COST-BENEFIT ANALYSIS OF LAND RESTORATION IN THE ASSEGAAIBOS CATCHMENT AREA WITH REGARD TO WATER YIELD AND TOURISM BENEFIT

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DECLARATION

I, BIANCA CURRIE, hereby declare that:

- the work in this dissertation is my own original work;
- all sources used or referred to have been documented and recognized; and
- this dissertation has not been previously submitted in full or part fulfilment of the requirements for an equivalent or higher qualification at any other recognized education institution.

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ABSTRACT

With the emergence of the new field of resource economics, one now has the ability to value and to include natural resources in decision making. This thesis aims to explore the valuation of natural resources by reviewing the economic values, techniques, methods and ecological aspects of restoration. Assegaaibos mountain catchment in the Western Cape Province has been used as a case-study example. A cost-benefit analysis of the restoration of the mountain catchment, in terms of the direct benefits of water and tourism, has been performed. The costs of restoration were observed to see whether they outweighed the benefits (income) derived (water and tourism).

The results show that the water and tourism benefits did outweigh the costs of a basic restoration scenario. However, the basic restoration scenario did not fulfil the ecological requirements of the project. The results also illustrated that in the moderate restoration scenario, costs only outweighed the benefits when a three percent discount rate was applied. With the optimistic restoration scenario, costs outweighed benefits only when an eight percent discount rate was used. In the comprehensive restoration scenario, costs were shown to outweigh by far the water and tourism benefits over a thirty-year time frame. However, it should be noted that the deterioration of the environment (accelerated erosion, reinvasion, reduced water quality) was not factored into the costs of failure to rehabilitate.

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CHAPTER 1: INTRODUCTION

Ecologically speaking, the value of biodiversity has long been recognized as vital for the functioning of the earth's life-support systems, hence, vital for human well-being. The loss of biodiversity means the loss of ecosystem function and production. Such a loss has the potential to compromise natural ecosystem stability (Naeem *et al*, 1999). However, economically speaking, the value of natural resources was not fully appreciated until the last decade of the twentieth century. Many of the benefits of natural capital are still not wholly understood and many are considered as public goods which do not enter the markets. Today, natural capital is seen as a vital source of income and as something that it pays to sustain (Rees, Farley & Vesely, 2007).

In the past, the economic value of natural resources was not really measured or quantified because capital generated by humans was the limiting factor to economic development ('empty-world' economic era). At present, the industrial nations are entering an era where natural resources are becoming the limiting factor to exponential growth – resources are being used faster than they can be renewed, even with new technologies ('full-world' era) (Blignaut & De Wit, 2004; Costanza, 2001).

Another reason the field of economics had not previously considered the value of ecosystem services and products is that many of the benefits derived from ecosystems are intangible and therefore difficult to value. Furthermore, many feel there is an ethical issue when it comes to placing a value on ecosystem products and services. This attitude is, in effect, giving natural resources a zero value (Bräuer, 2003), which allows for the unrestricted use – and abuse – of ecosystems and sabotages sensible socio-political decision making.

As natural resources become progressively scarcer, their true value becomes increasingly pertinent. According to economists, the productivity of the limiting factor should then be maximized (Costanza, 2001). Despite the criticism and difficulties associated with valuing natural resources, the new science of resource economics has emerged from both this new economic-policy focus and the coming together of economists and ecologists. Environmental economics addresses what old-school economics classified as externalities (Markandya *et al*, 2001).

Externalities have now been allocated a variety of use and non-use values to make up a total economic value. Use values include the direct-use value, consisting of consumptive- and non-consumptive-use values. Indirect-use values include, for example, the ecological functions supplied by ecosystems (Turpie, Heydenrych & Lamberth, 2003). The future-use value is illustrated by the genetic library held in the biodiversity of an ecosystem. Lastly, the non-use value refers to existence values which are said to be motivated by a wish or sympathy for animals/nature or moral conviction (Markandya *et al.*, 2002).

This thesis makes mention of all the values encompassed in the total economic value, concentrating on the direct-use values of water and tourism which have entered the economic market. Although flood control, quantified through flood damage to built capital, has also entered the economic market, it is not included as part of this thesis.

The direct-use benefits that enter the economic market allow for fairly accurate valuation. However, many of the other values (indirect- and future-use) are not so easily calculated. Resource economics has developed several methods of evaluating the various intangible ecosystem benefits. Examples include the replacement cost and opportunity methods used to value water benefits and contingent valuation; and hedonic pricing and travel-cost methods used to value tourism benefits obtained from biodiversity. These values are then used in conjunction with various techniques or methods, such as cost-benefit analysis, to evaluate projects and policies which have an impact on the environment (Hanley & Spash, 1993).

This thesis focuses on cost-benefit analysis, a method which has been criticized for various reasons. One aspect that has prompted debate is that such analysis prioritizes the efficiency rule (Hansjürgens, 2004). The latter has been addressed in this thesis.

However, cost-benefit analysis provides a standard format, enabling natural resource value to be included in economic assessment. It has also successfully been used to justify management expenditure decisions.

One important direct benefit of biodiversity – indeed, perhaps the most important – is its influence on the hydrological system. The fynbos biome in the Western Cape Province of South Africa has been used as an example of the aforementioned direct benefit in this thesis. The biodiversity found in fynbos influences the hydrological functioning of the Western Cape mountain catchment areas, which yield 66% of the Western Cape's water supply, estimated at a value of US $15.3 billion (R107.1 billion) in 1992 (Van Wilgen, Cowling & Burgers, 1996). (Please note that throughout this thesis, all currency quoted in United-States dollars has been converted to Rand values, using the dollar exchange rate of R7.00 to $1.00). This water supply is crucial to the export agricultural industry (Van Wilgen *et al*., 1996), as well as for industrial and domestic use in the Western Cape metropolitan area.

Despite its fundamental role, this water supply is being compromised by the exploitation of resources, urban development and alien invasive plants (Turpie *et al.*, 2003). The hindrances to optimal catchment management in terms of biodiversity and water yield are the poor land-use options of forestry, water reservoirs and alien invasive plants (Cowling & Richardson, 1995).

The land-use option of forestry causes changes in soil hydrology, habitat structure, microenvironment, available food resources and ecological processes influencing indigenous species diversity and abundance. Indeed, certain species from afforested areas have even been eliminated (Armstrong & Van Hensbergen, 1996).

Reducing river systems to engineered plumbing systems is detrimental to the ecological services offered by the natural river systems. According to Miller (2004), 24% of the world's freshwater fish are endangered owing to dam water withdrawals disrupting hydrological system.

Alien invasive plants such as *Acacia*, *Hakea* and *Pinus* species compete with and displace the natural vegetation, altering the structure and function of natural ecosystems. This results in altered stream flows, increased fire and erosion risk and a reduction in the economic value of the ecosystems (Turpie *et al*., 2003; Higgins *et al*., 1999; Le Maitre *et al*., 1996; Samways, Caldwell & Osborn 1996; Breytenbach 1986).

To meet and sustain the escalating water demand of this rapidly developing, water-scarce country, the management of freshwater systems is clearly becoming a major priority. Extensive expenditure has been allocated to water delivery, reticulation and retention infrastructures, most of which inflict long-term environmental impacts. For example, approximately R490 million ($70 million) will be spent on the construction of the Berg River Dam alone (Department of Water Affairs and Forestry, South Africa, 1996a). Van Wilgen et al. (1996) showed that optimal catchment management, when compared with other water-supply infrastructure, provides water of the highest quality and at the cheapest rate, as well as providing other economic benefits.

Furthermore, cost-benefit analysis of alien clearing on a provincial level, has shown that the benefits of water yield alone make alien invasive plant clearing in mountain catchments economically viable (Turpie, 2004; De Wit, Crookes & Van Wilgen, 2001; Higgins *et* al.,1997; Van Wilgen *et al*., 1997).

The above-mentioned economic justification was the catalyst for the implementation of the Working for Water Programme, initiated by the Department of Water Affairs and Forestry. This programme has successfully returned most areas cleared of alien invasive plant species to their pre-invasive state without necessitating any further intervention. However, when alien plant invasion or plantations have dominated the natural plant community for lengthy periods exceeding natural seed longevity, alien invasive clearing is insufficient. The area fails to revegetate and erosion problems, as well as further invasions, are experienced (Galatowitsch & Richardson, 2005; Richardson & Van Wilgen, 2004). Further restoration is required to reinstate the natural vegetation structure and baseline ecosystem functioning.

Restoration is a costly exercise, especially in large or inaccessible areas, and total restoration is sometimes impossible to achieve because of social, economic and ecological deficiencies. This leads to the establishment of alternative trajectories to alternative ecosystems (Milton, 2003). This thesis examines whether the water and tourism benefits of a particular case-study restoration project outweigh the costs of restoration. The latter include the removal of alien invasive plants, erosion control and re-establishment of indigenous plants from seed.

An economic analysis has been generated by performing a cost-benefit analysis of restoration of the Assegaaibos mountain catchment, in terms of the water and tourism benefits derived. An economic and ecological review of the impacts resulting from alien plant invasion has been provided.

A literature review follows the introductory chapter and encompasses research on issues surrounding the controversial topic of placing a value on ecosystem benefits previously considered unquantifiable. This thesis focuses on the direct benefits (in particular, water and ecotourism) obtained from the mountain catchments of the Western Cape. Various methods used to calculate the monetary value of environmental goods and services are reviewed, and the criticisms and defending arguments surrounding the use of cost-benefit analysis in resource economics are discussed.

It is important to understand fully and to quantify the costs involved in restoring mountain catchments previously invaded by alien invasive plants. To this end, a comprehensive review of current literature regarding the ecological and economic impacts of alien invasive plant species has been provided. Furthermore, available literature dealing with fynbos recovery after alien invasive plant and fire impacts has also been reviewed.

The literature review is followed by a study-site chapter. This chapter provides the relevant characteristics of the Assegaaibos mountain catchment, the focal case-study site for rehabilitation in the thesis. Moreover, a benchmark site, the Swartboskloof mountain catchment, located in close proximity to Assegaaibos, has also been examined. The chapter provides detailed information of land-use history, climate, flora, fauna, surrounding infrastructure, the economic environment and details of the beneficiaries of benefits derived.

The study-site chapter is followed by the cost-benefit case study. This chapter describes the methods used to determine the costs (restoration) and benefits (water and tourism) and how they were assessed using a cost-benefit analysis. The issues of time horizon and discount rate are also discussed. The results of the cost-benefit analysis are displayed in the results chapter and discussed in the discussion section of the last chapter. This chapter is concluded with the author's recommendations pertaining to the restoration of the Assegaaibos mountain catchment and the cost-benefit analysis method.

Studies such as this can add value by offering an example of and greater insight into the valuation of the benefits available from the natural environment (natural resources). It also contributes an approach for incorporating natural resources in economic assessment and for using cost-benefit analysis in land-use planning policy. The value of natural resources has already justified government funding of the Working for Water Programme, a strategy for the removal of alien invasive plants, which results in benefits to the economy and humankind in general. Placing a monetary value on ecosystem services is vital in land-use decision making, "especially in developing countries where short term economic growth and social delivery take precedence over conservation" (Van Wilgen, Le Maitre & Cowling, 1998, p. 378).

This thesis endeavours to assess the costs and benefits of restoration after alien clearing, using a case-study cost-benefit analysis of mountain catchment restoration. It further hopes to encourage the same support for restoration as alien invasive clearing currently receives. It is anticipated that the thesis will add to the existing knowledge of the direct-use values methodology in terms of restoration costs beyond mere alien invasive plant clearing.

Finally, it is hoped that this thesis helps fill the gaps in knowledge, which unfortunately prevent the accumulation of valuations, or even comparisons of valuations, with regard to the differences in scale, types of values and methods used.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

The valuation of natural resources and processes is a fairly new development in economic analysis. In this chapter, a review is given of published literature discussing the issues surrounding the controversial topic of placing a monetary value on benefits previously considered unquantifiable. Various methods used to calculate the monetary value of environmental goods and services are reviewed, and the criticisms and defending arguments surrounding the use of cost-benefit analysis in resource economics are discussed. This literature review focuses on the direct benefits (in particular, water and ecotourism) obtained from the mountain catchments of the Western Cape.

The ecological and resultant economic impacts of alien invasive plant species are also examined in the literature review. This is to offer both a holistic understanding of what is ecologically required and an understanding of quantification techniques involved in restoring mountain catchments previously invaded by alien invasive plants. The chapter also discusses fynbos recovery after alien plant invasion and after the impacts of fire.

2.2 VALUING NATURAL RESOURCES

The environment provides a vast range of services and goods over enormously vast areas and lengthy, but biologically relevant, time-scales. Ecosystem services and natural stock (biodiversity) are crucial for the functioning of the earth's life-support system and are both directly and indirectly vital to human well-being (Costanza *et al*., 1997). For example, seafood, game animals, fodder, coal, oil, timber and even pharmaceutical products are all directly consumed.

Water purification, flood control, climate regulation, food production, soil formation and fertility, erosion control, nutrient cycling, detoxification and decomposition of waste, and recreation are consumed indirectly (Daily *et al*., 1997).

Environmental services are produced through intricate relationships between natural cycles which derive their energy from solar power (Daily *et al.*, 1997). Daily et al. (2000) highlighted the extent of service flows when they stated that, for any given site, such flows occur on several spatial scales: namely, locally (for example: pest control, serenity), regionally (for example: timber export and flood control) and globally (for example: climate stabilization).

To offer a more specific example of a service flow on a regional and global spatial scale, Daily et al. (1997) emphasized the stable relationship found between natural ecosystems and the climate. Transpiration of plants, for example, is an ecosystem service flow on a regional and global spatial scale. Transpiration of plants is a known cause of thunderstorms that reduces water loss and moderates a rise in the surface temperature on a regional scale (Daily *et al*., 1997). The deforestation occurring in the Amazon forest could so significantly reduce total precipitation that the forest might not be able to re-establish itself (Shukla, Nobre & Sellers, 1990). This has the potential to impact temperature on a global scale significantly, as forests are known to influence global temperature extremes (Daily *et al.*, 1997).

These ecosystem services are so vital to life and so large in scale that they are easy to take for granted. Until the last decade of the twentieth century, the benefits provided by ecosystems were only considered from an ecological point of view (Van Wilgen *et al*., 2001) and their economic value was historically ignored until their disruption or loss highlighted their importance (Daily *et al.* 1997).

They were considered incapable of being valued (Van Wilgen, 1996), having a purely intrinsic value which gave them a higher value than any marketable goods (Bräuer, 2003). Many of the ecosystem services are also infinite in value (for example, the value of the atmosphere to humankind), but it is the changes in the quality or quantity of environmental resources (products and services) which should be observed. Such changes are of vital importance and could potentially impact the well-being of all humans on earth (Costanza, 2001; Costanza *et al.*, 1997).

How, then, can the ecosystem products and services which do not enter the economic market be valued? Markandya et al. (2001) observed that the amalgamation of two disciplines, those of ecology and economics, have given rise to the science of environmental/resource economics, which concentrates on internalising what was previously considered to be externalities in economics. ‘Externalities’ is an economic term defined by Markandya et al. (2002, p. 94) as the unaccounted by-product of the actions of another which affect the welfare of others. An example of this is pollution.

For an externality to be recognized, it must be clear that the responsible party has not taken the impacts (costs and benefits) of their actions into account. The net value of the unaccounted for costs and benefits defines the externality. It can be either a negative or a positive incidental side effect of consumption or production (Blignaut & De Wit, 2004). By defining and characterising these intangible products and services, it becomes possible to introduce them into the economic market so that they may be evaluated.

With the formulation of the discipline of ecological economics came the ability to include ecosystem services and natural capital in the total economic value of the earth. This has met with resistance and criticism, however: the non-economists find putting a price on ecosystem services flawed and misguided (Perman *et al*., 2003). Some argue that valuation of ecosystems is not possible and is foolish, because a value cannot be placed on intangibles such as human life, environmental aesthetics and long-term ecological benefits.

In fact, such evaluations are made on a daily basis. For example, construction standards are set for highways and bridges; human life is evaluated by the amount of money spent on construction in order to save lives (Costanza *et al*. 1997).

To reject assigning a monetary value to the services and goods obtained from ecosystems is, in effect, to give the natural environment a zero value. This inevitably leads to the incorrect allocation of costs, to the detriment of the environment (Bräuer, 2003). An example of this is the misguided expenditure on dam building in order to provide water, rather than clearing alien invasive plant species to reduce water loss from mountain catchment areas.

Schulz and Schulz (1991, cited in Bräuer, 2003, p. 484) gave five justifications for placing a monetary value on environmental goods and services:

- *"Comprehensibility: money demonstrates to the public the social importance of nature conservation programs in an intelligible and easily understandable way.*
- *De-emotionalisation: Cost-benefit analysis demands a critical incorporation of all benefits and costs. The systematic and complete listing helps to get a better overview over the range of consequences of projects and promotes de-emotionalisation in the discussion about its usefulness.*
- *Dosificability: only the knowledge of the real costs, which means the costs of the project minus the avoided damage, offers the possibility to make decisions concerning the nature and the amount of environmental protection.*
- *Internalisation of external effects needs information about the potential damage to be internalised.*
- *Every kind of green accounting needs an economic evaluation of environmental goods."*

In an open-market system, money is used as an exchange medium and cannot be considered a factor of production or considered as income. It is a common and acceptable medium for the exchange of goods and services and is merely a means towards an end (Mohr, Fourie & Associates, 1995). Monetary value is the link that makes environmental goods comparable with marketable goods (Bräuer, 2003).

To show how the economy and the environment interact in reality, Blignaut and De Wit (2004) adapted the circular flow model of production and consumption, designed by Coddington in 1970, to include the environment (Figure 1).

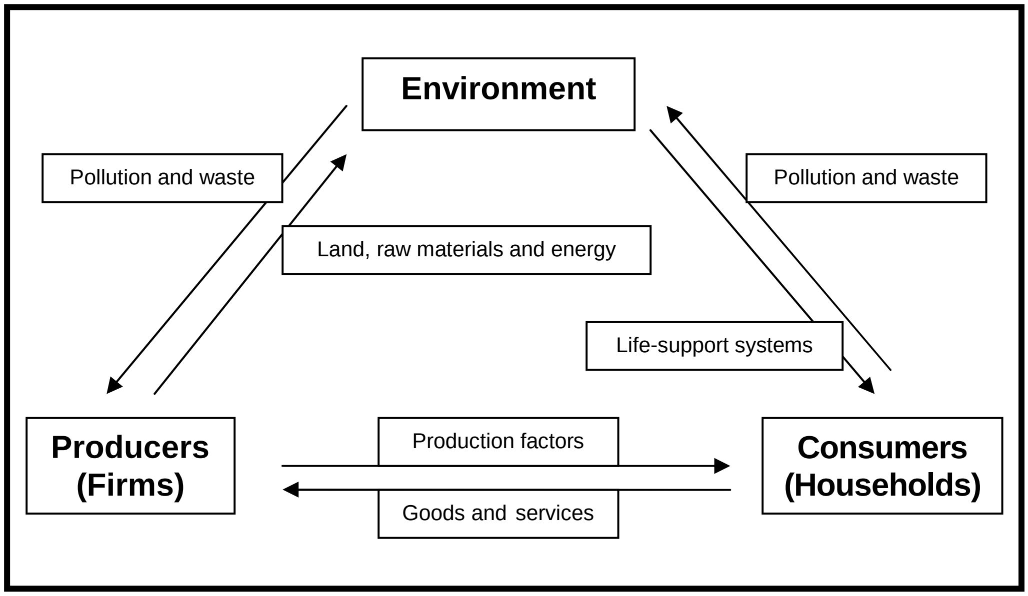

Figure 1: Economic circular flow model of production, consumption and the environment. (Adapted from Coddington, 1970, in Blignaut & De Wit, 2004, p. 54)

Expanding on the original producer/consumer circular flow model, this model illustrates how the environment provides resources and services which are necessary for man-made production and vital for life. More specifically, the environment provides life-support systems to consumers; and natural resources, in the form of land, raw material and energy, to man-made production.

Both consumers and producers return pollution and waste to the environment, which acts as a sink, absorbing all the returned products. The model examines the environment from a production-and-function-based approach (Blignaut & De Wit, 2004).

2.2.1 Goals in valuation

One cannot determine a value without stating the goal being served (Costanza, 2001). The goal being served in conventional economics is based on individual utility maximization. Costanza (2001) referred to a model of human behaviour based on individual utility maximization called *Homo economius*, in which humans act independently, rationally and in their own self-interest. This model is based on current individual preferences, which are expected to be fixed or given. The value is determined by the individual's willingness to pay in a properly functioning economic market. However, basing valuation on current individual preferences and utility maximization alone does not always lead to ecological sustainability or social fairness (Bishop, 1993).

Daly (1992, cited in Costanza, 2001, p. 462) provided three broad goals that are important when managing economic structures within the context of earth's ecological life-support system:

- *"Assessing and ensuring that the scale or magnitude of human activities within the biosphere is ecologically sustainable.*
- *Distributing resources and property rights fairly, both within the current generation of humans and between this and future generations, and also between humans and other species.*
- *Efficiently allocating resources, as constrained and defined by the two goals above, including both marketed and non-marketed resources, especially ecosystem services."*

Furthermore, Daly (1990, cited in Blignaut and De Wit, 2004, p. 59) gave three simple rules to help define a long-term sustainable limit to the production process:

- *"Renewable resource: the sustainable rate of use can be no greater than the rate of regeneration.*

- *Non-renewable resource: the sustainable rate of use can be no greater than the rate at which a renewable resource, used sustainably, can be substituted for it.*
- *Pollutant: the sustainable rate of emission can be no greater than the rate at which the pollutant can be recycled, absorbed or rendered harmless by the environment."*

2.2.2 Cost-benefit analysis in environmental decision making

The principal objective of natural-resource valuation is to include environmental impacts in the process of cost-benefit analysis (Perman *et al*., 2003). The placing of a monetary value on the benefits and costs derived from ecosystems has already become a tool in justifying management-expenditure decisions. Van Wilgen et al. (1998) used the Working for Water Programme as an example of how the monetary valuation of an ecosystem service, formalized in a cost-benefit analysis, was the major catalyst for the decision to launch such a project. This demonstrates the advantage of placing a monetary estimate on ecosystem goods and services (Van Wilgen *et al*., 1998).

According to Hansjürgens (2004), cost-benefit analysis is an economic method of choosing from a number of alternatives. If there is only one alternative, cost-benefit analysis may be used to conclude whether or not such an alternative should be implemented. Cost-benefit analysis is a technique which can be used to appraise projects and policies which impact on the environment (Hanley & Spash, 1993). It is used as a tool to rank alternatives or to choose the best of alternatives (Department of Environmental Affairs and Tourism, 2004). If the benefits are greater than the costs, the project or alternative should be carried out.

The advantages (benefits) and disadvantages (costs) of a particular project are weighed up against each other and the project with the highest net value is then recommended (Hansjürgens, 2004). The Department of Environmental Affairs and Tourism (2004) offered the rule that the alternative should be accepted if the lifetime benefits outweighed the lifetime costs.

The cost-benefit analysis method of valuation has several critics. The method is criticized for prioritizing the efficiency rule over other values (Hansjürgens, 2004). The efficiency rule states that if the net effects of costs are maximized, a project is considered to be efficient (Zylicz, 1995). Yet, Goodstein (1999) emphasized that efficiency was not necessarily fair and might not be of much use when social outcomes were considered. Bishop (1993) reiterated this by stating that utility maximization did not always result in ecological sustainability or social fairness.

Cost-benefit analysis is also criticized for ignoring distribution-related considerations (Hansjürgens, 2004): in other words, the beneficiaries of the costs and benefits have to be identified. The arguments against the use of cost-benefit analysis also include the ethical consideration of weighing up human life and health against economic concerns (Hansjürgens, 2004).

