which provides a table of all biodiversity features within each selected sub-quaternary catchment. This information is also recorded in the associated GIS layer.

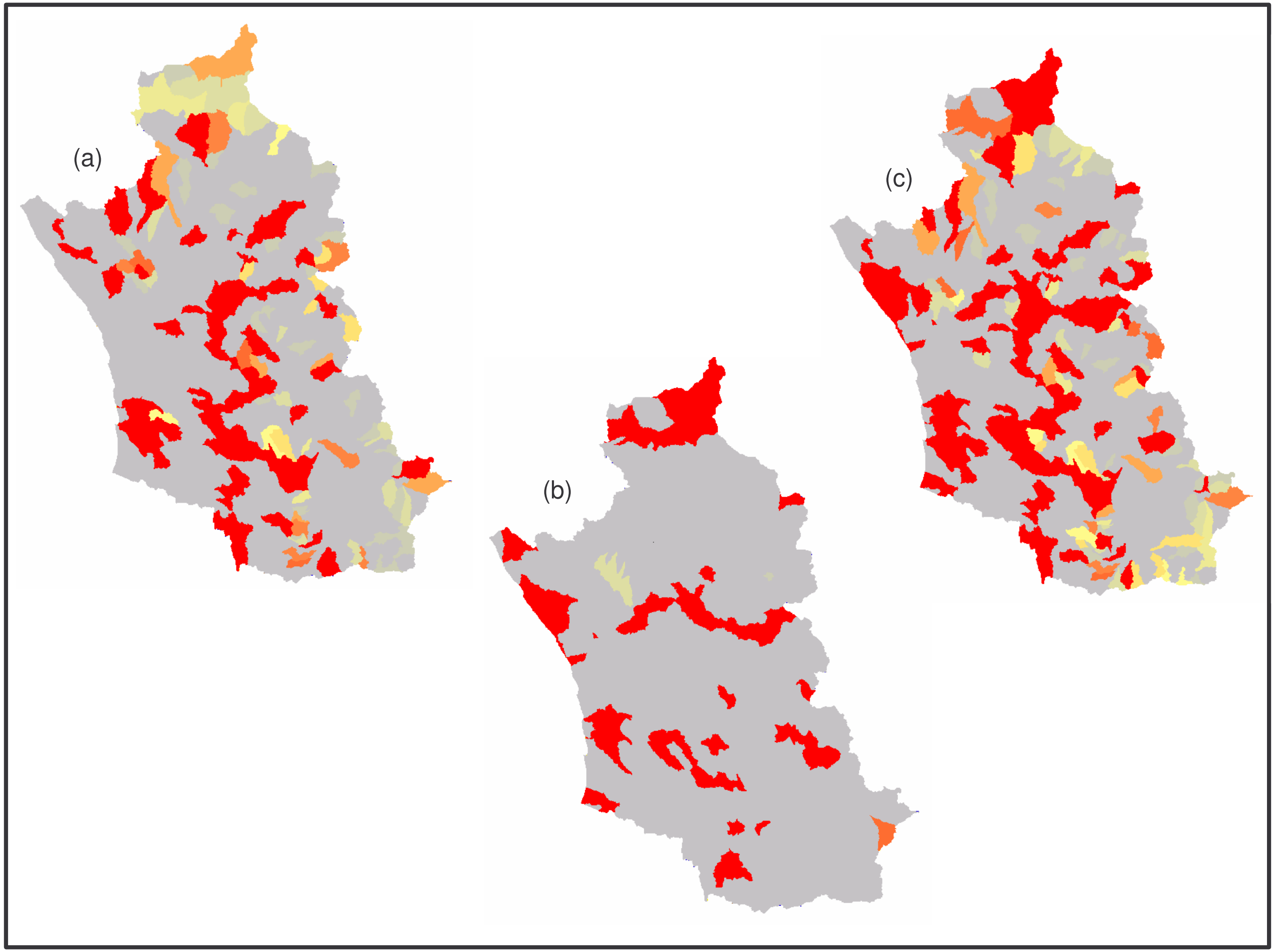

Figure 31: Irreplaceability for (i) rivers and fish, (ii) wetlands, and (iii) rivers and wetlands combined.
In many instances areas required for rivers and wetlands are not the same, resulting in (iii) having many areas of high irreplaceability

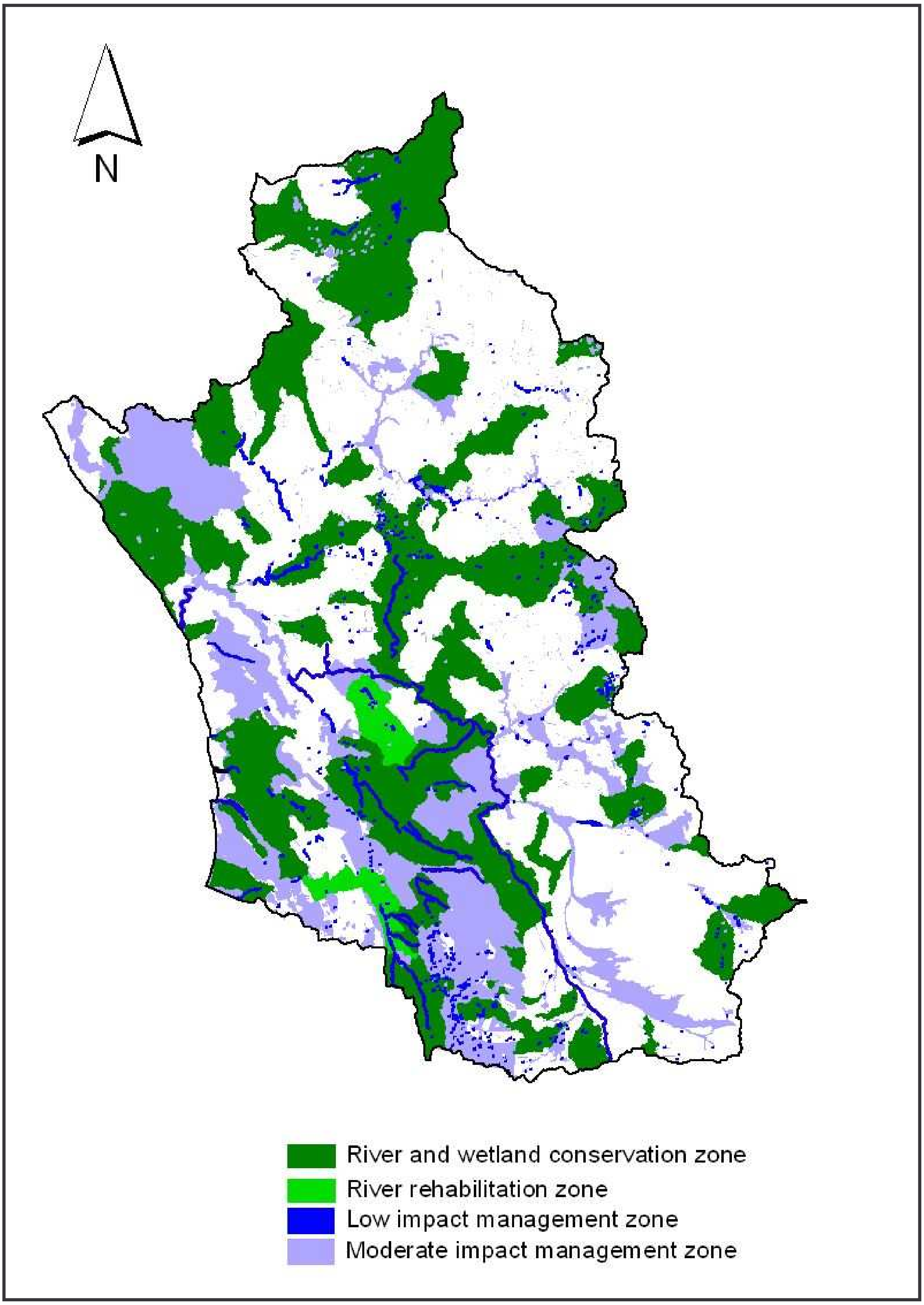

Figure 32: The conservation portfolio for the Olifants/Doorn Water Management Area

12.1 Rehabilitation assessment for river types

There are 25 river types in the Olifants/Doorn Water Management Area that cannot fully achieve their conservation target in the remaining intact rivers. Three of these 25 river types can achieve at least a 15 % target (instead of 20 %). Expert knowledge, the River Health desired state and the best attainable ecological management class (AEMC; Kleynhans 2000) were used to assess feasibility of rehabilitation. The consequences of not being able to meet targets in the water management area were examined. For unique, or endemic, river types (those that have more than 80 % of their national range within the Olifants/Doorn Water Management Area), not meeting targets in the water management area implies that a national target will not be met. There are 16 such Level 3 river types, of which four are not feasible to rehabilitate to an A- or B-category. For the remaining eight endemic river types, rehabilitation should be a serious consideration.

