Prioritising quaternary catchments for invasive alien plant control within the fynbos and karoo biomes of the Western Cape Province

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Executive Summary

Introduction

Invasive alien plant control requires the allocation of limited resources to control operations to maximise benefits. The priorities for such allocation are based on a mixture of fact and opinion, interpreted either subjectively or objectively, but often not explicitly so. This project sought to develop an approach that could assist managers and planners in the Working for Water Programme's Western Cape Region to prioritise their activities with a degree of transparency.

We used the Analytic Hierarchy Process (AHP) to facilitate prioritization. AHP is a multiple criteria decision-making tool for setting priorities when both qualitative and quantitative aspects of a decision need to be considered, and for achieving group consensus.

Priorities in primary catchment E

In the catchment of the Olifants and Doring rivers (E) the five catchments with the highest relative importance rankings are E10H, E 21K, E24A, E10A and E10C. These are located in the higher rainfall areas of the Groot Winterhoek Mountains and the Cedarberg.

Priorities in primary catchment G

In the Berg River catchment (G_1) the five quaternary catchments with the highest relative importance rankings are G10B, G10G, G22A, G22F and G10A. These are located in the high rainfall Boland Mountains and on the Cape Peninsula.

In the Overberg (G_2) the five most important quaternary catchments are; G40A, G50K, G40B, G40D and G40C. Three of these are in the Hottentots Holland Mountains and have a high rainfall while the remaining two are situated adjacent to the coast where conservation factors are important.

Priorities in primary catchment H

A total of 69 quaternary catchments occur within primary catchment H. The five most important quaternary catchments of these are found in the mountainous head waters of the Breede River. These are H10E, H60B, H60A, H10D and H10K.

Priorities in primary catchment J

Unlike in the other primary catchments the Gouritz River catchment (J) is mostly within the Nama and succulent Karoo biomes. Here the five quaternary catchments having the highest importance rankings are J25A, J12A, J22J, J33B and J12G. These are located mainly along the Swartberg mountain range with the exception of J22J which is in the Great Karoo.

Priorities in primary catchment K

Along the Garden Route (K) the five most important quaternary catchments are K60D, K70B, K30C, K30D and K60B. These include the Tsitsikamma mountain range to the east of Plettenberg Bay that also border on the Langkloof.

Conclusions and recommendations

This study has been successful in applying the approach developed by van Wilgen *et al*. (2008) at a quaternary catchment scale in the Western Cape. However, a number of follow-up actions will be needed if this approach is to deliver its full potential in terms of assisting the Working for Water Programme to improve its operations and its impact.

We recommend the following:

- That the techniques developed at the primary and quaternary catchment scale be adopted by Working for Water's national and regional planning offices to assist with prioritization, planning, and the allocation of resources to both existing and new projects on an ongoing basis.

- Each Working for Water region should maintain existing datasets and revise them on a regular basis. This should not be longer than 3 years so as to coincide with the medium term expenditure framework (MTEF) of government.

- The priorities given in van Wilgen *et al.* (2008) should be used to guide the allocation of funds between the major primary catchments of the Western Cape. Then the priorities identified in this study should be used to allocate funds amongst the quaternary catchments.

- That as soon as the National Invasive Alien Plant Survey has been completed by the Agricultural Research Council, the data on current state of invasion should replace the Versfeld *et al*. (1998) flow reduction data we have used for in this study;

- That a spatial database be developed to underpin effective comparisons of areas. This database could contain data relating to most of the criteria identified here, including mean annual runoff, the locality of important groundwater aquifers, the degree of water stress, conserved areas, threatened or critically threatened river and vegetation types, livestock production potential, the distribution of invasive alien species, land ownership, and the location of poverty nodes;

- That a presentation should be given to senior managers in the Working for Water Programme, with a view to (i) raising awareness of the study and its implications for decision-makers and planners within the programme; (ii) obtaining input regarding its adoption and/or modification, and (iii) agreeing on the process for its possible adoption and implementation elsewhere in the country; and

- That this work be published in the peer-reviewed literature. This will have a number of advantages, including (i) ensuring that the work is subjected to rigorous review; (ii) ensuring a permanent and widely-retrievable record of the work; and (iii) enabling the wider dissemination of the approach and results, particularly to other organizations involved in control operations.

Acknowledgements

We thank the Working for Water Programme of the Department of Water and Environment Affairs for funding this work. Mr Derek Malan, Mr Andrew Wannenburgh and Ms Ruhvene Miles of the Working for Water Programme of the Department of Water and Environment Affairs, and Ms Louise Stafford of the City of Cape Town made valuable inputs in their capacity as members of the project's reference group.

The following managers, implementing agents and researchers are thanked for their informed and enthusiastic participation in the workshops aimed at developing a model for assessing the priority quaternary catchments to clear in the portions of the Western Cape covered by fynbos, succulent and Nama Karoo biomes: Dawie Arendorff, Jonathan Britton, Andrew Brown, Winston Coe, Nicholas Cole, Rhett Hiseman, Philip Holthuisen, Radie Loubser, Derek Malan, Daniel Maphiri, Ruhvene Miles, Heinrich Neethling, Rudolph Roscher, Núria Roura-Pascual, Cobus Smit, Lindie Smith-Adao, Manfred Pauslen, Melissa Pieterse, Patrick van Coller, Francois van Heerden, Bertrand van Zyl, Johan Visser, Kasey Voges, Andrew Wannenburgh and Nigel Wessels.

The photographs appearing on the cover and inside the report were taken by Greg Forsyth.

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1. INTRODUCTION

Invasive alien plant control requires the allocation of limited resources to control operations to maximise benefits. The priorities for such allocation are based on a mixture of fact and opinion, interpreted either subjectively or objectively, but often not explicitly so.

The CSIR recently completed a study on the prioritisation of species and primary catchments for the purposes of guiding invasive alien plant control operations in the terrestrial biomes of South Africa (van Wilgen, Forsyth and Le Maitre, 2008). This study developed an approach that enables managers and planners in the Working for Water Programme to prioritise their activities in a way that is transparent, logical and defensible.

The study also developed methods for the identification of a priority list of (i) invasive alien plants, and (ii) areas (primary catchments) within the terrestrial biomes of South Africa that should be targeted for control by the Working for Water Programme. The biomes included the fynbos, grassland, savanna (both moist and arid) succulent karoo and Nama karoo.

Derek Malan of the Department of Water Affairs and Forestry (DWAF) requested the CSIR to assist in prioritising areas to clear within the Western Cape Province by applying these methods at a quaternary catchment scale.

This report presents the results of our study to determine the priority quaternary catchments to clear in each of the main primary catchments of the Western Cape. We also make recommendations for further improvements to the prioritisation process and its implementation by the Working for Water Programme.

2. SCOPE OF WORK

This project is conducted as part of a collaborative agreement between the Department of Water Affairs and Forestry (DWAF) and the Council for Scientific and Industrial Research (CSIR). The work was guided and reviewed by a reference group, appointed by DWAF at the initiation of the project, in terms of the collaborative agreement. Members of the reference group were:

- Mr Derek Malan (Department of Water and Environment Affairs – Working for Water Programme)
- Ms Ruhvene Miles (Department of Water and Environment Affairs – Working for Water Programme)
- Mr Andrew Wannenburgh (Department of Water and Environment Affairs – Working for Water Programme)
- Ms Louise Stafford (City of Cape Town)

The planned scope of the work recognised that the study was exploratory in nature and that with the resources and time available there was a strong possibility that not all the objectives would be fully met. An important issue was whether the Expert Choice 2000 decision support software would be able to provide an alternative to the large number of manual pairwise comparisons that we would have had to complete. For example, in primary catchment H alone there are 69 quaternary catchments and each of these needed to be compared to one another for each of 15 different criteria or sub-criteria, amounting to 2380 multiplied by 15 or a total of 35700 comparisons. In practice this would not have been possible to do manually. In the event we were successful in generating and importing the weighted values for each criterion and sub-criterion for each quaternary catchment. This enabled us to make the necessary comparisons in a semi automated manner.

It was agreed at the outset of the study that the planned schedule of activities would entail:

The work would be limited to the three biomes; fynbos, succulent karoo and Nama karoo that cover the major portion of the Western Cape.

- The work would entail prioritising areas to clear at a quaternary catchment scale within the portions of primary catchments E (Olifants / Doring), G (Berg River), H (Breede River), K (Garden Route) and J (Gouritz) occurring in the Western Cape. We selected all the quaternary catchments which had at least a part falling within the Western Cape. Additional quaternary catchments were included when there were clearing projects managed by Working for Water Programme's Western Cape Region.

- The Analytic Hierarchy Process (AHP)[1] would be used to facilitate the prioritization of quaternary catchments using Expert Choice decision support software (Anon. 2002).
- The criteria to use for prioritising the quaternary catchments for the clearing of invasive alien plants was identified and agreed to at two expert workshops.
- An obvious criterion was whether or not priority alien invasive species are present or likely to spread in a quaternary catchment. In this regard it was agreed that we would work from the list of priority species identified for the fynbos, succulent karoo and Nama karoo (see Appendix 1) by the recent CSIR study (van Wilgen, Forsyth and Le Maitre, 2008).
- The work of Rouget *et al*. (2004) would be used to identify areas that are likely to become invaded by the species identified in the CSIR study as priority species for clearing.
- In addition to the data sets used in the recent CSIR study we would obtain relevant data on the occurrence and status of priority invasive species data for the primary catchments in question from the Department of Water Affairs and Forestry's WIMS (Working for Water Information Management System) database. The so called NBAL (**N**atural**, B**iology, **Al**ien) data.
- Where applicable and available we would also made use of river (Nel *et al.* 2007) and terrestrial (Driver *et al.* 2005) conservation prioritization datasets for various spatial scales, and the C.A.P.E. fine scale planning data.
- The assessment would focus on (a) the criteria and (b) the relative weighting of those criteria that will be used in prioritising the quaternary catchments and not on direct pairwise catchment comparisons. The primary reason for this is that the AHP approach requires a pairwise ranking and there are, for example, 58 quaternary catchments in primary catchment G and 69 in primary catchment H that need to be analysed. A pairwise comparison would be very time consuming. We would therefore develop a procedure for doing this which to some degree would automate these comparisons.

The relevance of the study to the Working for Water Programme

The Working for Water Programme's strategic plan for 2008 – 2012 lists "the reduction of impact of existing priority invasive alien plant problems" as one of three primary goals relating to natural resource management. The other two are related to preventing problems, and building capacity to address problems. This project will assist in the identification of such priorities at a quaternary scale in the Western Cape, which are largely undefined at present.

[1] AHP is a multiple criteria decision-making tool for setting priorities when both qualitative and quantitative aspects of a decision need to be considered. It involves setting a goal, breaking it down into its constituent parts and then assigning relative weights to each of these, thereby progressing from the general to the specific. Scoring is on a relative basis comparing one choice with another. Relative scores for each choice are computed with each level of the hierarchy. Scores are then synthesised through a model contained in Expert Choice. This yields a composite score for each choice at every level as well as an overall score.

3. APPROACH

3.1 WORKSHOPS TO DETERMINE RANKING CRITERIA

Two one-day workshops were held. The first of these was in the Wilderness on 29th September 2008 and focussed on primary catchments J (Gouritz) and K (Garden Route). The second workshop was held in Stellenbosch on 23rd October 2008 and focussed on primary catchments E (Olifants / Doring), G (Berg) and H (Breede). Sixteen delegates attended each workshop (see Appendix 1). They were mainly staff responsible for implementing Working for Water projects, DWAF officials responsible for water management areas and representatives of conservation agencies.

The topics addressed at each workshop were:

- Presenting the finding of the CSIR study (van Wilgen, Forsyth and Le Maitre, 2008)
- Explaining the Analytic Hierarchy Process
- Discussing the current rankings of priority invasive alien plants for the primary catchments in question (See Appendix 1)
- Agreeing on the goal, criteria (objectives) and sub-criteria (sub-objectives) for prioritising quaternary catchments
- Completing pairwise comparisons (ranking) of the agreed criteria and sub-criteria
- Determining what datasets, based on the agreed criteria and sub-criteria, are available to assist in the ranking of quaternary catchments

3.1.1 Results of the workshop held in the Wilderness

At this workshop we identified the criteria to use as a basis for the prioritisation of quaternary catchments areas within the primary catchments K (Garden Route) and J (Gouritz).

A sizable portion of primary catchment J is covered in karroid vegetation and therefore it was decided to develop separate criteria for this area than that for the areas covered by fynbos in primary catchments J and K. The goal decided on for primary catchment K and the fynbos portion of primary catchments J was, "To control invasive alien plants to reduce the impacts on biodiversity and water supply".

The workshop participants (see Appendix 2) agreed on six main criteria. The Analytic Hierarchy Process (AHP) was used to compare each criterion to each other and to assigned weightings to each according to their relative importance (Saaty, 1990). The criteria together with their assigned weightings are shown in Figure 1 in their order of importance.

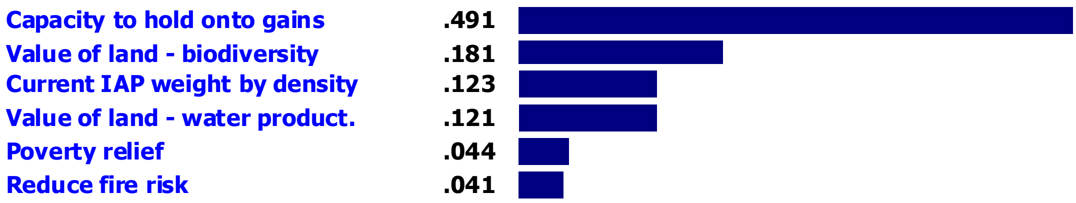

Figure 1: ***Ranked criteria identified as significant for the purposes prioritizing quaternary catchments occurring within primary catchment K (Garden Route) and the fynbos portion of primary catchment J (Gouritz) for the clearing of invasive alien plants. Relative weightings, out of a total of 1.0, are given for each criterion.***

The most important criterion identified is the ability to hold onto gains made once an area has been cleared of invasive alien plants. This carries a weighting of 49.1%. Next in order of importance are the value of land for biodiversity conservation (18.1%), the current extent of invasion (12.3%) by priority invasive alien plants identified by van Wilgen *et al.* (2008) and the value of land for water production (12.1%). Poverty relief was assigned a weighting of 4.4% while the reduction of fire risk received a weighting of 4.1%.

The reason for poverty only being weighted at 4.4% was that it was seen as pervasive throughout the Western Cape. Delegates felt that where ever a Working for Water project was established in the province there would be many more people in the vicinity living below the mean living level than such projects would be able to employ.

Many of the criteria were further divided into sub-criteria. For example, sub-criteria of public and private land were identified for the capacity to hold on to gains. The final ranking for primary catchment K and the fynbos portions of primary catchment J, considering all the criteria and sub-criteria, is given in Table 1.