The Department of Environmental Affairs and Tourism (2004) stated that decisions should be based on the efficiency rule, leaving the governmental redistribution mechanisms (taxation, unemployment benefits) to take responsibility for rectifying social inequities. Many economists caution against taking the distribution issue into account and believe that if the net present value is positive, those who gain can compensate those who lose (Hansjürgens, 2004), a situation known as the “Kaldor Criterion” (Department of Environmental Affairs and Tourism, 2004, p. 10). Hansjürgens (2004) agreed that economic valuation should not consider the distribution issue and should only highlight the waste-free economic alternatives; society should be responsible for distribution.

Hanley and Spash (1993) considered cost-benefit analysis to be only one piece of the puzzle and that it should not be the sole criterion influencing the decision. They were of the opinion that redistribution should be achieved through political processes (Hanley & Spash, 1993). In response to the issue of valuing human life, Goodstein (1999) stated that one should consider a reduction in human mortality as a benefit when valuing environmental improvement.

Hansjürgens (2004) commented that determined values were constantly affixed to human life and health, and that death and suffering were regularly and deliberately accepted and weighed up against monetary reimbursement. An example of this would be the ‘danger pay’ that employees receive in certain life-threatening occupations, such as with fire-fighters and police officers. A further example given by Goodstein (1999) is the judicial system awarding damages for wrongful death.

There is criticism of the inadequate specifications of cost-benefit analysis. Certain methodological shortcomings are highlighted: for example, uncertainty of data; arbitrariness in data selection and conception; and feigned accuracy (Hansjürgens, 2004). Bräuer (2003) also stated that natural resources are undervalued, owing to a lack of scientific knowledge. Furthermore, irremediable project impacts, ecosystem complexity, institutional capture and sustainability constraints are said to be important methodological issues to consider within the context of cost-benefit analysis (Hanley & Spash, 1993). Goodstein (1999, p. 190) used the term “agenda control” – cost-benefit analysis being undertaken by public bodies in such as way as to serve their own interests and not public interest.

The fact that cost-benefit analysis has the ability to reduce most impacts to a single number is also considered a disadvantage as it can oversimplify intricate cause-and-effect relationships (Department of Environmental Affairs and Tourism, 2004). This issue can be overcome by either performing a sensitivity analysis, which draws attention to the effects of vicissitudes in key variables, or by unifying cost-benefit analysis with multi-criteria decision analysis. The latter allows concerns and impacts, identified as significant, to be weighted (Department of Environmental Affairs and Tourism, 2004).

In response to the criticism directed at the methodological limitations of cost-benefit analysis, Hansjürgens (2004) agreed that uncertainty of data and arbitrariness in data selection and conception were deficiencies in the method. However, these shortcomings and criticisms were more related to the issue of human error rather than being shortcomings of the cost-benefit analysis method itself.

Hanley and Spash (1993) discussed credibility of data, saying that it should be assessed by focusing on the following factors:

- repeatability of the results;
- validity of the results; and
- the esteem in which the academic community held the method.

A further criticism is the use of cost-benefit analysis in the political decision-making arena (Hansjürgens, 2004). A point raised in support of this argument is that cost-benefit analysis has an apparently one-sided exertion of interests, a bias in favour of hard quantitative facts obtained from producers and consumers. These hard quantitative facts are being weighted against soft qualitative data from the environment. Furthermore, the sometimes lengthy process of data collection is also blamed for causing delays in the regulatory process and for confusing politicians with scientific jargon (Hansjürgens, 2004). Goodstein (1999) also examined similar issues of the “hard numbers problem” (p. 190) and “paralysis by analysis” (p. 190) as impacts on regulatory politics.

In defence of the involvement of cost-benefit analysis in political decision making, Goodstein (1999) stated that it actually reduces political influence in the policy arena and “allows the numbers to speak” (p. 188), though he admitted this to be a rather naïve claim. Goodstein (1999) conceded that while cost-benefit analysis was not immune to political agendas, it defined rules that characterized a good study, thereby limiting manipulation. Hansjürgens (2004) highlighted the fact that cost-benefit analysis was aimed at contributing to rational thought in political decision making, thereby avoiding one-sided deliberation or consideration.

Cost-benefit analysis is believed by some to be an instrument that helps to reduce inadequacies and illogical decision making with regard to the environment. While it has the ability to encourage erroneous assumptions and ill-considered priorities, it does fulfil a need for a standard, systematic method which can be used to collect and organize the data essential for environmental evaluation. Furthermore, political agendas are supposed to be made transparent through cost-benefit analysis (Hansjürgens, 2004).

The criticism that regulatory process causes delays has been acknowledged by Hansjürgens (2004). Although delays can be avoided, this is dependent on the nature of the costs and benefits to be quantified. Furthermore, not all evaluations require the same depth of data analysis. The Department of Environmental Affairs and Tourism (2004, p. 2) identified a number of advantages of cost-benefit analysis (cited verbatim below):

- *"The decision rules it uses are standard and well known.*
- *It provides non prescriptive information in a standard format that informs decision makers and stakeholders.*
- *It is adaptable and flexible enough to reflect income distributional impacts, intergeneration sustainability, financial efficiency and the effects of externalities.*
- *It can be extended to match the EIA process. A cost-benefit analysis report can be adapted to include a stakeholder analysis showing a project's downstream impact on interested and affected parties. Where projects are large enough to affect macroeconomic variables the cost-benefit analysis accounts for these. The report can be further enhanced to include other economy wide effects such as multiplier based impacts on employment and gross domestic product.*
- *It has a logical place in the integrated environmental management process. In environmental impact assessments for example, information on project impacts are generated. The economic and social relevance of these is not always clear. Also the data is not always comparable and easily integrated. Cost-benefit analysis can reduce most impacts to a single number which describes either a benefit/cost ratio, an internal rate of return or a net present value. The cost-benefit format establishes a clear link between data collection and the information provided for decision making."*

2.2.3 Classification of value types

The costs and benefits of projects require economic valuation in order to perform a cost-benefit analysis. Various types of values are used to quantify the different categories of benefits derived from the environment. Even though a short description of all the value types is given below, this thesis limits its scope to the consumptive direct-use value of water and the non-consumptive direct-use value of tourism.

Direct-use values include both consumptive and non-consumptive use values, as described below:

2.2.3.1 *Consumptive-use values*

Consumptive-use values are given to products directly and indirectly obtained from the environment. Natural products, such as Protea flowers (*Protea* species) and Buchu (*Agathosma* species), are examples (Turpie *et al.*, 2003).

2.2.3.2 *Non-consumptive-use values*

These are also known as passive-use values and refer to tourism activities which have little impact on the environment (Turpie *et al.*, 2003). Examples are whale and bird watching (Markandya *et al.*, 2002).

2.2.3.3 *Indirect-use values*

Such values include ecological functions. Examples are water purification by wetlands; and bees, originating from fynbos areas, pollinating fruit trees and thereby supporting a large fruit-export industry (Turpie *et al.*, 2003).

2.2.3.4 *Option values*

Option values refer to the value placed on having the option of future use of the environment or resource (Bräuer, 2003). For example, genetic information from species could yield a new pharmaceutical drug in the future. Markandya et al. (2002) stated that this value was based on two points: namely, uncertainty regarding the future use and availability of the environmental resources; and the irremediable loss of natural resources.

2.2.3.5 *Existence values*

These refer to existence and bequest values which reflect an individual's willingness to pay for conserving or restoring natural resources for future generations. This is despite the fact they do not utilize the resource directly or indirectly themselves (Bräuer, 2003;

Markandya *et al.*, 2002). The existence value is the intrinsic value (Markandya *et al.*, 2002) of the service or product, the satisfaction of knowing it merely exists.

2.2.3.6 Total economic value

Resource economists are able to calculate a total economic value of environmental resources by totalling the use values (direct and indirect), non-use or passive values (bequest and existence values) and the options values (Department of Environmental Affairs and Tourism, 2004; Bräuer, 2003). The above-mentioned values have been depicted graphically in Figure 2, which shows how each value is included in a total economic value.

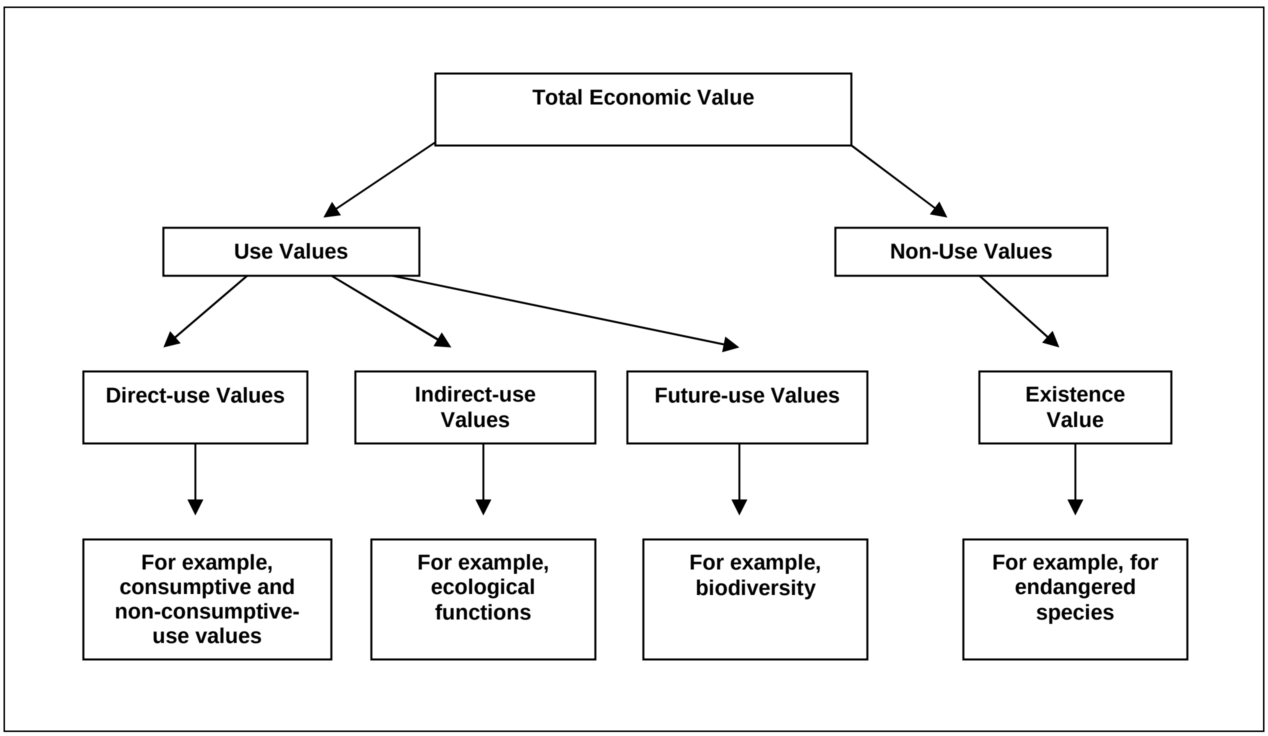

Figure 2: Total economic value (Turpie *et al.*, 2003, p. 235)

Few studies have attempted to calculate the total economic value of natural resources, but have preferred to concentrate on specific resources or values. Costanza et al. (1997) were the first to attempt to value ecological services and products on a global scale.

They admitted that there were many conceptual and empirical problems inherent in their evaluation, but at least they offered a preliminary approximation of the relative magnitude of the monetary value of ecosystem services. Costanza et al. (1997) achieved this evaluation by estimating the economic values, per unit area by biome, of 17 ecosystem services from 16 biomes. The resulting amount was multiplied by the total area of each biome and all values were totalled. The value of the entire biosphere was estimated to be between R112 trillion and R378 trillion ($16–54 trillion) per year, with an average of R231 trillion ($33 trillion) per year.

2.3 THE VALUE OF MOUNTAIN CATCHMENTS

A total economic value of mountain catchments in the Western Cape has yet to be determined. However, related studies have shown quantifiable consumptive-use values for mountain catchments. For example, Higgins et al. (1997) undertook a detailed study of the value of a hypothetical four-square kilometres of mountain fynbos with and without alien invasive plant clearing. This economic evaluation was based on six benefits: water production, wildflower harvesting, hiking, ecotourism, endemic species and genetic storage. Higgins et al. (1997) did not reflect the total economic value of mountain catchments, as, in common with most other studies, theirs did not include option, existence or bequest values.

2.3.1 Water

The most commonly valued mountain catchment benefit is water. Water is considered to be the most irreplaceable natural resource, as life would not be possible without it. The environmental-use values of water are listed by King (2004) and include the safeguarding of aquatic ecosystems, primary and secondary contact recreation, visual amenity value, maintenance of water sources for irrigation and industrial purposes, stream-flow regulation, sedimentation control, flood control, water-quality control and maintenance of ecosystem functions and environmental services.

South Africa receives a mean annual precipitation of 500 millimetres and can be considered a water-scarce country when its rainfall is compared to the world average of 860 millimetres per year (King, 2004). Owing to the uneven spatial and temporal distribution of rainfall experienced in the country, the availability of water in South Africa is seasonally variable and unpredictable. This is expected to worsen in light of the projected trends in global climate change and, therefore, it is likely that local and regional water shortages will escalate. Furthermore, observed trends of urbanisation and economic growth indicate that water demand is expected to increase in the future and water supply and demand imbalances are expected to expand. It is predicted that supply will be unable to meet demand (King, 2004). Despite the fact that water is becoming scarcer, water prices fail to reflect user values. This facilitates market failure, resulting in incorrect pricing and allocation of resources, thereby impacting on economic development (Blignaut & De Wit, 2004).

Economic growth in South Africa would be impossible without water as industry is one of the fastest growing sectors of the economy. Moreover, industry relies, in one way or another, on water as essential for many production processes. Agriculture is seen to be the most important water consumer, accounting for 54% of the total use in the country (King, 2004). Furthermore, in 2004, Blignaut and De Wit observed that 30% of agricultural income was generated under irrigation.

The mountain catchments of the Western Cape supply two thirds of the water requirements of the province (Van Wilgen *et al.*, 1996). Van Wilgen et al. noted in 1996 that this water source supported a large deciduous fruit industry which was valued at R3.92 billion ($560 million) and employed approximately, 250 000. The catchment also supplies the domestic and industrial water demand for the metropolitan city of Cape Town (Van Wilgen *et al.*, 1996). The value of water has been quantified using methods mentioned by Turpie (2004).

2.3.1.1 Replacement-cost method

The first method Turpie (2004) identified is the replacement-cost method. This entails the valuation of water gain or loss in terms of the cost of buying water from a national water supply scheme (average bulk-water costs). Water can also be valued in relation to the cost of future water-supply schemes which have been planned for the area.

Van Wilgen et al. (1996) used the replacement-cost method to value water benefits from mountain catchments. This was done by taking the costs of alternative water-supply schemes and comparing them to the costs of alien invasive plant clearing. Van Wilgen et al. (1996) determined that optimal catchment management provided the highest quantity of water at the cheapest rate. Van Wilgen et al. (2004) used the relationship between the biomass of a typical alien invasive plant species and stream-flow reduction to quantify the stream-flow benefit from biological control of alien invasive plants. They concluded that long-leafed wattles (*Acacia longifolia*), golden wattles (*Acacia pycnantha*), silky hakea (*Hakea sericea*) and red sesbania (*Sesbania punicea*) were consuming 1881, 1860, 1034 and 758 cubic metres per hectare per year respectively. Implementing biological control of invasive alien plants would be considered a saving. It must be noted that their study does not take the density of invasion into consideration.

2.3.1.2 Opportunity-cost method

The second method used to value the water benefit derived from mountain catchments is the opportunity-cost method. This method values water gain or loss in terms of the opportunity cost of water already used downstream. Alternatively stated, it is the value of the direct or indirect use which could have been added to the national income (Turpie, 2004).

2.3.1.3 Average-value method

A third method mentioned by Turpie (2004) is to value water by using the average value added to the economy per unit of water used by identifiable economic sectors. This is then multiplied by the proportion of total available water consumed.

2.3.2 Biodiversity

Ecosystems sustain and manufacture biodiversity with their immense range of living conditions and the fortuitous events which mould the evolutionary pathways of organisms. According to Daily and Ehrlich (1995, cited by Daily et al., 1997, p. 5), "…the benefits that biodiversity supplies to humanity are delivered through populations of species residing in living communities within specific physical settings – in other words, through complex ecological systems."

Considered globally, very large numbers of species and populations are needed to sustain ecosystem services. This can be illustrated by describing an example from Daily et al. (1997) who used a square yard of pasture in Denmark to demonstrate the scale and detail needed to construct the services obtained from such a field. The soil alone is inhabited by an estimated 50 000 small earthworms and their relatives, 50 000 insects and mites and approximately 12 million roundworms. The number of these worms, insects and mites is insignificant in comparison to the micro-organisms found in the soil. Less than a teaspoonful of soil could potentially contain around 30 000 protozoa, 50 000 algae, 400 000 fungi and billions of bacteria which are needed for organic matter breakdown and vital for nutrient assimilation by higher plants (Daily *et al.*, 1997).

Naeem et al. (1999) drew attention to experimental studies, relating to biodiversity and ecosystem functioning, which showed how the productivity of natural ecosystems increased with species diversity and vice versa. These researchers observed that ecosystem functioning decreased as species diversity decreased within a community (Naeem *et al.*, 1999). Thus, a loss in species diversity has the potential to compromise natural ecosystem stability.

Three points highlighted by past research were listed by Naeem et al. (1999, p. 7) as follows:

- *"Declining species richness can lead to declines in overall levels of ecosystem functioning. This is especially pronounced at lower levels of diversity.*
- *At least one species per functional group is essential to ecosystem functioning. Having more than one species per functional group may or may not alter overall levels of ecosystem functioning, but it may nevertheless insure against loss of functioning in times of disturbance if species within functional groups are able to replace or compensate for one another.*
- *The nature of an ecosystem's response to declining biodiversity is dependent on community composition."*

Not only is biodiversity vital for the proper functioning of ecosystems, enabling them to supply life-supporting services, but it also provides a direct source of ecosystem goods. Biodiversity supplies the genetic and biochemical resources upon which agricultural and pharmaceutical organisations are founded (Daily *et al.*, 1997). This genetic and biochemical resource could possibly aid vital enterprises to prepare for future challenges arising from climate change. For example, the use of genetic biodiversity is responsible for an annual increase of 1% in crop productivity, valued at R7 billion ($1 billion) by the National Research Council in 1992 (cited in Daily *et al.*, 1997). A number of significant benefits are derived from the mountain fynbos biodiversity comprising 8 500 different species (Cowling & Richardson, 1995). A variety of different values is associated with this biodiversity, ranging from direct and indirect consumptive-use values and non-consumptive-use values to option values.

Direct consumptive use refers to the direct use of the fynbos covering the mountain catchments in the Western Cape. Both Honeybush tea (*Cyclopia* species) and Buchu (*Agathosma* species) are harvested from mountain catchments in the Cape Floristic Region, and Turpie et al. (2003) used the gross value of the final output to estimate the value these species added to the national income from harvested resources.

In 2003, the Buchu export industry was valued by Turpie et al. to be worth R13.5 million ($1.928 million) per annum. Half of the export total of this product was harvested from the natural veld.

The flower industry, both freshly cut and dried flowers, and the thatching-grass industry, are further examples of direct consumptive use of mountain catchment areas. These industries combined earned between R126 million and R133 million ($18 to $19 million) in 1996 and employed approximately 20 000 to 30 000 people (Van Wilgen *et al.*, 1996). Turpie et al. (2003) isolated the different vegetation types in order to quantify wild-flower harvesting and determined that, in 2003, the total net income per year from mountain fynbos was R7.7 million ($1.1 million).

The unique fynbos flora is an internationally recognized ecotourism resource. The Wesgro IQ Unit (2007) observed that approximately 1 591 648 million international tourists and 3 million domestic tourists visited the Western Cape in 2005. In the same year, international tourists exercised a spending power of R14.9 billion ($2.1 billion) and domestic tourists a spending power of R1.97 billion (Wesgro IQ Unit, 2007). The author appreciates that not all of the income generated under the auspices of tourism in the Western Cape should be attributed to the biodiversity of the province. Tourists could be visiting the Western Cape for historical, cultural, family, business and academic reasons, or even while in transit to other destinations (Turpie, *et al*. 2003).

By isolating the environment from other motivations for visiting ecotourism destinations, Turpie et al. (2003) demonstrated the degree to which the environment played a part in people's decision to visit the Western Cape. This was done via a questionnaire carried out in the Agulhas Plain region, where visitors to the locale were asked to indicate their main interests in the area. These included the village aspect, rural landscapes, friends/family, festivals, culture, business and the natural environment. Turpie et al. (2003) established that R6 406 million of the R9 304 million spending power in 2003 could be ascribed to the natural environment. In fact, 80% of tourists stated that the natural, or semi-natural, attractions were the main reason for their visit.

Furthermore, in 1996, Van Wilgen et al. stated that approximately 400 000 people were recorded as visiting the Cape of Good Hope Nature Reserve annually, principally for its enormous biodiversity. In 2004, Turpie, Winkler and Midgley discussed a survey conducted to determine the contribution of biodiversity to the value of tourism. It was concluded that 16% of the recreational value of Hluhluwe Game Reserve could be attributed to species diversity. Furthermore, a survey conducted within households of the Western Cape revealed that residents would visit local reserves less often if the vegetation was lacking, yet a quarter of the participants said it would make no difference (Turpie *et al.*, 2004).

Hedonic pricing is another method used to calculate the value of the aesthetic appeal (environmental characteristics) of the natural environment. Hedonic pricing uses related marketable goods to deduce the value of environmental characteristics (Markandya *et al.*, 2002). For example, from property prices, one can infer the value of an area's aesthetic appeal or quality of air. This is the revealed-preference method as opposed to the stated-preference method of contingent valuation. The latter examines responses to hypothetical questions (Markandya *et al.*, 2002). The travel-cost method has also been used to estimate the recreational demand of a site. It uses the cost of travelling to the site as a substitute value for entrance fees (Markandya *et al.*, 2002).

As explained earlier, biodiversity also has an option value. This refers to the future-use value placed on a natural resource and can be explained as the value of having the option of using the resource in the future. For example, the Rooibos tea industry is based on a single genetic strain of *Aspalathus linearis* (Van Wyk & Van der Bank, 1996, cited in Turpie, Heydenrych & Lamberth, 2003). This dependence on a single strain would be considered risky for any industry, yet there is a large gene pool of diversity within *A. linearis*, which could be used if necessary (Van Wyk & Van der Bank, 1996, cited in Turpie, Heydenrych & Lamberth, 2003). This possibility creates the option value for natural populations of *A. linearis* which could be exploited by the industry in future.

Daily et al. (1997) emphasized that approximately 80% of the human population used traditional medical systems and about 85% of traditional medicine was derived from plant extracts. Even differing populations of the same species have the ability to produce different types and quantities of defensive chemicals which could be used in pharmaceuticals or pesticides in the future. Different populations of a species also have the potential to show different levels of tolerance to environmental disturbances, such as excessive heat, drought and salinity variables.

The ability to acclimatize to environmental variation could be a great help in adaptation to climate change. The rice tests highlighted by Daily *et al.* (1997) offer a good example of this. Rice from a variety of locations was tested for variations in resistance to grassy-stunt virus, a disease that threatened the rice crop around the world (Daily *et al.*, 1997). As a further example more relevant to this thesis, Scott (1993) predicted that the loss of 50 000 species by the turn of the twentieth century would result in the estimated loss of 25 medicinal drugs with a market value of R175 000 million (US$ 25 000 million).

Turpie et al. (2003) used Scott's prediction to estimate a loss of 1 400 Red Data Book status species from the Cape Floral Region in the same time frame. According to Turpie et al. (2003), this would amount to a relational loss of R4.9 billion ($700 million) in pharmaceutical returns in the future. Unfortunately, with regard to the latter forecast, no specific time period was given.

