BAVIAANSKLOOF - TSITSIKAMMA PAYMENT FOR ECOSYSTEM SERVICES: A FEASIBILITY ASSESSMENT

SYNTHESIS REPORT

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ACRU	Agricultural Catchments Research Unit
BCR	Benefit-Cost Ratio
BMR	Baviaanskloof Mega-Reserve
C.A.P.E.	Cape Action for People and the Environment
DWA	Department of Water Affairs
ECP	Eastern Cape Parks
GIB	Gamtoos Irrigation Board
IAPs	Invasive alien plants
NPV	Net Present Value
NMBM	Nelson Mandela Bay Municipality
PES	Payments for ecosystem services
PV	Present Value
QC	Quaternary Catchments
SANBI	South African National Biodiversity Institute
URV	Unit reference values
WfW	Working for Water

1. INTRODUCTION

There has been recognition that current unsustainable land use practices on extensively farmed land in the Baviaanskloof and Tsitsikamma[1] watersheds can be highly problematic for the sustainable supply of important ecosystem services. These practices may increase farm incomes, particularly in the short term, and are often understandable given the financial incentives faced by farmers. However, they generally deliver relatively poor returns and come at the expense of long term veld condition and overall water security for downstream water users including farmers and water-stressed urban areas of Port Elizabeth, Jeffery's Bay and Cape St. Francis.

An economy focused on conventional extensive farming has proven unsustainable within the study area, and consequently, there is growing interest in promoting a more nature-based economy centred on the sustainable supply of a wide range of valuable watershed or ecosystem services, such as tourism, carbon sequestration, baseflow enhancement, sediment reduction, flood damage control and game farming. Interest in a nature-based economy is, however, generally not sufficient to achieve lasting outcomes unless the financial incentives faced by land owners are altered. Payment for Ecosystem Services (PES) systems (particularly watershed services in this case) essentially offer the opportunity to achieve sustainable outcomes by re-aligning the incentives faced by land owners to better meet the needs of wider society. In this way, it is possible to move towards win-win outcomes for both land owners and wider society and move away from situations where conflicting interests dominate interactions.

In response to the potentially significant opportunity offered by PES systems, SANBI through its C.A.P.E. programme in association with Working for Water (WfW), engaged Futureworks! to broadly assess the feasibility of establishing a PES system in the Baviaanskloof and Tsitsikamma watersheds focused on water and carbon sequestration services. The intention of this assessment was to emulate and refine the pioneering ecological-hydrological-economic modelling that was done for the Maloti-Drakensberg, which identified the suite of services the watershed may supply and for which there is a real demand.

With respect to report structure, the next section discusses the research method applied in this study. This is followed by two sections discussing the sectors who are most likely to demand and supply watershed services. A section detailing the preferred land use management and restoration activities follows next, supported by a section dealing with the cost of these actions. The hydrological outcomes that result from these management interventions are dealt with next, followed by the results of an integrated ecological economic model and feasibility assessment. The study is concluded with a section on the implications of the study outcomes.

[1] The Tsitsikamma watershed is used to collectively refer to the Kouga and Kromme watersheds, which both originate in the Tsitsikamma Mountains. These two watersheds are discussed in greater detail in sections to follow.

2. METHODOLOGY

The methodology adopted was as follows (see Figure 2.1):

- ✓ Identify the watersheds for modelling (1).
- ✓ Identify the demand for watershed services focused on water-related services and carbon sequestration (7).
- ✓ Identify the economic benefits of the services demanded (8).
- ✓ Hold a workshop (in Cape St. Francis) with experts to identify the feasible management options for each of the vegetation types in the watersheds, assess the condition of the vegetation (based on observation and the available literature) and to develop a series of future scenarios to be modelled (2).
- ✓ Delineate quinaries in each of the quaternary catchments and identify their specific hydrological data (4).
- ✓ Overlay the vegetation types on the quinary layer to identify the extent and distribution of vegetation types in each quinary (5).
- ✓ Define detailed vegetation management options for watersheds (3), including revegetation (3a) and alien plant management (3b), and cost these options (3c).
- ✓ Model the hydrological responses to the management options (6).
- ✓ Compute the benefits and costs of changing the service levels supplied (9).
- ✓ Assess the feasibility of the different management options (10).

Further details on methods are available in the supporting documentation.

Please note that this document uses the term ‘watershed’ to denote the catchment or area that intercepts rainfall and generates drainage lines consisting of rivers and streams. The choice of the term watershed is intentional and aimed at differentiating this concept from the government’s institutional entities – Catchment Management Agencies – in order to avoid any confusion that may arise.

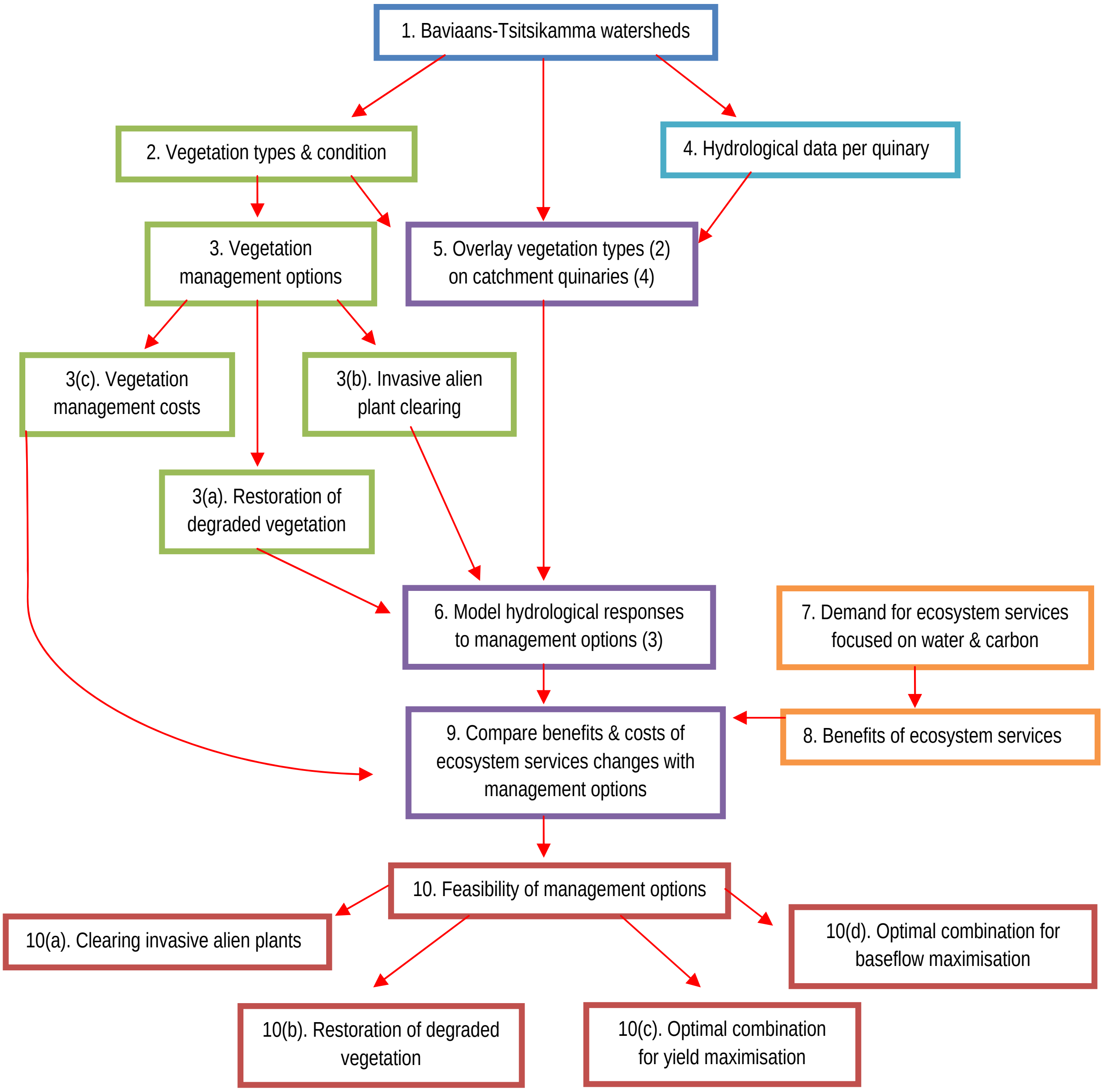


Figure 2.1: Schematic representation of the tasks undertaken in assessing the feasibility of a PES scheme in the region

3. DEMAND FOR WATER FROM BAVIAANSKLOOF AND TSITSIKAMMA WATERSHEDS

There are a number of factors, such as soil erosion, inappropriate burning, excessive livestock grazing, and extensive Invasive Alien Plant (IAP) infestations which impact negatively on the delivery of a sustained supply of high quality water within a watershed (Blignaut and Mander 2009). While the restoration and subsequent management of degraded lands can, and does improve the delivery of a suite of ecosystem goods and services, only a few of these services can have a direct and quantifiable economic benefit to a beneficiary who would be willing and able to pay for such service delivery.

The services commonly identified include water, carbon, and biodiversity (Blignaut and Mander 2008). Pagiola and Platatais (2007) refer to these marketable services as "umbrella services" because in attempting to improve the quantity and quality of such services, a host of others services are also addressed. This is an important point to consider as the greater the bundling of services, the greater the feasibility of payment for ecosystem to restore and maintain a greater portion of the watershed (Mander ed. 2008). Much work has been done on carbon within the study area (Mills *et al*. 2004, Mills *et al*. 2005, and Mills *et al*. 2006) and is incorporated into this assessment where relevant (for e.g., in order to understand synergies between bundled services). However, little knowledge currently exists for the biodiversity and water markets. Although the market for biodiversity credits is not well developed, the biodiversity market is linked, to some extent, to nature-based tourism, an actively promoted sector in the study area (Blignaut and Mander 2009). The focus of this feasibility study is therefore to assess the potential for the development of a market for water services within the Baviaans, Kouga, and Kromme Watersheds to which carbon and other considerations are added.

In developing a water market, it is important to understand that while the overall run-off of a system is important, the sustained flow of high quality water in rivers is also significant. As shown by Blignaut *et al*. (2007), Blignaut *et al*. (2008), Turpie *et al*. (2008), and Nel *et al*. (2009), the restoration and subsequent maintenance of natural capital can also:

- Increase water flow regulation and assurance of supply through improved baseflow.
- Improve yield through reduced spilling, dam sedimentation, and IAP evapo-transpiration.
- Improve water quality.

But, who would be willing and able to pay for these water-related services? There are three possible buyers which have been identified; the Nelson Mandela Bay Municipality (NMBM), Department of Water Affairs (DWA), and Gamtoos Irrigation Board (Blignaut and Mander 2009).

The NMBM is situated within a region characterised by chronic water shortages (Raymer 2008). The City of Port Elizabeth is already experiencing limitations with regards to water supply, and this is likely to continue and increase, with the future development of Coega. The impending water crisis prompted the inception of the Algoa Water Reconciliation Study, co-ordinated by the Department of Water Affairs (DWA). While the study seeks to identify potential water augmentation options, improved water supply through paying for improved watershed management has not been considered. Following a meeting with representatives of the NMBM, a keen interest was shown in the possibility of the NMBM buying increases in their water allocations from the Loerie, Mpophu, and Churchill Dams through increased water supply resulting from the restoration and improved land-use management in the Kouga, Baviaans, and Kromme Watersheds (Blignaut and Mander 2009).

The Gamtoos Irrigation Board has similarly shown an interest in the possibility of increasing their existing water allocations.

In summary, a major opportunity exists for the NMBM and Gamtoos Irrigation Board to become willing and able buyers of ecosystem services by paying for improved watershed management, and in doing so increase their water allocations.

4. THE SUPPLIERS OF WATER SERVICES IN THE WATERSHEDS

This section provides an overview of the landowners, land cover, and land use in the study area, so as to understand who the potential suppliers of ecosystem goods and services are, and how they are spatially orientated.

The study area encompasses the watersheds of the Baviaanskloof, Kouga, and Kromme Rivers, comprising a total of 20 quaternary catchments, with a surface area of 560,000 hectares. The area is exceptionally diverse in terms of abiotic features, resulting from the uplifting of geology over the millennia, and culminating in three distinct parallel mountain ranges (i.e. Tsitsikamma, Kouga, and Baviaanskloof Mountains) that run in an east-west direction. The area is located in the bimodal rainfall zone with spring and autumn maxima. Most rainfall events are associated with post-frontal circulation and warm-season thunderstorms are common in the north. The largest events – and associated floods – are produced by cut-off lows, whereby moist air is advected from the north and the south (Preston-Whyte & Tyson 1997). Mean annual precipitation ranges widely from approximately 225mm in the northern Baviaanskloof to over 1,600mm per annum in the high-lying Tsitsikamma Mountains. The topography also varies considerably and altitudes range from 0 to 1,757 meters above sea-level. Given the diversity and complexity of the study area, it seems prudent to examine the characteristics of each watershed in greater detail as is done in Table 4.1.

Table 4.1: Salient characteristics of Baviaanskllof, Kouga, Kromme watersheds within the study area

Description	Baviaanskloof	Kouga	Kromme
General	• Smaller than other two watersheds – 123,332 hectares in extent. • Mean annual rainfall is 300mm (188mm in summer and 112mm in winter). • Very rugged terrain. • Complex vegetation community structure and composition. • Provides greatest opportunity for carbon sequestration relative to other two watersheds (Euston-Brown 2006; Mills & Cowling 2006; Mills *et al*. 2005a,b; Lombard *et al*. 2002; Swart & Hobson 1994) . • Limited access.	• Largest of three watersheds – 282,040 hectares in extent (Jansen 2008). • Mean annual rainfall is approx. 500mm. • Renowned for deciduous fruit production. • Provides greatest opportunity for flood risk mitigation due to recent flood events and the resulting damage to crops and infrastructure. • Rugged terrain. • Largely inaccessible.	• Total catchment area is 155,631ha • Less rugged relative to other two watersheds. • Provides greatest opportunity for successful IAP clearing due to relatively good access. • Opportunity for locals to earn a livelihood by converting felled *A. mearsnii* to charcoal (Buckle 2009). • Area is considerably transformed, especially in the coastal lowlands. • Approximately 60% of the watershed was infested with IAP more than decade ago (Carpenter 1999).
Land tenure	• State is majority land owner - 62% or 75,871ha (Skowno 2008). • Private landowners (36.2% or 44,304 ha). • Three traditional rural communities (1.8% or 2.204 ha).	• Majority of land is privately owned (190,000ha). • State owns approx. 83,400ha. • Several privately-owned farms have been purchased and redistributed as part of Land Reform Programme - approx. 4,100ha (van der Merwe 2009). • Approx. 6,482ha of traditional rural land.	• Amount of state-owned land is considerably lower relative to other two watersheds (Approx. 8,062ha).
Land cover	• Majority of land cover is natural veld - 73% or 97,816ha (Skowno 2008). • Degraded vegetation accounts for approx. 19.2% or 23,637ha of watershed. • Limited agricultural production (808ha irrigated and 1,071ha dryland or old cultivated fields). • IAPs are currently a minor problem.	• Majority of land cover is natural mountainous area - 248,043ha (SANParks 2009; Skowno 2008). • Extensive farmland (14,022ha • Moderate agricultural land cover (3,524ha irrigated and 8,804ha dryland or old cultivated fields). • Approx. 4,146ha degraded (989ha due to IAP infestation). • Urban and Peri-urban land cover (Approx. 693ha)	• Majority of land cover is farmland (28,544ha) (SANParks 2009; Skowno 2008). • Large areas of natural vegetation (10,205ha). • Large areas of dryland or old cultivated fields (9,862ha). • Extensive areas of degraded vegetation (13,325ha, of which 3,350ha due to IAP infestation). • Urban and peri-urban land cover (3708ha) • Water bodies (1,077ha). Extensive wetlands, which have been highly degraded or transformed. • Extensive small stock farming.