Table 1/…

Table 1: ***Nested criteria identified as significant for the purposes of prioritizing quaternary catchments within primary catchment K (Garden Route) and the fynbos portion of primary catchment J (Gouritz) for the clearing of invasive alien plants. Higher-level criteria are divided into sub-criteria, and the relative weightings are given for each***

Criterion	Weighting assigned (%)	Sub-criterion	Weighting assigned (%)
Capacity to hold onto gains	49.1	Public conservation land	42.9
		Other land	6.1
Value of land for biodiversity	18.1	Conservation corridor alignment	10.8
		Conservation status of land	6.3
		• Cons. status of vegetation	*(3.9)*
		• Cons. status of rivers	*(1.5)*
		• Cons. status of estuaries	*(0.9)*
		Value of harvested products from the veld	1.0
Current IAP distribution and density	12.3	Low density	9.0
		Moderate density	2.3
		High density	1.0
Value of land for water production	12.1	Water stressed catchments	10.1
		Highest water yielding catchments	2.0
Poverty relief	4.4		4.4
Reduce fire risk	4.1		4.1
	100		**100**

Similarly the goal decided on for the karroid (Nama and succulent karoo) vegetation in primary catchment J was, "To control IAPs to protect the integrity of the ecosystems".

Workshop participants arrived at on six main criteria which are similar to those identified for the fynbos area (see Figure 1) except that, "reducing fire risk" was replaced by "maintaining land productivity" (see Figure 2) as a criterion. Criteria were compared to each and importance weightings were assigned using AHP. The criteria together with their assigned weightings are shown in Figure 2 in their order of importance.

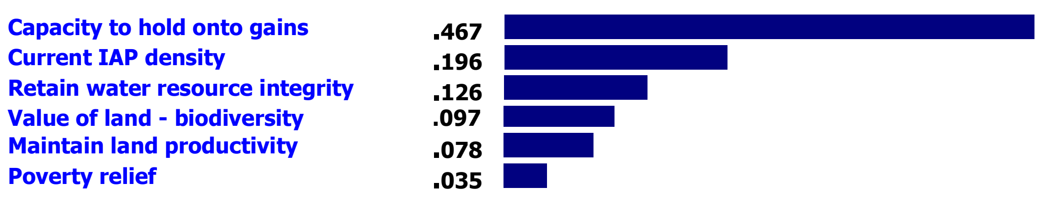

Figure 2: ***Ranked criteria, weighted in respect to the goal, identified as significant for prioritizing quaternary catchments occurring within the Nama and succulent karoo portions of primary catchment J (Gouritz) for the clearing of invasive alien plants. Relative weightings are given for each criterion***

The most important criterion identified is the ability to hold onto gains made once an area has been cleared of invasive alien plants. This carries a weighting of 46.7%. Next in order of importance are the current extent of invasion (19.6%) by priority invasive alien plants identified by van Wilgen *et al.* (2008), value of land for water production (12.6%) and the value of land for biodiversity conservation (9.7%). Maintaining land productivity (7.8) and poverty relief were seen as less important criteria and assigned weightings of 7.8% and 3.5% respectively. Poverty received a low weighting as it was seen as pervasive throughout primary catchments J and K.

Many of the criteria were further divided into sub-criteria. For example, sub-criteria of high, medium and low density levels of invasion were identified for the extent of invasive alien plant invasion. The final ranking for the karroid portion of primary catchment J, considering all the criteria and sub-criteria, is given in Table 2.

Table 2: ***Nested criteria identified as significant for the purposes of prioritizing quaternary catchments within the Nama and succulent karoo portions of primary catchment J (Gouritz) for the clearing of invasive alien plants. Higher-level criteria are divided into sub-criteria, and the relative weightings are given for each***

Criterion	**Weight assigned (%)**	**Sub-criterion**	**Weight assigned (%)**
Capacity to hold onto gains	46.7	Public conservation land	40.9
		Other land	5.8
Current IAP distribution and density	19.6	Low density	14.3
		Moderate density	3.7
		Low density	1.6
Retain, improve or restore water resource integrity	12.6	Water stressed catchments	9.9
		Protect surface water systems (restore functioning of rivers)	1.4
		Protect ground water systems	1.3
Value of land for biodiversity	9.7	Conservation corridor alignment	6.5
		Conservation status of land	3.2
		• Cons. status of rivers	(2.4)
		• Cons. status of vegetation	(0.8)
Maintain land productivity	7.8	Value of veld for grazing	6.7
		Value of harvested products from the veld	1.1
Poverty relief	3.5		3.5
	100		**100**

3.1.2 Results of the workshop held in the Stellenbosch

During this workshop we identified the criteria to use as a basis for the prioritisation of quaternary catchments areas within the primary catchments E (Olifants / Doring), G (Berg) and H (Breede). We did not differentiate between different vegetation types as we had in the Wilderness as we felt that the criteria developed for the Nama and succulent at the Wilderness workshop could be directly applied where and if necessary within primary catchments E, G and H. The criteria we developed at this workshop therefore had a fynbos bias.

The goal was stated as, "To reduce and control IAP to minimise their negative impacts on natural resources". This was similar to the goals arrived at during the workshop in the Wilderness.

Six criteria were identified by workshop participates (see Appendix 2) and using the AHP technique each criterion was compared to each other and assigned weightings according to relative importance (see Figure 3).

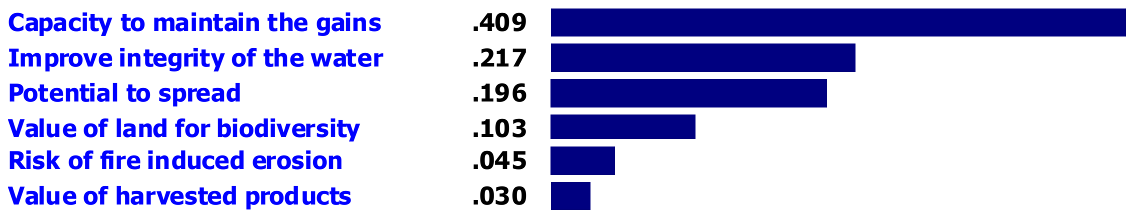

Figure 3: ***Ranked criteria, weighted in respect to the goal, identified as significant for the purposes prioritizing quaternary catchments occurring in primary catchments E (Olifants / Doring), G (Berg) and H (Breede) for the clearing of invasive alien plants. Relative weightings are given for each criterion.***

Once more the capacity to hold onto gains made once an area has been cleared of invasive alien plants was found to be the most important criterion and was assigned a weighting of 40.9%. The next most important criteria were to improve the integrity of water supplies (21.7%) and the potential of priority alien plants identified by van Wilgen *et al.* (2008) have to spread (19.6%). The value of the land for biodiversity was weighted at 10.3% while the risk of fire induced erosion (4.5%) and the value of products harvested from the veld (3.0%) were found to be the least important criteria in deciding on the prioritisation of quaternary catchments to clear.

In this case poverty was not chosen as a criterion as it was seen as pervasive throughout primary catchments E, G and H. Delegates felt that wherever a Working for Water project was established in the province there would be many more people in the vicinity living below the mean living level than such projects would be able to employ.

Many of the criteria were further divided into sub-criteria. For example, sub-criteria of high, medium and low density levels of invasion were identified for the extent of invasive alien plant invasion. The final ranking for primary catchments E, G and H, when all criteria were considered, is given in Table 3.

Table 3: Nested criteria identified as significant for the purposes of prioritizing quaternary catchments within primary catchments E (Olifants / Doring), G (Berg) and H (Breede) for the clearing of invasive alien plants. Higher-level criteria are divided into sub-criteria, and the relative weightings are given for each

Criterion	Weighting assigned (%)	Sub-criterion	Weighting assigned (%)
Capacity to hold onto gains	40.9	State land	30.7
		Other land	10.2
Retain, improve or restore water resource integrity	21.7	Water stressed catchments	13.9
		Highest water yielding catchments	4.9
		Maintain functioning of rivers	1.5
		Restore functioning of rivers	1.4
Current IAP distribution and density	19.6	Proportion of the catchment available for invasion	12.5
		Potential invasion by priority species	5.0
		Current invasion by priority species	2.1
Value of the land for biodiversity	10.3	Alignment with conservation corridors	3.6
		Conservation status of rivers	3.0
		Conservation status of vegetation types	2.3
		Legal status of protected areas	0.8
		Proportion of area protected	0.6
Risk of fire induced erosion	4.5		4.5
Value of harvested products from the veld	3.0		3.0
	100		**100**

3.2 MODIFICATION OF THE HIERARCHY MODEL

It was agreed at a meeting with the project reference group during January 2009 to consolidate the two models and their weightings, as shown in Tables 2 and 3, into a single model capable of accommodating the Fynbos, Succulent Karoo and Nama Karoo biomes found in the Western Cape.

At this stage it also became evident that certain datasets that were needed to address, for example, questions relating to fire induced erosion were not readily available (see Table 4). We realised that we did not have the time to generate and test suitable surrogate datasets for these relatively unimportant criteria. We, therefore, left them out of the revised version of the hierarchy model and reweighted the relative importance of the remaining criteria and sub-criteria (see Figure 4).

- **Goal: Reduce and control IAP to mimimise their negative impacts on natural resources**
  - **Improve the integrity of the water resource (L:.223)**
    - **Maintain the integrity of the river system (L:.073)**
      - **Rivers (L:.750)**
      - **Azonal ecosystems & wetlands (L:.250)**
    - **Highest yielding catchment (L:.205)**
    - **Water stressed catchments (demand) (L:.722)**
  - **Value of the catchment for biodiversity (L:.104)**
    - **Conservation status of rivers (L:.750)**
    - **Conservation status of vegetation type (L:.250)**
  - **Potential veld utilisation (L:.037)**
    - **Flower harvesting (fynbos) (L:.333)**
    - **Other harvestable products (Karoo) (L: .333)**
    - **Grazing (Karoo, renosterveld & grassland) (L:.333)**
  - **Capacity to maintain the gains (L:.424)**
    - **State: protected areas (L:.750)**
    - **Other (L:.250)**
  - **Potential to spread (L:.173)**
    - **Current invasion by priority species (L:.105)**
    - **Proportion of the catchment available for invasion (L:.637)**
    - **Potential invasion by priority species (L:.258)**
  - **Poverty relief (L:.038)**

Figure 4: ***Final consolidated model used for weighting criteria and sub-criteria for the fynbos, succulent and Nama karoo biomes occurring in the quaternary catchments of the Western Cape***

In the revised hierarchy model the ability to hold onto gains made by clearing projects was again assigned the highest weighting. This is followed by the criteria of improving the integrity of the water resources and the potential for invasive alien plants to spread. These three criteria account for 72% of the weighting assigned.

Table 4: Spatial datasets used to determine composite scores to assign to each of the quaternary catchments in primary catchments E, G, H, J and K. Quaternary catchments having the highest scores were assigned the highest priority. The listed criteria and sub-criteria are standardised from tables 1, 2 and 3.

Criteria	Sub-criteria	Primary catchments where applicable						Spatial data [1]
		E	G	H	J	J Karoo	K	
Capacity to hold onto gains	Public conservation land	✓	✓	✓	✓	✓	✓	• National Protected Areas Database (Biodiversity GIS, http://bgis.sanbi.org)
	Other land (mountain catchments)	✓	✓	✓	✓	✓	✓	• National Protected Areas Database (Biodiversity GIS, http://bgis.sanbi.org)
Value of land for biodiversity	Conservation status of vegetation types	✓	✓	✓	✓	✓	✓	• National Vegetation Map (Mucina and Rutherford, 2006)
	Conservation status of river systems	✓	✓	✓	✓	✓	✓	• Nel *et al.* (2007) • South African 1: 500,000 river coverage (DWAF, 2004)
	Proportion of protected areas	✓	✓	✓	✓	✓	✓	• National Protected Areas Database (Biodiversity GIS, http://bgis.sanbi.org)
Current IAP distribution and density	Current invasion by priority species	✓	✓	✓	✓	✓	✓	• South African Plant Invaders Atlas (Henderson 1998 and revisions) • NBAL (Working for Water) • Versfeld *et al.* (1998)
	Proportion of the catchment available for invasion	✓	✓	✓	✓	✓	✓	• National Land Cover Database 2000 (Van den Berg *et al.* 2008)
	Potential invasion by priority species	✓	✓	✓	✓	✓	✓	• Rouget *et al.* (2004)
	Legal status of protected areas	✓	✓	✓	✓	✓	✓	• National Protected Areas Database (Biodiversity GIS, http://bgis.sanbi.org)
Value of land for water production (Retain, improve or	Water stressed catchments	✓	✓	✓	✓	✓	✓	• Water Situation Assessment Model at quaternary catchment scale (WSAM, 2003)

		Primary catchments where applicable						
restore water resource integrity)	Highest water yielding catchments	✓	✓	✓	✓	✓	✓	• Water Resources 2005 copy supplied by A. Bailey of Stewart Scott International on behalf of the Water Research Commission.
	Protect surface water systems (Maintain and restore functioning of rivers)	✓	✓	✓	✓	✓	✓	• Present ecological status of South African rivers (Kleynhans, 2000) • South African 1: 500,000 river coverage (DWAF, 2004).
	Protect ground water systems					✓		• National Vegetation Map (Mucina and Rutherford, 2006)
Maintain land productivity	Value of harvested products from the veld	✓	✓	✓	✓		✓	• National Vegetation Map (Mucina and Rutherford, 2006)
	Value of veld for grazing					✓		• Areas of homogenous grazing potential (Scholes, 1998)
Poverty relief		✓	✓	✓	✓	✓	✓	• South African geospatial analysis platform (Naudé *et al.*, 2007)

[1] See reference section for complete references

3.3 SELECTING APPROPRIATE DATA

A summary of the data sets used, the rationale for using these to address the criteria (Figure 4) underlying the revised hierarchy model approach, and methods are given below. We were limited in our choice to those datasets that were readily available (in the public domain) and covered the entire Western Cape.

3.3.1 Capacity to maintain gains

i) State protected areas

These included areas managed by South African National Parks, the Western Cape Nature Conservation Board (CapeNature) and protected areas under the authority of local municipalities. These are areas where the controlling body has a legal mandate to manage the land for conservation objectives, including the control of invasive alien plants. The state protected area in each quaternary catchment was expressed as a percentage of its total area. The quaternary catchment with the greatest proportion was allocated the highest weight.

ii) Other land

We used the demarcated mountain catchment areas. These are privately owned but certain restrictions, aimed at water and environmental protection, are in place. The highest weight was allocated to the quaternary catchment with the greatest percentage of its total area within a mountain catchment area. Private conservancies were excluded as landowners are free to change their land use practices at any time. The stewardship programme of CapeNature is addressing this issue. However, where private property occurs within a priority catchment it will be treated together with state land in accordance with the policies of the Working for Water Programme.

3.3.2 Improve the integrity of the water resource

i) Maintain the integrity of the river system

- For surface water resources we used the present ecological status class (Kleynhans 2000) of each reach of the national 1: 500000 rivers (DWAF 2004) as a surrogate for river ecosystem integrity. We combined classes A (entirely natural), B (largely natural) and C (moderately modified) as being important for conservation. Other classes were not considered. We then calculated the proportion of the combined classes (A, B and C) as a proportion of the entire river length within each quaternary catchment. The greater the portion the higher the weight assigned.