The value of merely knowing biodiversity exists (existence value) is quantified by using the contingent-valuation method which works on the concept of the willingness of individuals to pay for the protection of biodiversity in South Africa. Turpie et al. (2003) made public the results of a contingent-valuation survey they had undertaken. The conclusion was that, within South Africa, the public was willing to pay R393 million ($56 million) per year for the protection of South Africa's biodiversity. Of this amount, R153 million ($21 million) could be allocated to the fynbos biome. This quantifies the amount South Africans were willing to pay to protect fynbos from the threats it faced so that it might be available for future use.

2.4 THREATS TO THE BENEFITS DERIVED FROM ECOSYSTEMS

A range of human activities are negatively impacting on the world's ecosystems, reducing the flow of natural products and services on a global scale. If present human behaviour and attitudes continue, human utilization of ecosystems is set to alter these ecosystems significantly within a few decades. The most immediate threats are the destruction of natural habitats and alien invasive species. Referring to the United States in 2000, Pimental et al. (2000) estimated the economic value of damages associated with non-indigenous species and the cost of their control at approximately R959 billion ($137 billion) per year.

Other threats include:

- over-fishing marine resources;
- degradation of farmland through unsustainable agricultural practices;
- pollution of land and waterways with toxic pollutants; and
- alteration of the earth's biochemical cycles through the burning of fossil fuels and the extravagant use of nitrogen-based fertilizers.

However, the most devastating threat is the irremediable loss of biodiversity, which is assumed, at a conservative rate, to be of one species per hour. Daily et al. (1997) pointed out that the loss far exceeded the rate of evolution of new species by a conservative factor of 10 000.

Subsidies and underpricing of resources can also be considered a threat to ecosystems which provide resources. For example, King (2004) discussed the fact that water in South Africa was underpriced, which could result in abuse of the resource. Such abuse would inevitably lead to environmental degradation, impacting present welfare improvement opportunities and future income benefits. The undervaluation of water threatens its sustainable use. Rapid unsustainable growth is one of two principal forces behind the threats to ecosystems. The other is the gap between short-term, individualistically-driven economic enticements and long-term community welfare (Daily *et al.*, 1997).

2.4.1 Threats to benefits derived from fynbos vegetation in mountain catchments

As in other terrestrial ecosystems, land-use options and inadequate land management threaten the economic and ecological benefits derived from mountain catchments. Turpie et al. (2003) listed exploitation of resources, urban development and invasive organisms as the three main threats to the Cape Floristic Region. In terms of the focus of this thesis – tourism and water benefits derived from the Assegaaibos mountain catchment – the foremost threat is considered to be alien invasive plant species.

It has been said that fynbos ecosystems are more susceptible to alien invasive plants than any other biomes (Van Wilgen *et al*., 2001). Yet, as Richardson et al. (1992) stated, it is not clear whether fynbos communities are more vulnerable to invasion by alien invasive plant species or whether the current extent of alien plant invasions is merely indicative of the bias of early/frequent introductions and the influence of human habitation.

It is evident that alien invasive species damage natural resources. Van Wilgen et al. (2001) commented that, in the mid-1990s, South African scientists began to quantify the economic impacts of alien invasive plants on the water resources of South Africa: they calculated that alien invasions had reduced the value of fynbos ecosystems by R82.25 billion ($11.75 billion). The impacts brought about by various ecological changes are primarily as a result of alien invasive plant species.

Invasions of alien plant species displace native vegetation and alter ecological processes. Many of the species used in commercial forestry have become significant invaders, spreading from plantation areas and becoming one of the main sources of alien invasive plants in South Africa (Mondlane, Van Wilgen & Shuttleworth, 2002). In fact, 38% of the invaded area in South Africa is occupied by species used in commercial forestry (Le Maitre, Versfeld & Chapman, 2000).

The most widespread invasive aliens in mountain catchment areas are *Pinus* and *Hakea* species (Richardson *et al*., 1997, cited in Holmes *et al.*, 2000). Pine plantations, just like other species of alien invasive plants, displace native vegetation and impact on ecological processes.

2.4.2 Threats to benefits derived from mountain catchments caused by *Pinus* species

Armstrong and Van Hensbergen (1996) provided an overview of the impacts of pine afforestation in particular on indigenous biota in South Africa. The main effects isolated by Armstrong and Van Hensbergen (1996) have been listed below:

- elimination of indigenous plant species;
- increased above-ground biomass;
- stream-flow reduction;
- lowering of the water table;
- soil compaction, impacting on the water-holding capacity of the soil and the hydrology in the area;
- acidification of the soil, which impacts on the nutrient cycle.

Forestry in South Africa began in the early nineteenth century with the arrival of European settlers (Van Wilgen *et al.*, 1996) and the establishment of plantations of alien species only began in the late nineteenth century (Le Maitre, 1998). The first records of the introduction of *Pinus* species to the Western Cape are found in reports of *Pinus pinaster* and *Pinus pinea* on the south-eastern slopes of Table Mountain in 1886 These and other alien invasive plants were introduced to the Western Cape Province to provide fast-growing timber for fuel and shelter as the indigenous forests shrank (Ackerman & Talbot, 2003).

In terms of current legislation, namely the Conservation of Agricultural Resources Act 43 of 1983, *Pinus* species are categorized as Category 2 invader species. Therefore, their growth is restricted by means of a permit system and the species is only allowed in demarcated areas (South Africa, 1983).

Furthermore, the legislation obligates land owners to control the species on their properties (Rouget *et al.*, 2002). It should be noted that forestry has a commercial value of its own: in 2001, for example, forestry contributed 2% – R42.8 million (US$ 6.1 million) – to the gross domestic product, with the industry employing over 100 000 people (Van Wilgen *et al.*, 2001).

Rouget et al. *(*2003) made a detailed assessment of the current and future extent of the threats to biodiversity in the Cape Floristic Region. This included forestry, which had transformed 1.6% of the natural vegetation alone. In fact, MacDonald, Kruger and Ferrar (1986) commented that, by 1986, approximately 4% (1 130 square kilometres) of mountain fynbos in the Southern and South Western Cape Province was covered in dense stands of *Hakea sericea* and *Pinus pinaster.* By 2001, fynbos covered 47% (129 314 square kilometres) of the Western Cape Province, of which 28.82% (37 274 square kilometres) had been invaded at a mean canopy cover of 16.80% (Van Wilgen *et al.*, 2001).

2.5 Ecological and economic impacts of biological invasions (pine plantations) in mountain catchments

Indigenous fynbos is an inherently low-water-demand vegetation type, which has adapted to the environment in which it is found. Its small water demand enables the plants to survive summer droughts. Its relatively low biomass allows growth in nutrient-poor soils and natural fires occur in this vegetation every 12 to 15 years (Van Wilgen *et al.*, 1996). The fires feeding on natural vegetation burn at low intensity, whereas the alien invasive plant species reach much greater temperatures when burning.

The establishment of plantations and the introduction of other alien invasive plant species added a major new life form (trees) to the tree-poor fynbos ecosystem. In this way, the biomass distribution has been altered (Van Wilgen & Van Hensbergen, 1992). Species such as *Pinus* are a good example of an alien invasive species that can treble above-ground biomass (Versfeld & Van Wilgen, 1986). The sustainable delivery of water of a high quality depends on the continued existence of low-biomass fynbos vegetation cover with its low water demand.

Alien plant invasions result in changes to the structure of the indigenous vegetation and have the potential to alter ecological processes. Features, such as plant density, vegetation height, leaf index, litter fall and decomposition rates, are altered (Van Wilgen *et al.*, 2001). Armstrong and Van Hensbergen (1996) observed that invasive alien plants caused changes in the soil, hydrology, habitat structure, microenvironment, food resources and ecological processes. Furthermore, it has been stated that biodiversity is reduced and local extinction of certain species may occur in afforested areas (Armstrong & Van Hensbergen, 1996).

The reduction in water yield, alterations to the fire regime, erosion, damage to soil seed beds, loss of biodiversity and tourism potential, nutrient cycle alterations and further secondary impacts are discussed from an ecological and economic point of view in this thesis.

2.5.1 Reduction in water yield

The increase in biomass caused by alien plant invasions has been shown to reduce water run-off by 30% to 80% (Cowling & Costanza, 1997). This is due to increased transpiration and water interception (Van Wilgen, 1996). A series of whole catchment experiments in 1936 demonstrated this in the Western Cape, showing that forestry has had a significant impact on water resources within the province. Since then, similar impacts on water run-off have been automatically assumed for many alien invasive species with high water demand (Van Wilgen *et al.*, 1998).

The Centre for Scientific and Industrial Research (CSIR) used their data to estimate the current impact of alien invasive plant cover on water use in Southern Africa. They concluded that cover of all alien invasive plant species in an area of 1.7 million hectares, uses 7% (3 300 million cubic metres) of the regional run-off (Van Wilgen *et al*., 1998).

Le Maitre et al. (1996) evaluated the impact, in terms of the water benefit, of not addressing the problem of alien plant invasions in the Western Cape. It was concluded that 87 million cubic metres of water could potentially be lost annually if no action was taken against such invasion. In 1996, this could be quantified as 34% of the annual water used by the city of Cape Town. This reduction in water yield increases substantially as the invasion reaches maximum densities, owing to an increased build- up of biomass.

Higgins et al. (1997) conducted a similar evaluation of the costs of ignoring the problems posed by alien invasive plants. An ecological economic-simulation model of mountain fynbos ecosystems was used to determine the value of a hypothetical area of four square kilometres. Two perspectives were taken into account: that of clearing alien invasive plants and that of ignoring them. The authors concluded that spending a small portion of the total value on clearing programmes would increase the value of a four square kilometre fynbos area from R21 million ($3 million) to R350 million ($50 million) by 1997 (Higgens *et al.*, 1997). In addition, Van Wilgen et al. (1996) and Van Wilgen et al. (1997) also conducted cost-benefit studies on alien plant-clearing programmes in the light of water benefits. They concluded that clearing would yield water at a mere 14% of the cost of developing new water-supply schemes.

2.5.2 Alteration of the fire regime

The physiology and higher structural biomass of alien invasive plant species is prone to altering the natural fire regime in fynbos (Van Wilgen & Van Hensbergen, 1992). Fires become less frequent (owing to the changes in fuel distribution) and more intense (owing to the higher fuel loads and extreme weather conditions under which fires will burn). The increased energy released by such fires makes them self-sustaining, difficult to control and potentially more damaging to ecosystems than fires in natural vegetation (Van Wilgen & Van Hensbergen, 1992). Such fires thus impact on the ecosystem economically. Unfortunately, no literature has attempted to quantify the economic impacts of an altered fire regime.

2.5.3 Erosion

The earth receives an annual amount of 119 000 cubic kilometres of rain (Daily *et al.,*1997). It is fortunate that this amount is not received all at once and that vegetation on the surface of the earth slows the force of rain drops hitting the soil surface. It is the vegetation that prevents rain drops from displacing the soil and slows the rush of water off the land. Plant-clearing operations interrupt the relationship between plants and the water cycle, leading to an increased surface run-off, which results in soil and nutrient loss (Daily *et al.*, 1997).

The impacts (costs) of erosion are not only found at the site of impact through soil loss, but also in the aquatic systems, natural and human-made, which transport the sediments. The deposition site is also negatively affected (Daily *et al.*, 1997): for example, the dust generated from a cleared construction site can negatively affect neighbouring human habitats during windy conditions. According to Blignaut, *et al.,* (2004) and Pimentel *et al*. (1995), these downstream impacts (costs) include:

- disrupted water supply or a water supply of lower quality;
- siltation, which impairs drainage and maintenance of river channels, harbours and irrigation systems;
- increased frequency and severity of floods; and
- decreased potential for hydroelectric power as reservoirs fill with silt.

Not only does the removal of vegetation leave the soil vulnerable, but also fuel loads are concentrated on the soil surface when alien invasive plants have been felled and not removed. This is common in timber plantations where fuel loads may be concentrated in slash piles. A concentrated fuel load on the soil surface can result in an intensive fire, damaging the soil and seed beds within the soil (Richardson & Van Wilgen, 2004).

Soil water repellency is one example of damage caused by high intensity surface fires. Usually soils can be wet easily, but following intensive surface fires, some soils become water repellent. This is a result of hydrophobic organic substances (un-decomposed and decomposed plant materials) forming a layer on top of the soil surface (Savage *et al*.,1992). Plant litter is the source of hydrophobic substances; thus, soils with higher humus content would show greater repellency than those with less humus (Scott & Van Wyk, 1992).

Furthermore, water repellency reduces the attraction between soil particles and inhibits water infiltration and/or percolation (DeBano *et al*., 1967, cited by Scott & Van Wyk, 1992). This leads to an increased frequency and volume of run-off over soils already susceptible to erosion by fire (Scott, Versfeld & Lesch, 1998). The subject of water repellency was studied by Scott and Van Wyk (1990, cited in Scott, Versfeld & Lesch, 1998), who conducted comparative tests of soil absorbency in burned and unburned pine and fynbos areas. They showed that fire had significantly increased the occurrence of water repellency in the burned soils and that the degree of repellency was positively related to the intensity of the fire.

Intense fires influence natural sediment loads in the rivers that drain mountain catchments of the South Western Cape Province. A fynbos-covered mountain catchment produces an average sediment yield of less than one ton per hectare per year and sandstone-dominated catchments appear to have lower erosion rates than those dominated by granite (Scott, Versfeld & Lesch, 1998). Scott, Versfeld and Lesch (1998) observed that fires in indigenous fynbos mountain catchments had an insignificant effect on erosion, but within timber plantations, soil-erosion rates were much higher. This is because high-intensity fires, caused by increased fuel loads (increased biomass) and occurring in the late dry season, have the potential to cause large increases in storm-water run-off and sediment loads in burned catchments.

Road systems accessing forestry plantations exacerbate surface run-off: most of the obvious soil movement in the catchment is associated with the road surfaces, culverts and cut-and-fill slopes, as they are the areas of least resistance (Scott, Versfeld & Lesch, 1998).

Intensive fires in invaded areas have the potential to destabilize mountain catchments, with resultant increases in soil erosion and decreases in water quality. The ability of mountain catchments to store water for future controlled release throughout the year is jeopardized because the invaded, and then burnt, watershed is denuded of soil.

Run-off after a rainfall event rapidly causes flooding and siltation (Richardson & Van Wilgen, 2004). This is particularly pertinent in areas with a long history of invasion, as problems of fire and soil erosion are expected to develop (Scott, Le Maitre & Van Wilgen, 1991).

2.5.4 Damage to soil-stored indigenous seed banks

High-intensity surface fires can also cause damage to the soil-stored seed banks, especially shallow seed beds. Seed banks are automatically reduced in density and richness by alien plant invasions (Vlok & Yeaton, 1999). With the further impact of intense soil-surface fires which damage seed beds, the biodiversity and resilience of the area are curtailed even further (Holmes *et* al., 2000; Van Wilgen, 1996).

2.5.5 Loss of biodiversity

Alien invasive plant species displace the natural vegetation, causing a loss of biodiversity. Invasion in fynbos areas has already contributed to the extinction of at least 26 species (Hall & Veldhuis, 1985, cited in Le Maitre *et al.*,1996) and, if alien invasions are left unchecked, a further 750 fynbos plant species (9% of the flora) are predicted to be at risk of extinction (Van Wilgen, Bond & Richardson, 1992, cited in Le Maitre *et al*.,1996). Blignaut et al. (2004) gave community respiration, decomposition, nutrient retention, plant productivity and water retention as five major ecosystem services which could be affected by changes or reductions in biodiversity.

Long-term alien plant invasions cause the loss of functionally important plant groups in fynbos. The recovery of fynbos vegetation, once a long-established alien plant invasion has been cleared from a mountain catchment, is characterized by the lack of an over-storey component (which would be made up of serotinous Protea species).

Richardson and Van Wilgen (1986) observed that sprouters dominated uninvaded sites, yet sprouters were negatively affected at invaded sites where soil-stored seed regeneration was more common. The lack of sprouter abundance at previously invaded sites jeopardizes catchment stability during the immediate post-fire phase (Holmes *et al.*, 2000).

Vlok and Yeaton (1999) have shown that the over-storey Protea component maintains the under-storey richness and is important in maintaining the patchiness component of fynbos plant communities. This is because the over-storey component inhibits the growth of under-storey resprouters, allowing for the creation of niches, which increases species richness. Fynbos communities deprived of certain functional guilds may be more vulnerable to disturbance than a community rich in functional guilds. Consequently, the capacity of biodiversity to fulfil its important role in buffering the ecosystem from disturbances is reduced (Holmes *et al*., 2000; Holmes & Richardson, 1999).

2.5.6 Loss of ecotourism potential

Alien invasive plants alter the appearance of the landscape, thus affecting the aesthetics and potential ecotourism benefit (Le Maitre *et al.*, 1996). Inadequate research has been conducted on the degree of impacts on various ecotourism activities. For example, it is assumed that hikers would not be as negatively affected by alien plant invasions as would bird watchers.

Le Maitre et al. (1996) believed educated citizens were fully aware of the global significance of fynbos vegetation. Such people were likely to be disenchanted by or critical of the presence of invasive alien plant species at the sites they visit, irrespective of the nature of the tourism activity.

Furthermore, with reference to the previously-mentioned survey in Turpie et al. (2004), three quarters of the participants stated that desertification of local reserves would influence the frequency of their visits to the area and the remaining quarter said it would not make a difference. This demonstrates the potential negative economic impact of a loss of biodiversity. Le Maitre et al. (1996) emphasized the importance of this issue to the ecotourism economy of South Africa.

2.5.7 Nutrient cycling alterations

Stock and Allsopp (1992) discussed the impact of nutrient enrichment on fynbos. They named the run-off from fertilized forestry lands as one of the many sources of nutrient pollution in the South Western Cape. Pine plantations, irrespective of fertilization, influence the spatial distribution of nutrients within an ecosystem. The inherent increase in biomass means that the dynamics of the litter fall are altered, which impacts on the input of organic matter and nutrients to the soil component (Stock and Allsopp, 1992).

Pinus radiata and *Pinus pinaster* have specialized ways of obtaining nutrients, including nitrogen-fixing symbionts, vesicular-arbuscular mycorrhizas (VAM), sheathing mycorrhizas and extensive proteoid root production (Stock & Allsopp, 1992). These species produce abundant seed, resulting in their domination of the landscape. Owing to their abundance and different resource utilization, these plants have the potential to alter the collective properties of the ecosystem being invaded (Stock & Allsopp, 1992). For example, decomposition of fynbos is extremely slow when compared to other vegetation types (Versfeld *et al.*,1992). Alien plant invasion thus has the potential to accelerate decomposition, owing to the related changes in vegetation composition and structure.

2.5.8 Secondary impacts

Richardson and Van Wilgen (2004) mentioned secondary impacts that have yet to be seriously considered in resource economics. For example, run-off reduction caused by alien plant invasions in mountain catchments will affect the release of fresh water into estuaries downstream, thereby affecting the dynamics of the estuary. In turn, this can severely impact fish stocks because their breeding grounds become unsuitable. It must be noted that Richardson and Van Wilgen (2004) stated these secondary links had not yet been clearly defined or quantified.

2.6 RECOVERY AFTER ALIEN CLEARING AND FIRE

In mountain catchment areas, the most important ecosystem function is assumed to be the supply of clean water. A sustainable cover of fynbos vegetation is required to ensure high water quality and yield from mountain catchments (Holmes *et al.*, 2000). Important ecological processes need a stable community of vegetative growth forms, regeneration and nutrient acquisition guilds (Holmes & Richardson, 1999). Without a balanced, indigenous vegetation cover, soils will be vulnerable to erosion and to the imminent establishment of invasive plant species (Holmes *et al.*, 2000).

The generally accepted treatment for the removal of *Pinus* and *Hakea* species, the most widespread invasive alien species in mountain catchment areas (Holmes *et al.*, 2000), involves mechanical removal and an initial application of fire to facilitate seed release. A year later, a follow-up burn is carried out to eradicate seedlings which may have germinated and grown since the initial removal (Holmes & Marais, 2000; Holmes *et al.*, 2000).

The costs of clearing operations have been evaluated in published literature. Marais, Van Wilgen and Stevens (2004) gave a preliminary assessment of the costs associated with South Africa's Working for Water Programme. It was determined that, in 2004, the total costs of clearing the alien invasive species from the nine provinces was R354 850 million ($50 692 million). The cost in the Western Cape alone amounted to R62 850 million ($978 million). This figure includes the clearing of Australian Wattles (*Acacia* species), Gums (*Eucalyptus* species), Pines (*Pinus* species) and Hakea (*Hakea* species).

These costs, however, did not take density of invasion into consideration. The omission is a shortcoming in evaluation as the costs of clearing rise in direct proportion to the density of invasion. This is relevant to both initial and follow-up clearing operations (Marais *et al*., 2004). However, Le Maitre et al. (1996) did take density into consideration and calculated that initial clearing of a moderate infestation would cost in the region of R500 ($71) per hectare, prior to burning. Further follow-up control efforts would cost approximately R33 ($4.7) per hectare. These quoted prices are assumed to be based on 1996 costs.

The costs of clearing are not only density-related, but are also influenced by the specific species to be removed (Marais *et al*. 2004). In South Africa, for an area of 2 464 hectares with 100% cover, the *Pinus* species alone had an initial clearing cost of R5.33 million ($761 000), with R3.99 million ($57 000) needed for follow-up costs, (Marais *et al*., 2004).

Holmes et al. (2000) conducted a study in which they reported on the recovery of fynbos vegetation after three different treatments to invasive species of *Hakea* and *Pinus*, namely:

- fell and burn;
- fell, remove and burn; and
- burn-standing treatments.

Holmes et al. (2000) concluded that the burn-standing treatment was the least damaging to vegetation variables. The other two treatments caused similar reductions in the richness and density of fynbos species, but the fell-and-burn treatment caused the greatest detrimental change to cover and guild structure. This is because of the increased biomass adding to the fuel load, thus allowing severely hot fires to burn.

The severity of fire can impact the recovery of indigenous fynbos too. Euston-Brown, Botha and Bond (2002) stated that severe fires could reduce biodiversity by as much as one quarter and seedling density by one fifth. Furthermore, alien density and diversity recovered better than indigenous fynbos after intensely hot burns. Fynbos on granite (Assegaaibos) is also more negatively affected (Euston-Brown, Botha & Bond, 2002).

Post-fire, the recovery of fynbos vegetation is determined by:

- the diversity and abundance of surviving plants in the area;
- medium-distance wind dispersal; and
- the depth, distribution and composition of soil seed banks (Holmes *et al.*, 2000).

Recovery after alien plant clearance was investigated by Holmes and Marais (2000) when a monitoring programme was established in the mountain catchment areas of the Western Cape. This was to assess the impacts of a dense stand of alien invasive plants on fynbos vegetation and its recovery following clearance and burning operations. This study revealed that areas invaded by dense alien stands for short periods of 45 years or less (Van Wilgen & Forsyth, 1992) recover fairly well following a fell-and-burn treatment. A functional cover of fynbos vegetation regenerated and further restoration was not necessary. Richardson and Van Wilgen (2004) confirmed that, assuming they had not been long established, alien invasive species would require no further management intervention after initial clearing. The fynbos should recover well without further assistance.

However, both Holmes and Marais (2000) and Richardson and Van Wilgen (2004) stated that sites with a longer invasive history (of more than 45 years) would probably require post-fire seed sowing to hasten vegetation recovery. To restore guild structure, locally harvested indigenous seeds should be sown over the area in early autumn (Holmes *et al.*, 2000) at a rate of between 40 and 70 seeds per square metre (Holmes, 2001). This rate is dependent on the predicted soil-stored seed component. The cost of sowing a fynbos-seed mix is calculated to be R3 402 ($486) per hectare (Holmes, Richardson & Marais, 2007).

Areas which experienced high-intensity fires (owing to high biomass) may require soil-erosion prevention to initiate vegetation recovery. Failure to restore an area adequately could cause soil erosion, poor water quality and reinvasion by alien invasive plant species (Vlok & Yeaton, 1999). Thus, it appears that alien-plant removal alone is not always enough to reinstate ecosystem functions and reseeding of missing functional groups may be required. Erosion control would probably be necessary in order to ensure a sufficient cover of fynbos.