Land use	• Dominant land use for state-owned land is watershed management, conservation, and biodiversity management (Boshoff 2008). • Dominant land use on privately-owned land is pastoralism, mainly sheep and goats (Teague *et al*. 1989). • Limited intensive agriculture in valleys, mainly alfalfa, maize, carrot & onion seed (de la Flor Tejero 2008; Noirton 2008). • Increasing number of farmers switching to tourism due to greater returns perha (de la Flor Tejero 2008; Turpie *et al*. 2003; Kerley *et al*. 1999). • Largely subsistence pastoralism and agriculture on communal lands (de la Flor Tejero 2008; Noirton 2008).	• Kouga valley is intensively farmed for deciduous fruit, Lucerne, citrus and fodder - approx. 7000ha (Jansen 2008). • Limited vegetable crop production (Approx. 61 ha), mainly potatoes, pumpkins, cabbages, onions, and tomatoes (van der Merwe 2009). • Currently 12ha intensively farmed with honey bush tea (*Cyclopia spp.*) (van der Merwe 2009; Joubert 2008). • Limited Buchu (*Agothosama* spp.) production (Approx. 10ha) (van der Merwe 2009; Moola & Viljoen 2008; Turpie *et al*. 2003). • Extensive livestock farming - range unknown (van der Merwe 2009).	• Kromme valley is intensively farmed for fruit, vegetables and large livestock. • Small number of game and holiday farms have been established in the area.
Vegetation	• Fynbos is dominant vegetation type (69,883ha). Generally well managed and intact (Euston-Brown 2006). • Biome-transitional vegetation types (25,606ha). • Thicket (22,983ha). The majority of degraded thicket occurs on privately-owned land (Lombard *et al*. 2002). • Savannah (3,361ha) • Forest (1,277ha) • Grassland (219ha)	• Fynbos is dominant vegetation type (182,000ha) (Vlok *et al*. 2008; Euston-Brown 2006). • Biome-transitional vegetation types (55,000ha). • Grassland (23,200ha) • Thickets (16,033ha) • Forest (1,264ha) • Savannah (498ha)	• Fynbos is dominant vegetation type (56,804ha) (Vlok *et al*. 2008; Euston-Brown 2006). • Grassland (15,479ha) • Thickets (12,087ha) • Renosterveld (11,366ha) • Forest (2,734ha)

There are a variety of economic benefits associated with the different land uses detailed above in Table 4.1. These benefits range from R4 per hectare for Buchu harvesting to R 150,000 per hectare for intensive potato cultivation. The lower and upper estimates of economic returns, for some of the more common land uses within the Baviaanskloof, Kouga, and Kromme Watersheds, are presented below in Table 4.2.

Table 4.2: Lower and upper estimates of economic benefits (R/ha) associated with common land uses within Baviaanskloof, Kouga, and Kromme watersheds

Land use	Lower Estimate	Upper Estimate
Citrus	R 74,250	R 103,950
Chicory	R 15,000	R 81,250
Potatoes	R 24,000	R 150,000
Pumpkins	R 9,000	R 66,000
Butternuts	R 17,500	R 87,500
Maize	R 9,000	R 19,500
Deciduous fruit	R -	R 87,000
Extensive small stock	R 37	R 80
Charcoal making	R 9,208	R 10,624
White wood	R 6,300	R 6,750
Small stock value (communities)	R -	R 240
Honeybush tea (intensive)	R -	R 4,000
Buchu harvesting (mountain fynbos)	R 4	R 25
Wild flower harvesting (mountain fynbos)	R 12	R 313
Tourism	R -	R 90
Hunting	R -	R 93

In summary, there is approximately 224,000 hectares of natural veld, in good condition, which currently supplies an optimal suite of ecosystem goods and services (Powell and Mander 2009). This area should be properly managed to sustain the current supply of these services. There exists an opportunity to restore a further 255,000 hectares of degraded land which is producing neither significant agricultural benefits nor optimal ecosystem services. Of these degraded lands, approximately 28,000 hectares is condensed IAP thicket, which if cleared, provides a major opportunity for enhancing water supply.

5. VEGETATION MANAGEMENT FOR THE OPTIMAL SUPPLY OF CARBON SEQUESTRATION AND WATER SERVICES IN THE WATERSHEDS

The aim of this part of the project was to identify the optimal vegetation management for water resources, whilst still maintaining biodiversity. To do this, the study area was divided into three dominant vegetation types based on the vegetation classes described by Euston-Brown (2006) and Vlok *et al*. (2008), and cross-referenced with the original Acocks (1975) vegetation types. This includes:

- Fire-prone fynbos vegetation, which dominates the Baviaanskloof-Tsitsikamma study area.
- Sub-tropical thickets, which occupy the remainder of the landscape.
- IAP infestations superimposed on prevailing natural vegetation.

5.1 MANAGEMENT OF FIRE-PRONE AREAS

Fire-prone vegetation occupies more than 80% of the area within all three watersheds, making fire management essential for the maintenance of biodiversity and ecosystem services. However, the adopted fire management regime must be sensitive to the land use. Where veld is used for livestock production, it should be managed to maintain grazing potential (65% of the study area), while conservation areas should be managed to maximise biodiversity, water services delivery, and minimise soil erosion (30% of study area) (Powell and Mander 2009). Table 5.1 below, summarises the characteristics of the study area that are salient for fire-prone vegetation management.

Table 5.1: Salient characteristics of three watersheds for management of fire-prone vegetation (Powell *et al*. 2009a)

Description		Baviaanskloof	Kouga	Kromme
Total area (ha)		123,332.3	277,365.6	119,037.2
Land tenure	State-owned	62.0%	30.1%	05.2%
	Privately-owned	36.2%	69.0%	94.8%
Land use	Veld-based	99.0%	92.2%	58.0%
	Cultivation	01.0%	08.8%	42.0%
Vegetation	Fire-prone vegetation	81.1%	93.6%	91.0%
	Class 1: Short fire-return interval (2-4 years). Past and present fire regimes have eliminated slow-maturing species and resulted in a high grass component that responds rapidly to fire (i.e. fuel accumulation).	0%	11.9%	24.9%
	Class 2: Medium fire-return interval (8-12 years). Generally found on relatively moist mountain slopes and inaccessible plateaus. Include slow-maturing proteoid shrubs that will be eliminated by short fire-return interval.	52.3%	59.2%	42.8%
	Class 3: Long fire-return interval (15-30 years). Generally found in very dry sites or topographies inaccessible to fire. Includes very slow maturing proteoids and / or other floristic elements which cannot persist under short to medium fire-return intervals.	47.7%	28.9%	32.3%

In developing fire management guidelines and practices for the eastern Cape Floristic Region, care should be taken in simply applying the outcomes of extensive fire-management related research from the western Cape Floristic Region to the study area, as there are some significant differences as outlined by Powell *et al*. (2009a: 4), van Wilgen (2008) and van Wilgen *et al*. (1992). One of the key differences between the two regions is that post-fire recruitment of proteoid species in the east shows no significant difference between cool and warm season burns (Heelemann *et al*. 2008). This greatly reduces the constraints on when in the year to implement prescribed burns, a factor that has seriously compromised prescribed burns in the west (van Wilgen *et al*. 1994; van Wilgen & Richardson 1985; van Wilgen & Burgan 1984).

There is a long history of the fynbos mountain areas within the study area being actively managed with fire (Boshoff 2008). Prescribed burns were initially introduced to reduce and fragment fuel loads, and to maintain biodiversity. However, when Eastern Cape Parks (ECP) took over the management of the area, a hands-off / natural fire regime policy was adopted (Jansen 2008). Van Wilgen (2008) argues that experience has shown that "fynbos fires are not fuel-dependent", and that prescribed burns do not limit the spread of wildfires. Wildfires appear to be driven by the concurrence of weather conducive to fires and a source of ignition (Forsyth & van Wilgen 2008; Seydack *et al*. 2007; Brown *et al*. 1991). Managers should therefore seek to manage fire regimes (i.e. the combination of frequency, season, intensity and type of fires that characterize a region) and not individual fire events (van Wilgen 2008). Table 5.2 below presents fire regime strategies which can potentially be applied within the study area.

Table 5.2: Appropriate fire regime strategies which can be applied within the study area (Seydack 1992)

Watershed	Management Action	Guidelines
Baviaanskloof	Natural Burning Zone (NBZ)	• No prescribed burns are implemented. Wildfire regimes are maintained and there is no intervention, irrespective of season, intensity, and veld age (Anon 2007a). • No firebreaks are required as the fire-prone vegetation is largely remote, inaccessible, and bounded by non-fire-prone thicket. • A Fire Protection Association is established (Anon 2007a). • Eastern Cape Parks (ECP) appoints requisite staff and conducts training, and has in good working order the appropriate fire fighting equipment.
Kouga	Adaptive Interface Zone The southern slopes of the Kouga Mountains between above NBZ to the north and the privately owned land to the south.	• Attempts to control wildfires should be contingent on risk to lives and infrastructure, and veld age. Fires should not be allowed to spread into areas where the veld age is less than the corresponding fire-return interval. • Annual monitoring of veld age, status of populations of indicator species, and IAP infestations is carried out. • Fire breaks (min. 15m) to be established on southern boundary. • A Fire Protection Association is established. • Eastern Cape Parks (ECP) appoints requisite staff and conducts training, and has in good working order the appropriate fire fighting equipment.
	Scheduled Block Burning – Grazing Management The privately owned land between the Baviaanskloof Nature Reserve and boundary of Kromme watershed.	• Brush-cut fire breaks (min. 15m) to be established on the boundary of each property (Erlank 2009). • Landowners apply short fire-return intervals to compartments (500ha to 1000ha) within their properties. • Attempts to control wildfires should be contingent on risk to lives and infrastructure. Veld age should not be taken into consideration. • A Fire Protection Association is established. • Eastern Cape Parks (ECP) appoints requisite staff and conducts training, and has in good working order the appropriate fire fighting equipment. The use of a helicopter for fire control should be budgeted for.
Kromme	Scheduled Block Burning – Fuel Reduction and Biodiversity Management The Tsitsikamma Mountain and plateau between the Garden Route National Park and commercial forestry plantations.	• Brush-cut fire breaks (min. 15m) to be established on the boundary of the conservation area (Erlank 2009; Anon 2007a). • Large compartments (500ha to 1000ha) are identified and burnt under safe conditions, during either spring or autumn, on an 8 year rotation. • All wildfires should be controlled. • A Fire Protection Association is established. • Eastern Cape Parks (ECP) appoints requisite staff and conducts training, and has in good working order the appropriate fire fighting equipment. The use of a helicopter for fire control should be budgeted for.
	Scheduled Block Burning – Grazing Management The Diep River watershed, southern slope of Zuuranys Mountains, Humansdorp Flats, and Kromme valley.	• Brush-cut fire breaks (min. 15m) to be established on the boundary of each property (Erlank 2009). • Landowners apply short fire-return intervals to compartments (500ha to 1000ha) within their properties. • Attempt to control wildfires should be contingent on risk to lives and infrastructure. Veld age should not be taken into consideration. • A Fire Protection Association is established. • Eastern Cape Parks (ECP) appoints requisite staff and conducts training, and has in good working order the appropriate fire fighting equipment. The use of a helicopter for fire control should be budgeted for.

5.2 MANAGEMENT OF INVASIVE ALIEN PLANTS (IAPS)

The impacts of IAPs are complicated and influenced by a host of factors, such as species, density, and age of invasion. While the influence of IAPs on water services is fairly well understood, the negative impacts on biodiversity are under-studied and should not be ignored (Lowe *et al*. 2008; Milton 2004; and Samways & Taylor 2004).

IAP infestation in the Baviannskloof is limited to isolated populations of various species, such as *Opuntia ficus-indica* (prickly pear), in the mountainous fynbos, main drainage channels, and mountain slopes where intact and degraded thicket occurs. The aridity of the area has largely precluded the successful establishment of IAPs (Powell *et al*. 2009a). In contrast, a total of 212,667 hectares of IAPs have been mapped in the Kouga watershed, indicating that a major challenge exists with regards to the control of IAPs. The main river channel in particular is highly infested with *A. mearsnii* (black wattle). The IAP populations in the Kromme watershed have been largely controlled in the main riparian zone, with approximately 10,391 hectares treated from 1996 to 2008. The chief species of concern within the three watersheds are *Acacia mearsnii*, *Pinus* spp., *Hakea sericea*, *Acacia Cyclops*, and *Eucalyptus* spp.

The need for restoration following IAP clearing is largely dependent on the quality of the IAP clearing and the species of IAP (Beater *et al*. 2008; Vosse *et al*. 2008; Holmes and Richardson 1999). The vast majority of areas, if cleared properly and the fire management is sensible, will not require vegetation restoration. However, it is recommended that where recovery is very slow and/or key species are missing, active restoration is undertaken through the planting of key woody species (Rienecke *et al*. 2008; Vosse *et al*. 2008; Blanchard and Holmes 2009; Holmes *et al*. 2008; Galatowitsch & Richardson 2005). Fortunately, vegetation baselines and reference frameworks, as well as vegetation restoration protocols for fynbos areas and riparian zones are available for the Western Cape, which should easily be repeated in the watersheds of the study area (Holmes *et al*. 2008; Holmes *et al*. 2005; Prins *et al*. 2004; Holmes & Richardson 1999). The use of fire to control IAPs, particularly in riparian zones, is a contentious issue, given that heat and soil temperatures during brush pile burning affects the viability of indigenous seed banks (Beater *et al*. 2008; Behenna *et al*. 2008; Richardson & Kluge 2008; Kruger & Bigalke 1984). It is therefore recommended that IAP biomass is removed from riparian zones and only burned when the soil is wet (Behenna *et al*. 2008; Holmes *et al*. 2008). These and other management actions for the correct clearing of IAP within the study area are summarised below in Tables 5.3 and 5.4.

Table 5.3: IAP management actions in the Baviaanskloof, Kouga, and Kromme watersheds (Powell *et al*. 2009a)

Baviaanskloof Watershed	Kouga & Kromme Watersheds
✓ Control and contain spread of low density IAP populations, such as *T. diversifolia* and *B. delagoense.* ✓ Develop programme to detect, monitor, and eradicate emerging weeds, such as *Anredera cordifolia* and Madiera vine. ✓ Develop a containment strategy to prevent *O. aurantiaca* from invading and becoming established in degraded subtropical thicket. ✓ Develop PES system which provides incentive and / or pressure for landowners to remove listed IAPs. ✓ ECP to take responsibility for an IAP control and extension programme. ✓ Fire management strategy for BMR to include control of IAPs in mountain fynbos with use of fire. ✓ Highly transformed or eroded riparian areas will require appropriate restoration (e.g. gabions, sediment traps, channels etc.).	✓ Low density landscape (i.e. not riparian) IAP infestation should be cleared in most cost effective method available. ✓ High density landscape IAP infestation should be cleared by only removing smaller stems, and ring barking or frilling larger trees, which are then left standing to burn. IAPs felled and stacked should only constitute sufficient biomass to cause seed germination. ✓ Where clear felling is unavoidable, all IAP biomass must be removed from 1:50 year flood zone and spread evenly. ✓ Cut stems should not be stacked, but spread evenly over terrain, and not higher than 0.3m above the ground. ✓ However, *H. sericea* populations should be cut and stacked in large piles to prevent seed being distributed by wind. ✓ Fire to only be used in riparian zones which are highly inaccessible for removal and / or high energy environments (e.g. Kouga River channel). Fire can also be used to eradicate *Pinus* spp. in the wetter portions of the Kouga catchment (i.e. Tsitsikamma Moutains) where the juvenile periods of pines are less than the slowest maturing proteoids. ✓ Where possible, fire should be used to flush IAP seedbank, reducing the need for herbicide on the first follow-up. ✓ Highly transformed or eroded riparian areas will require appropriate restoration (e.g. gabions, sediment traps, channels etc.). ✓ Seeds e.g. *Pinus* spp. from commercial forestry companies should be quantified and costs relayed to polluter.

Table 5.4: Recommendations for generalised IAP management within study area (Powell *et al*. 2009a)

Subtropical Thicket Biome			
Actions	Low IAP Density	Medium IAP Density	High IAP Density
Clearing methodology	Spot spray or stem injections. Woody species ring bark or frill.	Spot spray or stem injections. Woody species ring bark or frill.	Spot spray or stem injections. Woody species ring bark or frill. Excess woody biomass needs to be removed from the riparian zone.
Follow-up and follow-up frequency	3-6 month intervals.	3-6 month intervals.	3-6 month intervals.
Vegetation Restoration	Function of degradation.	Function of degradation.	Function of degradation.
Fire management	Exclude fire at all costs.	Exclude fire at all costs.	Exclude fire at all costs.
Fynbos Biome – Riparian Areas			
Actions	Low IAP Density	Medium IAP Density	High IAP Density
Clearing methodology	Fell sufficient biomass (all if needed) to flush IAP seed bank.	Fell minimum biomass (sufficient only to germinate seedbank) and kill remainder standing.	Fell minimum biomass (sufficient only to germinate seedbank), kill remainder standing, remove excess from the riparian zone.
Follow-up and follow-up frequency	Dynamic. First crucial follow-up will be a function of germination success and timing of rainfall (3-6 months after fire).	Dynamic. First crucial follow-up will be a function of germination success and timing of rainfall (3-6 months after fire). With regard to *A. mearnsii*, the main initial issue is resprouting	Dynamic. First crucial follow-up will be a function of germination success and timing of rainfall (3-6 months after fire).
Vegetation Restoration	Unlikely unless previous IAP management or over stocking has been evidenced.	Likely in areas where previous IAP management has occurred. Intensity of restoration is site specific.	Likely in the main channel banks. Intensity of restoration is site specific.
Fire management	Adopt natural fire regime (see Table 5.2)	Burn first spring after first rain. Adopt natural fire regime ASAP (see Table 5.2).	Burn first spring after first rain. Adopt natural fire regime ASAP (see Table 5.2).
	Fynbos Biome – Landscape Areas		
Actions	Low IAP Density	Medium IAP Density	High IAP Density
Clearing methodology	Fell small stem diameters, ring bark, or frill large stem diameters. Fire can also be used to clear juvenile pines less than 5 years in age.	Fell small stem diameters, ring bark, or frill large stem diameters. Fire can also be used to clear juvenile pines less than 5 years in age.	Fell small stem diameters, ring bark, or frill large stem diameters.
Follow-up and follow-up frequency	6-8 months for *Acacia* species. 8-12 months for *Hakea* and *Pinus* species. Fire can also be used to control juvenile pines.	6-8 months for *Acacia* species. 8-12 months for *Hakea* and *Pinus* species. Fire can also be used to control juvenile pines.	6-8 months for *Acacia* species. 8-12 months for *Hakea* and *Pinus* species.
Vegetation Restoration	Very unlikely.	Very unlikely.	Very unlikely.
Fire management	Adopt natural fire regime (see Table 5.2)	Burn first spring after first rain. Adopt natural fire regime (see Table 5.2)	Burn first spring after first rain. Adopt natural fire regime ASAP (see Table 5.2)

5.3 MANAGEMENT OF SUBTROPICAL THICKET

Management of intact subtropical thicket requires stocking of game and livestock at densities that do not lead to the degradation of the vegetation structure. The ideal stocking rate is a function of the vegetation structure, rainfall experienced in a particular year, and type of herbivore.