- For groundwater resources we used the azonal and wetland vegetation types as defined by Mucina and Rutherford (2006) as a surrogate for areas with relatively high groundwater storage that could be used by invasive alien plants. We expressed the total area of these vegetation types as a proportion of each quaternary catchment. The greater the portion the higher the weight assigned. In effect, wetlands received the greatest weights in the fynbos biome while the azonal systems were more important in the Karoo where they occupy a greater proportion of the catchments.

ii) Highest yielding catchment

The yield information was obtained from the Water Resources 2005 quaternary catchment dataset. The units used in the Water Resources 2005 data were expressed as the naturalised annual run-off in millions of cubic metres per year. These values were converted to mm using the area of the respective quaternary catchments to give the runoff in units of depth. The quaternary catchment with the highest water yield was given the highest weight.

iii) Water stressed catchments (water demand)

The data on water stress were obtained from the Water Situation Assessment Model (WSAM) database (WSAM, 2003). We used the quaternary yield balance (million cubic metres per annum) which is the difference between the available yield and the current demand. The yield was set at a 1: 50 year assurance level for the 1995 base year.

Water stress values range from a surplus (positive) to a deficit (negative). For our purposes the highest deficit should be assigned the highest weight and the greatest surplus the lowest weight. To do this we first changed all the positive values to negative ones and *vice versa*. We then added an offset equal to the lowest value to each value to convert all values to positive ones. The result of this process is that the most stressed catchment will have the largest positive value and the highest weight.

3.3.3 Potential to spread

Van Wilgen *et al*. (2008) identified priority species for, among others, the fynbos and karoo biomes. We only used the species whose cumulative weight was 50% of the total weight allocated. *Hakea sericia* was added to the fynbos list as it an important invasive species and capable of transforming large areas of fynbos. The list of species used is given below:

Fynbos species
Acacia mearnsii
Pinus (radiate, halenpensis and pinaster)
Populus canescens
Acacia pycnantha
Acacia longifolia
Acacia saligna
Paraserianthus lopthantha
Eucalyptus camaldulensis
Hakea sericea

Karoo species
Prosopis glanulosa
Eucalyptus camaldulensis
Populus canescens
Arundo donax
Nerium oleander
Tamarix ramosissima
Schnis molle
Myriophyllum spicatum

i) Current invasion by priority species

Ideally we would have liked to have made use of the results of the National Invasive Alien Plant Survey being compiled by the Agricultural Research Council. However the results of this survey will only be released once the verification process has been completed.

We considered using the presence and abundance (categories as either absent, rare, occasional, frequent, abundant or very abundant.) data on invasive alien plants contained in the SAPIA database (Henderson 1998). However this is mapped at a quarter degree square scale (roughly 20 x 25 km) and was too coarse for our purposes.

An alternative source of information on the current distribution of invasive alien plants is the NBAL (**N**atural**, B**iology, **Al**ien) data for each invasive alien clearing project managed by either CapeNature or Working for Water. The disadvantage of using this data is that it is incomplete because it only records data about invasions in areas that have been cleared.

We therefore reverted to the study conducted by Versfeld *et al.* (1998) and used the estimated flow reduction per quaternary catchment as a surrogate for the extent and impact of the current invasions. Although dated the mapping done for the Western Cape was the most thorough and complete so the relative values for the quaternary catchments are a reasonable surrogate. The greatest reductions in mean annual runoff were given the greatest weight.

ii) Proportion of the catchment available for invasion

We used the proportion of untransformed land per quaternary catchment, based on the National Land Cover 2000 database, to derive the weights. Untransformed land excludes plantations, urban areas, mines and quarries, cultivated agricultural, improved grasslands and water-bodies.

iii) Potential invasion by priority species

We estimated the potential invasions by priority species as identified by van Wilgen *et al.* (2008) and the potential ranges (invasion envelopes) developed for these species by Rouget *et al.* (2004). The potential invasion envelopes are based on a model which predicts the potential for invasion as a probability. Areas with probabilities > 0.5 are considered likely to be invaded. The envelopes for each of the priority species were summed to create a single surface with the total number of species in each grid cell (1.6 km x 1.6 km).

The analysis of fynbos invasions in the Western Cape identified a problem. The Rouget *et al.* (2004) models of potential pine species invasions exclude the high altitude areas of the Cape Mountains (roughly > 1100 m). However, we know from other data and from personal observations that these areas are invaded by pine species. We created new potential invasion surfaces for pines in the Western Cape Province by using the fynbos biome as defined for the national vegetation map (Mucina and Rutherford 2006) as the extent of potential invasions for the pines. Based on our knowledge we defined the area that each species can invade as follows:

- *Pinus halepensis* – can invade all types of fynbos i.e. the entire biome including the dry and arid types
- *Pinus radiata* and *Pinus pinaster* are both less drought resistant than *P. halepensis* and they have not been observed invading strandveld, the Karoo renosterveld or the dry to arid sand plain fynbos in the north-western parts of the biome. Therefore we excluded the following types:
    - Karoo Shale Renosterveld Bioregion situated along the escarpment including the Roggeveld and Sutherland areas.
    - Western and Southern Strandveld bioregions
    - The dry to arid Namaqualand and Leipoldtville Sand Fynbos vegetation types
    - Kamiesberg Granite Fynbos and Namaqualand Granite Renosterveld veld types.

The revised potential invasion envelopes for pines were added to the envelopes for the other species to produce a grid containing the total number of species (TNS).

In all cases we used only the remaining natural vegetation (i.e. untransformed) areas in our calculations. The TNS was then clipped to include only the remaining natural vegetation.

However the grid cell size in the Rouget *et al.* (2004) data is coarser than the grids used in the National Land Cover (about 30 x 30 m). To minimize the loss of the relatively small potentially invadable remnants of natural vegetation in the lowland areas, we resampled the TNS to the same resolution as the Land cover.

The riparian strips are particularly important because they are invaded by a range of species and riparian invaders have a relatively high water use.

We calculated the proportion of each quaternary catchment that was still natural vegetation and weighted it with the mean of the number of species that could potentially invade the remaining natural vegetation. Thus, if two quaternaries had the same proportion that was invadable (i.e. natural vegetation), the one with the greater mean number of species would get a greater weight.

3.3.4 Value of the catchment for biodiversity

i) Conservation status of the rivers

We used the conservation status of the river signatures in each quaternary catchment as defined for the National Spatial Biodiversity Assessment (Driver *et al.* 2005; Nel *et al.* 2007) to estimate the conservation status. The conservation status is expressed as: Critically endangered, endangered, vulnerable and least threatened. We calculated the weight for each quaternary catchment using the sum the lengths of the first three classes as a proportion of the total river length in each quaternary catchment. Quaternary catchments with the highest proportion were given the greatest weight.

ii) Conservation status of vegetation type

We used the conservation status of each vegetation type as given in the Mucina and Rutherford (2006). We first selected only the vegetation types rated as "Critically endangered", "Endangered" or "Vulnerable". We then clipped to exclude all transformed land based on the National Land Cover Database 2000. To avoid double counting we also excluded all state land in protected areas.

The resulting areas were expressed as a proportion of the total area of each quaternary catchment. The catchment having the highest proportion received the greatest weight.

3.3.5 Poverty relief

To prioritise catchments with regard to the need for socio-economic development we made use of data contained in the South African Geo-spatial Analysis Platform (Naudé *et al.* 2007). This database contains 25000 irregularly shaped meso-scale analysis units (meso-zones) approximately 7 x 7 km in size. The meso-zones are demarcated so as to nest within administrative and physiographic boundaries. Each meso-zone contains a variety of socio-economic data including the number of people living below the mean living level (MLL).

We used the proportion of the population living below the MLL in each meso-zone to calculate a mean value for each quaternary catchment. This proportion is a reasonable surrogate for the proportion of unemployed people because low income is directly related to unemployment. The quaternary catchments having the highest proportion of their population living below the MLL were given the greatest weight.

3.3.6 Potential for veld utilisation

i) Veld harvesting (fynbos)

The harvesting of flowers and other plant material is the most important form of veld utilisation in fynbos vegetation (Turpie *et al.* 2003) but harvesting is confined to certain areas because only certain vegetation types include commercially harvested species. Harvesting is not permitted in protected areas so these areas were excluded. Besides flowers certain Restionaceae are used for thatching and certain legumes are used for producing rooibos and honey bush tea.

We used the fynbos vegetation types as mapped by Mucina and Rutherford (2006) and selected the following types based on our knowledge:

Flowers and Dekriet
Agulhas limestone fynbos
Agulhas sandstone fynbos
Albertinia sandstone fynbos
Atlantis sand fynbos
Breede quarzitic fynbos
De Hoop limestone
Elim ferricrete fynbos
Hangklip sand fynbos
Kogelberg sandstone
North Sonderend sandstone
Overberg sandstone Fynbos
Potberg sandstone fynbos
South Sonderend Sandstone fynbos
Winterhoek sandstone fynbos

Rooibos Tea
Bokkeveld sandstone fynbos
Cedarberg sandstone fynbos

Honey Bush Tea
Kouga grassy sandstone fynbos
Kouga sandstone fynbos
Tsitsikamma sandstone fynbos

We calculated the proportion of untransformed harvestable vegetation types outside state protected areas in each quaternary catchment. The higher the proportion the greater the weight assigned.

ii) Other harvestable products (Karoo)

A range of plant products are harvested in the karoo biomes including fuel wood, fibre, aloe leaves, herbs and medicinal plants but it is difficult to determine where harvesting takes place.

The riverine woodlands of the karoo are the main source of fuel wood. We used a combination of buffered 1: 500 000 rivers, where the buffer width was 10x the Strahler (1952) river order in metres, and azonal vegetation types as mapped by Mucina and Rutherford (2006) to estimate the area where fuel wood species are found. We then removed all the transformed areas based on the National Land Cover Database 2000. We calculated the remaining woodland area as a proportion of each quaternary catchment. The greater the proportion the greater the weight allocated to the quaternary catchment.

iii) Grazing

The relative value of the land for livestock production was estimated by calculating the grazing potential of quaternary catchments. This potential was derived from Scholes' (1998) estimates of sustainable mean domestic livestock production (Table 5). This approach may underestimate the carrying capacity for browsing antelope but as game farming only occurs in limited areas this would not significantly affect the outcome.

Table 5: Grazing potential classes in large livestock units (LSU) per km² (Scholes 1998).

LSU range	LSU mid-point
0 - 1	0.5
1 - 2	1.5
2 - 3	2.5
3 - 4	3.5
4 -6	5
6 - 8	7
8 – 10	9
10 -14	12
14 - 18	16
18 - 22	20

We assumed that only untransformed (natural) vegetation would support livestock, and deducted the area of transformed vegetation (National Land Cover Database 2000) from the vegetation cover layer in each catchment before the above calculation was made.

We took the midpoint of each class, and multiplied it by the remaining area in that class in each quaternary catchment to get an area weighted mean grazing capacity. Catchments were prioritized according to the relative weights where the weights equalled the mean grazing capacity.

Calculating the weights used by the Export Choice Software

The Expert Choice software (Anon 2002) requires the weights of alternatives (quaternary catchments in this case) to be expressed as proportions that sum to one. For each of the criteria and sub-criteria used by the AHP model (Figure 4) we calculated the sum of the value for the corresponding variable for each quaternary catchment. Each quaternary catchment's value was then divided by the corresponding total to give the final weight.

4. RESULTS

The quaternary catchments prioritised for the clearing of invasive alien plants are presented for primary catchments; G_1 (Berg River), G_2 (Overberg), H (Breede River) and K (Garden Route) in a series of maps and bar diagrams. These show both the location and ranking of these quaternary catchments with respect to the goal of the study namely: To reduce and control invasive alien plants to minimise their negative impacts on the natural resources of the Western Cape (see Figure 4). The top ranking catchments mostly have a high proportion of protected areas on state land (maintaining the gains), high water yields and relatively high water flow reductions due to current invasions by alien plants.

4.1 PRIMARY CATCHMENT E (OLIFANTS / DORING)

In the catchment of the Olifants and Doring rivers (E) the five catchments with the highest relative importance rankings are; E10H, E 21K, E24A, E10A and E10C (see Figures 5 and 6). These are located in the higher rainfall areas of the Groot Winterhoek Mountains and the Cedarberg. The comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for primary catchment E indicates that are well aligned (see Figure 7). However there are no currently budgeted projects in catchments E10H, E21K, E24A, E10A and E10C which are all in the top five priority catchments identified in primary catchment E.

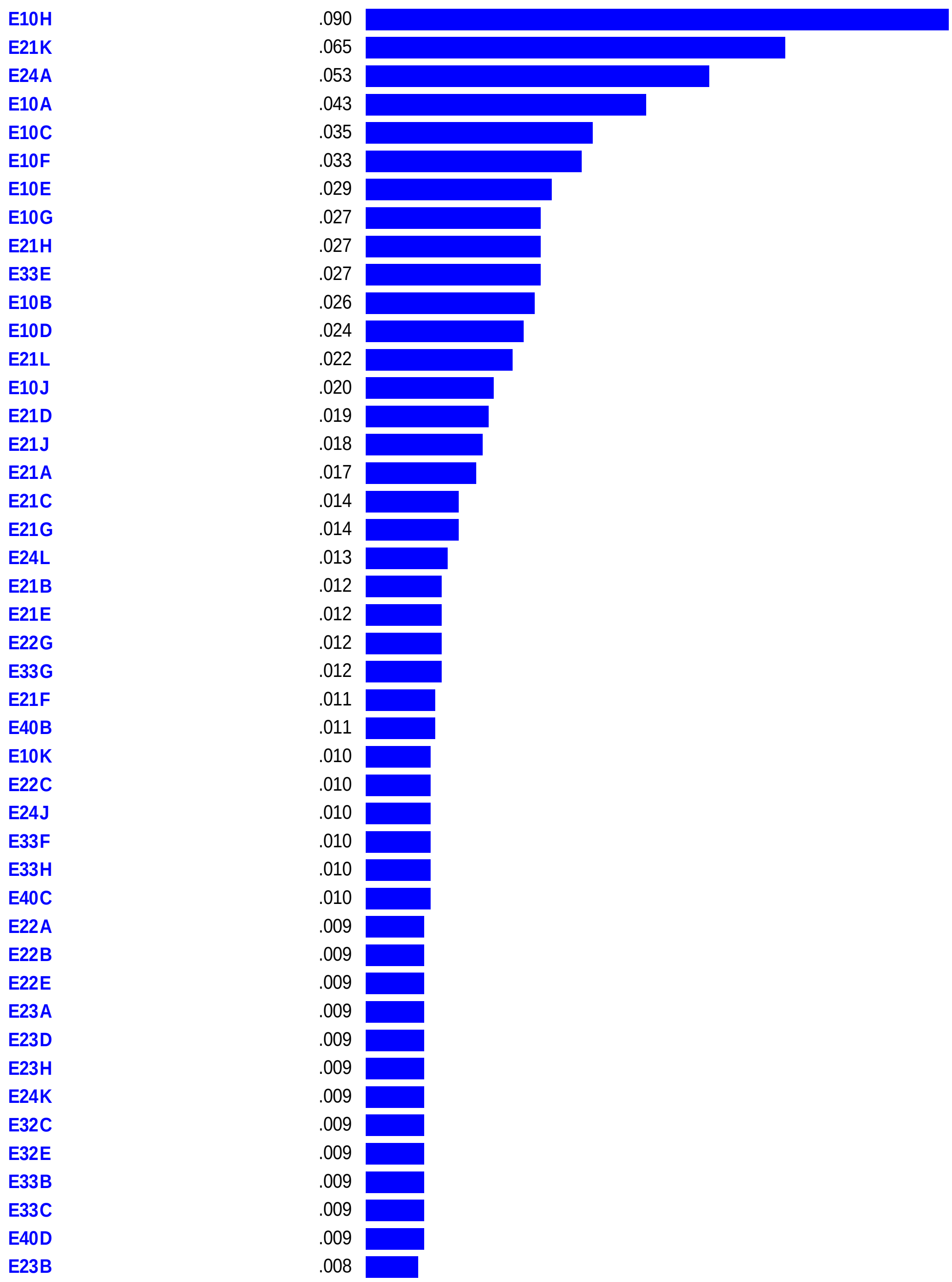

Figure 5: ***The relative importance and ranking of the top 45 of 63 quaternary catchments in the portion of primary catchment E (Olifants and Doring rivers) within the Western Cape Province and quaternary catchments E32A, B, C and E40A and B from the Northern Cape Province.***