Where examples of the river type occur elsewhere, a rapid (qualitative) assessment was made of the potential for that area to adopt the 20 % portion of the Olifants/Doorn target. This was based on an assessment of **Level 2** river types, and a preliminary analysis of river ecological integrity for the entire country, using existing data for main rivers and the percentage natural vegetation as a proxy for the integrity of tributaries (Section 7.1).

This assessment of rehabilitation potential divided the 25 river types assessed into five categories (Figure 33, Appendix 7):

(1) Best conserved elsewhere

- Includes two river types.
- Sub-quaternary catchments containing good examples of these river types have been flagged for rehabilitation in the subsequent conservation portfolio (Section 11.1.4).

(2) Rehabilitation is feasible

- Includes 11 river types.

(3) Rehabilitation is not feasible and conservation opportunities elsewhere also look bleak

- Includes five river types.
- An assessment at the national level should be undertaken to identify where it would be best to rehabilitate these river types.

(4) Rehabilitation is not feasible and cannot be conserved elsewhere (unique to study area)

- Includes four river types.
- These river types are now critically endangered in the country (i.e. have failed to meet the national target).

(5) Sufficiently achieved its conservation target (target > 15 % of total length can be achieved)

- Includes three river types.
- It is quite feasible to rehabilitate one of these river types, to fully achieve its target, but not essential.

As a result of this assessment the following sub-quaternary catchments were included in the conservation portfolio: 131, 248, 262, 264, 341, 353, 354, 358, 362, 364, 405, 508 and 512. Any 1:500 000 river within these sub-quaternary catchments are deemed feasible to rehabilitate to an A- or B-category for conservation target achievement.

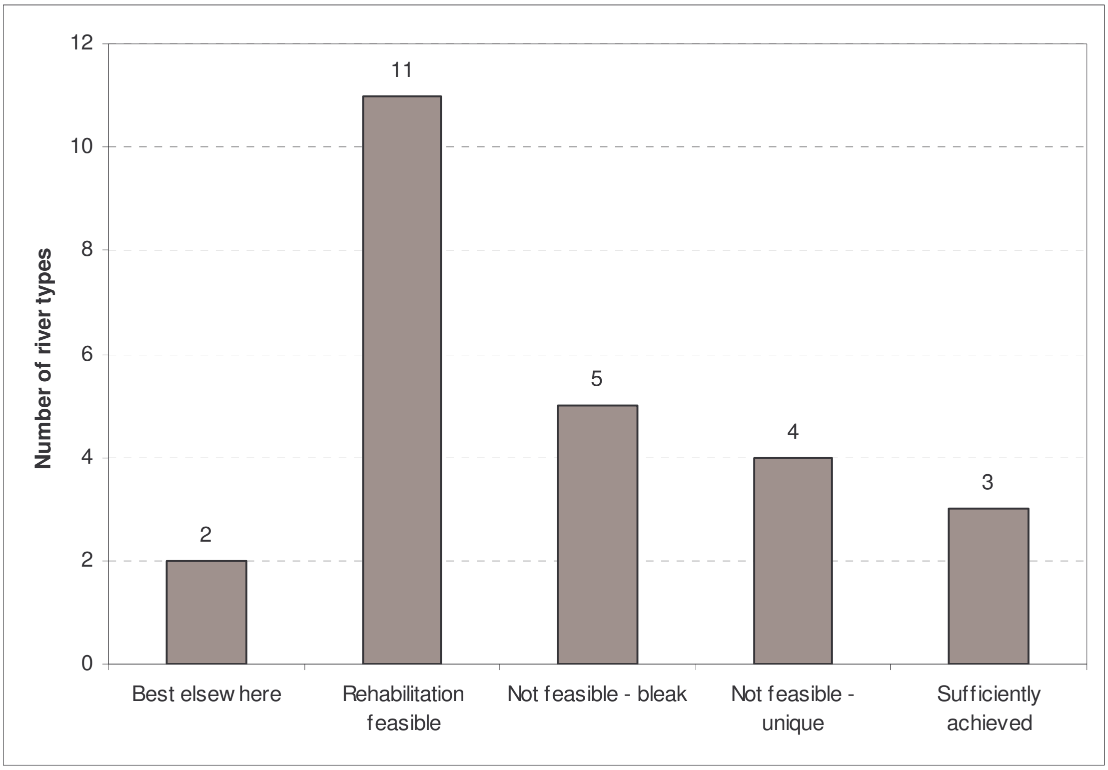

Figure 33: Rehabilitation assessment for river types that cannot fully meet their targets Showing river types that (1) are best conserved elsewhere; (2) should be rehabilitated to an A or B ecological integrity within the Olifants/Doorn Water Management Area; (3) not feasible to rehabilitate in the study area and conserving elsewhere looks bleak; (4) not feasible to rehabilitate in the Olifants/Doorn Water Management Area and unique to the area; and (5) cannot meet the entire 20 % target, but can meet some and deemed sufficiently achieved. See text in Section 12.1 for the implications of each category.

12.2 Assessment of targets achieved

12.2.1 River types

The sub-quaternary catchments selected as river and wetland conservation zones (Figure 32) would achieve the conservation targets of 56 (72 %) river types in the Olifants/Doorn Water Management Area (Table 20). If the 1:500 000 rivers in the sub-quaternary catchments selected as river rehabilitation zones (Figure 32) are rehabilitated, then 11 additional river types will meet their conservation targets. Thus, with feasible rehabilitation, 14 % of the river types can meet their targets in the Olifants/Doorn Water Management Area. It is not possible to meet conservation targets of the remaining 11 river types (or 14 %), as rehabilitation of examples of these river types in the area is not feasible. Section 12.1 details the consequences of not conserving the 11 river types that cannot meet their targets.

Table 20:Achievement of conservation targets for Level 3 river types
Numbers in brackets represent % of total number of river types.

Targets met without rehabilitation*	Targets achievable with rehabilitation	Rehabilitation is not feasible & cannot meet targets in study area
56 (72)	11 (14)	11 (14)

* Any river type that met a target of ≥15 % was considered sufficiently achieved

12.2.2 Wetland types

The sub-quaternary catchments selected as river and wetland conservation zones (Figure 32) would achieve the conservation targets of 37 (82 %) wetland types in the Olifants/Doorn Water Management Area. Eight of the 45 wetland types (18 %) cannot achieve targets in wetlands deemed intact. These are all associated with lowland areas:

- Floodplain - Alluvial
- Floodplain - Renosterveld
- Floodplain - Sand and Dune Fynbos
- Channelled valley bottom - Dune Strandveld.
- Channelled valley bottom - Sand and Dune Fynbos
- Unchannelled valley bottom - Sand and Dune Fynbos
- Channelled seeps - Sand and Dune Fynbos
- Unchannelled non-perennial depression - Renosterveld

Future work should investigate rehabilitation of prime examples of these types where possible.

12.2.3 Fish

The conservation portfolio achieves targets for eight of the nine endemic fish species, and for all three of the indigenous fish species. The Clanwilliam sandfish (*Labeo seeberi*), which was once widespread through the Olifants and Doring Rivers, now only occurs in the Doring River. It is not feasible to re-stock the Olifants River with populations of this species. Re-stockings will only be effective if invasive alien fish can be removed from the system altogether, and since this is unlikely for mainstem reaches, the only re-stocking projects that should be considered should be for those rivers coinciding with CapeNature's existing rotenone (alien fish control) programme, and these should be regarded as early trials. To replace the population on the Olifants River system, two populations, instead of one, were selected on the Doring River system.

12.2.4 Special features

All biodiversity elements mapped as special features (Section 4.3) enjoy a high level of protection in the conservation portfolio, being assigned to low-impact management zones. Some of these special features are particularly noteworthy, given their vulnerability to land and water use pressures. These are the:

- *Olifants estuary mouth* – attention needs to be given to ensuring that the ecological water requirements for this estuary, as per Brown *et al.* (2004), are met. Flows from the Doring River are important for ensuring that the water requirements are met, as the Olifants River system is already over-utilised.

- *Doring River* – There is considerable pressure to build a dam on this river, which represents one of the last few large rivers in the country that does not have a large dam on its mainstem. This will not only be catastrophic for the many endemic fish species, but will also have dire consequences for the Olifants estuary. At present, the Doring River improves water quality and quantity below its confluence with the Olifants River, thereby helping to meet the ecological water requirements for the Olifants River estuary.

- *Verlorevlei* – This is an internationally proclaimed RAMSAR site. Its current ecological integrity is unacceptable, and the area should be rehabilitated as a priority.

12.2.5 Free-flowing rivers

The Doring River is one of the few large rivers in the country with no major instream dam on its mainstem. It supports a high number of endemic fish, and is also important for maintaining the functioning of the economically important Olifants River estuary, through improving water quality and quantity below its confluence with the Olifants River. It contains mountain streams, as well as upper and lower foothill streams, but no lowland floodplains. This river qualifies as a free-flowing river in terms of the criteria set in this study, and it should be a national priority to maintain this status.