For example, thicket appears to be surprisingly sensitive to injudicious goat pastoralism, resulting in a reduction of species diversity, above-and-below ground carbon stocks, soil quality, and plant productivity (Lechmere-Oertel *et al*. 2005a; Mills *et al*. 2005; Mills & Fey 2004; Moolman & Cowling 1994; Stuart-Hill &

Aucamp 1993; Stuart-Hill 1992; Hoffman & Cowling 1990). Unfortunately, the rapid restoration of heavily impacted thicket cannot simply be achieved through removing the goats, as regeneration is often slow or non-existent (Stuart-Hill & Danckwerts 1988). Sigwela (2004) argues that regeneration is primarily hampered by a lack of shrub recruitment, and active intervention is therefore required to establish shrubs. The sowing of seeds in unlikely to be effective as the harsh micro-climate of the exposed soil in the transformed thicket appears to limit seed germination, and also prevents the seed recruitment of thicket plant species that normally establish beneath the shrub canopy (Sigwela 2004; Todkill 2001; Holmes & Cowling 1993).

Swart and Hobson (1994) propose planting cuttings of the succulent shrub, *Portulacaria afra* (i.e. spekboom), as a potentially cost-effective and practical restoration method. Although planting of cuttings of *P. afra* and other succulent plant species are unlikely to restore the thicket ecosystem in the short-term, it is hypothesized that *P. afra* in particular will reduce the abiotic barriers, such as temperature, moisture content, and soil crusts, restricting seedling establishment, as well as provide cover for seed-dispersing animals and birds, thereby facilitating natural ecosystem recovery in the long-term (Lechmere-Oertel *et al*. 2005b; Mills & Fey 2004; Sigwela 2004). Mills (2007) suggests that while restored some sites may ultimately show a greater dominance of *P. afra* than pristine thicket, this new, engineered ecosystem is preferable to the present transformed landscape because of the potential benefits of increased livestock forage, especially during dry periods (Lechmere-Oertel *et al*. 2005a; Stuart-Hill & Aucamp 1993; Stuart-Hill 1989; Aucamp *et al.* 1980), improved nature-based tourism opportunities (Boshoff *et al*. 2002; Kerley *et al*. 1995; Sigwela 2004), and increased carbon sequestration (Mills & Cowling 2009; Powell *et al*. 2009b; Mills & Cowling 2006; Mills *et al*. 2005).

There also exists the potential to create 'designer' ecosystems, which could potentially provide more benefits than the original or pristine thicket (Palmer *et al*. 2004; McNeely 1994; Gadgil *et al*. 1993). A hyper-beneficial thicket with a large *P. afra* component could for example include fruiting species (e.g. *Carrisa bispinosa*), valuable browse species (e.g. *Euclea undulata*), species utilized for cultural practices (e.g. *Olea europaea* subsp. *africana*), medicinal plants (e.g. *Bulbine* spp.), threatened species (e.g. *Encephalartos latifrons*), and succulents (e.g. *Euphorbia* spp.) of conservation significance and horticultural importance (Cocks & Wiersum 2003; Victor & Dold 2003).

In summary, there exists the opportunity to not only maintain the current provision of ecosystem goods and services, but to regain goods and services through active restoration, in accordance with the recommendations presented above, of areas where degradation has taken place (e.g. overgrazing and/or IAP infestation).

6. COSTS OF PREFERRED MANAGEMENT OPTIONS IN THE COMMERCIAL AND COMMUNAL FARMING AND PROTECTED AREAS CONTEXTS

Table 6.1 below presents a summary of the estimated costs per hectare of introducing the preferred land use management options identified in the previous section. These are the default values used as input data for the model, and have been derived from Blignaut *et al*. (2009).

Table 6.1: Summary table of estimated costs (R/ha) and job creation potential (person-days/ha) of implementing various different restoration and land use management options in different ecosystems and altitudes and under different conditions

		Fynbos			Thicket		
Clearing of invasive alien plants (R/ha)							
Infestation density	Action	Lower quin	Middle quin	Higher quin	Lower quin	Middle quin	Higher quin
Light	Clearing	2,592	2,592	2,592	365	365	365
	per follow-up	273.59	273.59	273.59	36.39	36.39	36.39
Medium	Clearing	6,526	6,526	6,526	1,339	1,339	1,339
	per follow-up	784.52	784.52	784.52	36.39	36.39	36.39
Dense	Clearing	15,804	15,804	15,804	6,265	6,265	6,265
	per follow-up	1816.8	1816.8	1816.8	1338.56	1338.56	1338.56
Revegetation (R/ha)							
Moderate degradation		945	1,890	3,308	1,777	3,436	6,424
Severe degradation		1,365	2,730	4,778	2,567	4,963	9,279
Management (R/ha)							
Fire management etc.		28.85	23.08	17.31	51.96	41.57	31.18
Opportunity cost (R/ha)							
Reduced returns by reducing cattle stocking rates by 50%		21.66	21.66	21.66			
Reduced returns by removing goats					86.64	86.64	86.64
Job creation potential (person-days/ha)							
Clearing of invasive alien plants							
Infestation density	Action	Lower quin	Middle quin	Higher quin	Lower quin	Middle quin	Higher quin
Light	Clearing	6	6	9	1	1	1
	per follow-up	1.20	1.20	1.20	0.10	0.10	0.10
Medium	Clearing	20.00	20.00	30.00	3	3	3
	per follow-up	3.50	3.50	3.50	1.00	1.00	1.00
Dense	Clearing	100.00	100.00	150.00	20.00	20.00	20.00
	per follow-up	6.50	6.50	6.50	3.00	3.00	3.00
Revegetation							
Moderate degradation		14	25	56	14	25	56
Severe degradation		2	3	7	17	30	67

7. HYDROLOGICAL IMPLICATIONS OF WATERSHED MANAGEMENT

7.1 OVERVIEW OF STUDY AREA'S HYDROLOGY

The following provides a broad overview of the hydrology of the study area so as to contextualise the hydrological implications of the various watershed management options discussed in the sections to follow.

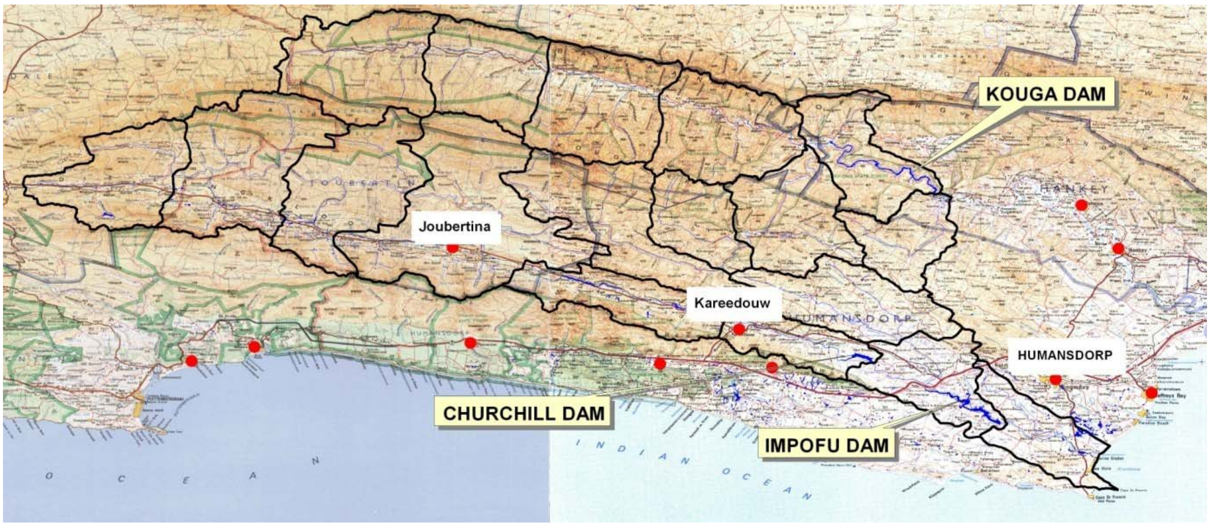


Figure 7.1: Study area overview highlighting major impoundments and DWA Quaternary Catchments

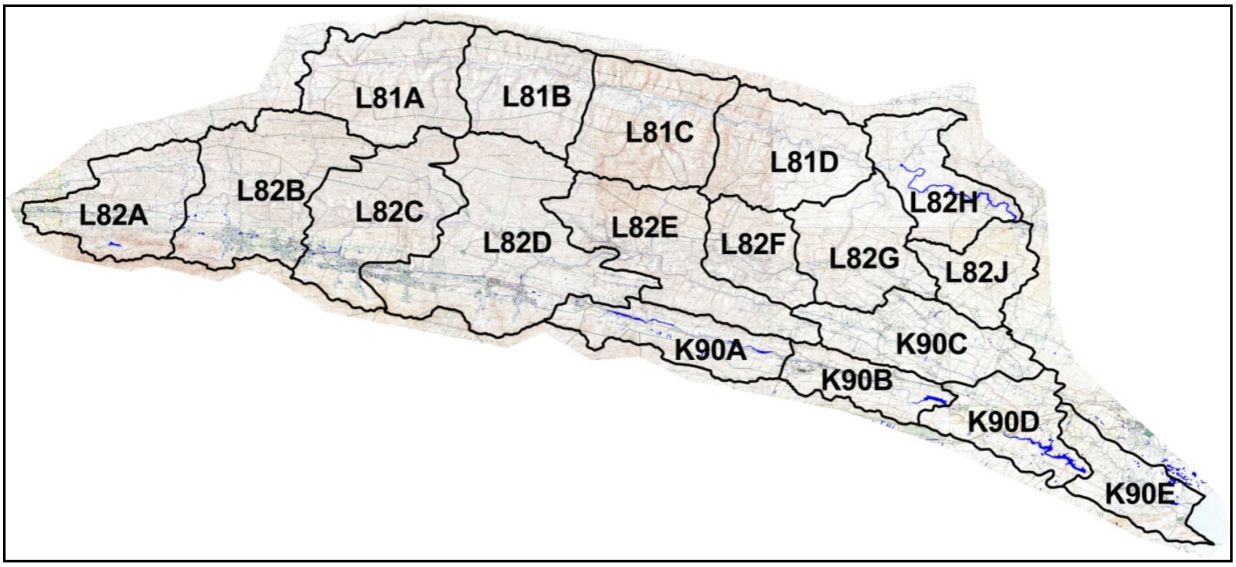
The Baviaans River rises in the mountains flanking the Baviaanskloof Valley, where direct abstraction by farmers has been estimated at roughly 2 Mm^3 / yr. The majority of its catchment falls within the Baviaanskloof Nature Reserve[2], of which Eastern Cape Parks (ECP) is the primary land owner. The Kouga River rises in the mountains surrounding the Langkloof farming area centred around Joubertinia to the south of the Baviaanskloof Nature Reserve. Some of its tributaries in this area flow south from ECP land in the Baviaanskloof Nature Reserve Area. After flowing primarily through the Langkloof farming area, it re-enters ECP land and joins the Baviaans River in the Baviaanskloof Nature Reserve before it flows into the Kouga Dam (capacity of 128 Mm^3) near Patensie. Water stored here is used primarily for irrigation below the dam through the Gamtoos Irrigation Board (which is allocated 50 Mm^3 / yr), for residential use in smaller towns nearby as well as in the Nelson Mandela Bay Municipality, NMBM (which is allocated 23 Mm^3 / yr). Direct abstraction by farmers from the Kouga River above the Kouga Dam has been estimated at 26 Mm^3 / yr with the majority of this occurring in the Langkloof[3].

The Kromme catchment to the south of and adjacent to the Kouga catchment drains a narrow valley between the Suuranys Mountains towards the interior and the Tsitsikamma Mountains towards the coast. It flows past the town of Kareedouw through agricultural areas (where direct abstraction by farmers occurs), along the R62 road, before flowing into the Churchill Dam (capacity of 32 Mm^3). Further downstream from this dam, the Diep River joins the Kromme from the north before flowing into the Impofu Dam (capacity of 87 Mm^3), approximately 25 km downstream from the Churchill dam. Both of these dams supply nearby small towns and the Nelson Mandela Bay Municipality, NMBM (which is allocated 36.5 Mm^3 / yr and is set to increase by a further 10 Mm^3 / yr) through a system of pipelines. A relatively large proportion of land in the Tsitsikamma Mountains, that includes the upper reaches of some of the Kromme River's tributaries, is managed by ECP in the form of the Formosa Nature Reserve. Alien invasive plant infestation is particularly advanced in this catchment and Working for Water is active there within. Working for Wetlands is also involved in major wetland restoration projects in the catchment (van Zyl *et al.,* 2008).

The study area was represented by the 18 Quaternary Catchments (QCs) shown in Figure 7.2 consolidated into three hydrological regions. The units of spatial representation are the DWA QCs.

2 The Baviaanskloof Nature Reserve represents the formal protected area component of the broader Baviaanskloof Mega-Reserve.

3 All figures from DWA Internal Strategic Perspective of Tsitsikamma to Coega Water Management Area, 2004. This document can be found at http://www.dwaf.gov.za/Documents/ and contains an overview of the water resources and water management issues in the area.



igure 7.2: Quaternary catchments and rivers of the study area

The 18 QCs were further divided into 54 relatively homogeneous response units or Quinary Catchments, also hydrologically interlinked, allowing for the upstream downstream interactions to be modelled.

Each of 54 quinary catchments was divided again into their respective veld types, with a total of 378 discrete veld units modelled. This provided the means to model each discreet land cover, either independently, or as part of a cascading system, thus allowing for assessing the impacts of the land management scenarios both at the veld unit scale or catchment scale depending on the required outcome.

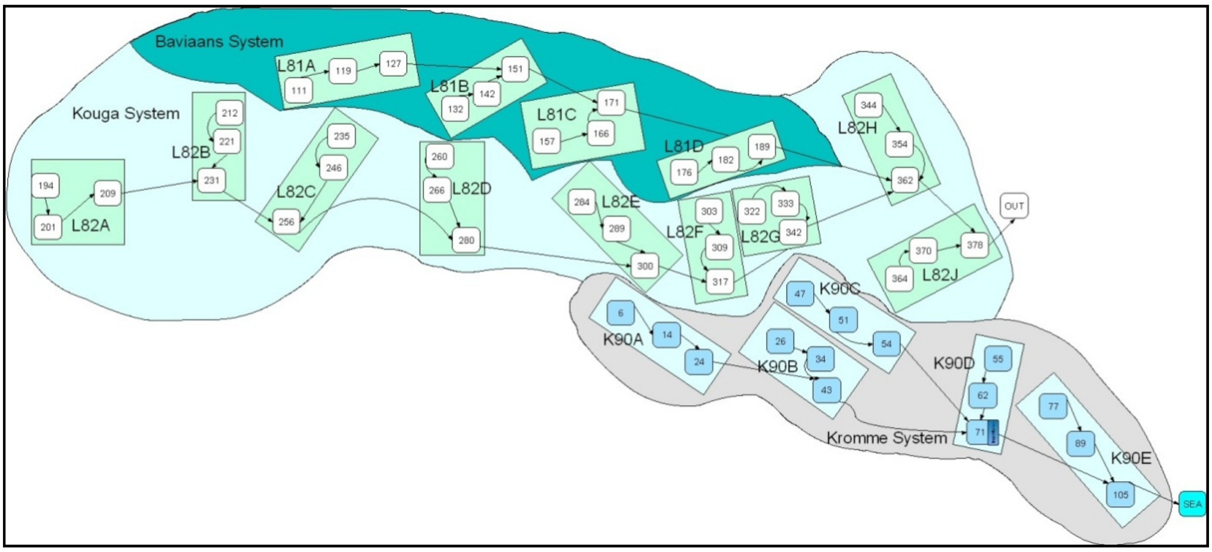


Figure 7.3: Quinary catchments and the major river systems of the study area depicting the inter-catchment flow paths

7.2 DEVELOPING THE HYDROLOGICAL MODEL

The challenge in developing a hydrological model for the study area, as in much of South Africa, is trading off between the different land uses and intensity of land uses, which alter the magnitudes, timing, and components of fresh water ecosystem services, for equitable and sustained water use in the present and future.