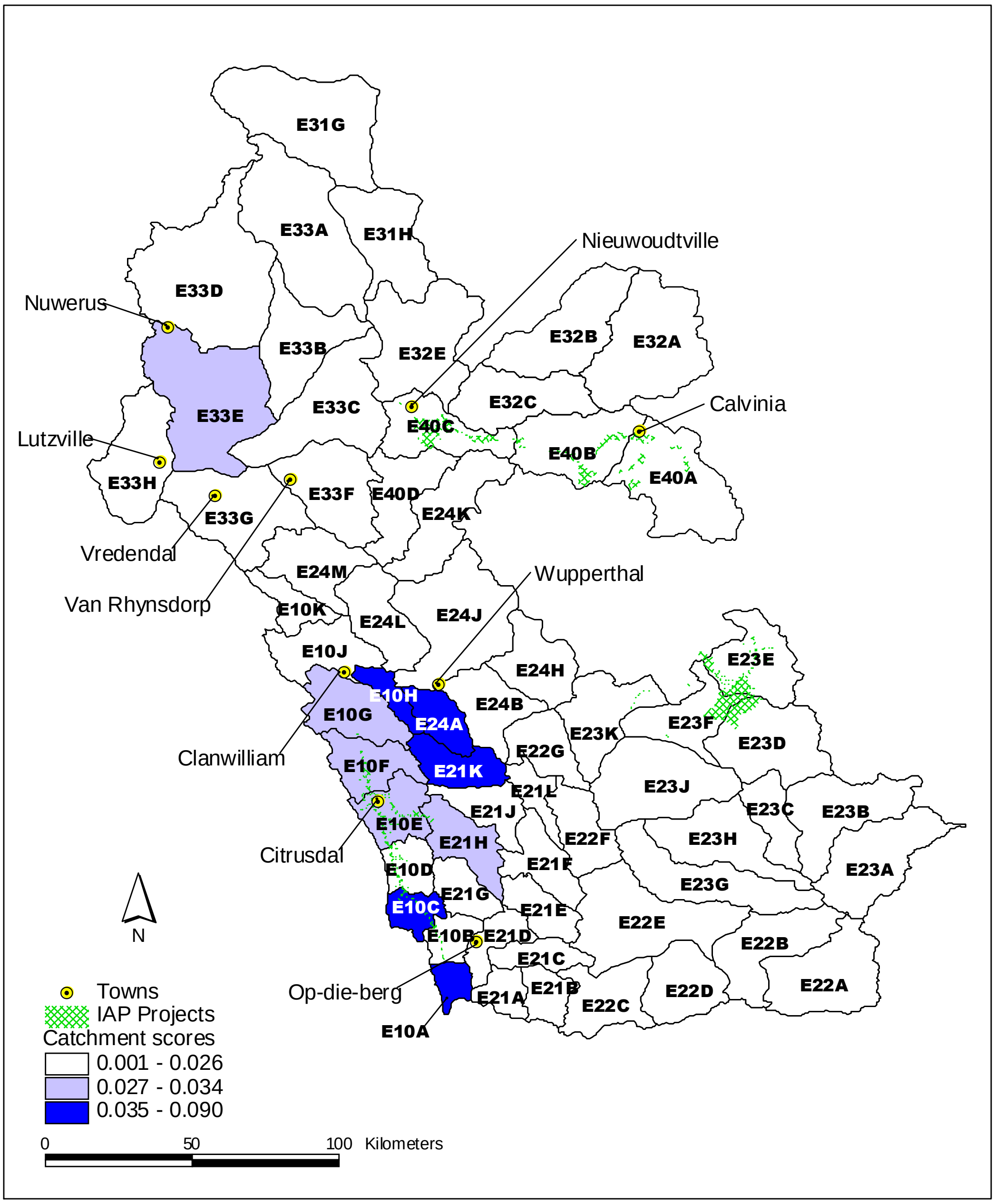

Figure 6: ***Catchment (AHP) scores for each of the quaternary catchments or portions thereof in primary catchment E (Olifants / Doring) within the Western Cape Province and quaternary catchments E32A, B, C and E40A and B from the Northern Cape Province. Darker shading indicates catchments having a higher priority for clearing invasive alien plants. Green hatching shows where both current and past clearing projects managed by CapeNature, SA National Parks and the Working for Water Programme are located.***

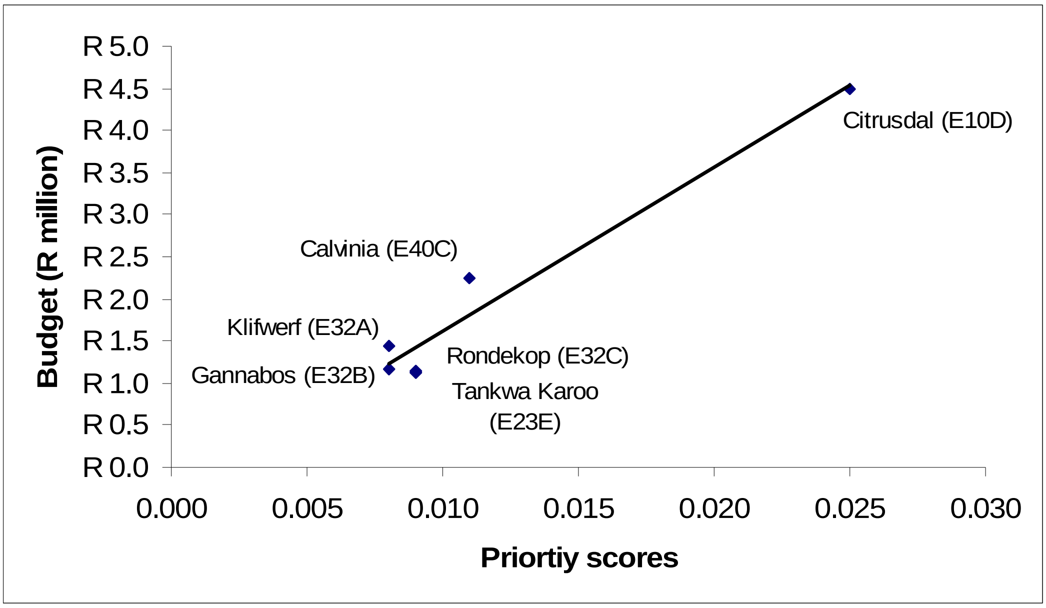

Figure 7: ***The 2009/10 budget for IAP clearing projects in primary catchment E in relation to priorities identified in this study (see Figure 5). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.***

4.2 PRIMARY CATCHMENT G_1 (BERG RIVER PORTION)

In the Berg River catchment (G_1) the five quaternary catchments with the highest relative importance rankings are; G10B, G10G, G22A, G22F and G10A (see Figures 8 and 9). These are located in the high rainfall Boland Mountains and on the Cape Peninsula. The comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for catchment G_1 (see Figure 8) indicates that they are mostly well aligned (see Figure 10). The "Asbos" project in quaternary catchment G10A appears to be receiving a disproportionate amount of the budget allocation but this is because: (a) it is the catchment of the newly completed "Berg" River Dam, (b) it was heavily infested especially in the riparian zones and (c) a commercial plantation was decommissioned as part of the development of the dam. However there are no projects at present in catchments G22F (Jonkershoek) or G10G (Twenty-Four Rivers) which are both in the top five priority catchments identified in catchment G_1.

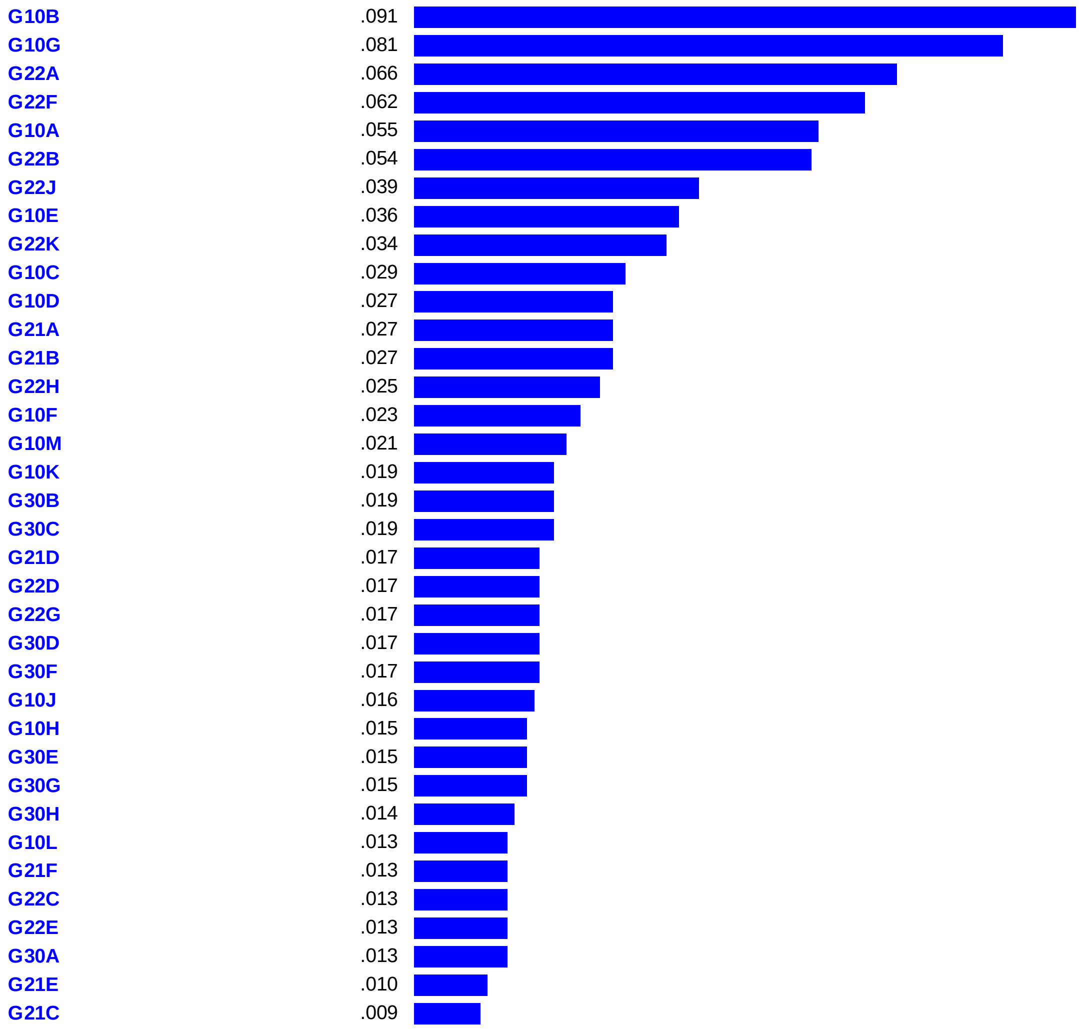

Figure 8: ***The relative importance and ranking of the 36 quaternary catchments in the primary catchment G_1 (Berg River).***

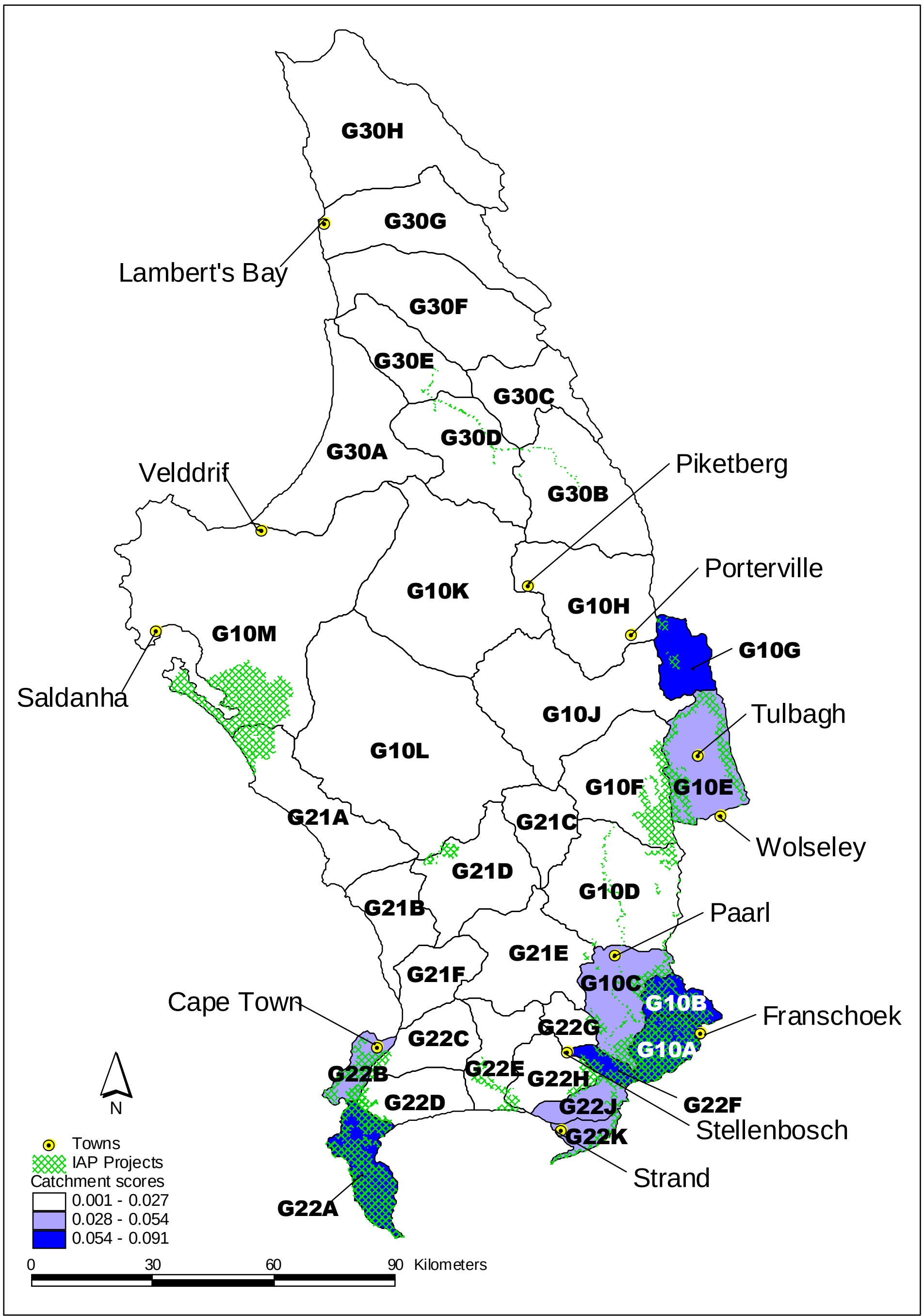

Figure 9: ***Catchment (AHP) scores for each of the quaternary catchments in primary catchment G_1 (Berg River). Darker shading indicates catchments having a higher priority for clearing invasive alien plants. Green hatching shows where both current and past clearing projects managed by CapeNature, SA National Parks and the Working for Water Programme are located***

