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2011-09-15
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The Development of an Ecological Integrity Index for Quaternary Catchments in South Africa

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Research report submitted in partial fulfilment of the requirements of the degree of

MSc. in Environmental Science

Department of Animal, Plant and Environmental Science,

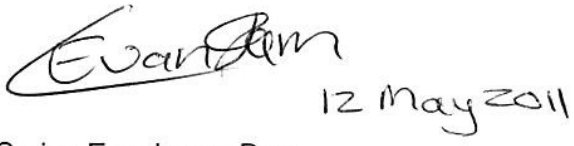
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"I hereby declare that this research report has been composed by myself and has not been accepted in any other previous application for a degree. Information drawn from other sources and assistance received has been duly acknowledged."



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May 2011

Abstract

A multifactor ecological integrity index, focusing on freshwater ecosystems on a quaternary catchment scale, can be of great benefit to conservation planning. No ecological integrity index has previously been developed for South African quaternary catchments. In this study an index was developed based on three environmental surrogates: land cover, river integrity and fish species conservation status, with the intention of identifying quaternary catchments of highest conservation concern. By developing such an index, the aim was to provide a general indication of the degree to which catchments have been transformed from a natural environment to a human altered environment, thereby identifying catchments most in need of conservation.

For the three available datasets, indices were developed using a five category point-scoring system. A score of one indicates a completely degraded environment and a score of five indicates a pristine environment. The original land cover data consisted of 49 different land cover types which were reduced to five land cover transformation scores. Available river integrity data already existed in five categories and a numerical score of one to five was applied to each category. Fish species conservation status was scored according to the IUCN red data list classifications on a similar basis.

Subsequently, a weighted mean score expressed as a percentage was calculated for the three indices for each quaternary catchment. These indices indicate the degree of change/transformation from a natural system (100%) to a largely degraded system (20%).

Ultimately, an ecological integrity index was calculated as a mean value of the three related but independent indices. However, the results of the developed ecological integrity index were not representative of real world conditions. This is largely attributed to the lack of complete data found in two out of the three datasets used in the study. Some of the main limitations encountered were the lack of river segment definitions within each catchment and the incomplete and un-systematic collected fish species data records. The land cover data, on the contrary, was of high definition and high standard. It is recommended that in the

interim, the developed land transformation index, based on a detailed analysis of land cover, be used as an indicator index of ecological integrity of catchments.

Abbreviations

ARC – Agricultural Research Council

CSIR – Council for Scientific and Industrial Research

DEAT – Department of Environmental Affairs and Tourism

DWAF – Department of Water Affairs and Forestry

FAII – Fish Assembly Integrity Index

IHI – Instream Habitat Integrity

PESC – Present Ecological Status Category

QDS – Quarter Degree Squares

SAIAB – South African Institute for Aquatic Biodiversity

WRC – Water Research Commission

WSAM – Water Simulation Model

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1 Introduction

Aquatic ecosystems are under severe pressure due to changing environments and loss of natural habitat. River ecosystem health in South Africa is described to be in a dire condition with 54% critically endangered, 18% endangered and 12% vulnerable (Nel, *et al,* 2007). Unless efforts are made, the condition will continue to deteriorate. In addition, there are few tools available to identify river catchments most in need of conservation on a national scale. No ecological integrity index, incorporating land cover, river integrity and fish conservation status data, exists for quaternary catchments in South Africa. Given the growing demand on water resources and the ever-increasing human population, an ecological integrity index would be beneficial to authorities and interest groups for planning purposes and for the prioritisation of efforts to protect our resources and maintain a sustainable water supply.

Environmental surrogates are connected within an ecosystem, and thus no component exists in isolation (Allan, 2004; Amis, *et al,* 2009; Roux, *et al,* 2002). Therefore, a multifactor ecological integrity index that incorporates surrogates from different sources at different spatial scales is required, and not just a river integrity index which focuses on instream river conditions. Such data by necessity comes at different geographic scales and different levels of detail within each catchment ecosystem. On a large scale, the condition of the surrounding land cover in each catchment needs to be considered; on a medium scale, the condition of the rivers needs to be determined; and on a small scale, the condition of the fish species (and other biota) needs to be studied. The catchment ecosystem needs to be studied on a scale that is both manageable and practical for government and/or interest groups to get involved (Wilson, *at el,* 2007). A quaternary catchment scale is ideal as it is large enough to incorporate ecosystem processes and environmental interactions, yet small enough for the implementation of conservation plans (Amis, *et al,* 2007; Harding, *et al,* 1998).

This study aims to develop an ecological integrity index of quaternary catchment which can be used to prioritise catchments most suitable for conservation efforts. The result will be a map of ecological integrity per catchment which decision makers could use as a guide for further, more detailed investigation.

2 Aim and Objectives

The aim of the study was to develop and evaluate an ecological integrity index for quaternary catchments in South Africa, using a land transformation index, a river integrity index and a fish conservation status index. The final result will be a map which can be used as a tool to promote conservation and effective water resource management.

In order to meet the aim of the study, the following key research question was to be answered:

How well does diverse catchment scale data lend itself to the calculation of an ecological catchment integrity index?

To answer this key research question, the following objectives needed to be met:

2.1 Determine a single weighted mean land cover transformation score per quaternary catchment.
2.2 Determine a single weighted mean river integrity score per quaternary catchment.
2.3 Determine a single weighted mean fish conservation status score per quaternary catchment.
2.4 Consolidation of the above results into a single score per catchment and to analyse the outcome against the key research question.
2.5 Assess the interrelatedness of each of the environmental indicators.
2.6 Use the assessment to identify and prioritise catchments which can later be used for management and conservation interventions.

3 Literature Overview

Ecological integrity can be defined as "the undiminished ability of an ecosystem to continue its natural path of evolution, its normal transition over time, and its successional recovery from disturbances" (Nel, *et al,* 2009: 4). In a natural system, communities are able to adapt to changes and the interrelationships between living things and their environment is maintained and unbroken (Amis, *et al*, 2007), even though their relative importance might change over time. Integrity has three main components: sustainability, maintaining ecosystems so they continue to provide goods and services; naturalness, undisturbed by human interference; and stability or resilience, resistant to environmental change and stress and the ability to be able to recover to the original condition (Andreasen, *et al,* 2001).

Ecological integrity in terms of natural resource management can be considered synonymous to environmental quality. It is concerned not only with ecological services from which humans can benefit, but it also incorporates the condition of the ecosystem for its own benefit and for the sake of species that depend on it (Andreasen, *et al,*2001).

In this study ecological integrity is assessed by three environmental indicators, land cover transformation, river integrity and fish species conservation status. These three indicators are assessed on a quaternary catchment scale. They were chosen as they reflect both the biotic and abiotic conditions within a catchment, and literature indicates that these three indicators are appropriate predictors of ecological integrity (Amis, *et al,* 2007; Nel, *et al,* 2004; Pont, *et al,* 2006; Roux, *et al,* 2002; Wessels, *et al,* 2003).

A quaternary catchment is a nested hydrological unit within primary, secondary and tertiary catchments. Main rivers will span more than one quaternary catchment while tributaries are completely contained within single quaternary catchments (Nel, *et al*, 2009). It is the fourth level of subdivision of catchments as defined by the Department of Environmental Affairs (2008). Quaternary catchments in South Africa can be easily identified using existing GIS data and are a practical size when implementing conservation efforts. They are also a hydrological unit which is able to maintain the longitudinal connectivity of freshwater systems

and the lateral connectivity between freshwater systems and surrounding landscapes (Nel, *et al,* 2009).

Conservation planning and natural resource management is important not only to protect species but also to maintain functional ecosystems as they provide many ecosystem services which people benefit from (van Wyk, *et al,* 2006; Wessels, *et al,* 2003). Conservation plans are most successful when implemented on a manageable scale which represents a functional ecosystem unit capable of maintaining long term ecosystem processes such as a quaternary catchment (Amis, *et al,* 2007; Nel, *et al*, 2009, Roux, *et al,* 1999b).

Ecological integrity was calculated with the use of a scoring system developed in this report. The scoring system is based on existing data. These data reflect biotic and abiotic elements of aquatic ecosystems. Data used were the land cover data from the 2000 National Land Cover dataset, the river integrity data were the same data used by the Department of Water Affairs and Forestry, and the fish occurrence data were supplied by the South African Institute for Aquatic Biodiversity (SAIAB), JLB Smith Institute for Ichthyology (now incorporated into SAIAB) and the Albany museum collection. If the integrity index developed from these existing datasets proves to be robust, it allows for the rapid assessment of large areas without the costly need for new data collection. A scoring system was applied to these existing datasets to calculate the ecological integrity on a quaternary catchment scale.

3.1 Land Cover

Land cover can be used as a surrogate of ecological integrity. Land cover transformation within a catchment greatly influences river integrity and subsequently impacts on the biotic species living in the river (Antwi, *et al,* 2008; Dudgeon, *et al,* 2005; Poff, *et al,* 2007). Land cover acts as an ideal surrogate and has been used as a predictor of river integrity for freshwater assessments in larger, catchment areas (Amis, *et al,* 2009).

Land cover is defined as: “all the natural and man-made features that cover the earth’s immediate material surface” (Thompson, 1996: 35). This definition refers to a description of what is covering the land and only indirectly what the land is actually used for.

Land cover within a quaternary catchment is heterogeneous (Benda, *et al,* 2004; Ward & Tockner, 2001). In an untransformed catchment, land cover will be determined by underlying environmental conditions, such as topography, geology, soil condition and water (Allan, 2004). These abiotic conditions set the environmental limits within which different vegetation communities will develop and exist (Laio, *et al,* 2001). Changes can occur within the catchment such as fire, drought or flooding. However, these events shape the landscape and are part of the ecosystem processes (Benda, *et al,* 2004; Poff, *et al,* 2007).

Anthropogenic land cover changes disrupt ecosystem processes (Allan, 2004; Poff, *et al,* 2007). Transformation such as agricultural development, industrial development, housing establishments and mining will result in extensive and long term land cover transformation within a catchment. These extensive transformations impact on, and can result in the loss of ecosystem processes (Allan, 2004; Antwi, *et al,* 2008; Goetz & Fiske, 2008). Agriculture, through the use of fertilizers and pesticides will change the soil chemistry and quality by adding chemicals and toxins to the soil. Industrial developments will change the water drainage patterns reducing infiltration and increasing overland flow velocity. Mining inevitably leads to the severe disturbance of natural processes, the loss of vegetation, increased surface erosion and widespread pollution such as dust, soil and water pollution (Allan, 2004; Antwi, *et al,* 2008; Goetz & Fiske, 2008).

Land cover transformation impacts river integrity. Water drains from the land and enters river channels (Dudgeon, *et al,* 2005). Surface conditions will determine water overland flow (Goetz & Fiske, 2008). Natural surface cover tends to retain water and slow down overland flow, allowing water infiltration, reducing water velocity thereby reducing its erosion potential. Hard, impermeable surfaces, which are found in transformed environments such as cities, reduce infiltration capacity and increase velocity, increasing potential erosion as water enters a river channel (Allan, 2004; Dudgeon, *et al,* 2005; Goetz & Fiske, 2008). As the water drains, the water quality is affected by the condition of the land cover. In natural environments, in the subsurface flow zone, water will dissolve nutrients and minerals in the

soil transporting it to the river. In a transformed environment, if the land is polluted by fertilizers and other substances, water will dissolve the chemicals and pollutants and transport them into the nearby river (Allan, 2004; Goetz & Fiske, 2008).

Land cover can be considered a surrogate of river condition due to the connectivity between surface conditions and water drainage into river channels (Dudgeon, *et al,* 2005; Nel, *et al,* 2009; Ward & Tockner, 2001). If a natural, pristine land is drained, the natural ecosystem processes are maintained. Nutrients are transported into river systems providing sustenance to aquatic plants and animals. If a polluted land is drained, then the water entering the river channel will be polluted and will degrade the river quality (Allan, 2004). Land cover is considered an appropriate indicator of river integrity, especially for studies on a catchment scale or larger.

A previous study by Amis, *et al* (2007)*,* found land cover to be a valuable indicator of river conditions and habitat integrity. GIS data were used to predict river integrity and the results were compared to the River Health Programme ecological integrity values for rivers (Kleynhans, 1999). Land cover data indicated different land uses which were then scored and assessed in a GIS system. Different land cover uses included natural vegetation, plantations, cultivated areas, degraded areas, residential areas, industrial developments, mines, roads and dams. The GIS data were further supplemented with human population density data. Amis, *et al* (2007), found river integrity was predictable when using land cover data. The results proved to be more accurate when using entire catchment data as opposed to focusing on smaller riparian strips. A second, more recent study by Amis, *et al* (2009), found the relationship to be so strong that land cover can be used as a surrogate for indicating the ecological integrity of rivers.

3.2 River Systems

River integrity is a reflection of the catchment condition (Goetz & Fiske, 2008; Nel, *et al,* 2007) and can be defined as the ability to support and maintain a balanced, integrated and adaptive community of organisms having a composition, diversity and functional organisation comparable to that of a natural untransformed habitat (Amis, *et al,* 2007). River integrity

dictates the instream habitat, thereby affecting the biota living in the river systems (Roux, *et al,* 1999b).

A river is a continuous ecological network which connects catchments upstream to the catchments downstream (Roux, *et al,* 2002). River networks are formed as water drains from the land and collects in channels. The condition of the land cover, through and over which the water drains, determines the water quality entering the channel (Allan, 2004; Goetz & Fiske, 2008; Nel, *et al,* 2007; Roux, *et al,* 2002). Natural land cover will provide nutrients and organic matter which enter the river systems. These will provide food and potentially shelter to aquatic biota, and maintain the natural ecosystems processes (Allan, 2004; Roux, *et al,* 2002).

Transformed land cover will result in an unnatural quality or quantity of matter entering the river system. Transformed land cover may release pollutants, chemicals and waste material into rivers and this will impair ecosystem functionality as it changes the water quality, pH and chemistry. A common consequence of waste entering water bodies is eutrophication. Eutrophication can cause water discoloration or turbidity resulting in less light penetration. It also reduces dissolved oxygen (Oberholster & Ashton, 2008). Surrounding land cover determines the material entering the river systems and therefore influences the river integrity (Allan, 2004; Dudgeon, *et al,* 2005; Roux, *et al,* 2002).

Land cover transformation leads to the loss of river integrity. Natural ecosystem processes are lost due to anthropogenic transformation (Poff, *et al,* 2007). In a natural system, precipitation would fall and be absorbed in the ground. Water would move through soil and then slowly be released into the river (van Wyk, *et al,* 2006). Transformation such as industrial development, urban development, built up areas and land clearance changes the hydrological cycles. Water cannot enter river systems naturally but either flows over the hard surfaces or is artificially channelled into rivers (Allan, 2004; Goetz & Fiske, 2008). This results in larger volumes of water, flowing at a higher velocity entering the river. A larger volume of water, flowing at a higher velocity increases silt loads and silt deposition. It further increases channel and stream bed erosion. A higher velocity allows for pollutants to be carried into the river system as it reduces infiltration. Pollutants are no longer filtered through the ground. Transformation no longer allows for natural ecosystem processes to occur and

as a result, the water quality deteriorates and river integrity is lost (Allan, 2004; Goetz & Fiske, 2008).

Degraded river integrity negatively impacts on biotic species (Dudgeon, *et al,* 2005; Goetz & Fiske, 2008; Roux, *et al,* 2002). As river integrity and water quality is degraded, habitats change, fewer nutrients are available and it becomes harder for species to survive. A study by Pont, *et al* (2006), indicated that river integrity is vital for the survival of fish species. This study used fish species as indicators of habitat quality of rivers. This study included information on local environmental variables (such as altitude, basin class (catchment class), geological type and flow), sampling strategy and river basin classification. Pont, *et al* (2006), also judged human induced alterations on a scale of one to five. Fish assemblage structure was assessed on five functional attributes: tolerance, trophic status, reproduction, habitat and migration. The study found that fish react significantly to the health of the aquatic environment and surrounding catchment and there is a significant negative linear response in respect of these attributes to a gradient of human disturbances.

3.3 Fish Species

Fish species are considered a good indicator of river integrity and ecological health (Nel, *et al,* 2009; Pont, *et al,* 2006). As fish species are dependent on river condition for their survival, they provide a direct, holistic and integrated measure of the river integrity (Nel, *et al,* 2009; Roux, *et al,* 1999b). They are adapted to survive and exploit river ecosystem conditions however; they are unable to survive the extreme events caused by anthropogenic changes (Dudgeon, *et al,* 2005; Lytle & Poff, 2004; Pont, *et al,* 2006). Fish have specific habitat requirements and if river integrity is compromised, they are one of the first aquatic species to be affected (Pont, *et al,* 2006).

The health of fish communities in rivers is a good indication of river integrity (Goetz & Fiske, 2008; Kleynhans, 1999; Pont, *et al,* 2006; Roux, *et al,* 2002). In natural ecosystems fish species are adapted to habitat specific conditions including water clarity, temperature and nutrient content. If the habitat condition is compromised by anthropogenic influences, the water quality deteriorates, less oxygen is available and nutrients are depleted, it will

negatively affect the health of the fish (Allan, 2004; Goetz & Fiske, 2008; Pont, *et al,* 2006; Roux, *et al,* 2002).

Changes to the condition of river channels alter biotopes and will affect fish species (Allan, 2004; Benda, *et al,* 2004). Some fish prefer pools whereas others thrive in turbulent water. Each biotope has its own characteristics such as sediment or gravel on the bottom of the channel, others will have large boulders in the river which provides shelter and allows algae to grow on the rocks providing an alternative food source (Allan, 2004).

Fish species have evolved through life history adaptations to be successful in specific biotopes (Skelton, 2001). Mudfish live in sandy, muddy river bottoms where they feed on small aquatic animals dredged from the bottom sands and mud (Potgieter, *et al,* 1971). Trout species are active hunting fish and need clear, oxygenated water (Potgieter, *et al,* 1971). Barbels have developed auxiliary respiratory organs enabling them to live as scavengers in environments with low oxygen content. Despite this adaptability, they migrate to vleis during summer floods as they need to breed in high oxygenated water (Potgieter, *et al,* 1971). Changes in natural ecosystem processes such as water flow regulation, increased sediment influxes, or polluted riparian environments such as vleis would hinder the success of species such as the hunting ability of the trout or the reproduction of even the most robust barbel species.

Land cover transformation, such as industrial development and the construction of large impermeable surfaces, will affect water drainage and overland flow; in turn this changes the river flow dynamics and alters biotopes (Allan, 2004; Goetz & Fiske, 2008). Loss of preferable biotopes will impact fish adapted to these specific locations. An increase in water volume entering river systems may prevent turbulent water developing in shallow channels and will result in fewer available habitats and less available oxygen. An increase in water velocity will disturb sediments, reducing water clarity (Allan, 2004).

In a natural ecosystem, fish species are able to exploit natural ecosystem processes by timing behavioural adaptations to achieve the maximum benefit from the environmental conditions such as breeding when seasonal flood plains develop (Dudgeon, *et al,* 2005;

Lytle & Poff, 2004). They can time their breeding to coincide with, and exploit optimal environmental conditions. They are able to survive extreme events such as droughts by finding sanctuary tributaries and sections within the river where they can survive (Allan, 2004; Lytle & Poff, 2004; Nel, *et al,* 2007). However, they are not adapted to severe anthropogenic disturbances. If a factory was dumping organic waste into a stream, the water would be polluted, there would be less available oxygen and the food source would be contaminated. Fish species would not be able to survive, they would either need to move upstream or much further downstream to find new, unpolluted habitats. Losses of natural habitats and ecosystems processes reduce a species chance of survival (Allan, 2004; Goetz & Fiske, 2008).

3.4 Conservation Planning

Conservation planning is an intricate task. In a natural ecosystem, processes are always fluctuating between days, within seasons and within natural cycles, therefore conservation plans need to provide an integrated assessment and represent a solution which is holistic to the situation (Bendoricchio & Jørgensen, 1997; Dudgeon, *et al,* 2005; Maree, *et al,* 2006; Margules & Pressey, 2000). However, many challenges exist when taking an integrated approach. Not all ecosystem functions can be represented so surrogates need to be chosen as a representative sample of the system one hopes to protect (Allan, 2004; Balmford, *et al,* 2005; Maree, *et al,* 2006). Also due to the many challenges which exist, areas need to be prioritised so that limited resources can be used to ensure biodiversity representativeness and persistence (Margules & Pressey, 2000).

Margules and Pressey (2000) have identified six stages which are required for systematic conservation planning. These are:

1. Make a clear selection on appropriate surrogates to represent the biodiversity of the area and collect all appropriate data
2. Define explicit goals for the planning region
3. Review the success of existing conservation areas
4. Use simple explicit methods to select new conservation areas
5. Implement conservation actions
6. Adopt explicit objectives and methods to maintain the required values of conservation areas

The aim of this study is to develop an index which can be used to address some of these key stages in conservation planning as defined by Margules and Pressey (2000). Three surrogates, land cover, river integrity and fish species, have been selected to represent the ecosystem processes within a quaternary catchment. They represent the connectivity of ecosystem processes within a landscape at different scales. Land cover and river integrity can be used as surrogates of ecological systems (Goetz & Fiske, 2008; Nel, *et al,* 2009). Fish species can be used as a surrogate of a community living in an aquatic ecosystem as they are indicative of the system's health. All three environmental surrogates represent an integrated system at different spatial scales and changes to these surrogates represent changes in time (Lindenmayer, *et al*, 2008). This allows the resulting index to be inclusive of all ecosystem processes and allows for some predictability to future changes (Allan, 2004; Lindenmayer, *et al*, 2008; Margules & Pressey 2002).

Once explicit goals for a new conservation area have been defined, the ecological integrity index which is developed in this study will provide valuable information required to meet these goals. By incorporating catchments it ensures connectivity between regions and potentially between different conservation areas (Margules & Pressey, 2000). Quaternary catchments are also small enough to be a manageable size allowing for ecosystem monitoring and evaluation (Nel, *et al,* 2009; Margules & Pressey, 2000).

The ecological integrity index allows for the review of the success of existing conservation areas. If a catchment falls within a conservation area, the index will indicate the integrity of that catchment, comparing natural areas to transformed ones. This information not only indicates the current ecological state but can also be used to make a decision on which remaining catchments require conservation efforts.

Conservation tools need to be fast and reliable (Balmford, *et al,* 2005). Opportunities and resources for conservation are limited; therefore a process for assessing the ecological integrity of an ecosystem must be quickly available and must be a thorough representation of what is happening on the ground. To fast track the process, many assessments have been developed using existing datasets. These help save time, which without them, is otherwise spent collecting raw data. Provided reliable, detailed and complete datasets are

available, it can greatly benefit the results of conservation plans by improving speed, accuracy and reliability (Antwi, *et al,* 2008; Hughes, 2004; Nel, *et al,* 2007).

3.5 Scoring Systems

Scoring systems have been used in many international and national conservation assessments and if used appropriately they provide valuable information in a resource limited context (Hoffmann, *et al,* 2008; Labovitz, 1971; Mace, *et al,* 2007; Possingham, *et al,* 2007).

The scoring process begins with assigning a score to each variable based on specific criteria, such as loss of integrity indicated by the degree of transformation, river integrity or species conservation status as used in this assessment. Once each variable has a score, they can be added to give an overall priority score. In order to avoid misleading results, a weighting or a categorical approach based on a combination of scores can be used (Mace, *et al,* 2007).

One of the main concerns with scoring approaches is that high scores may result for a particular species or index when criteria are closely related. This will lead to misleading results (Mace, *et al*, 2007). Results of scoring systems seem to be less accurate on fine scales (Hoffmann, *et al,* 2008; Scardi, *et al,* 2008). Human error and misinterpretation can also lead to poor results. People may misinterpret the rules and decision making criteria when applying scores. The boundaries between scores and criteria may also be unclear and could lead to misclassification and inconsistencies (Regan, *et al,* 2005; Rodrigues, *et al,* 2006). However, despite these concerns, there are many benefits to scoring systems.

Scoring systems prove to be invaluable when applied in the right context. They are effective and provide a good initial indication of areas of concern on broad scales (Hoffmann, *et al,* 2008; Labovitz, 1971; Regan, *et al,* 2005; Scardi, *et al,* 2008). Scoring systems have proved to be extremely beneficial when assessing conservation priorities where there is a lack of funding, rapidly deteriorating environments or the need for quick decisions. Scoring systems allow for quick decisions to be made (Knapp, *et al,* 2003). It is often hard to understand the

complex processes of ecosystems and data gathering requires extensive time and effort. Scoring systems help to simplify complex ecosystem interactions and prioritise these areas for conservation (Knapp, *et al,* 2003). There are many examples, both internationally and nationally, where scoring systems have proved to be beneficial such as the International Union for the Conservation of Nature (IUCN) red list of threatened species, the Fish Assemblage Integrity Index (FAII) and the Instream Habitat Integrity (IHI) Assessment.

The IUCN red list of threatened species is a global resource which looks at the conservation status of plant and animal species. The red list aims to classify all species into threat categories. The initial classification system was based solely on expert opinion which was criticised as the results were biased by personal preference and political opinion (Rodrigues, *et al,* 2006). The system has since been improved, incorporating a data-driven and objective criteria-based approach. Expert opinion is still incorporated but opinions must be justified and supported by data. Large amounts of data are required for each species to provide a defensible assessment. Scores and estimates of uncertainty are also included (Rodrigues, *et al,* 2006). At the moment, species which have been assessed tend to be the more common, well-known species but with a continuous, combined effort, the database continues to grow. The IUCN aims at developing a global standardised list to ensure consistency in conservation (Rodrigues, *et al,* 2006).

A South African system, FAII also makes used of scoring. It is based on fish species expected to be present in certain biotopes of a river (Kadye, 2008; Kleynhans, 1999). Fish species and the species' preferences, such as trophic and habitat preferences, requirements for flowing water during different life stages and association with habitats with unmodified water quality are used to determine the biological integrity of rivers (Kadye, 2008; Kleynhans, 1999). Integrity refers to the current condition of the river in comparison to its near-natural state. FAII is an intolerance index that compares which species are expected to occur in the river system to the species which currently occur under the present human altered state (Kleynhans, 1999; Roux, *et al,* 1999a; Roux, *et al,* 1999b). Results are grouped into one of six descriptive fish assemblage integrity index classes. The index provides a broad estimation of the biological integrity of the river. The index as it currently exists provides qualitative, descriptive criteria for the desired integrity state of a river (Kleynhans, 1999).

Another South African system which incorporates scoring is the IHI Assessment. According to Kemper (1999), the IHI Assessment was developed as a tool for immediate assessment of the Ecological Reserve for rivers in South Africa. Many of the calculations in the IHI Assessment, such as scoring, weighting and calculating the impact due to transformation, are very similar to the calculations used in this study. In the IHI methodology, river integrity is assessed on 12 main criteria. Any anthropogenic modification to one of the 12 criteria will lead to the deterioration of river integrity. Severity of the impact is assessed by six descriptive categories, each with a five point rating score. The score applied is guided by a description of the severity of the impact of modification from a natural situation to a transformed one. A weighting is then applied to each of the 12 criterion based on the perceived impact they will have on the river's integrity. The estimated impact of all 12 criteria are calculated, summed and then expressed as a percentage. For the benefit of conservation planning, if multiple criteria have serious impacts, an additional negative weighting is applied to represent the cumulative impacts of any disturbances.

4 Study Site and Available Data

The study site was the Republic of South Africa. River and fish data were not available for Lesotho and the Kingdom of Swaziland even though some of South Africa's rivers have their source in these countries. The study used existing land cover, river integrity and fish species occurrence datasets. Data were collected from various sources and the information in each dataset was used to further analyse each quaternary catchment in South Africa (Figure 4-1).

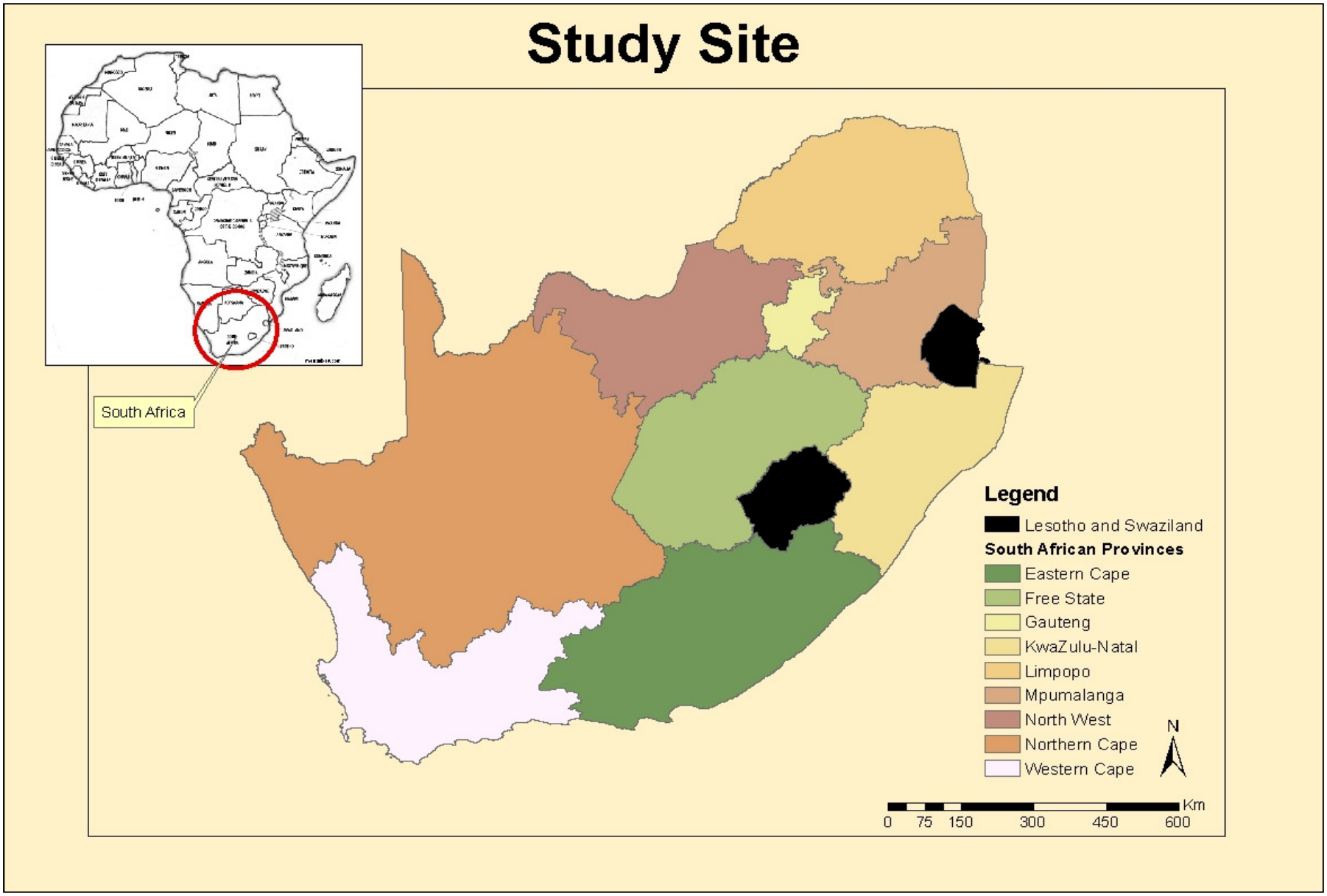


Figure 4-1: The study site focuses on South Africa.

4.1 Quaternary Catchments

Datasets were developed by the Water Research Commission (WRC) of South Africa in conjunction with the Department of Water Affairs and Forestry (DWAF). Drainage regions separated by watershed lines were divided into smaller hydrological units from a primary catchment level to secondary catchments, tertiary catchments and quaternary catchments (Nel, *et al,* 2007). This study focused on quaternary catchments (Figure 4-2). There were just less than 2000 quaternary catchments which vary in size from 50km^2 to 18 000km^2 (Hughes, 2004).

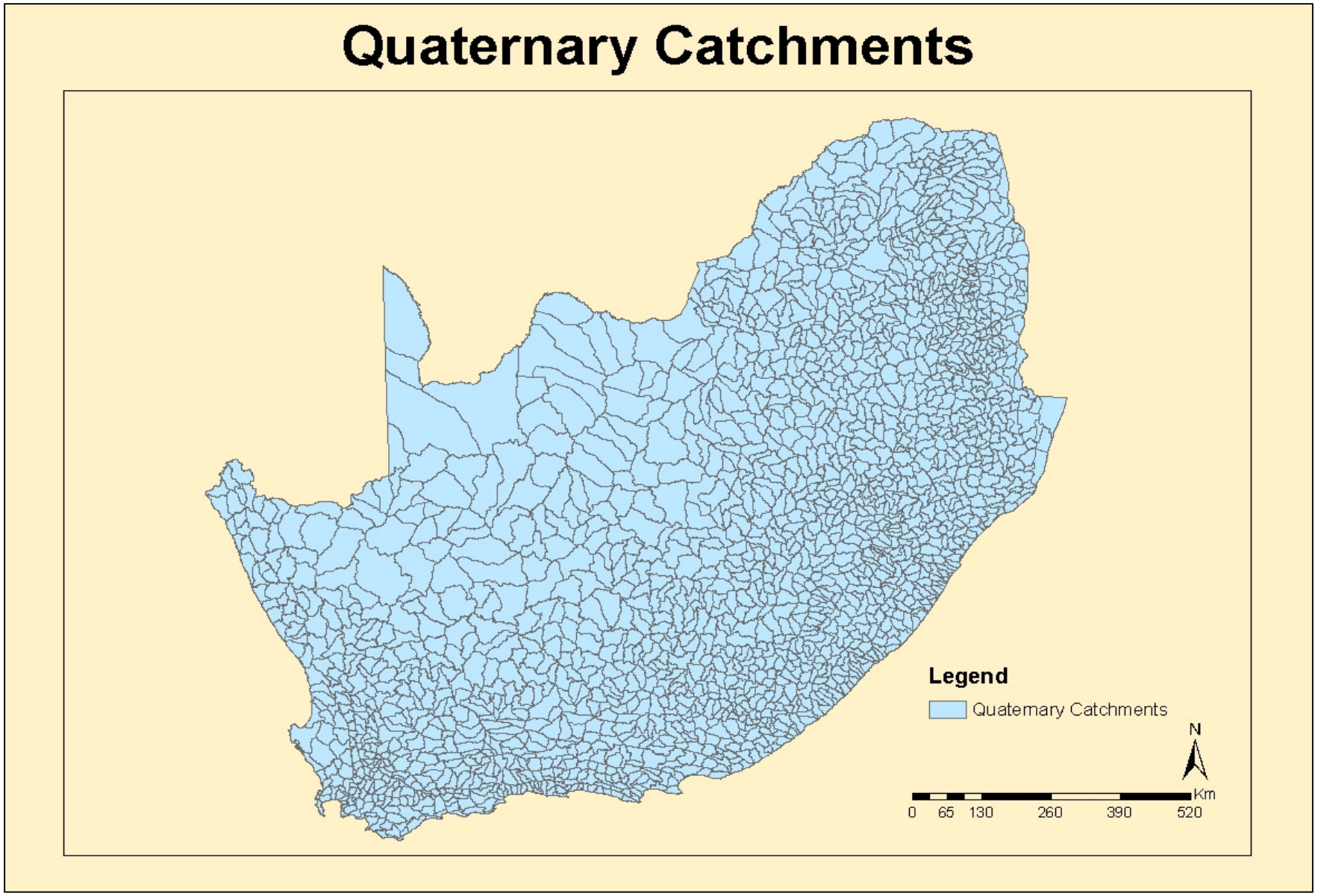


Figure 4-2: Quaternary catchments of South Africa developed by the Water Research Commission.

4.2 2000 National Land Cover Dataset

The 2000 National Land Cover dataset was developed by the Agricultural Research Council (ARC) of South Africa as an update to the 1994 land cover dataset. It was developed to be a standardised land cover layer where the categories can further be subdivided to provide more detailed information for specific projects (Thompson, 1996). The 1994 National Land Cover dataset had 31 different land cover categories. The 2000 National Land Cover dataset used for this study consisted of 49 different land cover types (Appendix, Section A), and the data were provided at a high level of detail with a 30m pixel resolution. The land cover database was derived from seasonal, high resolution satellite imagery from Landsat 7 ETM+, which was acquired during 2000 to 2002. The land cover data had a high resolution within the quaternary catchment level and were suitable for 1:50 000 scale mapping and modelling applications (Figure 4-3). At the time of this study, comprehensive metadata on the 2000 National Land Cover dataset was not available, and personal communications with the authors of the data provided important background information.

Each land cover type was clearly defined by the ARC and provided sufficient information to determine whether the land cover exists in a natural condition or whether it is degraded. The least transformed categories for this study are natural land cover, such as forests, herb lands and woodlands (and would have received a score of five in the transformation analyses). Other categories include cultivated grasslands and dry land. Completely transformed categories (later given a score of one) include urban and built up environments and mining environments (van den Berg, 2008, *pers.comm*).

Transformed environments are unable to fully maintain natural ecosystem processes, thereby affecting the natural water flow of an area or the quality of the water passing through an area or both (Goetz & Fiske, 2008; Lindenmayer, *et al,* 2008). For a detailed explanation of the different scores applied refer to the Appendix, Section A. Differences in opinion regarding the scores applied will occur, but unless the land cover type occupies a large area of a catchment, it will have little effect on the final score.

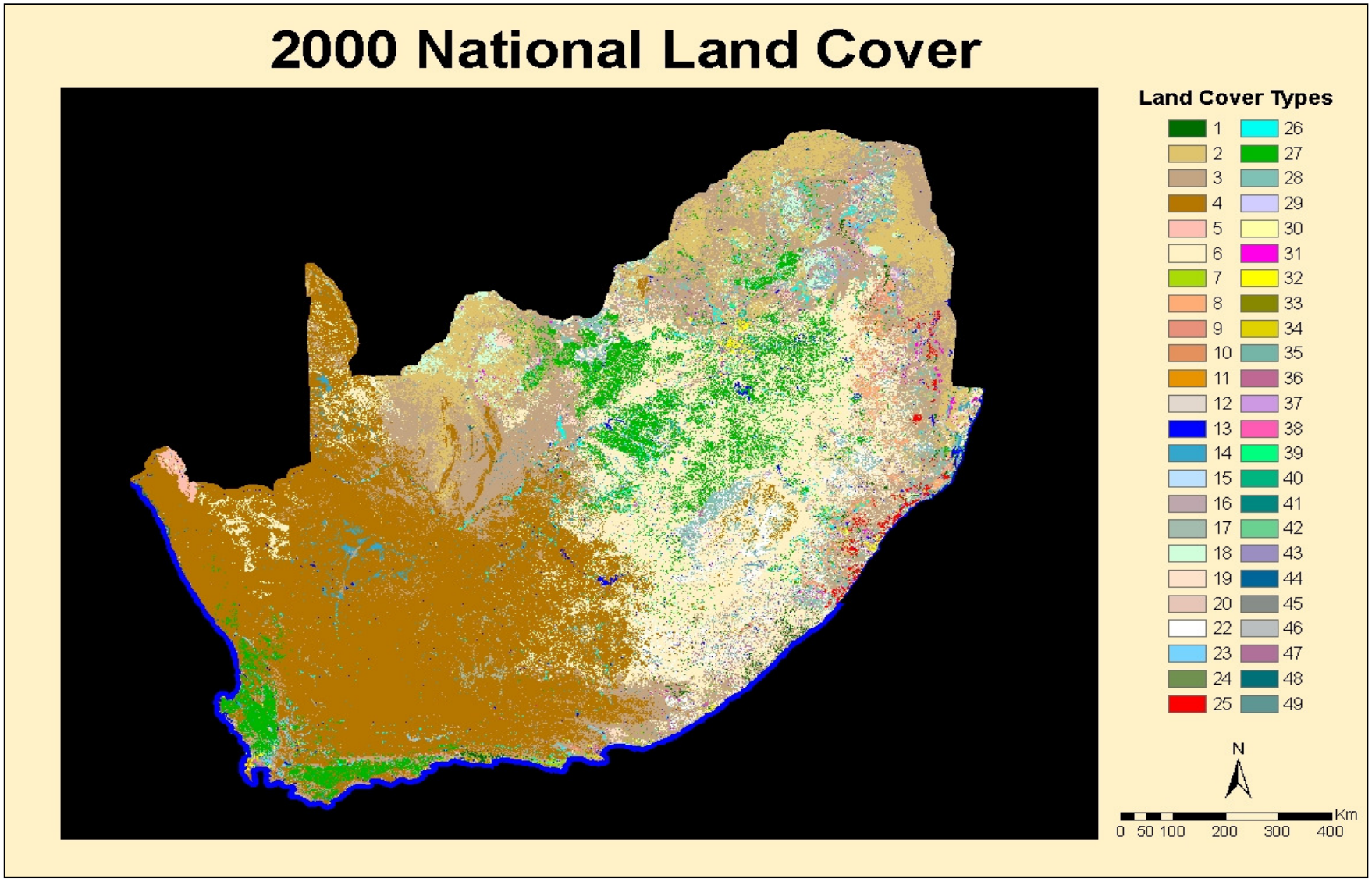


Figure 4-3: 2000 National Land Cover dataset developed by ARC (Refer to Table 5-1 for descriptions of the different land cover types).