Rainfall is the primary source of water supporting hydrologically related ecosystems and associated ecosystem services. However, the manner and extent to which fresh water ecosystems are either well managed or misused by humans is largely shaped by land management, where rainfall may either be partitioned into stormflows on the one hand, or baseflows on the other hand. These two components of runoff constitute the so-called "blue water flows" of the hydrological cycle. Similarly, it is management actions that significantly determine whether the so-called "green water flows" of evaporation are largely productive transpiration or non-productive soil water evaporation.

The basic premise made above is that with direct hydrological responses, such as stormflows or baseflows, as well as less direct responses, such as sediment yields or soil water evaporative losses, the management of a given land cover is frequently more influential than the type of land cover *per se*.

So, what then is the impact of various land management options on the direct and less direct hydrological responses and how can this be modelled? The following three steps were undertaken in developing the hydrological model for this project:

1. Construct the hydrological baseline model and determine the preliminary vegetation cover/land use scenarios for modelling.
2. Model the various vegetation cover/land use scenarios.
3. Determine and model the implications of management options on the above vegetation cover/land use scenarios.

7.3 CONSTRUCT THE HYDROLOGICAL BASELINE MODEL AND DETERMINE THE PRELIMINARY VEGETATION COVER/LAND USE SCENARIOS FOR MODELLING

A GIS-linked hydrological baseline model was constructed to model the pristine land cover conditions and to simulate current and future vegetation cover/land use scenarios. ArcGIS was used to interrogate spatial data received from former mapping studies in the study area. The spatial information was translated into hydrological parameters and input via a menu system into the (Agricultural Catchments Research Unit) *ACRU* Agrohydrological Modelling System (Schulze 1995).

Such a hydrological model requires ***INPUT*** of known, measurable, or derivable factors made up of data and information on, *inter alia*:

- climate (e.g. daily rainfall, maximum and minimum temperature, potential evaporation),
- physiography (e.g. altitude, its range within a catchment, slope gradients),
- soils (e.g. thicknesses of the various soil horizons, as well as soil water retention at critical soil water contents and saturated drainage rates from the respective horizons, the inherent erodibility of the soil),
- land uses (e.g. natural vegetation and crop types, levels of management, planting dates, growth rates, above, as well as surface and below-ground vegetation attributes at different growth stages during the year and for different management strategies/scenarios),
- soil water budgeting threshold and rates (e.g. onset of plant stress, degrees of stress, capillary movement),
- runoff producing mechanisms (e.g. stormflow generation, recharge and resultant baseflow rates, flows from impervious areas),
- irrigation practices (e.g. crop type, above-and-below-ground attributes at different growth stages, modes of scheduling and their controls, source of water, application efficiencies) and, where relevant, information on:
    - dams (e.g. inflows, full supply capacities, surface areas, evaporation rates, releases, abstractions and inter-basin transfers), or
    - other abstractions (e.g. domestic, livestock by amount, season and source of water).

This information is then ***TRANSFORMED*** in the model by considering the following:

- the climate, soil, vegetative, hydrological and management *subsystems;*
- how they *interact* with one another;
- what *thresholds* are required for responses to take place;
- how the various responses are *lagged* at different rates; and
- whether there are *feedforwards* and *feedbacks* which allow the system to respond in a positive or reverse direction.

The model then produces ***OUTPUTS*** of the variable to be assessed, such as:

- streamflow (e.g. the blue water flows, from different parts of the catchment, including stormflows and baseflows (e.g. being modelled explicitly and on a daily basis, and hence high and low flows),
- evaporation (e.g. the green water flows, from different parts of the catchment, and made up of productive transpiration through the plant and non-productive evaporation from the soil surface),
- crop yield (e.g. per season, annum or growth cycle; dryland or irrigated; and where relevant, with economic analysis),
- irrigation water requirements (e.g. gross or net requirements; associated crop yields; deep percolation and stormflow from irrigated areas; water use efficiencies under different modes of scheduling water for irrigation; analysis of incremental benefit of applying irrigation versus dryland farming),
- peak discharge, and
- sediment yield (from different parts of the catchment and computed on an event-by-event basis for the pertinent hydrological, soil, slope, plant cover and management conditions),

This is done with all of the above output available as a risk analysis (e.g. month-by-month and annual statistics under median/mean conditions and for, say, driest and wettest years in 10 or 20 years; flow variability or extreme value analysis).

The AAHMS was used to assess and quantify the links between vegetation cover/land use changes and hydrological outcomes in the Baviaanskloof, Kouga and Kromme watersheds. A team workshop generated the following vegetation cover/land use scenarios:

1. Pristine or natural state land use, based on the Euston-Brown (2006) and Vlok *et al.* (2008) vegetation assessments.
2. Invasion by alien invasive plant species (see Section 7.4.1).
3. Degradation of the landscape by overstocking and overgrazing (see Section 7.4.2).

A ***status quo*** scenario was constructed to reflect the current state of infestation and degradation as far as possible, based on the inputs available.

7.4 MODELLING OF VEGETATION COVER/LAND USE SCENARIOS

As mentioned previously, the information used in developing the vegetation cover/land use scenarios for the hydrological model was provided by a team of experts at the Cape St Francis workshop. This input proved invaluable in modelling the changes to ecosystems. The *ACRU* model was used for all hydrological modelling to facilitate comparisons with the outcomes of similar modelling exercises (such as that being conducted for the Maloti-Drakensberg PES feasibility and other DWA and WfW projects). The baseline model was constructed to take account of all existing veld types in the study area. The veld types were modelled in pristine condition, and then adjusted through various time steps to reflect invasion by the relevant alien species to a point of total infestation, as well as a series of time steps of degradation to reflect the worst case scenario of unchecked over stocking and subsequent overgrazing.

These scenarios would then be modelled to determine the potential outcomes in terms of:

1. Changes in water yield.
2. Impacts upon sedimentation and siltation.

3. Changes in, and sustainability of, base flows.

The results were compiled both per veld unit and as an interlinked system to identify "hot spots" both in terms of areas already in a damaged state, areas under threat, the most viable areas to manage (accessibility and cost) and areas which are too severely impacted to be able to rehabilitate without large financial investment.

7.4.1 Invasion by alien species

The project team identified, on a veld type basis, the susceptibility of each veld to invasion by alien species. The invasive species were mainly the commercial forestry species, which are prevalent in the Eastern Cape and KwaZulu-Natal. *A. mearnsii* was perceived to be the biggest threat to the widest area. The team then attempted to determine the level of threat of invasion, by likening the invasion to an invasion period (see Table 7.1). For example, invasion periods range from 10 years in areas that are very prone to invasion with the most susceptible veld types, to 120 years in areas with hardier veld types, rugged terrain, and/or with limited water available which makes invasion much more difficult. The complete list is available in Appendix 2.

Table 7.1: Example of veld types and the degree to which they are susceptible to invasion by alien plant species

Veld type	"Invasibility"	Invasive species and time
Gamtoos Bontveld	4	None
Gamtoos Bontveld	4	None
Langkloof Renosterveld	3	*A. mearnsii* 80 years
Langkloof Grassy Fynbos	2	*A. mearnsii* 80 years
Gamtoos Valley Thicket	4	None
Baviaanskloof Thicket Savanna	3	*A. mearnsii* 30 years
Langkloof Bontveld	3	*A. mearnsii* 60 years

Four invasion periods were selected for modelling the invasion by alien species. These included:

1. No invasion (i.e. pristine).
2. Full invasion in 10 years.
3. Full invasion in 50 years.
4. Full invasion in 120 years.

The invasion periods were used to accommodate for the diversity in susceptibility of the various veld types to alien plant invasion. For example the Baviaanskloof Thicket Savanna was depicted not to have been invaded in the pristine or 10 year period, but to have been completely invaded by *A. mearnsii* by the time the 50 year period is calculated. It follows therefore that if it is fully invaded in 50 years, it will remain so at the 120 year mark. The term full invasion implies an infestation density equivalent to density of commercial stand of that alien species.

The implications of alien plant invasion in terms of land cover attributes were perturbed to represent an increase in biomass, increased water use, interception increases, as well as a deeper mulch and litter layer and altered abstraction coefficients, within the Baviaanskloof, Kouga, and Kromme watersheds.

For example, in the Kromme watershed at the early stages of alien plant invasions, the main effect of the invasive trees is that of a mulch layer covering the soil surface which reduces runoff (i.e. mulch suppresses evaporation and allows infiltration to occur), and a deeper rooting system with an evergreen canopy giving rise to more water use. The increased biomass of the invasive alien plants contributes to the drying-out of the system that reduces both the streamflow and catchment yield. As the aliens become more established and their rooting systems more extensive along with the increase in biomass, the alien plants have access to more soil moisture, thereby transpiring at a faster rate. This has the effect of drying out the soil and the subsoil, and therefore reduces the push through to baseflow. As the invasion becomes denser and established, so the streamflow reduction increases, but mainly by virtue of the reduction in baseflow, the water which sustains the environment through the dry months.

The Baviaans River catchment is unique in this study in that it has very low rainfall and has a very steep and rugged terrain. The nature of the catchment is such that no alien invasion was seen in the short term, but was predicted for the longer time frame. However, any future invasion of vegetation on these surfaces is predicted to increase the surface runoff (stormflow), especially since the shading of and succeeding the existing vegetation is likely to lower the amount of surface basal cover, and thus reduce infiltration and increase the stormflow. The reduction in infiltration will lead to a reduction in soil moisture as will the increase in biomass of the alien plants. This soil moisture reduction will again lessen the push through to baseflow and cause baseflow reductions. A highly invaded state will have an established mulch layer and a large biomass, leading to a decrease in surface runoff, a decrease in soil moisture, and therefore an overall reduction in total water yield, as well as a reduction in the seasonal baseflow.

The Kouga catchment is the largest of the three systems and yields the most water. However, invasion will cause similar responses to the other two catchments in that the initial infestation is likely to exhibit an increase in the mulch and surface cover and thus the reduction in surface runoff. The biomass establishing itself over time uses more and more soil moisture as the aliens become more abundant. This in turn leads to more water use, especially through the dry periods where the indigenous vegetation would senesce. The impacts are a decrease in total catchment water yield as well as a decrease in the baseflow which sustains the reserve, the environment and ecosystem services.

7.4.2 Degradation by overstocking and overgrazing

The degradation of the catchments by overstocking and overgrazing was modelled to allow a mosaic to be created of a combination of the different degrees of degradation. Three scenarios were used to represent the varying degrees of degradation, and included:

1. No degradation (i.e. pristine).
2. Moderate degradation.
3. Severe degradation.

This facilitated the structuring of the ecological-economic model (see Section 8) to reflect the differing current states of degradation as well as to allow for piecemeal, specific or total rehabilitation interventions. This process also permits certain areas to be isolated for example by cost, accessibility or priority to assess the viability of certain interventions.

The implications of degradation by overgrazing with cattle, sheep and/or goats, in terms of land cover attributes, were perturbed to represent the denudation or “laying bare” of the soil surface. This has the combined effect of increasing the susceptibility to erosion as well as exposing it to unsuppressed impacts of atmospheric conditions, such as rainfall. The removal of the above ground biomass allows rainfall to impact the ground uninhibited and therefore with maximum kinetic energy and greater erosive force. The absence of any ground cover or litter layer further enhances the impact by providing little or no barrier to the incoming rainfall. The lack of a litter layer reduces the organic matter and nutrients entering the soil and allows for no binding of the soil particles at the surface. The increased evaporation from the soil surface leads to a lack of soil moisture and therefore a stress situation for the little vegetation that remains. This stress leads to a greater degradation of the biomass, and so the cycle continues. Lack of soil moisture also reduces the cohesive forces between the soil particles which render them vulnerable to wind and rainfall impacts.

Of concern within the study, is the impact of degradation on stream flow and sediments, the impacts of which are discussed in greater detail in the sections to follow.

Impacts of veld degradation on streamflow

At first glance it would appear that the degradation of the natural veld, purely from a water yield perspective is a positive situation. Instinctively one knows that this would not be the ideal management scenario.

All three catchments do exhibit an increase in streamflow due to moderate degradation, and even more under the severe degradation scenario. It is however the composition of that streamflow which is of crucial importance. All examples exhibit an increase in streamflow, accompanied by a large increase in stormflow or same day, flash response. This instant or fast response is high energy, high volume, but short lived. It has the effect of eroding the river bed and banks, removing, in this case, the already vulnerable top soil, increasing the sediment loads and therefore shortening the lifespan of any downstream impoundments and other water infrastructure.

The stormflow increase is an area of concern in terms of the structural design of roads, culverts, bridges and impoundments. This could have an impact on the flood lines and therefore on human safety and rural livelihoods. The marked reduction in baseflow modelled to occur in both the moderate and severe degradation scenarios is cause for concern. The baseflow supports the sustained flow through the dry months and therefore is critical to the human and environmental reserves (river and estuary) as well as providing a source of water for commercial use without necessitating the construction impoundments. It is essential for the delivery of sustainable benefits over time as opposed to often unwanted or dangerous 'bursts' of water.

Impacts of veld degradation on sediments

The Kromme watershed to the south of the system is modelled to yield approximately 3,000 tonnes of sediment per month under pristine conditions. With a moderate degradation, that amount increases by an additional 5,000 tonnes to around 8,000 tonnes per month. Under the severe mismanagement scenario, that amount is increased by a further 10,000 tonnes to a total of approximately 18,000 tonnes per month. That tonnage at an average bulk density of 1,400kg.m^{-3} would equate to a volume of approximately 13,000m^{3} per month being potentially deposited in any impoundments.

The Baviaans watershed located in a steep and rugged catchment yields similar results even though it has a drier climate. Again the pristine yield is around 3,000 tonnes with an increase of 5,000 tonnes under the moderately degraded scenario. An overall increase in sediment yield of 15,000 tonnes to a 18 000 tonne total is also predicted under the severe mismanagement scenario.

The Kouga watershed, being the largest system, yields the most sediment in its pristine state. It is modelled to produce an average of 10,000 tonnes per month with an increase of 15,000 tonnes to 25,000 tonnes in the moderately degraded state. In the severe condition, an increase of up to 40,000 tonnes over the pristine is modelled, giving rise to a total yield of 50,000 tonnes per month. This 50,000 tonnes equates to a volume of approximately 35,000m^{3} per month potentially finding its way into the reservoir systems.

At an overall level these results for increased sedimentation indicate the potential for degradation to result in substantial decreases in the efficacy and lifespan of costly impoundments.

7.5 MODELLING THE IMPLICATIONS OF MANAGEMENT OPTIONS ON VEGETATION COVER/LAND USE SCENARIOS

The hydrological modelling of the 54 quinary catchments and 378 vegetation specific quinary subdivisions for the six vegetation cover/land use scenarios resulted in the generation of large quantities of data. Modelling generated 2,268 suites of results, each with 4 outputs, namely baseflows (dry season flows), stormflows, sediments yields, and annual yields (or stream flow). Based on these results, the following four management options were identified:

1. Control and clearing of alien invasive plants only.
2. Revegetation of denuded areas only.
3. Maximisation of base flow.
4. Maximisation of yield.

The implications of these management options on the vegetation cover/land use scenarios were then used as a basis for the ecological-economic model, which is discussed in detail in Section 8.

7.5.1 Control & clearing of invasive alien plants

This management option considers only alien plant clearing across all invaded habitats – with no revegetation at all.

Note that the Baviaanskloof produces little benefit in this option as there are minimal invasive alien plant infestations of hydrological significance. However, this does not preclude low level maintenance to ensure the exclusion of infestations. The results of this management option show a significant increase in stream flow or yield of some 8.2 million m^3 per annum, with management in the Kromme delivering the greatest volumes (see Table 7.2 and Appendix 1.1). The increase in baseflow is lower at 4.6 million m^3 per annum. This option has minimal impact on sediment reduction benefits.