CHAPTER 3: STUDY SITE

3.1 INTRODUCTION

The purpose of this chapter is to introduce the physical and biological setting for the research on costs and benefits of removal of alien invasive plants and post-clearing restoration of the Assegaaibos mountain catchment. It describes the location in the context of its conservation value and potential to provide ecosystem services to surrounding cities. It provides an indication of the history of hydrological and ecological research in the area that is relevant to this thesis. Furthermore, it will show the relevance of what was discussed in the literature review through its application to the study site.

3.2 LOCATION

The two areas under discussion in this chapter are the Assegaaibos and Swartboskloof mountain catchments.

3.2.1 Assegaaibos mountain catchment

Found in the fynbos biome, the Assegaaibos mountain catchment is located in the South Western Province of South Africa, approximately three kilometres from the town of Franschhoek. The catchment is shaped by the Groot Drakenstein, Franschhoek and Jonkershoek Mountains forming the source and the mountain-stream zone of the Berg River (Ractliffe & Dallas, 2004). See Annexure 1 for a satellite image of the Assegaaibos mountain catchment.

This thesis focuses on the upper-Berg River, the area above the G1H004 gauging weir (Annexure 2). The area is 806.44 hectares in extent (Barend Gerricke, *personal communication*, 7 June 2006) and is centred on 33º58´S and 19º04´E coordinates. It is surrounded by the Hottentots Hollands Nature Reserve, the Jonkershoek Nature Reserve, the town of Franschhoek and the remnants of the La Motte Pine Plantation.

3.2.2 Swartboskloof mountain catchment

Swartboskloof catchment area has been selected as the vegetation benchmark reference site for Assegaaibos. This is due to its close proximity to the study site, as well as its similarity with regard to geology, climate and slope. Furthermore, hydrology and ecology of the Swartboskloof has been well researched by contributors to Van Wilgen et al. (1992), particularly Van Wilgen & McDonald, who cite Bands *et al.* (1987) in this respect. This prior research has resulted in an abundance of available information. Reference to Swartboskloof will be made throughout this chapter for comparison purposes.

Like Assegaaibos, the Swartboskloof catchment is found in the South Western Cape Province of South Africa. It forms part of the Hottentots Holland Nature Reserve in the Jonkershoek Valley, situated 15 kilometres from the town of Stellenbosch. The Swartboskloof mountain catchment is centred on 33º57´S and 18º55´E coordinates and is 373 hectares in extent (Van Wilgen *et al.*, 1992). See Annexure 3 for the location of Swartboskloof.

3.3 LAND USE AND FIRE HISTORY

This section discusses the Assegaaibos and Swartboskloof mountain catchment areas in terms of historical land use and fire history.

3.3.1 Assegaaibos mountain catchment

Assegaaibos mountain-catchment area is state-owned land which probably remained in a natural state until the late 1920s when, during the depression, the La Motte Plantation, 4 200 hectares in extent, was afforested (Department of Water Affairs and Forestry, South Africa, 1996a). With the inception of the Western Cape Systems Analysis commissioned by the Department of Water Affairs and Forestry and the City of Cape Town in 1993, it was acknowledged that water-storage facilities were required in the Western Cape Province (Department of Water Affairs and Forestry, South Africa, 1993).

The Skuifraam Dam, now called the Berg River Dam, downstream of the Assegaaibos study site, was proposed at a cost of R490 million (Department of Water Affairs and Forestry, South Africa, 1996a). Construction of the dam would require the inundation of a portion of the La Motte Plantation which was managed by the South African Forestry Company Limited (SAFCOL) (Department of Water Affairs and Forestry, South Africa, 1996b).

SAFCOL did not dispute the decision made in the Western Cape Systems Analysis, since the profitability of forestry in the south-western part of the Western Cape, including the La Motte Plantation, was considered marginal (Department of Water Affairs and Forestry, South Africa, 1996b). This was due to low production, steep terrain and a high fire risk produced by the hot, dry summers (Uys, 1996). It resulted in the Western Cape Province not being identified as a growth point in the first Forestry Guide Plan for South Africa (Uys, 1996). In light of this, SAFCOL formulated an exit plan from the province and handed the area over to Mountain to Ocean (MTO).

Assegaaibos remained under plantation until 2000 when, despite efforts to exclude fire from the plantation, the Assegaaibos catchment was extensively burnt (Barend Gerricke, *personal communication*, 7 June 2006). MTO had no intention of replanting the area and this prompted the removal of the alien invasive plants from the catchment by the Working for Water Programme (Barend Gerricke, *personal communication*, 7 June 2006). The clearing operation began in 2001, a year after the fire and is planned to continue to 2011 (Nigel Rossouw, *personal communication*, 18 July 2006; Manfred Paulsen, *personal communication*, 5 July 2006).

The 2000 fire was not the only fire to burn the area: 190 hectares of the catchment was burnt in May 2004 and the entire area was extensively burnt again in 2006 (Barend Gerricke, *personal communication*, 7 June 2006). The only recorded fire history in Assegaaibos is given in Table 1.

Table 1: Recorded fire history at Assegaaibos mountain catchment

Fire date	Assegaaibos
2000	Extensively burnt
2004	Less extensively burnt
2006	Extensively burnt

What is particularly pertinent is the high fire frequency experienced at Assegaaibos. There is a four-year gap between the first and second fires and a two-year gap between the second and third fires, showing a fire frequency of less than eight years. According to Van Wilgen (1981), this would definitely result in the elimination of *Protea repens*.

It is also pertinent that a lot of the felled pine trees had been stored in slash piles, which resulted in high-intensity surface fires. This regime of high-intensity and high-frequency fires had detrimental impacts (damaged soil seed beds, accelerated soil erosion, water repellency and decreased water quality) which have been discussed in the literature review (Chapter 2) of this thesis.

Knowledge of the fire history in Assegaaibos is pertinent because it provides an indication of the present-day condition of the veld. Furthermore, it influences the extent and schedules of alien-eradication operations in restoration programmes, as well as the methods employed in such operations. These factors therefore directly affect the cost of the alien-removal programmes and future restoration costs.

3.3.2 Swartboskloof mountain catchment

The first known history of Swartboskloof states that the area was used by nomadic herdsmen for a period of about 1000 years (Schweitzer & Scott, 1973, cited in Van Wilgen *et al.*, 1992). Van Wilgen et al. (1992) mentioned how the San hunter-gatherers might have burnt the veld deliberately to stimulate the growth of bulbous species of plants which they utilized as a food source.

Later, history indicates that the first European families arrived in the early nineteenth century and demarcated the area into farms. The Swartboskloof was allocated as grazing grounds. It has been assumed that burning the area for grazing must have occurred during this time too. The fire records for Swartboskloof are far more extensive than for Assegaaibos and show that an extensive burn occurred in 1927. In 1932, the land was sold to the Municipality of Stellenbosch and later, in 1935, placed under the management of the Government Forestry Department as a nature reserve. At this time, the area was afforested with *Pinus radiata* A research station was also established in order to investigate the impact of forestry on water conservation (Van Wilgen *et al*., 1992). This research has resulted in an insight into and a more comprehensive understanding of the effects of fire and forestry on water resources.

Extensive fires were recorded during the years of 1942 and 1958; less extensive fires occurred in 1936 and 1973, with a prescribed burn in 1977. The Swartboskloof was eventually incorporated into the Hottentots Holland Nature Reserve in 1979 and the only fire recorded during this time was a prescribed burn in 1987. With the use of a grid overlaid on fire maps, fire intervals at 291 points were recorded, showing a maximum fire-return interval of 29 years and a minimum fire-return interval of 7 years. The mean fire-return interval was 16 years (Van Wilgen *et al*., 1992). The recorded fire history of Swartboskloof is shown in Table 2.

Table 2: Recorded fire history at Swartboskloof mountain catchment (data from Van Wilgen *et al*., 1992)

Fire date	Swartboskloof
1927	Extensively burnt
1936	Less extensively burnt
1942	Extensively burnt
1958	Extensively burnt
1973	Less extensively burnt
1977	Less extensively burnt
1987	Prescribed burn

The fire histories of both Swartboskloof and Assegaaibos cannot really be compared as Assegaaibos fire history has not been as extensively recorded as that of Swartboskloof. What is known is that, in the last decade, Swartboskloof has not been subject to as long a period of forestry impact; nor has it experienced as frequent a fire regime as Assegaaibos. Consequently, the Swartboskloof today is in a condition closer to natural.

3.4 GEOLOGY AND SOILS

The geological history of the Assegaaibos and Swartboskloof mountain catchments can be traced to before the breaking up of Gondwanaland, when, around 950 million years ago, the oldest rocks in the fynbos region accumulated (Cowling & Richardson, 1995). They are derived from a base of sedimentary depositions becoming fine-grained shales, sandstones and limestones (Cowling & Richardson, 1995).

During the Cambrian period, between 500 and 600 million years ago, seismic activity resulted in a granitic extrusion, named the Cape Granite Suite (Deacon, Jury & Ellis, 1992). Today, the Assegaaibos and Swartboskloof consist of granite from the Cape Granite Suite, which intruded through the Malmesbury formation in the Precambrian eon and was often overlaid by the Table Mountain Series (Ractliffe & Dallas, 2004). The Assegaaibos and Swartboskloof areas also have Arenite (quartzitic sandstone), derived from Table Mountain Sandstone, as their dominant geology (Patrick Shone, *personal communication,* 5 July 2006; Institute for Soil, Climate and Water, 2000a). See Annexure 4 for the dominant geology of the Assegaaibos mountain catchment.

The mountainous regions of the South Western Cape consist predominantly of rock, but do have limited soils at a maximum soil-depth class of less than 450 mm (Institute of Soil, Climate and Water, 2000b). They fall within the topsoil clay class of less than 15% (Institute of Soil, Climate and Water, 2000c) and the soil-leaching status class of non-calcareous (Institute of Soil, Climate and Water, 2000d). The soils of the high, steep slopes are called lithosols and consist of partially-weathered rock and rock fragments forming a shallow, weakly-developed (skeletal) soil (Deacon *et al.*, 1992; Soil Classification Working Group, 1991).

The soil types are directly representative of their underlying geology and, in the Assegaaibos and Swartboskloof, the soils derived from the quartzitic sandstones are mineral deficient, sandy and well drained (Department of Water Affairs and Forestry, South Africa, 1998; Cowling & Richardson, 1995). Quartzitic sandstone is fairly resistant to erosion (Department of Water Affairs and Forestry, South Africa, 1998; Cowling & Richardson, 1995), and Arenite is no different, characteristically resistant to weathering and considered chemically stable (Gore, 2004). On the other hand, the soils derived from the Cape Granites erode very easily. In fact, the Assegaaibos study site has eight erosion dongas presently being monitored by Cape Nature (Barend Gerricke, *personal communication*, 7 June 2006). See Annexures 5 and 6 for the location and size of the monitored erosion sites.

Hydromorphic soils are also found in the seepage areas at the source of the Berg River (Ractliffe & Dallas, 2004). Soil types vary considerably in depth, fertility, erodibility, structure and porosity. Thus, response to rehabilitation and restoration meets with varying degrees of success, a situation which must be considered and incorporated into the costing of such programmes.

3.5 CLIMATE

The fynbos biome experiences a wet Mediterranean climate, which is considered to have a less intense summer drought than regions with a true Mediterranean climate (Versfeld *et al.*, 1992). The South Western Cape climate is dominated by a high-pressure cell, which is situated at 37ºS in summer and 32ºS in winter (Deacon *et al.*, 1992).

The climate is characterized by hot, dry summers from November to March, with high solar irradiance and dry south-easterly winds creating a fire hazard (Department of Water Affairs and Forestry, South Africa, 1996a; Verfeld *et al*., 1992). Very little rain falls during the summer, resulting in a low-flow period in the Berg River (Ractliffe & Dallas, 2004; Cowling & Richardson, 1995; Harrison & Elsworth, 1958).

The winters are wet and cold, with a low solar irradiance (Versfeld *et al*., 1992). North-westerly and south-easterly winds dominate in the month of July (Department of Water Affairs and Forestry, South Africa, 1998; Department of Water Affairs and Forestry, South Africa, 1996a). The cyclonic nature of the rainfall creates cold fronts which move over the area and cause a few days of clear skies before the next series of frontal systems moves over the area again (Ractliffe & Dallas, 2004; Cowling & Richardson, 1995; Harrison & Elsworth, 1958). This pattern causes periodic flooding, with rapid subsidence to normal flow (Harrison & Elsworth, 1958). Occasionally, snow falls on the mountain peaks and upper slopes during the cold winters and, while frost is rare, mist often occurs in the area (Harrison & Elsworth, 1958).

3.5.1 Rainfall

Very little summer rainfall is experienced in the western parts of Southern Africa. There is a relative difference in the amount of rain that falls in summer on a west-to-east gradient: the further west, the more winter rainfall occurs (Cowling & Richardson, 1995). Winter rainfalls are frequent, generally occurring between April and September (Department of Water Affairs and Forestry, South Africa, 1996a). Rainfall is also extremely inconsistent over the fynbos biome, displaying an orographic gradient (Verfeld *et al*., 1992). It ranges from 200 millimetres in the inland valleys to 400 millimetres on the coastal lowlands. In the mountainous regions, rainfalls between 800 and 3 000 millimetres and above occur (Cowling & Richardson, 1995).

Unfortunately, the Assegaaibos mountain catchment does not have a weather station. The closest station to the study site is Jonkersnek, where data has been collected since 1945 and which shows a mean annual precipitation of 3 296 millimetres per year (Patrick Shone, *personal communication*, 5 July 2006). This amount will be assumed for Assegaaibos and indicates a high risk of flooding and soil erosion, should the soil surface be exposed. An overview of the annual rainfall at Jonkersnek from 1945 can be seen in Figure 3.

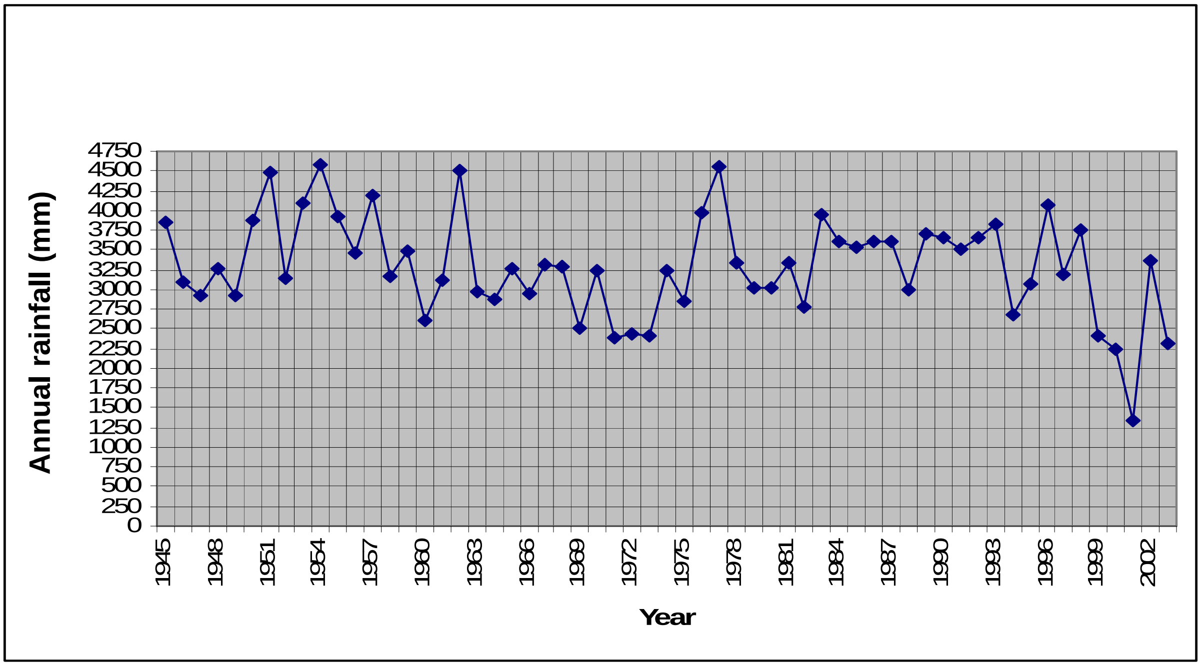

Figure 3: Annual Rainfall at Jonkersnek, from 1945 to 2003 (Data supplied by Patrick Shone, Conservation Manager, Jonkershoek Nature Reserve, 2005)

Upon closer evaluation of the rainfall data obtained from Jonkersnek, one sees that 67% of rain falls during the months between May and September. The remaining 33% falls between October and April, the drier months of the year. This is reflected in Table 3.

The weather station at Swartboskloof in Jonkershoek has recorded between 1 523 millimetres of annual rainfall at the base of Swartboskloof, which has an elevation of 305 metres, and 2 815 millimetres at an elevation of 910 metres. Six kilometres away from Swartboskloof, Dwarsberg Plateau, with an elevation of 1 220 metres, records the highest rainfall in the country at 3 635 millimetres per year (Versfeld *et al*., 1992). Thus, both the Swartboskloof and Assegaaibos mountain catchments are similar in terms of rainfall distribution.

Table 3: Average monthly rainfall and percentage of average annual rainfall at Jonkersnek (Data supplied by Patrick Shone, Conservation Manager, Jonkershoek Nature Reserve, 2005)

Month	Average rainfall (mm)	Percentage of average annual rainfall (%)
January	104	3
February	88	3
March	116	4
April	283	9
May	398	12
June	513	16
July	492	15
August	488	15
September	319	10
October	205	6
November	167	5
December	127	4

3.5.2 Temperature

The fynbos region experiences a hot, dry summer between November and March. Researchers at the Department of Water Affairs and Forestry, South Africa (1998) observed that summer temperatures measured at Bien Donne Farm, located near Stellenbosch, showed a recorded maximum of 29ºC and a minimum of 15ºC. They also observed that the average winter temperatures, also measured at Bien Donne Farm, reflected a maximum of 18ºC and a minimum of 5ºC (Department of Water Affairs and Forestry, South Africa, 1998). This is confirmed by Versfeld et al. (1992) who recorded a mean summer temperature of 22ºC and a mean annual temperature of 16.2ºC at Swartboskloof in the Jonkershoek Valley near Stellenbosch.

The most extreme winter temperature experienced at the Swartboskloof weather station was 0.2ºC; the highest summer maximum was 39ºC. One must also bear in mind temperature decreases with altitude. The Swartboskloof has an altitudinal range of 700 metres for every temperature depression of 3.8ºC (Versfeld *et al*., 1992) and this can also be assumed for the Assegaaibos mountain catchment.

The scheduling of restoration efforts is greatly influenced by seasonal climatic conditions. To ensure a high success rate, seeding should occur during times when conditions are most suited to the germination and growth of plants. Failing to do this would result in the need for additional, expensive follow-up operations. Extreme weather during the wet season at Assegaaibos can also substantially limit the number of working days and the accessibility to portions of the area. Furthermore, degradation of exposed areas can be accelerated by high rainfall and winds.

3.6 TOPOGRAPHY

Both the Assegaaibos and Swartboskloof mountain catchments are situated in the high-lying areas of the Western Cape Province, where the mountains rise steeply from inland plains. The backdrop mountain of the Assegaaibos mountain catchment area consists of the north-facing slope of the Noordkloof Mountain in the Franschhoek mountain range. This slope has an elevation of 1 500 metres (Department of Water Affairs and Forestry, South Africa, 1996a). The north-facing slope of the Jonkershoek Mountains coming from the west also forms part of the Assegaaibos mountain catchment walls.

The Groot Drakenstein Mountains, which Ractliffe and Dallas (2004) recorded as reaching 2 060 metres, are to the north-west of the Franschhoek Mountains. The Groot Drakenstein range forms the south-facing slope of the Assegaaibos mountain stream, as well as the west side of the catchment, where the slope and stream broaden out. A neck, extending in a northerly direction from the Franschhoek Mountains, forms the easterly face of the catchment and continues to form a south-facing slope. As a result, the Assegaaibos Mountain has a predominantly north-facing aspect, but also has east-, west- and south-facing sides (Franschhoek, South Africa, 2007).

Swartboskloof, on the other hand, is not as varied in aspect as Assegaaibos – it only has a north-facing slope (Van Wilgen & McDonald, 1992). This can be considered a shortcoming if a researcher wishes to use Swartboskloof as a benchmark site because aspect, slope, soil type, depth, nutrient status and soil water content are all factors influencing the type of vegetation which grows in a particular area (Van Rooyen, 2002). However, the predominant slope at Assegaaibos is north facing and Swartboskloof is the nearest well-documented catchment sharing a similar geology and climate to the Assegaaibos mountain catchment.

In terms of temperature, soil and fuel moisture, north-facing slopes are much warmer and drier, and have a characteristically different vegetation type. For example, *Ericaceous* fynbos is found on the south-facing slopes as these plants prefer the cooler environment. The north-facing slopes experience drier conditions and dry fynbos is found to dominate (Cowling & Richardson, 1995). The north-facing slopes can therefore be considered more combustible, allowing for a higher fire frequency as well.

The sandstone mountains in the Assegaaibos mountain catchment form vertical cliffs which develop into slopes covered in colluvial material. These slopes eventually become the undulating granite floor of the catchment (Ractliffe & Dallas, 2004; Van Wilgen & McDonald, 1992). The difficult terrain has meant that specialized mountaineering techniques have had to be employed to access these difficult areas. The foothill zone comprises slopes of between 31º and 40º and is accessible by foot from the 40 kilometres of contour forestry tracks available. The gradient of the Jonkershoek Valley, in which Swartboskloof is found, has a similar range of between 5º and 45º, with steep slopes averaging 30º (Van Wilgen & McDonald, 1992).

3.7 FLORA

Besides soil type and moisture availability, vegetation is ultimately characteristic of its dominant geology and, in the Western Cape mountainous regions, a plethora of soil types occurs. Rapid soil-type changes may be observed from one site to the next, making the identification of plant communities extremely difficult (Van Wilgen & McDonald, 1992).

Authors, such as Cowling, Richardson and Pierce (1997), have highlighted three major environmental gradients which also determine the vegetation-community change in the mountainous regions. These consist of a coast-to-interior gradient, a west-to-east gradient and an altitude-aspect gradient (Cowling *et al.*, 1997).

Proteoid vegetation can be found growing on the mixed granite-and-sandstone soils of the lower slopes. *Restionaceae* and *Cyperaceae* grow in the shallow, sandy soils of the drier slopes (Cowling *et al.*, 1997; Macdonald, Jarman & Beeston, 1985). Hygrophilous communities are also found in the seepage areas. Assegaaibos itself has a multitude of aspects and a range of altitudes, creating a variety of microhabitats.

3.7.1 Assegaaibos mountain catchment

The Assegaaibos mountain catchment was afforested in the late 1920s (Barend Gerricke, *personal communication*, 7 June 2006) with 70% *Pinus radiata*, 25% *Pinus canariensis* and about 5% *Pinus pinaster*. The in-stream vegetation of the upper reaches of the Berg River was observed in a helicopter survey in 1995 when the area was still inundated with pine species (Jones & Boucher, 2004). The survey reported aquatic moss and sedge in the source zone, as well as *Acacia longifolia* and *Acacia mearnsii* dominating certain portions of the riparian vegetation (Jones & Boucher, 2004).

Since 2001, the Working for Water Programme has been actively clearing the area (Nigel Rossouw, *personal communication*, 18 July 2006; M. Paulsen, *personal communication*, 5 July 2006). The majority of the alien invasive plant species have been cleared. The remaining stands of pine are found at high altitudes and are presently being cleared by specialized high-altitude teams. The regeneration of the indigenous vegetation occurs naturally in the cleared areas and is of a mesic mountain-fynbos form (MacDonald *et al.*, 1985). One shortcoming the author observed with regard to the alien invasive plant-clearing operation at Assegaaibos was that high-altitude areas were being cleared last. This is a source of seed at the highest, and most beneficial, point for distribution, which certainly guarantees the chances of reinvasion.