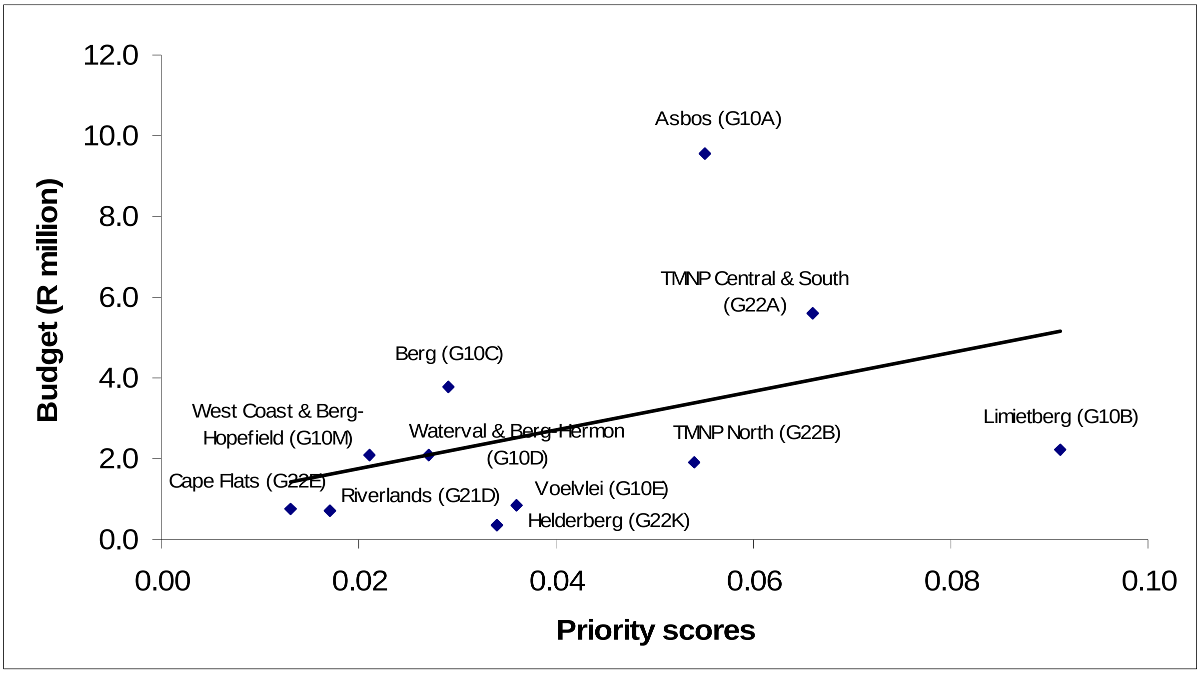

Figure 10: ***The 2009/10 budget for IAP clearing projects in the G_1 (Berg) portion of primary catchment G in relation to priorities identified in this study (see Figure 8). The alignment is shown by deviations from the trend line. Each project's quaternary catchment is given in parentheses after the project name.***

4.3 PRIMARY CATCHMENT G_2 (OVERBERG PORTION)

In the Overberg (G_2) the five most important quaternary catchments are; G40A, G50K, G40B, G40D and G40C (see Figures 11 and 12). Three of these are in the Hottentots Holland Mountains and have a high rainfall while the remaining two are situated adjacent to the coast where conservation factors are important. The comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for catchment G_2 (see Figure 11) indicates that they are mostly well aligned (see Figure 13). The trend line indicates that the budget allocations are not well aligned with the priorities identified by this study. Steenbras and De hoop projects are located in quaternary catchments which have high priorities but are under funded compared with others. The Cape Agulhas project is located in a high priority catchment and is receiving a large budget, probably because it is situated within a national park. There are no projects at present in G40D (Grabouw area) which falls within the top five quaternary catchments

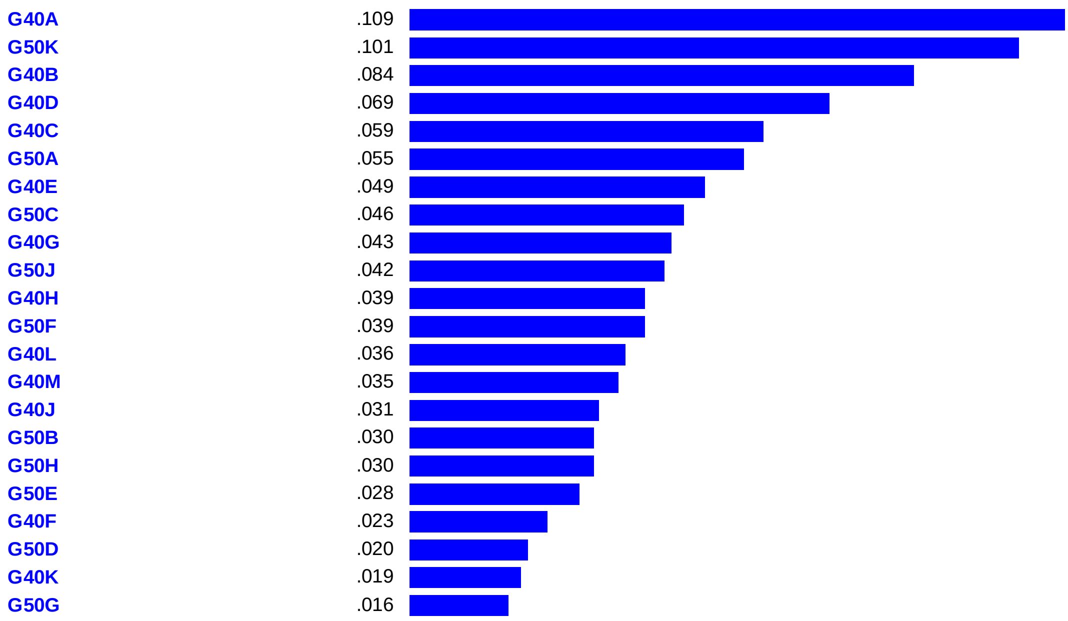

Figure 11: ***The relative importance and ranking of the 22 quaternary catchments in primary catchment G_2 (Overberg).***

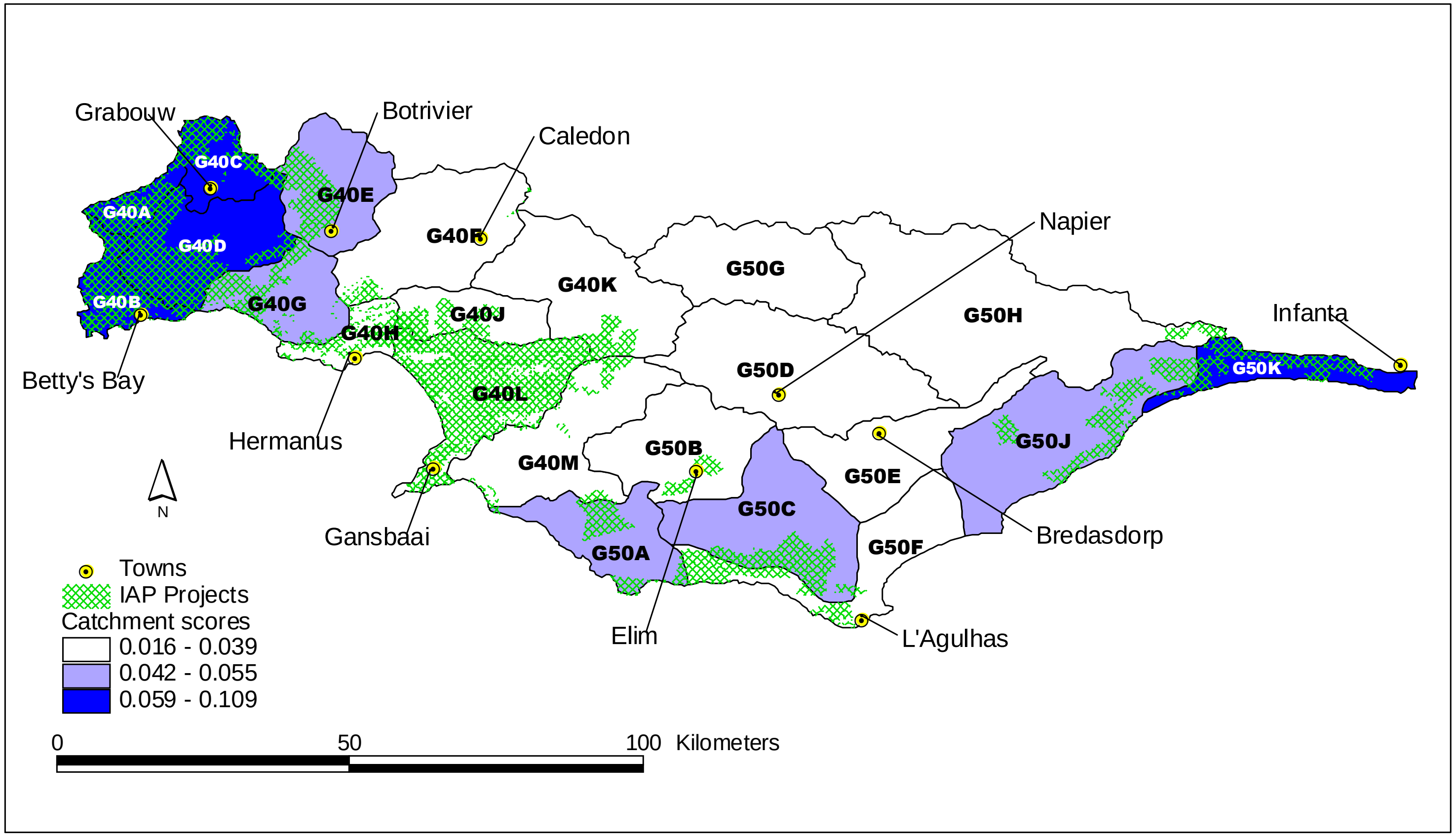

Figure 12: ***Catchment (AHP) scores for each of the quaternary catchments in primary catchment G_2 (Overberg). Darker shading indicates catchments having a higher priority for clearing invasive alien plants. Green hatching shows where current and past clearing projects managed by CapeNature, SA National Parks and the Working for Water Programme are located.***

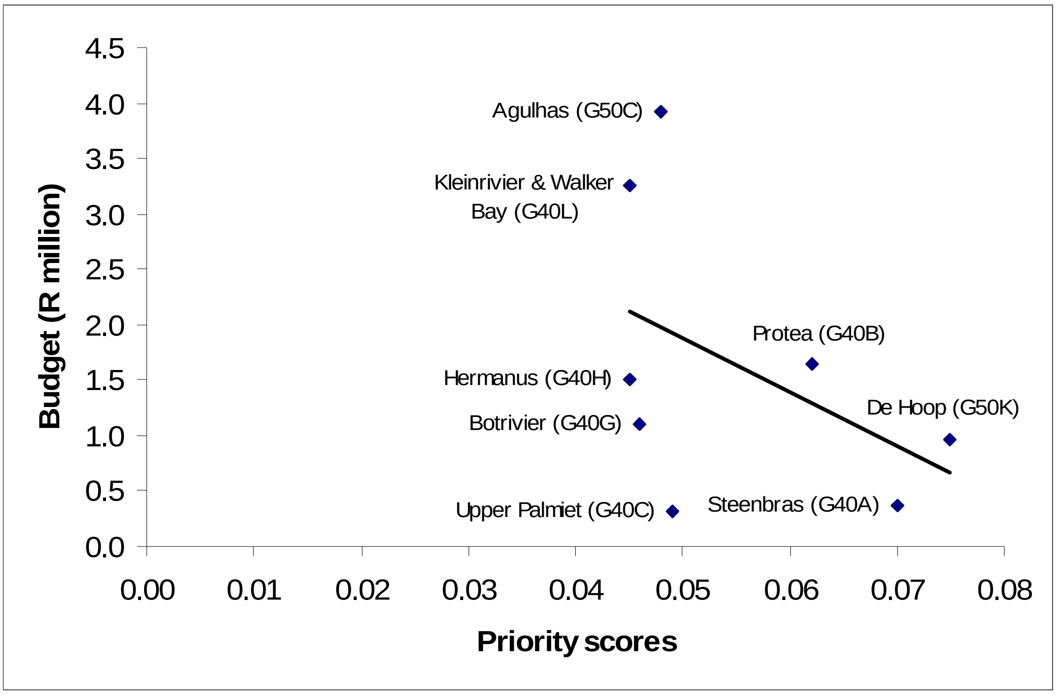

Figure 13: ***The 2009/10 budget for IAP clearing projects in G_2 (Overberg) portion of primary catchment G in relation to priorities identified in this study (see Figure 11). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.***

4.4 PRIMARY CATCHMENT H (BREEDE RIVER)

The five most important quaternary catchments primary catchment H are found in the mountainous head waters of the Breede River. These are; H10E, H60B, H60A, H10D and H10K (see Figures 14 and 15). A comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for catchment H (see Figure 14) indicates that they are, in some cases, well aligned (see Figure 16) but most are either over or under budgeted for in relation to priorities. There are no projects at present in quaternary catchments H60A, H10D and H10K even though they all fall in the top five priorities. Catchment H10D (near Ceres) and H10K (near Rawsonville) are both located in the upper reaches of the Breede River while H60A in the catchment of the Riversonderend River. All the current projects fall within the top half of the priority ranking for the 69 quaternary catchments.