Table 7.2: Changes in yield, baseflows, and sediment reduction with control and clearing of alien invasive plants only

	Kromme	Kouga	Baviaanskloof	Total
Change in yield: m^3 per yr	4,441,006	3,838,286	-	8,279,293
Change in baseflow: m^3 per yr	2,409,231	2,276,552	-	4,685,782
Sediment reduction: m^3 per yr	-	-	-	-

7.5.2 Revegetation of denuded areas

This management option would entail only revegetation of denuded areas across denuded habitats – with no invasive alien plant removal (i.e. revegetation is applied and only in those quinaries where denuded landscapes exist).

This option results in the greatest reduction in yield with a 14.2 million m^3 per annum reduction, largely from the Kouga. On the other hand, this option generates a 41.5 m^3 million increase in baseflow, with substantial contributions from all three systems (see Table 7.3 and Appendix 1.2). It produces a similar sediment reduction services to the maximising baseflow management option.

Table 7.3: Changes in yield, baseflows, and sediment reduction with revegetation of denuded areas only

	Kromme	Kouga	Baviaans	Total
Change in yield: m^3 per yr	-1 931 146	-10 599 850	-1 708 949	-14 239 945
Change in baseflow: m^3 per yr	20 028 219	15 861 808	5 649 308	41 539 335
Sediment reduction: m^3 per yr	91 522	112 693	44 571	248 786

7.5.3 Maximising the baseflow (dry season flows)

This includes a combination of invasive alien plant removal and revegetation, but optimising for baseflow only. This implies that each quinary was individually evaluated and whichever intervention showed the greater impact in increase baseflow, was selected as the preferred intervention. Please note that a combination of revegetation and the removal of invasive alien plant within a single quinary were not possible to model.

In this management option, a mix of largely revegetation (in 49 quinaries) and limited invasive alien plant removal (in 5 quinaries), results in an increase of 42.3 million m^3 in baseflow or dry season flows per year (see Table 7.4 and Appendix 1.3). Such a management strategy, however, does reduce the total streamflow or yield by some 13 million m^3 per year. The Kromme delivers the greatest increase in baseflow and the Kouga the greatest reduction in yield. This management option also generates the greatest reduction in sediment loads, with the Kouga making the biggest sediment reduction contribution.

Table 7.4: Changes in yield, baseflows, and sediment reduction with combination of control clearing of alien invasive plants and revegetation to maximise baseflows

	Kromme	Kouga	Baviaans	Total
Change in yield: m^3 per yr	-1 931 146	-9 227 209	-1 708 949	-12 867 304
Change in baseflow: m^3 per yr	20 028 219	16 688 029	5 649 308	42 365 556
Sediment reduction: m^3 per yr	91 522	112 693	44 571	248 786

The trade-off between yield and baseflow is a particularly vexing paradox. Historically water management practises was aimed, and rightly so, on supplying water with a very high assurance of supply. This strategy necessitates a focus on yield maximisation or total streamflow to enable the water storage maximisation. This means that the storage dams are often 'over-engineered' to enable the capturing of flood water and, consequently, for receiving large volumes of sediment. This over-engineering often comes at a high construction cost.

Such a water management practice and storage system is, however, not optimal under conditions of degradation and the need for in-stream water flow. A degraded watershed that receives rainfall is unable to retain the water and generates immediate high stormflows causing further erosion, sedimentation, loss of land productivity and flood damage, to mention but a few consequences. A degraded watershed is less productive for land users due to poorer soils and less soil moisture. Perennial rivers turn into seasonal ones with little dry season flow that seriously impacts on river ecology that limits or even temporarily interrupting the supply of ecosystem services like water abstraction, organic waste discharge assimilation, waste water dilution, water pathogens control, sediment content control and aquatic pest control (plants and animals). The temporary interruption or seasonal reduction in these service levels have important implications for human welfare – with less water for people who use the river directly and with greater exposure of health risks due to higher pollution concentrations. This becomes even more so where waste water treatment works exceed permissible waste water discharge levels. These compounding factors generate a need for increasingly robust river systems to assimilate greater pollution discharges. Maximising baseflow supports more robust river ecology and also provides greater surety of supply to river water users.

Clearly a unilateral trade-off between yield and baseflow is not sustainable since both have their role to play within the water supply and distribution system. The value of baseflow is also, in part, recognised through the concern there is for specific streamflow reduction activities such as timber production. The Department of Water Affairs makes considerable investments into the management and control of such streamflow reduction activities. This may be seen as a contradiction as there is great concern regarding the state of one streamflow reduction land use – timber production - and not for other streamflow reduction activities that cumulatively have a great impact on baseflow, and hence the ability of an ecosystem to survive and all those human and economic activities that depend on in-stream water flows.

There is therefore a need to reconcile and water use requirements of those who reside in watersheds and directly use the land and river and those users of water stored in dams in those watersheds. With increasing scarcity of many aquatic ecosystem services and not just a scarcity of water for abstraction, the implications of the current watershed management paradigm for societal welfare need to be reviewed, particularly in the light of the outcomes of this research.

7.5.4 Maximising yield (streamflow)

This permutation includes a combination of invasive alien plant removal and revegetation, but optimising for yield – i.e., whichever intervention showed the greater impact in terms of increased yield within a specific quinary was selected and the alternative was ignored. Please note, as mentioned above, it was not possible to model a combination of invasive alien plant removal and revegetation within a single quinary.

In this management option, revegetation is applied in 26 quinaries, and invasive alien plant clearing is applied in the other 28 quinaries. This option generates the greatest increase in yield, some 11 million m^3 per annum, with an increase of 14 million m^3 per annum in baseflow (see Table 7.5 and Appendix 1.4). Importantly, interventions in the Kromme have the greatest positive impacts on both yield and baseflow. Alien plant management has a small positive impact on sediment reduction.

Table 7.5: Changes in yield, baseflows, and sediment reduction with combination of control clearing of alien invasive plants and revegetation to maximise yields.

	Kromme	Kouga	Baviaans	Total
Change in yield: m^3 per yr	5,986,263	3,838,286	1,267,183	11,091,733
Change in baseflow: m^3 per yr	8,936,255	2,276,552	2,781,529	13,994,335
Sediment reduction: m^3 per yr	13,492	-	8,747	22,239

8. THE INTEGRATED ECOLOGICAL-ECONOMIC MODEL

An integrated ecological-economic model, using Excel, has been constructed based on the information provided by the hydrological model above. The basic model structure is provided below.

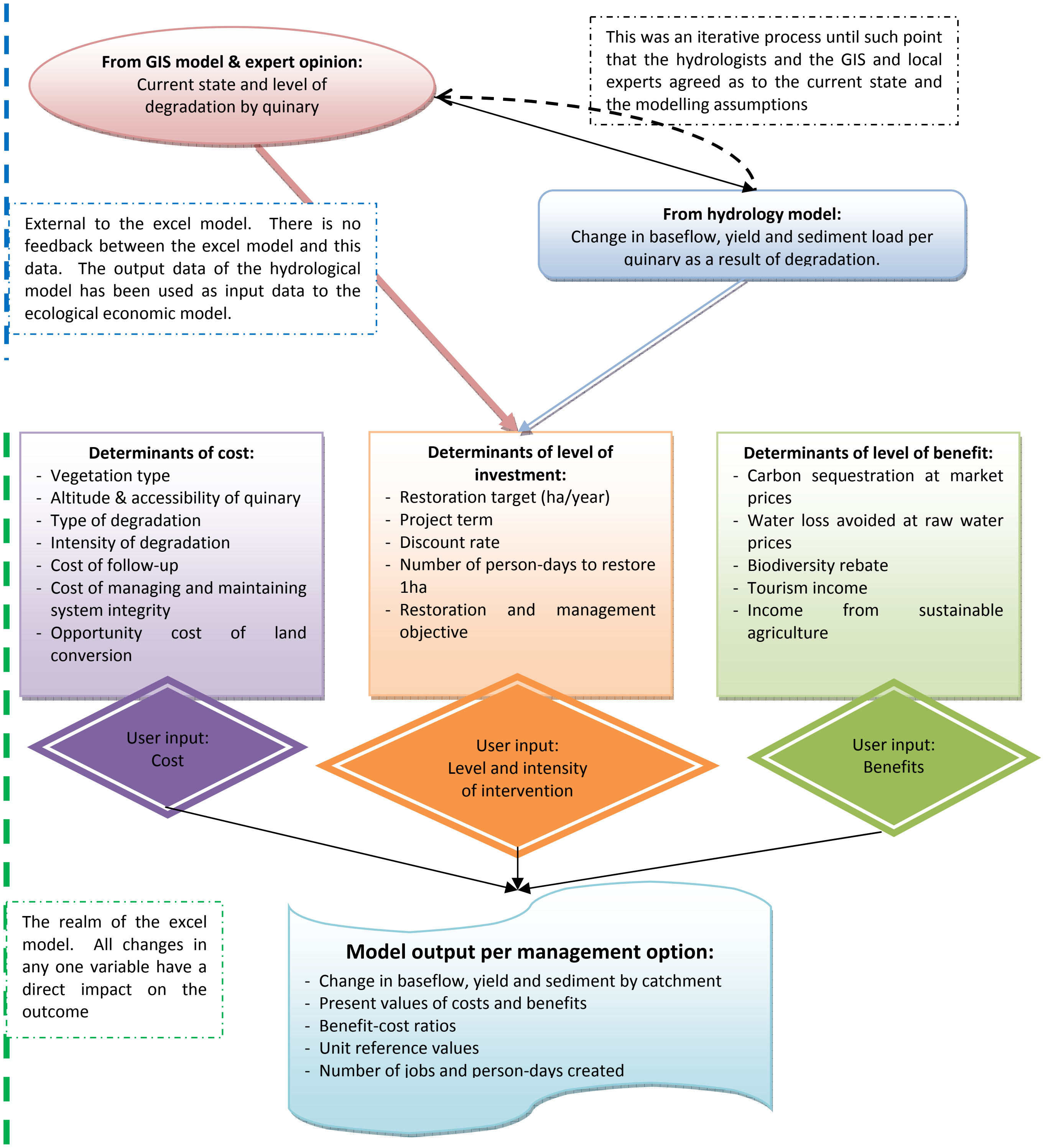


Figure 8.1: Basic structure of the ecological-economic model

The model accepts the information received from the hydrological and GIS modelling teams, teams that worked in close collaboration with local and regional ecologists, concerning the type and level of degradation and the resultant change in baseflow, yield and sediment by quinary as a result of the degradation, as exogenous input data. Endogenous to the model, however, and subject to user input, are a number of variables. These variables can be categorised into being cost, benefit or general input related.

The cost data are by and large driven by:

- the type of degradation, i.e. whether it is invasive alien plants species or areas denuded of indigenous vegetation mainly as a result of overgrazing,
- the severity of degradation, i.e. pristine, low, medium of high density of invasive alien plants, or moderate or severe degradation as a result of overgrazing,
- the altitude and accessibility of the quinary, i.e. whether it is a low lying (valley-bottom) quinary, or whether it is a high altitude (mountainous) quinary with steep slopes,
- the cost of restoration,
- the cost of follow-up treatments after restoration,
- the cost of ongoing management after restoration over the entire project lifetime to maintain system integrity, such as the control and maintenance of fire breaks, and
- the opportunity cost of land conversion, i.e. the difference between the current return (R/ha) from agriculture and the return from sustainable agriculture.

The benefits are determined predominantly by:

- the level and the rate of carbon sequestration as a result of the change in land use (including restoration) and the avoided carbon loss due to sediment reduction,
- the additional water in the system, either as delayed flows, also called baseflows, and yield. Water has been valued in terms of the prevailing raw water tariff and in terms of the opportunity cost of water if not added to the system, valued at the highest block water tariff. This value provides an indication of the economic value of the water if added to the system and utilised at the margin,
- the value of added nature-based tourism, especially in the Baviaanskloof (including hunting),
- the return from sustainable, non-competing, agriculture, and
- biodiversity by the introduction of income tax advantages for biodiversity conservation as agreed to by the National Treasury under strict conditions of land use change.

The set of general assumptions and variables include:

- the determination of a project period,
- the determination of a preferred project discount rate,
- the setting of a restoration target, i.e. the number of ha per year per quinary that can be realistically restored. This target determines the length of the restoration period and is different from and not to be confused with the project period,
- the number of person days required to restore 1ha of degraded land (either with invasive alien plants or through overgrazing)
- the establishment of management options. There are four mutually exclusive management options to select from, these are:
    1. Baseflow maximisation (the model determines, for each quinary, whether the clearing of invasive alien plants or the revegetation of the land, will maximise baseflow and pick that management intervention for the quinary),
    2. Yield maximisation (the model determines, for each quinary, whether the clearing of invasive alien plants or the revegetation of the land, will maximise yield and pick that management intervention for the quinary),
    3. Clearing of invasive alien plants (this intervention assumes no revegetation – for all quinaries), and

4. Re-vegetation of areas denude of vegetation (this intervention assumes clearing of invasive alien plants – for all quinaries).

The combination of the above allows the model user to determine, at a high-level, whether restoration and the management of the land according to sound ecological principles will be financially and economically viable. This is done using a standard cost-benefit approach, based on the project period and discount rate as well as project objective selected. The model also estimates the unit reference values for each of the benefits as well as in combination.

Unit reference values have been popularised by water resource planners in South Africa and are effectively the present value of the total cost of producing water (conventionally this is the cost of producing a certain amount of total annual yield) divided by the present value of the volume of water (the total annual yield). This implies that the unit reference value is the cost of producing one unit of water normalised over the entire project lifespan. In this case the model estimates the unit reference value as discussed here, but also adds other benefits as negative costs, i.e. the model subtracts the benefits from, for example, carbon, from the cost of producing the water and hence lowering the unit reference value to the point where it is actually possible to achieve a negative unit reference value. A negative unit reference value implies that by not implementing the management, there is a net loss to society.

Lastly, the model determines the number of person-days and the discounted present value of the cost of the jobs created. This is an important indicator since one of the project objectives is likely to be poverty alleviation and job creation.

The model has a user input module and a model output module. This allows for ease of use and for its use in roundtable discussions. Any of the user inputs can be changed and the model outcome is immediately registered. The model has been developed for high-level assessment within the context of conducting a feasibility assessment. The model is not refined enough to provide assistance as to optimal land use management practices within any or each of the quinaries. The model is also not refined enough to engage in a payments for ecosystem goods and services transaction. That will require farm-level data and a site specific intervention strategy. This is due to the 54 quinaries in the model varying considerably in size, with the smallest being 878ha and the largest 38,987ha. Despite these shortcomings, the model will, and does, indicate in which quinary, and based on which management objective, the likelihood of achieving or obtaining a positive (or financially and economically viable) outcome following restoration and land use conversion is best.

9. THE FEASIBILITY OF IMPLEMENTING A PAYMENT FOR ECOSYSTEM OR WATERSHED SERVICES SCHEME

The economic feasibility of paying for the management of watersheds for ecosystem services delivery can be modelled and understood at a number of scales. As noted previously, this assessment focuses on the broad scale with the 54 quinaries in the 3 watersheds being modelled individually and collectively for four different management options. In Table 9.1 and 9.2 below, a summary of all the aggregated estimates for all three watersheds in each management option is outlined. The summary highlights the water services changes, the costs of management, the benefits of management, the benefit-cost ratio, the unit reference values, and the potential jobs generated. Please note:

1. All these estimates are the totals for a 30 year project period at a 4% discount rate.
2. The hectare based estimates are averages for an entire watershed.

From Table 9.1 and 9.2 it is evident that baseflow maximisation and revegetation of denuded areas options are financially and economically feasible as market-based PES schemes. The yield maximisation option, while not financially feasible, is economically feasible as a public works PES scheme, given the value added to the economy by the additional water. The results of this study should not be interpreted such that yield is no longer important. The results indicate changes in addition to an existing baseline where yield is indeed very important.

The alien plant removal option is neither financially nor economically feasible because it focuses on managing light and dense infestations across the entire watershed, which greatly increases management costs. The actions of the Working for Water programme (WfW) are most comparable to the yield maximisation option (aside from this option including undertaking revegetation where WfW doesn't) as both focus only on the management of densely infested areas, thereby reducing management costs.

In the sections which follow the summary table, key findings are explored further.

Table 9.1: Summary of feasibility assessment results (all values in current terms using a 4% discount rate)
Colour codes: Green = good values; yellow/orange = moderate or marginal values; red = suboptimal or poor values

Water services changes: per annum	Control and clearing of IAP	Baseflow maximisation	Revegetation of denuded areas	Yield maximisation
Change in yield: m^3	8 279 293	-12 867 304	-14 239 945	11 091 733
Change in baseflow: m^3	4 685 782	42 365 556	41 539 335	13 994 335
Sediment reduction: m^3	-	248 786	248 786	22 239

Comments: The baseflow maximisation and revegetation options show the greatest gains in baseflow, but also show significant losses in yield. The yield maximisation option shows a similar good increase in both baseflow and yield. The control and clearing of invasive alien plants generates the least additional water services.