The fynbos in Assegaaibos has been classified as *Macchia* Fynbos (Institute for Soil, Climate and Water, 2000g) and described by Macdonald, Jarman & Beeston (1985) as shrubland fynbos. The vegetation types found in the Assegaaibos mountain catchment have been classified. Representative of their geology, they are Koggelberg Sandstone and Boland Granite Fynbos (Patrick Shone, *personal communication*, 5 July 2006).

No surveys of plant species have been done expressly for Assegaaibos, but it is safe to assume that the full complement of species will not be found, owing to the eighty-year period of forestry activity in the area. Most species of the indigenous soil-stored seeds are likely to have died, since the maximum longevity found in soil-stored seeds does not exceed the time period of forestry activity. For example, at Swartboskloof, a maximum soil-stored-seed longevity of 45 years is found in the species present (Van Wilgen & Forsyth, 1992).

The author has personally observed a lack of an over-storey component (Protea species), which is characteristic of vegetation recovery post-extensive alien plant invasion and a frequent fire regime (Holmes, 2001; Van Wilgen, 1981). The recent fire has also been a setback for the regeneration of indigenous vegetation, as well as exacerbating the existing gully erosion which has developed on certain slopes.

One species from the Red Data Book worth mentioning is *Serruria florida* (Blushing Bride) which is listed as 'Vulnerable' (Hall & Veldhuis, 1985, cited in Le Maitre *et al.*,1996). This species occurs endemically only in the Assegaaibos. *Serruria florida* was discovered in 1773 by Carl Thunberg in the Franschhoek Mountains. The species disappeared for a period of 100 years, even being considered extinct. In 1914, Professor Harold Pearson rediscovered a specimen and harvested seed for the then newly-formed Kirstenbosch Botanical Gardens. These seeds were said to have established the commercial cultivation of the species. The natural colonies subsequently spread out over a couple of kilometres and appear to be in fair condition. They are dependent on fire for regeneration (*Serruria florida*, 2007).

3.7.2 Swartboskloof mountain catchment

As mentioned, the Swartboskloof will be used as a benchmark site, representative of the type of vegetation that should be present in Assegaaibos. Two vegetation types occur at Swartboskloof: namely, mesic mountain fynbos and forest communities (Van Wilgen & Mcdonald, 1992). This thesis will focus on the mesic forms which are briefly described below.

Soils derived from sandstone in Swartboskloof have been observed to support *Cunonia capensis* and a hygrophilous community with two distinct strata. The upper stratum supports two-metre-high shrubs, such as *Berzelia lanuginosa*, *Elegia capensis* and *Osmitopsis asteriscoides*, and the lower stratum is dominated by *Elegia asperiflora*, *Tetraria fasciata* and *Merxmuellera cincta* (Van Wilgen & McDonald, 1992).

A proteoid shrubland forms a stratum on the sandstone and granite-derived soils and can be characterized by *Protea neriifolia* and *Protea repens* fighting for dominance, with *Protea nitida* in the rocky areas of the soil profile. *Olea europaea* is also found on the granite-derived soils. A second stratum of species containing *Rhus angustifolia*, *Cliffortia cuneata*, *Cliffortia ruscifolia*, *Brunia nodiflora* and *Erica hispidula* is also found on the granites. Geophytes, such as *Aristea major*, are present, as are grasses and restios, such as *Merxmuellera stricta* and *Ischyrolepis gaudichaudiana*. One also finds *Cymbopogon marginatus* and ferns, such as *Pteridium aquilinum* (Van Wilgen & McDonald, 1992).

A further Ericoid/Restoid shrubland is found in the Swartboskloof catchment and is characterized by species such as *Ischyrolepis sieberi*, *Hypodiscus albo-aristatus, Tetraria capillacea, Tetraria involucrata, Brunia nodiflora, Nebelia paleacea, Erica hispidula, Erica coccinea, Cliffortia cuneata, Cliffortia polygonifolia* and *Protea neriifolia* (Van Wilgen & McDonald, 1992). Swartboskloof is not immune to the spread of alien invasive species. *Hakea sericea, Pinus pinaster* and *Pinus radiata* have been most successful invaders, as have *Pinus halepensis, Acacia longifolia* and *Briza maxima* grass species. See Annexure 7 for a list of alien invasive flora found in the Swartboskloof.

3.8 FAUNA

The fynbos biome in general is said to have a very low biomass of fauna as the nutrient-poor soils cannot support the food demands of large animals (Cowling & Richardson, 1995). Large mammals, such as *Diceros bicornis* (black rhinoceros), *Panthera leo* (lion) and *Loxodonta Africana* (elephant), were seen in the area when European settlers arrived at the Cape, but their populations have been destroyed since then.

The largest mammals still found in the fynbos are *Panthera pardus*, (leopard) and *Papio ursinus*, (chacma baboon). Other mammals include *Aonyx capensis*, (Cape clawless otters), mongoose species and two genet species, as well as *Mellivora capensis* (honey badger), *Orycteropus afer* (ant bear) and the *Procavia capensis* (hyrax) (Cowling & Richardson, 1995). The most widespread antelope species in the fynbos mountainous regions are the *Sylvicapra grimmia* (common duiker), *Raphicerus melanotis* (grysbok), *Oreotragus oreotragus* (klipspringer) and *Damaliscus dorcas* (bontebok) (Cowling & Richardson, 1995; Skinner & Smithers, 1990). See Annexure 8 for a detailed faunal list, giving the scientific and common names of species recorded in Assegaaibos itself.

Despite the lack of large mammals, smaller species dominate, with the rodents being the most significant granivores (Van Wilgen & McDonald, 1992). There are many species of mice, rats, dormice, gerbils, mole rats and porcupine. Elephant shrews and hares are also found. Insectivores include the endemic Cape dune mole-rats and shrews (Cowling & Richardson, 1995). Furthermore, of the thirty snake and six tortoise species found in fynbos, one of them is endemic. Of the thirty frogs and toad species, nine are endemic.

There are also approximately 50 lizard species, which include agamas, skinks, geckos and chameleons (Cowling & Richardson, 1995). Insects, spiders, scorpions and molluscs are the best-represented invertebrate species found in fynbos (Cowling & Richardson, 1995). Ants are especially important as they play a vital role in seed dispersal of many plants. Dominant species found at Swartboskloof in Jonkershoek include *Anoplolepis custodiens* and *Pheidole capensis*, and the invasive Argentine ant, *Iridomyrmex humilis*, is also present (Van Wilgen & McDonald, 1992).

Fynbos avifauna does not have high diversity, but does include a number of endemic species. This is accredited to the uniform structure of the vegetation (providing fewer niches) and the lack of food availability (Cowling & Richardson, 1995). There are six endemic bird species (Cowling & Richardson, 1995), namely the *Chaetops frenatus* (Cape Rockjumper), *Bradypterus victorini* (Victorin's Warbler), *Promerops cafer* (Cape Sugarbird), *Nectarinia violacea* (Orange-breasted Sunbird), *Pseudochloroptila totta* (Cape Siskin) and *Serinus leucopterus* (Protea Canary). Other bird species found in the fynbos are *Cossypha caffra* (Cape Robin), *Prinia maculosa* (Karoo Prinia), *Nectarinia famosa* (Malachite Sunbird) and *Nectarinia chalybea* (Lesser Double-collared Sunbird), as well as *Cisticola fulvicapilla* (Neddicky) (Cowling & Richardson, 1995).

The Berg River has been known to contain several species of critically endangered fish (Clark, 2004; Department of Water Affairs and Forestry, South Africa, 1998). Historically, *Pseudobarbus burgi* (Berg River Redfin) and *Barbus andrewi* (Cape whitefish) had a wide distribution along the Berg River. Now, only vestiges of *Pseudobarbus burgi's* former prolificacy before 1900 remain, limited to the headwater streams of the Berg River (Clark, 2004). Clark (2004) commented that there was evidence that *Barbus andrewi* (Cape whitefish) had disappeared from the Berg-River system altogether. *Galaxias zebratus* (Cape galaxies), considered near-threatened, is still found in the Berg River and *Sandelia capensis* (Cape kurper) is common (Clark, 2004; Department of Water Affairs and Forestry, South Africa, 1998).

Alien invasive fish species are also found in the Berg River. *Oncorhynchus mykiss* (Rainbow trout) and a few *Micropterus dolomieu* (Smallmouth bass) were recorded by Sieberhagen in 2000 (Clark, 2004) and a study by Rall in 2004 recorded *Oncorhynchus mykiss* in sites situated above the Theewaterskloof syphon (Clark, 2004). *Oncorhynchus mykiss* were first introduced to South Africa in 1897 and fry from this batch were released into the Berg River (Clark, 2004), spreading rapidly and with ease. The angling success is a good indication of their wide distribution along the river.

The Berg River catchment streams are unique systems with their summer low flows, winter flooding, high diversity of habitats and underlying geology giving rise to a highly specialized array of aquatic fauna. Of the 300 species of aquatic fauna in the Cape Floristic Region, 64% are endemic (Snaddon, 2004). Snaddon (2004) commented that invertebrate orders with high potential as indicators of good water quality are stoneflies (Plecoptera, especially Notonemouridae), caddisflies (Trichoptera) and mayflies (Ephemeroptera).

Snaddon (2004) also observed that families in these orders were most abundant in the study-site area, above the Theewaterskloof syphon and that caddisflies (Sericostomatidae, Barbarochthonidae, Petrothrincidae, Glossosomatidae and Lepidostomatidae) were found in great diversity above, but not below, the syphon. Other invertebrate studies show the Assegaaibos stream is unimpacted and has shown little change since the 1950s (Dallas, 2004; Harrison & Elsworth, 1958).

3.9 INTERESTED AND AFFECTED PARTIES AND THE CONTEXT FOR THE STUDY OF VALUES

Management and land-use decisions regarding Assegaaibos involve several parties. Annexure 9 reflects a list of interested and affected parties compiled during the environmental-impact assessment prepared for the Berg River Dam feasibility study (Department of Water Affairs and Forestry, South Africa, 1996b).

The main role players in Assegaaibos itself include:

- the forestry organisation, Mountain to Ocean (MTO);
- the provincial conservation authority, Cape Nature;
- residents of the Franschhoek Valley;
- the Department of Water Affairs and the domestic and industrial water users in the Greater Cape Town Metropolitan area;
- agricultural water users in the Berg River Valley; and
- various non-governmental organisations.

The benefits these interested and affected parties derive from Assegaaibos are diverse. For example, the residents of the Franschhoek Valley derive a scenic, mountain view from the catchment, which supports a thriving tourism industry. Furthermore, the catchment also serves as a local recreational area for horse-riding, cycling, birding and hiking – even the South African National Botanical Society frequently uses the area for botanical excursions (*Serruria florida*, 2007).

A quantifiable direct benefit derived from the Assegaaibos mountain catchment is the water drawn by the farmers along the Berg River and Cape Town's urban and agricultural water users. This water is utilized to irrigate a variety of crops and as a domestic and industrial water supply. A second quantifiable direct benefit derived from this mountain catchment is the income MTO obtains from the sale of recreational permits for access to Assegaaibos.

3.9.1 Water

As stated in Chapter 2, the mountain catchments of the Western Cape supply approximately two thirds of the province's water requirement. This contributed R107.1 billion ($15.3 billion) to the gross domestic product in 1992. The Berg River catchment is said to be the largest in the Western Cape, measuring 9 000 square kilometres (Ractliffe & Dallas, 2004). Records show it discharged 690 million cubic metres into the ocean in 1990, half of which is said to have been generated from the catchment area south of Paarl. This water supports industrial, residential and agricultural sectors alike and is supplied via the Riversonderend (RSE) Government Water Scheme (Department of Water Affairs and Forestry, South Africa, 1996a).

The RSE scheme links the Theewaterskloof Dam with the Berg River, Wolwekloof, Banhoek and Dasbos catchments via a series of tunnels. Furthermore, the Berg River syphon is also linked to the Wemmershoek Treatment Works via the Cape Town City Council's pipeline (Department of Water Affairs and Forestry, South Africa, 1996a).

The large quantity and high quality of the water, as well as the proximity of the Berg River and the RSE Government Water Scheme to the Greater Cape Town Metropolitan Area (GCTMA) made it an attractive site for further water development schemes. An example is the Berg River Dam which has a full supply level of 250 metres, with a gross capacity of 126 million cubic metres. This dam is said to supply an additional 70 million cubic metres per annum to meet the urban water demand in the Greater Cape Town region, as well as the demand for irrigation water in the Berg River Valley (Department of Water Affairs and Forestry, South Africa, 1996a).

3.9.1.1 Agricultural water beneficiaries

As stated above, the water derived from the Berg River, with Assegaaibos as its source, supplies an irrigation water source to the Berg River Valley via the RSE water scheme. The agricultural beneficiaries consist of vineyards in the upper-Berg River and, to a lesser degree, fruit and vegetable farmers. Further north of the town of Wellington, grain and stock farming dominate. Projections of this agricultural demand are forecast to be in the region of 73 million cubic metres per annum by 2010 (Department of Water Affairs and Forestry, South Africa, 1996a).

3.9.1.2 Domestic and industrial water beneficiaries

Water from the Berg River syphon is transported to the Wemmershoek water-treatment plant so that it may contribute to the urban and industrial sectors in the GCTMA. Assegaaibos and the Berg River also supply a water source to the Western Cape and the Cape Winelands. The Western Cape Trade and Investment Promotion Agency (WESGRO) listed the sectors and their contribution to the gross regional product in the Western Cape and the Boland municipal area (Cape Winelands). These sectors and their contributions can be seen in Table 4.

Table 4: Western Cape Gross Geographic Product Statistics 2005 (Wesgro IQ Unit, 2007)

Gross geographic product at basic values (Rm current prices)	**Western Cape**	**Cape Winelands**
Total	**190,977**	**16,860**
Agriculture, forestry and fishing	7,543	2,334
Mining	329	29
Manufacturing	34,810	3,725
Electricity & water	3,382	131
Construction	6,075	464
Wholesale & retail trade; catering and accommodation	32,974	2,618
Transport & communication	19,868	1,449
Finance & business services	55,636	3,398
Community, social and other personal services	10,208	742
General government services	20,241	1,970
Gross Geographic Product per Capita	**41,109**	**26,085**
Export of Goods (Rm at current prices)	**37,937**	**7,111**
Agriculture, forestry & fishing	7,604	1,959
Mining	2,205	0
Manufacturing	28,049	5,145
World	**37,937**	**7,111**
Africa	7,140	314
Americas	4,026	837
Asia	7,392	1,032
Europe	16,770	4,813
Oceania	624	114
Not allocated	1,986	1
Import of Goods (Rm at current prices)	**70,132**	**18,180**
Agriculture, forestry & fishing (11-13)	783	412
Mining	32,913	14,656
Manufacturing	36,418	3,111
World	**70,132**	**18,180**
Africa	5,307	2,151
Americas	5,081	565
Asia	43,468	13,945
Europe	15,611	1,400
Oceania	641	118
Not allocated	24	0

Researchers at the Department of Water Affairs and Forestry, South Africa (1998) highlighted the fact that water is a limiting resource which underpins the economy in the province, as many industrial, commercial and agricultural processes are dependent on it. For example, in 1996, the deciduous fruit industry contributed R3.92 billion ($560 million) in gross export earnings and employed 250 000 people (Van Wilgen *et al.*, 1996). The provision of adequate water supplies is considered essential for future regional economic growth and development.

3.9.2 Tourism

The Western Cape is said to be the gateway to the African continent and has become a key destination in South Africa. Of all overseas visitors to South Africa, 1 million (53%) are attracted to the Western Cape. In 2004, The Western Cape Tourism sector contributed just over 9% to the provincial gross domestic product (GPD), employing over 300 000 people, which amounted to 10% of the Western Cape labour market. Approximately 744 000 overseas tourists and 294 000 visitors from the African continent visited the Western Cape Province in 2004. It has become the destination where tourists spend the bulk of their money – indeed, in 2003, foreign tourists spent R8.2 billion ($1.17 billion) and domestic tourists R8.3 million ($1.18 million) in the Western Cape (Wesgro IQ Unit, 2005/2006).

The Western Cape has six distinct tourism regions, of which the Cape Winelands is one. Of the visitors to the Western Cape, 14% of foreigners and 14% of domestic visitors come to the Cape Winelands. Assegaaibos is part of the Franschhoek Mountain Range, forming the Franschhoek Valley. The Valley is known for the high quality of its soils, as well as for producing white wines of good quality on one of the popular Cape Wineland routes (Wesgro IQ Unit, 2005/2006). The Franschhoek Mountain Range, together with the vineyards and orchards, creates a visually scenic landscape which is an important tourist attraction for the Western Cape Province.

Tourism, together with agriculture, is the most important economic activity in the Valley, with the town of Franschhoek offering a picturesque, rural setting. Known as the culinary capital of South Africa, Franschhoek attracts between 150 000 and 200 000 tourists annually (Department of Water Affairs and Forestry, South Africa, 1996a).

The village of Franschhoek is home to approximately 4 000 people and three informal settlements (Department of Water Affairs and Forestry, South Africa, 1996a). There are more than three dozen top restaurants, including several which are internationally recognized, and three of the country's top five eateries. A range of accommodation is available and establishments have ratings ranging between two and five stars. These facilities include guest houses, hotels, chalets and bed-and-breakfast establishments, and, among them all, offer more than 600 beds (Wesgro IQ Unit, 2005/2006). However, no camping sites, caravan parks or youth hostel facilities are available (Department of Water Affairs and Forestry, South Africa, 1996a).

The town of Franschhoek offers a blend of cultural, historical and culinary interests, including wine-tasting on the surrounding farms. It is steeped in French-Huguenot history, with Victorian and Edwardian architecture, the Huguenot Monument and the museum all serving as prominent tourist attractions. Indeed, Franschhoek enables visitors to enjoy historical and cultural attractions, as well as to savour good food and wine in a tranquil setting (Department of Water Affairs and Forestry, South Africa, 1996a). Furthermore, development of a hotel/resort-and-spa complex in excess of R300 million ($42.8 million) is planned for the area. Further development of the existing rail infrastructure for vintage- and tourist-train operations in the Winelands is envisaged (Wesgro IQ Unit, 2005/2006).

Despite its setting, Franschhoek offers a paucity of opportunities for outdoor recreation (Department of Water Affairs and Forestry, South Africa, 1996a). However, two picnic sites are available, one adjacent to the Huguenot Museum and the other some distance away in the direction of Stellenbosch. Three short day-walks are also offered at Monte Rochelle Farm.

Until 2006, the La Motte Plantation and, in particular, Assegaaibos were open to the public for use as recreational areas, offering horse riding, hiking, birding and cycling. Sadly, access to visitors had to be restricted, owing to the high fire risk. The riverine corridor is also an underutilized natural asset of the subregion. The restricted access to the Berg River limits opportunities for relaxation, picnicking and swimming. This is particularly of concern to the local community, many of whom require suitable facilities within walking distance of their homes (Department of Water Affairs and Forestry, South Africa, 1998).

The availability of water-related activities is presently restricted to the Theewaterskloof Dam, approximately 28 kilometres from the town of Franschhoek. This will possibly change on completion of the Berg River Dam construction (Keyser, 1996). A little further downstream, the reach from the Franschhoek tributary to the estuary is used for K1- and K2-classified canoeing activities and the Berg River Canoe Marathon, which is held on an annual basis and draws international interest (Department of Water Affairs and Forestry, South Africa, 1998).

CHAPTER 4: ASSEGAAIBOS MOUNTAIN CATCHMENT COST-BENEFIT ANALYSIS CASE STUDY

4.1 INTRODUCTION

This chapter will show the relevance and scope of work covered in the previous chapters entitled *Literature Review* and *Study Site*. The information derived from the literature review will be applied to the study site. The chapter begins with a discussion detailing the restoration requirements needed to meet the benchmark standard at Swartboskloof. This is followed by a detailed description of each aspect of restoration required at Assegaaibos and how the cost of each has been calculated. The same is expressed for the direct benefits provided by Assegaaibos mountain catchment. The chapter ends with a description of the process undertaken to perform the cost-benefit analysis. This offers a means of determining a net present value and includes a sensitivity analysis.

4.2 HYPOTHESIS

The water-yield increment and tourism benefit of the Assegaaibos mountain catchment area outweighs the costs of restoring the catchment to a condition similar in structure, function and composition to that of an undisturbed site.

4.3 ASSUMPTIONS

The following assumptions pertaining to this thesis have been made:

- All currency quoted in United States dollars has been converted to South African rand value, using the dollar-rand exchange rate of R7.00 to $1.00.
- All calculations in Annexure 10 reflect Rand values.
- The majority of costs involved in reseeding will be borne within the first year.
- The water benefit will increase from year one.
- The purpose of the restoration project is to return the Assegaaibos catchment area to a condition similar in structure, function and composition of an undisturbed site. The actions listed are assumed to be necessary and the cost thereof will be taken into account for and reflected in the cash-flow analysis.

- The term *normal* is found in Annexure 10, specifically in the alien invasive plant-removal spreadsheet. It is assumed to mean alien invasive plant removal of an average pine plantation typical of the study site area, with no exceptional circumstances or complications.
- It has been assumed that had permit sales making up the direct tourism benefit continued, this benefit would still be attained and (based on actual sales figures from the years 2001 to 2004) would experience an annual increase. This can be seen in Annexure 10.

4.4 DELIMITATION OF RESEARCH

For the purpose of this thesis, the area under analysis will be the catchment area above the Theewaterskloof syphon only. This ensures all data is relevant to an isolated catchment without the influence of inputs other than the historical forestry activity.

This cost-benefit analysis will investigate the costs of restoration including that of alien clearing. It will examine only the water supply and tourism benefits. The direct benefits of products in this catchment are negligible, since no harvesting has occurred. Most of the products derived from fynbos are now grown in plantations (for example: tea, thatch, flowers), making harvesting of products from the wild less likely. Such a decline will negatively affect the consumptive-use value of such products over time (Turpie *et al*., 2003). Therefore, products derived from fynbos will neither be valued nor included in this cost-benefit analysis.

The term *restoration* is contentious, with a variety of meanings, but for the purposes of this thesis, *restoration* will refer to the definition offered by the Society for Ecological Restoration Science & Policy Working Group (2004, p. 3), which states "Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed." It will comprise the reconstitution of the ecosystem to a state similar in structure, function and composition to that of an undisturbed site. In this case, the disturbance is that of alien invasive plant species; in particular, that of the genus *Pinus*, the dominant alien invasive plant in the catchment.

The Society for Ecological Restoration Science & Policy Working Group (2004, pp. 3-4) gives nine attributes of a restored ecosystem, which are provided below:

1. *"The restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and that provide appropriate community structure.*
2. *The restored ecosystem consists of indigenous species to the greatest practicable extent.*
3. *All functional groups necessary for the continued development and/or stability of the restored ecosystem are represented or, if they are not, the missing groups have the potential to colonize by natural means.*
4. *The physical environment of the restored ecosystem is capable of sustaining reproducing populations of the species necessary for its continued stability or development along the desired trajectory.*
5. *The restored ecosystem apparently functions normally for its ecological stage of development, and signs of dysfunction are absent*
6. *The restored ecosystem is suitably integrated into a larger ecological matrix or landscape, with which it interacts through abiotic and biotic flows and exchanges.*
7. *Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape have been eliminated or reduced as much as possible.*
8. *The restored ecosystem is sufficiently resilient to endure the normal periodic stress events in the local environment that serve to maintain the integrity of the ecosystem.*
9. *The restored ecosystem is self sustaining to the same degree as its reference ecosystem and has the potential to persist indefinitely under existing environmental conditions. Nevertheless, aspects of its biodiversity, structure and functioning may change as part of normal ecosystem development, and may fluctuate in response to normal periodic stress and occasional disturbance events of greater consequence."*

4.5 RESTORATION REQUIREMENT

Assegaaibos mountain catchment has been exposed to relatively few negative impacts and has remained isolated and undisturbed. However, the extended forestry history and frequent and intensive fire regime experienced has caused a reduction in biodiversity and has increased soil erosion.