4.3 River Integrity Data

River information was captured and developed by the Council for Scientific and Industrial Research (CSIR) from 1:500 000 scale river data for the Department of Water Affairs and Forestry (DWAF). River attributes recorded by DWAF were: the length of the river, whether the river is perennial, the order and the reach of the river, percentage of erosion, the ecological importance and sensitivity of the river and if it is a main river or a tributary. Lower order geomorphic information is attached to rivers to describe if the river is a mountain headwater stream or if the river lies in the lower foothills. The geomorphic classification was based on Rowntree and Wadeson's (1999) classification.

River integrity data were derived from desktop estimates of the Present Ecological Status Category (PESC) from the national Water Simulation Model (WSAM) (Kleynhans, 2000). The river's present ecological status was assessed by river scientists and river practitioners between 1998 and 1999 on a national scale (Nel, *et al,* 2009). Ecological status was based on the modification of six attributes: flow of the river, inundation, water quality in the river, stream bed condition, introduced in-stream biota, and riparian or stream bank condition (Table 4-1 and Figure 4-4) (Nel, *et al*, 2004). These six attributes were combined (by calculating the median present ecological status category) to estimate the instream and riparian integrity of the river (Nel, *et al*, 2004; Nel, *et al,* 2007). River integrity described the degree to which a river had been transformed from its natural state by anthropogenic activity. Integrity was categorised into five classes, from 'A' being natural to 'E-F' being highly modified (Nel, *et al,* 2007).

The resulting river integrity data (classes 'A' to 'E-F') were made available for this study (Nel, *et al,* 2004). As ecological status was assessed based on six detailed attributes, it was anticipated that river integrity data would be available for individual segments of rivers, however, it was found during the study that for the data available, all rivers within a quaternary catchment had the same integrity.

Table 4-1: The six attributes which were assessed to determine river integrity (adapted from Nel, *et al,* 2004).

Assessment attributes	**Consideration for assessment**
Flow	How the stream deviates from the expected natural flow.
Inundation	Inundation of weirs and impoundments altering instream habitats and causing fragmentation.
Water quality	Change in water quality from the expected natural condition and the resulting biological impacts.
Stream bed condition	Disturbances to natural stream bed condition.
Introduced instream biota	The severity of impact by introduced species on habitat and native biota.
Riparian/Stream bank condition	Deviation from the expected natural condition.

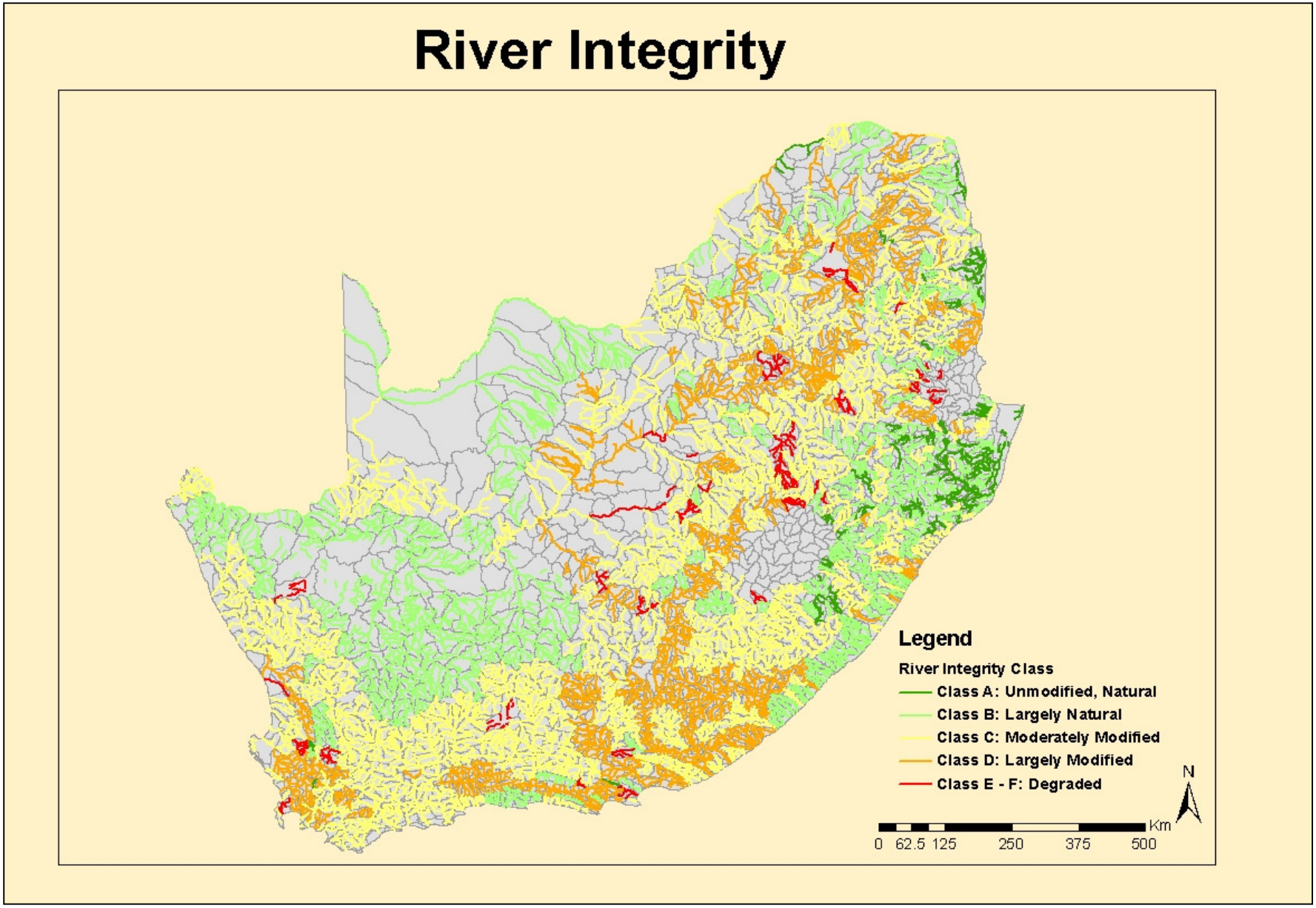


Figure 4-4: River integrity classes developed by Nel, *et al* (2007).

4.4 Fish Species Occurrence Data

Point data were provided to indicate the location of fish species (Figure 4-5). The dataset was a combination of years of data collected from 1897 to 2006 by multiple organisations including the South African Institute for Aquatic Biodiversity (SAIAB), JLB Smith Institute for Ichthyology and the Albany museum collection (Scott, *et al,* 2006). The resolution and comprehensiveness of the data were limited as sets of records were collected using different methods. In many instances, some of the recorded fish occurrence locations do not coincide with rivers or dams. These erroneous fish occurrences may be because some of the data primarily came from old museum records and data were recorded at Quarter Degree Square (QDS) or cadastral unit scale. In the case of data recorded in QDS, often the centre point of the square was taken as the location of the species.

Data were further edited to add the conservation status of each species based on the IUCN global assessment classification system (IUCN, 2008). A total number of 16 937 fish occurrences appeared in the database covering 123 species. Unfortunately, 1 028 fish occurrences (three species) were data deficient according to the IUCN classification and a further 4 989 fish occurrences (37 species) did not have an IUCN classification. Both data deficient species and species without a conservation status were excluded from the study.

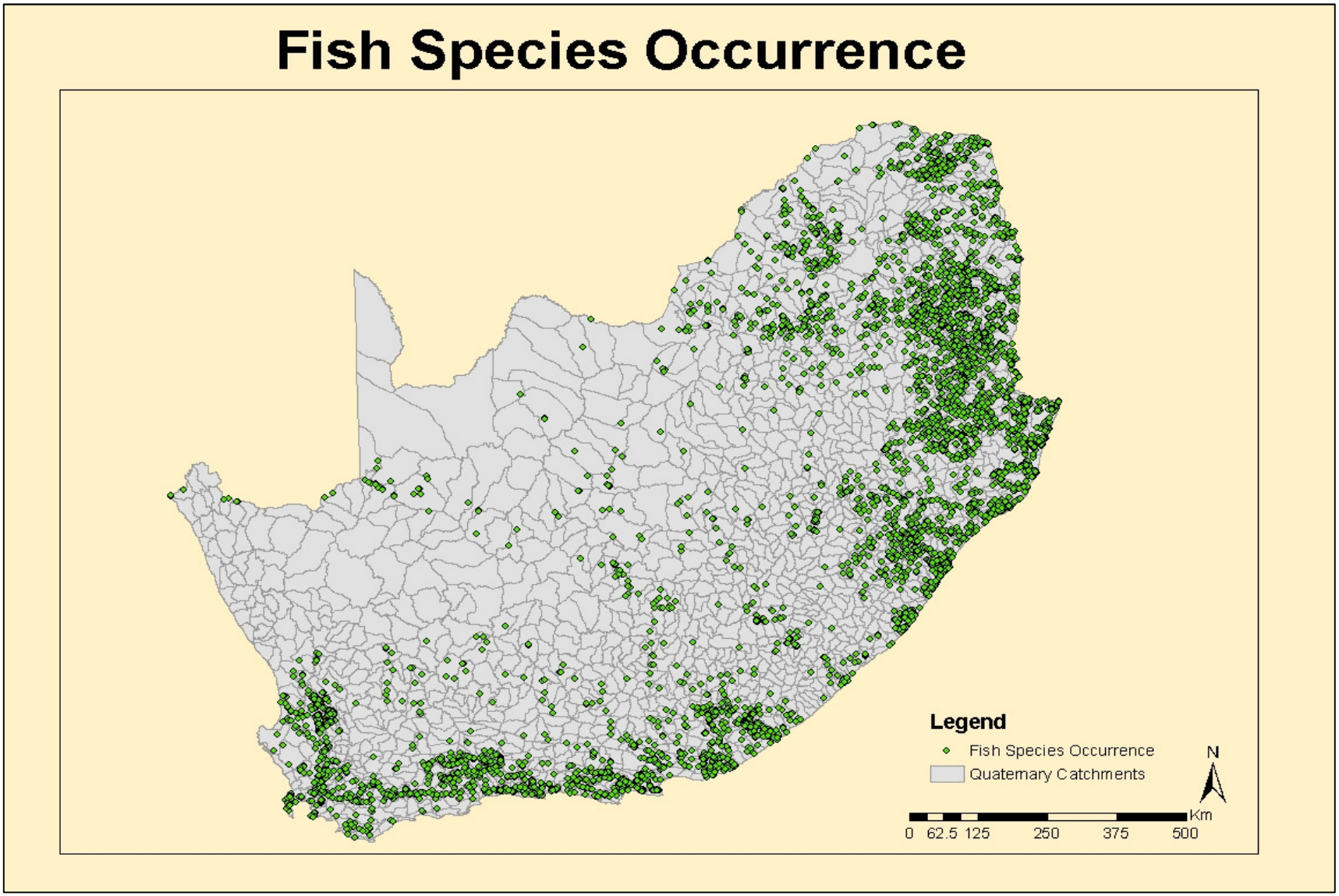


Figure 4-5: Fish species occurrence data developed by SAIAB, JLB Smith Institute of Ichthyology and the Albany museum collection (Scott, *et al*, 2006).

5 Methods

5.1 Overview

In order to obtain an ecological integrity index per catchment, three environmental indicators, namely land cover, river integrity and fish species conservation status, were assessed. These indicators are able to represent integrity as they show a change from natural conditions to transformed ones. An environmental indicator is able to maintain integrity as long as it remains unimpaired. If natural processes no longer occur, such as unnatural water drainage patterns or change in river flow dynamics, the integrity is compromised (De Leo & Levin, 1997).

The land cover data consisted of 49 different land cover types, which were reduced to five land cover transformation scores (see Appendix, Section A for score allocation). The length and integrity category of each river segment was available and a one to five score was assigned for each of the integrity categories. Fish species occurrence data were available and the conservation status of each fish species, based on the IUCN red data list classification, was assigned. Five conservation status categories exist in the IUCN red data list (data deficient categories were excluded) and a score of one to five was assigned to each conservation status.

A land cover transformation index, a river integrity index and a fish conservation status index were calculated using these scores. These results were then evenly combined to develop an ecological integrity index at a quaternary catchment level.

Frequency histograms and cumulative frequency plots were used to display the data distributions and indicate the quality of the datasets. Spearman's rank correlation, called Spearman's rho (ρ), was used to test the relationship between the three indices.

5.2 Land Cover Transformation Index

Land cover data were derived from the 2000 National Land Cover dataset. The 49 different land cover types were assigned a transformation score of one (transformed) to five (natural) (Table 5-1). The one to five score was weighted by the surface area each score represented in each quaternary catchment when calculating the land transformation index [a similar process has been used by Kemper (1999) and Pont, *et al* (2006)]. The scores were based on the presumed degree of transformation from a natural environment to a human degraded environment (Appendix, Section A for a detailed description of the scoring criteria).

To meet the objective in section 2.1 a weighted mean land cover transformation score per quaternary catchment was determined as follows:

a) A one to five land cover transformation score was assigned for each of the 49 land cover types based on the assessed impact land cover transformation will have on terrestrial and aquatic ecosystems (Table 5-1).
b) The surface area for each land cover transformation score per quaternary catchment was extracted in ArcGIS.
c) An area weighted mean land cover transformation score per quaternary catchment was obtained by multiplying the area of each class by the land transformation score and dividing the sum of all the classes' scores by the total area of the catchment (Equation 5.1).

$$Weighted\ mean\ land\ transformation\ score\ per\ catchment = \frac{\sum(Surface\ area\ of\ each\ transformed\ land\ cover\ \times score)}{\sum(Surface\ area\ of\ each\ transformed\ land\ cover)} \quad (5.1)$$

d) A relative land transformation index was calculated and expressed as a percentage by dividing the weighted mean score by the maximum land cover transformation score (five), (Equation 5.2).

$$Index(Land\ transformation) = \frac{Weighted\ mean\ score}{Max\ score} \times 100 \quad (5.2)$$

The result represents the percentage of each catchment which remains in a natural condition as opposed to a transformed environment. Results with a value of 0% to 20% represent highly degraded conditions, and results between 80% and 100% represent pristine, natural environments.

Table 5-1: The 49 land cover types with the allocated land cover transformation score.

ID	Land cover type	Allocated score
1	Forest (indigenous)	5
2	Woodland (previously termed Forest and Woodland)	5
3	Thicket, Bushland, Bush Clumps, High Fynbos	4
4	Shrubland and Low Fynbos	5
5	Herbland	4
6	Unimproved (natural) Grassland	5
7	Improved Grassland	3
8	Forest Plantations (Eucalyptus spp)	2
9	Forest Plantations (Pine spp)	2
10	Forest Plantations (Acacia spp)	3
11	Forest Plantations (Other/mixed spp)	3
12	Forest Plantations (clear felled)	1
13	Water Bodies	3
14	Wetlands	4
15	Bare Rock and Soil (natural)	5
16	Bare Rock and Soil (erosion : dongas/gullies)	1
17	Bare Rock and Soil (erosion : sheet)	2
18	Degraded Forest & Woodland	3
19	Degraded Thicket, Bushland, etc	2
20	Degraded Shrubland and Low Fynbos	3
21	Degraded Herbland	1
22	Degraded Unimproved (natural) Grassland	2
23	Cultivated, Permanent, Commercial, Irrigated	2
24	Cultivated, Permanent, Commercial, Dry Land	2
25	Cultivated, Permanent, Commercial, Sugarcane	2
26	Cultivated, Temporary, Commercial, Irrigated	2
27	Cultivated, Temporary, Commercial, Dry Land	2
28	Cultivated, Temporary, Subsistence, Dry Land	1
29	Cultivated, Temporary, Subsistence, Irrigated	1

30	Urban/Built-up (residential)	2
31	Urban/Built-up (rural cluster)	2
32	Urban/Built-up (residential, formal suburbs)	3
33	Urban/Built-up (residential, flatland)	1
34	Urban/Built-up (residential, mixed)	2
35	Urban/Built-up (residential, hostels)	1
36	Urban/Built-up (residential, formal township)	2
37	Urban/Built-up (residential, informal township)	1
38	Urban/Built-up (residential, informal squatter camp)	1
39	Urban/Built-up (smallholdings, woodland)	3
40	Urban/Built-up (smallholdings, thicket, bushland)	4
41	Urban/Built-up (smallholdings, shrubland)	3
42	Urban/Built-up (smallholdings, grassland)	3
43	Urban/Built-up, (commercial, mercantile)	1
44	Urban/Built-up, (commercial, education, health, IT)	3
45	Urban/Built-up, (industrial/transport : heavy)	1
46	Urban/Built-up, (industrial/transport : light)	2
47	Mines & Quarries (underground/subsurface mining)	1
48	Mines & Quarries (surface-based mining)	1
49	Mines & Quarries (mine tailings, waste dumps)	1

5.3 River Integrity Index

Each river segment has been derived and classified based on the river's integrity. Kleynhans (2000) developed the national water simulation model which was later applied by Nel, *et al* (2007). Nel, *et al* (2007), assessed river integrity based on six categories: (i) river flow, (ii) inundation, (iii) water quality, (iv) stream bed condition, (v) introduced instream biota and (vi) riparian and river bank condition. These six variables were analysed to determine five river integrity classes: (A) unmodified/natural, (B) largely natural, (C) moderately modified, (D) largely modified, or (E-F) degraded. A numerical score of one (degraded) to five (unmodified/natural) was assigned to the five river integrity classes (Table 5-2).

To meet the objective in section 2.2 a weighted mean river integrity score per quaternary catchment was determined as follows:

a) A numerical score of one to five was assigned to the existing five river integrity classes (A, B, C, D and E-F).
b) The length of each river segment per score for all the rivers in each quaternary catchment was extracted in ArcGIS.
c) A weighted mean river integrity score was obtained per quaternary catchment area by multiplying the length of each segment by the appropriate score and dividing the sum by the total river length per catchment (Equation 5.3).

$$Weighted\ mean\ river\ integrity\ score\ per\ catchment = \frac{\sum(Length\ of\ river\ segment\ \times score)}{\sum(Length\ of\ river\ segments)} \quad (5.3)$$

d) A river integrity index was calculated by dividing the weighted mean score by the maximum river integrity score, presented as a percentage (Equation 5.4).

$$Index(River\ integrity) = \frac{Weighted\ mean\ score}{Max\ score} \times 100 \quad (5.4)$$

Table 5-2: River integrity categories (Nel, *et al,* 2007) with applied integrity score.

River integrity	Score
Class A: Unmodified, natural	5
Class B: Largely natural	4
Class C: Moderately modified	3
Class D: Largely modified	2
Class E - F: Degraded	1

5.4 Fish Conservation Status Index

Fish species data came from the combined collections of the South African Institute for Aquatic Biodiversity (SAIAB), the JLB Smith Institute for Ichthyology (now incorporated into SAIAB) and the Albany Museum collection (Scott, *et al,* 2006). It was further edited to include the IUCN conservation status. The IUCN is an internationally recognised conservation tool which aims to classify each species based on their conservation status (Rodrigues, *et al*, 2006). The IUCN threatened species data were used to allocate a conservation status for each fish species where classifications were available. A five score linear weighting system is used (Table 5-3), although ecologically, the difference between categories may not be as simple as a difference of one (or 20%). In the absence of more detailed data on the extent of occurrence of the species in question, any attempt to rectify this short coming fell outside the scope of this study. The one to five weighting system is comparable to the river integrity and land transformation scores where one represents low impacts and high integrity while five represents highly impacted and low integrity.

To meet the following objective in section 2.3 a weighted mean fish conservation status score per quaternary catchment was determined as follows:

a) A numerical score of one to five was assigned to the conservation status of the fish species using the existing IUCN classification (Table 5-3).
b) Occurrences for fish species with a recorded conservation status per quaternary catchment were extracted in ArcGIS. Fish without a recorded conservation status were excluded.
c) Fish species occurrences per catchment were determined.
d) A weighted mean fish conservation status score per quaternary catchment area was obtained by multiplying the number of occurrences by the conservation status score and dividing the sum by the total number of counted occurrences per catchment (Equation 5.5).

$$Weighted\ mean\ fish\ conservation\ score\ per\ catchment = \frac{\sum(Number\ of\ occurances\ of\ each\ fish\ species\ with\ conservation\ status\ \times score)}{\sum(Number\ of\ occurances\ of\ each\ fish\ species\ with\ conservation\ status)} \quad (5.5)$$

e) Calculate the conservation status index by dividing the weighted mean score by the maximum conservation status score as a percentage (Equation 5.6).

$$Index(Fish\ conservation\ status) = \frac{Weighted\ mean\ score}{Max\ score} \times 100 \quad (5.6)$$

f) When a catchment had no recorded fish species these catchments were excluded from analyses. This was done deliberately to prevent a mean value assignment from skewing any results.

Table 5-3: IUCN category with applied fish species score.

IUCN Category	Score
Critically endangered	1
Endangered	2
Vulnerable	3
Near threatened	4
Least concern	5
Data deficient	Excluded

This study is a broad scale study which aims to provide an initial overview of catchment integrity. Closer, more detailed studies will be required to determine the state of each individual catchment. Of the total 16 938 fish occurrences (123 species), only 10 921 (83 species) or 64% of fish occurrence data could be classified and used. It is recommended that data deficient species and species without a conservation status classification be excluded (Hoffmann, *et al*, 2008)

5.5 Ecological Integrity Index

To meet objective 2.4, the mean of the individual index scores (land transformation index, river integrity index and fish conservation status index) was taken as the overall catchment ecological integrity index (Equation 5.7).

$$Total\ ecological\ index\ per\ quaternary\ catchment = \frac{\boldsymbol{I}(Land\ transformation) + \boldsymbol{I}(River\ integrity) + \boldsymbol{I}(Fish\ conservation\ status)}{3} \quad (5.7)$$

The three indices are comparable as they were all calculated using the same method and score range and all results were represented as a percentage. The combined results were equally weighted in the ecological integrity index for quaternary catchments of South Africa. Catchments without river integrity data or fish occurrence data were excluded from the analyses and final results.

5.6 Interrelatedness of Indices

In order to determine the interrelatedness of the indicators and to meet objective 2.5, relationships between the indicators were quantified using Spearman's rank correlation coefficient (ρ). This is a non-parametric measure of statistical dependence between two variables and was found to be the most appropriate method as it is appropriate for count and scoring data, and avoids any linear constraints caused by the river and fish data (Anderson, *et al,* 2003; McDonald, 2009). Each of the three indices were compared against each other in this way. As data for two of the three indices was not available for all catchments, the maximum sample set for each pair of indices was used. The null hypothesis test determined if the ranks of one index do not covary with the ranks of the other index. A value smaller than 0.05 (α=5%) rejects the null hypothesis, and the difference is considered significant (Anderson, *et al,* 2003). The result is indicated by the p-value.

5.7 Prioritisation of Catchments for Management and Conservation

As a final output of the study and to meet objective 2.6, catchments were prioritised for potential management and conservation interventions. Results presented ecological integrity of quaternary catchments in 20% increments indicating transformation from completely transformed (0-20%) to natural, undisturbed (81% to 100%).

Results were represented on a map and should be considered indicative, to be used to identify priority areas for conservation. Once these areas are identified, the broad extent and summarised nature of the input data may necessitate additional detailed studies for the selected catchments.

5.8 Summary Data for Each Index

Index scores for quaternary catchments were presented as frequency plots in which the number of catchments in each of the five integrity classes, each with intervals of 20%, was plotted. Further, the cumulative frequency percentage of each index was plotted separately.

6 Results

6.1 Overview

The results section is presented on an index by index basis. First the land transformation index is presented, then the river integrity index, then the fish conservation status index and finally the combined ecological integrity index. For each index, the statistical results are discussed and then a series of maps follow.

The first map will present an area at a detailed scale of resolution (located in the Springbok flats area, east of Modimolle, Limpopo Province) illustrating the conversion from raw data to catchment-based data. This area was selected as it shows the advantage of good quality data such as the detailed land cover data which produced the index of land cover transformation. The disadvantage of poor source data, where data limited the production of a meaningful index, was also demonstrated in the high resolution maps. The second map will show the complete index distribution for all quaternary catchments in South Africa. Where possible a third map has been included so the results of this study can be visually compared to the results of other studies. In the case of the land transformation index, it is compared to an assessment by the Department of Environmental Affairs and Tourism (DEAT), (2006), representing the ecosystem status of terrestrial ecosystems. The results from a study by Nel, *et al* (2007) are included, comparing the condition of main river ecosystems to the developed river integrity index. No appropriate assessment of fish species was available for comparison. Once all three indices and the final ecological integrity index have been presented a final map is included. This map compares the developed indices to actual conditions by comparing the index results to satellite imagery from Google Earth (2008). Two catchments are selected, an area in the Kruger National Park, representing a pristine environment, and a portion of the city of Johannesburg, representing a completely transformed environment. Thereafter the relationship between the indices is tested.

Spearman's rank correlation coefficient (ρ) was calculated between the three indices. This was done to see if any combinations of two indices covary. The coefficient indicates the strength of the relationship between the two indices and the p-value shows the significance of the relationship (McDonald, 2009). Correlation does not indicate causality however the possibility that a relationship exists between any two indices cannot be ignored and for the

examples below, is strongly supported by other research (Anderson, *et al,* 2003; McDonald, 2009).

6.2 Land Transformation Index

The per catchment land transformation index has a relatively normal frequency histogram distribution of data around an offset mean. Nearly half of the catchments have a land cover transformation index value between 61% and 80% showing that they still exist in a largely natural condition (Figure 6-1), and nearly 24% of all South African catchments can still be described as relatively pristine. Approximately 29% of catchments exist in a 41% to 60% natural condition, and 0.5% of catchments are degraded.

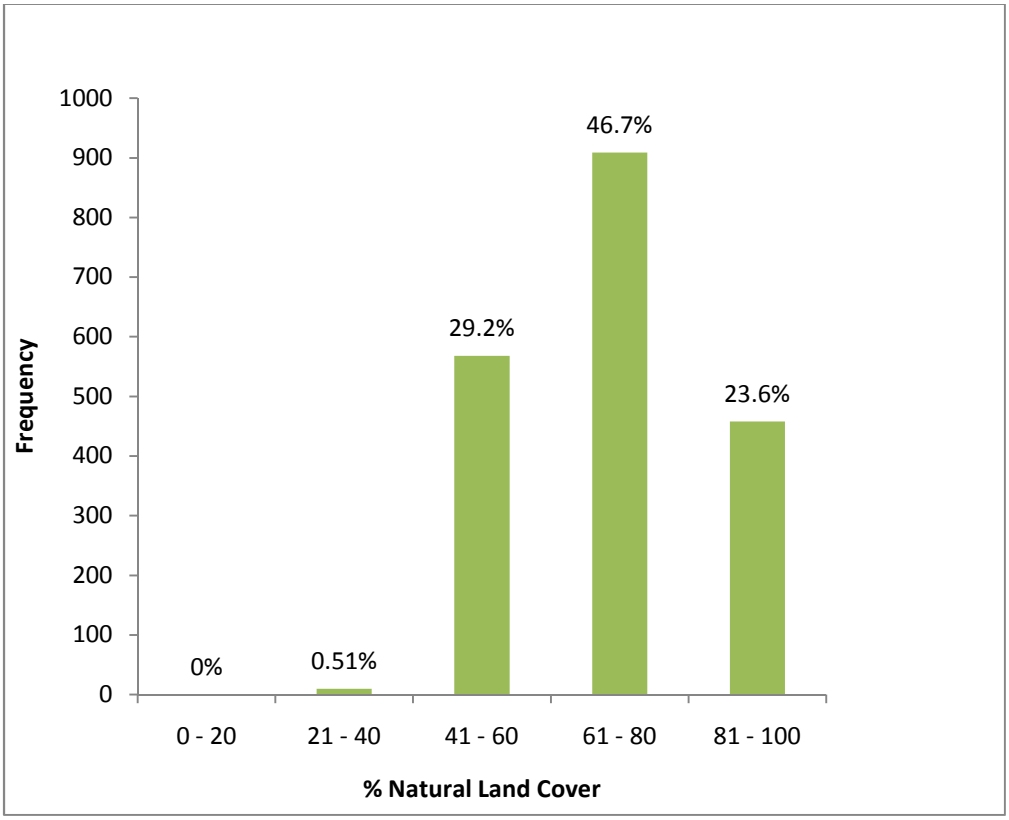


Figure 6-1: Frequency histogram distribution for the land transformation index per quaternary catchment for South Africa. The percentage of each catchment falling within each land cover category is represented above each bar in the frequency histogram.

The cumulative frequency plots (Figure 6-2) for the land cover transformation index shows a smooth distribution representing a natural range of conditions. The transformation values for

all quaternary catchments are distributed throughout each land transformation category, excluding the first (0% to 20%) category. No catchments occur in the 0% to 20% category as no catchment is more than 80% transformed. The data are slightly favourable to pristine conditions, as is found in actual conditions (ENPAT, 2001), but the data show a range of values within each class, suggesting that there is a variety of land cover scores of different areas in each catchment.

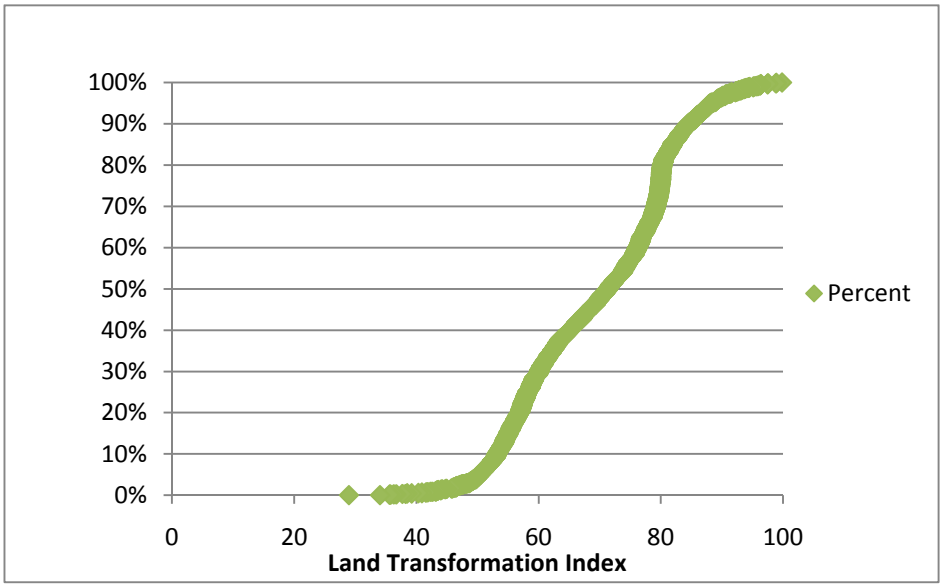


Figure 6-2: Cumulative frequency plot of the results of the land cover transformation index showing a natural data distribution.

The raw, original 2000 National Land Cover dataset originated from the interpretation of satellite imagery captured in detail at approximately 30m pixel resolution. The land usage was classified to provide the dataset of 49 different land cover types used in this assessment. Although reduced from detailed images to 49 categories, the process is well documented and repeatable and is therefore defensible (Fairbanks, *et al,* 2000; Thompson, 1996). The 2000 National Land Cover dataset can be considered an accurate representation of actual conditions. As the land transformation index has been developed from the 2000 National Land Cover dataset, the results of the index are compared to the raw data to determine how good a representation of actual conditions the index provides.

Summary results of the original 2000 National Land Cover dataset showed the majority of South Africa's land cover is classified as "shrubland and low fynbos" covering 33.28% of the country. The second most dominant land cover type is unimproved (natural) grassland

covering 20.24% and a further 18.06% of South Africa is covered by thicket, bushland, bushclumps and high fynbos. Together with other vegetation types, the combined natural vegetation covers a total of 1 009 925km^2 (79.7%) of the country. Different agricultural practices cover an additional 10.7% of the land (135 536km^2). Mining only covers 0.16%, industrial and commercial land covers 0.11% and residential areas (all residential areas including townships, small holdings, urban and built up environments) cover 1.41% (Table 6-1). All disturbed land cover types add up to 20.3%.

Table 6-1: Percentage of a *selection* of different land cover types in South Africa calculated from the original 2000 National Land Cover dataset.

Land cover	Land Area (%)	Area (km^2)
Commercial/Industrial	0.11	1 357.75
Mining	0.16	2 026.27
Residential	1.41	17 835.08
Plantations (Forest)	1.45	18 373.91
Agricultural	10.70	135 536.25
Natural vegetation	79.74	1 009 925.20

It is clear that a very large percentage of the country still exists in a relatively natural, unmodified condition. Although it is true that most of the land cover is natural, the effect of some smaller transformed areas can have a large negative impact on natural systems.

Once the land transformation index was calculated, the results for the catchments were grouped into five categories. If one combines the dominantly natural catchments (61% to 100%), they make up 70.3% of the total catchments in the land transformation index. This value compares well with the 79.7% natural land cover calculated from the 2000 National Land Cover dataset. 29.2% of catchments in the developed land transformation index fall into the 41% to 60% category which compares closely to the 20.3% transformed land cover calculated from the 2000 National Land Cover dataset. Based on this comparison, the

developed index for quaternary catchments is representative of the 2000 National Land Cover dataset which is representative of actual conditions.

Referring to Figure 6-3 (Springbok Flats) a comparison can be made between the developed land transformation index and the original land cover data.

In catchment B31A, 77% of the catchment land cover is natural woodland, thicket and bushveld. Degraded forest, woodland and thicket covers approximately 8% of the catchment and 13% of the land cover consists of cultivated, temporary, commercial dry land agriculture. This catchment exists in a largely natural state and therefore receives a land cover transformation score of 84%. In catchment B11J, 57% of the land cover is natural woodland, thicket and bushveld. Degraded forest and woodland make up an additional 14%. Cultivated, temporary, commercial, dry land covers another 14% of the catchment and wetlands cover 10% of the catchment area. As the majority of this catchment is covered by natural undisturbed vegetation, it receives a land transformation score of 78%, however, it is slightly more degraded than catchment B31A. Catchment A92B is the most degraded of the three example catchments and only receives a land transformation score of 56%. This is because only 30% of the catchment exists in a natural condition covered by woodlands, thicket and bushveld. Degraded forest and woodland cover 29% of the land. Cultivated, temporary commercial and subsistence farming covers 37%. 1% of the catchment consists of informal townships and 0.5% of the land cover is mining and industry. The degraded forest and woodland will lead to an increase in sedimentation affecting the river. The influence of the townships and industry will have a negative effect on the natural environment due to increased levels of pollution. Both pollution and sedimentation will degrade the river quality and therefore this low transformation score will contribute to a lower ecological integrity for this catchment.

Referring to Figure 6-4 (the land transformation index) the following general observations can be made at a catchment level.

No catchments have a land transformation index that can be described as completely degraded with an index score between 0% and 20%. This does not mean that degraded

areas do not exist within a catchment or close to rivers. There are numerous degraded areas, especially in regions with high populations, large industries, open cast mines and excessive agricultural practices. Land cover in densely populated areas and transformed areas tend to be more degraded. Looking at Gauteng as an example, the province only covers 1.3% of the country yet 7.3 million people (18.1% of South Africa's population) live there (StatsSA, 2009). The majority of the catchments in Gauteng fell into the 41% to 60% natural areas (in other words they were between 59% and 40% transformed). The largest province in South Africa, the Northern Cape (covering 30.5% of the country) has only 0.8 million people (2.07% of the country's population) (StatsSA, 2009). All catchments within this sparsely developed province have between 61% and 100% natural land cover. This shows that more remote regions with sparse populations and limited infrastructure tend to have less transformed environments.

As a final, visual comparison, the land cover transformation index is compared to the DEAT (2006) map of terrestrial ecosystem status (Figure 6-5). The DEAT (2006) ecosystem status map was calculated using different environmental variables to the ones used in this assessment. A primary concern was the loss of natural ecosystems; in order to map ecosystems, DEAT decided to include plant and animal species and spatial features linked toecosystem processes. It is very difficult to get accurate representations of all the indicators on a national scale. For this reason only species of special concern (i.e. endemic species and threatened species) for plants and animals were included. Spatial features linked to ecosystems process included the Great Escarpment and associated mountain ranges, biogeographical nodes, carbon sequestration areas and areas of biome resilience to climate change. Loss of natural habitat and land use was mapped as an indication of loss of terrestrial ecosystems (Driver, *et al,* 2005). Based on these environmental indicators Figure 6-5 was produced.

Based on a visual comparison, results within provinces and smaller areas, and results along the coastlines indicate similar trends. Further, by visual assessment, a correlation is found between natural and degraded areas. Therefore, the terrestrial ecosystem status map (DEAT, 2006) and the land transformation index can be considered a close comparison. Similar trends can be seen in the following areas: a large portion of the Free State, North West and Limpopo Province and the majority of Mpumalanga and Gauteng show similar land transformation and areas of concern. Areas of concern are also similar in the Western Cape and along the coast line of KwaZulu-Natal. There is some discrepancy between the

two maps in the Northern Cape. The land transformation index indicates that some catchments in the Northern Cape are slightly transformed (between 61% and 80% natural) whereas the DEAT ecosystem status map shows this area to have least threatened ecosystems. This may be as the area is in the Nama Karoo which although it has high levels of unique species, it also has low rainfall (Mucina & Rutherford, 2006). Grazing and low density agriculture is not uncommon however, the lower rainfall and harsher conditions makes the area unsuitable for intense agriculture. As agriculture occurs at lower densities it is less threatening to biodiversity (Tainton, *et al*, 1999; Driver, *et al*, 2005). The Northern Cape has a smaller population spread over a much larger area when compared to more developed provinces such as Gauteng. Therefore the urban and industrial development is much lower, not affecting the biodiversity. Another explanation of this discrepancy is that different environmental variables used in both assessments will indicate different environmental scenarios. The DEAT ecosystem status assessment used plant and animal species as environmental variables and the Nama Karoo is rich in endemic succulent species which the land transformation index would not have indicated (Mucina & Rutherford, 2006).