By South African standards, the Doring River is arguably one of the better candidates to set aside as an example of a large, intact river with no major dams on its mainstem. However, international standards for a free-flowing river are more stringent, stipulating that in addition to having no major dams on the mainstem, only one of the major tributaries are allowed to be dammed. Under these more stringent criteria, the Doring River would not qualify. Although there are no large dams on the Doring River, numerous small farm dams have been constructed throughout the upper Doring catchment, which undoubtedly have a cumulative impact on the flow of the river. To minimise the impact of existing abstractions, abstraction should be more focussed towards winter (June to September). The focus should also be on using these existing abstractions optimally and preventing further building of in-stream dams. The upper Doring River also receives a water transfer from the Breede Water Management Area for irrigation purposes. However, the ecological impact of this transfer appears to be highly localised, impacting only the portion of the Doring River flowing through the Koue Bokkeveld.

That the Doring is still one of the best candidates for free-flowing rivers in South Africa, despite the numerous small dams, highlights how heavily utilised and highly regulated South Africa's large rivers are. There is a strong need to set a national imperative for identifying and representing at least the best examples of the last few remaining free-flowing rivers in South Africa.

13 INTERFACING WITH THE NATIONAL WATER RESOURCES CLASSIFICATION SYSTEM

The National Water Act (Act No. 36 of 1998) provides for the classification of water resources to protect aquatic ecosystems, as well as terrestrial ecosystems that are dependent on groundwater, in order to ensure sustainable utilisation and protection of the resources. This water resources classification will therefore assist in achieving a balance between the long-term ecological health and integrity of all water resources, and the continuing availability of water for social development and economic activities.

A system for water resources classification is currently being developed to provide a consistent framework within which water resources can be classified, each class representing a different level of protection. Three management classes are being considered (Table 1): Class I: Minimally used; Class II: Moderately used; and Class III: Heavily used. A fourth class, 'Unacceptably Degraded' , was considered but was not put forward for gazetting as planning for unacceptable degradation is not considered an option. Increasing restrictions on use will apply as the level of protection increases, and the system will provide specifications against which management decisions can be made about the nature and extent of permissible, sustainable resource use. The system will also provide guidance on the involvement of water users and other stakeholders in the process of classifying water resources.

There may be numerous possible class configurations for a particular water management area. On the one extreme, a catchment may adopt the sustainability baseline configuration in which water resources are configured to derive a D ecological integrity at catchment outlets (equivalent of the proposed management Class III). This scenario is driven by water allocation, with secondary consideration to ecological requirements. At the other end of the spectrum, a catchment could be maintained in a near-pristine condition, where an A or B ecological integrity category is adopted throughout (equivalent of the proposed management Class I). This scenario is driven by ecological requirements first, and then by water allocation.

One of the objectives of this study (Section 1.3) was to test how conservation planning can be tailored to inform the ecological configurations put forward by the proposed National Water Resources Classification System. A catchment configuration was derived using a combination of the rivers selected for achieving river type targets, and the desired state proposed by the River Health Programme's State of Rivers Report (RHP 2006). The social, economic and ecological implications of this configuration scenario, hereafter termed the "Targets + REC Configuration", were then examined further by the team developing the National Water Resources Classification System.

The section below briefly describes the approach used to derive the "Targets + REC Configuration", and the early lessons that are emerging regarding the interfacing of conservation plans and the National Water Resources Classification System.

13.1 Deriving the "Targets + REC Configuration"

To derive this scenario, MARXAN/CLUZ was run[10] to achieve river targets only (see Appendix 5 for details on calculating planning unit cost for these runs). This produced a GIS layer with sub-quaternary catchments selected by MARXAN/CLUZ as the most efficient set to achieve river targets.

This resulting MARXAN/CLUZ GIS layer was manipulated as follows:

- Two sub-quaternary catchments that contain rivers in a D ecological category in the Koue Bokkeveld (sub-quaternary catchments 384 and 429) were removed, as well as one on the Koebee River system (sub-quaternary catchment 195). These were considered artefacts selected by MARXAN/CLUZ through applying the boundary length cost, and do not contribute toward river targets.
- Any fish sanctuaries selected in rivers that are not currently intact (i.e. their present ecological category is lower than an A or B) were flagged for rehabilitation.
- Sub-quaternary catchments where rivers should be rehabilitated to an A or B ecological integrity category to help achieve targets for river types (see Section 12.1) were added.
- Sub-quaternary catchments that are required in a desired state one up from their present ecological status were selected and flagged as "PES-One-up". A sub-quaternary catchment qualified for this selection if it satisfied one of the following two criteria:
    - Located upstream of a conservation zone, with a present ecological status lower than a C ecological integrity category; or
    - Just upstream from a River Health Programme site that has been flagged as requiring a desired state better than the present state (RHP 2006).

Figure 34a shows the resulting sub-quaternary catchments flagged as river conservation zones, river rehabilitation zones, and those containing rivers which require rehabilitation to one category above their present ecological status. These zones were then used to code desired ecological integrity of the 1:500 000 rivers GIS layer (Figure 34b), as follows:

- Rivers within river conservation zones were assigned a desired ecological integrity category of AB (i.e. natural or largely natural);
- Rivers within river rehabilitation zones were assigned a desired ecological integrity category of AB;
- Rivers within a "PES-One-up" zone were assigned a desired ecological integrity category that was one category improved from its present ecological status (modelled for tributaries, see Section 7.1). For example, a river in a sub-quaternary catchment of D ecological integrity category coded as "PES-One-up", was assigned to a desired ecological integrity category of C; and
- The present ecological integrity category of all remaining rivers was used as the desired ecological integrity category, i.e. no further degradation of ecological integrity was accepted.

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[10] Starting proportion 0.20, BLM 1, Clumping - default step function, Algorithm Used: Annealing and Iterative Improvement, No Heuristic used, Number of runs 100, Number of iterations 5000000, Initial temperature set adaptively, Cooling factor set adaptively, Number of temperature decreases 10000

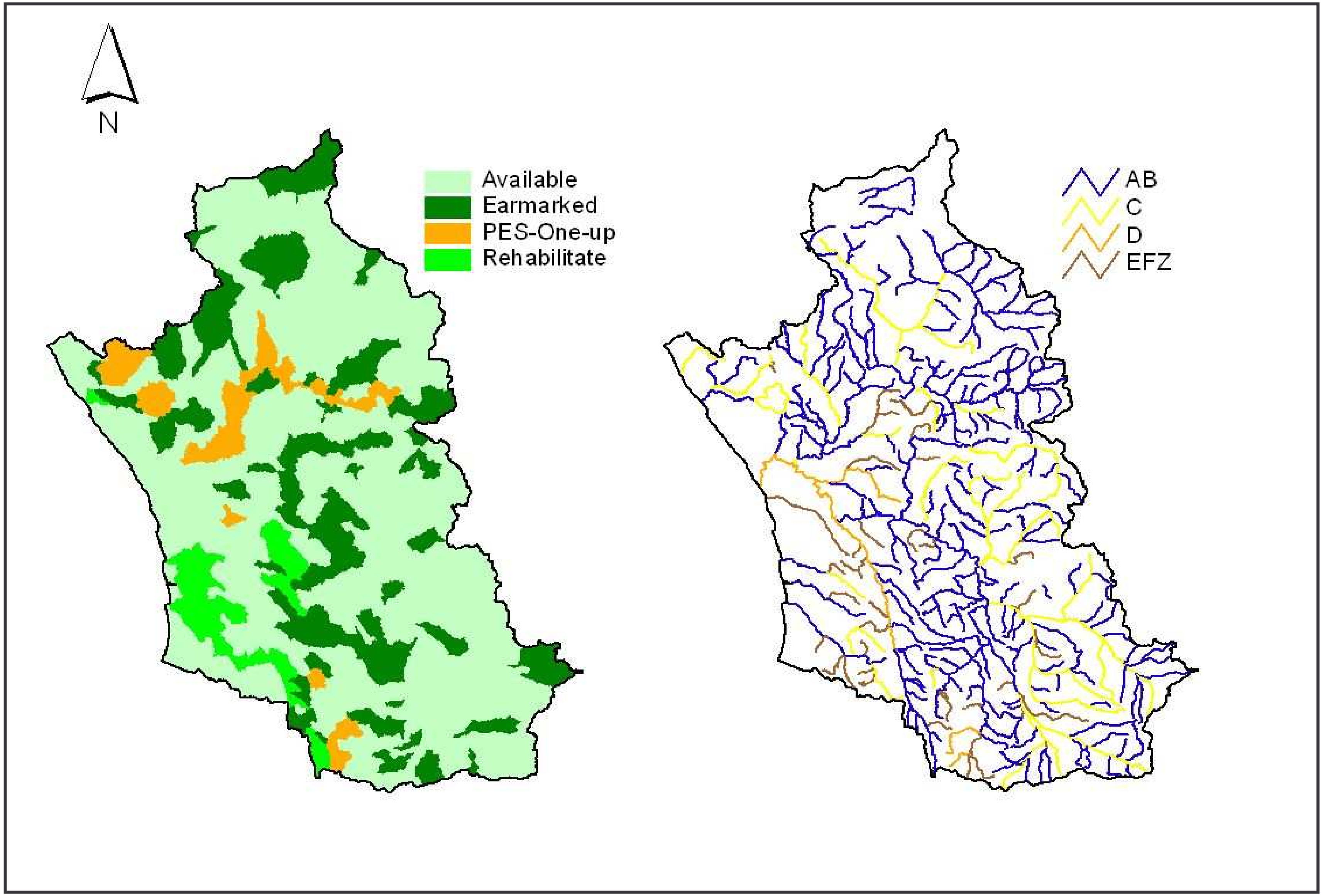

Figure 34: (a) Zones used to derive the "Targets + REC Configuration" scenario shown in (b)

13.2 Lessons learnt

13.2.1 Spatial scale discrepancies

The National Water Resources Classification System as it stands at present is at too coarse a spatial scale to be meaningful for finer scale conservation plans.