Its closed canopy inhibited the natural propagation of fynbos and the extended period of forestry activity rendered certain seed banks and, in particular, the Proteoid over-storey component redundant. This is due to the seed longevity of some indigenous species being shorter than the duration of forestry activity in the area, as explained in the literature review found in Section 2.5 in Chapter 2.

Furthermore, the fire regime experienced in the Assegaaibos mountain catchment consisted of high-frequency, heat-intensive fires. This was due to the large volume of biomass available in pine plantations, which is considerably greater than the available biomass in indigenous fynbos vegetation. Fires experienced during the alien invasive plant-clearing operations also had an abundant source of biomass to burn, in the form of felled trees. The biomass was concentrated on the soil surface in slash piles, allowing for hot, intensive surface fires which damaged the soil seed bed. These fires impacted on the ability of the catchment to revegetate, as was explained in Chapter 2.

Without the capacity to revegetate properly, the soils in the Assegaaibos mountain catchment lay exposed to the elements of wind and water. This proved particularly unfortunate during the windy season (February). Gully erosion developed on the northern and eastern slopes of the catchment. Despite a lack of available data, it is also expected that an increase in sediment loads would be experienced in the Berg River. Not only did the historical forestry activity reduce biodiversity and cause soil erosion, but also consumed four million cubic metres of water annually (Gerald Howard, *personal communication*, 5 April 2006; Ractliffe & Dallas, 2004), depriving indigenous vegetation and other water users.

In order to restore the Assegaaibos mountain catchment to a state comparable to that of Swartboskloof mountain catchment in Jonkershoek, three operations are required:

- removal of alien invasive plants, which entails the removal of pine plantations long established at Assegaaibos;
- repair of gully erosion which has developed over time; and

- reseeding of species lost through the negative impacts of forestry activity and high-frequency, hot fires.

These operations will be detailed in Sections 4.5.1 and 4.5.2.

4.5.1 Alien invasive plant-removal operation

The first step to take in ecological restoration is the removal of the cause of transformation (Holmes & Richardson, 1999) – the pine plantation. The alien invasive plant-removal operation entailed the removal of pine plantations over an area of 806.44 hectares (Barend Gerricke, *personal communication*, 7 June 2006). In a personal communication (18 July 2006), Nigel Rossouw divulged the information that the operation had begun in 2004 and was being undertaken by the Working for Water Programme, with the financial support of the Trans Caledon Tunnel Authority (TCTA).

As is usual with the Working for Water Programme, the alien invasive vegetation is being cleared using labour-intensive techniques. It includes the utilization of hand tools, such as bow saws, hatchets, knives for young trees and chainsaws for mature trees. Mature trees have also been killed using a frilling technique. Most of the alien invasive plant removal programme is complete, apart from the clearing of the high-altitude infestations and the first two follow-up operations. These started in mid-July 2006 and were still continuing at the time this thesis was published (Nigel Rossouw, *personal communication*, 18 July 2006). It is important to note that no income was derived from the pine as most of it had been burnt standing in an accidental fire. The portions which had been felled were burnt as slash piles before collection of the timber could take place. This, as discussed in the literature review (Chapter 2), has a significant negative impact on the ecosystem and should be avoided if at all possible.

The costs of the alien invasive plant-removal operation have been obtained from personal communications with Nigel Rossouw at TCTA (18 July 2006) and are in accordance with the work standards of the Working for Water Programme.

The costs include initial clearing and follow-up operations calculated on a per-person-per-day basis. These costs amount to R130.00 ($18.5) and are inclusive of wages, protective clothing and transport. Furthermore, the costs include project-management costs (salaries, transport, telephone, computer and other day-to-day management costs) and regional-management costs. The latter are calculated as a standard 10% of the operational costs and are inclusive of the regional services provided by the Department of Water Affairs and Forestry, Western Cape Province office (Nigel Rossouw, *personal communication*, 18 July 2006).

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Each of these aspects (project- and regional-management costs; initial and follow-up operations) was isolated for each year. However, none of the costs includes escalation (Nigel Rossouw, *personal communication*, 18 July 2006). Therefore, before these costs could be used, it was necessary to inflate them to those of 2006, the base-year applicable to this thesis. The inflation rate used for this purpose is the Consumer Price Index (CPI). The CPI is an index of consumer goods and service prices which is a measure of inflation used nationally, as it relates to consumers' cost of living and purchasing power (Mohr *et al.*, 1995).

Furthermore, according to the contract drawn up by the TCTA Working for Water Programme, the estimated budget includes operating in an area far more extensive than the Assegaaibos mountain catchment. According to Nigel Rossouw (*personal communication*, 18 July 2006), the total cost of Area 1 in the TCTA Working for Water project (7 640.32 hectares, including Assegaaibos) was used to determine an average cost per hectare. This was then extrapolated to reflect the Assegaaibos mountain catchment extent of 806.44 hectares (Barend Gerricke, *personal communication*, 7 June 2006).

Once the relevant adjustments (scale and inflation) had been made, the annual breakdown of the alien invasive plant-removal operation was expressed in the *Costs* section of the cash-flow spreadsheets (see Annexure 10).

4.5.2 Repair of gully-erosion operation

The gully-erosion operation requires the repair of eight erosion gullies. This repair necessitates the construction of weirs at two-metre intervals down the slope of each gully. Rocks and dry plant material should be packed behind each weir to act as a soil trap. Weirs can be built using various types of material – gabions (wire-mesh cages packed with rock material) are even commercially available. In the case of Assegaaibos, in situ materials (logs) have been left behind after the alien invasive plant-removal operation and are available for use. Rocks from the riverbed are also available as a packing material for the soil traps positioned behind the weirs.

The costs associated with repairing the gully erosion are based on the labour costs of constructing a total of 7 348 metres of weir and the in situ or ex situ material costs required for their construction. Purely for comparison and discussion purposes, the costs of using ex situ material and the same labour costs as when using in situ material were calculated. These calculations can be seen in Annexure 10 in the Gully-erosion spreadsheet.

The erosion-control operation also requires a five-year follow-up programme, at a cost of 20% of the total gully-erosion operation (4% per year). The above-mentioned costs were calculated according to information provided during a personal communication with Deon van Eeden (8 December 2006). However, the labour cost of R75 ($10.7) per person per day (Deon van Eeden, *personal communication*, 8 December 2006) is a direct cost only. Therefore, the labour rate of R130 ($18.5), as provided by the Working for Water Programme, has been used.

Furthermore, before seed broadcasting can occur, bed preparation is required and this entails the mechanical scarification of 40.3 kilometres (Barend Gerricke, *personal communication*, 7 June 2006) of old forestry road. It is necessary to rake the soil surface of the roads after scarification, as well as raking around the gully-erosion sites.

Please note that bed preparation and scarification of the old forestry roads have been priced separately from the gully-erosion control, but, for the sake of convenience and data management, these operations have been categorized under gully-erosion control. Moreover, the costs of bed preparation apply only to the old forestry roads and the gully-erosion sites and not to the entire area of Assegaaibos.

4.5.3 Reseeding operation

The reseeding operation consists of various processes which begin with choosing the particular species to reseed. Two lists detailing reseeding species were compiled for Assegaaibos, both of which are based on the species list pertaining to the Swartboskloof benchmark site. The first list was formulated for reseeding and consisted of a comprehensive mix of 60 different species, the choice of which was based on cost and ease of harvesting. The second list consisted of just three primary Protea species and was aimed at re-establishing the over-storey Protea component only. Focal issues were the establishment of a pioneer grass cover for soil stabilisation and the restoration of the over-storey Protea component. Deon van Eeden from Vula Environmental Services and Professor Sue Milton assisted in determining the comprehensive species mix, from which the Protea species list was extracted (Deon van Eeden & Sue Milton, *personal communication*, 8 December 2006).

Once the species list has been determined, the process of seed harvesting takes place. This is followed by seed preparation, which includes the drying or smoking of the seed. Lastly, once the seed is ready and bed preparation has been completed, the seed is broadcast over the area. Certain species require separate seed broadcasting and this has been included in the calculation. For example, the grasses *Themeda triandra* and *Merxmuellera stricta* both possess an awn which is designed to dig the seed into the ground. Should the awn be damaged or broken off, the seed will not germinate. Therefore, it is unwise to include either *Themeda triandra* or *Merxmuellera stricta* with a general seed mix for broadcasting, as these species should rather be separately broadcast (Deon van Eeden, *personal communication*, 8 December 2006).

The costs associated with reseeding the species listed were obtained during a personal communication with Deon van Eeden (8 December 2006) and include harvesting, seed preparation and broadcasting. As discussed above, two species lists were formulated for Assegaaibos: a comprehensive species list and a list of only Protea species. The reseeding of Protea species is far less expensive than that of a full complement of fynbos species and has been priced separately for comparison and discussion purposes. The reseeding operation also requires a five-year follow-up programme. As recommended by Deon van Eeden, (*personal communication*, 8 December 2006), the cost of the follow-up programme has been calculated at 20% of the total reseeding cost, 4% per year for five years.

4.5.4 Area management cost

A general area-management cost was obtained through a personal communication with Patrick Shone (8 June 2007). It includes staff salaries, transport and contracts for fire-break management, but is not inclusive of wild-fire management. The costs obtained from Patrick Shone (*personal communication*, 8 June 2007) refer to the Jonkershoek Nature Reserve, which is much larger in extent (15 000 hectares) than Assegaaibos. Nevertheless, the costs were used to obtain a per-hectare cost which was extrapolated to reflect a general area-management cost specific to the Assegaaibos mountain catchment.

4.6 THE BENEFITS DERIVED FROM ASSEGAAIBOS MOUNTAIN CATCHMENT

Assegaaibos mountain catchment has the potential to supply a variety of products and services, but, for the purposes of this thesis, only the direct benefits of water and tourism have been quantified. A description of how each benefit value was obtained is provided below.

4.6.1 Water benefit

The net water yield derived from the Assegaaibos mountain catchment was obtained through personal communication with Gerald Howard (hydrologist on the Berg River Monitoring Programme) on 5 April, 2006 and from Ractliffe and Dallas (2004).

Recorded volumes of water at the G1H004 gauging weir in the Berg River, both historical and present, were used to determine a naturalized mean annual run-off. This volume was then valued according to the supply cost of bulk raw water provided by the Department of Water Affairs and Forestry, which, according to King (2004), included a resource-management charge recently incorporated for catchment management.

4.6.2 Tourism benefit

The estimated tourism-benefit value is based purely on the direct benefit obtained from permit sales for access to the Assegaaibos mountain catchment. It must be borne in mind that the area was not strongly marketed as a tourist venue by the local community or the Franschhoek Tourism Association. Furthermore, it was closed to the public from 2006 onwards. This was due to a lack of profit and the fire risk of unsupervised visits (Barend Gerricke, *personal communication*, 7 June 2006). Furthermore, during a personal communication on 7 June 2006, Barend Gerricke is quoted as saying “The money made from Assegaaibos did not justify the administration effort and fire risk in the plantation.”

Nevertheless, day and annual permits were sold for cycling, hiking and horse-riding activities from 2001 to 2006 (Dewdale Trout Farm, 2005; Tourism Association, Franschhoek, 2005). See Annexure 10 for details. These data gave an indication of the potential direct-tourism benefit of the Assegaaibos mountain catchment. It is assumed that should permit sales have continued, this benefit would still have been attained. Therefore, the recorded sales were used to determine the average annual percentage increase observed between 2001 and 2004. This annual percentage increase was rather erratic, varying between 67% in 2001 and 2002; 10% in 2002 and 2003; and 33% in 2003 and 2004.

Sales declined by 57% in 2005. The most realistic increase of 10% in 2003 was used to extrapolate the data up to and including 2036 in order to determine an expected future income from tourism for these years.

Various relevant aspects involved in the restoration of Assegaaibos (alien invasive plant removal, gully-erosion control, reseeding and general area management) and the income generated (water and tourism) have been expressed in a cash-flow spread sheet (Annexure 10). In order to calculate the cash flow, the costs and income are escalated and then the cash outflow is deducted from the cash inflow. This results in a net cash flow over a thirty-year time frame. This calculation was done for three different options, namely the comprehensive, moderate and basic restoration options, which are classified below.

4.6.2.1 Comprehensive restoration option

This includes all the restoration operations: alien invasive plant removal, gully-erosion control, comprehensive reseeding and general area management. This option will bring the Assegaaibos mountain catchment to a condition similar in structure, function and composition to that of an undisturbed site most quickly. Furthermore, the gully erosion has been costed using ex situ material (R24.00 – $3.4) and not in situ (R5.00 – $0.7) as proposed in the moderate and basic restoration options. These calculations can be seen in Annexure 10.

4.6.2.2 Moderate restoration option

A moderate restoration option involves alien invasive plant removal, gully-erosion control, reseeding with the Protea reseeding species only and general area management. Gully erosion has been costed using in situ material. Over time, this option has the potential to bring the Assegaaibos mountain catchment to a condition similar in structure, function and composition to that of an undisturbed site.

4.6.2.3 Basic restoration option

This only includes alien invasive plant removal, gully-erosion control and general area management. This restoration option excludes any reseeding operation and gully erosion has been costed using in situ material. In the author's opinion, the basic restoration option will not restore Assegaaibos mountain catchment to a condition similar in structure, function and composition to that of an undisturbed site.

According to the Society for Ecological Restoration Science & Policy Working Group (2004, p. 3), one of the attributes of a restored ecosystem is that "all functional groups necessary for the continued development and/or stability of the restored ecosystem are represented or, if they are not, the missing groups have the potential to colonize by natural means." The missing over-storey Protea component is unable to restore itself over time as the dispersal mechanisms are dominated by myrmecochory in the Cape flora. This is characterized by short distance dispersal only, averaging between two and three metres. It must be said, however, that a record distance of seventeen metres was observed for a *Leucospermum* seed (Bond & Slingsby, 1983).

For each option (basic, moderate and comprehensive), further analysis includes a cash-flow calculation for an optimistic, a realistic and a pessimistic scenario. This is explained below and each cash-flow option can be seen in Annexure 10:

- Optimistic scenario is based on the realistic costs and benefits where income has been increased by 5% and costs have been reduced by 5%.
- Realistic scenario refers to the realistic 2006 costs and benefits calculated without further manipulation.
- Pessimistic scenario is also based on the realistic costs and benefits, but the income has been reduced by 5% and the costs increased by 5%.

This amounts to nine different cash flows:

- the comprehensive restoration option – optimistic, realistic and pessimistic ;
- the moderate restoration option – optimistic, realistic and pessimistic; and
- the basic restoration option – optimistic, realistic and pessimistic.

4.7 THE COST-BENEFIT ANALYSIS

The cost-benefit analysis is the main thrust of this thesis. This section will detail how a net present value is obtained and provides the formula according to which the NPV is calculated.

4.7.1 Cost-benefit analysis method

A cost-benefit analysis is used to show the costs and benefits for the duration of the restoration project at Assegaaibos mountain catchment as a single value, the net present value. The formula is expressed as follows:

$$\mathbf{NPV} = \sum_{t=1}^{n} \frac{C_t}{(1+k)^t} - I$$

Where:	NPV	=	net present value
	Ct	=	net cash flow at time t
	I	=	cost of investment
	k	=	cost of capital
	t	=	time

(Correia *et al.,* 2007, p. 270)

This value method determines the net present value of the expected future net cash-flow estimates, which is, in turn, discounted at a required rate of return, usually the cost of capital (Correia *et al*., 2007).

More simply put, in order to determine the net present value of the restoration of Assegaaibos, the cash flow must first be determined by deducting the cash outflow from the cash inflow to get a net cash flow. The net cash flow is discounted, which Correia et al. (2007) referred to as the opposite of compounding, over a determined time frame to ascertain the net present value.

This gives an indication, from an economic point of view, of whether the project is viable. Net present values have been calculated for each term, from one to thirty years, for all three options, all three scenarios and at three different discount rates.

4.7.2 Discount rate

A discount rate is used to ascribe a lower value over time to future benefits and costs, illustrating that a South African Rand today is worth more than that Rand tomorrow. Markandya et al. (2002) defined this as time preference (the time value of money) and declared it to be the rationale behind discounting in cost-benefit analysis. Hanley and Spash (1993) identify two different methods of discounting: firstly, each value for each element of a project can be discounted and totalled; and, secondly, the cost for each time period can be deducted from the net value benefits on an annual basis. Then, the annual benefits are discounted consistently through the lifetime of the project.

It is evident that no agreement on the use of an appropriate discount rate has been reached by resource economists (Department of Environmental Affairs and Tourism, 2004; Turpie, 2004). Typically, projects have been valued using a discount rate of 8%. However, as Turpie (2004) stated, costs are calculated upfront, leading to the undervaluation of the long-term benefits of alien-control programmes. Furthermore, Turpie (2004) drew attention to the fact that since investment in alien control was a contribution by society, a 3% discount rate would be more appropriate for future benefits to future generations. Rees et al. (2007) stated that discounting might not be justified and proceeded to justify negative discounting on the basis of economic decline, commenting that the resource value was likely to increase over time as availability declined.

The Department of Environmental Affairs and Tourism (2004) suggested that for government-funded projects, the cost of long-term government borrowing offered one possible rate. Another suggestion was that government borrowing was blocking out the private sector, so the rate should be the private sector's pre-tax marginal rate of return on capital.

The Department of Environmental Affairs and Tourism (2004) also suggested the "social rate of time preference" (p. 8) be utilized. This term was defined by Markandya et al. (2002) as a rate determined by economists and philosophers as ethically justifiable to apply to costs.

NPVs were calculated utilizing the above-mentioned nine cash flows. However, in light of the uncertainty regarding which discount rates are applicable (Department of Water Affairs and Tourism, 2004; Turpie, 2004) and because the discount rate will have a significant impact on the NPV, this thesis has replicated the analysis using three different discount rates. The standard real rate used in South Africa is 8% (Department of Environmental Affairs and Tourism, 2004) and, typically, projects have been evaluated using this rate (Turpie, 2004).

It is also the rate used by the Department of Water Affairs and Forestry for comparing candidate water-supply schemes (Van Wilgen *et al.*, 1997). This thesis has replicated the net present value calculations using discount rates of 3%, 8% and 12% as recommended by the Department of Environmental Affairs and Tourism (2004). The higher discount rate gives more weight to the initial project cost and the lower discount rate places more weight on the future project costs (Tietenberg, 2002). The use of three different discount rates has also been introduced to test the sensitivity of net present values to the discount rate. Sensitivity analysis will be discussed shortly.

4.7.3 Ranking of decision

Projects need to be classified in order to determine their ranking. Projects may be classified into replacement or expansion decisions and further classified as independent or mutually exclusive. Some capital-budgeting techniques are used to accept and/or rank projects (Correia *et al*., 2007). Two value methods which are used are the net-present and the Internal-Rate-of-Return (IRR).

The IRR method is the discount rate at which a zero NPV is obtained and compared to the cost of capital (Correia *et al.*, 2007). The NPV and the IRR-value methods allow for comparison of projects using the same units (NPV and IRR value), thereby comparing identical entities. This thesis uses the NPV method and confirmed the findings using the IRR-value method. However, the IRR calculations have not been shown.

The NPV method discounts future cash flows to a base year and deducts the cost of the investment, expressing a net present value. It is considered beneficial to accept the project if the NPV is positive and reject the project if the NPV is negative. Furthermore, multiple projects can be ranked according to the NPVs.

4.7.4 Sensitivity analysis

By analysing the three different restoration options (comprehensive, moderate and basic) under three different sets of scenarios (optimistic, realistic and pessimistic) and at three different discount rates, a sensitivity analysis is performed. This is to see how sensitive the recommendations of the cost-benefit analysis are and to test the robustness of the NPV when input variables – the costs and benefits – on which it is based change. In this case, a sensitivity analysis of the NPV to a change in discount rate has been shown by performing the analysis using three different discount rates.

Furthermore, a comparison of the NPV of the three different economic scenarios (optimistic, realistic and pessimistic) tests the sensitivity of the NPV to changes in the costs and benefits on which it is based. This is because each scenario is based on a 5% increase or decrease from the realistic-scenarios benefits or costs. Of particular interest is the stage at which the net present value changes from negative to positive (Bräuer, 2003).

Although it is a common risk-analysis technique used at present, several limitations to the sensitivity analysis are mentioned by Correia et al. (2007). These include failure to take interrelationships between variables into account; failure to indicate the likely occurrence of each value, within the range of values, for each variable; and subjectivity, as it does not in itself result in a decision rule.

4.7.5 Time horizon

A time horizon must be established because calculating values over an unlimited time horizon often results in ambiguity. It must be noted that the Assegaaibos Restoration Project, like most restoration projects, involves biological processes. While the full benefits of these processes will not be entirely received in a short time span, the costs have to be borne within a short time frame. Thus, the full benefits will not be realized within a ten- or twenty-year time horizon, especially for fynbos ecosystems. Higgins et al. (1997) used a fifty-year timeline when valuing a pristine fynbos ecosystem. A short-term focus with regard to land-use decisions can potentially burden future generations with high costs (Daily *et al.*, 1997).

The above-mentioned calculations for each aspect of restoration and the benefits derived from the catchment can be seen in the working models in Annexure 10. This has allowed for the testing of the hypothesis, the results of which are expressed in Chapter 5.

CHAPTER 5: RESULTS

5.1 INTRODUCTION

This chapter presents all the findings from the cost-benefit analysis performed in the previous case study found in Chapter 4. Each of the nine cash-flow calculations was used to calculate NPVs over a ten-, fifteen-, twenty- and thirty-year time frame.

In this chapter, the NPVs for the three restoration options have been graphically expressed, accompanied by a short written description. As a reminder, the three options include the basic restoration option, which involves alien invasive plant removal, erosion control and management fees. The moderate restoration option includes all that the basic restoration option offers, as well as a reseeding operation, limited to Protea species only. Lastly, the comprehensive restoration option includes all the aspects of the moderate restoration option; however, the reseeding component involves the reseeding of a far more comprehensive fynbos seed mix. An Excel model, which shows how each aspect has been calculated, is attached as Annexure 10. As Chapter 6 focuses on the discussion of the results for the three options expressed in this chapter, no results will be discussed here.

5.2 COMPREHENSIVE RESTORATION OPTION

The hypothesis states that the water-yield increment and tourism benefit from the Assegaaibos mountain catchment outweigh the costs of restoring the catchment to a condition similar in structure, function and composition to that of an undisturbed site. The results have shown the hypothesis to be incorrect when applying optimistic, realistic and pessimistic scenarios using any of the three discount rates (3%, 8% and 12%) over ten-, fifteen-, twenty- and even thirty-year time frames. At no point is a positive NPV reached within a time frame of 30 years. This shows that under no scenarios (optimistic, realistic or pessimistic) is comprehensive restoration of Assegaaibos worth the water and tourism benefits derived within a thirty-year time horizon. The NPVs are depicted in Figures 4, 5 and 6.