Cost of implementation: over 30 yrs	Control and clearing of IAP	Baseflow maximisation	Revegetation of denuded areas	Yield maximisation
PV: Restoration cost: Tot	R 346 260 444	R 395 873 218	R 341 891 809	R 419 796 768
PV: Restoration cost: R/ha	R 686	R 784	R 677	R 832
PV: Management cost: Tot	R 629 331 095	R 258 267 310	R 201 589 099	R 615 243 354
PV: Management cost: R/ha	R 1 247	R 512	R 399	R 1 219
PV: Total cost: R	R 975 591 539	R 654 140 529	R 543 480 909	R 1 035 040 122
PV: Total cost: R/ha	R 1 933	R 1 296	R 1 077	R 2 051

Comments: The revegetation option shows the least costs for implementation, but still a very significant cost. The yield maximisation and control of invasive alien plant species are double the costs of the revegetation option. These management approaches show a significant difference in implementation costs – ranging between R500 million and R1 billion.

Benefits of implementation: over 30 yrs	Control and clearing of IAP	Baseflow maximisation	Revegetation of denuded areas	Yield maximisation
PV: Above ground carbon	R 0	R 1 076 515 224	R 1 104 600 213	R 319 107 186
PV: Above ground carbon / ha	R 0	R 2 133	R 2 189	R 632
PV: Avoided loss: Soil carbon	R 0	R 26 036 536	R 26 036 536	R 2 967 719
PV: Avoided loss: soil carbon/ ha	R 0	R 52	R 52	R 6
PV: Total carbon	R 0	R 1 102 551 760	R 1 130 636 749	R 322 074 904
PV: Total carbon / ha	R 0	R 2 185	R 2 240	R 638
PV: Water: Value of sales	R 38 394 873	R 347 139 495	R 340 369 520	R 114 668 306
PV: Water: Value of sales / ha	R 76	R 688	R 674	R 227
PV: Water: Economic value	R 626 604 334	R 5 665 316 559	R 5 554 830 565	R 1 871 386 757
PV: Water: Economic value / ha	R 1 242	R 11 225	R 11 006	R 3 708
PV: Land use change: (Agric., biodiversity & tourism)	R 314 459 527	R 668 988 435	R 648 055 639	R 438 270 881
PV: Land use change: (Agric., biodiversity & tourism) / ha	R 623	R 1 326	R 1 284	R 868
PV: Sediment reduction	R 0	R 21 078 379	R 21 078 379	R 1 884 204
PV: Sediment reduction / ha	R 0	R 42	R 42	R 4
PV: Total (excluding economic value of water)	R 352 854 400	R 2 139 758 069	R 2 140 140 287	R 876 898 296
PV: Total (excluding economic value of water)/ ha	R 699	R 4 240	R 4 240	R 1 737

Comments: Management that focuses exclusively on invasive alien plant clearing has no carbon sequestration benefits, resulting in benefits 2.5 to 7 times less than the other options. The baseflow maximisation and revegetation options generate similar benefits levels, some R4,200 per hectare pa. In these two options the carbon and tourism benefits are both substantial. The yield maximisation benefits are 2.5 times greater than the invasive alien plant control option, but 2.5 times smaller than the other baseflow maximisation and revegetation options. The motivation for a nature-based economy is even more attractive if the economic value of water is considered.

Table 9.2: Diagnostic assessment of feasibility assessment
Colour codes: Green = good values; yellow/orange = moderate or marginal values; red = suboptimal or poor values

Net Present Value	Control and clearing of IAP	Baseflow maximisation	Revegetation of denuded areas	Yield Maximisation
Net Present Value	R -622 737 140	R 1 485 617 540	R 1 596 659 378	R -158 141 827
Net Present Value per ha	R -1 234	R 2 944	R 3 164	R -313
Benefit-Cost Ratio	**Control and clearing of IAP**	**Baseflow maximisation**	**Revegetation of denuded areas**	**Yield maximisation**
Restoration + Management: Carbon	0.00	1.69	2.08	0.31
Restoration + Management: Water sales	0.04	0.53	0.63	0.11
Restoration + Management: Land use change	0.32	1.02	1.19	0.42
Restoration + Management: Sediment	0.00	0.03	0.04	0.00
Restoration + Management: Total	0.36	3.27	3.94	0.85
Comments: In essence, the control of invasive alien plants option does not break even. The yield maximisation option gets close to breaking even at 0.85, but the revegetation and baseline maximisation options, show significantly positive ratios. These latter two options are therefore highly feasible. These results also show that water sales alone cannot pay for the management and restoration required. The implication is that if water is the focus of any watershed management, then the water consumers could pay for the management only and not the restoration costs as well. To make a watershed restoration and management programme economically feasible and sustainable, then carbon sequestration and/or tourism/game need to be added to the suite of sales, to finance both restoration and management required.				
Unit Reference Value	**Control and clearing of IAP**	**Baseflow maximisation**	**Revegetation of denuded areas**	**Yield maximisation**
URV: Water only	7.19	0.93	0.80	3.59
URV: Water & above ground carbon	7.19	-0.60	-0.82	2.48
URV: Water, above ground carbon, land use change & sediment	4.87	-1.58	-1.81	0.96
Comments: In terms of water sales, the control of invasive alien plant species and yield maximisation have similar URVs to waste water recycling and the construction of dams. The baseflow maximisation and revegetation options are less than 1, showing very attractive URVs. The negative values show that carbon sequestration, land use changes, and sediment reduction services are very costly to society if not implemented. A negative URV indicates a societal loss for every day the project is not implemented.				
Jobs creation: over 30 years	**Control and clearing of IAP**	**Baseflow maximisation**	**Revegetation of denuded areas**	**Yield maximisation**
Restoration: Person-days	2 337 130	3 431 131	3 216 009	3 196 410
Management: Person-days	1 520 098	1 305 166	1 164 872	1 632 271
Total: Person-days	3 857 228	4 736 296	4 380 881	4 828 682
Comments: The invasive alien plant control option will generate some 640 jobs a year for 30 years, while the yield maximisation and baseflow maximisation will generate some 800 jobs a year for 30 years.				

For details of the respective watersheds, see the disaggregated estimates per watershed in Appendix 1.1 to 1.4. Importantly, there are significant differences between watersheds, and between quinaries within watersheds, due to rainfall, vegetation cover, current condition and altitude. A summary of the benefit-cost ratio analyses for each individual watershed per ecosystem service and for the total bundle of services is outlined in Table 9.3 below.

Table 9.3: Summary of the benefit-cost ratios for management options in the three watersheds

Colour key: **benefit-cost ratio** >2 = green, **benefit-cost ratio** <1 = red

Baseflow maximisation	Kromme	Kouga	Baviaanskloof	Total
Restoration + Management: Carbon	1.34	1.45	2.19	1.69
Restoration + Management: Water sales	1.01	0.52	0.20	0.53
Restoration + Management: Land use change	0.23	1.24	1.34	1.02
Restoration + Management: Sediment	0.05	0.04	0.02	0.03
Restoration + Management: Total bundle of services	2.63	3.25	3.74	3.27
Control & clearing of IAPs	**Kromme**	**Kouga**	**Baviaanskloof**	**Total**
Restoration + Management: Carbon	0.00	0.00	0.00	0.00
Restoration + Management: Water sales	0.05	0.03	0.00	0.04
Restoration + Management: Land use change	0.05	0.50	0.00	0.32
Restoration + Management: Sediment	0.00	0.00	0.00	0.00
Restoration + Management: Total bundle of services	0.10	0.53	0.00	0.36
Revegetation of denuded areas	**Kromme**	**Kouga**	**Baviaanskloof**	**Total**
Restoration + Management: Carbon	1.34	2.71	2.19	2.08
Restoration + Management: Water sales	1.01	0.87	0.20	0.63
Restoration + Management: Land use change	0.23	2.01	1.34	1.19
Restoration + Management: Sediment	0.05	0.06	0.02	0.04
Restoration + Management: Total bundle of services	2.63	5.64	3.74	3.94
Yield maximisation	**Kromme**	**Kouga**	**Baviaanskloof**	**Total**
Restoration + Management: Carbon	0.23	0.04	2.25	0.31
Restoration + Management: Water sales	0.20	0.03	0.24	0.11
Restoration + Management: Land use change	0.08	0.48	1.38	0.42
Restoration + Management: Sediment	0.00	0.00	0.01	0.00
Restoration + Management: Total bundle of services	0.52	0.55	3.88	0.85

The benefit-cost ratios show clearly that carbon and land use change (tourism and sustainable agriculture) are key drivers in determining the feasibility of a PES scheme. It is only in the Kromme that water can stand alone as a driver of a PES scheme, and only then when restoration takes place.

Following from the results above it is possible to chart a possible PES scheme for the study area. Figure 9.1 outlines the potential flows in a PES scheme. Note the – or + symbols at the arrowheads, which show the nature of the relationship or feedback. Importantly, carbon sequestration and tourism sales are the deal makers in these three watersheds, and hence the management options that include large scale restoration are feasible.

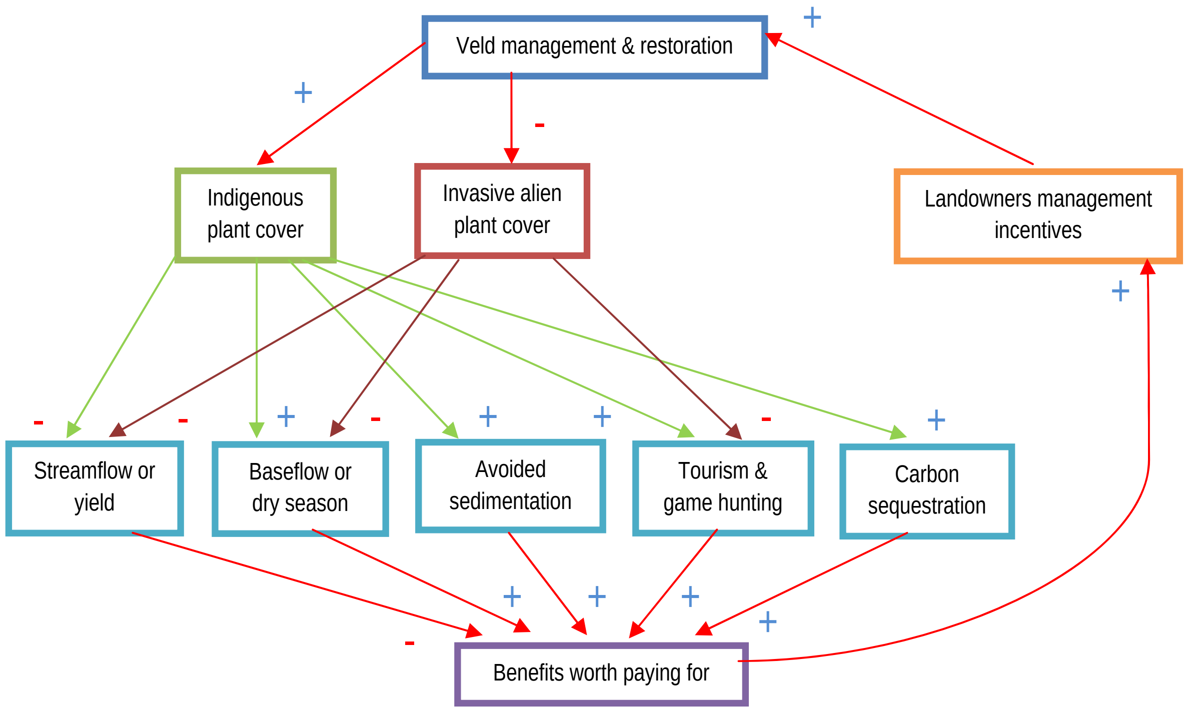


Figure 9.1: A schematic representation of PES system in the Baviaanskloof-Tstitiskamma watersheds

10. THE IMPLICATIONS OF THE FEASIBILITY ASSESSMENT

At the farm level, for any new land use to be feasible, its financial returns need to be greater than current returns per hectare. In the project area, intensive irrigated fruit and vegetable crops generate between R 15,000 and R 150,000 per hectare per year. Cleary these returns are at least 100 times greater than the value of watershed services, and consequently payment for ecosystem services will not be able to influence farmers' land use decisions regarding **intensive** agriculture in the foreseeable future. The current net returns to **extensive** stock farming are, however, between R 37 to R 80 per hectare per year (Blignaut *et al.* 2009). When comparing the returns of payments for ecosystem services to these extensive stock uses, management of the watershed becomes a feasible or attractive option for farmers. Table 10.1 outlines the annual returns to payment for watershed and ecosystem services. It is especially baseflow maximisation and restoration where the economic values (net returns) exceed the possible returns from unsustainable stock farming by at least a margin of 23% (the difference between R 80 and R 98,12) but also by a possible 185% (the difference between R 37 and R 105,46).

In terms of the feasibility of the different management strategies, Figure 10.1 shows the baseflow maximisation and revegetation options to be beneficial for farmers, largely a factor of the benefits of carbon sequestration and land use change. The latter is likely to qualify farmers for biodiversity conservation related income tax advantages in accordance with National Treasury guidelines, returns from tourism and hunting as well as sustainable agriculture practises.

At the watershed or society scale, this assessment shows that the benefits of farming for baseflow maximisation and revegetation are 3 to 4 times greater than implementation costs making this an attractive option for society to invest in. However, the returns to invasive alien plant clearing and yield maximisation are 0.36 and 0.85 times the costs respectively, providing limited incentive at present for society to implement different land use management focused on these outcomes only at a catchment-wide scale. Figure 10.1 shows that invasive alien plant control and yield maximisation options are not financially feasible, but that the baseflow maximisation and revegetation options are feasible, with the revegetation option showing the greatest revenue to land owners.

Table 10.1: Returns to farmers for watershed and ecosystem services (in current prices)

Returns to ecosystem services	Control and clearing of IAP	Baseflow maximisation	Revegetation of denuded areas	Yield maximisation
Above ground carbon / ha	R -	R 71.10	R 72.95	R 21.08
Avoided loss: soil carbon/ ha	R -	R 1.72	R 1.72	R 0.20
Water: Value of sales / ha	R 2.54	R 22.93	R 22.48	R 7.57
Land use change: (Agric., biodiv & tourism)/ ha	R 20.77	R 44.18	R 42.80	R 28.95
Sediment reduction / ha	R -	R 1.39	R 1.39	R 0.12
Total benefits: R/ha/yr	R 23.30	R 141.32	R 141.35	R 57.92
Total cost[4]: R/ha/yr	R 64.43	R 43.20	R 35.89	R 68.36
Net returns: R/ha/yr	R -41.13	R 98.12	R 105.46	R -10.44

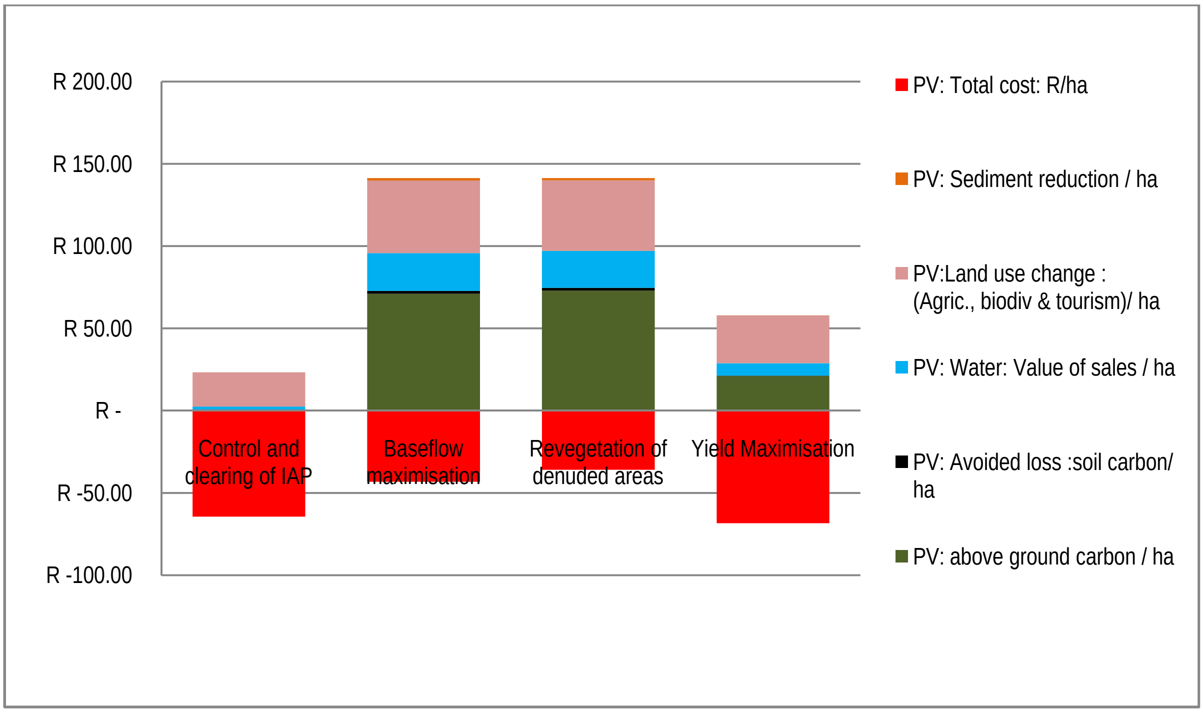


Figure 10.1: Returns per hectare for restoration and management per year

When conducting a feasibility study of this nature it is important to differentiate between the possible economy-wide and societal economic benefits and the possible financial (actual monetary) returns to the land-owner. The challenge of all such PES schemes is to convert economic benefit into financial return since it is the latter that acts as incentive for land-use change. The former motivates why such as change in land-use is advisable or preferred from a societal perspective, but it is the financial returns that makes it viable for the farmer. This is also illustrated here where the societal level economic benefits of land use change exceeds the

[4] Total cost includes the opportunity cost of reducing stock levels to sustainable levels.

financial benefits land owners receive from unsustainable practises under two of the four scenario's, and that by quite some margin (between 23% and 185%). The clearing of alien plants has costs greater than returns[5].