A preliminary[11] output of the "Targets + REC Configuration" was provided to the team developing the National Water Resources Classification System as one of the scenario configurations for testing. Each configuration tested will have implications in terms of the water quality and quantity required at certain monitoring nodes, and these are translated to quantifiable social, economic and ecological impacts. To quantify these impacts at the nodes, it is necessary to have data on ecological water requirements, or at least a fair amount of confidence in extrapolating ecological water requirements to that node. This necessitates analysis at a very broad scale that considers main rivers only, since there is very little, if any, data at the scale of smaller tributaries.

Therefore, the National Water Resources Classification System was only able to apply the "Targets + REC Configuration" to *main rivers of quaternary catchments*. Moreover, the desired class of all rivers within a quaternary catchment was generalised to the condition required at the *outlet* of that catchment. This implies that any tributary selected as a river conservation zone within a quaternary catchment that has a C-category desired at its outlet will also be classified as a category C, rather than A or B, within the National Water Resources Classification System.

Using only main river recommendations to classify water resources has profound implications from a biodiversity perspective. Main rivers in South Africa are heavily utilised and regulated to provide water security for socio-economic demands. Tributaries are often less impacted than main rivers and therefore play a critical role in conserving the freshwater biodiversity of South Africa. It is of concern that the National Water Resources Classification System caters for main rivers only. Use of qualitative data at finer scales, based on expert knowledge of the area, is a possible avenue to explore for classification of tributaries.

13.2.2 Conservation assessments should be further prioritised to facilitate trade-offs

The freshwater conservation assessments that have been developed for South Africa to date have focussed on providing a set of catchments that achieve conservation targets in as efficient an area as possible. Although ecological integrity is often associated with socio-economic conditions, the allocation of the catchments is done in isolation to explicit social and economic trade-offs. The National Water Resources Classification process will involve considerable trade-offs between social, economic and ecological goals. It is therefore important that the conservation assessment is further prioritised to get an idea of the absolute non-negotiable areas, as well as the areas where there are more options. A map of irreplaceability is a very useful tool for this

[11] An initial output, based on a rapid conservation assessment, was produced for testing during the development of the National Water Resources Classification System. This GIS layer was later refined to produce Figure 34.

prioritisation (Figure 31a), providing a measure for each sub-quaternary catchment of the likelihood that it will be required in the conservation portfolio for achieving targets. A sub-quaternary catchment is totally irreplaceable (non-negotiable) if it contains a biodiversity feature whose targets can be achieved nowhere else in the planning domain. From Figure 31a it is clear that there are a number of sub-quaternary catchments that have a low irreplaceability. For these sub-quaternary catchments, trade-offs may be possible.

13.2.3 Integrating conservation planning and ecological reserve studies

It is very important, particularly in a water limited country such as South Africa, to quantify the impacts that different resource use scenarios are likely have on flow. Conservation assessments help identify which rivers are best suited for conservation purposes, and which upstream areas are thus important for management. However, they provide insufficient detail on exactly how these upstream areas are maintained in a state that promotes downstream integrity. For example, if a main river is required in a certain ecological integrity category for conserving biodiversity, then how many of its tributaries can be dammed before being in danger of degrading the main river through over-abstraction? These questions require developing an understanding of the ecological water requirements necessary for maintaining a particular system in a certain ecological integrity category, which is the objective of ecological reserve studies.

The portfolio of freshwater conservation areas should be considered the first cut in planning. To obtain the level of detail necessary to provide concrete management guidelines that address the questions above, it is necessary to prepare detailed integrated water resources management plans in catchments selected for the conservation portfolio.

14 NEXT STEPS: ACHIEVING COOPERATIVE CONSERVATION ACTION

The conservation portfolio presented in Section 12 identifies spatial areas for conservation action. This alone is not enough to catalyse conservation action and should not be seen as the completed conservation plan (Figure 35). These spatial priorities need to be coupled to an implementation strategy developed in collaboration with the key stakeholders who implement conservation actions, and/or impact freshwater ecosystems (Driver *et al.* 2003, Knight et al. 2006).

A major value of systematic assessments lies not only in the selected conservation areas they identify, but also in the **mechanism they provide for stakeholder collaboration** around conservation action. Providing such a mechanism for collaboration is immensely important in conserving freshwater ecosystems, which can be considered one of the greatest governance challenges faced by modern societies - water affects every activity of human society and everyone needs to be part of the solutions for conserving freshwater ecosystems.

Cooperation, however, does not just happen. The management, or governance, of freshwater ecosystems takes place in a complex environment where decision-making is typically associated with low levels of certainty and potentially high levels of disagreement among stakeholders. In this environment, active and respectful negotiations are required to ensure that organisations, departments and agencies with different professional identities and mandates can successfully agree to and achieve shared objectives. One of the organisations will have to play a leadership role in facilitating the establishment and maintenance of a network of role players that share a passion and commitment for conserving a representative and functional sample of the freshwater biodiversity of this Water Management Area. If this level of leadership does not emerge naturally, a "river conservation steward" could be appointed to fulfil this cross-cutting function.

Different organisations will have different skills and interests, and the outputs of this systematic conservation assessment can be manipulated for different implementing agencies during the strategy development process. For example, DWAF's interest may lie in setting recommended management classes for rivers, Working for Wetlands may be particularly interested in priority areas for wetland rehabilitation, Working for Water could draw strategic guidance on the priority areas for clearing of alien invasive plants, whilst CapeNature may be interested in fish sanctuary areas.

There are two immediate next steps, which could be undertaken in parallel. The first is to begin developing an effective implementation strategy in collaboration with stakeholders. The second is to field verify the conservation portfolio, and in turn refine the strategy where necessary. This latter step is very important as many selected areas are based on best available data, some of it modelled. To begin developing an implementation strategy, it is essential to identify key responsible parties for implementing freshwater conservation from the different spheres of government (national, provincial and local), business and civil society. This should include organisations responsible for water resource management; environmental monitoring, reporting and management; biodiversity conservation; and land management. Other aspects that should receive close attention in the implementation strategy include:

- Development of a cooperative governance framework which would form the building block for the implementation of the conservation plan for the region;
- Capacity (skills and knowledge) required to implement conservation action and to "do the right thing";
- Financial resource requirements;
- Providing clear definition of roles and responsibilities, and possibly of required institutional and functional design aspects that may currently be lacking;
- Problem-solving, negotiation and conflict management skills (this is an inevitable requirement where overlapping responsibilities and conflicting of interests are realities); and
- Developing a monitoring and evaluation system, not only for achievement and revision of ecological and conservation targets or objectives, but also for institutional and individual performance measurements.

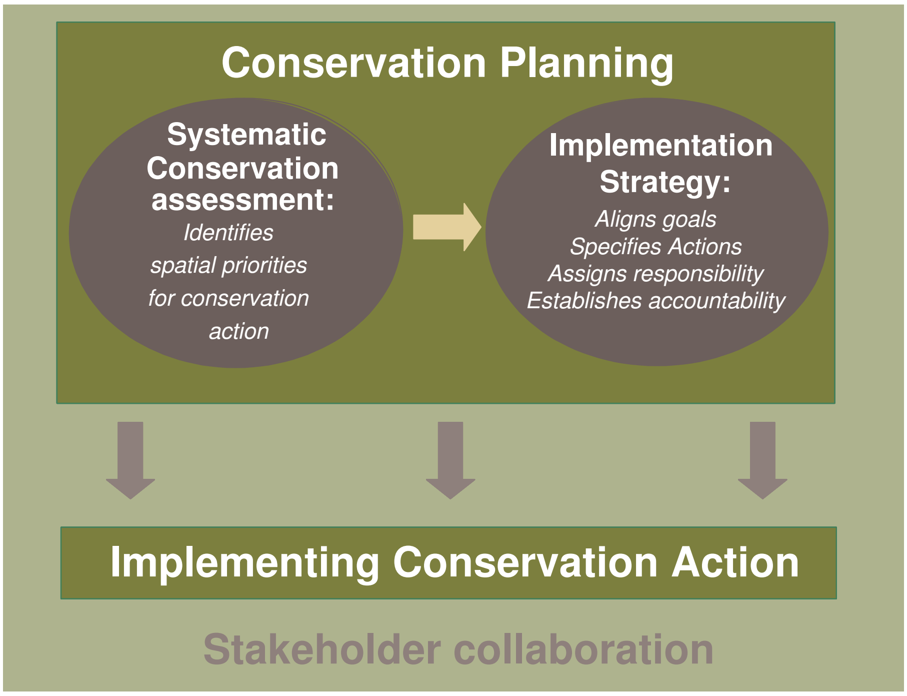

Figure 35: A framework for an effective conservation planning process
After Knight et al. *(2006). This framework contains at least three complementary processes: (1) undertaking a systematic conservation assessment, (2) developing an implementation strategy, underpinned by (3) stakeholder collaboration.*