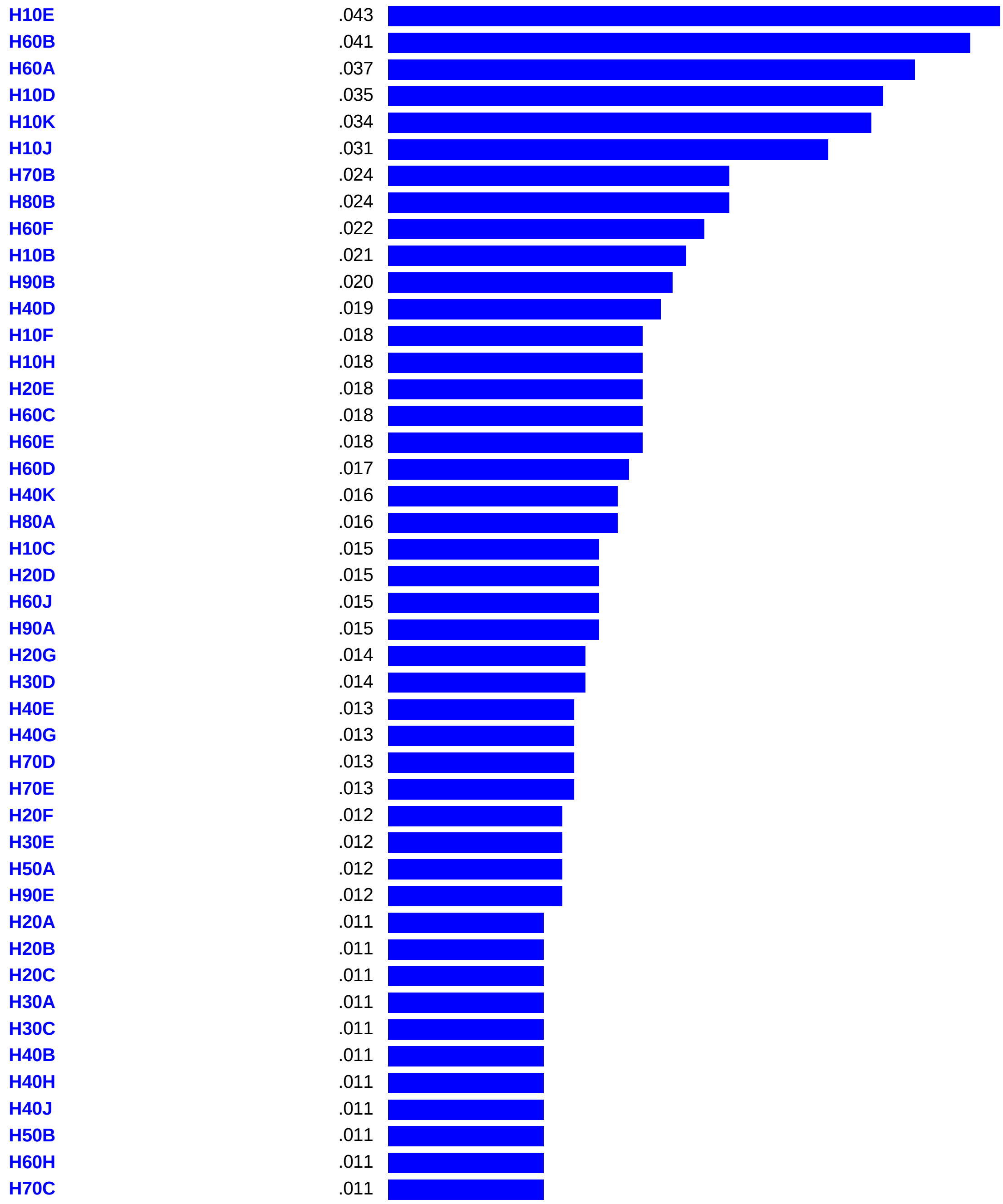

Figure 14: ***The relative importance and ranking for 45 of the 69 quaternary catchments in the primary catchment H (Breede River)***

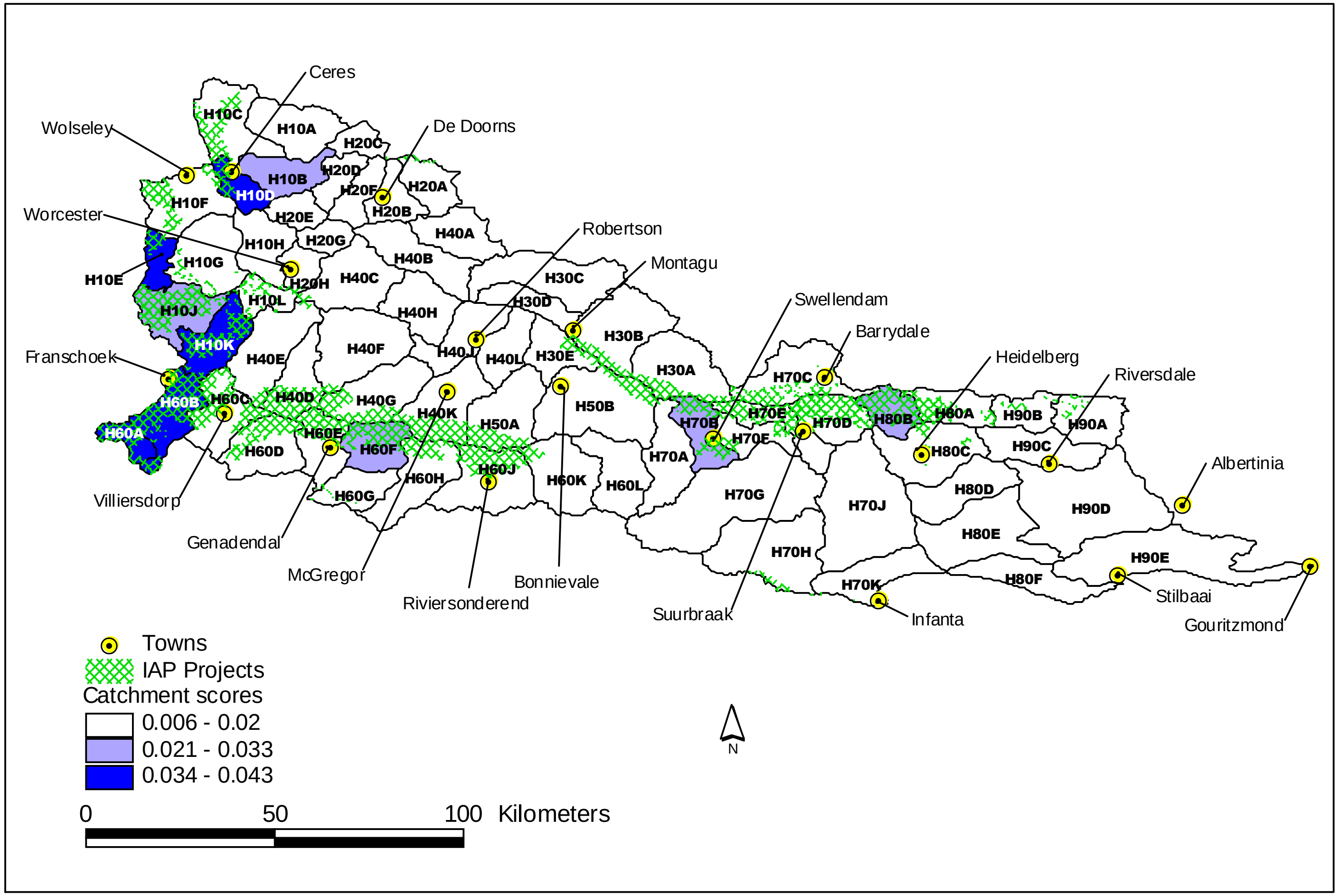

Figure 15: *Catchment (AHP) scores for each of the quaternary catchments in primary catchment H. (Breede River). Darker shading indicates catchments having a higher priority for clearing invasive alien plants. Green hatching shows where current and past clearing projects managed by CapeNature, SA National Parks and the Working for Water Programme are located.*

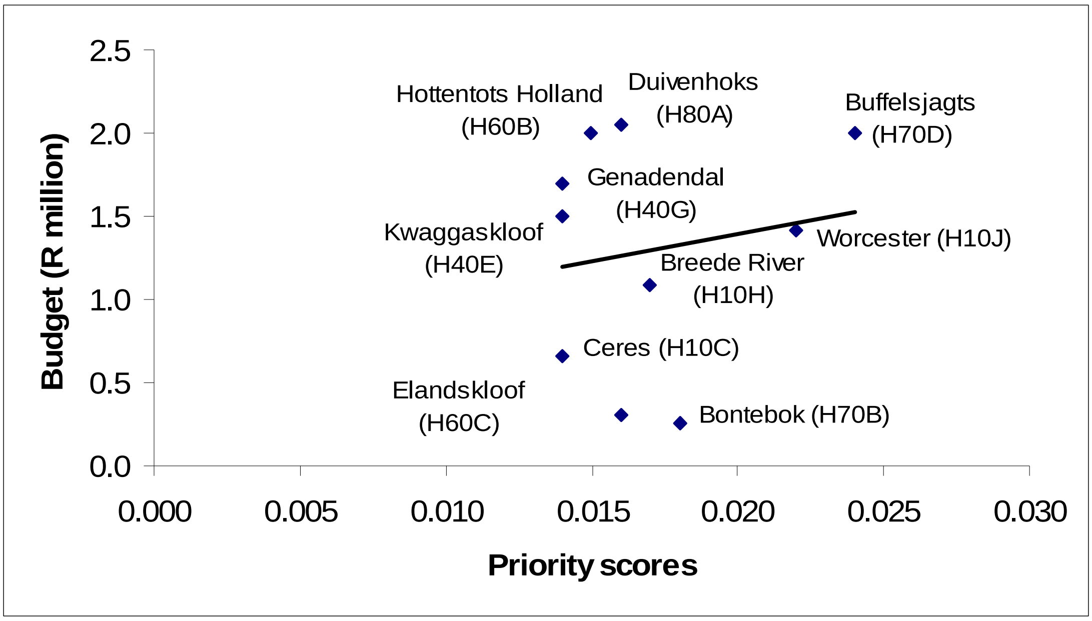

Figure 16: ***The 2009/10 budget for IAP clearing projects in primary catchment H in relation to priorities identified in this study (see Figure14). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.***

4.5 PRIMARY CATCHMENT J (GOURITZ RIVER)

Unlike the other primary catchments the Gouritz River catchment (J) is mostly within the Nama and succulent Karoo biomes. Here the five quaternary catchments having the highest importance rankings are: J25A, J12A, J22J, J33B and J12G (see Figures 17 and 18). These are located mainly in the proximity of the Swartberg mountain range with the exception of J22J which is in the Great Karoo. A comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for catchment J indicates that they are poorly aligned (see Figure 19) with many of the projects situated in low priority catchments. Only the Kammanassie project in quaternary catchment J35B is in a catchment listed in the top five priorities and catchments J25A, J12A, J22J and J12G have no budgeted projects at present. The Uniondale project, which has the largest budget, is located in a medium priority catchment but this catchment is adjacent to others which have fairly high to high priorities.

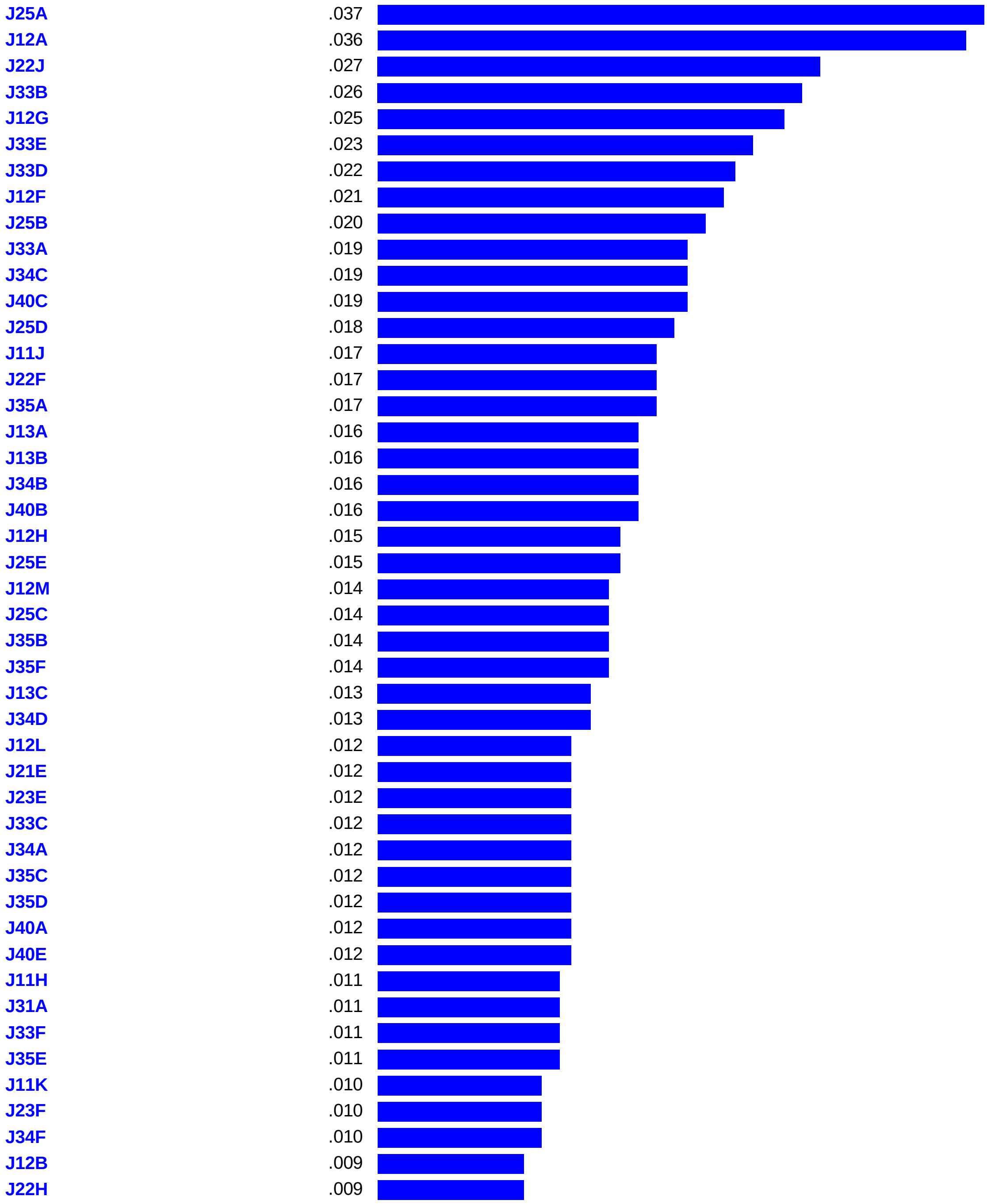

Figure 17: ***The relative importance and ranking of 46 of the 91 quaternary catchments in the portion of primary catchment J (Gouritz River) within the Western Cape Province.***