While the benefits of the options differ, the costs are also significantly different, with alien plant clearing and yield maximisation costs being substantially greater than the revegetation and baseflow maximisation costs. Figure 10.2 shows the relative scale of a portion of the social benefits measured using the economic value of water[6] and costs of the different options. Clearly, the baseflow maximisation and the revegetation options are the most feasible from a net social benefit perspective. However, these benefits are only possible if carbon or tourism are traded which can then finance the restoration and management costs.

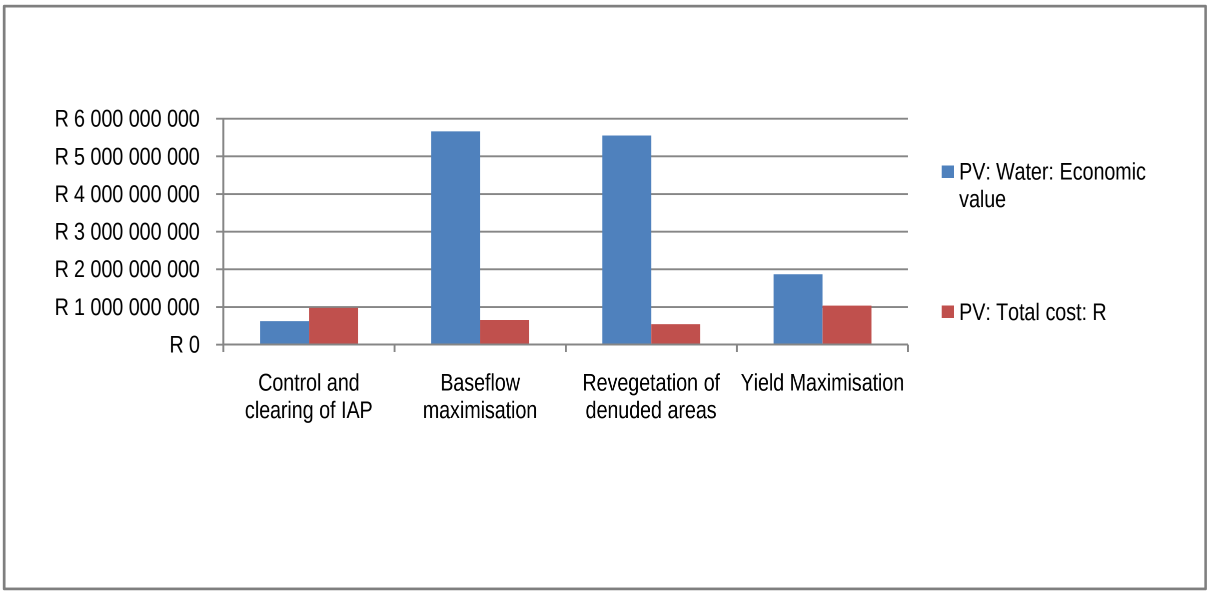


Figure 10.2: The economic value of water versus the costs of producing the water and other services

The key implications of these findings for the watershed community are as follows:

Farmers:

- It is financially feasible to change from stock farming, which is not sustainable, to a multiple service focus, which includes:
  - reduced but sustainable stocking rates,
  - vegetation restoration and management to generate carbon sequestration, game habitat, tourism assets, sediment avoidance, avoided soil carbon loss and increased water security.
- This is dependent on access to a market. While the tourism and hunting market is growing in the region, access to the carbon market is limited. However, there is a good case for carbon sequestration in addition to tourism and hunting, given the current downward trend in the condition of the vegetation and the likelihood of no state support to restore thicket on private land.
- The global carbon market is growing in scale and competitiveness - accessing it requires initiative, collaborative effort and willingness to take on risks in order to gain potentially significant rewards.

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[5] Note – this analysis does not include job creation as a societal objective and consequently is not comparable to current Working for Water programmes, which serves the dual objectives of creating jobs and water. This feasibility assessment focuses strictly on potential income streams from ecosystem or watershed services. In the event that the government wishes to provide incentives for job creation and pay for the labour component, then the picture changes. This, however, is a generic fact also applicable to the other management interventions.

[6] The economic value of water is estimated by multiplying the change in water quantity potentially available by the NMBM highest block tariff (R8.16 per m^3).

- A water market can be developed whereby farmers either lease or sell their current registered water use licenses to a party (notably the municipality) to augment the water sources for the municipality and thereby generate an income stream for the farmers. It is also possible to engage in water neutral schemes and other such PES options whereby water can be sold to non-catchment specific buyers. It would also be possible to link the sale of water (or better: the sale of the right to use the water and not actually the water licence itself) to conservation agencies who might be interested in the biodiversity benefits such added water might bring to the ecosystem, especially in the case of the Baviaanskloof whereby the beneficiary would be a Word Heritage Site.

To illustrate the benefits to the farmer to convert to a natural capital base economy, herewith a hypothetical example of the financial benefits to a farmer on a hypothetical farm with particulars as provided below:

Table 10.2: Hypothetical example of benefits to farmer from converting to natural capital based economy

Hypothetical farm inputs:	
Farm size:	500ha
Farm % under thicket	60% (20% seriously and 30% moderately degraded)
Farm % under fynbos	40% (20% seriously and 30% moderately degraded)
Water use licence	linked to 100ha of existing farm land
Water allocation	7500kl/ha/a under water use agreement
Costs:	
Thicket	R 3,900 and R 5,000 for moderate and severe degradation respectively
Fynbos	R 1,900 and R 2,700 for moderate and severe degradation respectively
Management cost	15%/a of restoration cost
Transaction cost:	R1 million in the first year (larger areas result in spreading transactions costs so this amount would be relatively similar for a larger area including a number of farms)
Current net return	R150/ha/a on existing operations (this acts as the opportunity cost for converting to a new land use option and is factored in as a cost item in the model)
Returns:	
Carbon sequestration	5tCO_2/ha/yr for thicket and 1tCO_2/ha/t for fynbos
Carbon price	$15/t$CO_2$/yr at an exchange rate of R7.5/$
Value of water	R1/kl sold to third party for use
General model inputs:	
Discount rate	4%
Term	20 years
Model results:	
Benefit-cost ratio	1.6
Internal rate of return	23%
Net present value	R 3.97m over 20 years
Net return	R 397.56/ha/yr

From the above it is evident that the farmer stands to gain substantially by converting his land use management practises.

Water suppliers or managers:

- The water managers could focus on either baseflow or yield. As discussed previously, water planners may prefer a focus on water yield. If that is the case, then the yield maximisation option delivers some R 1,737 per ha worth of benefits over 30 years at a cost of R 2,051 per ha. This implies a 15% loss and an annual shortfall of R 10,44/ha/yr.
- Should this option be pursued due to the perceived gains from the economic value of water (not the financial value) (see Figure 10.1), where the economic gains of the water are substantial and where the

net social benefit is greater than the costs, then government will need to find the outstanding balance, with implications for the taxpayer or for a potential water tariff increase.

- Whether baseflow maximisation or yield maximisation is selected, carbon sequestration and tourism would still need to be key elements of farm income to ensure that incentives are in place to implement the desired land use and management. A critical element in promoting water security would be for water managers to support the establishment of associated carbon and tourism markets.
- The 'new' water may be useful for meeting the environmental flows of the affected rivers if the assurance of supply is considered too low.
- The findings of the study indicate that water management programmes, such as Working for Water, could be substantially bolstered if their approach was broadened to include PES components.

Water consumers:

- Water consumers have an alternative or additional mechanism to support water security. The options to increase baseflow and/or yield offer opportunities for 'new' water albeit that this water is likely to have a lower assurance of supply given its links to land surface management.
- For run-of-river water users, water security will be enhanced under all options, and therefore they should support any such watershed management actions.

Conservation agencies:

- If conservation agencies wish to facilitate land use changes to support the growth of local biodiversity on private land, then they should support farmers in accessing carbon trading and tourism markets to ensure that sufficient incentives are in place for farmers to change land use.
- In terms of gaining additional revenue streams from carbon and water services supply from the conservation estate, there are three possibilities.
    1. Eastern Cape Parks (ECP) is an organ of state and they are mandated to conserve biodiversity. Therefore they should be restoring and managing the system's biodiversity as a matter of course and therefore one may not be able to claim any additionality in terms of carbon sequestration.
    2. ECP is unable to access sufficient state funds to undertake active restoration as current budgets are only sufficient to fund ongoing management. Therefore the sale of carbon offsets would generate the monies for restoration which could then be argued to be additional. However, with this option, the additionality driver is a risk as government could increase state funding to ECPB for management putting carbon offsets sales at risk. This option is inherently risky for a carbon buyer as the long term future of claiming offsets is uncertain.
    3. ECP goes into a bilateral agreement with a carbon buyer who is willing to accept the risks, and buys the carbon credits. This is likely to be a buyer who is also interested in biodiversity services.

Agencies promoting sustainable land use:

- An agency/facility needs to be established to facilitate the trade in carbon offsets which have high potential to be produced in this system, particularly the Baviaanskloof system through spekboom restoration. This will create substantial incentives for land owners to engage in restoration of the thicket. It would appear that this future market is critical to transforming the current farming systems to a nature-based economy, particularly where tourism has limited benefits.
- A facility needs to be established to promote tourism, as a vibrant tourism trade would support farmers in reducing stock numbers and in pursuing habitat restoration.
- A vibrant carbon and tourism market in this region would provide substantial impetus for widespread land use change.

Government – local, district, provincial and national:

- The Baviaanskloof-Tsitiskamma watersheds house natural assets with high value ecosystem services of considerable value to all levels of government:
    - A critical water resource for the local municipalities,
    - An outstanding tourism asset for the province to attract national and international visitors,
    - A flood reduction service for district, provincial, and national roads,
    - A basis for the revival and diversification of the district's rural economies,
    - An option for augmenting water security for the Nelson Mandela Metro, and for enhancing the longevity of existing water infrastructure, and
    - A World Heritage Site which offers RSA prestige, but also responsibilities.
- This asset is, however, being run down by disparate use and excessive consumption of ecosystem goods or plain neglect – such as stock fodder use, inappropriate burning, or neglect of alien plant infestations. The loss of these assets will have large and significant costs for government – already illustrated by regional flood damage repairs and water shortages.
- A concerted effort is required by government to promote the integrated and harmonious use of the Baviaanskloof-Tsitsikamma watersheds as the combined benefits of a suite of compatible ecosystem services far outweigh the management costs and the individual benefits of destructive over-consumption.
- The need to optimise the use of existing natural capital or natural infrastructure is growing daily and should be viewed as an economic development imperative for the region.

11. AREAS FOR FURTHER RESEARCH

Areas for further research include:

- Finding a champion who will convert the feasibility assessment into a trade benefiting people and the environment.
- Developing the practical institutional framework for implementing the PES scheme.
- Quantifying the value of baseflow to the environment and people who depend on a perennial river.
- Developing a GIS linked model to facilitate management decisions in the 54 quinaries.
- Identify the role of wetlands, particularly peat wetlands in the Kromme system, in water security and carbon sequestration.

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APPENDIX 1.1: CONTROL & CLEARING OF ALIEN INVASIVE PLANTS

OUTPUT DATA:
Control & clearing of IAPs

	Krom	*Kouga*	*Baviaans*	*Total*
General				
Change in yield: m^3	4 441 006	3 838 286	-	8 279 293
Change in baseflow: m^3	2 409 231	2 276 552	-	4 685 782
Sediment reduction: m^3	-	-	-	-

Cost				
PV: Restoration cost: Tot	R 248 280 677	R 381 373 430	R 0	R 629 654 107
PV: Restoration cost: R/ha	R 2 439	R 1 571	R 0	R 1 248
PV: Management cost: Tot	R 362 553 889	R 515 162 048	R -0	R 877 715 936
PV: Management cost: R/ha	R 3 561	R 2 123	R -0	R 1 739
PV: Total cost: R	R 610 834 565	R 896 535 478	R -0	R 1 507 370 043
PV: Total cost: R/ha	R 6 000	R 3 694	R -0	R 2 987

Benefit				
PV: Above ground carbon	R 0	R 0	R 0	R 0
------------------------- / ha	R 0	R 0	R 0	R 0
PV: Avoided loss: Soil carbon	R 0	R 0	R 0	R 0
------------------------- / ha	R 0	R 0	R 0	R 0
PV: Total carbon	R 0	R 0	R 0	R 0
------------------------- / ha	R 0	R 0	R 0	R 0
PV: Water: Value of sales	R 34 994 075	R 33 066 915	R 0	R 68 060 990
------------------------- / ha	R 344	R 136	R 0	R 135
PV: Water: Economic value	R 571 103 302	R 539 652 056	R 0	R 1 110 755 358
------------------------- / ha	R 5 610	R 2 224	R 0	R 2 201
PV: Land use change: (Agric., biodiv & tourism)	R 33 392 541	R 483 825 205	R 0	R 517 217 746
------------------------- / ha	R 328	R 1 994	R 0	R 1 025
PV: Sediment reduction	R 0	R 0	R 0	R 0
------------------------- / ha	R 0	R 0	R 0	R 0
PV: Total (ex ecn value of water)	R 68 386 616	R 516 892 120	R 0	R 585 278 736
------------------------- / ha	R 672	R 2 130	R 0	R 1 160

B-C ratio				
Rest + Man : Carbon	0.00	0.00	0.00	0.00
Man : Carbon	0.00	0.00	0.00	0.00
Rest + Man : Water sales	0.06	0.04	0.00	0.05
Man : Water sales	0.10	0.06	0.00	0.08
Rest + Man : Land use chnge	0.05	0.54	0.00	0.34
Man : Land use change	0.09	0.94	0.00	0.59
Rest + Man : Sediment	0.00	0.00	0.00	0.00
Man : Sediment	0.00	0.00	0.00	0.00
Rest + Man : Total	0.11	0.58	0.00	0.39
Man : Total	0.19	1.00	0.00	0.67

URV				
URV: Water only	4.73	8.04	0.00	6.27
URV: Water & above gr carbn	4.73	8.04	0.00	6.27
URV: Water, above gr carbn, landuse change & sediment	4.48	3.70	0.00	4.12

Jobs: Person-days				
Restoration: Person-days	694 517	899 078	0	1 593 595
Restoration: R/person-day	R 357	R 424	#DIV/0!	R 395
Management: Person-days	405 224	808 323	0	1 213 547
Management: R/person-day	R 895	R 637	#DIV/0!	R 723
Total: Person-days	1 099 741	1 707 401	0	2 807 142
Total: R/person-day	R 555	R 525	#DIV/0!	R 537

APPENDIX 1.2: REVEGETATION OF DENUDED AREAS

OUTPUT DATA: Revegetation of denuded areas	*Krom*	*Kouga*	*Baviaans*	*Total*
General				
Change in yield: m^3	-1 931 146	-10 599 850	-1 708 949	-14 239 945
Change in baseflow: m^3	20 028 219	15 861 808	5 649 308	41 539 335
Sediment reduction: m^3	91 522	112 693	44 571	248 786

Cost				
PV: Restoration cost: Tot	R 105 752 235	R 67 187 400	R 164 643 050	R 337 582 684
PV: Restoration cost: R/ha	R 1 039	R 277	R 1 028	R 669
PV: Management cost: Tot	R 61 747 117	R 127 817 081	R 139 537 976	R 329 102 174
PV: Management cost: R/ha	R 607	R 527	R 871	R 652
PV: Total cost: R	R 167 499 352	R 195 004 480	R 304 181 026	R 666 684 858
PV: Total cost: R/ha	R 1 645	R 804	R 1 899	R 1 321