At a finer level of detail, the implementation strategy should address the development of management plans for each area selected in the conservation portfolio. These management plans should outline the most appropriate strategies to employ for each selected *AND field verified* area, depending on criteria such as the characteristics of the biodiversity features requiring conservation, the main land use pressures and threats in the area, the socio-economic opportunities and constraints, and specific financial and institutional arrangements. The biodiversity features in each selected area, as well as some key management interventions, are provided in Appendix 6 to guide the development of these management plans. Generic management interventions include:

- Retaining natural flow regime (both in terms of magnitude and variability). Flow is one of the most effective management tools available to flush out invasive alien fish and plants, as well as accumulated sediment in rivers, thereby increasing the quantity and quality of spawning habitat for fish, and providing cues for migration and spawning. Management actions to maintain natural flow regime should include:
    - Existing abstractions should be more focussed towards winter (May to September on the Olifants River system; June to September on the Sandveld, Doring and Knervlakte systems).
    - Water release from the Clanwilliam Dam should take note of the ecological requirements of the Olifants-Doring River system (Brown et al. 2004). This includes at least one winter release (preferably August), even if the dam is not full.
    - Optimal use should be made of existing abstractions through demand-management measures.
    - Controlling groundwater abstractions, particularly in the Sandveld and Koue Bokkeveld sub-areas.
    - No further building of instream dams and weirs (not only do these restrict movement, but it has also become common practise in the area to ignore the requirement of allowing summer water releases).
- Prohibiting the stocking of farm dams (even off-stream dams) with alien fish.
- Regular spear-fishing and netting of alien fish as a rehabilitation or control measure.
- No further granting of licenses for extensive agriculture. The catchment as a whole is only just in water balance (water demand equals water availability).
- Enforcing the 35 m riparian buffer zone. This applies to crops, since rivers and their associated biota are highly susceptible to crop pesticides. It also applies to excluding livestock, which cause considerable bank erosion, with subsequent degradation of water quality.

One of the most appropriate frameworks within which to implement this conservation assessment would be the Catchment Management Agencies under the auspices of DWAF. The Olifants/Doorn Water Management Area is a relatively well-resourced area, and there is considerable momentum towards establishing a Catchment Management Agency (DWAF 2005c), with the mobilisation of 11 catchment management forums. Strategies and plans for these forums are in the process of development, providing an excellent opportunity for incorporating aspects of this conservation plan into the strategies and business plans of these forums. It is recommended, that in order to capitalise on this opportunity, the implementation strategy to accompany this conservation assessment should be developed as a matter of urgency.

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Appendix 1: Policy objectives and guiding principles for conserving freshwater biodiversity

The national goal, cross-sector policy objectives and implementation principles for conserving freshwater biodiversity in South Africa are summarised below. These are from Roux *et al*. (2006).

The national goal is to conserve a sample of the full variety or diversity of inland water ecosystems that occur in South Africa, including all species as well as the habitats, landscapes, rivers and other water bodies in which they occur, together with the ecosystem processes responsible for generating and maintaining this diversity, for both present and future generations.

Five cross-sector policy objectives are imperative to achieving the national goal, namely:

Objective 1: Set and entrench quantitative biodiversity targets for inland water biodiversity. To implement this objective:

- Target setting must be coordinated and directed from a national level and endorsed by sub-national implementation agencies. The national guideline is to conserve at least 20% of each inland water ecosystem type.
- The responsibility for target achievement should be shared by national and sub-national statutory structures.
- Target should be subject to review every few years.

Objective 2: Plan for representation of inland water biodiversity. This objective aims to ensure adequate representation of the full spectrum of inland water biodiversity, based on the systematic description and depiction of this biodiversity within the region of concern. To implement this objective:

- Landscape or ecoregion-scale measures can be used as indictors to describe and classify inland water biodiversity.
- Fine-scale indicators of freshwater biodiversity should be used where available to supplement coarse-scale surrogates.
- Local ecological knowledge should be used to supplement biodiversity data that are more readily available.

Objective 3: Plan for persistence of inland water biodiversity. This objective addresses the need to conserve the ecological and evolutionary processes that generate and maintain inland water biodiversity. To implement this objective:

- Ecosystems of high ecological integrity should be selected as conservation resources.
- Ecological connectivity along longitudinal, lateral and vertical gradients must be restored and maintained.
- Natural disturbance regimes should be allowed to operate within their natural ranges of variability.
- Selected areas should be of sufficient size to ensure that the targeted biodiversity feature can be maintained.

Objective 4: Establishing a portfolio of inland water conservation areas (IWCAs). This objective addresses the incorporation of the first three objectives into a spatial design that will constitute the portfolio of inland water conservation areas (IWCA) of South Africa. The portfolio of IWCA should:

- Be legislated through existing statutory mechanisms;
- Be designed in a land-use efficient manner;
- Reflect the vulnerability and threat status of constituent ecosystems so that conservation action can be initiated timeously;
- Be treated as heritage resources for current and future generations rather than resources that can be used now and restored later; and
- Be subject to the development of management plans and performance monitoring programmes.

Objective 5: Enable effective implementation. This objective addresses the creation of an institutional environment that can ensure sustained conservation actions for all designated inland water conservation areas. To achieve this:

- Key stakeholders should be engaged in a way that would facilitate stakeholder adoption of both biodiversity targets and identified priority areas.
- Organisations or agencies with a mandated responsibility for conserving inland water biodiversity should reflect this responsibility as an explicit function in their institutional design.
- Responsible parties should plan and deploy their skills and resources in a coordinated and cooperative fashion to maximise the impact of their conservation actions.
- Conservation scientists, policy analysts/makers and decision-makers/practitioners should jointly debate what is feasible, desirable and acceptable and use knowledge from all three of these domains to adaptively improve their respective hypotheses, policies and management strategies.
- The relevant authorities should actively promote basic discovery, inventory and improved understanding of inland water biodiversity.

Appendix 2: Level 3 river types

The first part of the river type describes the flow variability (permanent, seasonal or ephemeral); the second part describes the Level 1 ecoregion, the third part is a number describing the Level 2 ecoregion; and the last part describes the longitudinal zone (mountain stream, upper foothills ,lower foothills or lowland river). Total length is the total length of each river type in the Olifants/Doorn Water Management Area, Length intact is the length of the river type in ecological integrity category A or B, Target is calculated as 20 % of the total length.. River types where Rehab = 1 cannot achieve the target in intact rivers, and need to be investigated for rehabilitation (see Appendix 7 for a detailed assessment of the rehabilitation potential for these river types).% Target conserved is the proportion of the target that is conserved within the proposed conservation portfolio.

River type name	Total length (km)	Length intact (km)	Target (km)	Rehab	% Target Conserved
Permanent-South Western Coastal Belt-2-Mountain stream	13	0	2545	1	0
Permanent-South Western Coastal Belt-2-Upper foohills	17	0	3338	1	0
Permanent-South Western Coastal Belt-2-Lower foohills	14	0	2900	1	0
Permanent-South Western Coastal Belt-4-Mountain stream	2	0	460	1	0
Permanent-South Western Coastal Belt-4-Upper foohills	48	0	9613	1	0
Permanent-South Western Coastal Belt-4-Lower foohills	88	0	17552	1	0
Permanent-South Western Coastal Belt-4-Lowland river	4	0	707	1	0
Permanent-Western Coastal Belt-1-Mountain stream	4	4	761	0	500
Permanent-Western Coastal Belt-1-Upper foohills	6	3	1279	0	254
Permanent-Western Coastal Belt-1-Lower foohills	29	17	5845	0	294
Permanent-Western Coastal Belt-2-Upper foohills	42	32	8451	0	376
Permanent-Western Coastal Belt-2-Lower foohills	18	0	3525	1	0
Permanent-Western Coastal Belt-2-Lowland river	113	2	22674	1	10
Permanent-Western Folded Mountains-1-Mountain stream	115	98	22929	0	226
Permanent-Western Folded Mountains-1-Upper foohills	375	308	75042	0	218
Permanent-Western Folded Mountains-1-Lower foohills	60	38	11906	0	109
Permanent-Western Folded Mountains-1-Lowland river	36	22	7231	0	116
Permanent-Western Folded Mountains-2-Mountain stream	38	15	7601	0	102
Permanent-Western Folded Mountains-2-Upper foohills	193	74	38625	0	131
Permanent-Western Folded Mountains-2-Lower foohills	189	24	37855	1	63
Permanent-Western Folded Mountains-2-Lowland river	6	0	1156	1	0