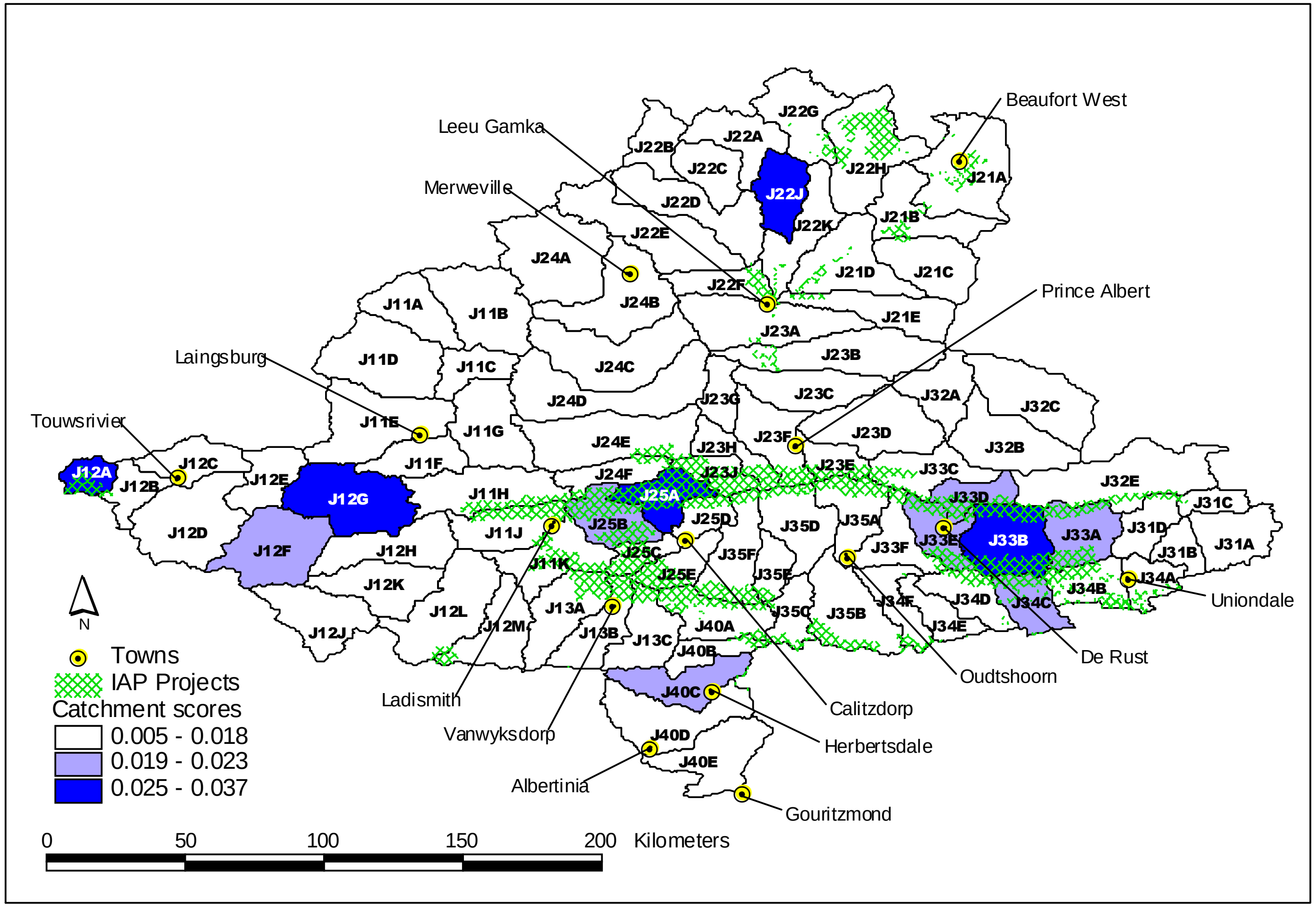

Figure 18: ***Catchment (AHP) scores for each of the quaternary catchments or portions thereof in primary catchment J (Gouritz River) in the Western Cape Province. Darker shading indicates catchments having a higher priority for clearing invasive alien plants. Green hatching shows where current and past clearing projects managed by CapeNature, SA National Parks and the Working for Water Programme are located.***

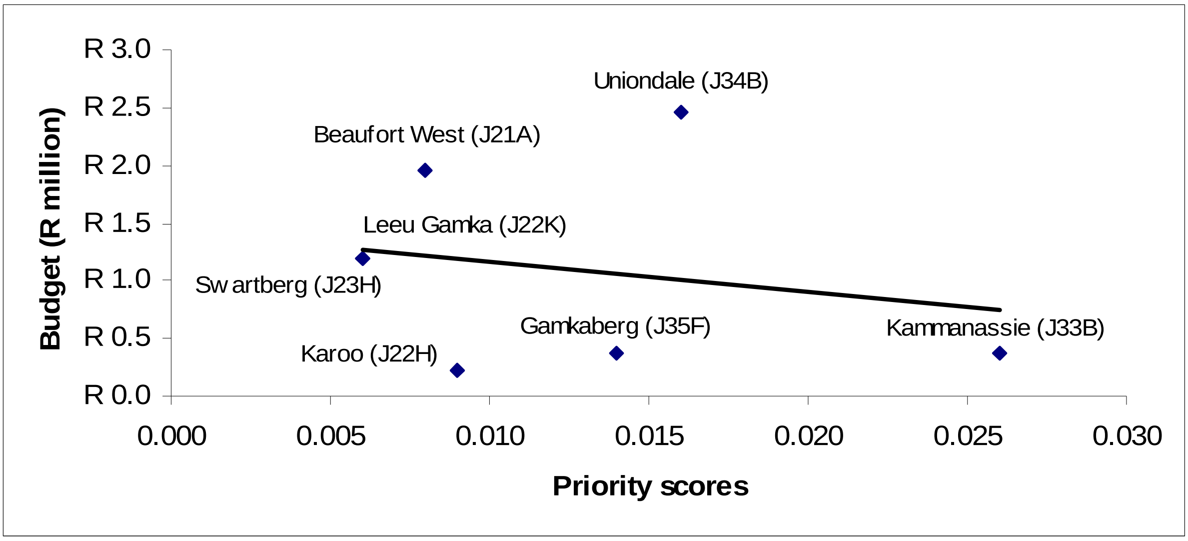

Figure 19: ***The 2009/10 budget for IAP clearing projects in primary catchment J in relation to priorities identified in this study (see Figure 17). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.***

4.6 PRIMARY CATCHMENT K (GARDEN ROUTE)

Along the Garden Route (K) the five most important quaternary catchments are; K60D, K70B, K30C, K30D and K60B (see Figures 20 and 21). These include the Tsitsikamma mountain range to the east of Plettenberg Bay that also border on the Langkloof. A comparison of the planned expenditure for the 2009/10 financial year and the priorities defined by this study for catchment K (see Figure 20) indicates that there is no discernable trend (see Figure 22). Catchments with similar priorities currently have vastly differing budgets.

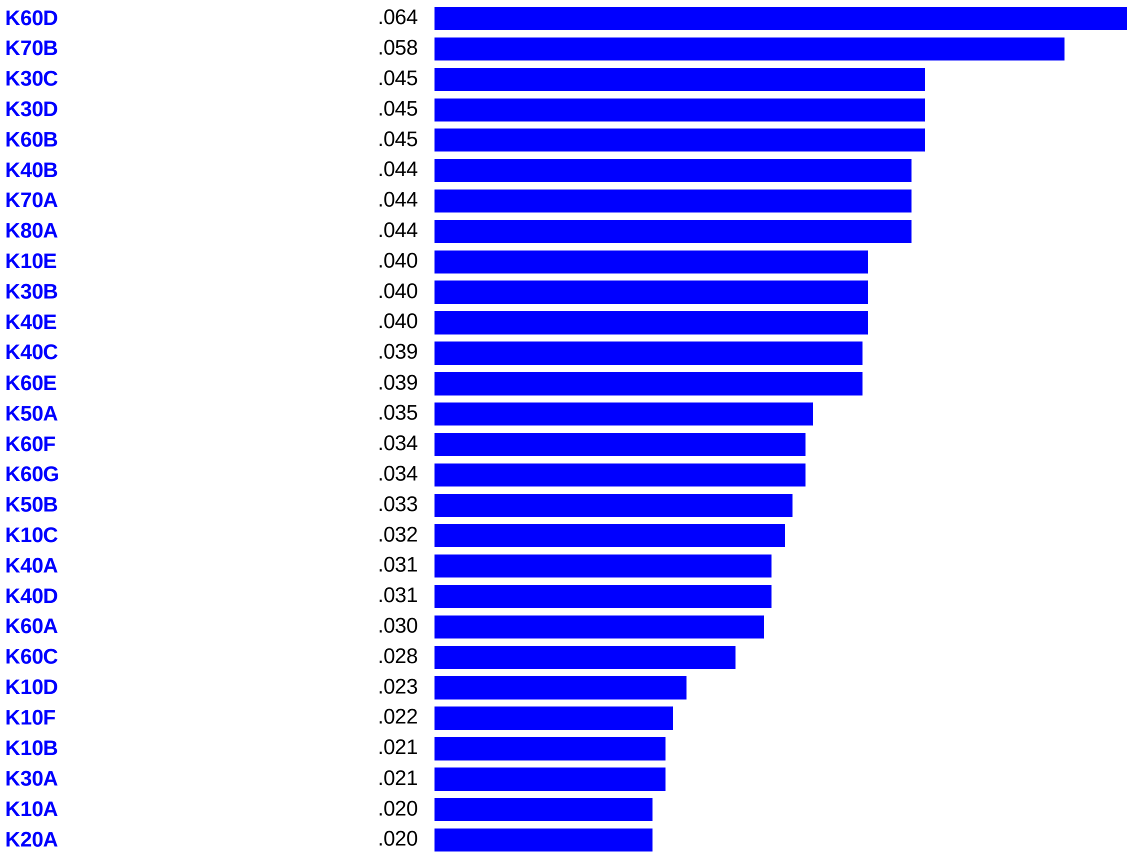

Figure 20: ***The relative importance and final ranking of the 28 quaternary catchments in the portion of primary catchment K (Garden Route) in the Western Cape Province and quaternary catchment K80A in the Eastern Cape Province.***

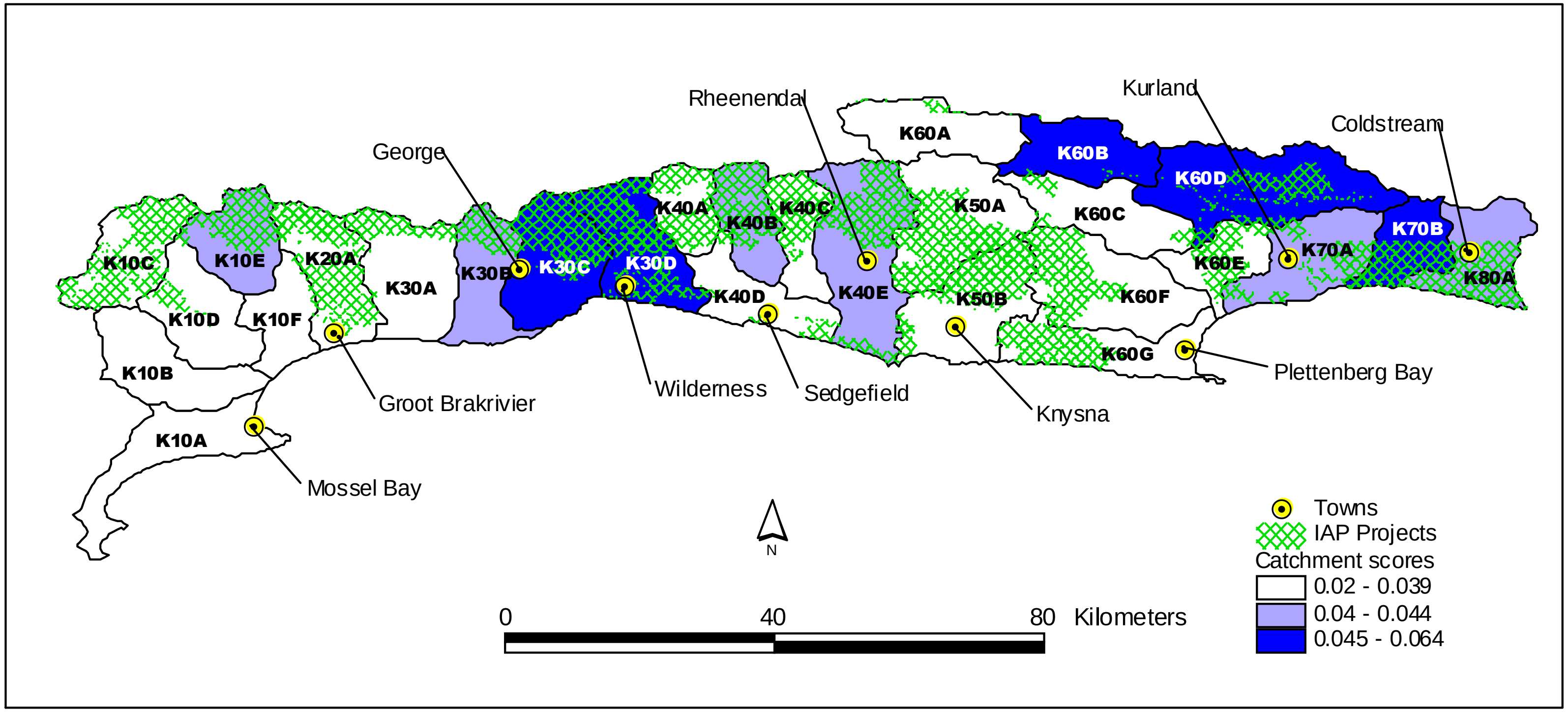

Figure 21: ***Catchment (AHP) scores for each of the quaternary catchments in the portion of primary catchment K (Garden Route) in the Western Cape Province and quaternary catchment K80A in the Eastern Cape Province. Darker shading indicates catchments having a higher priority for clearing invasive alien plants. Green hatching shows where the current and past clearing projects managed by CapeNature, SA National Parks and the Working for Water Programme are located.***

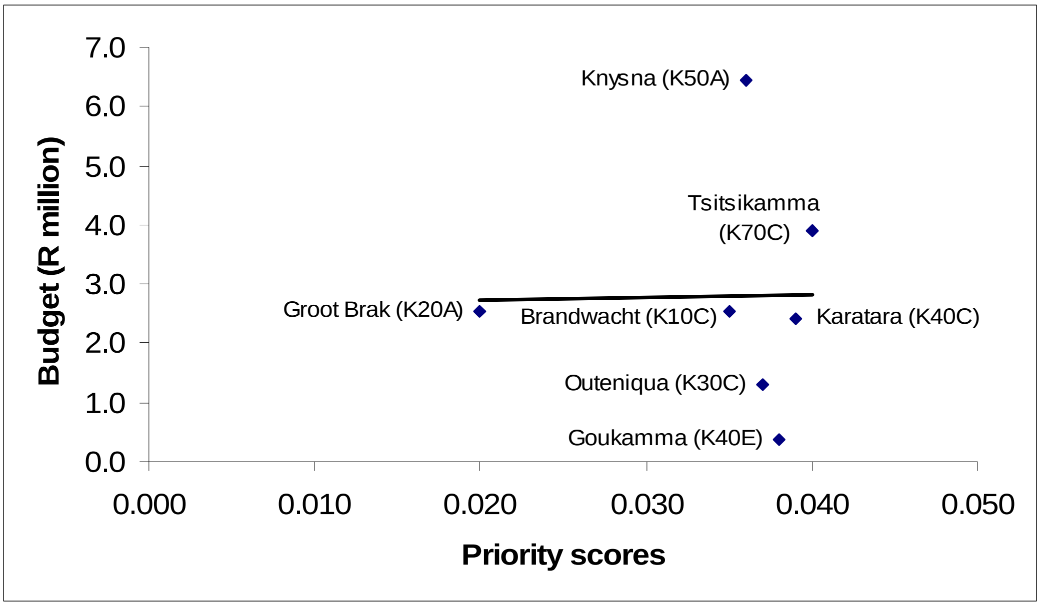

Figure 22: ***The 2009/10 budget for IAP clearing projects in primary catchment K in relation to priorities identified in this study (see Figure 20). The alignment is shown by the deviation from the trend line. Each project's quaternary catchment is given in parentheses after the project name.***

4.7 OVERVIEW OF WESTERN CAPE PRIORITY QUATERNARY CATCHMENTS

The top five priority quaternary catchments in each of the main primary catchments within the Western Cape Province are shown in Figure 23. The highest priority catchments are mainly those that occur in mountainous areas, yield large volumes of water and supply the major domestic, industrial and agricultural water schemes in the province.