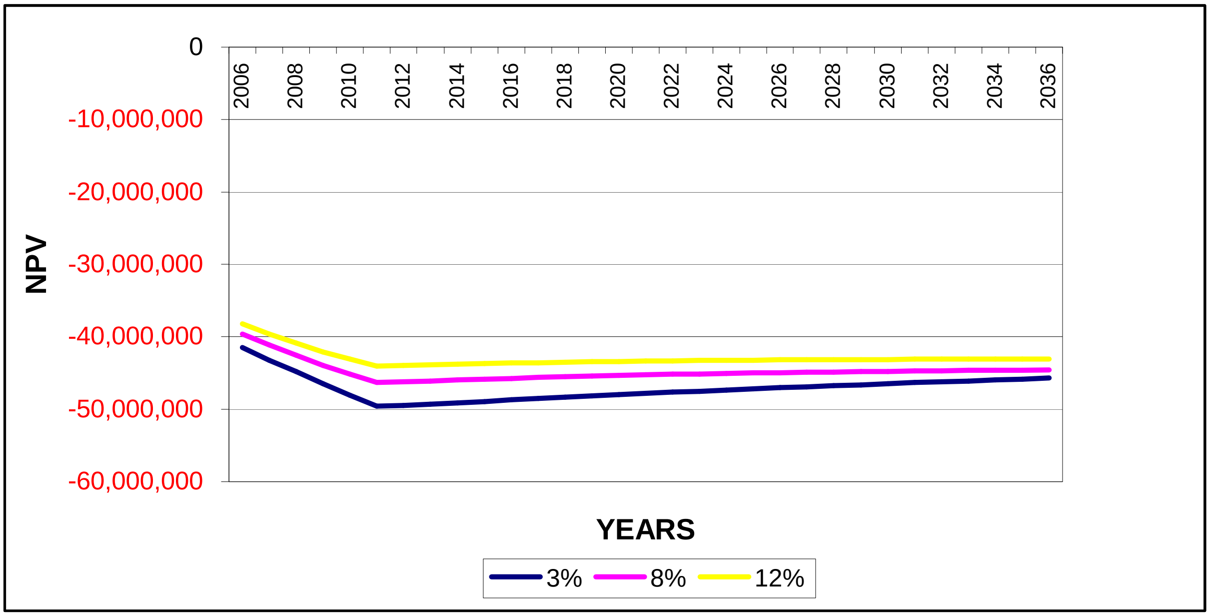

Figure 4: Net present value results of the comprehensive restoration option, realistic scenario, over 30 years

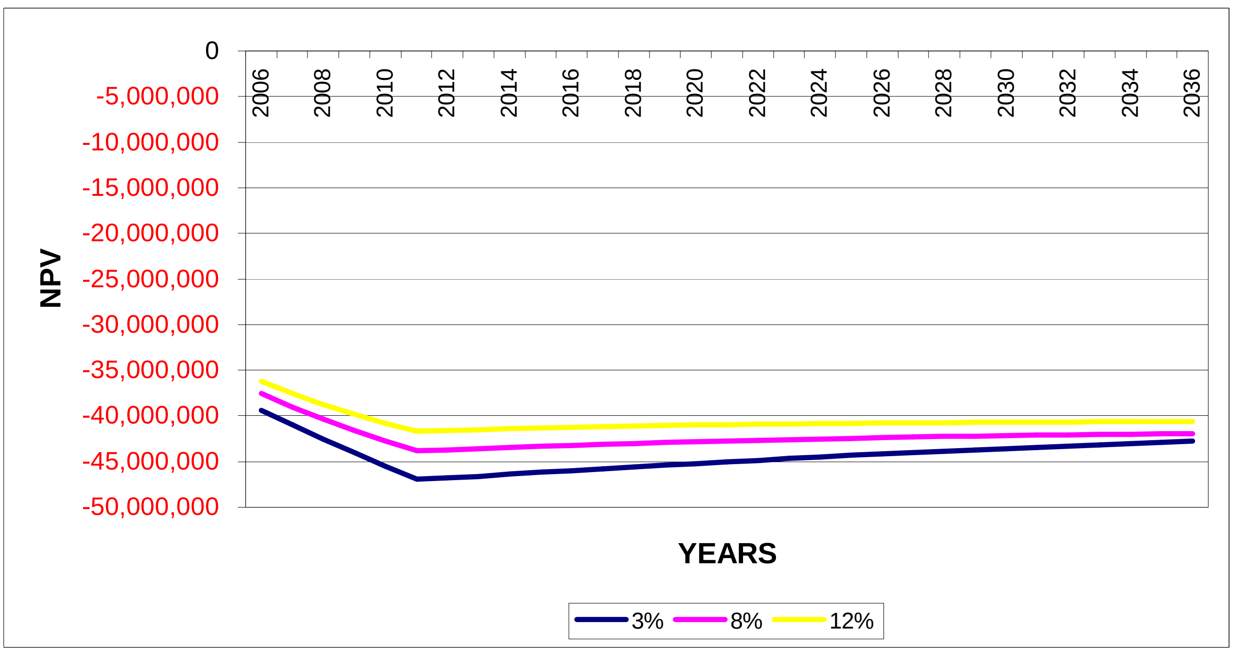

Figure 5: Net present value results of the comprehensive restoration option, optimistic scenario, over 30 years

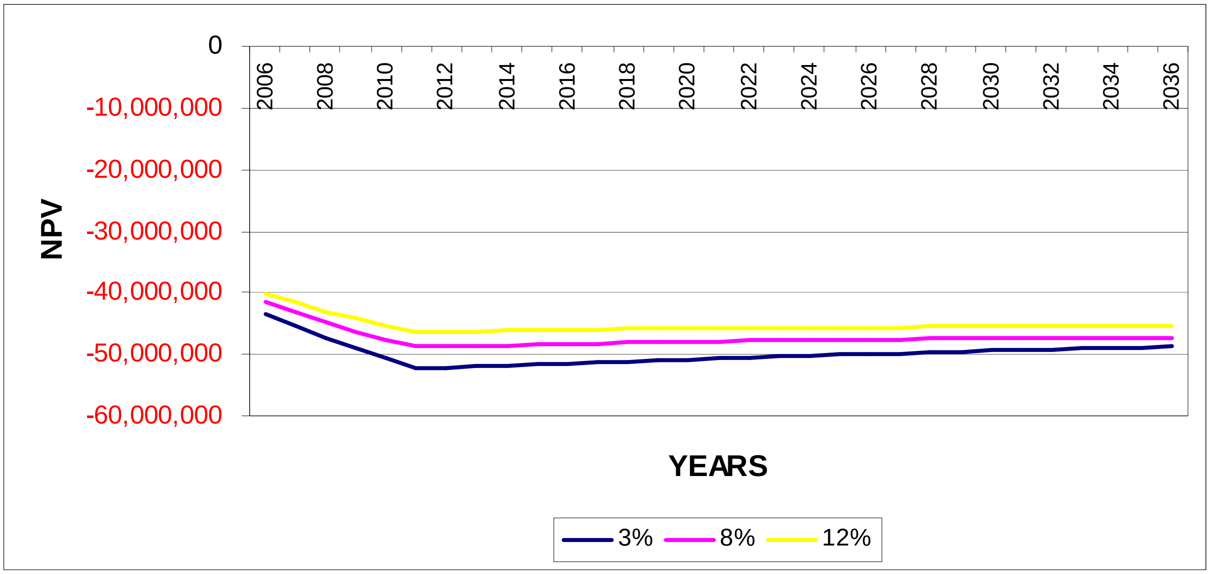

Figure 6: Net present value results of the comprehensive restoration option, pessimistic scenario, over 30 years

5.3 MODERATE RESTORATION OPTION

The moderate restoration option differs from the comprehensive restoration option in that it does not include a comprehensive seed mix for restoration and focuses on reseeding a Protea-only seed mix. The results differ from the comprehensive restoration option in that they show a positive NPV under different options, as seen below.

5.3.1 Realistic cost scenario

Under the realistic scenario of the moderate restoration option, a positive NPV of R84 906 ($12 129) is reflected in year 2023 (eighteenth year) using a 3% discount rate only. When using an 8% or 12% discount rate, the realistic cost scenario does not achieve a positive NPV within a thirty-year time frame.

Therefore, the hypothesis has been proved correct over a thirty- or even a seventeen-year time frame, using a 3% discount rate. However, the hypothesis has been proven incorrect when using an 8% or 12% discount rate over a thirty-year time frame. This has been graphically represented in Figure 7.

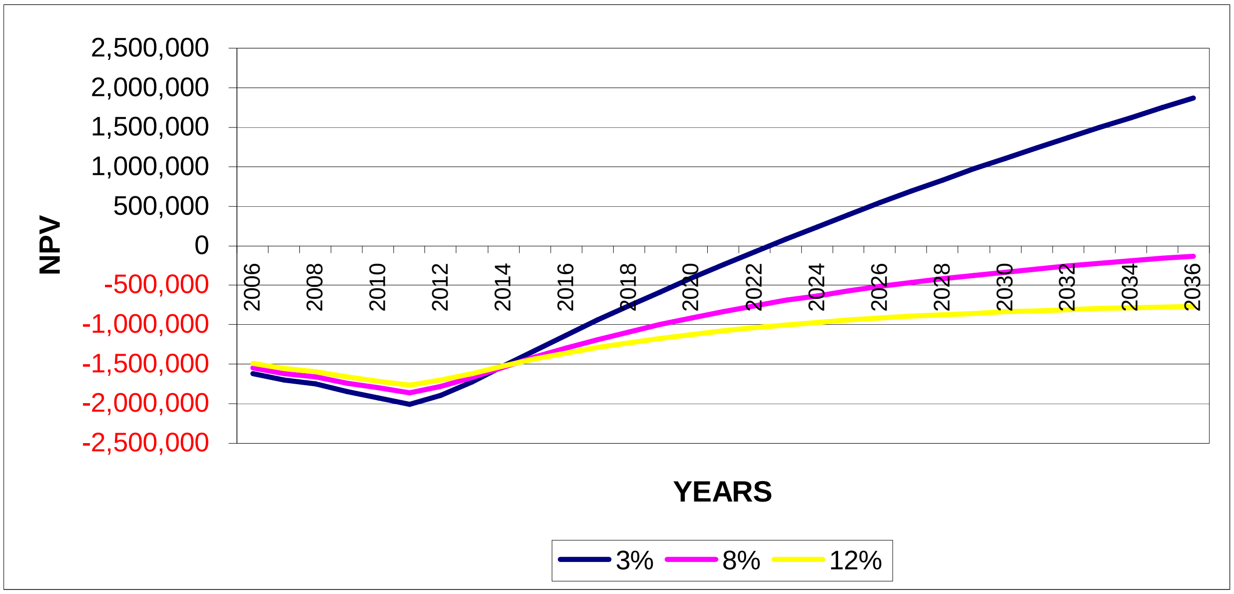

Figure 7: Net present value results of the moderate restoration option, realistic scenario, over 30 years

5.3.2 Optimistic cost scenario

Under the optimistic scenario of the moderate restoration option, a 3% discount rate shows a positive NPV of R47 851 ($6 836) in year 2018 (twelfth year). An 8% discount rate shows a positive NPV of R8 243 ($1 178) in year 2029 (twenty-third year). When using a 12% discount rate, a positive NPV is not achieved within a thirty-year time frame.

Therefore, the hypothesis has been proven correct over a thirty-, a twenty- and even a fifteen-year time line when using a 3% discount rate. The hypothesis is also correct over a thirty-year time frame when using an 8% discount rate. However, when using a 12% discount rate, a positive NPV is not reached within a thirty-year time frame, proving the hypothesis incorrect. This is graphically represented in Figure 8.

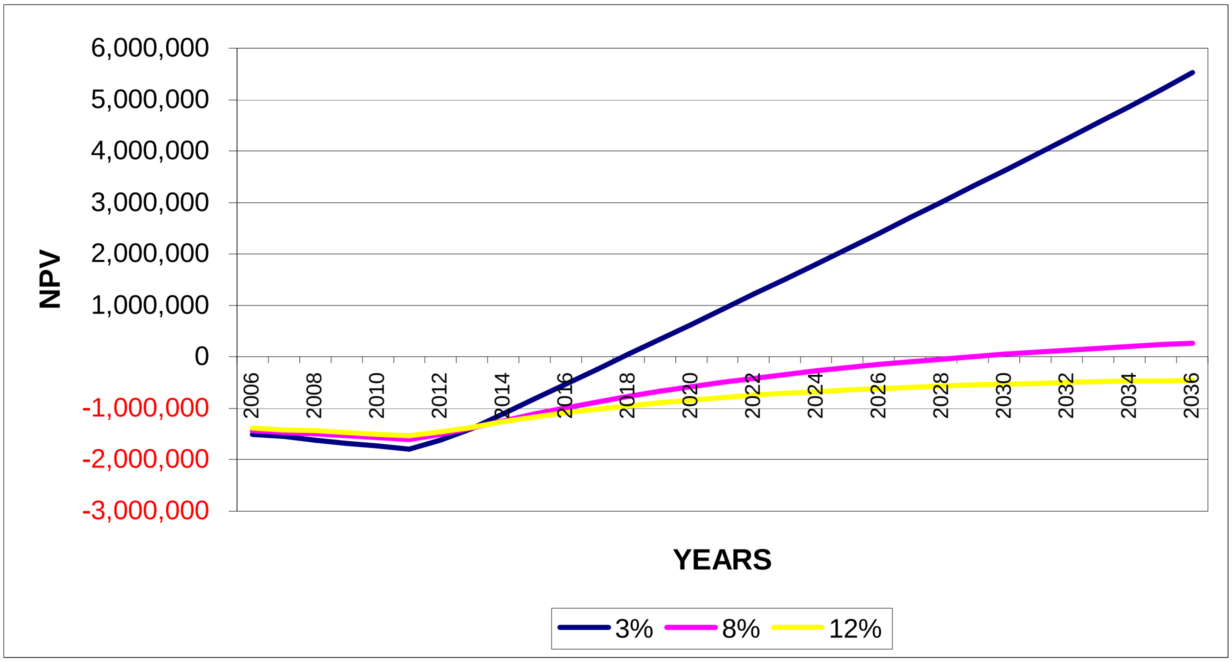

Figure 8: Net present value results of the moderate restoration option optimistic scenario, over 30 years

5.3.3 Pessimistic cost scenario

Under the pessimistic scenario of the moderate restoration option, a 3% discount rate shows a positive NPV of R37 728 ($5 389) in year 2026 (twentieth year). However, when using an 8% or 12% discount rate, a positive NPV is not achieved within a thirty-year time frame.

Therefore, the hypothesis has been proven correct over a twenty- and a thirty-year time horizon when using a 3% discount rate, yet incorrect over a ten- or a fifteen-year time horizon, using the same discount rate. It has also been shown that the hypothesis is incorrect over a thirty-year time horizon when using an 8% and a 12% discount rate. This is illustrated in Figure 9.

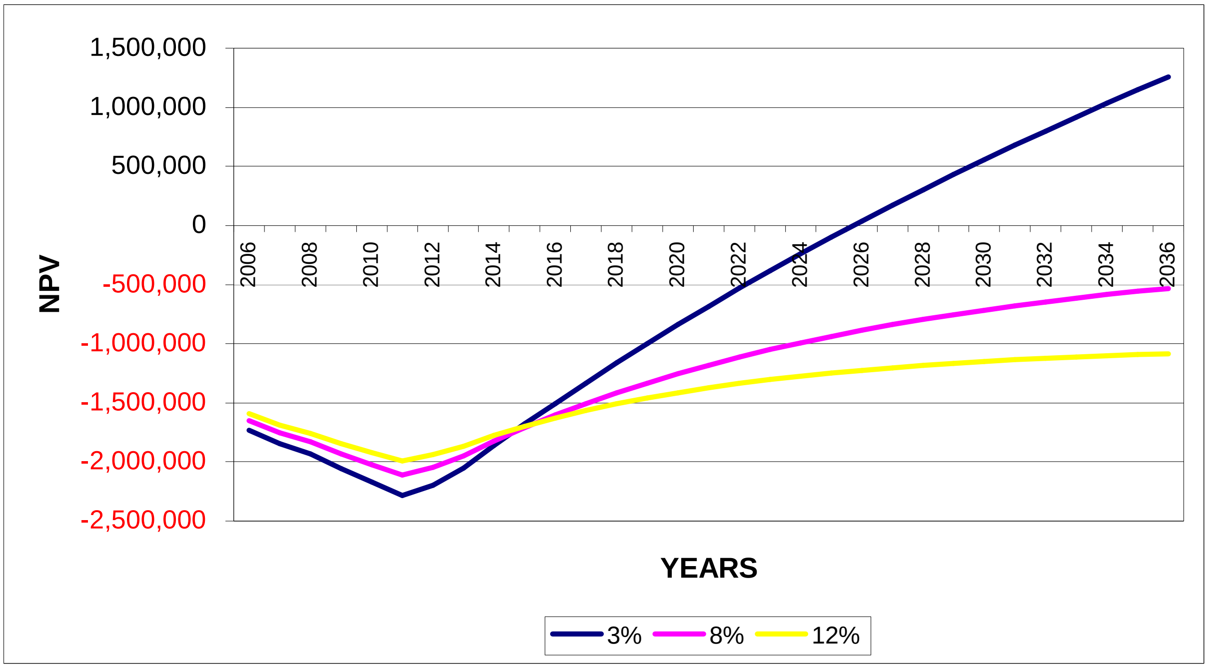

Figure 9: Net present value results of the moderate restoration option, pessimistic scenario, over 30 years

5.4 BASIC RESTORATION OPTION

The basic restoration option differs from the comprehensive and moderate restoration options in that it does not have a reseeding component at all, concentrating only on the general management costs, alien invasive plant removal and erosion control. The results from the basic restoration option show positive NPVs far earlier than the comprehensive and moderate restoration options. This can be seen in the following results.

5.4.1 Realistic cost scenario

Under the realistic scenario of the basic restoration option, a positive NPV of R16 040 ($2 291) is reached in year 2014 (eighth year) when using a 3% discount rate; R26 403 ($3 771) in year 2015 (ninth year) using an 8% discount rate; and, lastly, R9 408 ($1 344) in 2016 (tenth year) using a 12% discount rate.

The first portion of the hypothesis has been proven correct as the water-yield increment and tourism benefit from the Assegaaibos catchment area outweigh the cost of the basic restoration option over ten-, fifteen-, twenty- and thirty-year time lines for all three discount rates. This is graphically represented in Figure 10. However, this result does not include the ecological aspect. The author does not believe that the basic restoration option fulfils the second half of the hypothesis, which requires restoring the catchment to a condition similar in structure, function and composition to that of an undisturbed site. This is discussed in Chapter 6.

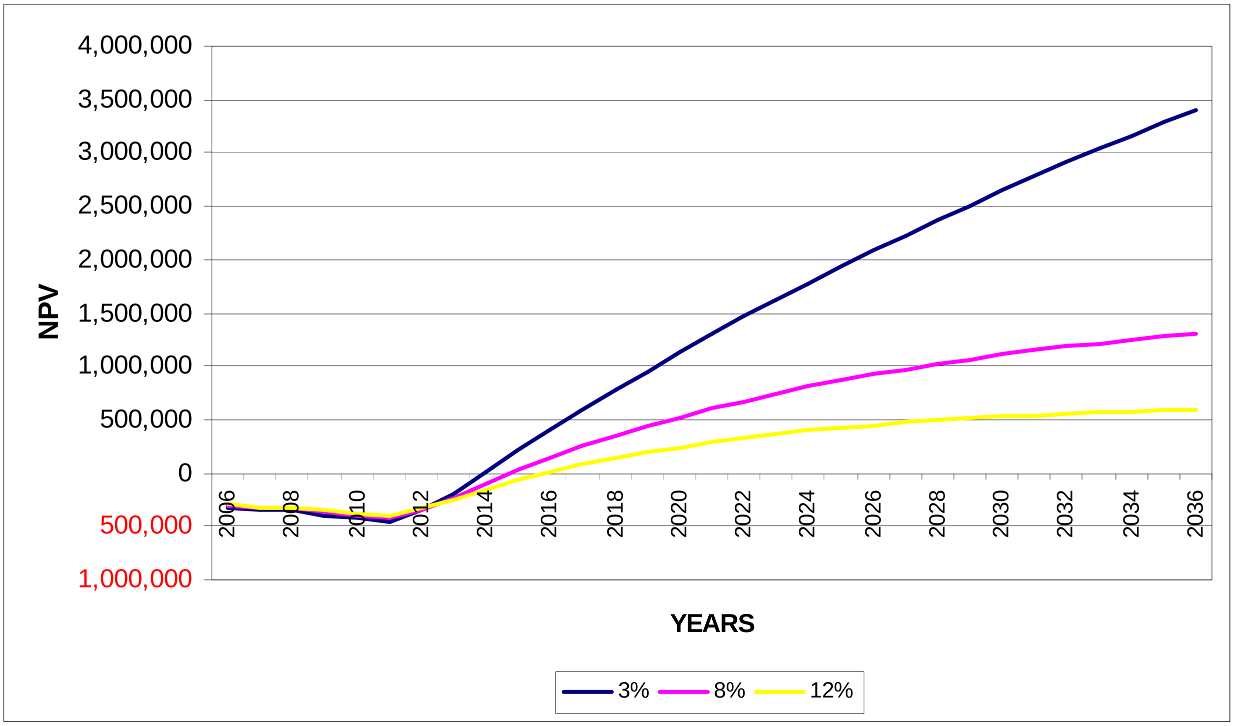

Figure 10: Net present value results of the basic restoration option, realistic scenario, over 30 years

5.4.2 Optimistic cost scenario

Under the optimistic scenario of the basic restoration option, a positive net present value of R60 013 ($8 573) is reached in year 2013 (seventh year) when using a 3% discount rate and R119 922 ($17 131) and R34 989 ($4 998) in year 2014, using an 8% and 12% discount rate respectively.

As in the realistic scenario of the basic restoration option, the hypothesis has only partially been proven correct for the ten-, fifteen-, twenty- and thirty-year time frames, using 3%, 8% and 12% discount rates. The above results are graphically depicted in

Figure 11 below. However, the author does not believe that the basic restoration option fulfils the second half of the hypothesis which requires restoring the catchment to a condition similar in structure, function and composition to that of an undisturbed site.

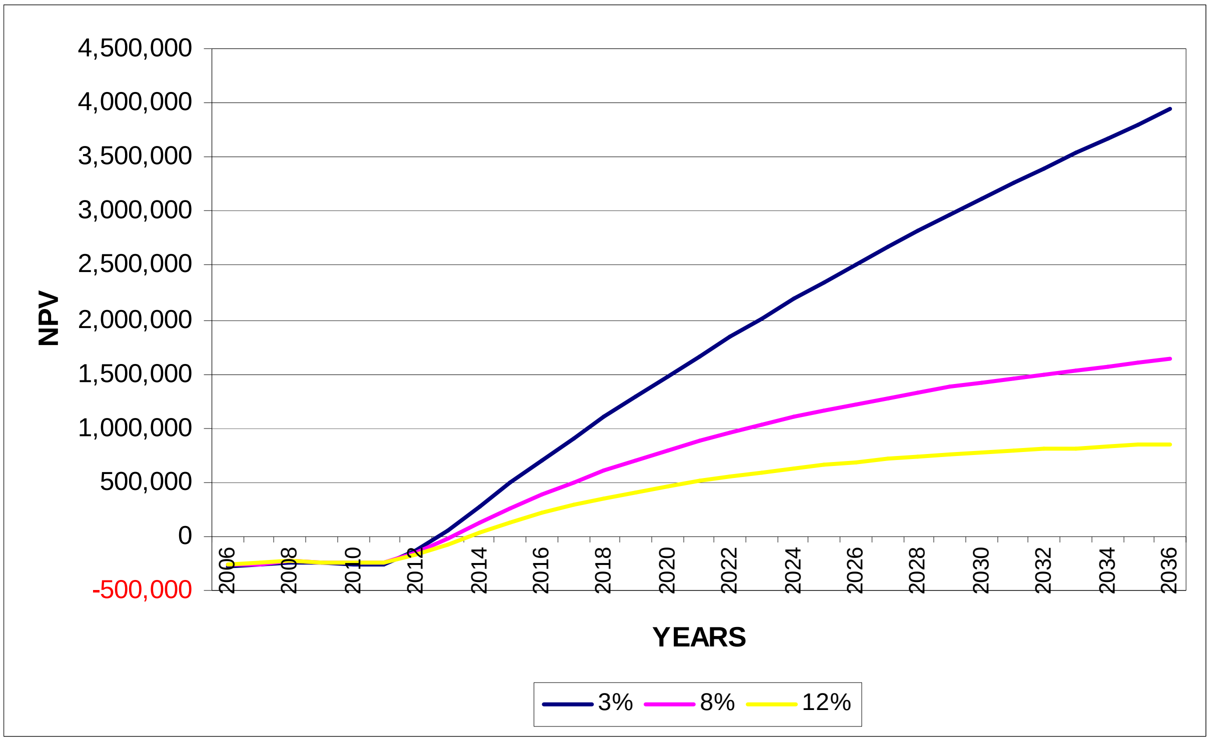

Figure 11: Net present value results of the basic restoration option, optimistic scenario, over 30 years

5.4.3 Pessimistic cost scenario

Under the pessimistic scenario of the basic restoration option, a positive net present value of R112 089 ($16 012) is achieved in 2016 (tenth year) when using a 3% discount rate. This is followed by positive net present values of R2 893 ($413) in 2017 (eleventh year), using an 8% discount rate and R24 233 ($3 462) in 2020 (fourteenth year), using a 12% discount rate.