River type name	Total length (km)	Length intact (km)	Target (km)	Rehab	% Target Conserved
Permanent-Western Folded Mountains-3-Mountain stream	28	15	5674	0	258
Permanent-Western Folded Mountains-3-Upper foohills	53	12	10614	0	114
Permanent-Western Folded Mountains-3-Lower foohills	18	0	3599	1	0
Seasonal-Great Karoo-1-Mountain stream	22	16	4368	0	192
Seasonal-Great Karoo-1-Upper foohills	165	108	33097	0	129
Seasonal-Great Karoo-1-Lower foohills	53	17	10649	0	158
Seasonal-Great Karoo-2-Mountain stream	3	3	580	0	346
Seasonal-Great Karoo-2-Upper foohills	164	103	32786	0	106
Seasonal-Great Karoo-2-Lower foohills	26	19	5187	0	119
Seasonal-Great Karoo-3-Mountain stream	26	21	5298	0	209
Seasonal-Great Karoo-3-Upper foohills	360	271	71972	0	94
Seasonal-Nama Karoo-4-Mountain stream	26	21	5240	0	123
Seasonal-Nama Karoo-4-Upper foohills	161	141	32172	0	165
Seasonal-Nama Karoo-4-Lower foohills	61	16	12169	0	119
Seasonal-South Western Coastal Belt-1-Upper foohills	20	0	4095	1	0
Seasonal-South Western Coastal Belt-1-Lower foohills	30	0	6001	1	0
Seasonal-Western Coastal Belt-1-Mountain stream	7	4	1311	0	111
Seasonal-Western Coastal Belt-1-Upper foohills	32	8	6336	0	106
Seasonal-Western Coastal Belt-1-Lower foohills	62	9	12445	1	75
Seasonal-Western Coastal Belt-2-Lower foohills	22	0	4420	1	0
Seasonal-Western Coastal Belt-2-Lowland river	33	0	6562	1	0
Seasonal-Western Folded Mountains-1-Mountain stream	23	23	4520	0	166
Seasonal-Western Folded Mountains-1-Upper foohills	68	68	13645	0	213
Seasonal-Western Folded Mountains-2-Mountain stream	56	37	11277	0	116
Seasonal-Western Folded Mountains-2-Upper foohills	265	179	53088	0	145
Seasonal-Western Folded Mountains-2-Lower foohills	213	190	42686	0	325
Seasonal-Western Folded Mountains-4-Mountain stream	8	0	1591	1	0
Seasonal-Western Folded Mountains-4-Upper foohills	63	0	12638	1	0
Seasonal-Western Folded Mountains-4-Lower foohills	8	0	1647	1	0
Ephemeral-Great Karoo-1-Mountain stream	5	4	971	0	116
Ephemeral-Great Karoo-1-Upper foohills	88	58	17593	0	209
Ephemeral-Great Karoo-1-Lower foohills	17	5	3444	0	136
Ephemeral-Great Karoo-2-Mountain stream	42	31	8326	0	125

River type name	Total length (km)	Length intact (km)	Target (km)	Rehab	% Target Conserved
Ephemeral-Great Karoo-2-Upper foohills	483	355	96579	0	100
Ephemeral-Great Karoo-2-Lower foohills	554	131	110849	0	78
Ephemeral-Great Karoo-3-Mountain stream	93	81	18635	0	101
Ephemeral-Great Karoo-3-Upper foohills	839	575	167896	0	89
Ephemeral-Great Karoo-3-Lower foohills	127	21	25496	1	73
Ephemeral-Nama Karoo-2-Lowland river	5	5	1039	0	500
Ephemeral-Nama Karoo-2-Upper foohills	388	353	77668	0	102
Ephemeral-Nama Karoo-2-Lower foohills	346	329	69192	0	151
Ephemeral-Nama Karoo-4-Mountain stream	26	23	5126	0	112
Ephemeral-Nama Karoo-4-Upper foohills	68	52	13643	0	201
Ephemeral-Nama Karoo-4-Lower foohills	35	0	6971	1	0
Ephemeral-Namaqua Highlands-1-Mountain stream	5	3	957	0	244
Ephemeral-Namaqua Highlands-1-Upper foohills	220	123	43927	0	201
Ephemeral-Namaqua Highlands-1-Lower foohills	77	26	15391	0	139
Ephemeral-South Western Coastal Belt-1-Upper foohills	32	0	6302	1	0
Ephemeral-South Western Coastal Belt-1-Lower foohills	19	0	3733	1	0
Ephemeral-Western Coastal Belt-1-Mountain stream	17	8	3390	0	150
Ephemeral-Western Coastal Belt-1-Upper foohills	569	374	113753	0	101
Ephemeral-Western Coastal Belt-1-Lower foohills	394	111	78722	0	100
Ephemeral-Western Coastal Belt-2-Upper foohills	86	28	17184	0	147
Ephemeral-Western Coastal Belt-2-Lower foohills	148	32	29586	0	109
Ephemeral-Western Coastal Belt-2-Lowland river	10	0	1957	1	0
Ephemeral-Western Folded Mountains-2-Mountain stream	18	9	3669	0	170
Ephemeral-Western Folded Mountains-2-Upper foohills	90	52	17961	0	107

Appendix 3: Wetland types

Areas provided are based on potential, not actual wetlands, and therefore require field verification (see Section 5.1). The first part of the wetland type describes the drainage (channelled or unchannelled); the second part describes landform (Valley bottom, Floodplain, Seep or Depression); and the last part describes vegetation grouping. Total area is the total area of each wetland type in the Olifants/Doorn Water Management Area. Area intact is the area of the wetland type in a ecological integrity modelled as intact (see Section 7.2), Target is calculated as 20 % of the total area. Wetland types where Rehab = 1 cannot achieve the target in intact wetlands, and need to be investigated for rehabilitation.% Target conserved is the proportion of the target that is conserved within the proposed conservation portfolio.

Wetland type	Total area (ha)	Intact area (ha)	Target (ha)	Rehab	% Target conserved
Channelled-Valley bottom-Alluvial	3173	1155	635	0	110
Channelled-Valley bottom-Dune Strandveld	329	0	66	1	0
Channelled-Valley bottom-Fynbos	1794	610	359	0	161
Channelled-Valley bottom-Nama Karoo	70	70	14	0	500
Channelled-Valley bottom-Renosterveld	199	60	40	0	151
Channelled-Valley bottom-Sand & Dune Fynbos	1656	26	331	1	8
Channelled-Valley bottom-Succulent Karoo	3462	2806	692	0	237
Unchannelled-Valley bottom-Alluvial	445	185	89	0	107
Unchannelled-Valley bottom-Dune Strandveld	301	301	60	0	492
Unchannelled-Valley bottom-Fynbos	154	64	31	0	131
Unchannelled-Valley bottom-Renosterveld	38	32	8	0	423
Unchannelled-Valley bottom-Sand & Dune Fynbos	14	0	3	1	0
Unchannelled-Valley bottom-Succulent Karoo	116	39	23	0	166
Channelled-Floodplain-Alluvial	12069	0	2414	1	0
Channelled-Floodplain-Fynbos	3420	3420	684	0	116
Channelled-Floodplain-Renosterveld	649	0	130	1	0
Channelled-Floodplain-Sand & Dune Fynbos	4177	0	835	1	0
Unchannelled-Floodplain-Succulent Karoo	1614	1513	323	0	421
Channelled-Seep-Alluvial	1709	951	342	0	251
Channelled-Seep-Fynbos	1533	538	307	0	132
Channelled-Seep-Nama Karoo	65	42	13	0	320

Wetland type	Total area (ha)	Intact area (ha)	Target (ha)	Rehab	% Target conserved
Channelled-Seep-Renosterveld	866	408	173	0	228
Channelled-Seep-Sand & Dune Fynbos	1337	40	267	1	15
Channelled-Seep-Succulent Karoo	5844	4789	1169	0	152
Unchannelled-Seep-Alluvial	45	20	9	0	225
Unchannelled-Seep-Fynbos	107	74	21	0	199
Unchannelled-Seep-Nama Karoo	12	12	2	0	221
Unchannelled-Seep-Renosterveld	190	62	38	0	141
Unchannelled-Seep-Sand & Dune Fynbos	49	16	10	0	167
Unchannelled-Seep-Succulent Karoo	360	318	72	0	307
Channelled-Depression (non-perennial)-Alluvial	1380	1380	276	0	244
Channelled-Depression (non-perennial)-Fynbos	66	26	13	0	110
Channelled-Depression (non-perennial)-Nama Karoo	41	41	8	0	417
Channelled-Depression (non-perennial)-Salt Marsh	429	400	86	0	456
Channelled-Depression (non-perennial)-Salt Pans	127	127	25	0	500
Channelled-Depression (non-perennial)-Succulent Karoo	416	416	83	0	156
Channelled-Depression (perennial)-Salt Pans	199	199	40	0	500
Unchannelled-Depression (non-perennial)-Alluvial	507	477	101	0	286
Unchannelled-Depression (non-perennial)-Fynbos	23	16	5	0	116
Unchannelled-Depression (non-perennial)-Nama Karoo	82	82	16	0	412
Unchannelled-Depression (non-perennial)-Renosterveld	51	0	10	1	0
Unchannelled-Depression (non-perennial)-Salt Marsh	260	260	52	0	378
Unchannelled-Depression (non-perennial)-Salt Pans	120	46	24	0	104
Unchannelled-Depression (non-perennial)-Sand & Dune Fynbos	63	23	13	0	136
Unchannelled-Depression (non-perennial)-Succulent Karoo	274	274	55	0	305

Appendix 4: National Land Cover classes

Land cover classes deemed natural (1) in the National Land Cover 2000 GIS layer. For land cover class 13 (Waterbodies), 1:50 000 farm dams were used to distinguish man-made waterbodies from natural waterbodies.