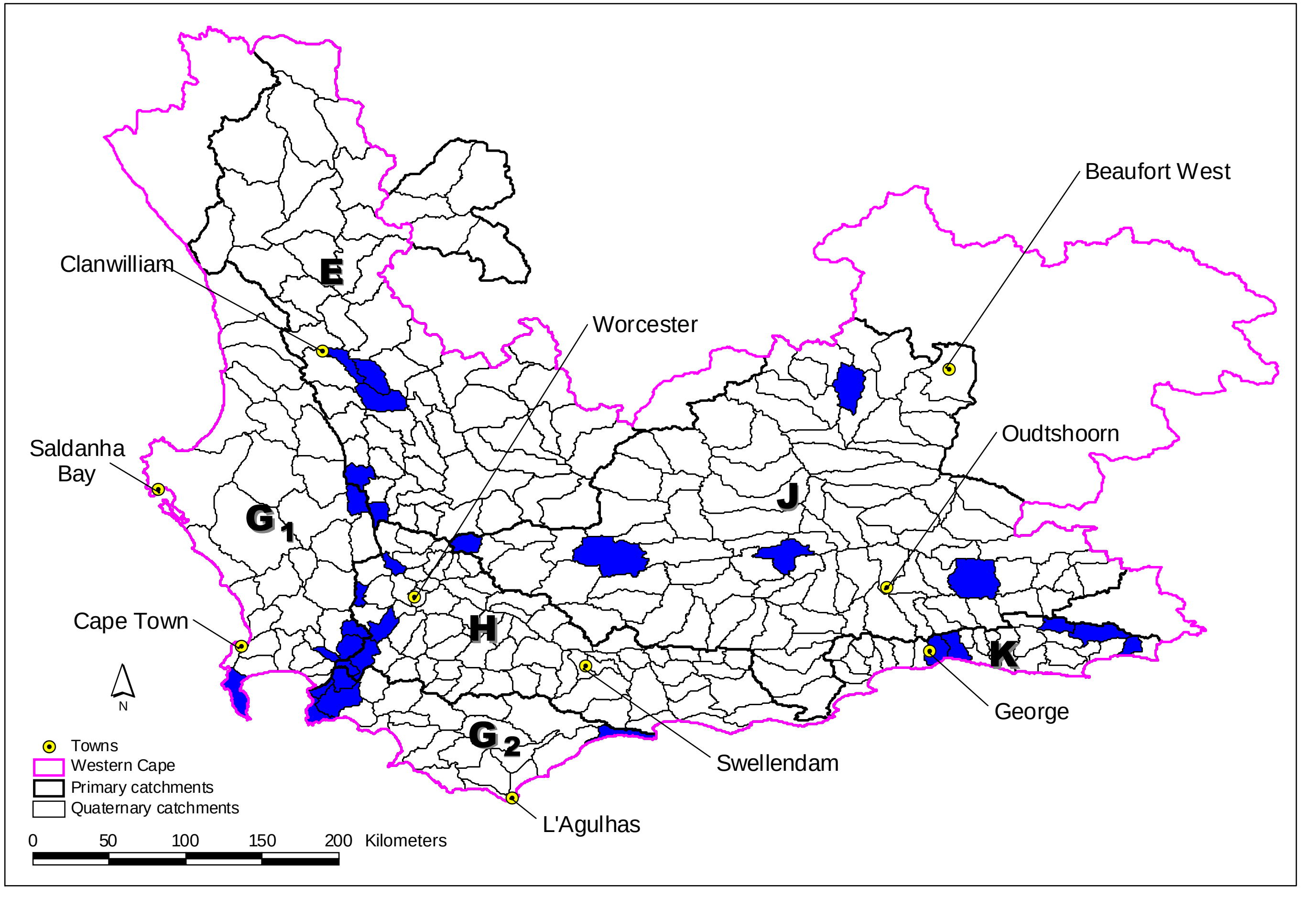

Figure 23: ***The five top priority quaternary catchments identified (dark shading) within each of the major primary catchments (labelled) of the Western Cape***

5. CONCLUSIONS

This study has identified the highest priority for managing invasive alien plants within each major primary in the Western Cape and compared them with the current budget allocations. In some cases, primary catchments E and G_1, the priorities and budgets are well aligned but in others, primary catchments G_2, H, J and K, they are not to varying degrees. The regional Working for Water planning team needs to assess how best to improve the current alignment between budgets and priority catchments over time.

The study by van Wilgen et al. (2008) assigned priorities to each of those primary catchments, giving the highest priority to catchment G_1 followed by H. This indicates that out of the overall funding for the Western Cape that more funding should be allocated to G1 than to H. Even though the top priority quaternary catchment identified in Primary catchment H may have a higher score than its counterpart in G1, it should still receive a lower allocation than the top priority in G1. The reason for this is that each primary catchment contains a different number of quaternary catchments and the values for attributes e.g. mean annual run-off, flower harvesting potential differ between quaternary and primary catchments.

The techniques we have developed to determine the priority areas for clearing invasive alien plants at a quaternary catchment scale are workable and the results correspond with what we would intuitively expect. The difference being that the method allows for evaluation of the individual data elements contributing to each score assigned by the Expert Choice (AHP) software.

An advantage of using AHP is that it can handle a large number of alternatives enabling comparisons to be made on any number of quaternary catchments.

Our answers are as good as the underlying spatial datasets but as new or revised datasets become available they can easily be accommodated by the hierarchy model and used to generate a revised set of rankings (catchment scores).

On the other hand, as our understanding improves we can adjust the weightings assigned to the criteria and sub-criteria in the hierarchy model, and we can add or remove criteria and sub-criteria.

This study has made us aware of a number of shortcomings regarding the available spatial data and, in other instances, the lack of appropriate spatial data to represent the criteria and sub-criteria that were considered important by the experts. For example, the NBAL data is only available in areas where Working for Water has active projects. This problem should be eliminated when the National Invasive Alien Plant Survey becomes available. Other examples include the use of surrogate data, the limitations of Rouget's climate based models for determining the potential distribution of invasive alien plants, and the lack of information on the spatial distribution of harvested veld products.

6. RECOMMEDATIONS

This study has been successful in applying the approach developed by van Wilgen *et al.* (2008) at a quaternary catchment scale in the Western Cape. However, a number of follow-up actions will be needed if this approach is to deliver its full potential in terms of assisting the Working for Water Programme to improve its operations and its impact. With this in mind, we recommend the following:

- That the techniques developed at the primary and quaternary catchment scale be adopted by Working for Water's national and regional planning offices to assist with prioritization, planning, and the allocation of resources to both existing and new projects on an ongoing basis. This would assist in establishing a uniform approach to prioritization across the organization and allow for regular reassessments as needed and when new or improved datasets become available;

- Each Working for Water region should maintain existing datasets and revise them on a regular basis. This should not be longer than 3 years so as to coincide with the medium term expenditure framework (MTEF) of government.

- The priorities given in van Wilgen *et al.* (2008) should be used to guide the allocation of funds between the major primary catchments of the Western Cape. Then the priorities identified in this study should be used to allocate funds amongst the quaternary catchments.

- That as soon as the National Invasive Alien Plant Survey has been completed by the Agricultural Research Council, the data on current state of invasion should replace the Versfeld *et al.* (1998) flow reduction data we have used for in this study;

- That a spatial database be developed to underpin effective comparisons of areas. This database could contain data relating to most of the criteria identified here, including mean annual runoff, the locality of important groundwater aquifers, the degree of water stress, conserved areas, areas of threatened or critically threatened conservation importance, livestock production potential, the distribution of invasive alien species, land ownership, and the location of poverty nodes. We recommend using the Working for Water Information Management System (WIMS) to store the necessary data;

- That a presentation should be given to senior managers in the Working for Water Programme, with a view to (i) raising awareness of the study and its implications for decision-makers and planners within the programme; (ii) obtaining input regarding its adoption and/or modification, and (iii) agreeing on the process for its possible adoption and implementation elsewhere in the country; and

- That this work be published in the peer-reviewed literature. This will have a number of advantages, including (i) ensuring that the work is subjected to rigorous review; (ii) ensuring a permanent and widely-retrievable record of the work; and (iii) enabling the wider dissemination of the approach and results, particularly to other organizations involved in control operations.

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APPENDICES

APPENDIX 1: PRIORITY INVASIVE ALIEN PLANTS IN THE FYNBOS, NAMA KAROO AND SUCCULENT KAROO BIOMES

(A) The 23 invasive alien plant taxa selected for prioritization in the fynbos biome listed in order of importance (van Wilgen, Forsyth and Le Maitre, 2008)

Species	Life form	Rank
Acacia mearnsii (black wattle)	Medium evergreen tree	1
Pines (*Pinus halepensis*, Aleppo pine; *Pinus pinaster*, cluster pine; and *Pinus radiata*, Monterey pine).	Tall evergreen coniferous trees	2
Populus canescens (grey poplar)	Tall deciduous tree	3
Acacia pycnantha (golden wattle)	Medium evergreen tree	4
Acacia longifolia (long leaved wattle)	Medium evergreen tree	5
Acacia saligna (Port Jackson willow)	Medium evergreen tree	6
Paraserianthes lophantha (stink bean)	Medium evergreen tree	7
Eucalyptus camaldulensis (red river gum)	Tall evergreen tree	8
Eucalyptus cladocalyx (sugar gum)	Tall evergreen tree	9
Solanum mauritianum (bugweed)	Small tree	10
Lantana camara (lantana)	Shrub	11
Leptospermum laevigatum (Australian myrtle)	Medium evergreen tree	12
Acacia cyclops (red eye)	Medium evergreen tree	13
Hakea sericea (silky hakea)	Tall evergreen shrub	14
Hakea gibbosa (rock hakea)	Tall evergreen shrub	15
Acacia melanoxylon (blackwood)	Tall evergreen tree	16
Arundo donax (giant reed)	Tall reed	17
Eucalyptus lehmannii (spider gum)	Medium evergreen tree	18
Hakea drupacea (sweet hakea)	Tall evergreen shrub	19
Cortaderia selloana (Pampas grass)	Tall evergreen tussock grass	20
Pennisetum setaceum (fountain grass)	Tufted perennial grass	21
Rubus fruticosus (European blackberry)	Thorny shrub	22
Pennisetum clandestinum (Kikuyu grass)	Perennial grass	23

(B) The 18 invasive alien plant taxa selected for prioritization in the Nama and succulent karoo biomes listed in order of importance (van Wilgen, Forsyth and Le Maitre, 2008)

Species	Life Form	Occurrence	Rank
Prosopis x glandulosa (mesquite)	Multi-stemmed small tree	Nama and succulent karoo	1
Eucalyptus camaldulensis (red river gum)	Tall evergreen tree	Nama karoo, succulent karoo and fynbos transition	2
Populus x canescens (grey poplar)	Tall deciduous tree	Nama karoo, succulent karoo and fynbos transition	3
Arundo donax (giant reed)	Tall reed	Nama karoo, succulent karoo and fynbos transition	4
Nerium oleander (oleander)	Multi-stemmed evergreen shrub	Succulent karoo and fynbos transition	5
Tamarix ramosissima (pink tamarisk)	Small evergreen tree	Nama karoo, succulent karoo and fynbos transition	6
Schinus molle (pepper tree)	Evergreen tree	Nama and succulent karoo	7
Myriophyllum spicatum (spiked water-milfoil)	Rooted submerged water plant	Nama and succulent karoo	8
Cacti without effective bio-control agents	Spiny and un-armed succulent shrubs	Nama and succulent karoo	9
Casuarina equisetifolia (beefwood)	Tall evergreen tree	Nama karoo, succulent karoo and fynbos transition	10
Annual grasses	Annual grass	Succulent karoo and fynbos transition	11
Caesalpinia gilliesii (bird-of- paradise bush)	Large shrub	Nama karoo	12
Pinus halepensis (Aleppo pine)	Tall evergreen coniferous tree	Nama karoo and fynbos transition	13
Cacti with effective bio-control agents	Spiny and un-armed succulent shrubs	Nama and succulent karoo	14
Atriplex nummularia (old man saltbush)	Erect multi-stemmed shrub	Succulent karoo	15
Pennisetum setaceum (fountain grass)	Tufted perennial grass	Nama karoo, succulent karoo and fynbos transition	16
Xanthium spinosum (boetebos)	Much branched annual	Nama and succulent karoo	17
Solanum elaeagnifolium (Satan's bush)	Herbaceous shrublet with annual stems and perennial roots	Nama karoo	18

APPENDIX 2: PARTICIPANTS IN EXPERT WORKSHOPS

(A) STELLENBOSCH WORKSHOP

Participants in the workshop held at the CSIR, Stellenbosch on 23rd October 2008 to rank the importance of the criteria to use in prioritising quaternary catchments to clear of invasive alien plants in primary catchments E (Olifants), G (Berg) and H (Breede)

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(B) WILDERNESS WORKSHOP

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