Benefit				
PV: Above ground carbon	R 431 054 550	R 811 281 886	R 1 266 440 310	R 2 508 776 746
------------------------- / ha	R 4 234	R 3 343	R 7 905	R 4 971
PV: Avoided loss: Soil carbon	R 146 157 951	R 179 967 997	R 71 179 661	R 397 305 609
------------------------- / ha	R 1 436	R 742	R 444	R 787
PV: Total carbon	R 577 212 502	R 991 249 882	R 1 337 619 971	R 2 906 082 355
------------------------- / ha	R 5 670	R 4 084	R 8 349	R 5 758
PV: Water: Value of sales	R 290 909 885	R 230 392 767	R 82 056 195	R 603 358 846
------------------------- / ha	R 2 858	R 949	R 512	R 1 195
PV: Water: Economic value	R 4 747 649 319	R 3 760 009 953	R 1 339 157 099	R 9 846 816 371
------------------------- / ha	R 46 638	R 15 493	R 8 359	R 19 510
PV: Land use change: (Agric., biodiv & tourism)	R 67 046 619	R 494 234 480	R 495 125 694	R 1 056 406 793
------------------------- / ha	R 659	R 2 036	R 3 090	R 2 093
PV: Sediment reduction	R 13 745 482	R 16 925 161	R 6 694 119	R 37 364 762
------------------------- / ha	R 135	R 70	R 42	R 74
PV: Total (ex ecn value of water)	R 948 914 488	R 1 732 802 290	R 1 921 495 979	R 4 603 212 757
------------------------- / ha	R 9 322	R 7 140	R 11 994	R 9 121

B-C ratio				
Rest + Man : Carbon	3.45	5.08	4.40	4.36
Man : Carbon	9.35	7.76	9.59	8.83
Rest + Man : Water sales	1.74	1.18	0.27	0.91
Man : Water sales	4.71	1.80	0.59	1.83
Rest + Man : Land use chnge	0.40	2.53	1.63	1.58
Man : Land use change	1.09	3.87	3.55	3.21
Rest + Man : Sediment	0.08	0.09	0.02	0.06
Man : Sediment	0.22	0.13	0.05	0.11
Rest + Man : Total	5.67	8.89	6.32	6.90
Man : Total	15.37	13.56	13.77	13.99

URV				
URV: Water only	0.29	0.42	1.85	0.55
URV: Water & above gr carbn	-0.45	-1.34	-5.86	-1.53
URV: Water, above gr carbn, landuse change & sediment	-0.59	-2.45	-8.92	-2.43

Jobs: Person-days				
Restoration: Person-days	137 268	127 034	162 532	426 835
Restoration: R/person-day	R 770	R 529	R 1 013	R 791
Management: Person-days	220 952	462 265	481 656	1 164 872
Management: R/person-day	R 279	R 277	R 290	R 283
Total: Person-days	358 219	589 299	644 188	1 591 707
Total: R/person-day	R 468	R 331	R 472	R 419

APPENDIX 1.3: BASEFLOW MAXIMISATION

OUTPUT DATA: Baseflow maximisation	*Krom*	*Kouga*	*Baviaans*	*Total*
General				
Change in yield: m^3	-1 931 146	-9 227 209	-1 708 949	-12 867 304
Change in baseflow: m^3	20 028 219	16 688 029	5 649 308	42 365 556
Sediment reduction: m^3	91 522	112 693	44 571	248 786
Cost				
PV: Restoration cost: Tot	R 105 752 235	R 143 135 771	R 164 643 050	R 413 531 055
PV: Restoration cost: R/ha	R 1 039	R 590	R 1 028	R 819
PV: Management cost: Tot	R 61 747 117	R 187 545 616	R 139 537 976	R 388 830 709
PV: Management cost: R/ha	R 607	R 773	R 871	R 770
PV: Total cost: R	R 167 499 352	R 330 681 386	R 304 181 026	R 802 361 764
PV: Total cost: R/ha	R 1 645	R 1 363	R 1 899	R 1 590
Benefit				
PV: Above ground carbon	R 431 054 550	R 753 935 007	R 1 266 440 310	R 2 451 429 867
------------------------- / ha	R 4 234	R 3 107	R 7 905	R 4 857
PV: Avoided loss: Soil carbon	R 146 157 951	R 179 967 997	R 71 179 661	R 397 305 609
------------------------- / ha	R 1 436	R 742	R 444	R 787
PV: Total carbon	R 577 212 502	R 933 903 004	R 1 337 619 971	R 2 848 735 477
------------------------- / ha	R 5 670	R 3 848	R 8 349	R 5 644
PV: Water: Value of sales	R 290 909 885	R 242 393 619	R 82 056 195	R 615 359 699
------------------------- / ha	R 2 858	R 999	R 512	R 1 219
PV: Water: Economic value	R 4 747 649 319	R 3 955 863 865	R 1 339 157 099	R 10 042 670 283
------------------------- / ha	R 46 638	R 16 300	R 8 359	R 19 898
PV: Land use change: (Agric., biodiv & tourism)	R 67 046 619	R 528 493 822	R 495 125 694	R 1 090 666 135
------------------------- / ha	R 659	R 2 178	R 3 090	R 2 161
PV: Sediment reduction	R 13 745 482	R 16 925 161	R 6 694 119	R 37 364 762
------------------------- / ha	R 135	R 70	R 42	R 74
PV: Total (ex ecn value of water)	R 948 914 488	R 1 721 715 606	R 1 921 495 979	R 4 592 126 073
------------------------- / ha	R 9 322	R 7 094	R 11 994	R 9 099
B-C ratio				
Rest + Man : Carbon	3.45	2.82	4.40	3.55
Man : Carbon	9.35	4.98	9.59	7.33
Rest + Man : Water sales	1.74	0.73	0.27	0.77
Man : Water sales	4.71	1.29	0.59	1.58
Rest + Man : Land use chnge	0.40	1.60	1.63	1.36
Man : Land use change	1.09	2.82	3.55	2.80
Rest + Man : Sediment	0.08	0.05	0.02	0.05
Man : Sediment	0.22	0.09	0.05	0.10
Rest + Man : Total	5.67	5.21	6.32	5.72
Man : Total	15.37	9.18	13.77	11.81

URV				
URV: Water only	0.29	0.66	1.85	0.64
URV: Water & above gr carbn	-0.45	-0.85	-5.86	-1.32
URV: Water, above gr carbn, landuse change & sediment	-0.59	-1.93	-8.92	-2.23

Jobs: Person-days				
Restoration: Person-days	137 268	302 185	162 532	601 985
Restoration: R/person-day	R 770	R 474	R 1 013	R 687
Management: Person-days	220 952	563 394	481 656	1 266 002
Management: R/person-day	R 279	R 333	R 290	R 307
Total: Person-days	358 219	865 580	644 188	1 867 987
Total: R/person-day	R 468	R 382	R 472	R 430

APPENDIX 1.4: YIELD MAXIMISATION

OUTPUT DATA:
Yield maximisation

	Krom	*Kouga*	*Baviaans*	*Total*
General				
Change in yield: m^3	5 986 263	3 838 286	1 267 183	11 091 733
Change in baseflow: m^3	8 936 255	2 276 552	2 781 529	13 994 335
Sediment reduction: m^3	13 492	-	8 747	22 239

Cost				
PV: Restoration cost: Tot	R 234 408 210	R 371 326 947	R 94 871 697	R 700 606 855
PV: Restoration cost: R/ha	R 2 303	R 1 530	R 592	R 1 388
PV: Management cost: Tot	R 330 486 379	R 507 374 781	R 53 382 181	R 891 243 340
PV: Management cost: R/ha	R 3 246	R 2 091	R 333	R 1 766
PV: Total cost: R	R 564 894 589	R 878 701 728	R 148 253 878	R 1 591 850 195
PV: Total cost: R/ha	R 5 549	R 3 621	R 925	R 3 154

Benefit				
PV: Above ground carbon	R 167 130 764	R 46 621 127	R 547 293 328	R 761 045 219
------------------------- / ha	R 1 642	R 192	R 3 416	R 1 508
PV: Avoided loss: Soil carbon	R 21 546 923	R 0	R 13 968 378	R 35 515 301
------------------------- / ha	R 212	R 0	R 87	R 70
PV: Total carbon	R 188 677 687	R 46 621 127	R 561 261 706	R 796 560 520
------------------------- / ha	R 1 853	R 192	R 3 503	R 1 578
PV: Water: Value of sales	R 129 799 098	R 33 066 915	R 40 401 709	R 203 267 722
------------------------- / ha	R 1 275	R 136	R 252	R 403
PV: Water: Economic value	R 2 118 321 278	R 539 652 056	R 659 355 889	R 3 317 329 223
------------------------- / ha	R 20 809	R 2 224	R 4 116	R 6 573
PV: Land use change: (Agric., biodiv & tourism)	R 51 483 095	R 451 739 216	R 213 969 017	R 717 191 328
------------------------- / ha	R 506	R 1 861	R 1 336	R 1 421
PV: Sediment reduction	R 2 026 389	R 0	R 1 313 662	R 3 340 050
------------------------- / ha	R 20	R 0	R 8	R 7
PV: Total (ex ecn value of water)	R 371 986 269	R 531 427 259	R 816 946 094	R 1 720 359 621
------------------------- / ha	R 3 654	R 2 190	R 5 099	R 3 409

B-C ratio				
Rest + Man : Carbon	0.33	0.05	3.79	0.50
Man : Carbon	0.57	0.09	10.51	0.89
Rest + Man : Water sales	0.23	0.04	0.27	0.13
Man : Water sales	0.39	0.07	0.76	0.23
Rest + Man : Land use chnge	0.09	0.51	1.44	0.45
Man : Land use change	0.16	0.89	4.01	0.80
Rest + Man : Sediment	0.00	0.00	0.01	0.00
Man : Sediment	0.01	0.00	0.02	0.00
Rest + Man : Total	0.66	0.60	5.51	1.08
Man : Total	1.13	1.05	15.30	1.93

URV				
URV: Water only	1.77	7.88	1.83	3.12
URV: Water & above gr carbn	1.25	7.46	-4.94	1.63
URV: Water, above gr carbn, landuse change & sediment	1.08	3.41	-7.60	0.22

Jobs: Person-days				
Restoration: Person-days	623 473	875 819	71 767	1 571 059
Restoration: R/person-day	R 376	R 424	R 1 322	R 446
Management: Person-days	401 875	780 447	180 471	1 362 793
Management: R/person-day	R 822	R 650	R 296	R 654
Total: Person-days	1 025 348	1 656 266	252 238	2 933 852
Total: R/person-day	R 551	R 531	R 588	R 543

APPENDIX 2: VELD TYPES AND EXPECTED INVASIVE SPECIES AND INVASION PERIOD

Veld type	"Invasibility"	Invasive species and time
Barandas Arid Spekboomveld	4	None
Baviaanskloof Afromontane Forest	4	None
Baviaanskloof Renoster Sandolienveld	3	A. mearnsii 80 years
Baviaanskloof Sandolienveld	3	A. mearnsii 80 years
Baviaanskloof Spekboom Thicket	4	None
Baviaanskloof Subtropical Forest	4	None
Baviaanskloof Sweet Grassland	3	A. mearnsii 60 years
Baviaanskloof Temperate Forest	4	None
Baviaanskloof Temperate Thicket	4	None
Baviaanskloof Thicket Savanna	3	A. mearnsii 30 years
Bosfontein Spekboom Thicket	4	None
Eastern Swartberg Fynbos Gwarrieveld	3	A. mearnsii 120 years
Elands Forest Thicket	4	None
Elands Spekboom Thicket	4	None
Elands Woodland	2	Pinus 60 years (as per com)
Elandsberg Grassy Fynbos	2	A. mearnsii 80 years
Elandsberg Mesic Fynbos	1	Pinus 40 years (as per com)
Elandsberg Sour Grassland	2	A. mearnsii 60 years
Elandsrivier Renosterveld	3	A. mearnsii 80 years
Gamtoos Bontveld	4	None
Gamtoos Duneveld	1	A. cyclops, A. saligna 60 years
Gamtoos Forest Savanna	2	A. mearnsii 60 years
Gamtoos Fynbos Woodland	2	A. mearnsii 60 years
Gamtoos Strandveld	1	A. cyclops, A. saligna 80 years
Gamtoos Thicket	4	None
Gamtoos Valley Thicket	4	None
Gamtoos Wetland	1	A. mearnsii 10 years
Garden Route Estuary	4	None
Garden Route Riverine Saltmarsh	4	None
Garden Route Wetlands	1	A. mearnsii 10 years
Georgida Arid Spekboomveld	4	None
Groendal Fynbos Woodland	2	A. mearnsii 60 years
Groot Apronveld	4	None
Groot Arid Spekboomveld	4	None
Groot Doringveld	3	A. mearnsii 40 years
Groot Gannaveld	4	None
Groot Randte Gwarrieveld	4	None
Groot Woodland	2	A. mearnsii 60 years
Haarlem Fynbos Renosterveld	2	Pinus 120 years (as per com)
Haartebeesvlakte Renoster Sandolienveld	3	A. mearnsii 80 years
Hartenbos Primary Dune	1	A. cyclops, A. saligna 60 years
Humansdorp Perennial Stream	2	A. mearnsii 10 years
Humansdorp Thicket-Grassy Fynbos	2	A. mearnsii 80 years
Inland Drift Sands	1	A. cyclops, A. saligna 60 years
Inland Primary Dune	1	A. cyclops, A. saligna 60 years
Kabeljous Renoster Thicket	3	A. cyclops, A. saligna 80 years
Kabeljous Valley Thicket	4	None
Kleinkrantz Drift Sands	1	A. cyclops, A. saligna 60 years
Kouga Arid Fynbos	3	A. mearnsii 120 years

Kouga Asbos Renosterveld	4	None
Kouga Grassy Fynbos	2	A. mearnsii 80 years
Kouga Mesic Fynbos	1	A. mearnsii 30 years
Kouga Mesic Proteoid Fynbos	1	A. mearnsii 30 years
Kouga Renoster Sandolienveld	3	A. mearnsii 80 years
Kouga Restioid Fynbos	2	Hakea sericea 80 years
Kouga Subalpine Fynbos	3	Hakea sericea 60 years
Kromrivier Thicket-Forest	4	None
Langkloof Bontveld	3	A. mearnsii 60 years
Langkloof Grassy Fynbos	2	A. mearnsii 80 years
Langkloof Renosterveld	3	A. mearnsii 80 years
Langkloof Thicket-Grassy Fynbos	2	A. mearnsii 80 years
Langkloof Thicket-Renosterveld	3	A. mearnsii 80 years
Langkloof Waboomveld	2	A. mearnsii 80 years
Loerie Fynbos Woodland	2	A. mearnsii 80 years
Mellville Perennial Stream	1	A. mearnsii 10 years
Nuwekloof Fynbos Woodland	2	A. mearnsii 60 years
Osbosch Thicket-Renosterveld	3	A. cyclops, A. saligna 120 years
Otterford Afromontane Forest	4	None
Otterford Forest Thicket	4	None
Oyster Bay Thicket-Grassy Fynbos	1	A. cyclops, A. saligna 60 years
Perdehoek Arid Thicket	4	None
Pietslaagte Apronveld	4	None
Pietslaagte Arid Spekboomveld	4	None
Pietslaagte Asbos Gwarrieveld	4	None
Sand River Pans	1	A. cyclops, A. saligna 40 years
Snyberg Gravel Apronveld	4	None
Soutvlei Inland Pans	3	A. mearnsii 60 years
St Francis Dune Stream	1	A. cyclops, A. saligna 40 years
St Francis Strandveld	1	A. cyclops, A. saligna 60 years
Sundays Randte Gwarrieveld	4	None
Sundays Spekboom Thicket	4	None
Sundays Spekboomveld	4	None
Sundays Thicket	4	None
Suuranysberg Sour Grassland	2	A. mearnsii 60 years
Tsitsikamma Dune Forest	4	None
Tsitsikamma Ericaceous Fynbos	1	Pinus 50 years (as per com)
Tsitsikamma Mesic Proteoid Fynbos	1	Pinus 40 years (as per com)
Tsitsikamma Mountain Forest	4	None
Tsitsikamma Mountain Proteoid Fynbos	1	Pinus 40 years (as per com)
Tsitsikamma Pans	1	A. mearnsii 10 years
Tsitsikamma Plateau Forest	4	None
Tsitsikamma Plateau Proteoid Fynbos	1	Pinus 30 years (as per com)
Tsitsikamma River and Floodplain	1	A. mearnsii 10 years
Tsitsikamma Subalpine Fynbos	2	Pinus 60 years (as per com)
Uniondale Asbos Renosterveld	4	None
Vlakteplaas Gannaveld	4	None
Zeekoei Limestone Strandveld	1	A. cyclops, A. saligna 80 years
Zuurberg Forest Thicket	4	None