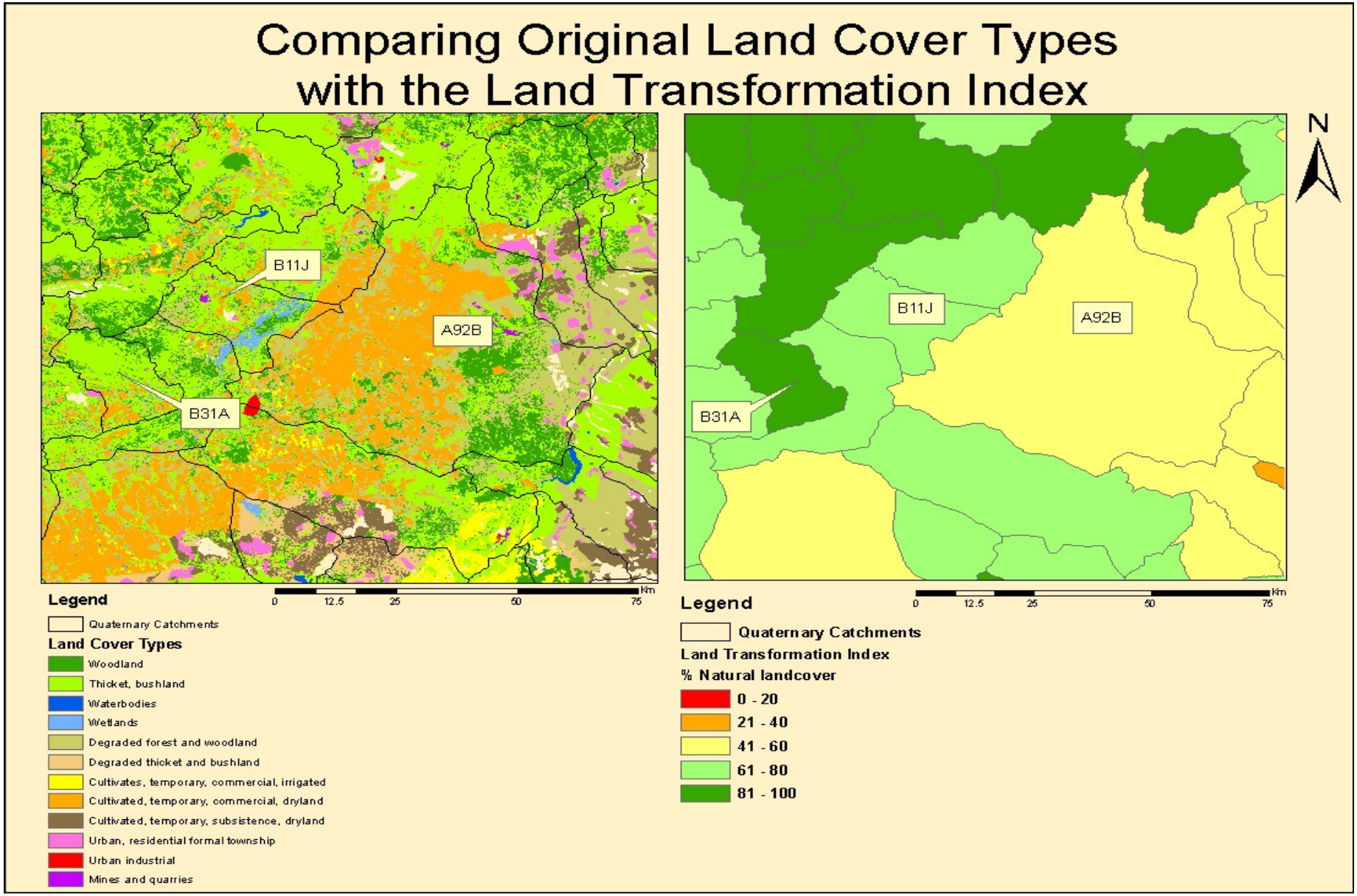


Figure 6-3: Comparison of the original land cover data against the developed land transformation index, located in the Springbok Flats, Limpopo Province.

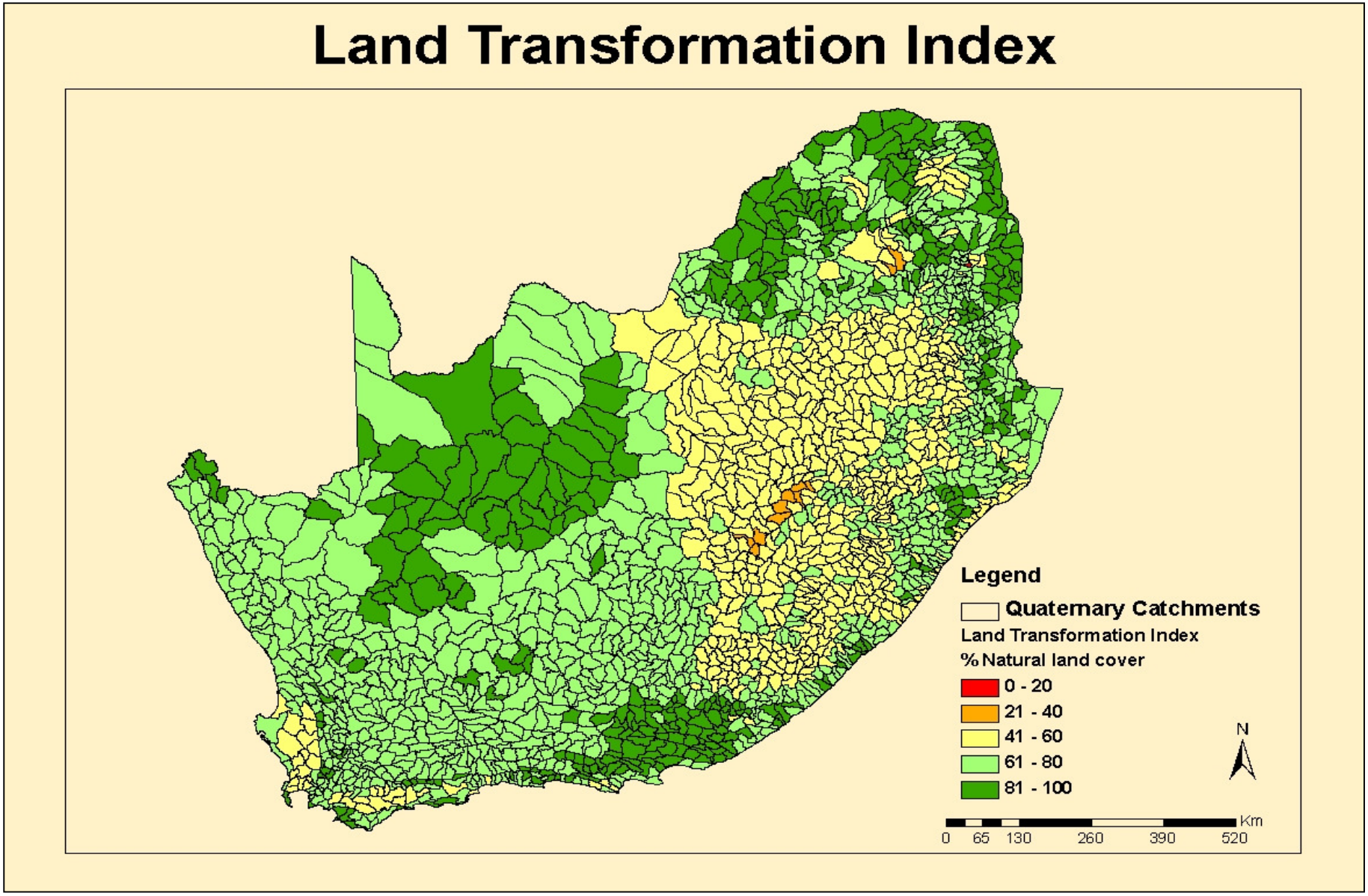


Figure 6-4: Land cover transformation index results for quaternary catchments of South Africa.

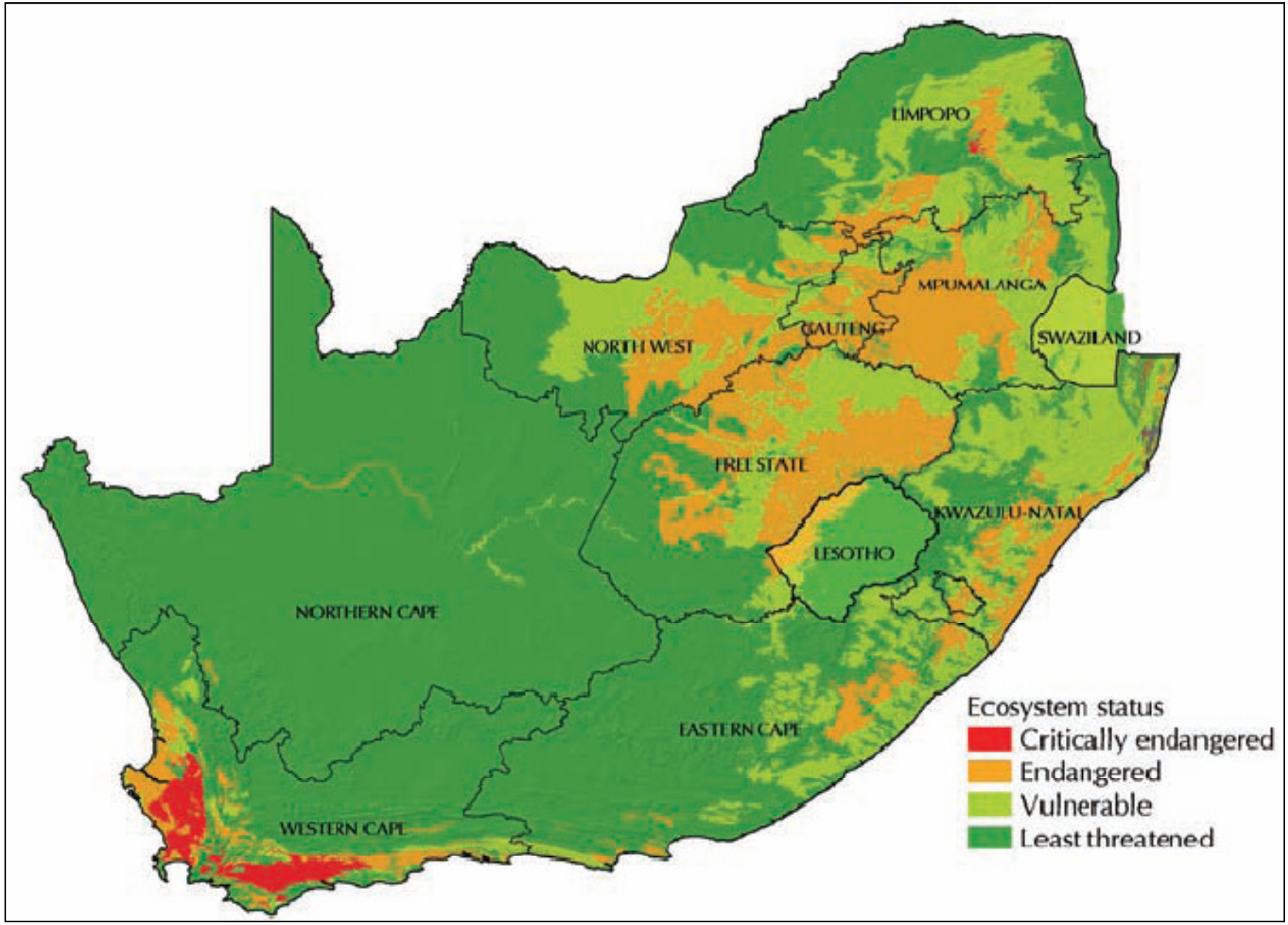


Figure 6-5: Ecosystem status of terrestrial ecosystems (DEAT 2006; Driver, *et al*, 2005).

6.3 River Integrity Index

Rivers exist in all conditions from natural to highly modified, with the majority of rivers being moderately modified (between 41% and 60%), (Figure 6-6). This result is different to the land transformation index results, most river data falls into the 41% to 60% class while most land cover data falls into the 61% to 80% class.

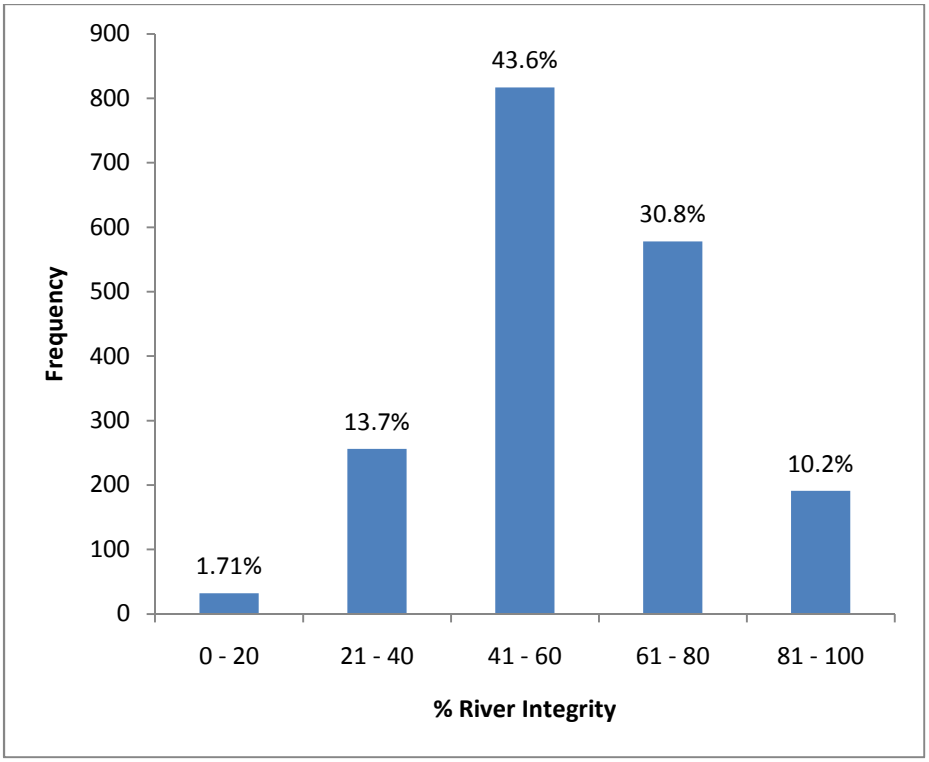


Figure 6-6: Frequency histogram distribution for the river integrity index for rivers in South Africa. Percentage of each catchment falling within each river integrity category is represented above the bar.

On a per catchment basis, the river integrity index represents the integrity of the rivers from a natural condition to a degraded condition across all quaternary catchments in South Africa. For all the South African rivers, 1.7% are completely degraded, 13.7% are significantly affected by human activity, 43.6% suffer from broad anthropogenic impacts, 30.8% are relatively unaffected and 10.2% of all South African rivers remain in a pristine condition (Figure 6-6). Only South African rivers were included as river data was not available for Lesotho and Swaziland, where some of South Africa's main rivers, such as the Gariep River (originating from the Senque River in Lesotho), find their source.

The cumulative frequency plot shows that the river integrity index data are classified into four discrete categories with little to no continuity in the distribution per catchment (Figure 6-7). The curve of the graph has distinct steps with sharp increments around the 40, 60 and 80 values. This indicates that the data distribution is largely grouped at these values. When looking at the original river integrity data it becomes clear that river integrity was not actually based on sampled, individual river segments (Nel, *et al,* 2004), but rather reflects a generalised description, already based on a quaternary catchment scale. All rivers within a quaternary catchment were given the same integrity class even though rivers were broken up into detailed segments and the actual value per river or stream segment was not recorded. This means that the length-weighting of the integrity scores did not have a large influence in the final value of the river integrity index. This has also resulted in the clearly stepped groupings seen in the cumulative frequency plot (Figure 6-7).

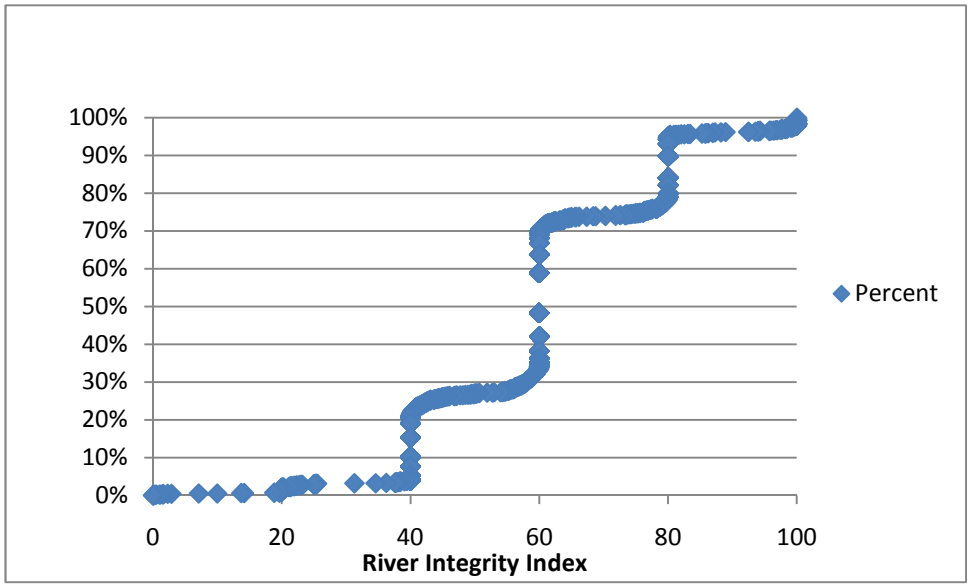


Figure 6-7: Cumulative frequency plot of the results of the river integrity index showing distinct stepped grouping in the data distribution.

The area at a detailed scale of resolution (Figure 6-8) compares the original segmented river integrity data to the weighted average scored per catchment data developed in the river integrity index.

All river segments within the example catchments (Springbok Flats) have been allocated the same score, irrespective of the adjacent land cover. This result is definitely not in agreement with the land cover classification figure and does not truly represent what occurs in a real world situation. There is little or no correlation of catchment classification if one compares the right hand maps of Figure 6-8 and Figure 6-3, largely due to the lack of differentiation in the integrity of the different river segments. The correlation problem will be further quantified later.

The river integrity index is shown in Figure 6-9. Rivers tend to be more pristine in remote areas where there is less transformation of the natural land cover and less human interference. This is clearly seen in the Northern Cape where only 2.07% of the country's population occurs (StatsSA, 2009). In other areas of the country, some rivers are severely degraded (between 0% and 20% natural). Degraded rivers occur in regions with significant human interference, such as along the border of Lesotho where the river integrity has been altered due to poor agricultural practices and resulting high levels of erosion.

The eastern region of South Africa is highly impacted whereas the western region of the country is more natural. River density is higher in the eastern region of the country due to the higher rainfall (Tainton, 1999). However, due to the high population density, and high levels of land cover transformation, most of the catchments have a river integrity index score from 0% to 60% natural. The river integrity index for most of the Northern Cape catchments is between 61% and 80% natural. River integrity in the Western Cape varies between 21% and 60%. This is due to the very unique environment created by the dry summer climate and winter rainfall (Mucina & Rutherford, 2006). Population density is also higher in the Western Cape (9.75% of the country's population living on 10.62% of the land) compared to the Northern Cape (StatsSA, 2009). Rivers south of the escarpment have a range of integrities varying between 21% and 60% natural.

Finally, as a visual comparison, the results of the river integrity index are compared to a map of the ecosystem status of main rivers in South Africa, developed by Nel, *et al* (2007), (Figure 6-10). Ecosystems status was determined using the rivers hydrological index, which considers the amount and variability of water flow in a river system, and the rivers integrity, describing the extent to which a river has been modified by human activity. Ecosystem

status was then determined by combining the river integrity along with the total intact length of each main river ecosystem. The proportion of intact river to the total length of the river was considered and if 20% or less was conserved the river system was considered critically endangered. Between 20% and 40% is considered endangered, between 40% and 60% is considered vulnerable and more than 60% is currently not threatened (Nel, *et al,* 2007).

When comparing the results of the river ecosystem status by Nel, *et al* (2007), and the results of the river integrity index, they were found to be highly comparable. Transformed and threatened rivers in all provinces corresponded well. There is only a slight discrepancy in KwaZulu-Natal and this may be attributed to different methods and variables used to calculate the ecosystem status and river integrity. The river integrity index included the integrity of tributary rivers within each catchment which are known to have a diluting effect on river condition and this may be the reason for improved results. The results by Nel, *et al* (2007), focused only on main river systems and considered the proportion of intact river sections to the total river length. It was therefore not restricted by catchment boundaries. By including the length of the river it included impacts on a much larger scale.

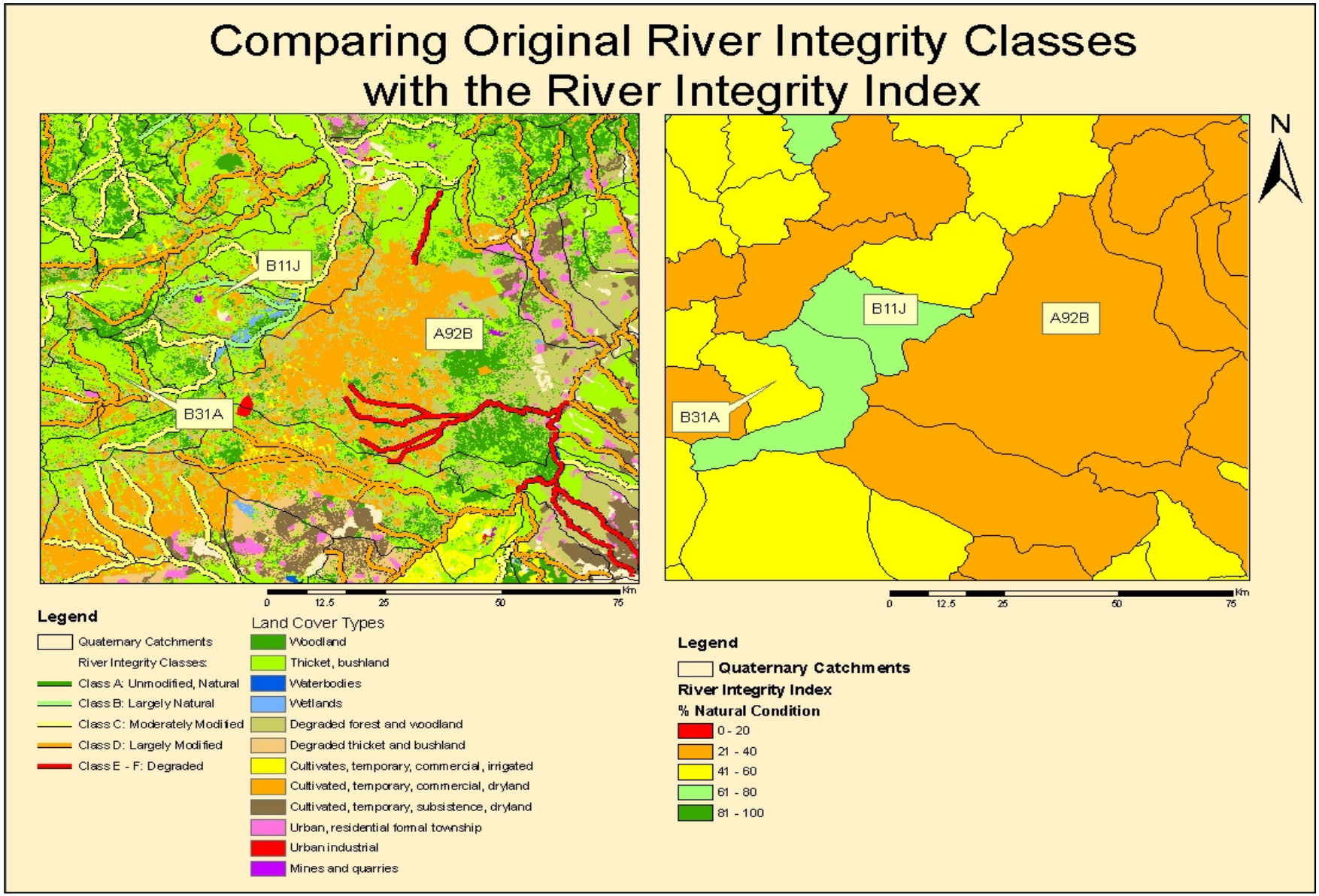


Figure 6-8: Comparison of the original river integrity classes developed by Nel, *et al* (2007), to the developed river integrity index, located in the Springbok Flats, Limpopo Province.

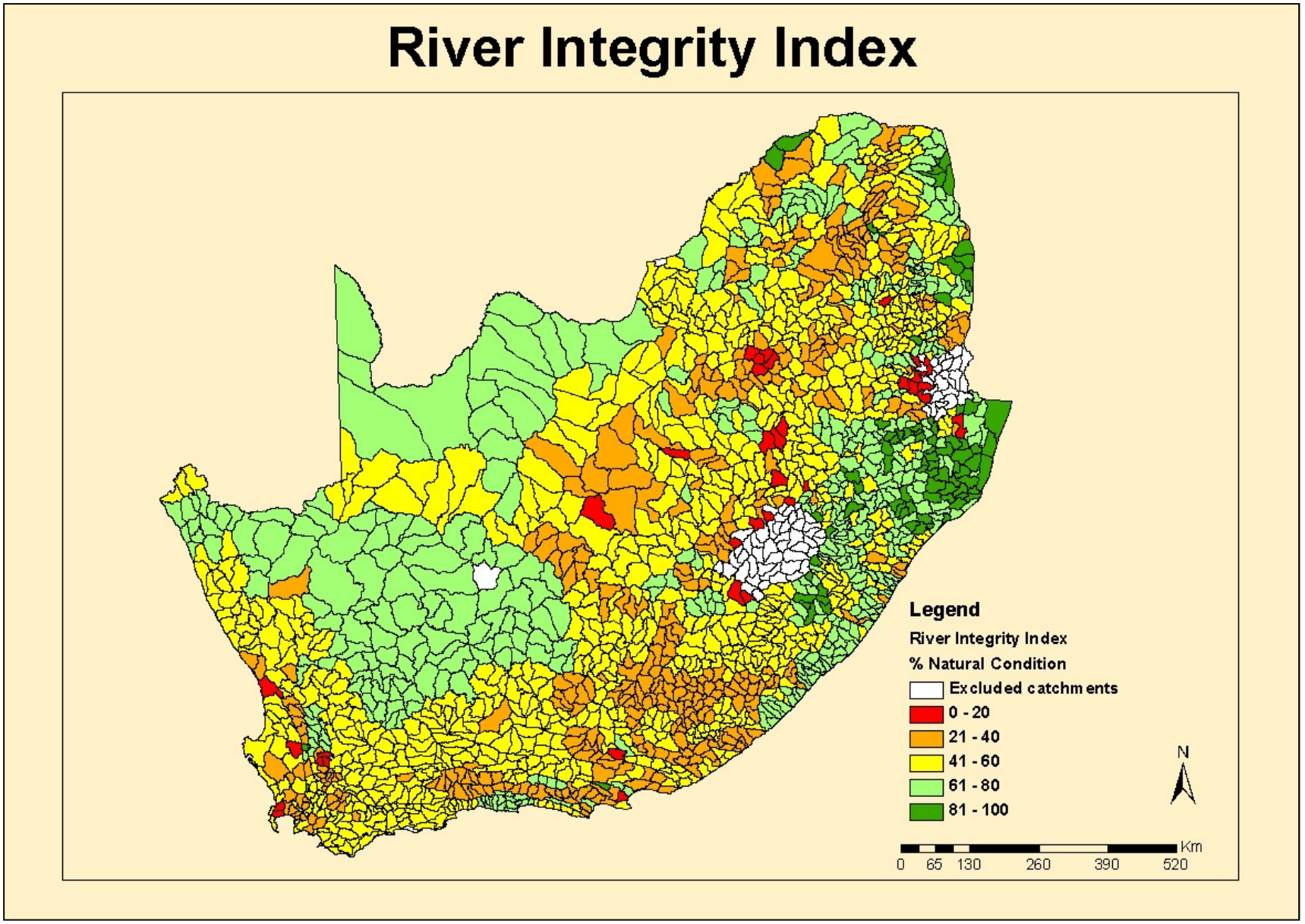


Figure 6-9: River integrity index results for rivers in South Africa.

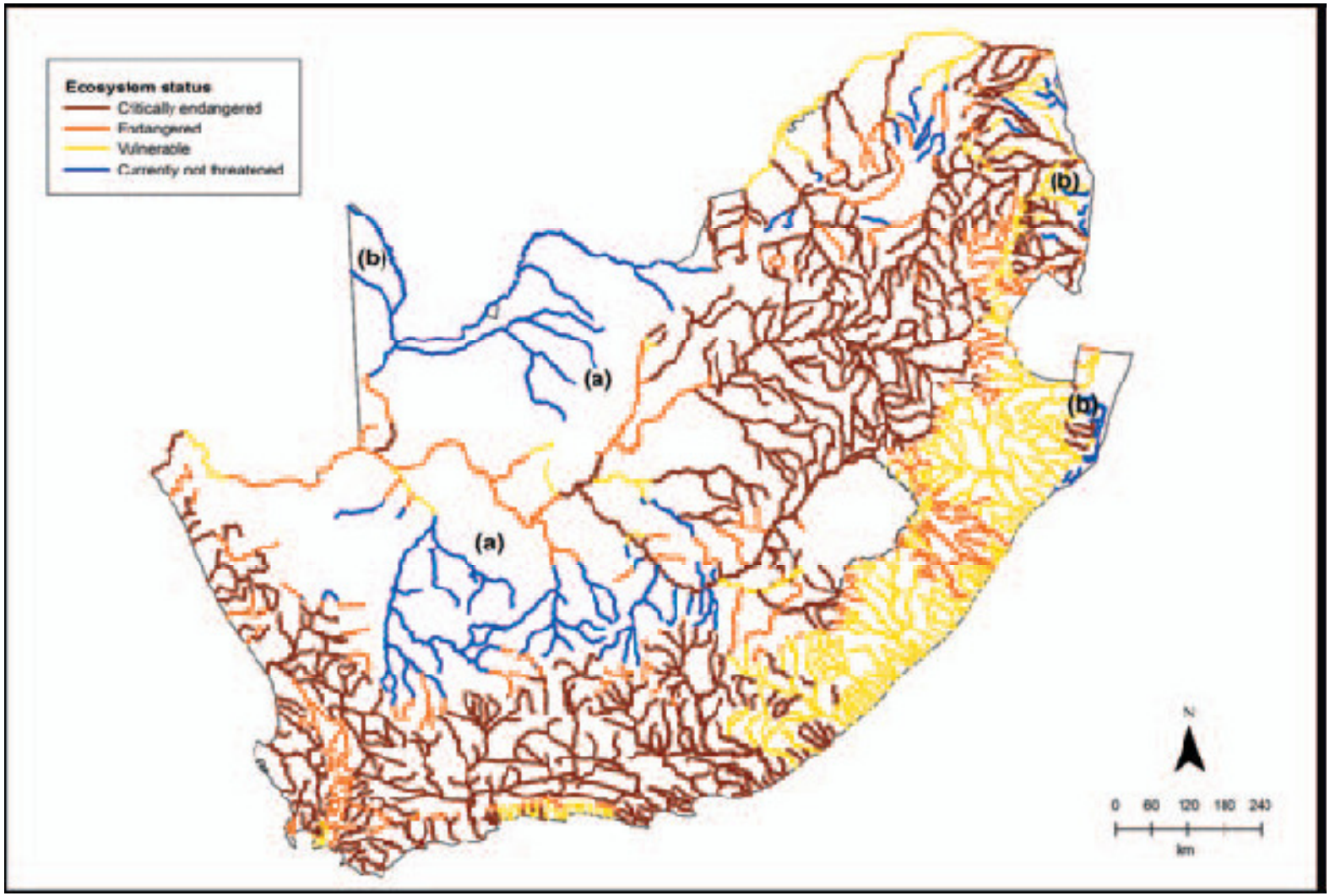


Figure 6-10: Ecosystem status of main rivers in South Africa (Nel, et al, 2007).

6.4 Fish Conservation Status Index

The frequency histogram for the fish conservation status index showed a biased distribution with a negative skewness of 2.2. This skewed data distribution is very much a function of the fish data, which lacked systematic sampling. When the analysis was conducted, only fish species with a recorded conservation status were out of necessity included in the study. This resulted in approximately 50% of all catchments being excluded and in addition, 36% of fish species which had not been classified or were classified as “data deficient” were therefore also excluded.

The results represent favourable conditions indicating that 82% of the catchments have fish species with a “least concerned” conservation status (Figure 6-11). Less than 20% of catchments contain fish with other conservation status categories.

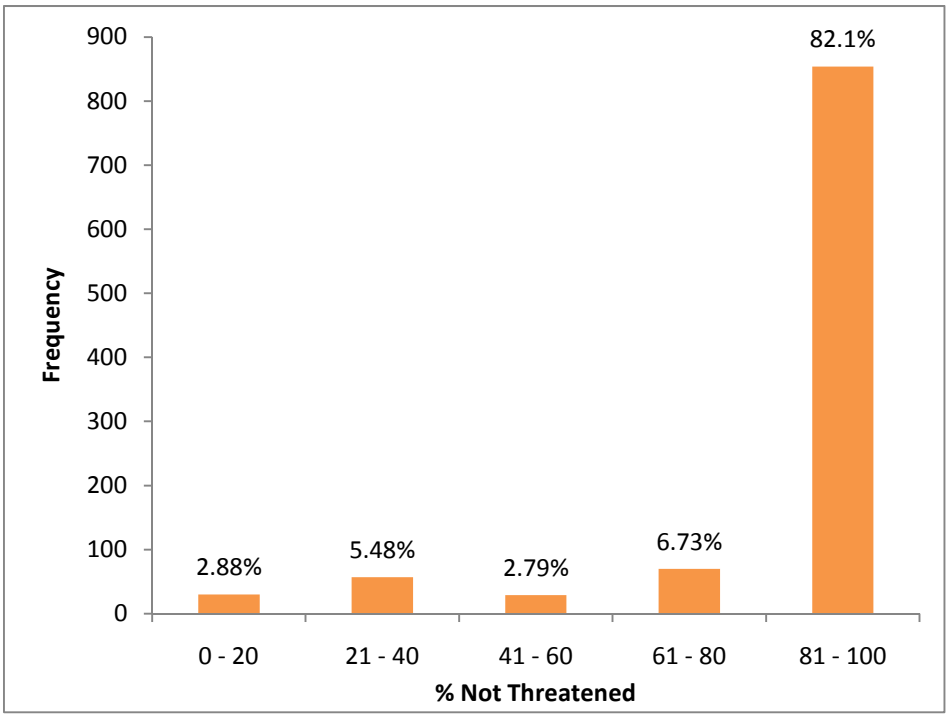


Figure 6-11: Frequency histogram distribution for the fish conservation status index per quaternary catchment in South Africa. Percentage of each catchment falling within the conservation status category is represented above the bar.

The cumulative frequency plot (Figure 6-12) shows a situation where the majority of the results fall in the 81 to 100 category. This almost exponential distribution is an unrealistic representation with species in the 81 to 100 category being over represented and species in all other categories being underrepresented. This underrepresentation is due to incomplete records as not all species have been assigned a conservation status, and lack of detailed fish species data as the number of records per catchment is very limited. The incomplete dataset resulted in 36% of the fish records being excluded from the study.

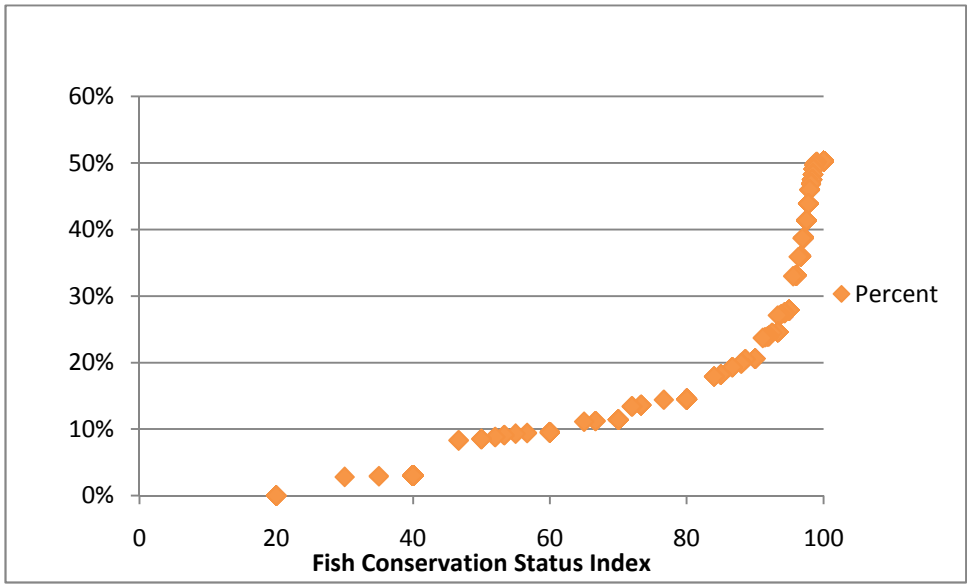


Figure 6-12: Cumulative frequency plot of the results of the fish conservation status index.

Figure 6-13 illustrates the original fish data compared to the developed index. In this example the developed fish conservation status index is a good representation of the original data, however, the original data are incomplete. Not all catchments have recorded occurrences of fish species even though the rivers are main rivers and permanently contain water making it highly likely that fish should occur. Again, the lack of correlation with the catchment results of Figure 6-3, Figure 6-8 and Figure 6-13 must be highlighted and the validity of the latter two results needs to be questioned.

The fish conservation status index is represented in Figure 6-14. Many catchments, for example catchments in the Kalahari and Namaqualand, lack permanent rivers and do not permanently support any fish species. However, other catchments do include permanent rivers, such as the Gariep River along the southern border of Namibia, yet these catchments have no records of fish species. There was insufficient data for fish species in remote

locations, and as a result, many of the catchments in the less human populated western parts of South Africa have been excluded. Due to the limited data, only approximately 50% of catchments have records of fish species occurrences.

Most of the fish species occurrences tend to be recorded in regions which are easily accessible, such as the eastern part of the country and along the coastal regions. These areas have higher human population densities (StatsSA, 2009), higher rainfall and smaller catchments, therefore making sampling locations more accessible and record keeping easier. Results in the eastern part of South Africa suggest that conservation status of fish species is between 81% and 100% natural condition (i.e., between 20% and 0% of concern). The western part of South Africa has fewer records of fish species even though many of the rivers are perennial and are more than likely to support fish populations.

Environmental conditions influence the type and distribution of species. Catchments with recorded fish species data in the Western Cape indicate that fish species are threatened. The Western Cape, due to its climate, winter rainfall and acidic soils gives rise to very unique environments, such as the Fynbos and Succulent Karoo (Mucina & Rutherford, 2006). These unique environments result in high levels of endemism and species specialisation, although generalists may still occur (Skelton, 2001). The results of the fish conservation status index may be accurate as more generalist species which have a high resilience occur in the east, and endemic, sensitive species are found in the west (Skelton, 2001); however, these results conflict with the river integrity index results and the broader trend in the land cover transformation index.

No other assessment of fish conservation status in South Africa could be found and as a result, no visual comparison was available.

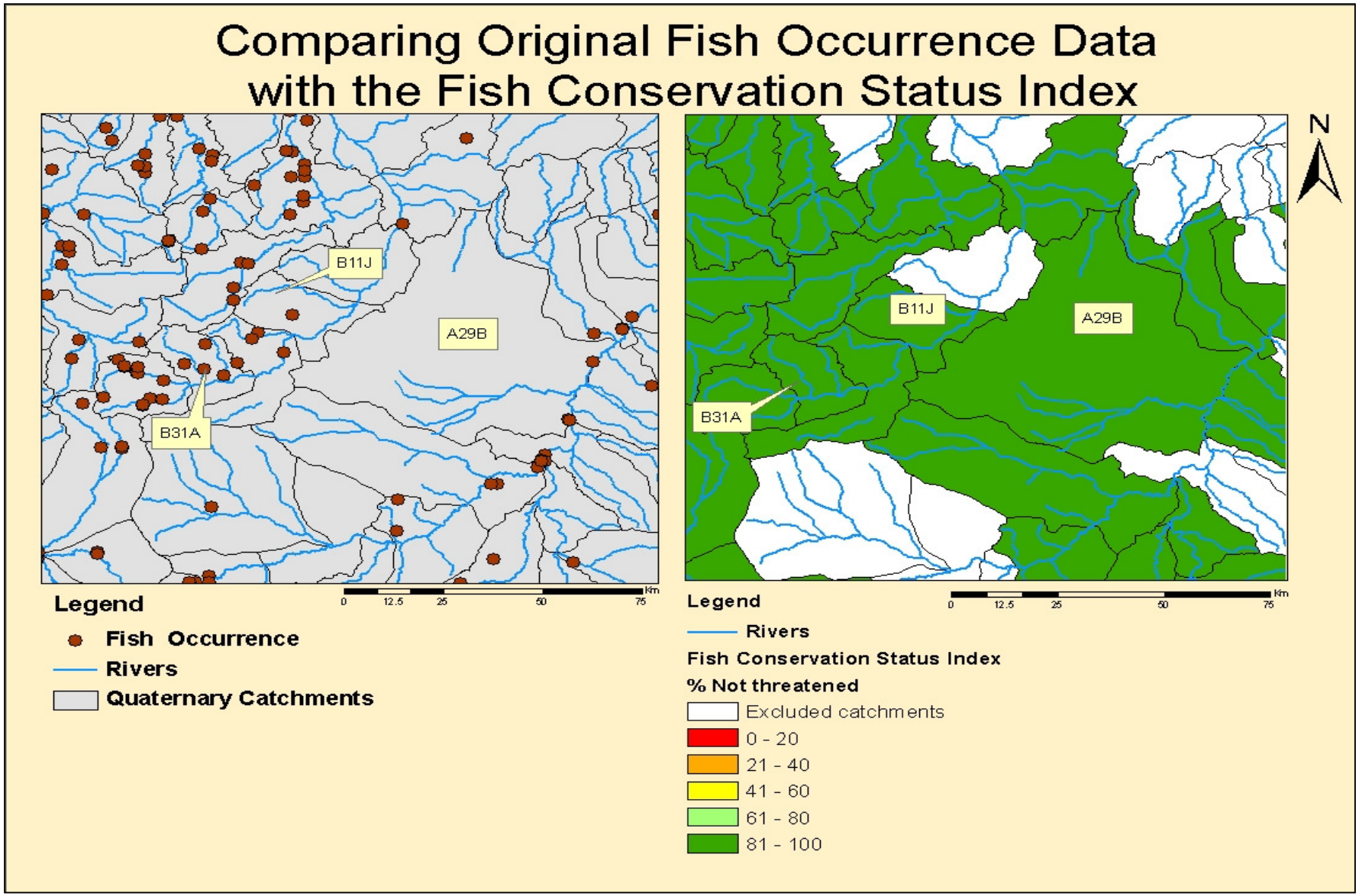


Figure 6-13: Comparison of the original fish occurrence data (Scott, *et al,* 2006) with the developed fish conservation status index, located in the Springbok Flats, Limpopo Province.