ID	National Land Cover 2000 class description	Natural	ID	National Land Cover 2000 class description	Natural
1	Forest (indigenous)	1	25	Cultivated, permanent, commercial, sugarcane	0
2	Woodland (previously termed Forest and Woodland)	1	26	Cultivated, temporary, commercial, irrigated	0
3	Thicket, Bushland, Bush Clumps, High Fynbos	1	27	Cultivated, temporary, commercial, dryland	0
4	Shrubland and Low Fynbos	1	28	Cultivated, temporary, subsistence, dryland	0
5	Herbland	1	29	Cultivated, temporary, subsistence, irrigated	0
6	Unimproved (natural) Grassland	1	30	Urban / Built-up (residential)	0
7	Improved Grassland	0	31	Urban / Built-up (rural cluster)	0
8	Forest Plantations (Eucalyptus spp)	0	32	Urban / Built-up (residential, formal suburbs)	0
9	Forest Plantations (Pine spp)	0	33	Urban / Built-up (residential, flatland)	0
10	Forest Plantations (Acacia spp)	0	34	Urban / Built-up (residential, mixed)	0
11	Forest Plantations (Other / mixed spp)	0	35	Urban / Built-up (residential, hostels)	0
12	Forest Plantations (clearfelled)	0	36	Urban / Built-up (residential, formal township)	0
13.1	Waterbodies – natural	1	37	Urban / Built-up (residential, informal township)	0
13.2	Waterbodies – farm dams	0	38	Urban / Built-up (residential, informal squatter camp)	0
14	Wetlands	1	39	Urban / Built-up (smallholdings, woodland)	0
15	Bare Rock and Soil (natural)	1	40	Urban / Built-up (smallholdings, thicket, bushland)	0
16	Bare Rock and Soil (erosion : dongas / gullies)	0	41	Urban / Built-up (smallholdings, shrubland)	0
17	Bare Rock and Soil (erosion : sheet)	0	42	Urban / Built-up (smallholdings, grassland)	0
18	Degraded Forest & Woodland	0	43	Urban / Built-up, (commercial, mercantile)	0
19	Degraded Thicket, Bushland, etc	0	44	Urban / Built-up, (commercial, education, health, IT)	0
20	Degraded Shrubland and Low Fynbos	0	45	Urban / Built-up, (industrial / transport : heavy)	0
21	Degraded Herbland	0	46	Urban / Built-up, (industrial / transport : light)	0
22	Degraded Unimproved (natural) Grassland	0	47	Mines & Quarries (underground / subsurface mining)	0
23	Cultivated, permanent, commercial, irrigated	0	48	Mines & Quarries (surface-based mining)	0
24	Cultivated, permanent, commercial, dryland	0	49	Mines & Quarries (mine tailings, waste dumps)	0

Appendix 5: Calculating planning unit cost

For the conservation portfolio

Planning unit cost was calculated for each sub-quaternary catchment using the following formula:

Cost = [Base] – [PACNPdiscount] – [WetABdiscount] – [SFdiscount]

BaseCost
All sub-quaternary catchments were assigned a base cost of 4000 points

PACNPdiscount
The rationale for using this discount is that sub-quaternary catchments containing protected areas generally have land and rivers in better condition, and better opportunities exist as there is already conservation momentum in the area. The protected areas GIS layer developed for the National Spatial Biodiversity Assessment (Driver *et al.* 2005) was used to identify these sub-quaternary catchments: all categories of protected areas, public and private, were used except for Mountain Catchment Areas. These were included elsewhere in the portfolio as high water yield areas. Sub-catchments with ≥ 10 % of their area within protected areas were given a PACNPdiscount = 100; those not qualifying were assigned a PACNPdiscount = 0.

In addition, CapeNature has identified properties in the Cederberg and the Sandveld as priorities for the 2006 stewardship negotiations. These priorities were based on tested and perceived conservation willingness and through the identification of 5-10 year development intentions for the farms and the impact these developments would have on the corridor in respect of connectivity. The Sandveld corridor was prioritised primarily based on threat from transformation, while the Cederberg was engaged due to willingness and the ecological process contribution. Only the Cederberg properties were used, as we did not want to encourage MARXAN/CLUZ to select biodiversity features in the Sandveld (a high conflict area) when options exist elsewhere. Any sub-quaternary catchment with ≥ 10 % of its area within a Cederberg CapeNature priority area was given a PACNPdiscount = 100, *PROVIDED* it had not already been given a discount for containing protected area activity.

WetABdiscount
Sub-quaternary catchment containing a high proportion of intact wetlands should be favoured wherever possible to optimize retention of ecological functioning. The proportion of intact wetland area to sub-quaternary catchment area was calculated. All sub-quaternary catchments with ≥ 2 % of its area under intact wetlands were considered to have a high proportion of wetlands in an intact state and were afforded a WetABdiscount = 100; those sub-quaternary catchments below this threshold were assigned WetABdiscount = 0.

Sub-quaternary catchments qualifying for SFdiscount
All sub-quaternary catchments containing a special feature (see Section 4.3) were given a discount of 100 points; all those without were given a 0.

For the "Targets+REC Configuration" used in the National Water Resources Classification System

Planning unit cost was calculated for each sub-quaternary catchment using the following formula:

Cost = [Base] – [PACNPdiscount] – [SFdiscount]

Appendix 6: Biodiversity features and management guidelines

Appendix 7: Rehabilitation assessment for river types

Rehabilitation potential for 25 Level 3 river types that cannot completely achieve their 20 % targets. The table below shows Level 3 river types, with the associated national range (% range) of the Level 2 river types. Any river type with over 80 % of its national range within the study area is considered unique, or endemic (there are 16 of these river types) to the area. There are a number of river types that can meet some (but not all) of their target, as indicated by "% target intact", which is calculated as the length of the river type in its intact state expressed as a percentage of the conservation target. Rehabilitation assessment was based on feasibility of rehabilitation in the study area using expert knowledge of the area, desired states set by the River Health Programme, and the best Attainable Ecological Management Class (AEMC; Kleynhans 2000). Conservation opportunities were assessed based on the extent of Level 2 river type elsewhere in the country and the predicted ecological integrity of those rivers, assigning rivers to one of the following categories: (1) river types are best conserved elsewhere; (2)river types should be rehabilitated to an A or B ecological integrity within the Olifants/Doorn Water Management Area; (3) river types are not feasible to rehabilitate in the study area and conserving elsewhere looks bleak; (4) river types are not feasible to rehabilitate in the Olifants/Doorn Water Management Area and unique to the area; and (5) river types have achieved target sufficiently (> 15 % can be conserved), but potential for rehabilitation was still assessed.

River type	% Range	%Target intact	Category	Notes
Permanent-Western Folded Mountains-2-Lower foothills	88	64	5	The majority of the Olifants after the gorge forms this river type. Not possible to rehabilitate back to a B-category, only a C-category. Although there may be some opportunity in the Olifants/Doorn and Breede water management to achieve some representation, it will not be enough to achieve a full national representation. Rehabilitate sub-quaternary catchments 405 and 354 from just after gorge to Citrusdal. The key management intervention here is ensuring summer flow and removal of alien plants from flood zone
Permanent-Western Folded Mountains-2-Lowland river	88	0	3	Not feasible to rehabilitate. Lowland river which now forms Ebenezer Dam. The area is under heavy irrigated cultivation with permanent and temporary crops. Present ecological category is D; best Attainable Ecological Management Class is D. Rehabilitation unlikely elsewhere too.