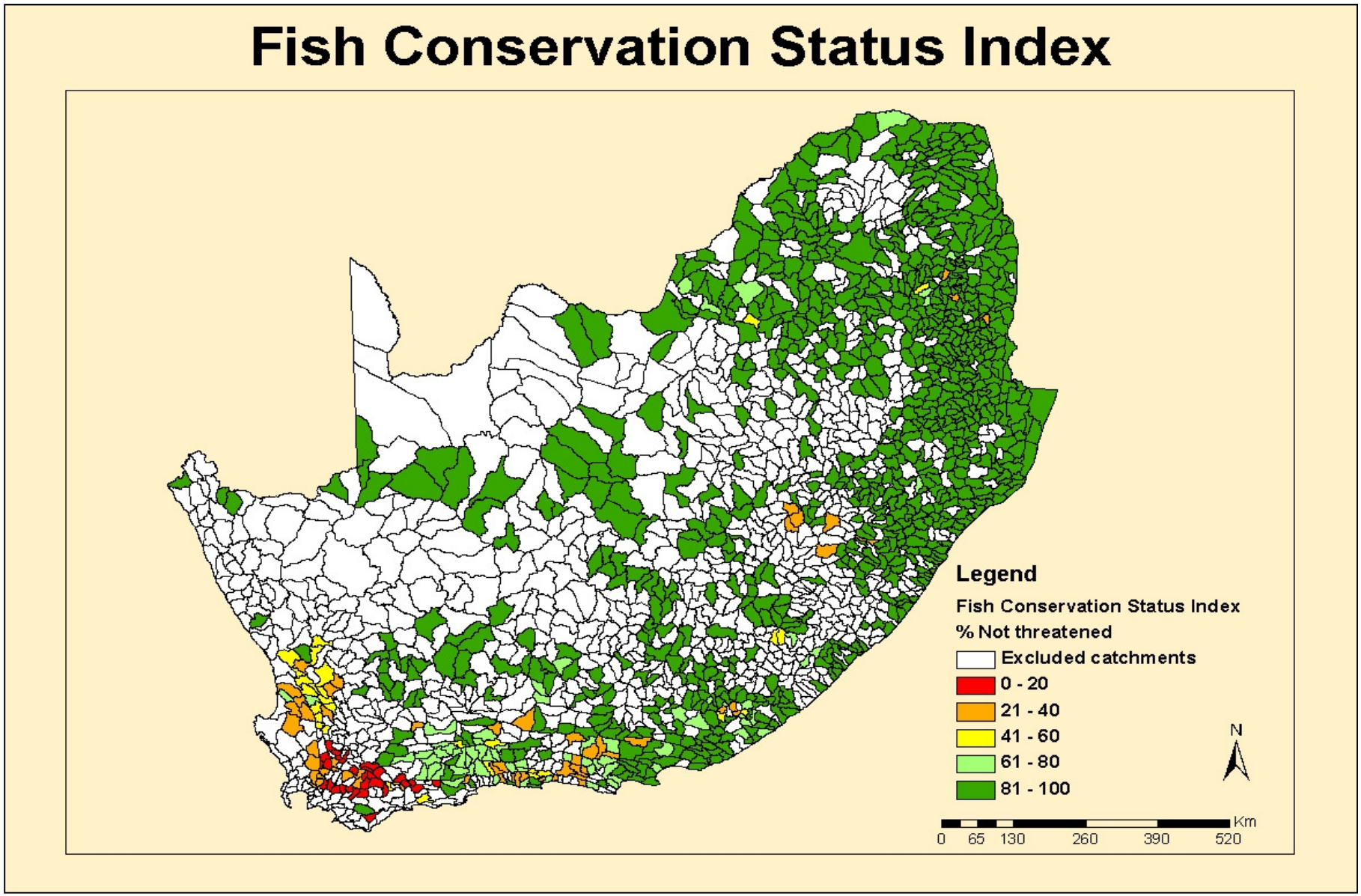


Figure 6-14: Fish conservation status index results for fish species in South Africa.

6.5 Ecological Integrity Index

The developed ecological integrity index is an unweighted, mean percentage combination of the three individual indices (land transformation index, river integrity index and fish conservation status index). The ecological integrity index shows that the integrity of the majority of catchments in South Africa is in a good condition. The distribution of the data has a skewness of 1.62, the bias indicating that the majority of catchments exist in a very good condition. Just under 65% of the catchments have an ecological integrity between 61% and 80%, and an additional 22.5% of the results fall into the 81% to 100% category (Figure 6-15). This high score could possibly be due to the data having been averaged over whole catchments and thereby diminishing the disproportional effect of specific impacts within a catchment. This population of data excludes all catchments with less than 3 component data.

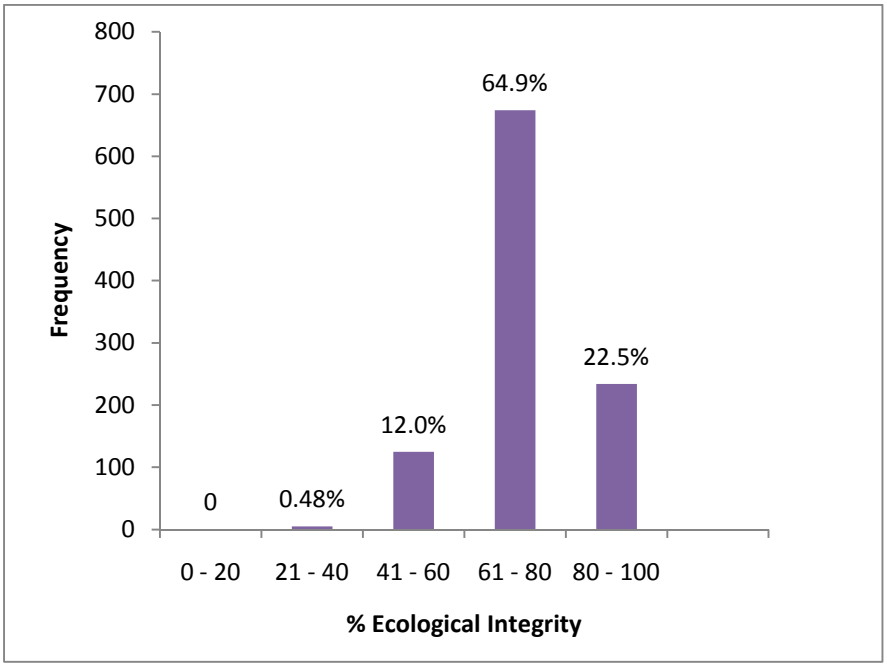


Figure 6-15: Frequency histogram distribution for the ecological integrity index for quaternary catchments in South Africa. Percentage of each catchment falling within the ecological integrity is presented above the bar.

The area at a detailed scale of resolution (Figure 6-16) is a comparison of the developed ecological integrity index compared to the land transformation index. This figure suggests that a strong relationship exists between the land transformation index and the ecological integrity index. It shows that where land cover receives a high score, the ecological integrity

also receives a comparative, although not exact, score. For example, catchment A29B receives a land transformation score of 56% and the ecological integrity score is 59%. Catchment B31A receives a land transformation score of 84% and an ecological integrity score of 77%. The lower ecological score is because the largely modified river integrity reduces the overall score. It is thus encouraging to observe that the ecological integrity index score does vary from the land transformation due to the influence of the river and fish species indices, where such were available and more specific in nature. The ecological integrity index is thus influenced by all three indices.

The ecological integrity index was developed to represent the overall integrity of quaternary catchments in South Africa, with the intention that it may be used in future conservation planning to highlight catchments most in need of conservation. The land transformation index, river integrity index and fish conservation status index were combined to develop the "ecological integrity index" (Figure 6-17). Catchments which are coloured white were excluded in the final results. These catchments were excluded because of the lack of recorded fish data or the catchments were in Lesotho or Swaziland and there was no recorded river data. This restriction is unfortunate but necessary from a standardisation point-of-view. A mixed ecological integrity index of a combination of one to three indices might be available but would not provide the valid scientific outcome.

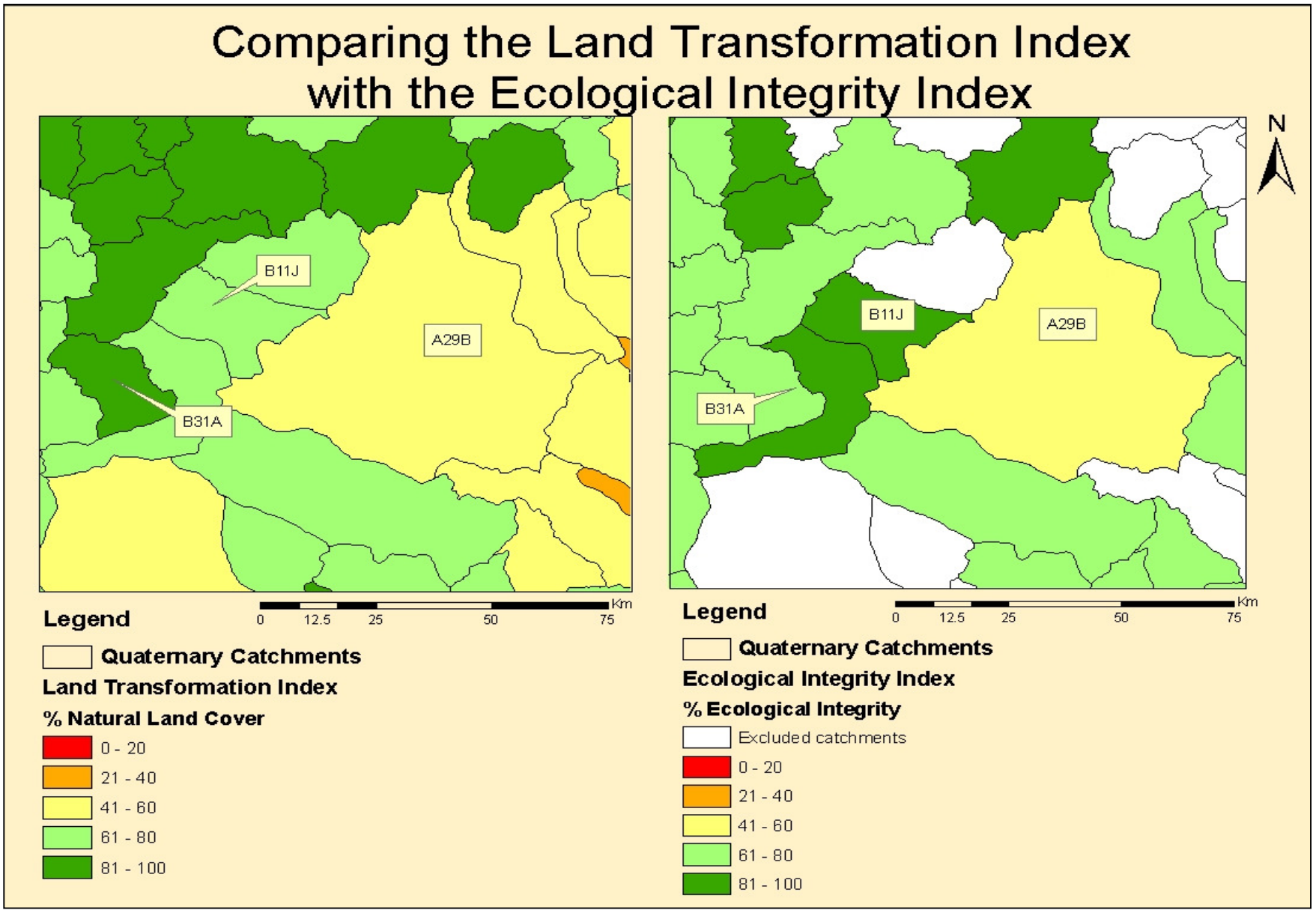


Figure 6-16: Comparison of the results for the land transformation index and the ecological integrity index.

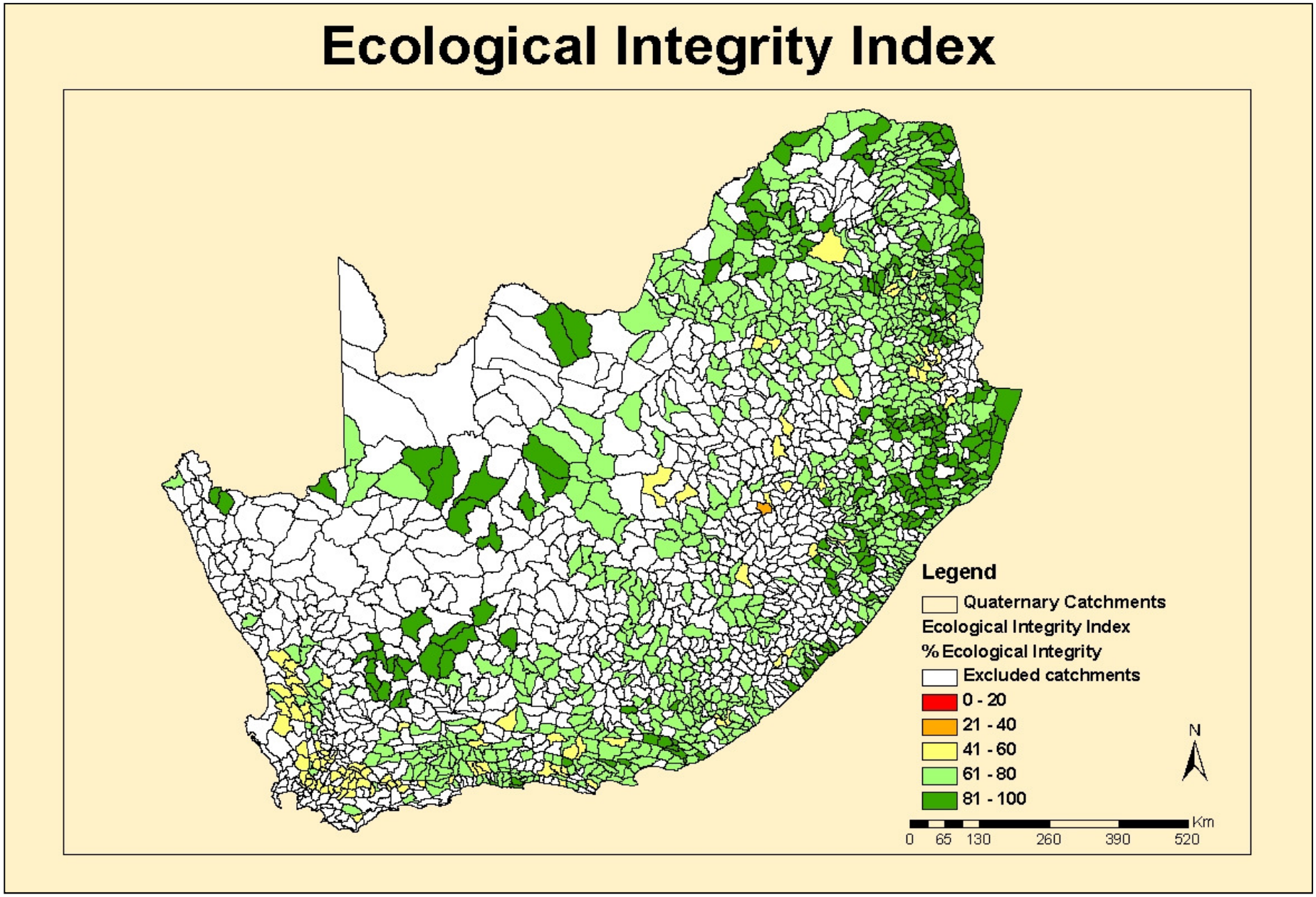


Figure 6-17: Ecological Integrity index for quaternary catchments of South Africa.

6.6 Comparison with Ancillary Information

A final visual comparison is done to compare the results of the indices to existing information. Observed information is taken from Google Earth (2008) and can be considered a true reflection of existing natural versus transformed conditions. Two contrasting catchments were selected, catchment B11L is situated in the pristine natural environment of the Kruger National Park while catchment C52M is situated in the centre of Johannesburg (Figure 6-18).

The Kruger National Park catchment covers an area between the Satara and Skukuza rest camps. Apart from the two rest camps, a tar road and a few gravel roads, the area can be considered largely natural and untransformed. The area is dominated by savannah vegetation (Granite Lowveld vegetation type, Mucina & Rutherford (2006)) and when looking at the image it shows no obvious signs of transformation. It can be assumed that all natural ecosystem processes occur with no unnatural disturbances. Here the land transformation index, the river integrity index, the fish species conservation status index and the ecological integrity index all receive natural scores between 81% and 100%. This specific catchment has records of four different fish species so it can be considered representative however this was not the case in all catchments.

The upper portion of the Johannesburg catchment includes Germiston and Alberton in the west to Boksburg in the east and goes as far south as Katlehong. This area is highly transformed with large industrial areas in Germiston and Boksburg. Industries include steel production, waste recycling, manufacturing of building materials and other heavy industries. The catchment is considerably developed with high to moderately dense residential establishments, road and railway networks. A large portion of the centre of the catchment and the southern region of the catchment contains high density informal settlements. This area can be considered highly transformed from a natural environment with permanent anthropogenic disturbances. The land transformation index indicated levels of transformation between 41% and 60%. The river integrity index indicates severe degradation with integrity between 0% and 20%. Contradicting to the other results, the fish conservation status index shows 81% to 100% not threatened value. Upon close analyses, the cause of this misleading result is that only one fish species has been recorded in the entire catchment. The species, *Barbus anoplus* (common name chubbyhead barb) has been described to live

by the *desert fish rule* “to boldly thrive where no other fish can make it”, (Cambray, 1984). Given the description, it is no surprise that the species can survive such harsh conditions and have a least concern conservation status. It is unclear why no other fish has been recorded and may be due to incomplete records or due to no other species being able to survive such a transformed environment. Unfortunately the data were not adequate to answer this question.

Based on the two comparisons, it can be interpreted that the land transformation index and river integrity index (although generalised) are good representations of the real world situation. The fish conservation status index is unreliable and the ecological integrity index, although buffered by the land transformation index and river integrity index is corrupted by the fish conservation status index and needs to be viewed with caution.

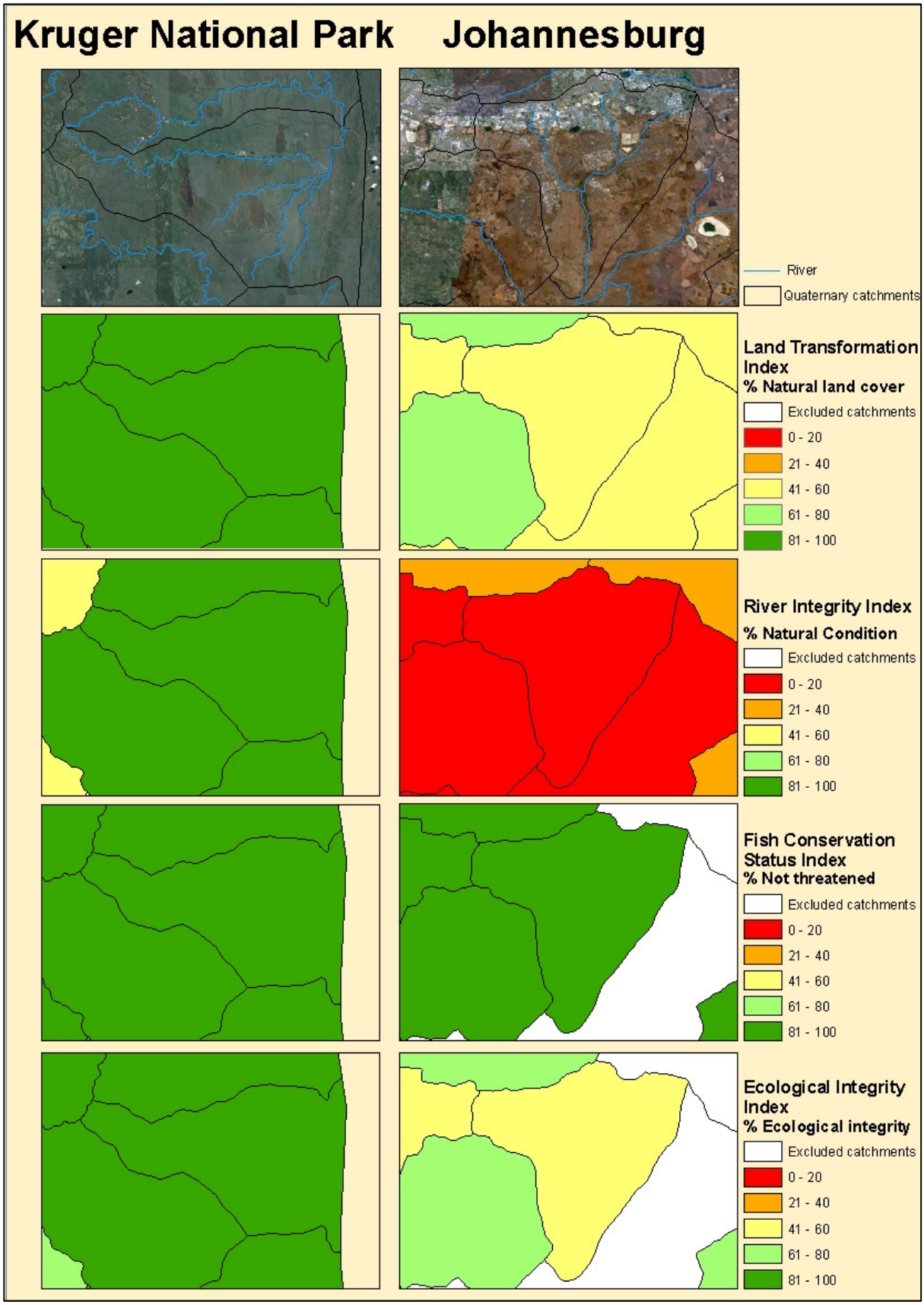


Figure 6-18: A comparison of the developed indices to observable conditions of the pristine, natural environment in the Kruger National Park and the permanently transformed environment of Johannesburg.

6.7 Relationships between Indices

Spearman's rank correlation coefficient (ρ) was used to determine significance between two indices. It is a non-parametric measure of the relationship between two variables and was used as the river integrity index and fish species index data were not normally or linearly distributed.

The land cover data in itself is a good representation of the condition of the catchments at a quaternary level. Comparing the distribution of the results for the land transformation index and river integrity index as seen in the scatter graph below (Figure 6-19), the expected pattern was not observed. Firstly, instead of finding data normally distributed, the river data form discrete classes at specific percentage levels (40%, 60% and 80%). Secondly ρ is 0.1133 which shows a very weak relationship between the land transformation index and the river integrity index. The p-value of 0.0085 shows that the weak relationship between the two indices is significant. The significance of the p-value is supported by the large sample size of the data used. Therefore based on the data available, land cover cannot be used to predict river integrity. This was unexpected as there is an almost certain correlation indicated in literature and other studies (Allan, 2004; Goetz & Fiske, 2008; Nel, *et al,* 2007).

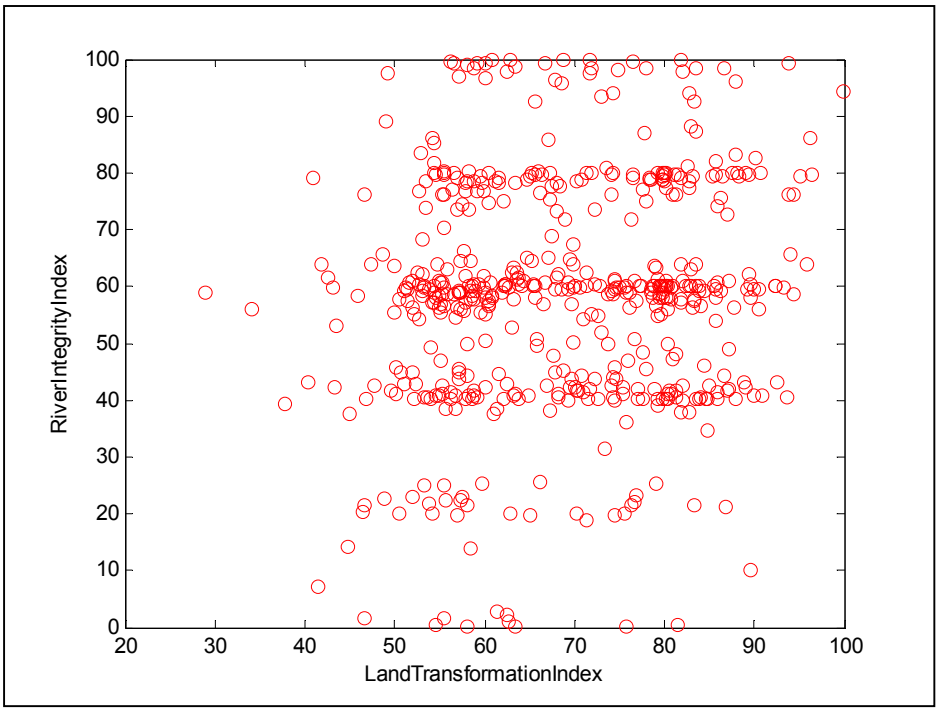


Figure 6-19: Scatter plot between the land transformation index and the river integrity index.

Rivers appear to have originally been classified on a very broad scale, which once the score was applied resulted in virtually the same integrity index classification within each catchment. The river integrity index seems to group rivers into one of five categories which are similar to the original classification. This is actually non specific and has limited detail. When looking closer at the original data and comparing quaternary catchments, all rivers within one catchment have the same classification even though some rivers may start in natural environments and others may begin in highly transformed environments. The only variation in the river dataset may then be due to data capturing errors or rivers that border more than one catchment. This data cannot truly reflect the integrity status of South African rivers. The land transformation index itself may even be a better quantifier for the status of South African rivers.

Spearman's rank correlation coefficient (ρ) was even lower between the river integrity index and the fish conservation status index with a value of 0.0178 (Figure 6-20). The p-value of 0.5716 indicated no significant relationship between the river integrity index and the fish species conservation status index. It must again be mentioned that although the results indicate an insignificant, weak relationship between the two indices, literature indicates a strong affiliation between the two (Goetz & Fiske, 2008; Kleynhans, 1999; Pont, *et al,* 2006; Roux, *et al,* 2002). The very weak relationship found in the results is attributed to the fish species data and resulting index being misleading, and the river data being too simplified to provide detailed information on a quaternary catchment level.

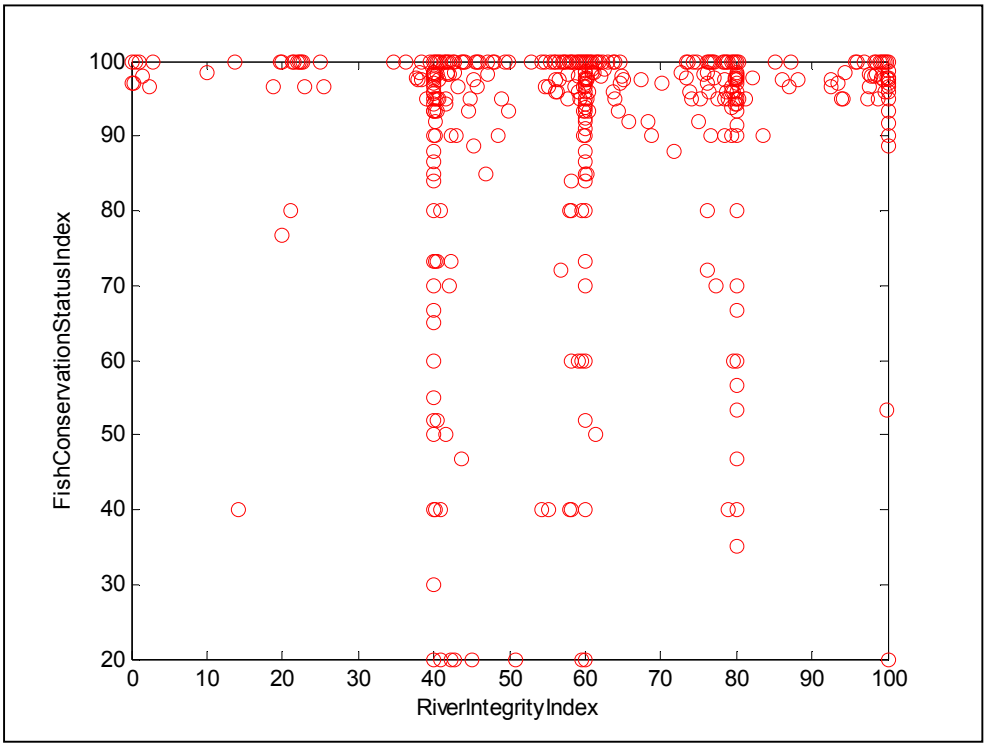


Figure 6-20: Scatter plot between the fish conservation status index and the river integrity index.

A ρ value of -0.2175 was found when comparing the land transformation index and the fish conservation status index (Figure 6-21). The low p-value <0.0001 indicated the significance of this relationship. This negative correlation is not realistic and is in strong contrast to other assessments (Antwi, *et al,* 2008; Dudgeon, *et al,* 2005; Poff, *et al,* 2007). The cause of the negative correlation is due to the poor fish species data. As seen previously (Figure 6-11 and Figure 6-12), and again in Figure 6-21 the majority of the included fish species data fell into the results range of 81% to 100%. It appears as if all fish, regardless of the surrounding land cover and river conditions, have a “least concern” conservation status. A degraded, transformed land cover does not promote healthy fish populations as incorrectly indicated in the scatter graph. In contrast to this negative correlation, other studies have indicated positive relationships but no other fish data were available for this study to prove otherwise (Nel, *et al,* 2009). These issues will be address in more detail in the discussion.

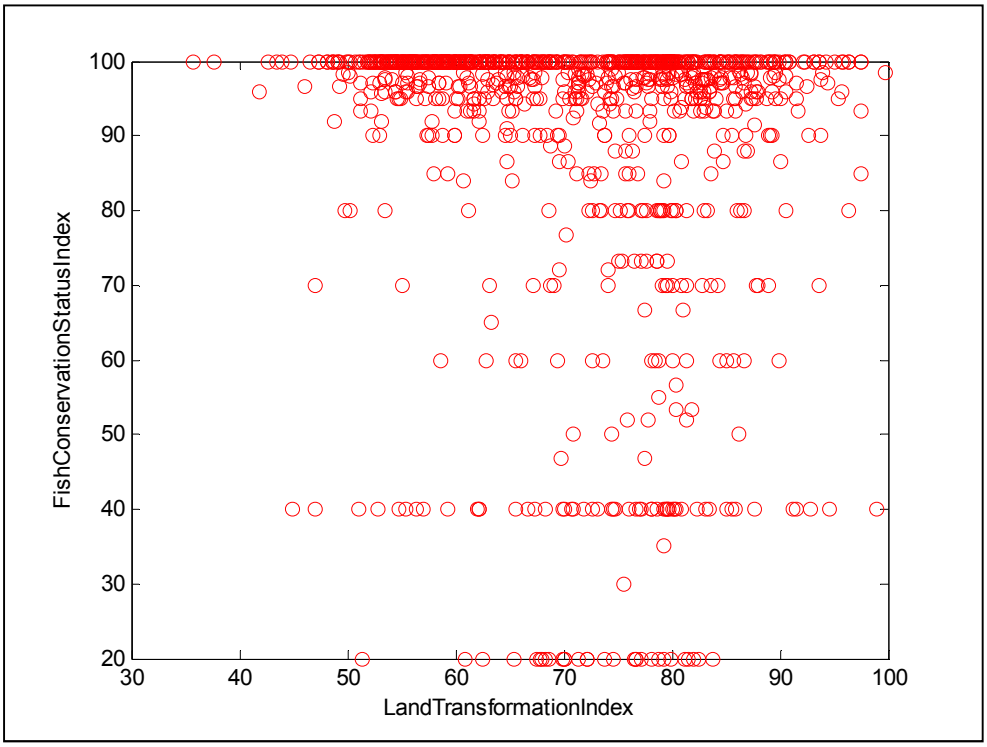


Figure 6-21: Scatter plot between the fish conservation status index and the land transformation index.

7 Discussion

7.1 Overview

The National Spatial Biodiversity Assessment (Nel, *et al*, 2007) indicated, along with numerous other small area studies (Dollar, *et al*, 2006; Roux, *et al,* 1999b) that South African river systems are degraded and continue to deteriorate due to anthropogenic impacts. The situation should not be allowed to persist and plans need to be developed to reduce current impacts and prevent future degradation. However, not all areas can be protected at the same time and the best utilisation of limited resources could benefit from prioritising conservation areas.

The purpose of this study was to develop a map of ecological integrity for quaternary catchments which could be used by authorities and conservation planners. Surrounding land cover has an impact on river integrity. Compromised river integrity will affect the aquatic species living within the rivers (Arthington, *et al*, 2006; Lytle & Poff, 2004; Rashleigh, *et al,* 2009). All three environmental indicators in a natural ecosystem are therefore connected (Nel, *et al,* 2007). In this study, an attempt was made to integrate and quantify this connection. However, in results from this study, this connection has, for a number of reasons, been ambiguous.

7.2 Data Quality

Three datasets (land cover, river integrity and fish species conservation status), were used as environmental surrogates. These datasets represented integrity as they showed the change from a natural system by indicating the degree of transformation. It is very important to discuss the quality of the datasets as this was found to be the main limiting factor in this study. Despite data being developed as national datasets, they were developed by scientists for their specific application, for this reason the characteristics of the data may not have been entirely appropriate for this study. Data quality was assessed on the spatial completeness of the data for quaternary catchments across the entire country, data coverage of only subsets of the country were found to be inadequate. The detail of each dataset within quaternary catchments greatly improved the index results and accuracy, whereas lack of detail resulted in generalisation and misrepresented results. The more

current and accurate the data, the better the indices were able to represent current environmental conditions. These datasets have also been used in other studies; although for different applications and the results of other studies do differ. Despite limitations found in two of the three datasets, analyses continued as these datasets have been used in national and other small scale studies with success and are currently the only data available (Amis, *et al,* 2007; Driver, *et al,* 2005; Nel, *et al,* 2004; Nel, *et al,* 2007).

The land cover dataset proved to be a valuable resource. Different land cover types affect river integrity differently. Transformed land cover such as urban areas, changes water surface flow patterns (Allan, 2004; Antwi, *et al,* 2008; Wessels, *et al,* 2003). Hard impermeable surfaces reduce infiltration and increase water velocity and runoff. The increased velocity increases the amount of substrate entering or being discharged into a river and the increased runoff results in change to water flow patterns (Allan, 2004). Different land cover types will have different impacts on river systems. With the use of detailed satellite imagery, these impacts can be predicted (Nel, *et al,* 2009). 2000 National Land Cover source data were captured from 30m resolution Landsat 7 ETM+ satellite imagery over a period of three years (2000 to 2002). All digitising was done systematically, following strict criteria, resulting in a detailed land cover dataset with a minimum mapping unit of 1 ha over the entire country (Majeke, *et al,* n.d.; van den Berg, 2008, *pers comm*). Satellite imagery was available for the whole country and was of sufficient detail and clarity for this assessment. During capturing, land cover data were represented by 49 different land cover types. By assigning 49 land cover types this resulted in the loss of some information, for example the category natural grassland does not distinguish between the different types of grasslands. However, for a quaternary catchment assessment where catchments vary in size from 50km^2 to 18 000km^2, the dataset provided substantial detail at the 30m resolution.

River integrity data at first appeared to be very detailed as rivers were clearly divided into segments. Data were captured by river practitioners, then further developed by the CSIR for the Department of Water Affairs and Forestry and has even been used in the National Spatial Biodiversity Assessment (Nel, *et al,* 2004; Nel, *et al,* 2007; Nel, *et al,* 2009). However, insufficient detail was available for application in this assessment as upon closer analyses of the river data, although captured on a segment by segment basis; each segment within a quaternary catchment had an identical integrity class. Original river integrity data were captured for 1:500 000 main rivers only and then inferred across the river segments for quaternary catchments (Nel, *et al,* 2004). Data were captured systematically based on a

standardised method but as only information for main rivers was captured, it was insufficient for tributary channels. Results were therefore generalised over a broader scale and may not have been representative of the catchment as such. One classification for all river segments captured at 1:500 000 scale was found to be inaccurate and unrealistic for more detailed application on a quaternary catchment scale. All variation and detail within the catchment is lost (Hughes, 2004). In addition, the river integrity data were found to be incomplete for the purposes of this study as data were only captured for South Africa and not for Lesotho or Swaziland. This is unfortunate as a number of South African rivers find their sources in these countries, such as the Gariep River originating in Lesotho.

The fish species dataset was the least comprehensive of all the data used in the assessment as, amongst other factors, it was incomplete. It was an *ad hoc* collection of museum and other data from various records, recorded since 1897, agglomerated into one dataset (Scott, *et al,* 2006). Historical fish records occurred outside of water bodies. Some catchments, despite having main perennial rivers, did not have fish species occurrence records. Previous studies have similar problems with museum data, finding inaccuracies with grid cell references and also finding sampling bias (Austin, 2007). Inaccurate geographical reference is possible as museum records were first captured on quarter degree squares. Once converted to a digital location the fish species could have been placed in the wrong quaternary catchment. Museum data often tends to be presence-only data and a more comprehensive database are then required if one needs more informed results (Austin, 2007). 78% of the data have been collected in the last 40 years, however some of the remaining data are up to a century old. Not all records reflect current fish distribution situations. Data were found to be distorted due to temporal and spatial changes. For example, the data did not indicate whether a species occurs in its historical habitat. Since 1897, and even in the last 40 years, dams have been built, river divergences have been implemented, habitat fragmentation has occurred and it is unclear whether these changes are reflected in the fish species distributions (Rashleigh, *et al,* 2009). Despite specific processes for subsets of data, no systematic method or technique was applied to the dataset as a whole. Once combined, it became a collection of unsystematic, under sampled, unrepresentative records. The combined dataset covered most of the country but still, the resolution and detail of the dataset covering the country is questionable (Amis, *et al,* 2009). Approximately 50% of catchments were left unpopulated. On closer analyses this becomes more apparent as even the Gariep River, one of South Africa's main perennial rivers, has no recorded species occurrences in some of the catchments through which it flows.

Fish species scores were based on the existing IUCN red list of threatened species categories as the South African red data list is felt to be out of date (Amis, *et al,* 2009; Skelton, 1987). IUCN is based on a global assessment which may at times be misleading as a species population could be threatened locally, but thriving internationally or vice versa (Rodrigues, 2006). This could give an impression that conditions are better locally than they realistically are. However, the IUCN remains a comprehensive, defensible dataset, and is the most complete and up to date red data list available.

The three datasets were further adjusted to reduce them to a score of one to five. A score of one for the land cover will have the same value as a score of one in the river integrity data or fish species occurrence data as the value represents the same extreme. This makes the scoring system relative and dependant on expert opinion. Expert-based scoring may result in misclassification due to misrepresentation. To minimise this risk, clear rules, criteria and boundaries need to be specified. Sufficient detail and information is required to minimise assumptions (Regan, *et al,* 2005; Rodrigues, *et al,* 2006)

All data used are national datasets which have been used in numerous other assessments in South Africa. The land cover data have been used in the State of the Environment Report as a surrogate of current patterns of land and resource use and it was used to predict future patterns of land and resource use (DEAT, 2006). It was also used in the National Spatial Biodiversity Assessment as a component to calculate ecosystem status of terrestrial ecosystems (Driver, *et al,* 2005 and Nel, *et al,* 2004) and it was used by other small scale studies by Nel, *et al* (2009). The river integrity data have also been used in the National Spatial Biodiversity Assessment to show the ecosystem status of South African rivers (Driver, *et al,* 2005 and Nel, *et al,* 2004). It has also been used in other small scale studies by Amis, *et al* (2007), Nel, *et al* (2007) and Nel, *et al* (2009). The fish species occurrence data have been used by Amis, *et al* (2007) and Nel, *et al* (2009).

Amis, *et al* (2007), assessed if broad land cover variables could be used to predict riparian and instream habitat integrity. They used existing land cover data and GIS datasets to predict river integrity. They also determined existing conditions though the use of instream habitat integrity (which was used to develop the river integrity data used in the assessment)

and the fish assemblage integrity index (which was developed with the fish species data used in this study). Amis, *et al* (2007) study differed from this study as they used more detailed GIS data by incorporating human population density data, road information and other impacting criteria such as the number of mines in the area likely to affect the river condition.

Nel, *et al* (2007) used the same river integrity data used in this assessment to determine the state of main river integrity for the country. Nel, *et al* (2007) completed a conservation assessment of South African rivers by looking at river integrity and river ecosystem status. The portion of intact river length was compared to the portion of degraded river integrity length to assess the state of ecosystems associated with main rivers. In Nel, *et al* (2007) it was commented that the main river data were out of date and insufficient information was available on smaller tributaries. The lack of river data for Lesotho and Swaziland was also noted.

A further study by Nel, *et al* (2009) aimed to identify conservation areas targeting river conservation. The same three datasets were used as in this study. The 2000 National Land Cover dataset was used to model the present ecological status of river integrity for tributary rivers by assessing the percentage of natural land cover around the tributary. Main river and tributary river integrity data were used as one of the criteria to assess river condition. Other criteria included topology, to distinguish between upstream and downstream river sections, and the extent to which the ecological integrity had been modified by human activity was also considered. The fish species data were used but were filtered by focusing on endemic species presence and absence data. Only catchments with two or more endemic species recorded at different dates were included and records were not allowed to be older then the 1940's. This limited the study to including only 47 endemic species. The ecological condition of these species was not considered. Nel, *et al* (2009) found that river integrity data would benefit from being updated. They felt that more detailed freshwater ecosystem studies incorporating a wider array of freshwater taxa would be beneficial. They felt that the land cover data added value and that conservation planning units for rivers would need to be at a catchment scale for the benefit of river biodiversity.

Of the three environmental indicators assessed in this study, the land cover data were by far the most realistic contributor and provided an accurate representation of land transformation. River integrity data lacked detailed description within quaternary catchments and fish species data were found to be incomplete country wide. As a result, further assessment although still mathematically possible, was largely compromised by the latter two datasets.

7.3 Methodology

In this study the usefulness of three diverse datasets for an integrated index were assessed using a scoring system. The scoring system was used so indices were comparable and to minimise profusion and the possibility of interpretational error when used by different individuals. The use of a scoring system was appropriate given the scale of the project and the data available. It is also comparable to a number of similar studies (Amis, *et al,* 2007; Amis, *et al,* 2009; Kemper, 1999; Kleynhans, 1999; Pont, *et al,* 2006).

Amis, *et al* (2007), used 13 parameters to assess river ecological integrity. Weights were applied to each parameter for their relative impact on integrity and then a score was applied. The impact of the parameter on ecological integrity was calculated. The impact of the parameters was summed and a percentage was calculated to provide an indication for riparian integrity. Kemper (1999) applied a five point weighting system and calculated a percentage. The percentage was subtracted from 100% to provide an assessment of instream and habitat integrity. For both studies (Amis, *et al,* 2007 and Kemper, 1999) scores and a weighting procedure were applied. The actual value of the score is irrelevant; the purpose of the score is to apply a quantitative simplified estimate to a complex, intangible condition so that changes to an environment are easy to monitor.

The use of scoring systems was appropriate for this study given the nature of the input data. Concerns regarding scoring systems include questions about accuracy on fine scales and static results despite a dynamic environment (Knapp, *et al,* 2003; Regan, *et al,* 2005). However, on a broad scale such as this study, when only an understanding of the general trend is required, scoring systems have proved to be useful and often invaluable (Hoffmann, *et al,* 2008; Regan, *et al,* 2005; Scardi, *et al,* 2008). Another common mistake with scoring systems is the incorrect allocation of scores and criteria due to human assumption (Regan,

et al, 2005). To prevent this mistake, scores were allocated to existing pre-defined classes, so if used by other scientists the mistake cannot be made. The scoring and methodology used in this assessment is similar to that of the IHI assessment and to a smaller degree the FAII system (Kemper, 1999; Kleynhans, 1999).

The method of this study can be compared to the IHI assessment (Kemper, 1999) as a similar calculation and scoring system was applied. In both instances a five category point score was applied, weighted and assessed against a maximum score representing ideal conditions. The difference is the scores applied in this assessment were, where possible, based on existing categories to remove personal assumptions. This study used an area weighting factor to calculate a mean value per catchment. For this study a maximum value was incorporated so that the impact could be compared to an untransformed, "pristine" condition. Scores in the IHI are applied based on expert assessments. In the IHI, criteria were assessed against the maximum expert score and each criteria carried a weight based on its presumed impact to a natural system. The total estimated impact is expressed as a percentage. Impact in this study was also expressed as a percentage for the three independent indices and the resulting ecological integrity index.

The FAII system measures the biological integrity of a river based on the condition of fish communities. The methodology differs considerably from the methodology in this study, but the point to be made is that the FAII system is successful because of the use of a five point scoring system (Kleynhans, 1999).

Methodology developed in this study was designed to handle different datasets captured at different spatial scales and the results were meant to remain broad, on a country-wide scale. The methodology was developed using existing available data, focused on current environmental conditions and involved the reduction of huge amounts of data to concise single numbers for each catchment. To achieve this, the use of scoring systems was regarded as a necessity. By multiplying the weighted mean score by the maximum possible score per catchment, the degree of transformation or impact can be calculated (similarly to the IHI system, Kemper, 1999). In this study, it allowed for the comparison between ideal conditions and actual, recorded data. The success of the results did differ between the indices. The land transformation index, due to variations within the catchments proved to

have the best results. Weighting of the river integrity index was redundant as there was no variation within the catchment for river segment values. Weighting of the fish index was appropriate but the benefit was minimised by applying it to the conservation status. Due to the nature of the data, the majority of fish species (82.1%) had the same conservation status. The influence of the weighting was lost although the value was seen in catchments that contained fish records of different conservation statuses.

Once each index had been developed, Spearman's rho (ρ) rank correlation and associated p-value was used to describe the relationship between the three indices. Spearman's rank correlation coefficient (ρ) was the best method to describe the relationship between the indices, given the river integrity index and fish conservation status index results not being normally or linearly distributed (Austin, 2002). Results indicated consistently weak relationships between the indices which is different to other studies (Goetz & Fiske, 2008; Nel, *et al,* 2009; Roux, *et al,* 1999a; Roux, *et al,* 1999b). Other studies have found these relationships to be stronger although the purpose and methods of the other studies varies greatly. Goetz and Fiske (2008) used stepwise multiple linear regression and decision tree statistics to link land cover change to the disruption of both hydrological processes and ecological stream conditions. Decision tree statistics allowed different methods to be tested to evaluate which combination of variables provided the most accurate results. Nel, *et al* (2009) developed a conservation algorithm to integrate multiple conservation objectives, based on data similar to that used in this study, in a spatially efficient manner in order to determine the best location for conservation initiatives. They derived appropriate conservation focus areas using the Marxan conservation planning algorithm. Roux, *et al* (1999b) compared in-field sampling results to the results of reference conditions and determined that biota inhabiting a river are a direct and integrated measure of the river conditions. Although all these studies vary in terms of the location, the size of the study area, the data collected and the methods of analyses, stronger relationships have been found to exist between land cover change, river integrity and biotic conditions. The source of these differences is discussed in section 7.4.

Ideally, an index should consist of uncorrelated components to ensure that as much of the underlying variation, which is already simplified by a scoring approach, is captured. The purpose of this study was not to find the best data to make an index, but to see if widely available and used data will make a useful index, independent of whether they should be, or are, correlated. There is a strong precedent to use data on transformation, habitat integrity

and species conservation status in terrestrial priority area selection procedures and this study shows that similar data for aquatic environments is not yet good enough for anything but a coarse analysis. Even though relationships between fish conservation status, land transformation and river integrity have been shown to be strong in the literature cited above, the exact nature of that relationship is likely to vary greatly between environments for different levels and type of transformation. It will be a useful exercise to explore the nature of these relationships for South African environments with more complete and representative data, and their implications for priority area selection procedures, but this falls outside the scope of the study presented here.

To calculate the ecological integrity index, all three indices were combined. Due to inconclusive ρ and p-value results, it was not clear that one index bore more weight then another so it was best to combine all three with an even weighting (Andersen, *et al,* 2001).

The method developed incorporated fixed rules, was mathematically accurate and transparent although, the results were poor due to datasets that are not representative. The accuracy of the results in this system is dependent on the accuracy and detail of the initial data used, just as the accuracy of the FAII system is dependent on the sampling efficiency (Kleynhans, 1999).

7.4 Assessment of Developed Indices

The three indices were compared to other studies to determine their accuracy. In addition ρ and p-values were calculated to assess the relationship between combinations of two indices. Statistically significant, although extremely weak relationships were found between the indices and the final results of the ecological integrity index were inconclusive.

The per catchment land transformation index is felt to be an accurate representation of the 2000 National Land Cover dataset and the ecosystems status of terrestrial ecosystems developed by DEAT (2006). By looking at the data distribution and comparing the index to the 2000 National Land Cover dataset, the index can be considered a good representation of anthropogenic changes per quaternary catchment country wide. Areas with higher population densities will be more transformed due to additional development and

infrastructure. More industries and commercial areas will be present (Porter, 2009; van Wilgen, *et al,* 2008). The land transformation index clearly indicates a larger degree of transformation in areas known to have higher population densities (StatsSA, 2009; Tainton, 1999). Furthermore, the 2000 National Land Cover dataset showed 79.7% of South Africa's total surface area is covered by natural vegetation; the land transformation index is in agreement indicated by 70.3% of the catchments in the index being relatively non-transformed. The implication for inaccurately applied scores would be a lack of correlation between the land cover transformation index, the 2000 National Land Cover dataset and the terrestrial ecosystem map, but this was not the case.

Results from the river integrity index visually compare well to the river ecosystem status map by Nel, *et al* (2007), but upon closer analyses differed largely from other assessments. Results showed that 41% of South African rivers were in a relatively natural condition (from 61% to 100% natural) and a further 43.6% of the rivers were in a moderate condition (41% to 60% natural). 15.4% (1% to 40% natural) of rivers were found to be degraded. Results of this study differ from results of other studies which although they were calculated differently and may have had different assessment criteria, should illustrate similar trends. Amis, *et al* (2007), reports that 44% of the main stems of South African rivers to be critically endangered. Driver, *et al* (2005), found 82% of river ecosystems to be threatened. Driver, *et al* (2005) assessed the instream and riparian habitat of different river signatures. River signatures are distinguished by the geomorphological and hydrological characteristics and only main rivers were considered. Both these results (Amis, *et al,* 2007 and Driver, *et al,* 2005) differ greatly from the 15.4% calculated in this study. This study considered the river integrity of river segments within a quaternary catchment for both mainstreams and tributaries. Although data were captured on a segment by segment basis, the integrity value was for the entire catchment and not for individual segments. As a consequence, the results were largely grouped at the 20%, 40%, 60% and 80% intervals and were not reflective of natural conditions.

The developed fish conservation status index was a poor representation of current conditions on a quaternary catchment scale. Results of the index indicate that 82.1% of fish species with a recorded conservation status fall in the category 81% to 100% of a least conservation concern. These results differ from a regional assessment completed by the IUCN that indicate only 2.5% of fish species in southern Africa are not threatened and 66% have a least concerned conservation status (Darwall, *et al,* 2009).

Numerous studies have indicated that a strong relationship exists between land cover, river integrity and fish species (Amis, *et al,* 2007; Goetz & Fiske, 2008; Nel, *et al,* 2009; Pont, *et al,* 2006; Roux, *et al,* 2002). Anthropogenic changes to land cover and land cover degradation negatively impacts on river integrity and degraded river integrity will affect the habitats and health of fish species. Some studies have even gone so far as to say that land cover can be used as a predictor or surrogate of river integrity (Nel, *et al,* 2009). The lack of strong relationships in this study is in contrast to the consensus found in literature. This is not because a relationship does not exist, nor is it due to mathematical error, but it is due to incomplete datasets as will be discussed below (Goetz & Fiske, 2008; Nel, *et al,* 2009; Roux, *et al,* 1999b; Pont, *et al,* 2006).

Spearman's rank correlation coefficient (ρ) was calculated between the land cover transformation index and the river integrity index and a very weak but significant relationship was found despite literature indicating that the two environmental indicators share a strong relationship (Amis, *et al,* 2007; Harding, *et al,* 1998; Roux, *et al,* 2002). The low ρ can be attributed to the generalised river integrity data which lacked detail on a river segment basis within a quaternary catchment. The river integrity data were derived from multiple samples, but the sampling density was low relative to the variation found across South Africa, an understandable logistic constraint that was acceptable for the initial purposes for which the authors collected this data. This low sampling density is in strong contrast to the land transformation data, which, being based on remotely sensed satellite imagery, effectively sampled the entire landscape and will be more representative of the variation across the country. This sampling discrepancy is the most likely reason for the lack of a stronger relationship between these two indices. The significance of the weak relationship is likely due to the high number of catchments, which increases the statistical power of the test, but not necessarily its biological usefulness.

No significant relationship was found to exist between the river integrity index and the fish conservation status index. This result is in sharp contrast to intuition and, more to the point, to a number of studies which have indicated that the two environmental indicators share a strong relationship (Kayde, 2008; Roux, *et al,* 1999b). However, due to the poor source data, it became a logical consequence that no relationship would be found between the developed indices. River data lacked sufficient detail on the scale required. Fish data were collected on

an ad hoc basis over long periods of time, and there were also insufficient numbers of fish occurrence records available. Combined, these two factors resulted in fish data mismatched in terms of scale and age to the river integrity data. Only including fish with a conservation status further reduced the number of records in the dataset. Fish of conservation concern tend to have restricted ranges, and in some cases, very specific habitat requirements. The nature of the interaction between small ranges and different levels of transformation, and its effect on the relationship between river integrity and fish conservation status is likely to vary spatially at fine scales, but should still exhibit a strong relationship.

Spearman's rank correlation coefficient (ρ) was calculated between the land transformation index and the fish conservation status index (for catchments with fish data only). Although literature does not indicate a direct relationship between these two environmental indicators, literature does indicate that land cover and land cover transformation controls the biological attributes of rivers and streams (Amis, *et al,* 2007; Goetz & Fiske, 2008; Lindenmayer, *et al,* 2008; Roux, *et al,* 2002; Stanford, 1998), which in turn should affect the composition of fish communities in these rivers. The significant, weak, negative correlation is unexpected; it is highly unlikely that a degraded land cover will promote healthy fish populations. This contradicting result is attributed to the conservation status applied to the fish data. 82.1% of the records showed a conservation status of least concerned, possibly skewing the fish data towards the negative correlation. The difference in sampling densities pointed out earlier also pertains here.

The incomplete data has lead to many discrepancies in this study. Refer back to the example between the catchment in the Kruger National Park and Johannesburg (Figure 6-18). The catchment in Johannesburg only had one record of an individual fish which happened to be a highly generalised, resilient species that is able to survive extreme conditions. No other records of fish were found in this catchment and many other catchments were found to be lacking. Another example is the Gariep River, one of South Africa's major rivers, and yet some of the catchments had no recorded fish species. By combining combinations of two indices which are contradictory in accuracy and detail, the result was that an illogical relationship was found. It was clear when analysing the data that the results of the river integrity index and fish conservation status index represented untainted, yet highly unrepresentative conditions (Nel, *et al,* 2004). The abnormal population distributions and essentially unrelated information for both indices prevented the results of ρ from showing any realistic or representative relationship (Hughes, 2004). This is due to the

stepped river data not reflecting actual conditions and the fish data being under sampled and heavily skewed by the conservation status. The consequence of these poor datasets is that only very weak relationships were found, therefore not indicating a connection between the indices. The idea that as land cover deteriorates, river integrity is degraded and affects the condition of fish species could not be shown and points to systemic shortcomings in the data that precludes using them for a reliable ecological integrity index.

7.5 Ecological Integrity Index

After comparison of the indices it became clear that due to the distortions imposed by the two less representative indices, the ecological integrity index cannot be used in conservation planning, nor for prioritising catchments for remedial action. Of all the indices generated, the most suitable and the only one which is considered to be accurate when representing real world conditions, is the land transformation index. Previous assessments indicate that land cover can be used as an indicator (Amis, *et al,* 2007; Nel, *et al,* 2009 and Roux, *et al,* 2002).

The datasets that were tested to generate a combined index were shown to be unsuitable for this purpose. The method is transparent and repeatable, but should be applied to detailed data with more equal sampling densities. For use in future conservation planning, it is recommended that the land cover transformation index be used. It is a generalised index, but was found to be the most accurate when wanting to evaluate ecological integrity at a quaternary catchment scale. It also compared well to the National Spatial Biodiversity Assessment, terrestrial ecosystems status map (DEAT, 2006).

Conservation planners and natural resource managers face many challenges such as understanding the complexity of ecosystems, managing long term ecological processes and the unpredictability of natural disturbances and human influences (Roux, *et al,* 1999b). Resource managers are still required to make decisions despite the unpredictability and uncertainty of the environment they work in. The results of this study assist by prioritising catchments which can be selected for conservation. Once catchments have been prioritised, it is recommended that more detailed assessments are conducted within and around the catchments. The source of the cause of ecological degradation needs to be identified before a solution can be developed. Different categories (0 to 20%, 21% to 40%, 41% to 60%, 61%

to 80% and 81% to 100%) have been determined in the land transformation index. Conservationist can use these categories as an early warning system and as a prioritisation tool to set management goals.

Different management option can be evaluated to determine which will be most beneficial and which can be implemented within existing constraints. Ongoing monitoring is required to determine if the management option is working and if it will achieve the desired goal (Lindenmayer, *et al,* 2008; Roux, *et al,* 1999b). Although any cause or loss of integrity requires attention and logic dictates to attend to the worst cases first, it is suggested that attention is focused on the 41% to 60% category. Although there is an almost complimentary connotation to this category, it is more urgently in need of protection because it is the category where limited funding will have the biggest impact and prevent further deterioration. The method developed in this study can be reapplied at regular intervals (for example every three to five years) to monitor and assess the success of management options. If the integrity of the area improves, then the management measures are working, if not, the approach should be adapted.

For the development of an ecological integrity index in the future, the method developed in this study is appropriate. The method is of mathematical soundness and it is the author's opinion that no fault can be found with the applied methods and developed equations. It is also of environmental soundness as the methods applied incorporate accepted ideas on ecological processes including ideas such as when land cover deteriorates it will impact on river integrity and that fish species are dependent on a healthy environment for survival. Conflicting results and the poor relationships between indices is attributed to the poor supplied source data for two out of the three datasets. Results conflict with other studies of a similar nature. The lack of relationship between indices is also in contrast to other studies. A strong relationship between indices would improve the predictive results of the indices and improve the reliability of the ecological integrity index. The developed methods would have been useful if the datasets used were of comparable detail, quality and scale. River integrity data should be more detailed to include integrity scores for river segments of both tributaries and main rivers and complete fish species occurrence data for all quaternary catchments would be required with recent records, collected using one systematic method. In additional, all fish species would require an assessed conservation status.

To answer to the research question: *How well does diverse catchment scale data lend itself to the calculation of an ecological catchment integrity index?* is yes, very well, the method and process developed is valuable in itself and was found to be useful and applicable. If reapplied at regular intervals, it will indicate the magnitude and direction of change to ecological integrity and can be used to monitor the success of management options. However, the results obtained in this study are conflicting as two out of the three datasets were not representative and rather unrealistic. The diverse data used in the assessment are known to give a representative overview of ecological conditions and were appropriate surrogates, but due to the lack of detail and poor quality on a quaternary catchment scale, the results were inconclusive (Allan, 2004; Amis, *et al,* 2009; Nel, *et al,* 2009; Roux, 1999b). To improve results in future assessments, coordinated sampling and comparable datasets are a prerequisite. Data must be sampled systematically and sampling should be conducted on detailed scales within a quaternary catchment for the method developed to provide indicative results. Furthermore, it was intended to see if widely available and used data would make a useful index. For the ecological integrity index, it did not as the developed indices did not show the relationships that hydrological and ecological processes would suggest. However, the land transformation index, due to its systematic sampling and high level of detail proved to be most valuable.

8 Conclusion

An ecological integrity index has great potential in assisting future conservation plans. It would be an index which could specify areas from most degraded (with a low integrity) to least degraded (with a high integrity). Conservationists could use this index to identify areas where their intervention may be required and once areas of concern are identified, then more detailed, focussed, site-specific studies can be conducted and management plans can be developed.

One of the main challenges found in this assessment was lack of sufficiently detailed source data. Two of the three datasets were found to be inadequate. The river data required details for each river segment and not just a general integrity for the whole catchment. The fish species occurrence data were not complete for a country wide assessment and records were found to be out of date and deficient.

Out of the three datasets, the land cover data were found to be the most useful. It was sufficiently detailed within quaternary catchments to calculate a sensible weighted index per catchment, something which was not possible with the other two datasets. The combination of the three datasets used in this study do not make a useful index as the components do not show the relationships that hydrological and ecological principles would suggest and therefore casts serious doubt on how well these variables represent the underlying variation in the landscape.

The study was successful as all key objectives were met despite the challenges encountered. Furthermore, the methods developed were appropriate for the study as they captured the detail of the source data sufficiently. A simple yet accurate method was developed which can be used and applied by any scientist and the results will be consistent. Should appropriate data have been available, the results would have been representative and the final ecological integrity index would have been valuable to decision makers and conservation planners.

For future studies, data used in assessments must be captured at a detailed scale within quaternary catchments. All data should be captured within a similar time frame and each dataset should have a clear and consistent methodology. The use of land cover, river integrity and fish species conservation status as indicators remains appropriate as confirmed by Amis, *et al* (2007), Nel, *et al* (2004), Pont, *et al* (2006), Roux, *et al* (2002), Wessels, *et al* (2003), and others.

9 Acknowledgements

I would like to thank the following people:

Dr. Barend Erasmus, my supervisor, for his advice and guidance.

My dad for his constant support, guidance, advice and patience. Without him behind me this journey would have been much harder.

My mom and brother for their continuous support and good spirits. You both were always willing to help and always ready to assist. In addition, a special thanks to Carel for his super skill in Excel.

Alex for always being behind me and his constant support. My other pillar of strength and my biggest support.

Gordon for his advice with all the number crunching.

My close friends for their advice, suggestions and editing skills.

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Appendices

Section A: Description of the 49 Land Cover Types followed by an explanation of scores applied

No	Land-cover Class	Definition
1	**Forest (indigenous)**	All wooded areas with tree canopy > 70%. A multi-strata community, with interlocking canopies, composed of canopy, sub-canopy, shrub and herb layers. The canopy is composed mainly of self-supporting, single stemmed, woody plants > 5 metres in height. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species). Excludes planted forest (and woodlots).
2	**Woodland** (previously termed *Forest & Woodlands*)	All wooden areas with a tree canopy between 10 – 70%. A broad sparse – open – close canopy community, typically consisting of a single tree canopy layer and a herb (grass) layer. The canopy is composed mainly of self-supporting, single stemmed, woody plants > 5 metres in height. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species). Excludes planted forests (and woodlots) Canopy cover density classes may be mapped if desired, based on sparse (< 40%), open (40 – 70), and closed (>70 %).
3.	**Thicket, Bushland, Bush Clumps, High Fynbos**	Communities typically composed of tall, woody, self-supporting, single or multi-stemmed plants (branching at or near the ground), with in most cases no clearly definable structure. Total canopy cover is greater than 10%, with canopy heights between 2 – 5 metres. Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species, especially along riparian zones). Presence of alien exotic species can be modelled spatially using broad principles or unlikely structural / temporal occurrences within a given vegetation biome or region. Dense bush encroachment would be included in this category. Canopy cover density classes may be mapped if desired, based on sparse (, 40%), open (40 – 70 %), and closed (>70%).
4.	**Shrubland and Low Fynbos**	Communities dominated by low**, woody**, self supporting, multi-5stemmed plants, branching at or near the ground, Between 0.2 and 2 m in height. Total tree cover < 0.1 Typical examples are low Fynbos, Karoo and Lesotho (alpine) communities.

5.	**Herbland**	Communities dominated by low**, non-woody,** self supporting, multi-5stemmed plants, branching at or near the ground, between 0.2 and 2 m in height. Total tree cover < 0.1 Typical examples are found in Namaqualand or "weed" dominated degraded areas.
6.	**Natural Grassland (previously termed *Unimproved Grassland)***	All areas of grassland with 10% tree and/or shrub canopy cover, and >0.1% total vegetation cover. Dominated by grass-like, non-woody, rooted herbaceous plants. *Essentially indigenous species growing under natural or semi-natural conditions.*
7.	**Planted Grassland (previously termed *Improved Grassland*)**	As above, except ... Planted grassland, containing either indigenous or exotic species, growing under man-managed (including irrigated) conditions for grazing, hay or turf production, recreation (i.e. golf) etc
8.	**Forest Plantations (Eucalyptus spp)**	All areas of systematically planted, man-managed tree resources composed of primarily exotic species (including hybrids). Category includes both young and mature plantations that have been established for commercial timber production, seedling trials and woodlot / windbreaks of sufficient size to be identifiable on satellite imagery. Excludes all non-timber based plantations such as, sisal, citrus, nut crops etc.
9.	**Forest Plantations (Pine spp)**	
10.	**Forest Plantations (Acacia spp)**	
11.	**Forest Plantations (Other / mixed spp)**	
12.	**Forest Plantations (clear felled)**	
13	**Water bodies**	Areas of (generally permanent) open water. The canopy includes both natural and man-made water bodies, which are either static or flowing, and fresh, brackish and salt-water conditions. This category includes features such as rivers, major reservoirs, farm-level irrigation dams, permanent pans, lakes and lagoons.
14	**Wetlands**	Natural or artificial areas where the water level is permanently or temporarily at (or very near) the land surface, typically covered in either herbaceous or woody vegetation cover. The category includes fresh, brackish and salt-water conditions. Examples include pans (with non-permanent water cover), and reed-marsh or papyrus-swamp. Dry pans are included in this category unless they are *permanently dry.*
15	**Bare Rock and Soil (natural)**	Natural areas of exposed sand, soil or rock with no, or very little vegetation cover during any time of the year, (excluding agricultural fields with no crop cover, and open cast mines and quarries). Examples would include rock outcrops, beach sand, and dry riverbed material.
16	**Bare Rock and Soil (erosion : dongas / gullies)**	Non-vegetated areas (or areas of very little vegetation cover *in comparison to the surrounding natural vegetation*), that are primarily the result of active gully erosion processes. Typically located in association with areas of poor grassland cover along existing streamlines and / or on slightly steeper slopes than sheet erosion areas (i.e. greater than 6 degree slope). In some areas the full extent of donga activity may be obscured by either overhanging adjacent bushes, encroaching thorn bush, or, in the case of more stable dongas, by bush or grass cover along the actual streamline.

17	**Bare Rock and Soil (erosion : sheet)**	Non-vegetated areas (or areas of very little vegetation cover *in comparison to the surrounding natural vegetation*), that are primarily the result of active sheet erosion processes. Typically located in association with areas of severe donga erosion and / or poor grassland cover (i.e. low image NDVI rating). In some areas the full extent of this process may be obscured by encroaching bush. Typically located on slopes less than or equal to 6 degrees.
18	**Degraded Forest & Woodland**	Permanent or near-permanent, man-induced areas of very low vegetation cover (i.e. removal of tree, bush, or herbaceous cover) *in comparison to the surrounding natural vegetation cover*. Typically associated with subsistence
19	**Degraded thicket, Bushland, etc**	Level agriculture and rural population centres, where overgrazing or livestock and /or wood-resource removal has been locally excessive. Often associated with severe soil erosion problems.
20	**Degraded Shrubland and Low Fynbos**	
21	**Degraded Herbland**	
22	**Degraded Unimproved (natural) Grassland**	
23	**Cultivated, permanent, commercial, irrigated**	Land which has been ploughed and / or prepared for the raising of crops (excluding timber production). Unless otherwise stated, includes areas currently under crop, fallow land, and land being prepared for planting. Class boundaries are broadly defined to encompass the main areas of agricultural activity, and are not defined on exact field boundaries. As such all sub-classes may include small inter-field cover types (e.g. hedges, grass strips, small windbreaks), as well as farm infrastructure. Several sub-classes are defined, based on the following parameters: <u>Commercial:</u> characterised by large, uniform, well managed field units (i.e. <u>+</u> 50 ha), with the aim of supplying both regional, national and export markets. Often highly mechanised. <u>Semi-Commercial</u>: characterised by small – medium sized field units (i.e. <u>+</u> 10 ha), within an intensively cultivated site, often in close proximity to rural population centres. Typically based on multi-cropping activities where annual (i.e. temporary crops) are produced for local markets. Can be irrigated by either mechanical means or gravity-fed channels and furrows. Medium – low levels of mechanisation. <u>Subsistence:</u> characterised by numerous small fields units (less than <u>+</u> 10 ha) in close proximity
24	**Cultivated, permanent, commercial, dry land**	
25	**Cultivated, permanent, commercial, sugarcane**	
26	**Cultivated, temporary, commercial, irrigated**	
27	**Cultivated, temporary, commercial, dry land**	
28	**Cultivated, temporary, subsistence, dry land**	

		to rural population centres. Field units can either be grouped either intensively or widely spaced, depending on the extent of the area under cultivation and the proximity to rural dwellings and grazing areas. Includes both rainfed and irrigated (i.e. mechanical or gravity-fed), multi-cropping of annuals, for either individual or local (i.e. village) markets. May include fallow and 'old fields', and some inter-field grazing areas (which are often classified as degraded).
29	**Cultivated, temporary, subsistence, irrigated**	Permanent Crops: lands cultivated with crops that occupy the area for long periods and are not re-planted after harvest. Examples would include sugar cane and citrus orchards. Note in the case of sugar cane, the growing season is typically 15 – 18 months per ratoon (i.e. harvest), with 2 – 3 ratoons possible before re-planting. Sugar cane is mapped as a separate crop type, and includes both large and small- scale commercial activities, as well as fallow (i.e. burnt / cleared) areas. Temporary Crops: land under temporary crops (i.e. annuals) that are harvested at the completion of the growing season, and that will remain idle until re-planted. In general this refers to maize and soya bean cultivation within the Pongola catchment, although cotton is locally dominant amongst the larger commercial sugar cane plantation areas. Irrigated / Non-irrigated: major irrigation schemes (i.e. areas supplied with water for agricultural purposes by means of pipes, overhead sprinklers, ditches or streams), and are often characterised.
30	**Urban /Build-up**	**A generic urban class,** essentially comprising all formal built-up areas, in which people reside on a permanent or near- permanent basis, identifiable by the high density of residential and associated infrastructure. Includes both towns, villages, and where applicable, the central nucleus of more open, rural clusters. **This class should be used if it is not possible to identify more** industrial and transportation land-uses. Low-density smallholdings frequently located on the urban / peri-urban fringe should be mapped as separate smallholding sub-classes, subdivided by the appropriate (level 1) background vegetation type. If visible, individual farm units are to be mapped as isolated urban /built-up units (if no other class is applicable). **Specific urban /built-up sub-classes as listed below** – in such cases it could include residential, commercial.

31	**Urban / Built-up (rural cluster)**	Areas of **clustered a rural dwelling (i.e. kraals) whose structural density is** too low to be classified as a formal village, but are of sufficient level to be easily identifiable as such on satellite imagery. Small scale cultivation /garden plots often form a major spatial component, and are located amongst the residential structures.
32	**Urban / Built-up (residential, formal suburbs)**	Permanent residential structures, either single or multi-level, located within **new or well-established residential areas, i.e. '*garden-suburbs'*,** (often refers to 'middle-class' and 'upper class' residential areas). Includes both low and high building densities.
33	**Urban / Built-up (residential, flatland)**	Permanent residential structures, consisting mainly of 3 or more levels (often up to 10), resulting in a concentration of mid-to-high rise buildings, f or example Hillbrow (Jhb) or Sunnyside (Pta).
34	**Urban / Built-up (residential, mixed)**	Mixture ...
35	**Urban / Built-up (residential, hostels)**	Permanent residential structures, typically located in formal township districts, consisting mainly of 1 or 2 levels in concentrated block- like structures.
36	**Urban / Built-up (residential, formal township)**	Permanent (i.e. brick etc) structures (predominately single level), usually located on serviced sites within formal black residential areas, laid out in a organised, pre-planned manner. Includes both low and high building densities.
37	**Urban / Built-up (residential, informal township)**	Permanent / semi-permanent shack type dwellings (i.e. corrugated tin structures) laid out and established in an organised, pre-planned manner on both serviced and non-serviced sites. Includes both low and high building densities.
38	**Urban / Built-up (residential, informal squatter camp)**	Non-permanent shack type dwellings (i.e. tin, cardboard, wood etc) typically established on an informal, ad hoc basis, on non-serviced sites. Typically high building densities.
39	**Urban / Built-up (smallholdings, forest & woodland ...)**	See "residential" definition above ...
40	**Urban /Built-up (smallholdings, thicket, bushland ...)**	See "residential" definition above ...
41	**Urban / Built-up (smallholdings, shrubland ...)**	See "residential" definition above
42	**Urban / Built-up (smallholdings, grassland ...)**	See "residential" definition above
43	**Urban / Built-up (commercial, mercantile)**	Non-residential areas used primarily for the conduct of commercial and other mercantile business, typically located in the central business district (CBD). Often consisting of a concentration of multi-level buildings, but also includes small commercial zones (i.e. spaza shops) within former black townships.

44	**Urban / Built-up (commercial, education, health, IT)**	Non-residential, non-industrial sites or complexes associated with education (i.e. schools, universities), business development centres such as industrial 'techno-parks', and / or social services (i.e. hospitals), often consisting of a concentration of multi-level buildings (Note: only mapped if clearly identifiable, otherwise included within 'commercial / mercantile' or 'suburban' categories.
45	**Urban /Built-up (industrial / transport : heavy)**	Non-residential areas with major industrial (i.e. manufacture and / or processing of goods and products) or transport related infrastructure. Examples would include power stations, steel mills, dockyards, train stations and airports (i.e. Johannesburg).
46	**Urban/Built-up (industrial / transport : light)**	Non-residential areas with major technology, manufacturing or transport related infrastructure. Examples would include **light manufacturing units**, warehouse dominated business development centres, and small airports (i.e. Lanseria). Also includes similar structures such as farm**-based pig and battery hen breeding units**.
47	**Mines and Quarries (underground / subsurface mining)**	Active or non-active underground or sub-surface based mining activities. Category includes all associated surface infrastructure etc.
48	**Mines and Quarries (surface-based mining)**	Active or non-active surface-based mining activities. Includes both hardrock or sand quarry extraction sites, and opencast mining sites i.e. coal. Category includes all associated surface infrastructure.
49	**Mines and Quarries (mine tailings, waste dumps)**	Primarily non-vegetated, exposed mining (and heavy industry) extraction or waste material. Major areas of managed vegetation re-habilitation on these sites can be mapped according to the appropriate vegetation category.

In order to calculate the land transformation index, scores of one to five were allocated to the 49 different land cover types. A score of one was used to represent a degraded, transformed environment and a score of five was used to indicate a pristine natural environment. A degraded, transformed environment refers to a complete loss of natural land cover, with a subsequent loss of natural systems and processes.

Detailed metadata for the 2000 National Land Cover dataset was not available at time of writing and the motivations below are a combination of general class descriptions, detailed research from other references, and correspondence with one of the authors (van den Berg, 2008, *pers comm*). In some cases Google Earth was consulted to verify or confirm land cover extent. For some of the classes below, the land cover class may include alien invasive vegetation; however, for the chosen mapping scale and methods used in the 2000 National Land Cover dataset, the exact extent and location of such patches was not distinguished from natural vegetation with similar cover characteristics. It is well known that alien vegetation affects river flow negatively but this effect could not be included in this study due to the shortcomings of the land cover dataset. Since this study was conducted, a national map of alien invasive plants has been released (Kotze, *et al*, 2010)

1. Forest (indigenous), Score: 5.
   The definition of this category refers to “Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species)”, (van den Berg, 2008, *pers.comm*). Although some areas may have exotic species, the area would be too small to detect when developing and digitising this category therefore a score of five indicating a completely natural area was allocated.

2. Woodland (previously termed Forest and Woodland), Score: 5.
   The definition of this category refers to “Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species)”, (van den Berg, 2008, *pers.comm*). Although some areas may have exotic species, the area would be too small to detect when developing and digitising this category therefore a score of five indicating a completely natural area was allocated.

3. Thicket, Bushland, Bush Clumps, High Fynbos, Score: 4.
   The definition of this category mentions “Presence of alien exotic species can be modelled spatially using broad principles... Dense bush encroachment would be included in this category”, (van den Berg, 2008, *pers.comm*). The extent of encroachment is unknown in this dataset, but its presence will affect rivers negatively. This indicates that the area is slightly transformed from its natural state so a score of four was applied to indicate this transformation.

4. Shrubland and Low Fynbos, Score: 5.
   The definition of this category makes no reference to alien vegetation, weeds or bush encroachment (van den Berg, 2008, *pers.comm*). It can therefore be assumed it is a completely natural system and is allocated the highest score.

5. Herbland, Score: 4.
   The definition refers to "'weed' dominated degraded areas", (van den Berg, 2008, *pers.comm*), indicating that although it is primarily a natural area there is a degree of transformation and a score of four indicating this was allocated.

6. Unimproved (natural) Grassland, Score: 5.
   "Essentially indigenous species growing under natural or semi-natural conditions", (van den Berg, 2008, *pers.comm*), indicated that although minor transformation was possible, it was not detected when classifying this category. It was allocated a completely natural score of five.

7. Improved Grassland, Score: 3.
   The definition refers to planted grasslands with indigenous or exotic species, growing under managed conditions; it may be irrigated as it is used for hay or turf production or even recreational activities such as golf (van den Berg, 2008, *pers.comm*). This indicated that it is not a natural environment, it will require excess water and in the case of golf courses the use of fertilisers, composts and other additives may be used (Schueler, 2000). A score of three was allocated, as although the area is quite transformed, these areas can support biodiversity associated with agricultural lands. Furthermore, these are usually restorable to some form of natural grassland. The presence of some form of vegetative ground cover limits sediment transfer to rivers and allows for water filtration reducing pollutants entering the river system.

8. Forest Plantations (Eucalyptus spp), Score: 2.
   The definition refers to "All areas of systematically planted, man-managed tree resources composed of primarily exotic species...", (van den Berg, 2008, *pers.comm*). This indicated that it is a highly transformed environment, with no natural plant species occurring and also indicates a change in ecosystem functionality. A study conducted by Scott, *et al* (1998), indicated that eucalyptus trees can reduce the total flow in river systems by between 16% and 42%. Rivers have minimum flow requirements and reduction to water availability will impede natural river processes, change river flow dynamics and impact on river biodiversity. It therefore received a score of two.

9. Forest Plantations (Pine spp), Score: 2.
   The definition refers to "All areas of systematically planted, man-managed tree resources composed of primarily exotic species...", (van den Berg, 2008, *pers.comm*). This indicated that it is a highly transformed environment, with no natural plant species occurring and also indicates a change in ecosystem functionality. A study conducted by Scott, *et al* (1998), indicated that pine trees can reduce the total flow in river systems by between 32% and 56%. Rivers have minimum flow requirements and reduction to water availability will impede natural river processes, change river flow dynamics and impact on river biodiversity. It therefore received a score of two.