River type	% Range	%Target intact	Category	Notes
Permanent-Western Folded Mountains-2-Lower foothills	88	0	1	Arises in the Koue Bokkeveld in apple and pear orchards. Also part of the Ebenezer system on the Houdenbek River. This river type is more extensive in the Breede Water Management Area, with some in the Berg Water Management Area. It is more feasible to seek representation in the Breede Water Management Area for this river type.
Permanent-South Western Coastal Belt-2-Mountain stream	92	0	3	Although this river type looks like it could be a data artefact resulting from a GIS overlay, upon examination of level 2 ecoregions more closely the small size and distribution is purely a result of level 2 ecoregion delineations (as opposed to an overlay artefact resulting from combining of ecoregion and hydrological indices). This river type would be better represented in the Berg Water Management Area, but present ecological status is a D for this type within the Berg Water Management Area.
Permanent-South Western Coastal Belt-2-Upper foothills	92	0	3	Although this river type looks like it could be a data artefact resulting from a GIS overlay, upon examination of level 2 ecoregions more closely the small size and distribution is purely a result of level 2 ecoregion delineations (as opposed to an overlay artefact resulting from combining of ecoregion and hydrological indices). This river type would be better represented in the Berg Water Management Area, but present ecological status is a D for this type within the Berg Water Management Area.
Permanent-South Western Coastal Belt-2-Lower foothills	92	0	3	Although this river type looks like it could be a data artefact resulting from a GIS overlay, upon examination of level 2 ecoregions more closely the small size and distribution is purely a result of level 2 ecoregion delineations (as opposed to an overlay artefact resulting from combining of ecoregion and hydrological indices). This river type would be better represented in the Berg Water Management Area, but present ecological status is a D for this type within the Berg Water Management Area.
Permanent-South Western Coastal Belt-4-Mountain stream	33	0	2	Rehabilitation is feasible and important, as this is the Verlorevlei-Kruismans system, which is a RAMSAR site. Best Attainable Ecological Management Class is A or B category. The following sub-quaternary catchment should to be rehabilitated: 362. The key intervention is alien plant eradication from flood zone.
Permanent-South Western Coastal Belt-4-Upper foothills	33	0	2	Rehabilitation is feasible and important, as this is the Verlorevlei-Kruismans system, which is a RAMSAR site. River Health data put the Bergvallei tributary in this area as a desired state of "Natural" and the Kruismans with a desired state of "Good". Best Attainable Ecological Management Class is A or B. The following sub-quaternary catchments should be rehabilitated: 362. The key intervention is alien plant eradication from flood zone.

River type	% Range	%Target intact	Category	Notes
Permanent-South Western Coastal Belt-4-Lower foothills	33	0	2	Rehabilitation feasible and important as this is the Verlorevlei-Kruismans system. RHP puts the Bergvallei tributary in this area as a desired state of "Natural" and the Kruismans with a desired state of "Good". Best Attainable Ecological Management Class is A or B. The following sub-quaternary catchments should be rehabilitated: 341, 364, 358, 353. The key intervention is alien plant eradication from flood zone.
Permanent-South Western Coastal Belt-4-Lowland river	33	0	2	Rehabilitation feasible and important as this is the Verlorevlei-Kruismans system. RHP puts the Bergvallei tributary in this area as a desired state of "Natural" and the Kruismans with a desired state of "Good". Best Attainable Ecological Management Class is A or B. The following sub-quaternary catchments should be rehabilitated: 512. Key interventions are alien plant eradication from flood zone, controlling groundwater abstraction, preventing crops within 35 m of river.
Permanent-Western Coastal Belt-2-Lower foothills	100	0	4	Unique to study area. Olifants River Lower foothills. All in D-category and best Attainable Ecological Management Class is a C-category. Not feasible to rehabilitate. Cannot conserve elsewhere. A minimum of a C-category should be maintained in this river. This would be made possible through ensuring good summer flows.
Permanent-Western Coastal Belt-2-Lowland river	100	10	4	Unique to study area. Olifants River Lower foothills. All in D-category and best Attainable Ecological Management Class is a C-category. Not feasible to rehabilitate. Cannot conserve elsewhere. A minimum of a C-category should be maintained in this river. This would be made possible through ensuring good summer flows.
Seasonal-Western Folded Mountains-4-Mountain stream	57	0	2	Area around the Brandewyn River. Heavily impacted by dryland cultivation, but rehabilitation of the upper reaches is feasible. For the Brandewyn River, the best Attainable Ecological Management Class is a C-category, but the River Health data puts the desired state as "Good" not "Fair". For other smaller tributaries of the same type, the best Attainable Ecological Management Class is an A- or B-category. The Brandewyn River is a potential refuge in amongst fish sanctuaries so if it is possible to rehabilitate this would be a very good site to rehabilitate. This would require rehabilitation of the following sub-quaternary catchment: 264

River type	% Range	%Target intact	Category	Notes
Seasonal-Western Folded Mountains-4-Upper foothills	57	0	2	Area around the Brandewyn River. Heavily impacted by dryland cultivation, but rehabilitation of the upper reaches is feasible. For the Brandewyn River, the best Attainable Ecological Management Class is a C-category, but the River Health data puts the desired state as “Good” not “Fair”. For other smaller tributaries of the same type, the best Attainable Ecological Management Class is an A- or B-category. The Brandewyn River is a potential refuge in amongst fish sanctuaries so if it is possible to rehabilitate this would be a very good site to rehabilitate. This would require rehabilitation of the following sub-quaternary catchments: 264, 262, 248. The key intervention would be to remove invasive alien plants, Port Jackson in particular.
Seasonal-Western Folded Mountains-4-Lower foothills	57	0	3	Area around the Brandewyn River. Heavily impacted by dryland cultivation, but rehabilitation of the upper reaches is feasible. For the Brandewyn River, the best Attainable Ecological Management Class is a C-category, but the River Health data puts the desired state as “Good” not “Fair”. For other smaller tributaries of the same type, the best Attainable Ecological Management Class is an A- or B-category. The Brandewyn River is a potential refuge in amongst fish sanctuaries so if it is possible to rehabilitate this would be a very good site to rehabilitate. This would require rehabilitation of the following sub-quaternary catchments: 262, 248. The key intervention would be to remove invasive alien plants, Port Jackson in particular.
Seasonal-South Western Coastal Belt-1-Upper foothills	100	0	4	Unique to study area. Area around the midwaters of the Langvlei River. Currently in a C-category and best Attainable Ecological Management Class is an A- or B-category, although River Health data put the desired state as “Fair”. This is not feasible to rehabilitate, as it is a massive potato farming area.
Seasonal-South Western Coastal Belt-1-Lower foothills	100	0	4	Unique to study area. Area around the midwaters of the Langvlei River. Currently in a C-category and best Attainable Ecological Management Class is an A- or B-category, although River Health data put the desired state as “Fair”. This is not feasible to rehabilitate, as it is a massive potato farming area.
Seasonal-Western Coastal Belt-1-Lower foothills	100	75	5	Unique to study area. Have already achieved 75 % of the target and it is not worth trying to rehabilitate more of this type. It is part of the Troe-Troe system with a present ecological status of D and a best Attainable Ecological Management Class of C. The River Health data put the desired state as “Fair”.

River type	% Range	%Target intact	Category	Notes
Seasonal-Western Coastal Belt-2-Lower foothills	100	0	2	Unique to study area. River types found at the Langvlei mouth and Olifants-Doring confluence. Present ecological state is a C for both areas. River Health desired state for Langvlei is “Fair” and is probably not feasible to rehabilitate. The Lower Doring before the confluence is a borderline B-category, and to prevent it from slipping into a C-category, will require management of cumulative catchment impacts.
Seasonal-Western Coastal Belt-2-Lowland river	100	0	2	Unique to study area. Verlorevlei mouth. Present ecological status is a C-category. Need to rehabilitate this to an A- or B-category. Key management interventions include retaining linkages with the sea through removal of the sand bags that farmers use, and prevention of further development within flood zone.
Ephemeral-Great Karoo-3-Lower foothills	39	84	5	Extensive outside Olifants/Doorn Water Management Area in the Gouritz Water Management Area, where there seem to be several intact tributaries.
Ephemeral-South Western Coastal Belt-1-Upper foothills	100	0	2	Unique to study area. Present ecological status is a C-category, the River Health site on this river is assessed as “Fair” and the desired state is put at “Fair”. The best Attainable Ecological Management Class is an A- or B-category. It is feasible to rehabilitate =sub-quaternary catchment 508 (there are good habitat and riverine pools in this area). The key management interventions are removal of alien invasive plants and control of groundwater abstractions, which are becoming imminent.
Ephemeral-South Western Coastal Belt-1-Lower foothills	100	0	2	Unique to study area. Present ecological status is a C-category, the River Health site on this river is assessed as “Fair” and the desired state is put at “Fair”. The best Attainable Ecological Management Class is an A- or B-category. It is feasible to rehabilitate =sub-quaternary catchment 508 (there are good habitat and riverine pools in this area). The key management interventions are removal of alien invasive plants and control of groundwater abstractions, which are becoming imminent.
Ephemeral-Western Coastal Belt-2-Lowland river	100	0	2	Unique to study area. Area around the Sout River in the Knersvlakte. Present ecological status is a C-category, the River Health site on this river is assessed as “Good” and desired state should be “Good”; best Attainable Ecological Management Class is A- or B-category. This is one of the few lowland rivers that are feasible to rehabilitate. Rehabilitate sub-quaternary catchment 131.
Ephemeral-Nama Karoo-4-Lower foothills	3	0	1	Extensive range outside of study area in the Lower Orange Water Management Area, with many conservation opportunities. Rehabilitating the Oorlogskloof River (currently=C) just above the gorge, waqs considered, but this goes through extensive agriculture as well as through Calvinia (catchment 182), so rehabilitation is not feasible.