10. Forest Plantations (Acacia spp), Score: 3.
    The definition was the generic definition for all plantations and refers to "All areas of systematically planted, man-managed tree resources composed of primarily exotic species...". The definition indicated that it is a highly transformed environment. Studies have shown the exotic acacia species have lower water demands (6% to 41%) then pine and eucalyptus species. Apart from having less demanding water requirements, acacia species will support a wider variety of biodiversity (Scott, *et al,* 1998). For these reasons they received a score of three still indicating it is

transformed from a natural environment but having less of a negative impact then pine and eucalyptus.

11. Forest Plantations (Other/mixed spp), Score: 3.
    The definition refers to “All areas of systematically planted, man-managed tree resources composed of primarily exotic species...”, (van den Berg, 2008, *pers.comm*). This indicated that it is a transformed environment, impacting on water use, soil chemistry and naturally occurring biodiversity. The definition of other/mixed was not specified so these areas where viewed in Google Earth (2008). Although it is hard to identify, these areas were allocated a score of three. They are transformed from a natural environment but it has been found that mixed plantations have higher water use efficiency, therefore having less of an impact on freshwater systems then monocultures (Forrester, *et al,* 2010).

12. Forest Plantations (Clear felled), Score: 1.
    Clear felling is the process of removing all vegetation from the plantation. Clear felling may be seen to have positive impact as often it removes large areas of exotic species. With less exotic species more water becomes available to improve stream flow in water limited areas (Prinsloo & Scott, 1999). However, large scale clear felling causes abrupt, sudden environmental changes. The ground surface is exposed to wind and water erosion and tree roots are no longer present to hold soil in place resulting in a large sediment influx in the river systems (Farley, *et al,* 2005). Clear felling also causes complete land cover transformation and was therefore allocated a score of one.

13. Water Bodies, Score: 3.
    The definition refers to water bodies which are both natural and man-made. This category includes features such as rivers, reservoirs, farm irrigation dams, etc., (van den Berg, 2008, *pers.comm*). South Africa is a country with very few natural water bodies, apart from our river systems, and all major river systems are artificially regulated by dams (SOER, 1999(b)). Reservoirs and irrigation dams are not natural features (Nel, *et al,* 2009). Water regulation changes river flow dynamics, storing water upstream and limiting water flow downstream. It also changes hydrological cycles, managing flood and drought conditions thereby eliminating river ecosystem services (Allan, 2004). The condition of South African rivers is of grave concern due to high water extraction levels and severe pollution. For these reasons a transformed score of three was allocated.

14. Wetlands, Score: 4.
    The definition refers to “natural or artificial areas...” (van den Berg, 2008, *pers.comm*). Despite wetlands being of high biodiversity importance, they cannot receive a score of five indicating completely natural if the definition includes artificial systems. In addition to this, only 10% of wetlands are fully protected in national parks, natural reserves and sanctuaries and 8% are partially protected (Rouget, *et al,* 2004; SOER, 1999(a)). There is little protection for the remaining wetlands. This indicates that the majority of wetlands are at a high risk of being degraded. In addition, Amis, *et al (*2007) indicated that the majority of wetlands currently occur in a partially transformed or impacted state.

15. Bare Rock and Soil (natural), Score: 5.
    The definition refers to “natural areas of exposed sand, soil or rock...” (van den Berg, 2008, *pers.comm*), there is no indication of an unnatural environmental therefore a score of five was allocated.

16. Bare Rock and Soil (erosion : dongas/gullies), Score: 1.
    These areas are defined as “non-vegetated areas that are primarily a result of active gully erosion processes”, (van den Berg, 2008, *pers.comm*). These areas are known to be completely unproductive and totally degraded. Often gullies form due to overgrazing and poor land management practices. Once gullies have formed, water overland flow and velocity increases, thereby increasing the amount of sediment and surface pollution entering river systems, resulting in active channel erosion (Allan, 2004). The chance of natural rehabilitation of the land is minimal. This category scored a one indicating complete transformation from its natural surroundings and impact to river integrity though increased sedimentation and long term river channel deterioration (Poesen, *et al,* 2003; Valentin, *et al,* 2005).

17. Bare Rock and Soil (erosion : sheet), Score: 2.
    The definition mentions that these areas suffer from active sheet erosion and are associated with areas of severe donga erosion and poor grass cover (van den Berg, 2008, *pers.comm*). The score of two indicates that although the area is highly transformed and severely degraded they still have remnants of natural vegetation and some remaining ecosystem functionality which will help reduce but not prevent sediment entering river systems. It will result in slower sediment influx.

18. Degraded Forest & Woodland, Score: 3.
    A comparison was made between the definitions of Woodland (previously termed Forest and Woodland) and the category Degraded Forest and Woodland. The first category refers to “Essentially indigenous species, growing under natural or semi-natural conditions (although it may include some areas of self-seeded exotic species)”, and the second categories definition is “Permanent or near-permanent, man-induced areas of very low vegetation cover...”, (van den Berg, 2008, *pers.comm*). This area is heavily impacted upon typically in the form of subsistence for rural communities. Vegetation losses also contribute to reduced soil stability and increased sedimentation in river systems. The score of three indicated the level of degradation and transformation but it also indicates the resilience of such a system to recover (Wessels, *et al,* 2004).

19. Degraded Thicket, Bushland, etc, Score: 2.
    The definition refers to “level agriculture and rural population centres, where overgrazing or livestock and /or wood-resource removal has been locally excessive. Often associated with severe soil erosion problems”, (van den Berg, 2008, *pers.comm*). The earlier definition of Thicket, Bushland, Bush Clumps, High Fynbos refers to the presence of alien species and dense bush encroachments. Through considering both definitions, a score of two was allocated indicating the severe level of transformation and lower probability of the area to recover in the near future.

20. Degraded Shrubland and Low Fynbos, Score: 3.
    The definition refers to “level agriculture and rural population centres, where overgrazing or livestock and /or wood-resource removal has been locally excessive. Often associated with severe soil erosion problems”, (van den Berg, 2008, *pers.comm*). The earlier definition of Shrubland and Low Fynbos makes no reference to alien vegetation of bush encroachments therefore the score of three indicates the level of transformation but also indicated the potential ability of the system to recover in the future.

21. Degraded Herbland, Score: 1.
    When comparing the definition of Herbland with the definition of Degraded Herbland it is clear that not only are there invasive weed species but also severe erosion

problems which will result in increased sediment enter river systems (van den Berg, 2008, *pers.comm*). A transformed score of one was applied indicating severe loss of the natural environment and ecosystem processes.

22. Degraded Unimproved (natural) Grassland, Score: 2.
    The definition of Degraded Unimproved (natural) Grassland and the definition of Unimproved (natural) Grassland were compared. This area is prone to severe erosion leaving the land fallow, with hard impenetrable soils which are poor in nutrients (van den Berg, 2008, *pers.comm*). Although grasses are often the first species to be used when rehabilitating an area, these are typically low-nutrient coloniser annual species. Therefore this category received a score slightly higher than the Degraded Herbland category, although it did not receive a score high enough to indicate the potential for full recovery in the immediate future.

23. Cultivated, Permanent, Commercial, Irrigated, Score: 2.
    This area has been prepared for raising crops. It will be ploughed, heavily irrigated and intensely managed. It is for commercial use therefore; the use of herbicides, pesticides and fertilizers will be common (Goetz & Fiske, 2008). The use of pesticides will impact in the surrounding natural environment, killing animal species such as small rodents, birds and invertebrates. Chemicals are also likely to leach into the soils and pollute nearby water systems (Allan, 2004). This type of agriculture, although highly productive, results in the loss of all natural land cover (Wessels, *et al,* 2003). A study by Harding, *et al* (1998)*,* concluded that agricultural practices which occur on a large-scale for an extended period of time within a catchment will hinder the recovery of stream biodiversity for many decades. Commercial farms require large quantities of water, often extracted from nearby rivers or groundwater, affecting water availability in the river itself (Allan, 2004). As the area is managed it will ensure that the land does not become degraded by over utilisation, rendering the land unproductive, therefore the score of two indicates that it is completely transformed but not degraded.

24. Cultivated, Permanent, Commercial, Dry Land, Score: 2.
    This area has been prepared for raising crops. It will be ploughed and intensely managed ensuring long term sustainability. It is for commercial use therefore; the use of herbicides, pesticides and fertilizers will be common (Goetz & Fiske, 2008). The use of pesticides will impact in the surrounding natural environment, killing animal species such as small rodents, birds and invertebrates. Chemicals are also likely to leach into the soils and pollute nearby water systems (Allan, 2004). This type of agriculture, although highly productive, results in the loss of all natural land cover (Wessels, *et al,* 2003). Agricultural practices which occur on a large-scale for an extended period of time within a catchment will hinder the recovery of stream biodiversity for many decades (Harding, *et al,* 1998). As the area is managed it will ensure that the land does not become degraded by over utilisation, rendering the land unproductive, therefore the score of two indicates that it is completely transformed but not degraded.

25. Cultivated, Permanent, Commercial, Sugarcane, Score: 2.
    This area has been prepared for farming sugar cane. It will be ploughed, irrigated and intensely managed. It is for commercial sugar production therefore; the use of herbicides, pesticides and fertilizers will be common (Graham, *et al,* 2002). The use of pesticides will impact in the surrounding natural environment, killing animal species such as small rodents, birds and invertebrates. Chemicals are also likely to leach into the soils and pollute nearby water systems (Allan, 2004). This type of agriculture, although highly productive, results in the loss of all natural land cover.

Agricultural practices which occur on a large-scale for an extended period of time within a catchment will hinder the recovery of stream biodiversity for many decades (Harding, *et al,* 1998). Sugarcane farming may use destructive methods of burning the sugar fields for faster harvesting. This will result in air pollution and the loss of nutrients stored in leaves and soil (Graham, *et al,* 2002). Although the area is highly transformed it is often strictly managed ensuring that the area does not degrade completely and does support levels of biodiversity and maintain some ecosystem functionality, hence the score of two.

26. Cultivated, Temporary, Commercial, Irrigated, Score: 2.
    This area has been prepared for raising crops. It will be ploughed, irrigated and intensely managed. It is for commercial use therefore; the use of herbicides, pesticides and fertilizers will be common (Goetz & Fiske, 2008; Wessels, *et al,* 2003). The use of pesticides will impact in the surrounding natural environment, killing animal species such as small rodents, birds and invertebrates. Chemicals are also likely to leach into the soils and pollute nearby water systems (Allan, 2004). This type of agriculture does allow fields to recover between crops but does not allow for the regeneration of natural vegetation. Agricultural practices which occur on a large-scale for an extended period of time within a catchment will hinder the recovery of stream biodiversity for many decades (Harding, *et al,* 1998). The farms will require large quantities of water, often extracted from nearby rivers or groundwater (Allan, 2004). The score of two indicates that it is transformed but not degraded.

27. Cultivated, Temporary, Commercial, Dry Land, Score: 2.
    This area has been prepared for raising crops. It will be ploughed, irrigated and intensely managed ensuring long term productivity. It is for commercial use therefore; the use of herbicides, pesticides and fertilizers will be common (Goetz & Fiske, 2008; Wessels, *et al,* 2003). The use of pesticides will impact in the surrounding natural environment, killing animal species such as small rodents, birds and invertebrates. Chemicals are also likely to leach into the soils and pollute nearby water systems (Allan, 2004). This type of agriculture does allow fields to recover between crops but does not allow for the regeneration of natural vegetation. Agricultural practices which occur on a large-scale for an extended period of time within a catchment will hinder the recovery of stream biodiversity for many decades (Harding, *et al,* 1998). The score of two indicates that it is completely transformed but not degraded.

28. Cultivated, Temporary, Subsistence, Dry Land, Score: 1.
    This area is prepared primarily for raising crops and often multi-cropping practices are implemented. Often subsistence areas are prepared though manual labour and not mechanical means. The fields are not planted all year round and will be given rest periods between crops, however these fields are often used for grazing during rest periods which can lead to long term land degradation if overgrazed (Wessels, *et al,* 2004). Irrigation will be natural by rainfall. With subsistence farming, often the fields are over utilised and mismanaged resulting in the ground becoming fallow and unproductive (Wessels, *et al,* 2004). The use of herbicides, pesticides and fertilizers is not uncommon but is done on an ad hoc basis which can result in environmental and water pollution (Allan, 2004). The low score of one indicates a completely transformed, unnatural environment prone to further degradation.

29. Cultivated, Temporary, Subsistence, Irrigated, Score: 1.
    This area is prepared primarily for raising crops and often multi-cropping practices are implemented. Often subsistence areas are prepared though manual labour and not mechanical means. The fields are not planted all year round and will be given rest periods between crops, however these fields are often used for grazing during

rest periods which can lead to long term degradation if over grazed. Irrigation will be artificial, though the use of ditches, streams or pipes and often water is wasted though inefficient use (Allan, 2004). With subsistence farming, often the fields are over utilised and miss managed resulting in the ground becoming fallow and unproductive (Wessels, *et al,* 2004). The use of herbicides, pesticides and fertilizers is not uncommon but is done on an ad hoc basis which can result in environmental and water pollution (Allan, 2004). The low score of one indicates a completely transformed and unnatural environment prone to further degradation.

30. Urban/Built-up (residential), Score: 2.
    According to the definition it is a broad term for most residential dwellings (van den Berg, 2008, *pers.comm*). The area will consist of high density complexes, cluster units and other residential categories. The area will have road and service infrastructure and many dwellings will have gardens. The gardens may support high levels of biodiversity but will often contain alien vegetation and will be completely transformed from the original natural land cover (Wessels, *et al,* 2003). Many surfaces will be covered by buildings, paving and roads, causing water to drain faster, resulting in water entering river channels at a higher velocity and volume. This causes unnatural, intense flood events without high volumes of rainfall (Goetz & Fiske, 2008). Rainfall will usually be channelled though municipal infrastructure and most likely returned to a river system at fixed points. Densely built up areas change the micro climate of an area, reduce the natural ground water recharge and often contribute to pollution, such as air pollution by vehicles and fires, and water and ground pollution though the use of chemicals, fertilizers and detergents (Allan, 2004). The score of two indicates complete transformation but the area is still able to maintain some ecosystem processes.

31. Urban/Built-up (rural cluster), Score: 2.
    The definition refers to “Areas of clustered rural dwelling (i.e. kraals) whose structural density is too low to be classified as a formal village... small scale cultivation/garden plots often form a major spatial component and are located amongst the residential structures.”, (van den Berg, 2008, *pers.comm*). These areas would have transformed a large portion of the natural environment. Ground cover clearing exposures bare soil which increases evaporation rates, increases sediment entering river systems and causes the land surface to become hard reducing infiltration (Allan, 2004). A score of two was applied to indicate land transformation and degradation with some remaining ecosystem processes.

32. Urban/Built-up (residential, formal suburbs), Score: 3.
    This definition refers to new or well-established residential areas or ‘garden-suburbs’ and includes both low and high density buildings (van den Berg, 2008, *pers.comm*). The area will have road and service infrastructure and many dwellings will have gardens. Gardens may support high levels of biodiversity although contain alien vegetation. These areas are permanently transformed from the original natural land cover, however with larger gardens and varying property densities, it will allow for more natural water drainage and infiltration (Goddard, *et al,* 2009).

33. Urban/Built-up (residential, flatland), Score: 1.
    The definition refers to high density structures varying between three, up to ten stories high and examples are given of city centres such as Hillbrow in Johannesburg and Sunnyside in Pretoria (van den Berg, 2008, *pers.comm*). These areas are completely transformed and, apart from small parks, the land surface area is covered by impermeable surfaces such as roads, parking lots and buildings. Due to the congestion in these areas there are high levels of air and surface pollution (Allan,

2004; Goetz & Fiske, 2008). All water drainage is managed and channelled. There are no remaining natural processes, systems or environments therefore a score of one was applied indicating total transformation.

34. Urban/Built-up (residential, mixed), Score: 2.
    As the definition was “mixture...” no reliable interpretation could be made (van den Berg, 2008, *pers.comm*). In this instance these areas were looked at in Google Earth (2008). The score of two indicates the majority of the area is severely transformed from a natural environment as only limited areas of gardens and open spaces remained, but more so then in city centres.

35. Urban/Built-up (residential, hostels), Score: 1.
    The definition refers to permanent buildings, usually one or two stories high in block like structures, located in formal township districts (van den Berg, 2008, *pers.comm*). Pollution is a common problem in these areas. There is little or no natural or introduced vegetation. Due to the density there is no opportunity for water drainage and often it is managed and channelled by artificial means (Allan, 2004). This area is completely transformed from a natural area and is thought to be degraded hence the low score of one.

36. Urban/Built-up (residential, formal township), Score: 2.
    The definition refers to brick structures located on serviced sites within formal black residential areas. It includes high and low building densities (van den Berg, 2008, *pers.comm*). A score of two indicates that this area will have less impact on the natural environments due to the services supplied but is still completely transformed from the original natural land cover.

37. Urban/Built-up (residential, informal township), Score: 1.
    Based on the description for this area, it is completely transformed from a natural environment, it will have a high percentage of the residents living off the land which is unsustainable and the area will suffer severe degradation (van den Berg, 2008, *pers.comm;* Wessels, *et al,* 2004). The area does not have adequate services to support the population and will have high levels of pollution.

38. Urban/Built-up (residential, informal squatter camp), Score: 1.
    This area has high building density with many people sharing houses. There are no services, the dwellings are not permanent, even though the residency in the area is for extensive periods of time, if not permanently. Communities are dependent on nearby river systems as a source of water which is used for consumption, bathing, washing cloths and waste disposal. As communities are poor, they live off the land as much as possible, leaving it degraded, barren and polluted (Wessels, *et al,* 2004). These areas are completely transformed and lose all traces of natural origin.

39. Urban/Built-up (smallholdings, woodland), Score: 3.
    The definition for this category was not descriptive and the scoring of this category was left to interpretation (van den Berg, 2008, *pers.comm*). These areas were looked at in Google Earth (2008) to get a better understanding of the land cover. Smallholdings would refer to very low density development, often large properties with a single large house and a few out buildings. Often a portion of the land is converted into a garden and the rest of the environment is left natural. Unfortunately habitat fragmentation by fencing reduces the naturalness of the area and this disturbance may lead to the encroachment of invasive plant species (Antwi, *et al,* 2008). The score of three represents that although natural areas remain, there have been transformations but the area still has the potential to recover.

40. Urban/Built-up (smallholdings, thicket, bushland), Score: 4.
    The definition for this category was not descriptive and the scoring of this category was left to interpretation (van den Berg, 2008, *pers.comm*). These areas were looked at in Google Earth (2008) to get a better understanding of the land cover. Smallholding refers to very low density development, often large properties with a single large house and a few out buildings. Often a portion of the land is converted into a garden and the rest of the environment is left natural. Unfortunately habitat fragmentation by fencing reduces the naturalness of the area (Antwi, *et al,* 2008; Wessels, *et al,* 2003). The score of four represents that although a large natural area remains there has been a transformation.

41. Urban/Built-up (smallholdings, shrubland), Score: 3.
    The definition for this category was not descriptive and the scoring of this category was left to interpretation (van den Berg, 2008, *pers.comm*). These areas were looked at in Google Earth (2008) to get a better understanding of the land cover. Smallholdings would refer to very low density development, often large properties with a single large house and a few out buildings. Often a portion of the land is converted into a garden and the rest of the environment is left natural. Unfortunately habitat fragmentation by fencing reduces the naturalness of the area (Antwi, *et al,* 2008). It is not uncommon for people to keep livestock such as horses or sheep on the property. Both fragmentation by fencing and overgrazing by livestock disturb the natural environment and may lead to the encroachment of invasive plant species. The score of three indicated that there is disturbance to the land, but the area still has the potential to recover.

42. Urban/Built-up (smallholdings, grassland), Score: 3.
    The definition for this category was not descriptive and the scoring of this category was left to assumption (van den Berg, 2008, *pers.comm*). These areas were looked at in Google Earth (2008) to get a better understanding of the land cover. Smallholdings would refer to very low density development, often large properties with a single large house and a few out buildings. Often a portion of the land is converted into a garden and the rest of the environment is left natural. Unfortunately habitat fragmentation by fencing reduces the naturalness of the area (Antwi, *et al,* 2008). It is not uncommon for people to keep livestock such as horses or sheep on the property. Both fragmentation by fencing and overgrazing by livestock disturb the natural environment and may lead to the encroachment of invasive plant species. The score of three indicated that there is disturbance to the land, but the area still has the potential to recover.

43. Urban/Built-up, (commercial, mercantile), Score: 1.
    The definition refers to trade and mercantile business in the CBD, as well as small commercial zones (van den Berg, 2008, *pers.comm*). These areas are completely transformed from the natural environment. They have a high density of people moving in and out of the area and are often highly congested. They are also associated with lots of structures and infrastructure such as parking lots, buildings and roads which alter natural drainage patterns (Allan, 2004; Goetz & Fiske, 2008). The score of one indicates complete transformation and no remaining natural environment or ecosystem processes.

44. Urban/Built-up, (commercial, education, health, IT), Score: 3.
    These areas, although completely transformed still retain some natural process and functionality. Examples are schools, universities and techno-parks (van den Berg, 2008, *pers.comm*). These locations contain many green areas and can even have natural or indigenous gardens. The buildings may be a couple of stories high but are

sparsely scattered allowing for natural water drainage (Allan, 2004). A score of three indicates that the areas are transformed but still maintain biodiversity and some natural functionality.

45. Urban/Built-up, (industrial/transport : heavy), Score: 1.
    Examples of this type of heavy industry include power stations, steel mills, dockyards, train stations and airports (van den Berg, 2008, *pers.comm*). These areas are completely transformed from a natural environment and have no remaining natural processes or systems occurring. Many of the areas are covered by impermeable surfaces so there is no natural water drainage. Many of these areas are associated with high levels of pollution (Allan, 2004; Goetz & Fiske, 2008).

46. Urban/Built-up, (industrial/transport : light), Score: 2.
    This category is very broad including light manufacturing units, warehouses and small airports to farm-based pig and battery hen breeding units. They are transformed from their original natural state although because all surrounding surfaces are not completely covered by impermeable surfaces, they can still maintain minor natural processes such as water drainage (Allan, 2004).

47. Mines & Quarries (underground/subsurface mining), Score: 1
    As underground mining occurs, the surface of the area appears relatively intact, however in the long term numerous impacts to the environment occur (Antwi, *et al,* 2008). Often with underground mining all underground water storage capacity is lost. Aquifers are dewatered and mined out, all rock and minerals underground are removed and waste material is dumped on the surface nearby. Once the mine has been shut down, often water pumping is stopped and as the water table rises this can then result in acid mine drainage polluting the ground and surrounding water systems (Bloodworth, *et al,* 2009; Boyer & Wratten, 2009, Kitula, 2006). The vegetation changes as the natural water tables no longer exist and species are unable to survive the extreme periods (Boyer & Wratten, 2009, Kitula, 2006). Although the immediate effect results in minimal transformation, the longer term effects are devastating and to date have proved to be irreversible (Otte & Jacob, 2008).

48. Mines & Quarries (surface-based mining), Score: 1.
    This type of mining is extremely destructive on the surface and impacts on underground processes. Impacts leave land with a low nutrient content, often with acidic soils, a low water capacity and a lack of biological activity (Antwi, *et al,* 2008; Boyer & Wratten, 2009). Quarries tend to impact smaller areas and the impacts tend to be localised, opencast coal mines can become excessively large and have widespread impacts (Bloodworth, *et al,* 2009). Often dewatering is required, especially as the mine gets deeper. Also the entire surface is cleared, removing all vegetation, habitats and natural biota (Antwi, *et al,* 2008). It is extremely expensive to refill these pits and they are often simply left open.

49. Mines & Quarries (mine tailings, waste dumps), Score: 1
    These dumps cover large areas on the surface and contribute to severe environmental pollution. Waste dumps, if left uncovered, create severe dust pollution and often the dust itself contains dangerous particles. Due to the material in these dumps, only exotic vegetation can survive and it is often planted on the sides of these dumps to reduce wind and water erosion (Young, 1950). Mine tailings are a large threat to the natural environment if not monitored properly. They contain all the waste from the mining process and, for example, in gold mining they will contain toxins such as cyanide (Otte & Jacob, 2008). It is difficult to stop water birds from being attracted to these sites and can lead to the death of many animals on a daily

basis. If they leak, which has happened before, all the pollutants and toxins enter the surrounding environment and impact on a much larger area, including river systems (Rivers-Moore & Jewitt, 2007). There sites not only completely transform the natural environment but also pose a big threat in terms of toxins and pollutants to the surrounding environments (Doshi, 2006).

Section B: Land Transformation Index, River Integrity Index, Fish Conservation Status Index and Ecological Integrity Index Results

DWAF Catchment Number	Catchment Number	Land Transformation Index	River Integrity Index	Fish Conservation Status Index	Ecological Integrity Index
A10A	0	81.30	76.18	80.00	79.16
A10B	1	82.77	60.10	97.14	80.00
A10C	2	86.30	75.63	98.33	86.76
A21A	3	86.17	60.00	98.75	81.64
A21B	4	86.63	40.00	97.14	74.59
A21C	5	80.36	40.34	98.18	72.96
A21D	6	93.90	76.13	98.46	89.49
A21E	7	87.27	61.08	98.46	82.27
A21F	8	83.23	92.44	97.50	91.06
A21G	9	81.79	57.24	100.00	79.68
A21H	10	70.14	78.39	100.00	82.84
A21J	11	84.32	80.00		0.00
A21K	12	77.27	60.15	97.78	78.40
A21L	13	76.66	40.00	96.67	71.11
A22A	14	95.76	63.97	100.00	86.58
A22B	15	84.48	80.00	97.50	87.33
A22C	16	89.09	40.00	97.78	75.62
A22D	17	70.06	60.00	100.00	76.69
A22E	18	87.27	48.92	95.00	77.07
A22F	19	82.87	88.21	97.50	89.52
A22G	20	98.85	100.00		0.00
A22H	21	86.58	44.24	100.00	76.94
A22J	22	76.52	60.00	100.00	78.84
A23A	23	66.25	80.00	90.00	78.75
A23B	24	60.78	60.00	98.46	73.08
A23C	25	79.34	60.00		0.00
A23D	26	90.69	60.00		0.00
A23E	27	87.95	83.09		0.00
A23F	28	65.83	60.00	100.00	75.28
A23G	29	49.58	41.75	98.33	63.22
A23H	30	96.39	60.00	100.00	85.46
A23J	31	88.86	80.00	95.00	87.95
A23K	32	67.30	80.00	100.00	82.43
A23L	33	99.82	94.27	98.57	97.55
A24A	34	65.79	50.66		0.00
A24B	35	76.55	40.00		0.00
A24C	36	79.64	40.00	100.00	73.21
A24D	37	41.73	40.00		0.00

A24E	38	82.19	40.00	95.00	72.40
A24F	39	52.12	40.17	93.33	61.87
A24G	40	67.20	80.00	97.50	81.57
A24H	41	82.84	40.00		0.00
A24J	42	50.24	40.00	98.00	62.75
A31A	43	85.73	82.03	97.78	88.51
A31B	44	93.17	40.00	100.00	77.72
A31C	45	94.42	58.62		0.00
A31D	46	54.86	60.00	95.00	69.95
A31E	47	59.57	55.41	100.00	71.66
A31F	48	55.46	60.00	96.00	70.49
A31G	49	79.54	55.19	96.67	77.13
A31H	50	90.49	56.02	96.00	80.84
A31J	51	85.63	54.00		0.00
A32A	52	86.96	60.00		0.00
A32B	53	59.23	40.00	85.00	61.41
A32C	54	77.54	77.14	97.78	84.15
A32D	55	89.46	80.00	100.00	89.82
A32E	56	46.62	76.28		0.00
A41A	57	52.39	42.88	90.00	61.76
A41B	58	85.77	60.00		0.00
A41C	59	62.05	75.03		0.00
A41D	60	48.02	60.00		0.00
A41E	61	68.32	77.53		0.00
A42A	62	78.44	40.00	100.00	72.81
A42B	63	97.54	80.00	100.00	92.51
A42C	64	70.86	40.00	100.00	70.29
A42D	65	66.78	60.61		0.00
A42E	66	69.40	40.00		0.00
A42F	67	87.71	40.00		0.00
A42G	68	63.19	57.64		0.00
A42H	69	47.17	80.00		0.00
A42J	70	64.57	40.00	98.46	67.68
A50A	71	81.96	60.93	98.57	80.49
A50B	72	61.62	78.08		0.00
A50C	73	89.43	62.15	98.00	83.19
A50D	74	84.21	80.00		0.00
A50E	75	76.60	61.04		0.00
A50F	76	89.98	40.76	97.50	76.08
A50G	77	90.57	40.00	98.00	76.19
A50H	78	89.11	40.00		0.00
A50J	79	66.60	56.95	100.00	74.52
A61A	80	74.19	40.00		0.00
A61B	81	63.38	78.25		0.00

A61C	82	65.46	40.00	98.57	68.01
A61D	83	82.95	60.00	96.00	79.65
A61E	84	83.02	63.08		0.00
A61F	85	89.65	58.17	100.00	82.61
A61G	86	88.26	79.29	100.00	89.18
A61H	87	64.94	40.00	100.00	68.31
A61J	88	75.92	40.00	100.00	71.97
A62A	89	87.47	79.93	95.00	87.47
A62B	90	70.44	41.73	98.46	70.21
A62C	91	86.88	40.00	90.00	72.29
A62D	92	69.80	59.92		0.00
A62E	93	59.71	40.00		0.00
A62F	94	83.71	60.00		0.00
A62G	95	84.32	80.00		0.00
A62H	96	77.95	60.00	97.50	78.48
A62J	97	82.84	37.86	97.50	72.73
A63A	98	80.30	59.99	100.00	80.10
A63B	99	91.54	60.00	97.14	82.89
A63C	100	86.56	40.00	97.78	74.78
A63D	101	83.94	59.96	100.00	81.30
A63E	102	81.66	60.00	98.75	80.14
A71A	103	71.96	60.00	100.00	77.32
A71B	104	82.11	42.58	100.00	74.90
A71C	105	77.88	45.38	97.50	73.59
A71D	106	80.10	60.00	97.78	79.29
A71E	107	93.83	99.40	97.50	96.91
A71F	108	85.89	60.78	100.00	82.22
A71G	109	95.47	40.00	95.00	76.82
A71H	110	79.56	60.00	100.00	79.85
A71J	111	67.12	40.00		0.00
A71K	112	75.26	40.00		0.00
A71L	113	79.72	60.00	100.00	79.91
A72A	114	56.29	40.00		0.00
A72B	115	56.23	60.00	100.00	72.08
A80A	116	75.08	59.65	100.00	78.24
A80B	117	83.68	40.00	97.78	73.82
A80C	118	80.90	47.18	98.18	75.42
A80D	119	87.88	40.00		0.00
A80E	120	87.91	40.00		0.00
A80F	121	74.61	59.83	96.67	77.04
A80G	122	96.29	86.25		0.00
A80H	123	93.97	65.58		0.00
A80J	124	89.53	60.32	100.00	83.28
A91A	125	83.00	60.01	97.50	80.17

A91B	126	52.22	40.00	96.00	62.74
A91C	127	54.44	59.01	96.00	69.82
A91D	128	80.19	40.00	100.00	73.40
A91E	129	81.68	100.00	96.67	92.78
A91F	130	85.72	60.00	100.00	81.91
A91G	131	91.62	80.00	93.33	88.32
A91H	132	81.89	79.06		0.00
A91J	133	95.98	40.00		0.00
A91K	134	59.02	40.00		0.00
A92A	135	89.10	79.96	100.00	89.69
A92B	136	55.69	22.40	100.00	59.36
A92C	137	46.11	40.00	96.67	60.92
A92D	138	82.98	60.00	100.00	80.99
B11A	139	81.54	80.00	100.00	87.18
B11B	140	62.47	40.00		0.00
B11C	141	74.11	60.00		0.00
B11D	142	82.17	40.00	100.00	74.06
B11E	143	65.18	60.00		0.00
B11F	144	79.84	40.29	100.00	73.38
B11G	145	72.55	40.12	100.00	70.89
B11H	146	73.63	40.00	100.00	71.21
B11J	147	78.47	78.89	100.00	85.79
B11K	148	86.96	40.00		0.00
B11L	149	81.98	97.73	98.00	92.57
B12A	150	78.64	60.00		0.00
B12B	151	43.40	40.00	100.00	61.13
B12C	152	84.67	40.12	100.00	74.93
B12D	153	73.76	58.48		0.00
B12E	154	87.42	40.00	100.00	75.81
B20A	155	87.48	40.00	100.00	75.83
B20B	156	79.88	58.84	100.00	79.57
B20C	157	85.83	100.00	100.00	95.28
B20D	158	78.86	63.68	100.00	80.85
B20E	159	83.98	56.67		0.00
B20F	160	82.58	60.00	93.33	78.64
B20G	161	75.73	60.00	100.00	78.58
B20H	162	39.24	40.00		0.00
B20J	163	74.10	76.21	72.00	74.10
B31A	164	84.37	46.07	100.00	76.81
B31B	165	56.73	38.47	97.50	64.24
B31C	166	50.16	60.00	98.46	69.54
B31D	167	53.10	68.36	92.00	71.15
B31E	168	80.87	60.00	93.85	78.24
B31F	169	62.63	80.00		0.00

B31G	170	87.70	40.00	96.67	74.79
B31H	171	78.15	40.00	100.00	72.72
B31J	172	90.57	60.00	100.00	83.52
B32A	173	76.17	56.20	97.50	76.63
B32B	174	88.12	79.83	100.00	89.32
B32C	175	83.51	87.29	100.00	90.27
B32D	176	68.49	80.00	90.00	79.50
B32E	177	73.15			0.00
B32F	178	71.26	60.10	85.00	72.12
B32G	179	67.24	100.00	100.00	89.08
B32H	180	85.43	40.00	100.00	75.14
B32J	181	48.74	65.70	92.00	68.81
B41A	182	61.08	37.64	97.78	65.50
B41B	183	64.74	78.83	95.00	79.52
B41C	184	69.00	60.00	100.00	76.33
B41D	185	73.07	80.00	100.00	84.36
B41E	186	69.22	60.00	100.00	76.41
B41F	187	87.86	60.00	95.00	80.95
B41G	188	52.40	60.00	97.14	69.85
B41H	189	79.02	60.00	97.78	78.93
B41J	190	79.58	80.00		0.00
B41K	191	51.96	22.83		0.00
B42A	192	67.65	47.75	100.00	71.80
B42B	193	86.50	80.00	100.00	88.83
B42C	194	76.73	60.00	100.00	78.91
B42D	195	79.23	79.90	100.00	86.38
B42E	196	72.26	60.34	100.00	77.53
B42F	197	76.77	80.00	93.33	83.37
B42G	198	36.30	60.00		0.00
B42H	199	66.43	79.77	94.29	80.16
B51A	200	68.22	62.01		0.00
B51B	201	56.13	60.00		0.00
B51C	202	86.16	40.00	100.00	75.39
B51E	203	83.09	79.41	93.75	85.41
B51F	204	65.63	57.91	40.00	54.51
B51G	205	87.73	80.00	91.43	86.39
B51H	206	82.01	100.00		0.00
B52A	207	93.02	60.00		0.00
B52B	208	54.56	40.67	95.00	63.41
B52C	209	82.57	60.00		0.00
B52D	210	80.61	80.00		0.00
B52E	211	61.73	80.00	94.29	78.67
B52F	212	67.25	75.31	95.00	79.19
B52G	213	89.32	79.56	96.00	88.29

B52H	214	66.86	42.53		0.00
B52J	215	63.04	60.00	100.00	74.35
B60A	216	59.16	80.00	97.14	78.77
B60B	217	65.55	80.00	100.00	81.85
B60C	218	77.98	74.89	92.00	81.62
B60D	219	64.25	60.86		0.00
B60E	220	75.63	80.00	100.00	85.21
B60F	221	60.92	40.00	100.00	66.97
B60G	222	78.67	60.00	100.00	79.56
B60H	223	65.59	60.21	95.00	73.60
B60J	224	73.77	80.00		0.00
B71A	225	63.52	62.38	100.00	75.30
B71B	226	67.06	65.04	97.50	76.53
B71C	227	77.21	60.00	100.00	79.07
B71D	228	81.28	41.52	95.00	72.60
B71E	229	72.31	73.62	100.00	81.98
B71F	230	83.45	64.02	100.00	82.49
B71G	231	62.58	80.00	90.00	77.53
B71H	232	64.17	60.09	100.00	74.76
B71J	233	94.36	76.21	97.14	89.24
B72A	234	69.41	42.33	90.00	67.25
B72B	235	88.88	43.17		0.00
B72C	236	74.48	45.73	96.67	72.29
B72D	237	89.16	60.00	100.00	83.05
B72E	238	81.21	40.00		0.00
B72F	239	76.37	60.00	100.00	78.79
B72G	240	68.72	45.24	88.57	67.51
B72H	241	87.90	95.92	100.00	94.61
B72J	242	58.65	59.98	60.00	59.54
B72K	243	85.07	40.00	93.33	72.80
B73A	244	66.67	60.00	100.00	75.56
B73B	245	72.41	60.00	80.00	70.80
B73C	246	74.36	40.37	95.00	69.91
B73D	247	71.64	80.00		0.00
B73E	248	62.12	40.00	100.00	67.37
B73F	249	77.57	48.53	90.00	72.04
B73G	250	68.19	60.00	100.00	76.06
B73H	251	69.61	60.00	86.67	72.09
B73J	252	60.84	60.00	100.00	73.61
B81A	253	88.99	42.16	70.00	67.05
B81B	254	86.91	41.63	94.29	74.28
B81C	255	82.14	60.00	97.14	79.76
B81D	256	63.86	60.00	97.14	73.67
B81E	257	70.16	20.04	76.67	55.62

B81F	258	87.83	56.31	96.00	80.05
B81G	259	66.39	60.00		0.00
B81H	260	83.15	60.00	97.50	80.22
B81J	261	70.32	60.00	100.00	76.77
B82A	262	68.32	40.00	100.00	69.44
B82B	263	75.79	60.00	88.00	74.60
B82C	264	75.63	40.00	97.14	70.92
B82D	265	76.09	60.00	90.00	75.36
B82E	266	83.78	60.00	100.00	81.26
B82F	267	83.45	59.96	96.00	79.80
B82G	268	60.75	58.27	84.00	67.67
B82H	269	72.95	80.00		0.00
B82J	270	87.91	40.07	96.00	74.66
B83A	271	79.63	80.00		0.00
B83B	272	73.19	60.00	40.00	57.73
B83C	273	60.84	60.00	100.00	73.61
B83D	274	79.01	60.00	97.50	78.84
B83E	275	80.43	55.92	100.00	78.78
B90A	276	83.96	60.00	93.33	79.10
B90B	277	76.89	57.35	100.00	78.08
B90C	278	69.62	56.86	72.00	66.16
B90D	279	60.44	74.66	100.00	78.37
B90E	280	74.65	43.66	100.00	72.77
B90F	281	83.94	59.12	98.00	80.35
B90G	282	71.44	60.00	97.14	76.19
B90H	283	51.92	60.91	100.00	70.94
C11A	284	72.31	60.00	97.50	76.60
C11B	285	85.88	60.00	96.67	80.85
C11C	286	79.31	39.09	95.00	71.13
C11D	287	62.68	40.00	100.00	67.56
C11E	288	80.80	59.73	93.33	77.96
C11F	289	66.09	60.00	100.00	75.36
C11G	290	73.40	60.00		0.00
C11H	291	77.89	60.00	100.00	79.30
C11J	292	89.28	60.00	90.00	79.76
C11K	293	70.41	60.00	86.67	72.36
C11L	294	72.65	54.69	96.67	74.67
C11M	295	79.05	60.00	80.00	73.02
C12A	296	78.52	60.00	100.00	79.51
C12B	297	68.62	40.00	100.00	69.54
C12C	298	74.29	60.00	94.29	76.19
C12D	299	55.23	60.00	100.00	71.74
C12E	300	66.69	60.00	100.00	75.56
C12F	301	72.32	60.00	85.00	72.44

C12G	302	75.93	60.00	100.00	78.64
C12H	303	60.75	60.00	100.00	73.58
C12J	304	62.68	60.00	100.00	74.23
C12K	305	73.20	40.00	94.29	69.16
C12L	306	76.02	46.82	85.00	69.28
C13A	307	85.83	60.00	100.00	81.94
C13B	308	84.69	60.00	97.14	80.61
C13C	309	62.61	59.82		0.00
C13D	310	67.77	60.00	100.00	75.92
C13E	311	58.61	60.00	100.00	72.87
C13F	312	59.01	60.00	100.00	73.00
C13G	313	53.17	58.35	100.00	70.51
C13H	314	64.72	60.00	86.67	70.46
C21A	315	64.46	60.00	100.00	74.82
C21B	316	70.95	54.31	40.00	55.08
C21C	317	76.55	79.02	100.00	85.19
C21D	318	71.37	80.00		0.00
C21E	319	67.42	60.00	100.00	75.81
C21F	320	76.87	80.00	100.00	85.62
C21G	321	84.25	60.00		0.00
C22A	322	88.23	60.00		0.00
C22B	323	68.35	60.00	100.00	76.12
C22C	324	71.05	40.00	98.18	69.74
C22D	325	83.05	60.00	95.00	79.35
C22E	326	55.51	40.00	100.00	65.17
C22F	327	52.00	44.91		0.00
C22G	328	72.79	60.00	85.00	72.60
C22H	329	59.22	40.62	100.00	66.61
C22J	330	81.94	60.00	93.33	78.42
C22K	331	64.55	60.00	90.00	71.52
C23A	332	50.73	40.00	100.00	63.58
C23B	333	51.17	60.00	95.00	68.72
C23C	334	57.91	60.00	100.00	72.64
C23D	335	58.78	40.00		0.00
C23E	336	64.95	60.00	93.33	72.76
C23F	337	49.92	55.37		0.00
C23G	338	61.55	60.00	100.00	73.85
C23H	339	57.78	60.00	90.00	69.26
C23J	340	61.55	60.00	100.00	73.85
C23K	341	67.41	68.75	90.00	75.39
C23L	342	55.41	79.95		0.00
C24A	343	60.39	60.00	100.00	73.46
C24B	344	58.70	40.00	100.00	66.23
C24C	345	85.69	58.18	60.00	67.96

C24D	346	76.40	71.87	88.00	78.76
C24E	347	57.30	60.00	90.00	69.10
C24F	348	70.86	60.00	92.50	74.45
C24G	349	53.05	60.00		0.00
C24H	350	58.41	59.09	100.00	72.50
C24J	351	64.06	60.00	100.00	74.69
C25A	352	75.71	60.15	85.00	73.62
C25B	353	56.00	60.00	100.00	72.00
C25C	354	73.78	60.00	96.00	76.59
C25D	355	67.34	38.09	98.46	67.96
C25E	356	50.60	60.00		0.00
C25F	357	54.45	40.00		0.00
C31A	358	73.49	80.00		0.00
C31B	359	65.26	60.00	84.00	69.75
C31C	360	66.18	40.00	98.00	68.06
C31D	361	57.87	60.00	92.00	69.96
C31E	362	70.13	100.00	88.57	86.23
C31F	363	59.38	60.00	100.00	73.13
C32A	364	52.19	60.00		0.00
C32B	365	64.26	60.00	100.00	74.75
C32C	366	57.00	60.00		0.00
C32D	367	62.21	40.32	92.00	64.84
C33A	368	49.88	40.00	100.00	63.29
C33B	369	49.91	40.00	100.00	63.30
C33C	370	70.21	60.00	100.00	76.74
C41A	371	59.27	60.00	100.00	73.09
C41B	372	67.94	73.31	97.78	79.68
C41C	373	63.05	60.00	100.00	74.35
C41D	374	71.36	79.90	97.78	83.01
C41E	375	62.85	60.00		0.00
C41F	376	57.02	60.00		0.00
C41G	377	64.82	60.00	91.11	71.98
C41H	378	80.57		98.67	0.00
C41J	379	56.74	60.00	100.00	72.25
C42A	380	65.66	79.79	97.78	81.08
C42B	381	56.97	60.00	100.00	72.32
C42C	382	56.38	77.14	100.00	77.84
C42D	383	54.41	60.00		0.00
C42E	384	79.72		98.46	0.00
C42F	385	46.56	40.00		0.00
C42G	386	55.02	60.00	100.00	71.67
C42H	387	52.40	60.00	100.00	70.80
C42J	388	54.38	60.00	100.00	71.46
C42K	389	81.16	79.77	97.50	86.14

C42L	390	64.78	64.97	98.00	75.92
C43A	391	53.82	60.00		0.00
C43B	392	51.92	56.19		0.00
C43C	393	55.86	40.00		0.00
C43D	394	49.32	40.00	100.00	63.11
C51A	395	84.54	80.00	97.78	87.44
C51B	396	57.47	60.00		0.00
C51C	397	53.25	40.45	100.00	64.57
C51D	398	49.30	40.00		0.00
C51E	399	60.05	42.35		0.00
C51F	400	45.86	58.19		0.00
C51G	401	73.93		97.14	0.00
C51H	402	64.22	60.00	100.00	74.74
C51J	403	44.02	60.00	100.00	68.01
C51K	404	51.05	59.24	100.00	70.10
C51L	405	54.52	40.00		0.00
C51M	406	55.57	76.30	96.00	75.96
C52A	407	54.65	20.00	100.00	58.22
C52B	408	76.37		100.00	0.00
C52C	409	77.69		97.14	0.00
C52D	410	58.80	80.00	100.00	79.60
C52E	411	55.92	58.60		0.00
C52F	412	61.85		100.00	0.00
C52G	413	53.48	73.93	96.00	74.47
C52H	414	55.33	20.00	100.00	58.44
C52J	415	50.10	40.00	100.00	63.37
C52K	416	58.37	13.75	100.00	57.37
C52L	417	54.07	40.00	100.00	64.69
C60A	418	82.73		96.00	0.00
C60B	419	79.56	80.00		0.00
C60C	420	72.11		98.18	0.00
C60D	421	62.70	1.09	100.00	54.60
C60E	422	59.61	20.00		0.00
C60F	423	85.64	79.58		0.00
C60G	424	55.77	80.00	100.00	78.59
C60H	425	60.00	58.94		0.00
C60J	426	64.67	20.00	100.00	61.56
C70A	427	63.47		96.92	0.00
C70B	428	55.84	60.00	100.00	71.95
C70C	429	51.48	57.53	100.00	69.67
C70D	430	49.26	40.00		0.00
C70E	431	81.44		96.67	0.00
C70F	432	55.01	40.67		0.00
C70G	433	60.05	20.00	100.00	60.02

C70H	434	53.33	60.11	100.00	71.15
C70J	435	54.74	60.00		0.00
C70K	436	53.99	80.00	100.00	78.00
C81A	437	57.54	23.02	96.67	59.08
C81B	438	58.72	40.00	100.00	66.24
C81C	439	56.82	40.00	100.00	65.61
C81D	440	53.14	40.00	100.00	64.38
C81E	441	52.95	40.00	100.00	64.32
C81F	442	62.54	2.33	96.67	53.85
C81G	443	55.90	60.00	100.00	71.97
C81H	444	74.93		95.00	0.00
C81J	445	48.93	60.00		0.00
C81K	446	56.03	60.00	100.00	72.01
C81L	447	60.47	56.81		0.00
C81M	448	79.51		97.78	0.00
C82A	449	70.94			0.00
C82B	450	58.66	20.00		0.00
C82C	451	53.81	60.00	100.00	71.27
C82D	452	58.05	44.23	100.00	67.43
C82E	453	54.80	64.01	95.00	71.27
C82F	454	61.38	40.00	96.67	66.01
C82G	455	71.32		97.14	0.00
C82H	456	56.50	40.00		0.00
C83A	457	61.36	2.91	100.00	54.76
C83B	458	80.78	41.12		0.00
C83C	459	54.12	57.21	100.00	70.45
C83D	460	67.95	61.53		0.00
C83E	461	57.80	78.23		0.00
C83F	462	82.39		96.00	0.00
C83G	463	76.18		100.00	0.00
C83H	464	57.01	56.39		0.00
C83J	465	60.39	40.00	100.00	66.80
C83K	466	57.46	60.00	97.78	71.74
C83L	467	51.09	60.00		0.00
C83M	468	58.80	57.75		0.00
C91A	469	56.43	40.00		0.00
C91B	470	56.99	19.64	100.00	58.87
C91C	471	53.71	40.51	100.00	64.74
C91D	472	55.76	38.37	100.00	64.71
C91E	473	55.39	60.00		0.00
C92A	474	79.00	63.26		0.00
C92B	475	72.17	80.00		0.00
C92C	476	53.57	40.00		0.00
D11A	477	55.49	1.51	98.00	51.67

D11B	478	55.33	42.69	98.57	65.53
D11C	479	52.99	60.00		0.00
D11D	480	52.40	60.00		0.00
D11E	481	56.10	60.00	100.00	72.03
D11F	482	71.30	18.88	96.67	62.28
D11G	483	74.08		97.78	0.00
D11H	484	69.33	59.64		0.00
D11J	485	81.41	0.31	97.14	59.62
D11K	486	53.71	40.00		0.00
D12A	487	57.10	40.00		0.00
D12B	488	52.07	60.00	100.00	70.69
D12C	489	57.18	43.77		0.00
D12D	490	63.81	40.16	100.00	67.99
D12E	491	53.58	40.00	100.00	64.53
D12F	492	56.50	60.00		0.00
D13A	493	57.13	58.95	100.00	72.03
D13B	494	86.94	72.60	98.46	86.00
D13C	495	80.94	80.00		0.00
D13D	496	53.97	40.34		0.00
D13E	497	64.42	40.00		0.00
D13F	498	79.25		98.18	0.00
D13G	499	74.46	19.66	100.00	64.71
D13H	500	57.35	40.00		0.00
D13J	501	55.39	58.62		0.00
D13K	502	55.49	25.02	100.00	60.17
D13L	503	62.77	80.00		0.00
D13M	504	54.32	59.96		0.00
D14A	505	81.20		97.50	0.00
D14B	506	50.54	57.69		0.00
D14C	507	48.60	80.00	100.00	76.20
D14D	508	48.69	80.00	100.00	76.23
D14E	509	76.74		97.50	0.00
D14F	510	54.64	58.03	100.00	70.89
D14G	511	53.95	40.00		0.00
D14H	512	58.67	40.00		0.00
D14J	513	53.91	40.00	100.00	64.64
D14K	514	51.47	59.46		0.00
D15A	515	54.40	57.29		0.00
D15B	516	57.70	80.00		0.00
D15C	517	56.53	58.53	96.67	70.57
D15D	518	84.26	100.00	98.67	94.31
D15E	519	54.15	60.00		0.00
D15F	520	73.23	100.00	91.76	88.33
D15G	521	71.32	62.55	98.95	77.61

D15H	522	76.94	80.00		0.00
D16A	523	57.71	80.00		0.00
D16B	524	52.93	40.00	97.14	63.36
D16C	525	89.18	59.47		0.00
D16D	526	84.40		97.14	0.00
D16E	527	55.05	55.48	100.00	70.18
D16F	528	53.13	40.00	95.56	62.90
D16G	529	76.43		96.36	0.00
D16H	530	53.43	40.00	97.78	63.74
D16J	531	50.80	60.00		0.00
D16K	532	72.96	93.54	97.14	87.88
D16L	533	54.43	60.00		0.00
D16M	534	61.21		97.14	0.00
D17A	535	81.86	57.71	95.00	78.19
D17B	536	55.10	80.00		0.00
D17C	537	57.41	60.00		0.00
D17D	538	48.73	40.00		0.00
D17E	539	75.72	0.08	97.14	57.65
D17F	540	49.84	60.00		0.00
D17G	541	57.06	59.29		0.00
D17H	542	50.17	45.81	100.00	65.33
D17J	543	57.94	40.33	100.00	66.09
D17K	544	60.24	60.00	96.67	72.30
D17L	545	74.41	60.87	99.00	78.09
D17M	546	55.23	60.64		0.00
D18A	547	88.47	80.00		0.00
D18B	548	74.05	59.14		0.00
D18C	549	51.68	60.00		0.00
D18D	550	61.38	38.37	100.00	66.58
D18E	551	57.77	66.15		0.00
D18F	552	89.66	10.02	98.57	66.08
D18G	553	60.49	40.00	100.00	66.83
D18H	554	58.03	60.00		0.00
D18J	555	53.04	62.22		0.00
D18K	556	56.20	60.00		0.00
D18L	557	79.14	56.54	97.50	77.73
D21A	558	65.46	60.02	97.78	74.42
D21B	559	59.18	60.00		0.00
D21C	560	53.09	80.00	100.00	77.70
D21D	561	68.56	95.72	100.00	88.09
D21E	562	71.72	42.07	98.33	70.71
D21F	563	52.19	60.00	100.00	70.73
D21G	564	54.38	60.00	100.00	71.46
D21H	565	55.08	56.91		0.00

D21J	566	53.31	60.00		0.00
D21K	567	60.67	60.82		0.00
D21L	568	69.93	63.77	100.00	77.90
D22A	569	71.88	80.00	98.00	83.29
D22B	570	61.33	80.00	100.00	80.44
D22C	571	57.23	80.00		0.00
D22D	572	54.35	80.12	100.00	78.16
D22E	573	63.44	100.00	100.00	87.81
D22F	574	87.29	40.00	98.33	75.21
D22G	575	51.69	80.00		0.00
D22H	576	53.56	60.00		0.00
D22J	577	58.04	78.58	100.00	78.87
D22K	578	66.72	100.00	100.00	88.91
D22L	579	62.11	80.00	100.00	80.70
D23A	580	54.35	20.00		0.00
D23B	581	80.82	57.61	98.33	78.92
D23C	582	53.90	21.87		0.00
D23D	583	59.08	60.00	100.00	73.03
D23E	584	87.26	41.86	100.00	76.37
D23F	585	55.68	80.00		0.00
D23G	586	73.12	80.00	98.18	83.77
D23H	587	71.83	98.52	98.33	89.56
D23J	588	75.03	80.00	98.57	84.53
D24A	589	57.79	76.84		0.00
D24B	590	62.44	97.66	98.33	86.15
D24C	591	57.13	60.00		0.00
D24D	592	75.70	100.00	100.00	91.90
D24E	593	88.56	60.00		0.00
D24F	594	66.80	99.13	97.78	87.90
D24G	595	54.14	85.98	97.50	79.21
D24H	596	65.92	80.00		0.00
D24J	597	62.69	80.00	100.00	80.90
D24K	598	58.23	80.00		0.00
D24L	599	65.76	80.00		0.00
D31A	600	57.35	60.00		0.00
D31B	601	85.75	100.00		0.00
D31C	602	57.09	96.95	100.00	84.68
D31D	603	70.93	40.00		0.00
D31E	604	48.97	60.00		0.00
D32A	605	52.00	20.00	100.00	57.33
D32B	606	66.59	80.00	100.00	82.20
D32C	607	71.65	97.43	95.00	88.02
D32D	608	81.54	60.00	100.00	80.51
D32E	609	57.91	61.90	100.00	73.27

D32F	610	54.53	60.00		0.00
D32G	611	66.01	80.28	100.00	82.10
D32H	612	86.26	80.00		0.00
D32J	613	56.07	100.00	100.00	85.36
D32K	614	77.82	86.95	96.67	87.15
D33A	615	60.47	79.92		0.00
D33B	616	53.15	80.00		0.00
D33C	617	50.50	20.02		0.00
D33D	618	55.72	60.00		0.00
D33E	619	57.31	60.00		0.00
D33F	620	66.08	76.41	100.00	80.83
D33G	621	92.65	80.00		0.00
D33H	622	56.94	60.00		0.00
D33J	623	59.88	100.00	100.00	86.63
D33K	624	81.79	99.97	97.78	93.18
D34A	625	62.62	60.00	95.00	72.54
D34B	626	67.81	96.37		0.00
D34C	627	93.61	40.50	100.00	78.04
D34D	628	69.02	80.00	100.00	83.01
D34E	629	50.98	60.00		0.00
D34F	630	55.27	76.26	100.00	77.17
D34G	631	55.91	60.00		0.00
D35A	632	69.64	100.00	90.00	86.55
D35B	633	63.08	52.77	100.00	71.95
D35C	634	50.24	60.00		0.00
D35D	635	47.40	63.77	100.00	70.39
D35E	636	63.50	98.62	95.00	85.71
D35F	637	62.23	60.37	93.33	71.98
D35G	638	52.73	60.00		0.00
D35H	639	54.89	60.00		0.00
D35J	640	57.61	60.00		0.00
D35K	641	53.62	60.00		0.00
D41A	642	48.23	60.00	100.00	69.41
D41B	643	63.93	100.00	97.50	87.14
D41C	644	62.96	80.00	100.00	80.99
D41D	645	56.18	99.65	100.00	85.28
D41E	646	77.93	98.51	98.33	91.59
D41F	647	68.06	80.00	100.00	82.69
D41G	648	53.02	80.00		0.00
D41H	649	57.63	80.00		0.00
D41J	650	69.44	64.80		0.00
D41K	651	54.01	80.00	100.00	78.00
D41L	652	88.93	60.00		0.00
D41M	653	49.77	60.00		0.00

D42A	654	51.45	40.00		0.00
D42B	655	59.29	60.00		0.00
D42C	656	67.22	60.00		0.00
D42D	657	48.85	22.73	100.00	57.19
D42E	658	74.22	93.93	95.00	87.72
D51A	659	65.78	49.49	100.00	71.76
D51B	660	49.04	88.93		0.00
D51C	661	49.73	20.00		0.00
D52A	662	81.14	60.00		0.00
D52B	663	50.52	60.00		0.00
D52C	664	95.95	60.00	100.00	85.32
D52D	665	55.54	60.00		0.00
D52E	666	65.09	80.00	90.00	78.36
D52F	667	50.38	60.00		0.00
D53A	668	51.07	60.00		0.00
D53B	669	54.34	81.63		0.00
D53C	670	65.01	79.36	96.67	80.34
D53D	671	51.58	60.00		0.00
D53E	672	47.50	80.00		0.00
D53F	673	70.23	100.00		0.00
D53G	674	57.32	64.59	100.00	73.97
D53H	675	58.24	80.00	100.00	79.41
D53J	676	74.83	98.19	98.00	90.34
D54A	677	54.32	80.00	100.00	78.11
D54B	678	56.32	40.00		0.00
D54C	679	56.69	40.00		0.00
D54D	680	84.37	40.00	100.00	74.79
D54E	681	51.27	80.00	97.14	76.14
D54F	682	52.40	60.00		0.00
D54G	683	68.67	99.98	100.00	89.55
D55A	684	92.30	59.98		0.00
D55B	685	74.65	100.00	93.33	89.33
D55C	686	51.85	60.00		0.00
D55D	687	62.26	60.01	100.00	74.09
D55E	688	50.46	60.00		0.00
D55F	689	56.23	41.50		0.00
D55G	690	73.86	100.00	90.00	87.95
D55H	691	55.11	60.00		0.00
D55J	692	96.34	79.80		0.00
D55K	693	87.67	60.00	100.00	82.56
D55L	694	89.53	60.00	95.00	81.51
D55M	695	52.51	60.00		0.00
D56A	696	81.77	60.00		0.00
D56B	697	53.36	60.00		0.00

D56C	698	56.54	80.03	100.00	78.86
D56D	699	61.14	78.46	100.00	79.87
D56E	700	55.06	55.48	100.00	70.18
D56F	701	64.95	100.00		0.00
D56G	702	85.45	100.00	97.78	94.41
D56H	703	74.33	80.08	100.00	84.80
D56J	704	43.15	80.00		0.00
D57A	705	62.77	99.93	100.00	87.57
D57B	706	58.68	58.36	100.00	72.35
D57C	707	47.35	80.00	100.00	75.78
D57D	708	54.51	60.00		0.00
D57E	709	54.32	85.25	100.00	79.85
D58A	710	64.00	40.00		0.00
D58B	711	58.62	80.00		0.00
D58C	712	59.20	60.00	100.00	73.07
D61A	713	52.96	60.00		0.00
D61B	714	54.28	20.02		0.00
D61C	715	48.90	60.00		0.00
D61D	716	73.48	80.89		0.00
D61E	717	52.19	55.18		0.00
D61F	718	60.72	80.00		0.00
D61G	719	53.42	60.00		0.00
D61H	720	57.17	60.00		0.00
D61J	721	91.59	60.00	95.00	82.20
D61K	722	79.92	60.00	100.00	79.97
D61L	723	95.19	79.51		0.00
D61M	724	64.61	100.00	96.67	87.09
D62A	725	78.09	100.00	95.00	91.03
D62B	726	69.49	80.00	100.00	83.16
D62C	727	61.14	80.00	100.00	80.38
D62D	728	96.25	60.00		0.00
D62E	729	53.86	60.00		0.00
D62F	730	65.67	92.49	96.67	84.94
D62G	731	60.12	50.31		0.00
D62H	732	58.29	59.98		0.00
D62J	733	55.65	60.00		0.00
D71A	734	54.18	80.00		0.00
D71B	735	83.45	60.00	96.00	79.82
D71C	736	54.68	100.00	100.00	84.89
D71D	737	57.57	60.00	90.00	69.19
D72A	738	78.52	60.00	100.00	79.51
D72B	739	67.23	80.06	100.00	82.43
D72C	740	53.65	60.00	100.00	71.22
D73A	741	63.01	80.00		0.00

D73B	742	67.09	85.78		0.00
D73C	743	67.54	20.00	100.00	62.51
D73D	744	54.98	56.15		0.00
D73E	745	84.07	40.50	95.00	73.19
D73F	746	59.55	80.00		0.00
D81A	747	59.73	25.28		0.00
D81B	748	53.19	59.82		0.00
D81C	749	52.92	83.41	90.00	75.44
D81D	750	57.27	22.28	100.00	59.85
D81E	751	71.51	80.00	100.00	83.84
D81F	752	80.24	60.00		0.00
D81G	753	89.96	60.00	100.00	83.32
D82A	754	58.79	78.42	90.00	75.74
D82B	755	59.80	60.00	100.00	73.27
D82C	756	71.00	100.00	96.00	89.00
D82D	757	90.61	79.94		0.00
D82E	758	71.32	100.00	96.00	89.11
D82F	759	72.61	80.00	100.00	84.20
D82G	760	61.00	60.00	100.00	73.67
D82H	761	54.15	60.00		0.00
D82J	762	76.12	100.00		0.00
D82K	763	56.99	80.00		0.00
D82L	764	53.46	80.00	80.00	71.15
E10A	765	52.47	62.39	100.00	71.62
E10B	766	79.67	60.20	97.50	79.12
E10C	767	59.61	60.00		0.00
E10D	768	53.50	78.38	97.50	76.46
E10E	769	79.97	78.60	96.00	84.86
E10F	770	80.00	79.94		0.00
E10G	771	57.63	55.67		0.00
E10H	772	53.30	25.05	100.00	59.45
E10J	773	58.50	100.00	97.14	85.21
E10K	774	54.67	60.00		0.00
E21A	775	59.80	78.33	100.00	79.38
E21B	776	56.22	40.11		0.00
E21C	777	49.87	60.00		0.00
E21D	778	66.19	25.52		0.00
E21E	779	58.18	80.32	95.00	77.83
E21F	780	56.37	60.00	95.00	70.46
E21G	781	80.00	80.00		0.00
E21H	782	55.44	79.66		0.00
E21J	783	56.20	60.00		0.00
E21K	784	57.21	58.88		0.00
E21L	785	69.84	67.37	97.50	78.24

E22A	786	55.20	47.07	100.00	67.42
E22B	787	86.51	79.28	96.00	87.26
E22C	788	83.56	98.52	100.00	94.03
E22D	789	74.63	80.00		0.00
E22E	790	85.84	100.00	93.33	93.06
E22F	791	58.83	60.00	95.00	71.28
E22G	792	83.19	56.15	100.00	79.78
E23A	793	56.95	78.96		0.00
E23B	794	65.09	19.69		0.00
E23C	795	59.51	79.49	100.00	79.67
E23D	796	46.59	21.37	100.00	55.99
E23E	797	68.08	78.26	100.00	82.11
E23F	798	51.28	40.00	100.00	63.76
E23G	799	86.72	98.30	100.00	95.01
E23H	800	38.51	40.00		0.00
E23J	801	40.34	43.14		0.00
E23K	802	95.14	80.00	100.00	91.71
E24A	803	59.86	76.64	90.00	75.50
E24B	804	55.05	60.00	100.00	71.68
E24C	805	59.22	99.30	100.00	86.17
E24D	806	54.92	60.87	100.00	71.93
E24E	807	78.18	20.00	100.00	66.06
E24F	808	53.90	60.00	100.00	71.30
E24G	809	67.42	77.51	95.00	79.98
E24H	810	69.60	80.00		0.00
E24J	811	48.66	80.00	100.00	76.22
E24K	812	58.12	21.61	100.00	59.91
E24L	813	44.27	60.00		0.00
E24M	814	55.50	70.27	97.14	74.30
E31A	815	82.62	81.24	95.00	86.29
E31B	816	79.80	79.86		0.00
E31C	817	79.24	80.00		0.00
E31D	818	80.50	80.00	100.00	86.83
E31E	819	79.92	80.00		0.00
E31F	820	69.30	60.79	100.00	76.70
E31G	821	55.15	60.69		0.00
E31H	822	73.27			0.00
E32A	823	62.05	80.00		0.00
E32B	824	71.68	60.00		0.00
E32C	825	63.13			0.00
E32D	826	52.67	60.48	100.00	71.05
E32E	827	65.47	60.45	96.00	73.97
E33A	828	52.36			0.00
E33B	829	62.30			0.00

E33C	830	42.65	61.55	100.00	68.07
E33D	831	34.07	56.10		0.00
E33E	832	82.72	80.00	96.00	86.24
E33F	833	49.30	97.60	96.67	81.19
E33G	834	56.54	60.00	100.00	72.18
E33H	835	56.70	80.00	97.14	77.95
E40A	836	78.26	78.89		0.00
E40B	837	37.72	39.45	100.00	59.06
E40C	838	68.35			0.00
E40D	839	76.51	99.61	96.00	90.71
F10A	840	61.63	44.57	93.33	66.51
F10B	841	93.18	59.79	100.00	84.32
F10C	842	80.08	80.00		0.00
F20A	843	54.59	79.71		0.00
F20B	844	75.22	80.00		0.00
F20C	845	63.38	0.10		0.00
F20D	846	46.59	1.64		0.00
F20E	847	68.55			0.00
F30A	848	80.98	80.00		0.00
F30B	849	79.93	80.00		0.00
F30C	850	80.86	80.00		0.00
F30D	851	55.93	60.00		0.00
F30E	852	62.30	100.00	100.00	87.43
F30F	853	80.65	60.00		0.00
F30G	854	41.92	63.82	96.00	67.25
F40A	855	63.09	62.28	100.00	75.12
F40B	856	52.20		100.00	0.00
F40C	857	60.49	60.00		0.00
F40D	858	92.31	60.00		0.00
F40E	859	59.37	60.40	100.00	73.26
F40F	860	57.08	60.00		0.00
F40G	861	80.60	80.00		0.00
F40H	862	90.19	82.53		0.00
F50A	863	55.83	63.11	100.00	72.98
F50B	864	60.10	100.00		0.00
F50C	865	81.72	80.00		0.00
F50D	866	82.72	94.03	95.00	90.58
F50E	867	85.26	79.29	100.00	88.18
F50F	868	67.91	80.00	100.00	82.64
F50G	869	59.92	80.00		0.00
F60A	870	28.98	58.96		0.00
F60B	871	57.51			0.00
F60C	872	61.57	80.00	100.00	80.52
F60D	873	81.98	80.00		0.00

F60E	874	44.85	14.18	40.00	33.01
G10A	875	73.86	80.00		0.00
G10B	876	76.25	80.00		0.00
G10C	877	58.64	80.00	100.00	79.55
G10D	878	69.51	60.00	100.00	76.50
G10E	879	52.70	54.35	100.00	69.02
G10F	880	57.40			0.00
G10G	881	60.46	56.52		0.00
G10H	882	62.05	60.05		0.00
G10J	883	55.08	60.00	97.14	70.74
G10K	884	92.19	60.00		0.00
G10L	885	61.30		100.00	0.00
G10M	886	85.00	42.51	100.00	75.84
G21A	887	90.61	80.00	100.00	90.20
G21B	888	79.83	79.33	90.00	83.05
G21C	889	57.46			0.00
G21D	890	49.13		100.00	0.00
G21E	891	61.65	60.00	95.00	72.22
G21F	892	42.31	40.00		0.00
G22A	893	79.98	80.00		0.00
G22B	894	58.24	40.71	100.00	66.32
G22C	895	80.28	80.00		0.00
G22D	896	87.09	80.00		0.00
G22E	897	62.03		40.00	0.00
G22F	898	60.18	96.74		0.00
G22G	899	81.36	80.00		0.00
G22H	900	61.54	80.00	100.00	80.51
G22J	901	81.56	40.00		0.00
G22K	902	79.58	60.00		0.00
G30A	903	44.96	37.61		0.00
G30B	904	57.39			0.00
G30C	905	79.89	80.00	95.00	84.96
G30D	906	59.31	80.00	100.00	79.77
G30E	907	57.43	74.36	100.00	77.26
G30F	908	47.06		40.00	0.00
G30G	909	60.34	60.00	96.67	72.34
G30H	910	85.85	74.17	95.00	85.01
G40A	911	58.70	80.00		0.00
G40B	912	63.59	61.29	100.00	74.96
G40C	913	66.16		100.00	0.00
G40D	914	51.82		100.00	0.00
G40E	915	38.24			0.00
G40F	916	64.35	60.00	96.00	73.45
G40G	917	67.33	60.00	96.67	74.67

G40H	918	70.71	78.72	100.00	83.14
G40J	919	79.74	78.79		0.00
G40K	920	57.00	73.40		0.00
G40L	921	60.80	58.08	100.00	72.96
G40M	922	56.44		40.00	0.00
G50A	923	87.90	40.00		0.00
G50B	924	68.82	60.00	100.00	76.27
G50C	925	56.03	40.00		0.00
G50D	926	74.95	80.00		0.00
G50E	927	61.55			0.00
G50F	928	66.17	60.00	100.00	75.39
G50G	929	81.22	80.00		0.00
G50H	930	77.54	40.00		0.00
G50J	931	44.11	40.00		0.00
G50K	932	63.07			0.00
H10A	933	70.64	60.00	95.00	75.21
H10B	934	62.12	80.00	100.00	80.71
H10C	935	63.29			0.00
H10D	936	71.76	80.00		0.00
H10E	937	60.51	80.00	100.00	80.17
H10F	938	70.38	80.00		0.00
H10G	939	58.84	60.00	100.00	72.95
H10H	940	71.21	60.00	95.00	75.40
H10J	941	59.93	60.00	93.33	71.09
H10K	942	61.31	60.00		0.00
H10L	943	77.67	40.00		0.00
H20A	944	62.28	60.00		0.00
H20B	945	79.52	60.01		0.00
H20C	946	56.76			0.00
H20D	947	84.75	60.00		0.00
H20E	948	41.54	7.14		0.00
H20F	949	76.51	79.64		0.00
H20G	950	53.79			0.00
H20H	951	57.63	80.00		0.00
H30A	952	56.54			0.00
H30B	953	65.23	64.43	93.33	74.33
H30C	954	81.87	63.77	100.00	81.88
H30D	955	46.74	40.20		0.00
H30E	956	65.20	79.93	100.00	81.71
H40A	957	58.46	80.00	95.00	77.82
H40B	958	57.25	60.00		0.00
H40C	959	80.46	80.00		0.00
H40D	960	55.58			0.00
H40E	961	69.38			0.00

H40F	962	36.72	40.00		0.00
H40G	963	88.24	80.00		0.00
H40H	964	79.96	80.00		0.00
H40J	965	83.89	80.00		0.00
H40K	966	53.22			0.00
H40L	967	58.96	60.00	100.00	72.99
H50A	968	71.61	40.23	95.00	68.95
H50B	969	77.56	40.00		0.00
H60A	970	61.00	60.00		0.00
H60B	971	53.89			0.00
H60C	972	80.32	49.82	93.33	74.49
H60D	973	66.42	60.00		0.00
H60E	974	60.29	80.00	100.00	80.10
H60F	975	59.20	80.00	40.00	59.73
H60G	976	65.97	80.00	100.00	81.99
H60H	977	63.51			0.00
H60J	978	58.20	80.00	100.00	79.40
H60K	979	57.20	44.92	95.00	65.71
H60L	980	53.02	59.33	100.00	70.78
H70A	981	59.04			0.00
H70B	982	77.59	40.00		0.00
H70C	983	76.68	80.00		0.00
H70D	984	79.78	60.19		0.00
H70E	985	59.94	61.94	100.00	73.96
H70F	986	83.80	80.00		0.00
H70G	987	56.60			0.00
H70H	988	63.05	40.00	97.50	66.85
H70J	989	58.22	73.50	100.00	77.24
H70K	990	78.91	60.12		0.00
H80A	991	79.08	40.00		0.00
H80B	992	35.75	60.00	100.00	65.25
H80C	993	59.98	80.00	100.00	79.99
H80D	994	56.84	54.65		0.00
H80E	995	60.16	99.35	100.00	86.51
H80F	996	58.18			0.00
H90A	997	59.90	59.87	90.00	69.92
H90B	998	76.82	60.00		0.00
H90C	999	80.36	80.00		0.00
H90D	1000	59.32	60.00		0.00
H90E	1001	43.25	42.28		0.00
J11A	1002	75.63	60.00		0.00
J11B	1003	71.78	60.00	100.00	77.26
J11C	1004	58.02	0.03	100.00	52.69
J11D	1005	67.81	59.43	95.00	74.08

J11E	1006	62.81	60.00	100.00	74.27
J11F	1007	50.99		40.00	0.00
J11G	1008	62.95	40.00	96.00	66.32
J11H	1009	64.84	80.00	100.00	81.61
J11J	1010	58.77			0.00
J11K	1011	59.23	76.84	100.00	78.69
J12A	1012	63.29	63.26		0.00
J12B	1013	54.65	60.00	100.00	71.55
J12C	1014	52.53			0.00
J12D	1015	35.63			0.00
J12E	1016	55.15			0.00
J12 F	1017	80.48			0.00
J12G	1018	83.06	80.00		0.00
J12H	1019	80.26	80.00		0.00
J12J	1020	53.63			0.00
J12K	1021	76.39	21.36		0.00
J12L	1022	57.86	40.00		0.00
J12M	1023	79.87	60.00		0.00
J13A	1024	60.32	40.00	95.00	65.11
J13B	1025	80.43	80.00		0.00
J13C	1026	68.81	60.00		0.00
J21A	1027	59.04	80.00	100.00	79.68
J21B	1028	77.43	40.00	100.00	72.48
J21C	1029	81.17	40.00	100.00	73.72
J21D	1030	79.47	60.00		0.00
J21E	1031	69.38	80.00		0.00
J22B	1032	61.71	80.00	95.00	78.90
J22C	1033	53.29	60.00	100.00	71.10
J22D	1034	57.97	60.00		0.00
J22E	1035	79.77	80.00		0.00
J22F	1036	70.07	80.00	96.00	82.02
J22G	1037	57.23	45.43	100.00	67.55
J22H	1038	40.91			0.00
J22J	1039	58.88	98.40	100.00	85.76
J22K	1040	81.27	60.00		0.00
J23A	1041	78.57	59.53		0.00
J23B	1042	58.90	40.00		0.00
J23C	1043	55.46	56.56	100.00	70.67
J23D	1044	43.51	52.99		0.00
J23E	1045	43.57			0.00
J23F	1046	55.79	60.00	100.00	71.93
J23G	1047	79.16	25.36	96.67	67.06
J23H	1048	57.64	80.00	100.00	79.21
J23J	1049	59.21	80.00		0.00

J24A	1050	80.20	80.00		0.00
J24B	1051	68.63	80.00	80.00	76.21
J24C	1052	79.88	60.00		0.00
J24D	1053	54.59			0.00
J24E	1054	60.09	80.00	95.00	78.36
J24F	1055	52.56	80.00	100.00	77.52
J25A	1056	56.41	60.00	100.00	72.14
J25B	1057	74.03	79.72	100.00	84.58
J25C	1058	48.19	60.00	100.00	69.40
J25D	1059	67.13	80.00		0.00
J25E	1060	83.70	60.00	96.67	80.12
J31A	1061	55.55	80.27		0.00
J31B	1062	57.69	60.00	100.00	72.56
J31C	1063	56.54	40.00		0.00
J31D	1064	53.11	80.00	100.00	77.70
J32A	1065	55.93			0.00
J32B	1066	59.22	40.00		0.00
J32C	1067	55.14	60.00		0.00
J32D	1068	54.56	0.51	100.00	51.69
J32E	1069	59.17	100.00	100.00	86.39
J33A	1070	79.72	80.00		0.00
J33B	1071	70.74	80.00		0.00
J33C	1072	79.33	54.80	100.00	78.04
J33D	1073	52.99	60.00		0.00
J33E	1074	51.40			0.00
J33F	1075	56.24	60.00		0.00
J34A	1076	62.36	60.00		0.00
J34B	1077	59.22	80.00		0.00
J34C	1078	67.83	80.00	90.00	79.28
J34D	1079	55.48	80.00	100.00	78.49
J34E	1080	63.70	60.42	100.00	74.71
J34F	1081	77.91	40.00	100.00	72.64
J35A	1082	71.57	80.00		0.00
J35B	1083	79.03	80.00		0.00
J35C	1084	78.77	60.00		0.00
J35D	1085	58.78	40.65		0.00
J35E	1086	75.01	60.00		0.00
J35F	1087	63.41	41.00		0.00
J40A	1088	58.14	80.00		0.00
J40B	1089	56.61	60.00		0.00
J40C	1090	77.80	60.00		0.00
J40D	1091	77.65	60.00		0.00
J40E	1092	58.97			0.00
K10A	1093	68.99	71.84		0.00

K10B	1094	64.15	60.00	100.00	74.72
K10C	1095	61.45	40.00	93.33	64.93
K10D	1096	73.83	40.00	90.00	67.94
K10E	1097	53.64	20.00		0.00
K10F	1098	60.90	99.97		0.00
K20A	1099	44.74	60.00	100.00	68.25
K30A	1100	57.87	60.00		0.00
K30B	1101	80.04	79.72		0.00
K30C	1102	75.39	40.95	100.00	72.11
K30D	1103	77.05	41.93	100.00	72.99
K40A	1104	79.94	80.00		0.00
K40B	1105	67.24	80.00		0.00
K40C	1106	70.92	60.00		0.00
K40D	1107	79.47	60.00		0.00
K40E	1108	60.07	60.00		0.00
K50A	1109	77.12	60.00		0.00
K50B	1110	52.76	76.62	100.00	76.46
K60A	1111	54.59	80.00	100.00	78.20
K60B	1112	59.21	100.00	100.00	86.40
K60C	1113	83.99	80.00		0.00
K60D	1114	79.09	60.00		0.00
K60E	1115	78.82	60.00		0.00
K60F	1116	51.24	60.00		0.00
K60G	1117	45.92	60.00		0.00
K70A	1118	82.36	80.00		0.00
K70B	1119	57.69	80.00		0.00
K80A	1120	76.64	22.06	100.00	66.23
K80B	1121	58.02	80.00		0.00
K80C	1122	81.36	80.00		0.00
K80D	1123	79.58	60.00		0.00
K80E	1124	53.29	60.00		0.00
K80F	1125	80.03	60.00		0.00
K90A	1126	58.02	100.00		0.00
K90B	1127	57.26	56.13		0.00
K90C	1128	49.39	80.00		0.00
K90D	1129	50.49	80.00		0.00
K90E	1130	75.76	36.26	100.00	70.67
K90F	1131	58.08	99.02	100.00	85.70
K90G	1132	82.85	80.00		0.00
L11A	1133	61.64	79.07		0.00
L11B	1134	58.70	80.00		0.00
L11C	1135	74.36	80.00		0.00
L11D	1136	79.46	80.00		0.00
L11E	1137	77.64	40.00		0.00

L11F	1138	49.86	60.00		0.00
L11G	1139	62.25	60.23	95.00	72.49
L12A	1140	56.64	99.39		0.00
L12B	1141	43.33	80.00		0.00
L12C	1142	72.32	43.72		0.00
L12D	1143	70.81	44.36		0.00
L21A	1144	63.64	80.00		0.00
L21B	1145	68.32	40.00		0.00
L21C	1146	54.21	80.00	100.00	78.07
L21D	1147	79.96	60.00		0.00
L21E	1148	55.76	60.00		0.00
L21F	1149	50.51	60.00		0.00
L22A	1150	82.64	80.00		0.00
L22B	1151	80.04	60.00		0.00
L22C	1152	51.31	59.89		0.00
L22D	1153	54.26	40.00	100.00	64.75
L23A	1154	82.70	78.37	95.00	85.36
L23B	1155	76.76	60.00		0.00
L23C	1156	78.41	60.00		0.00
L23D	1157	79.81	80.00		0.00
L30A	1158	55.50	60.00		0.00
L30B	1159	83.83	80.00		0.00
L30C	1160	76.48	60.00		0.00
L30D	1161	82.74	80.00		0.00
L40A	1162	80.45	80.00		0.00
L40B	1163	51.13	80.00	93.33	74.82
L50A	1164	49.93	60.00		0.00
L50B	1165	79.98	80.00		0.00
L60A	1166	80.01	80.00		0.00
L60B	1167	57.43	80.00		0.00
L70A	1168	49.95	63.69		0.00
L70B	1169	78.72	60.00		0.00
L70C	1170	79.80	60.00		0.00
L70D	1171	80.08	60.00		0.00
L70E	1172	80.07	60.00		0.00
L70F	1173	68.16	40.43		0.00
L70G	1174	72.18	60.00	96.00	76.06
L81A	1175	79.06	60.00		0.00
L81B	1176	61.83	60.00	100.00	73.94
L81C	1177	60.16	60.00	100.00	73.39
L81D	1178	64.91	40.00	96.67	67.19
L82A	1179	51.70	60.66		0.00
L82B	1180	58.81	60.27		0.00
L82C	1181	40.91	79.08		0.00

L82D	1182	61.15	60.00	100.00	73.72
L82E	1183	57.25	80.00		0.00
L82F	1184	80.04	80.00		0.00
L82G	1185	54.41	60.00		0.00
L82H	1186	60.16	60.00		0.00
L82J	1187	46.52	60.00		0.00
L90A	1188	58.48	64.55	97.14	73.39
L90B	1189	57.94	60.00		0.00
L90C	1190	73.70	49.96	93.33	72.33
M10A	1191	51.48	60.00		0.00
M10B	1192	79.31	60.00		0.00
M10C	1193	54.47	80.00	96.00	76.82
M10D	1194	74.02	60.00	100.00	78.01
M20A	1195	80.05	80.00	100.00	86.68
M20B	1196	78.77	60.00		0.00
M30A	1197	70.55	59.74		0.00
M30B	1198	76.73	60.00		0.00
N11A	1199	54.88	60.00		0.00
N11B	1200	57.29	60.00		0.00
N12A	1201	56.44	60.00	96.67	71.04
N12B	1202	66.10	60.00		0.00
N12C	1203	57.88	60.00		0.00
N13A	1204	51.13	60.00		0.00
N13B	1205	61.42	60.00	100.00	73.81
N13C	1206	79.95	60.00		0.00
N14A	1207	77.11	60.00		0.00
N14B	1208	60.12	60.00	100.00	73.37
N14C	1209	50.38	80.00		0.00
N14D	1210	80.45	80.00		0.00
N21A	1211	73.85	60.00		0.00
N21B	1212	50.47	80.00		0.00
N21C	1213	60.50	40.00		0.00
N21D	1214	59.01	60.00	100.00	73.00
N22A	1215	80.42	80.00		0.00
N22B	1216	79.24	60.00		0.00
N22C	1217	64.46	60.00		0.00
N22D	1218	57.39	60.00	100.00	72.46
N22E	1219	63.05	40.00		0.00
N23A	1220	60.74	60.00		0.00
N23B	1221	59.93	60.00	100.00	73.31
N24A	1222	80.14	80.00	100.00	86.71
N24B	1223	77.44	60.00	100.00	79.15
N24C	1224	58.24	60.00		0.00
N24D	1225	80.15	60.00		0.00

N30A	1226	57.45	60.00		0.00
N30B	1227	64.31	40.00		0.00
N30C	1228	79.36	60.00		0.00
N40A	1229	78.83	80.00		0.00
N40B	1230	80.17	60.01		0.00
N40C	1231	65.32	60.00		0.00
N40D	1232	62.54	60.00		0.00
N40E	1233	51.69	60.00		0.00
N40F	1234	80.21	79.90		0.00
P10A	1235	78.96	80.00		0.00
P10B	1236	65.62	80.00	95.00	80.21
P10C	1237	77.00	60.00		0.00
P10D	1238	76.20	60.00		0.00
P10E	1239	64.21	60.00	100.00	74.74
P10F	1240	67.61	60.00		0.00
P10G	1241	52.08	60.00		0.00
P20A	1242	79.20	80.00		0.00
P20B	1243	61.48	40.00		0.00
P30A	1244	62.29	80.00	100.00	80.76
P30B	1245	60.69	80.00	100.00	80.23
P30C	1246	61.53	60.00		0.00
P40A	1247	77.32	60.00	100.00	79.11
P40B	1248	65.53	60.00	100.00	75.18
P40C	1249	59.92	60.00	100.00	73.31
P40D	1250	78.85	80.00		0.00
Q11A	1251	78.47	58.97		0.00
Q11B	1252	79.70	80.00		0.00
Q11C	1253	60.76	80.00		0.00
Q11D	1254	79.18	61.23		0.00
Q12A	1255	71.85	60.00		0.00
Q12B	1256	53.26	60.00		0.00
Q12C	1257	75.45	60.00		0.00
Q13A	1258	72.85	60.00		0.00
Q13B	1259	79.46	60.00		0.00
Q13C	1260	65.89	80.00		0.00
Q14A	1261	52.44	60.00		0.00
Q14B	1262	78.83	80.00	100.00	86.28
Q14C	1263	51.99	60.00		0.00
Q14D	1264	76.09	59.03	100.00	78.37
Q14E	1265	57.96	60.00	100.00	72.65
Q21A	1266	79.95	80.00		0.00
Q21B	1267	58.50	60.00		0.00
Q22A	1268	79.26	80.00		0.00
Q22B	1269	74.90	60.00		0.00

Q30A	1270	74.31	60.00		0.00
Q30B	1271	65.63	40.00	100.00	68.54
Q30C	1272	62.81	60.00	60.00	60.94
Q30D	1273	79.20	80.00	100.00	86.40
Q30E	1274	76.86	80.00		0.00
Q41A	1275	75.66	60.00		0.00
Q41B	1276	76.83	60.00	100.00	78.94
Q41C	1277	73.81	40.00		0.00
Q41D	1278	79.81	80.00		0.00
Q42A	1279	79.41	80.00		0.00
Q42B	1280	76.26	60.00		0.00
Q43A	1281	63.70	61.47		0.00
Q43B	1282	80.42	60.00		0.00
Q44A	1283	66.10	60.00	60.00	62.03
Q44B	1284	78.10	80.00		0.00
Q44C	1285	79.11	80.00	100.00	86.37
Q50A	1286	74.31	58.76	100.00	77.69
Q50B	1287	61.22	60.00	80.00	67.07
Q50C	1288	78.18	80.00		0.00
Q60A	1289	71.04	80.00		0.00
Q60B	1290	69.91	80.00		0.00
Q60C	1291	75.20	40.00		0.00
Q70A	1292	77.27	40.00	100.00	72.42
Q70B	1293	78.02	80.00	100.00	86.01
Q70C	1294	56.91	60.00		0.00
Q80A	1295	78.73	80.00	60.00	72.91
Q80B	1296	73.59	40.00		0.00
Q80C	1297	78.96	80.00		0.00
Q80D	1298	56.63	60.00		0.00
Q80E	1299	56.18	60.00		0.00
Q80F	1300	58.43	57.72		0.00
Q80G	1301	82.07	80.00	100.00	87.36
Q91A	1302	60.82	60.00		0.00
Q91B	1303	57.84	60.00		0.00
Q91C	1304	74.66	60.00		0.00
Q92A	1305	80.19	61.03		0.00
Q92B	1306	80.00	80.00		0.00
Q92C	1307	61.07	80.00	93.33	78.13
Q92D	1308	57.34	60.00		0.00
Q92E	1309	62.69	40.00		0.00
Q92F	1310	54.91	60.00		0.00
Q92G	1311	77.28	60.00		0.00
Q93A	1312	89.07	80.00	90.00	86.36
Q93B	1313	57.80	57.03		0.00

Q93C	1314	80.45	60.00		0.00
Q93D	1315	53.55	40.00	100.00	64.52
Q94A	1316	54.77	60.00		0.00
Q94B	1317	78.31	79.10		0.00
Q94C	1318	75.15	60.00		0.00
Q94D	1319	50.55	60.00		0.00
Q94E	1320	51.89	60.00		0.00
Q94F	1321	55.01	58.21		0.00
R10A	1322	79.78	60.00		0.00
R10B	1323	60.17	55.14		0.00
R10C	1324	56.44	80.00	100.00	78.81
R10D	1325	80.09	80.00		0.00
R10E	1326	60.41	57.50		0.00
R10F	1327	71.76	40.00	100.00	70.59
R10G	1328	55.33	60.00		0.00
R10H	1329	83.05	80.00	93.33	85.46
R10J	1330	77.54	80.00	46.67	68.07
R10K	1331	80.94	60.14		0.00
R10L	1332	77.34	60.03		0.00
R10M	1333	70.07	60.00		0.00
R20A	1334	80.06	80.00	100.00	86.69
R20B	1335	79.97	80.00		0.00
R20C	1336	54.94	40.00	100.00	64.98
R20D	1337	60.84	40.00	100.00	66.95
R20E	1338	50.18	40.99	80.00	57.06
R20F	1339	79.62	60.02	100.00	79.88
R20G	1340	79.86	60.00		0.00
R30A	1341	76.33	40.00	100.00	72.11
R30B	1342	50.15	40.00		0.00
R30C	1343	79.49	60.00		0.00
R30D	1344	80.67	60.00		0.00
R30E	1345	70.88	41.48	50.00	54.12
R30F	1346	76.36	80.00		0.00
R40A	1347	68.36	40.00		0.00
R40B	1348	55.56	59.80		0.00
R40C	1349	57.48	40.00		0.00
R50A	1350	79.72	80.00	100.00	86.57
R50B	1351	52.83	40.00		0.00
S10A	1352	90.01	80.00	95.00	88.34
S10B	1353	60.40	40.00		0.00
S10C	1354	57.30	58.85		0.00
S10D	1355	80.19	60.00		0.00
S10E	1356	59.66	40.00		0.00
S10F	1357	75.72	80.00		0.00

S10G	1358	79.61	80.00	100.00	86.54
S10H	1359	51.66	40.00		0.00
S10J	1360	79.89	80.00	100.00	86.63
S20A	1361	76.08	80.00	100.00	85.36
S20B	1362	79.74	80.00		0.00
S20C	1363	63.32	20.00		0.00
S20D	1364	53.96	49.27		0.00
S31A	1365	49.75	40.00	80.00	56.58
S31B	1366	57.32	40.00	100.00	65.77
S31C	1367	72.36	60.00		0.00
S31D	1368	75.63	59.72	100.00	78.45
S31E	1369	50.24	40.00		0.00
S31F	1370	78.59	60.00		0.00
S31G	1371	50.51	40.00		0.00
S32A	1372	74.18	42.63	100.00	72.27
S32B	1373	76.12	40.00		0.00
S32C	1374	81.18	60.00	100.00	80.39
S32D	1375	75.33	40.00		0.00
S32E	1376	79.97	80.00	100.00	86.66
S32F	1377	56.20	60.00	100.00	72.07
S32G	1378	75.07	40.00	100.00	71.69
S32H	1379	78.68	40.00		0.00
S32J	1380	80.88	60.00	100.00	80.29
S32K	1381	80.15	80.00		0.00
S32L	1382	76.11	40.00	100.00	72.04
S32M	1383	56.16	40.00	100.00	65.39
S40A	1384	70.02	60.00	40.00	56.67
S40B	1385	46.12	40.00		0.00
S40C	1386	79.99	80.00	100.00	86.66
S40D	1387	80.71	60.00		0.00
S40E	1388	50.20	40.00		0.00
S40F	1389	44.07	40.00		0.00
S50A	1390	79.68	60.00	100.00	79.89
S50B	1391	79.73	80.00	100.00	86.58
S50C	1392	80.12	60.00	100.00	80.04
S50D	1393	59.29	40.00	100.00	66.43
S50E	1394	75.93	40.00		0.00
S50F	1395	83.87	40.33	93.33	72.51
S50G	1396	75.93	60.00	52.00	62.64
S50H	1397	61.02	40.00		0.00
S50J	1398	79.61	60.00	70.00	69.87
S60A	1399	79.97	80.00	100.00	86.66
S60B	1400	78.68	59.95	100.00	79.54
S60C	1401	57.21	40.00		0.00

S60D	1402	79.81	80.00		0.00
S60E	1403	45.74	40.00		0.00
S70A	1404	71.19	40.00		0.00
S70B	1405	56.89	40.00	100.00	65.63
S70C	1406	77.40	40.00		0.00
S70D	1407	73.85	40.00		0.00
S70E	1408	54.87	40.00		0.00
S70F	1409	76.55	40.00		0.00
T11A	1410	75.74	58.78		0.00
T11B	1411	59.14	40.00	100.00	66.38
T11C	1412	72.80	60.01		0.00
T11D	1413	69.74	43.70	46.67	53.37
T11E	1414	80.05	80.00		0.00
T11F	1415	67.26	80.00		0.00
T11G	1416	60.24	40.00		0.00
T11H	1417	75.21	80.00	100.00	85.07
T12A	1418	76.75	40.00		0.00
T12B	1419	72.34	60.00		0.00
T12C	1420	71.04	80.00	95.00	82.01
T12D	1421	50.76	44.81		0.00
T12E	1422	46.35	40.00		0.00
T12F	1423	52.97	40.00	100.00	64.32
T12G	1424	76.83	40.00	100.00	72.28
T13A	1425	74.03	60.00		0.00
T13B	1426	57.85	40.00		0.00
T13C	1427	61.60	60.00		0.00
T13D	1428	79.23	60.00		0.00
T13E	1429	49.16	40.00	100.00	63.05
T20A	1430	79.88	60.00		0.00
T20B	1431	79.67	60.00	40.00	59.89
T20C	1432	57.86	40.00	100.00	65.95
T20D	1433	80.51	41.59	100.00	74.03
T20E	1434	76.23	40.00		0.00
T20F	1435	77.99	80.00		0.00
T20G	1436	76.27	40.00	100.00	72.09
T31A	1437	69.37	40.00	60.00	56.46
T31B	1438	59.99	40.00		0.00
T31C	1439	79.59	80.00	100.00	86.53
T31D	1440	55.64	40.00		0.00
T31E	1441	52.40	40.00		0.00
T31F	1442	89.81	60.00		0.00
T31G	1443	75.89	40.00	100.00	71.96
T31H	1444	53.76	59.37		0.00
T31J	1445	58.67	80.00		0.00

T32A	1446	77.51	60.00	100.00	79.17
T32B	1447	57.60	60.00		0.00
T32C	1448	77.34	60.00		0.00
T32D	1449	62.71	40.00	100.00	67.57
T32E	1450	80.49	60.00		0.00
T32F	1451	64.48	40.00		0.00
T32G	1452	80.39	58.08		0.00
T32H	1453	75.43	40.00		0.00
T33A	1454	74.66	40.00	100.00	71.55
T33B	1455	76.53	40.00		0.00
T33C	1456	80.13	60.00		0.00
T33D	1457	74.74	40.00		0.00
T33E	1458	88.88	80.00	100.00	89.63
T33F	1459	71.62	40.00		0.00
T33G	1460	76.60	60.00		0.00
T33H	1461	72.17	80.00		0.00
T33J	1462	76.78	23.25		0.00
T33K	1463	74.42	59.59		0.00
T34A	1464	56.98	40.00		0.00
T34B	1465	79.58	60.00		0.00
T34C	1466	62.18	60.00	40.00	54.06
T34D	1467	80.01	80.00		0.00
T34E	1468	52.57	40.00	100.00	64.19
T34F	1469	78.24	60.00	100.00	79.41
T34G	1470	63.65	40.00	100.00	67.88
T34H	1471	79.76	80.00	100.00	86.59
T34J	1472	79.83	78.84	40.00	66.22
T34K	1473	70.98	80.00		0.00
T35A	1474	78.79	40.00	55.00	57.93
T35B	1475	80.01	80.00		0.00
T35C	1476	51.20	40.00		0.00
T35D	1477	78.92	60.00		0.00
T35E	1478	86.27	40.00	50.00	58.76
T35F	1479	77.68	60.00	80.00	72.56
T35G	1480	69.32	80.00		0.00
T35H	1481	78.95	60.00		0.00
T35J	1482	63.18	40.78		0.00
T35K	1483	68.53	59.42		0.00
T35L	1484	79.15	80.00	100.00	86.38
T35M	1485	78.31	60.00		0.00
T36A	1486	76.33	40.00	100.00	72.11
T36B	1487	80.12	60.00		0.00
T40A	1488	80.44	80.00	53.33	71.26
T40B	1489	60.42	40.00		0.00

T40C	1490	79.49	60.00		0.00
T40D	1491	67.26	40.00	100.00	69.09
T40E	1492	58.89	40.00	100.00	66.30
T40F	1493	67.25	60.00	70.00	65.75
T40G	1494	74.13	60.00	100.00	78.04
T51A	1495	80.12	60.00		0.00
T51B	1496	75.59	40.00		0.00
T51C	1497	79.85	60.00		0.00
T51D	1498	82.40	60.00		0.00
T51E	1499	75.22	60.00		0.00
T51F	1500	75.94	60.00		0.00
T51G	1501	61.02	40.00	100.00	67.01
T51H	1502	80.18	60.00		0.00
T51J	1503	78.83	42.04	100.00	73.62
T52A	1504	80.53	60.00	100.00	80.18
T52B	1505	80.00	60.00		0.00
T52C	1506	75.34	60.00		0.00
T52D	1507	80.15	60.02		0.00
T52E	1508	60.30	60.00		0.00
T52F	1509	78.20	60.00	100.00	79.40
T52G	1510	63.05	40.00	100.00	67.68
T52H	1511	80.05	80.00	100.00	86.68
T52J	1512	76.70	60.00	100.00	78.90
T52K	1513	61.76	80.00		0.00
T52L	1514	80.03	60.00		0.00
T52M	1515	80.04	80.00	100.00	86.68
T60A	1516	86.39	60.00		0.00
T60B	1517	74.23	44.00	100.00	72.75
T60C	1518	77.99	60.00		0.00
T60D	1519	77.69	60.00	100.00	79.23
T60E	1520	80.13	60.00	100.00	80.04
T60F	1521	77.53	40.00	66.67	61.40
T60G	1522	71.49	40.00	100.00	70.50
T60H	1523	69.89	60.00	40.00	56.63
T60J	1524	78.97	60.00	80.00	72.99
T60K	1525	81.41	79.53	60.00	73.65
T70A	1526	79.76	60.00		0.00
T70B	1527	63.43	60.00	100.00	74.48
T70C	1528	63.01	60.00	100.00	74.34
T70D	1529	79.34	60.00		0.00
T70E	1530	90.86	40.00	100.00	76.95
T70F	1531	63.56	80.00		0.00
T70G	1532	79.59	60.00	100.00	79.86
T80A	1533	80.15	77.30		0.00

T80B	1534	79.21	60.00	100.00	79.74
T80C	1535	80.31	41.15		0.00
T80D	1536	80.01	60.00		0.00
T90A	1537	79.10	40.00	100.00	73.03
T90B	1538	96.30	40.00	80.00	72.10
T90C	1539	87.02	40.00	100.00	75.67
T90D	1540	83.89	60.00	100.00	81.30
T90E	1541	80.08	60.00		0.00
T90F	1542	62.13	60.00	40.00	54.04
T90G	1543	77.82	40.00	52.00	56.61
U10A	1544	80.02	60.00		0.00
U10B	1545	80.04	60.00		0.00
U10C	1546	85.79	59.38	95.00	80.06
U10D	1547	52.80	60.00	40.00	50.93
U10E	1548	78.93	60.00		0.00
U10F	1549	73.55	60.00	80.00	71.18
U10G	1550	79.65	60.00		0.00
U10H	1551	87.80	60.00	100.00	82.60
U10J	1552	64.89	60.00	100.00	74.96
U10K	1553	82.36	59.94		0.00
U10L	1554	80.44	80.00	56.67	72.37
U10M	1555	96.31	40.00	100.00	78.77
U20A	1556	80.00	60.00		0.00
U20B	1557	80.21	60.00		0.00
U20C	1558	80.03	59.51		0.00
U20D	1559	94.54	60.00	40.00	64.85
U20E	1560	85.58	40.00		0.00
U20F	1561	86.30	60.00	80.00	75.43
U20G	1562	79.98	60.00		0.00
U20H	1563	95.14	60.00		0.00
U20J	1564	79.33	80.00	35.00	64.78
U20K	1565	97.48	40.00	85.00	74.16
U20L	1566	84.73	40.00	86.67	70.47
U20M	1567	85.21	40.00		0.00
U30A	1568	90.87	40.67	100.00	77.18
U30B	1569	80.05	60.00		0.00
U30C	1570	79.87	60.00		0.00
U30D	1571	80.04	80.00		0.00
U30E	1572	91.23	60.00		0.00
U40A	1573	79.70	60.00	100.00	79.90
U40B	1574	91.52	60.00	40.00	63.84
U40C	1575	80.00	60.00		0.00
U40D	1576	82.50	40.00		0.00
U40E	1577	78.36	40.00	100.00	72.79

U40F	1578	93.60	60.00	70.00	74.53
U40G	1579	80.01	60.00		0.00
U40H	1580	80.11	40.35	100.00	73.49
U40J	1581	83.10	60.00	100.00	81.03
U50A	1582	83.04	60.00		0.00
U60A	1583	80.03	60.00		0.00
U60B	1584	54.78	60.00	40.00	51.59
U60C	1585	64.87	40.87	100.00	68.58
U60D	1586	80.01	60.00		0.00
U60E	1587	63.37	40.00	65.00	56.12
U60F	1588	84.45	59.07	60.00	67.84
U70A	1589	62.00	58.82		0.00
U70B	1590	79.50	60.00	40.00	59.83
U70C	1591	80.59	60.00		0.00
U70D	1592	81.38	40.37	52.00	57.92
U70E	1593	76.81	40.00	100.00	72.27
U70F	1594	94.25	40.00	100.00	78.08
U80A	1595	93.32	60.00		0.00
U80B	1596	98.91	60.00	40.00	66.30
U80C	1597	89.86	59.50	60.00	69.79
U80D	1598	90.49	59.59	80.00	76.69
U80E	1599	79.71	60.00		0.00
U80F	1600	80.09	60.00		0.00
U80G	1601	81.25	40.00		0.00
U80H	1602	79.84	60.00		0.00
U80J	1603	82.38	40.00		0.00
U80K	1604	81.61	40.00	100.00	73.87
U80L	1605	69.04	40.00	70.00	59.68
V11A	1606	88.98	40.00		0.00
V11B	1607	79.48	60.00	100.00	79.83
V11C	1608	66.18	80.00		0.00
V11D	1609	81.00	76.04		0.00
V11E	1610	79.86	60.00		0.00
V11F	1611	80.03	60.00		0.00
V11G	1612	79.21	60.00		0.00
V11H	1613	58.92	59.29	100.00	72.74
V11J	1614	80.14	60.00		0.00
V11K	1615	80.42	60.00		0.00
V11L	1616	46.49	20.28		0.00
V11M	1617	77.79	80.00		0.00
V12A	1618	74.12	40.00		0.00
V12B	1619	46.99	40.00	70.00	52.33
V12C	1620	81.80	40.00	95.00	72.27
V12D	1621	80.16	60.00	100.00	80.05

V12E	1622	82.36	40.00	100.00	74.12
V12F	1623	81.84	99.96	53.33	78.37
V12G	1624	80.30	40.00	100.00	73.43
V13A	1625	84.71	40.08	90.00	71.60
V13B	1626	80.04	60.00	70.00	70.01
V13C	1627	90.46	40.00	100.00	76.82
V13D	1628	72.46	40.00	84.00	65.49
V13E	1629	80.01	60.00	40.00	60.00
V14A	1630	79.55	60.00		0.00
V14B	1631	83.39	57.61		0.00
V14C	1632	73.42	31.30		0.00
V14D	1633	81.60	40.00		0.00
V14E	1634	80.07	60.00	40.00	60.02
V20A	1635	74.40	61.38	50.00	61.92
V20B	1636	80.05	60.00		0.00
V20C	1637	80.06	60.00		0.00
V20D	1638	79.76	60.00		0.00
V20E	1639	75.79	40.00	93.33	69.71
V20F	1640	79.63	60.00	100.00	79.88
V20G	1641	50.65	40.00		0.00
V20H	1642	81.32	48.14	100.00	76.49
V20J	1643	87.45	40.00		0.00
V31A	1644	69.32	60.00	93.33	74.22
V31B	1645	80.21	60.00		0.00
V31C	1646	80.20	80.00		0.00
V31D	1647	97.47	40.00	93.33	76.94
V31E	1648	83.62	40.00	70.00	64.54
V31F	1649	47.69	42.66		0.00
V31G	1650	79.98	20.00		0.00
V31H	1651	81.93	20.00	100.00	67.31
V31J	1652	80.04	60.00		0.00
V31K	1653	79.90	60.00	100.00	79.97
V32A	1654	76.12	60.00	80.00	72.04
V32B	1655	80.01	60.00		0.00
V32C	1656	78.77	60.00	100.00	79.59
V32D	1657	79.13	60.00	100.00	79.71
V32E	1658	80.08	59.97		0.00
V32F	1659	80.77	40.00	100.00	73.59
V32G	1660	80.39	60.00	80.00	73.46
V32H	1661	77.87	60.00	100.00	79.29
V33A	1662	89.45	40.00	100.00	76.48
V33B	1663	81.95	40.03	100.00	73.99
V33C	1664	83.33	21.37	100.00	68.23
V33D	1665	79.71	60.00		0.00

V40A	1666	87.36	40.00	96.00	74.45
V40B	1667	78.82	60.00		0.00
V40C	1668	79.81	60.00		0.00
V40D	1669	70.05	60.00	100.00	76.68
V40E	1670	75.53	20.17		0.00
V50A	1671	80.04	60.00		0.00
V50B	1672	73.88	20.00		0.00
V50C	1673	78.61	60.00		0.00
V50D	1674	77.72	60.00		0.00
V60A	1675	79.30	60.00	40.00	59.77
V60B	1676	86.34	59.33	100.00	81.89
V60C	1677	93.62	40.00	100.00	77.87
V60D	1678	79.76	60.00	90.00	76.59
V60E	1679	81.91	60.00		0.00
V60F	1680	77.36	60.00		0.00
V60G	1681	69.39	40.00		0.00
V60H	1682	92.37	59.99	100.00	84.12
V60J	1683	69.96	40.00	95.00	68.32
V60K	1684	78.31	60.00		0.00
V70A	1685	80.38	60.00	40.00	60.13
V70B	1686	80.03	60.00		0.00
V70C	1687	79.20	60.00	80.00	73.07
V70D	1688	57.00	40.00	40.00	45.67
V70E	1689	77.34	60.00	80.00	72.45
V70F	1690	68.25	40.97	20.00	43.07
V70G	1691	75.73	60.00		0.00
W11A	1692	91.27	40.00	40.00	57.09
W11B	1693	79.39	59.99	100.00	79.79
W11C	1694	88.79	60.00	100.00	82.93
W12A	1695	78.40	40.00	60.00	59.47
W12B	1696	81.40	60.00	70.00	70.47
W12C	1697	73.27	60.00		0.00
W12D	1698	72.52	60.00		0.00
W12E	1699	77.61	60.00		0.00
W12F	1700	79.34	60.00		0.00
W12G	1701	74.72	40.00		0.00
W12H	1702	87.09	40.00	88.00	71.70
W12J	1703	86.68	40.00	88.00	71.56
W13A	1704	85.24	40.00	100.00	75.08
W13B	1705	79.92	60.00	80.00	73.31
W21A	1706	80.03	60.00	60.00	66.68
W21B	1707	78.66	60.00		0.00
W21C	1708	76.70	60.00		0.00
W21D	1709	90.10	60.00	86.67	78.92

W21E	1710	84.20	60.00	70.00	71.40
W21F	1711	78.53	60.00		0.00
W21G	1712	79.97	60.00	100.00	79.99
W21H	1713	79.75	58.08		0.00
W21J	1714	73.77	40.00		0.00
W21K	1715	80.41	60.00	80.00	73.47
W21L	1716	75.42	42.25	73.33	63.67
W22A	1717	78.18	60.00		0.00
W22B	1718	97.53	60.00	100.00	85.84
W22C	1719	83.48	40.00	100.00	74.49
W22D	1720	77.10	40.14	73.33	63.53
W22E	1721	78.12	60.00	40.00	59.37
W22F	1722	78.98	60.00	80.00	72.99
W22G	1723	76.48	40.00	73.33	63.27
W22H	1724	47.10	40.00		0.00
W22J	1725	71.38	40.00	20.00	43.79
W22K	1726	72.73	40.00	80.00	64.24
W22L	1727	81.61	40.00		0.00
W23A	1728	80.23	60.00		0.00
W23B	1729	72.62	40.00	80.00	64.21
W23C	1730	84.00	60.00	88.00	77.33
W23D	1731	95.71	60.00	96.00	83.90
W31A	1732	72.14	40.00	20.00	44.05
W31B	1733	77.51	40.00		0.00
W31C	1734	83.23	57.31		0.00
W31D	1735	75.32	40.00	80.00	65.11
W31E	1736	79.82	60.00		0.00
W31F	1737	72.79	40.00		0.00
W31G	1738	56.84	40.90		0.00
W31H	1739	78.65	57.99	80.00	72.22
W31J	1740	76.73	50.71	20.00	49.15
W31K	1741	92.68	40.00	90.00	74.23
W31L	1742	79.34	40.11	90.00	69.82
W32A	1743	77.66	40.35	73.33	63.78
W32B	1744	84.54	60.00	97.14	80.56
W32C	1745	77.99	40.00	93.33	70.44
W32D	1746	80.23	60.00	100.00	80.08
W32E	1747	79.75	60.00	100.00	79.92
W32F	1748	55.34	40.96	40.00	45.43
W32G	1749	85.99	41.33	100.00	75.77
W32H	1750	79.37	60.00	70.00	69.79
W41A	1751	79.50	60.00	70.00	69.83
W41B	1752	77.49	60.00		0.00
W41C	1753	82.35	60.00	40.00	60.78

W41D	1754	82.47	40.00	20.00	47.49
W41E	1755	80.55	80.00		0.00
W41F	1756	80.93	80.00	70.00	76.98
W41G	1757	88.97	60.00	90.00	79.66
W42A	1758	70.36	60.00		0.00
W42B	1759	92.54	43.09	96.67	77.43
W42C	1760	72.48	40.00	100.00	70.83
W42D	1761	75.95	40.00	80.00	65.32
W42E	1762	79.53	58.10	40.00	59.21
W42F	1763	80.92	80.00	40.00	66.97
W42G	1764	79.42	58.52		0.00
W42H	1765	70.04	42.23	20.00	44.09
W42J	1766	84.36	40.00	100.00	74.79
W42K	1767	70.16	41.79		0.00
W42L	1768	79.86	40.00	20.00	46.62
W42M	1769	76.06	60.00		0.00
W43A	1770	85.99	60.00	80.00	75.33
W43B	1771	92.24	60.00	100.00	84.08
W43C	1772	74.78	40.00	80.00	64.93
W43D	1773	82.00	100.00	20.00	67.33
W43E	1774	82.96	80.00	80.00	80.99
W43F	1775	71.43	60.00		0.00
W44A	1776	79.18	60.00		0.00
W44B	1777	76.76	40.00		0.00
W44C	1778	93.73	80.00	90.00	87.91
W44D	1779	51.33	40.00		0.00
W44E	1780	72.31	40.00		0.00
W45A	1781	73.81	40.00		0.00
W45B	1782	86.89	100.00	100.00	95.63
W51A	1783	78.67	40.00	73.33	64.00
W51B	1784	86.77	21.08	80.00	62.62
W51C	1785	78.70	40.00		0.00
W51D	1786	84.50	40.00	100.00	74.83
W51E	1787	79.87	60.00		0.00
W51F	1788	79.27	60.00	20.00	53.09
W51G	1789	78.92	40.00		0.00
W51H	1790	72.66	40.00	60.00	57.55
W52A	1791	78.60	40.00	40.00	52.87
W52B	1792	74.59	40.00	40.00	51.53
W52C	1793	79.59	60.00	73.33	70.98
W52D	1794	76.74	40.00		0.00
W53A	1795	84.76	34.60	100.00	73.12
W53B	1796	77.18	40.00	80.00	65.73
W53C	1797	82.81	77.31	70.00	76.70

W53D	1798	71.18	40.00	93.33	68.17
W53E	1799	79.15	60.00	70.00	69.72
W53F	1800	78.68	40.00	73.33	64.01
W53G	1801	68.32	40.00	40.00	49.44
W54A	1802	78.76	60.00	80.00	72.92
W54B	1803	83.24	40.00	80.00	67.75
W54C	1804	78.80	40.00	20.00	46.27
W54D	1805	71.89	55.22	40.00	55.70
W54E	1806	79.31	60.00	84.00	74.44
W54F	1807	87.77	40.00	70.00	65.92
W54G	1808	83.44	40.17	40.00	54.53
W55A	1809	77.46	60.00		0.00
W55B	1810	76.73	60.00	20.00	52.24
W55C	1811	80.16	58.11	80.00	72.76
W55D	1812	85.57	60.00	40.00	61.86
W55E	1813	76.58	60.00	20.00	52.19
W56A	1814	60.06	58.08		0.00
W56B	1815	83.65	40.00	85.00	69.55
W56C	1816	85.57	60.00		0.00
W56D	1817	87.68	40.00	40.00	55.89
W56E	1818	66.68	40.00	40.00	48.89
W56F	1819	72.60	40.00	40.00	50.87
W57A	1820	76.62	60.00		0.00
W57B	1821	74.51	20.00	100.00	64.84
W57C	1822	81.03	80.00	66.67	75.90
W57D	1823	74.42	40.04	40.00	51.49
W57E	1824	67.91	45.02	20.00	44.31
W57F	1825	81.83	37.82		0.00
W57G	1826	68.57	60.00	20.00	49.52
W57H	1827	85.08	80.00	60.00	75.03
W57J	1828	85.87	40.07	40.00	55.31
W57K	1829	75.93	60.00		0.00
W60A	1830	74.68	40.00	88.00	67.56
W60B	1831	76.00	60.00		0.00
W60C	1832	86.65	80.00	60.00	75.55
W60D	1833	83.21	80.00	40.00	67.74
W60E	1834	77.10	60.00	20.00	52.37
W60F	1835	58.81	41.80		0.00
W60G	1836	74.77	80.00	40.00	64.92
W60H	1837	84.20	80.00		0.00
W60J	1838	71.82	80.00		0.00
W60K	1839	76.85	40.00	85.00	67.28
W70A	1840	57.00	40.00		0.00
X11A	1841	53.09	20.00		0.00

X11B	1842	78.17	80.00	60.00	72.72
X11C	1843	75.98	80.00	40.00	65.33
X11D	1844	77.87	40.00		0.00
X11E	1845	80.83	60.00	86.67	75.83
X11F	1846	76.95	80.00	40.00	65.65
X11G	1847	85.13	80.00	40.00	68.38
X11H	1848	77.05	60.00		0.00
X11J	1849	76.04	40.00		0.00
X11K	1850	75.64	40.00	30.00	48.55
X12A	1851	74.11	60.00	70.00	68.04
X12B	1852	70.76	60.00	40.00	56.92
X12C	1853	76.68	40.00	40.00	52.23
X12D	1854	74.40	60.00		0.00
X12E	1855	92.77	80.00	40.00	70.92
X12F	1856	68.76	80.00	70.00	72.92
X12G	1857	74.65	60.00	20.00	51.55
X12H	1858	68.14	60.00		0.00
X12J	1859	78.07	60.00	20.00	52.69
X12K	1860	67.44	60.00	20.00	49.15
X13A	1861	66.44	60.00		0.00
X13B	1862	73.40	60.00	85.00	72.80
X13C	1863	60.12	60.00		0.00
X13D	1864	73.79	60.00	20.00	51.26
X13E	1865	87.95	80.00	70.00	79.32
X13F	1866	81.91	60.00		0.00
X13G	1867	75.11	60.00	73.33	69.48
X13H	1868	80.26	80.00	40.00	66.75
X13J	1869	54.81	40.00		0.00
X13K	1870	69.95	50.12		0.00
X13L	1871	85.49	80.00	90.00	85.16
X14A	1872	67.26	80.00	100.00	82.42
X14B	1873	73.80	60.00		0.00
X14C	1874	87.00	80.00		0.00
X14D	1875	68.66	60.00	100.00	76.22
X14E	1876	73.25	80.00	80.00	77.75
X14F	1877	83.83	60.00	20.00	54.61
X14G	1878	91.24	60.00		0.00
X14H	1879	78.19	60.00	40.00	59.40
X21A	1880	68.00	60.00		0.00
X21B	1881	84.76	60.00		0.00
X21C	1882	63.17	40.00	70.00	57.72
X21D	1883	81.27	60.00	20.00	53.76
X21E	1884	81.55	60.00	20.00	53.85
X21F	1885	67.27	60.00	40.00	55.76

X21G	1886	73.63	60.00	60.00	64.54
X21H	1887	58.11	49.95	100.00	69.35
X21J	1888	51.45	59.45	20.00	43.63
X21K	1889	77.16	60.00	40.00	59.05
X22A	1890	70.03	60.00	20.00	50.01
X22B	1891	55.04	60.00	70.00	61.68
X22C	1892	58.46	20.00		0.00
X22D	1893	57.94	60.00	85.00	67.65
X22E	1894	61.74	60.00		0.00
X22F	1895	67.83	60.00	20.00	49.28
X22G	1896	53.72	40.00		0.00
X22H	1897	68.87	40.00		0.00
X22J	1898	70.42	80.00	100.00	83.47
X22K	1899	71.67	60.00		0.00
X23A	1900	72.20	60.00	20.00	50.73
X23B	1901	65.44	60.00	20.00	48.48
X23C	1902	62.24	60.00		0.00
X23D	1903	61.39	60.00		0.00
X23E	1904	51.07	42.92		0.00
X23F	1905	48.29	60.00		0.00
X23G	1906	57.40	40.00		0.00
X23H	1907	60.91	60.00	20.00	46.97
X24A	1908	69.71	40.00		0.00
X24B	1909	66.26	40.00		0.00
X24C	1910	81.25	60.00		0.00
X24D	1911	49.76	60.00		0.00
X24E	1912	62.45	42.74	20.00	41.73
X24F	1913	61.18	60.00		0.00
X24G	1914	65.29	60.00		0.00
X24H	1915	64.44	40.00		0.00
X31A	1916	47.75	60.00		0.00
X31B	1917	64.97	60.00		0.00
X31C	1918	78.55	60.00		0.00
X31D	1919	57.05	60.00		0.00
X31E	1920	58.17	60.00		0.00
X31F	1921	58.69	40.15		0.00
X31G	1922	73.07	51.91		0.00
X31H	1923	65.60	60.00	60.00	61.87
X31J	1924	54.37	60.00		0.00
X31K	1925	55.74	60.00		0.00
X31L	1926	88.08	60.00		0.00
X31M	1927	43.16	59.80		0.00
X32A	1928	57.86	60.00		0.00
X32B	1929	77.68	40.00		0.00

X32C	1930	84.95	60.00		0.00
X32D	1931	71.36	60.00		0.00
X32E	1932	71.73	60.00		0.00
X32F	1933	81.82			0.00
X32G	1934	75.71	60.00		0.00
X32H	1935	54.51	60.00	100.00	71.50
X32J	1936	85.99	60.00		0.00
X33A	1937	91.43	60.00		0.00
X33B	1938	75.17	60.00		0.00
X33C	1939	82.65	60.00		0.00
X33D	1940	70.00	60.00	20.00	50.00
X40A	1941	76.67	60.00		0.00
X40B	1942	69.56	60.00		0.00
X40C	1943	66.62	60.00		0.00
X40D	1944	87.55	60.00		0.00