Yet again, the results have proved the hypothesis only partially correct for ten-, fifteen-, twenty- and thirty-year time frames when using a 3% discount rate. When using an 8% discount rate, the hypothesis is partially correct for fifteen-, twenty- and thirty-year time frames, but incorrect if assessed using a ten-year time frame. When using a 12% discount rate, the hypothesis has been proven partially correct when assessed using the fifteen-, twenty- and thirty-year time frames, but incorrect when using a ten-year time frame. These results can be seen in Figure 12.

Once again, the author does not believe that the basic restoration option fulfils the second half of the hypothesis, which requires restoration of the catchment to a condition similar in structure, function and composition to that of an undisturbed site. This is irrespective of the scenarios and is discussed in Chapter 6.

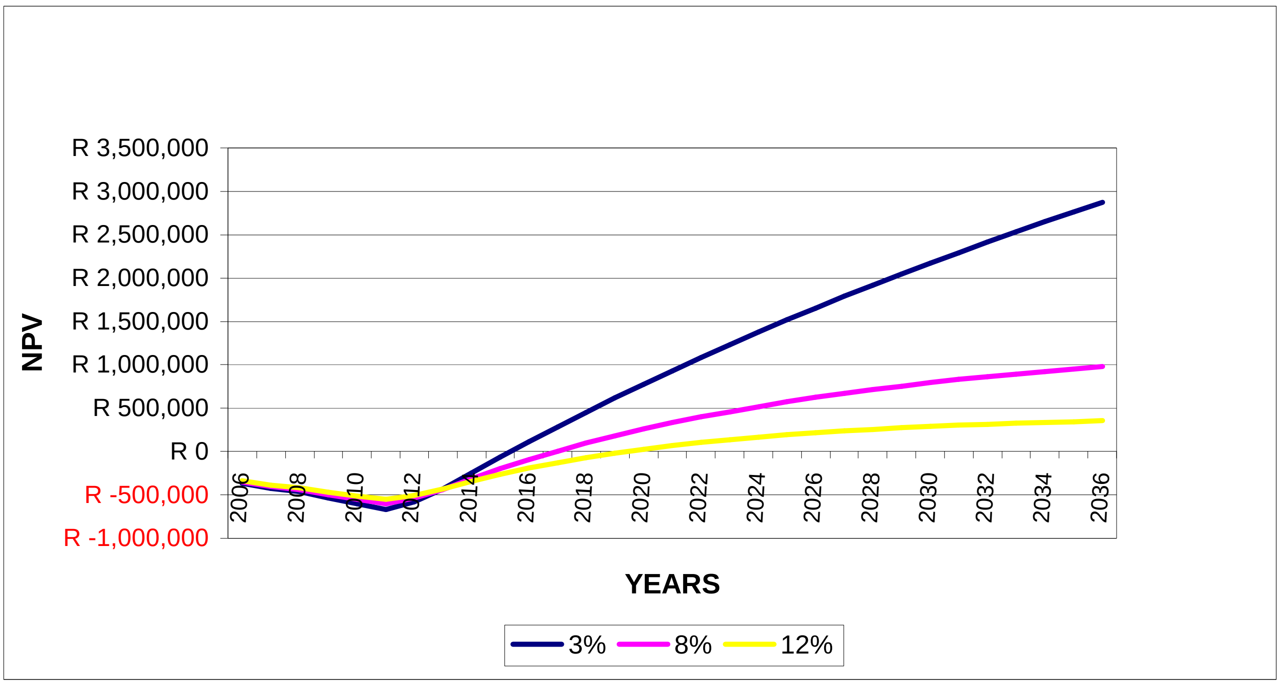

Figure 12: Net present value results of the basic restoration option, pessimistic scenario, over 30 years

5.5 SUMMARY OF RESULTS

The NPVs at ten-, fifteen-, twenty- and thirty-year time horizons have been set out in Table 5. As can be seen in this table, all negative NPVs are in red.

5.5.1 Scenario options

As previously explained, each option has various scenarios. These are described below:

- the realistic costs and benefits;
- the optimistic costs and benefits (where 5% has been added to the income and 5% deducted from the costs); and
- the pessimistic costs and benefits (where 5% has been deducted from the income and 5% added to the costs).

5.5.2 Description of results

The following is a written description of the results seen in Table 5.

5.5.2.1 Comprehensive restoration option

Irrespective of the scenario, the comprehensive restoration option does not show a positive NPV within a thirty-year time frame.

5.5.2.4 Moderate restoration option

The moderate restoration option only begins to show a positive NPV when using an 8% discount rate over the thirty-year time frame and thereafter a positive NPV can be seen within a fifteen-year time frame, depending on the scenario of the moderate option.

5.5.2.3 Basic restoration option

The basic restoration option only reflects a negative NPV within the first 10 years when a 12% or an 8% discount rate is used in conjunction with the pessimistic scenario. Otherwise, a positive NPV is shown from 15 years onwards, irrespective of the scenario or discount rate.

Table 5: Summary of NPV results for three economic options over periods of 10 to 30 years.

Discount rate	Option	Scenario	10 years	15 years	20 years	30 years
			2016	2021	2026	2036
			NPV	NPV	NPV	NPV
3%	Basic	Optimistic	703,357	1,665,736	2,511,027	3,937,525
3%	Basic	Pessimistic	112,089	932,634	1,654,136	2,875,231
3%	Basic	Realistic	407,723	1,299,185	2,082,582	3,406,378
8%	Basic	Optimistic	377,191	875,167	1,220,205	1,633,492
8%	Basic	Pessimistic	-95,046	329,532	624,033	977,742
8%	Basic	Realistic	141,073	602,349	922,119	1,305,617
12%	Basic	Optimistic	210,747	512,043	686,075	847,818
12%	Basic	Pessimistic	-191,931	64,953	213,493	351,900
12%	Basic	Realistic	9,408	288,498	449,784	599,859
3%	Moderate restoration	Optimistic	-531,566	923,094	2,404,416	5,522,099
3%	Moderate restoration	Pessimistic	-1,504,319	-683,774	37,728	1,258,823
3%	Moderate restoration	Realistic	-1,131,714	-240,251	543,145	1,866,942
8%	Moderate restoration	Optimistic	-989,673	-491,697	-146,659	266,628
8%	Moderate restoration	Pessimistic	-1,605,790	-1,181,213	-886,711	-533,002
8%	Moderate restoration	Realistic	-1,297,731	-836,455	-516,685	-133,187
12%	Moderate restoration	Optimistic	-1,089,524	-788,228	-614,196	-452,453
12%	Moderate restoration	Pessimistic	-1,629,072	-1,372,188	-1,223,649	-1,085,242
12%	Moderate restoration	Realistic	-1,359,298	-1,080,208	-918,922	-768,848
3%	Comprehensive restoration	Optimistic	-45,985,028	-45,022,649	-44,177,358	-42,750,860
3%	Comprehensive restoration	Pessimistic	-51,490,863	-50,670,318	-49,948,816	-48,727,721
3%	Comprehensive restoration	Realistic	-48,737,946	-47,846,483	-47,063,087	-45,739,290
8%	Comprehensive restoration	Optimistic	-43,224,347	-42,726,372	-42,381,333	-41,968,047
8%	Comprehensive restoration	Pessimistic	-48,286,220	-47,861,642	-47,567,141	-47,213,432
8%	Comprehensive restoration	Realistic	-45,755,284	-45,294,007	-44,974,237	-44,590,740
12%	Comprehensive restoration	Optimistic	-41,243,892	-40,942,597	-40,768,564	-40,606,822
12%	Comprehensive restoration	Pessimistic	-46,010,216	-45,753,332	-45,604,793	-45,466,386
12%	Comprehensive restoration	Realistic	-43,627,054	-43,347,964	-43,186,679	-43,036,604

CHAPTER 6: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

6.1 INTRODUCTION

This chapter discusses the calculated results from Chapter 5 in relation to the different options, discount rates and ranking of decision. A conclusion will be drawn and then recommendations will be offered.

6.2 DISCUSSION

The Assegaaibos Restoration Project, like any other, has various aspects that need to be considered and incorporated for success. Aspects that have to be borne in mind are of an ecological, an economic and a social nature. The ecologically sound conceptual framework mentioned by Holmes (2001) has a number of key factors which include the processes leading to degradation, recruitment dynamics, community structure, ecosystem function and disturbance regimes.

The primary goal of ecological restoration is to restore the ecosystem to its historic trajectory (Society for Ecological Restoration Science & Policy Working Group, 2002) – to a pre-disturbance condition which is self-regulating and integrated into the relevant ecological landscape (Cairns, 2000). When the desired trajectory has been achieved, restoration is considered complete (Society for Ecological Restoration Science & Policy Working Group, 2002).

However, if achieving a pure pre-disturbance condition is not possible, then the primary objective should be to achieve as close an approximation to such a condition as is possible (Cairns, 2000). The focus is on ecosystem function, which is related to the preservation of biodiversity. Naeem et al*.* (1999) stated that as the number of species in a community decreases, so does the functioning of the ecosystem. Furthermore, biodiversity plays an important role as a buffer, protecting ecosystems from loss of functionally important components.

The economic aspect refers to the financial analysis of the restoration project, which can be undertaken through a variety of tools. In this case study, a cost-benefit analysis was used. The satisfaction of the economic aspect is determined by the goals set out. However, conventional economic value is based on individual utility maximization. Costanza (2001) identifies other goals aimed for as:

- ecological sustainability;
- social equity (which ensures fair distribution of resources and property rights among current and future generations of humans, as well as among species); and
- efficient allocation of resources.

In the case study used in this thesis, only the water and tourism benefits have been taken into consideration. It must be reiterated that this is only a small portion of the total economic value of benefits derived from mountain catchments. Other benefits not included are the indirect-use benefits, future-use values and non-use values.

A further aspect not included in the cost-benefit analysis performed in this thesis, but worthy of mention, is the costs avoided through restoration. Le Maitre et al. (1996) modelled the consequences of uncontrolled invasion on water yield, using a geographic-information system. These researchers (Le Maitre *et al.*, 1996) used the Kogelberg Mountains, which had a cover of 5.4%. The model determined that the alien invasive plant cover would increase to 40% within 50 years and 80% within 100 years, with a corresponding increase in biomass of 150%. This would result in an average loss of more than 30% of the water supply to the GMCCT, the costs of which could be quantified and included in the cost-benefit analysis.

Rees et al. (2007) further highlighted how restoration could reduce flood damage and diminish storm damage to built capital. They pointed out that this could be quantified in monetary terms and could be included as costs avoided through restoration. Other inclusions to be considered are the costs for repairing erosion and the eradication of alien invasive plants which reappear on the site (Rees *et al.*, 2007).

The social aspect refers to the social acceptance of the project, as no major ecological restoration will occur unless the goals and objectives of society are met. Society has to be prepared to support the initiative and to supply sufficient resources with regard to restoration activities for ecologically relevant periods of time – years, decades and even centuries (Cairns, 2000). According to Simenstad, Reed and Ford, (2005), the outcome society expected regarding restoration was the replacement of what had originally been there or, at least, that which was more ‘natural’. Furthermore, society desired restoration to be permanent and degradation reversed (Simenstad, Reed & Ford, 2005). Social acceptance is vital, especially in the political environment in which South Africa finds itself: one which favours the needs of social development above conservation.

6.2.1 Comprehensive restoration option

The comprehensive restoration option has failed the economic aspect of the project. At no point within a thirty-year time frame does it reach a positive net present value under any scenario and at any discount rate. However, it is pertinent to remind the reader at this stage that in no way has this thesis calculated the total economic value, but has focused purely on the direct, easily quantifiable and tangible benefits of water and tourism. Should the total economic value be taken into account, the comprehensive restoration option might show a positive net present value.

According to Holmes and Richardson (1999), the comprehensive restoration option meets the requirements of ecological and social aspects in the quickest time as:

- it removes the cause of transformation, the negative impact of the alien plants;
- it stabilizes the soil-erosion gullies; and
- it restores a comprehensive vegetation community at all functional levels, thus ensuring maximum ecological function.

Furthermore, by restoring a comprehensive range of species (that is, increasing the biodiversity) within each functional guild, the ecosystem becomes less vulnerable to natural and other disturbances in the long term (Holmes & Richardson, 1999).

6.2.2 Moderate restoration option

The moderate restoration option only meets the economic aspects of the project if a 3% discount rate is used or, under the optimistic scenario, when using an 8% discount rate. It does not meet the economic requirements at any point within a thirty-year time frame when a 12% discount rate is used, irrespective of the scenario (optimistic, realistic or pessimistic). The moderate restoration option does, however, meet the ecological requirements: it removes the negative impacts of alien invasive plants and repairs the erosion gullies, as well as replacing the over-storey Protea component which has been lost through extensive forestry activity. This option certainly puts the ecosystem on the right trajectory, taking it to a pre-disturbance condition over time.

6.2.3 Basic restoration option

The basic restoration option meets the economic aspects of the project by producing positive net present values within the thirty-year time frame under all the scenarios and with all the discount rates. Even though the basic restoration option removes the cause of transformation (the first step in restoration), it does not meet the ecological requirements. This is because it leaves the ecosystem without the important over-storey Protea component. These Proteas play a vital role in maintaining patchiness within the fynbos community. They maintain the richness of plant species by inhibiting under-storey species, influencing the under-storey composition and opening up regeneration niches (Vlok & Yeaton, 1999).

It is unlikely that the basic restoration option would even put the ecosystem onto the right restoration trajectory. The extended forestry activity and the frequent, intensive fire regime have rendered soil seed banks redundant and the distances with regard to seed dispersal are very short in fynbos. It is necessary to sow seed on sites where the natural seed bed has been damaged and the transformed site exceeds 50 metres in diameter. Natural re-colonization will not occur at sites exceeding this diameter (Holmes & Richardson, 1999).

To add to this, fynbos species require several fire cycles to pass in order to re-colonize large, degraded areas from neighbouring sources. Community boundaries are no longer controlled by environmental factors and fire, but by roads, farmlands and urban areas. This means that natural colonization is slow, if possible at all, unless corridors remain for migrations (Holmes & Richardson, 1999). In particular, the re-colonization of the over-storey proteoid component is poor, owing to the rocky terrain which leads to clumped distributions. The lack of species diversity, and especially the lack of the over-storey Protea component, causes a loss of ecosystem stability (Naeem *et al.*, 1999). Indeed, Simenstad, Reed and Ford (2005) commented that if one cannot establish the necessary plants and introduce the animal-utilization component, any attempts at restoration would be futile.

6.2.4 Discount rate

Discounting is a significant problem in environmental projects. This is because these projects are intrinsically characterized by many intangible, long-term benefits which are difficult to measure and short-term costs. Consequently, cost-benefit analysis has a bias toward present generations (Department of Environmental Affairs and Tourism, 2004).

When using a high discount rate, the expected benefits are low. By using a low discount rate, some projects which would have not been considered financially viable become acceptable within a far shorter time frame. A low discount rate and a long time horizon result in a focus on the future and are preferred when dealing with biological processes and sustainability issues. On the other hand, a low discount rate means that the viability of a project is set at a relatively low level. Decreasing the discount rate cannot really be considered a solution to the problem. This would merely lower the expected required return of the project, thereby encouraging resource-intensive projects which would otherwise have a negative net present value (Department of Environmental Affairs and Tourism, 2004).

However, Rees et al. (2007) stated that discounting natural capital restoration may not be justified. They continued by justifying negative discounting on the grounds of economic decline, propounding that economic growth was consuming natural capital and not just natural interest. The result of this is a shrinking future economy.

6.2.5 Time horizon

Any time horizon within which the restoration project is economically assessed is of importance as it has to be biologically relevant. For example, there is no point in implementing a restoration project with a lifespan of one year when the plants need five years to establish. Furthermore, a short-term focus in land-use decisions can potentially burden future generations with high costs (Daily *et al.*, 1997). This thesis has evaluated the restoration project over a thirty-year time horizon. Results have shown this to be rather conservative: other studies have used fifty-year (Higgins *et al.*, 1997) and even up to a hundred-year time horizons. For example, when the Working for Water Programme performed a cost-benefit analysis, a time horizon of 100 years was set, using a 10.1% discount rate (Hosking, 2004). It is possible that further scenarios within the moderate restoration option, utilizing the 12% discount rate option, could prove economically acceptable when evaluated on fifty- or even a hundred-year time horizons.

6.2.6 Ranking of decision

Economic ranking is conducted by analyzing the NPVs and prioritizing them according to the highest value. However, economic ranking is not the only aspect which has to be taken into consideration. As Schmookler (1993, cited in Costanza, 2001, p. 463) observed, limiting evaluation and decision making to economic-efficiency goals inhibits democratic decisions and only leaves the “illusion of choice”. The broad range of goals needs to be acknowledged, as well as the technical difficulties involved. A balance between social, ecological and economic goals and objectives must be found for the success of ecological restoration projects. Without social support, a restoration project will not succeed and an economic assessment will influence what restoration is implemented at the site.

With regard to the ecological ranking of projects, this thesis has shown that comprehensive restoration is not always required to achieve the appropriate trajectory. As demonstrated, the moderate restoration option would be more easily able to get the ecosystem onto the required trajectory at a greatly reduced price than the comprehensive restoration option, albeit at a slower rate. However, the situation described in the previous paragraph is only applicable if the economic aspect compromises by using a 3% discount rate or by evaluating the costs and benefits in the light of an optimistic scenario using an 8% discount rate.

It must also be reiterated that this thesis has included only the direct benefits of water and tourism, as mentioned in Section 6.2.1. In some cases, this would be sufficient to justify expenditure. However, as shown in this case study, the direct, easily calculated values do not always justify the cost. Should more intangible values be included, such as indirect-use and future-use values, it is likely that even the comprehensive restoration option costs would be justified. Blignaut and De Wit (2004) stated that if only the use values were assessed, the resources would be grossly underestimated, although this would provide a lower bound-value estimate of the resources.

Turpie (2004) highlighted how most studies concentrated on estimates of costs and benefits without developing decision models or theoretical analyses. In this thesis, a framework for decision making outlines the scenarios under which restoration after alien invasive plant clearing is necessary and economically viable. Holmes and Richardson (1999) provided a flow diagram (Figure 13) showing the degree of vegetation degradation and the minimum restoration required to achieve a functional and diverse fynbos community. The flow diagram is supported by a set of protocols (Holmes & Richardson, 1999, p. 224), namely:

1. *"Assess extent of transformation.*
2. *Remove or ameliorate cause of transformation.*
3. *Identify missing guilds (regeneration, growth form, nutrient acquisition).*
4. *Create suitable recruitment environment (bare ground, germination cues, soil biota).*

5. *Reintroduce missing guilds.*
6. *Monitor recruitment success in relation to aims; identify failed guilds and reintroduce after next fire.*
7. *Maintain ecosystem processes, e.g. fire."*

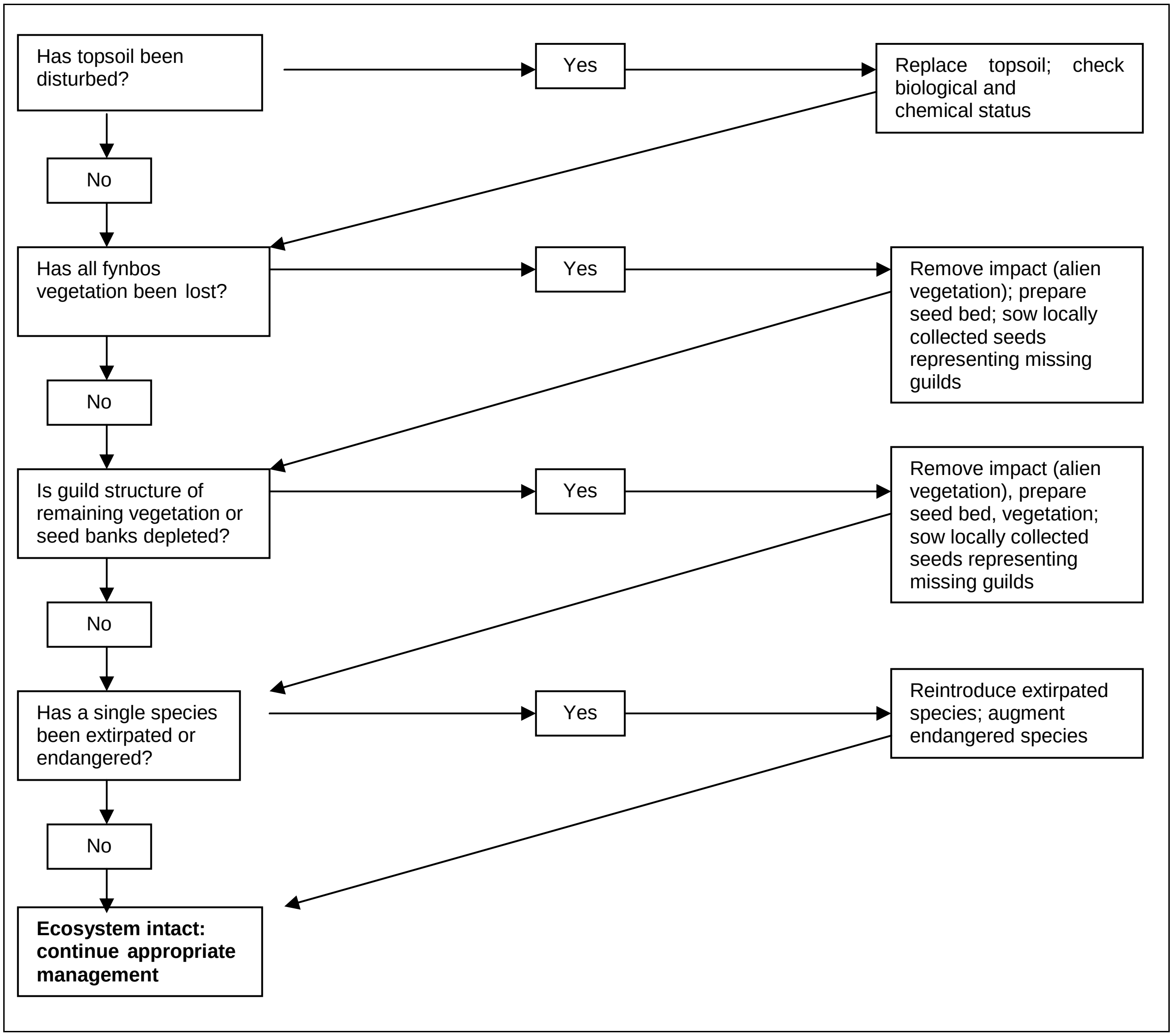

Figure 13: Flow diagram of restoration (Holmes & Richardson, 1999, p. 224)

Holmes and Richardson’s (1999) flow diagram, however, does not include the social and economic aspects of a restoration project and, in reality, without social awareness and support over ecological time frames, restoration projects will not be successful. The author has taken the flow diagram from Holmes and Richardson (1999) and adapted it to include social and economic aspects, as may be seen in Figure 14.

The original Holmes and Richardson flow diagram only considers the ecological aspects of a restoration project. The author’s adapted version takes into consideration the social acceptance and support required for restoration by placing a social arena (shown in yellow) within the flow diagram. This social arena shows that without social acceptance and support, the site will remain degraded. Furthermore, the author’s adapted version considers the economic feasibility of the restoration actions by including an economic arena (shown in blue), illustrating the fact that the ecological and economic aspects together determine the required actions to be taken. This will dictate whether or not the ecosystem will be restored or set on an alternative trajectory.

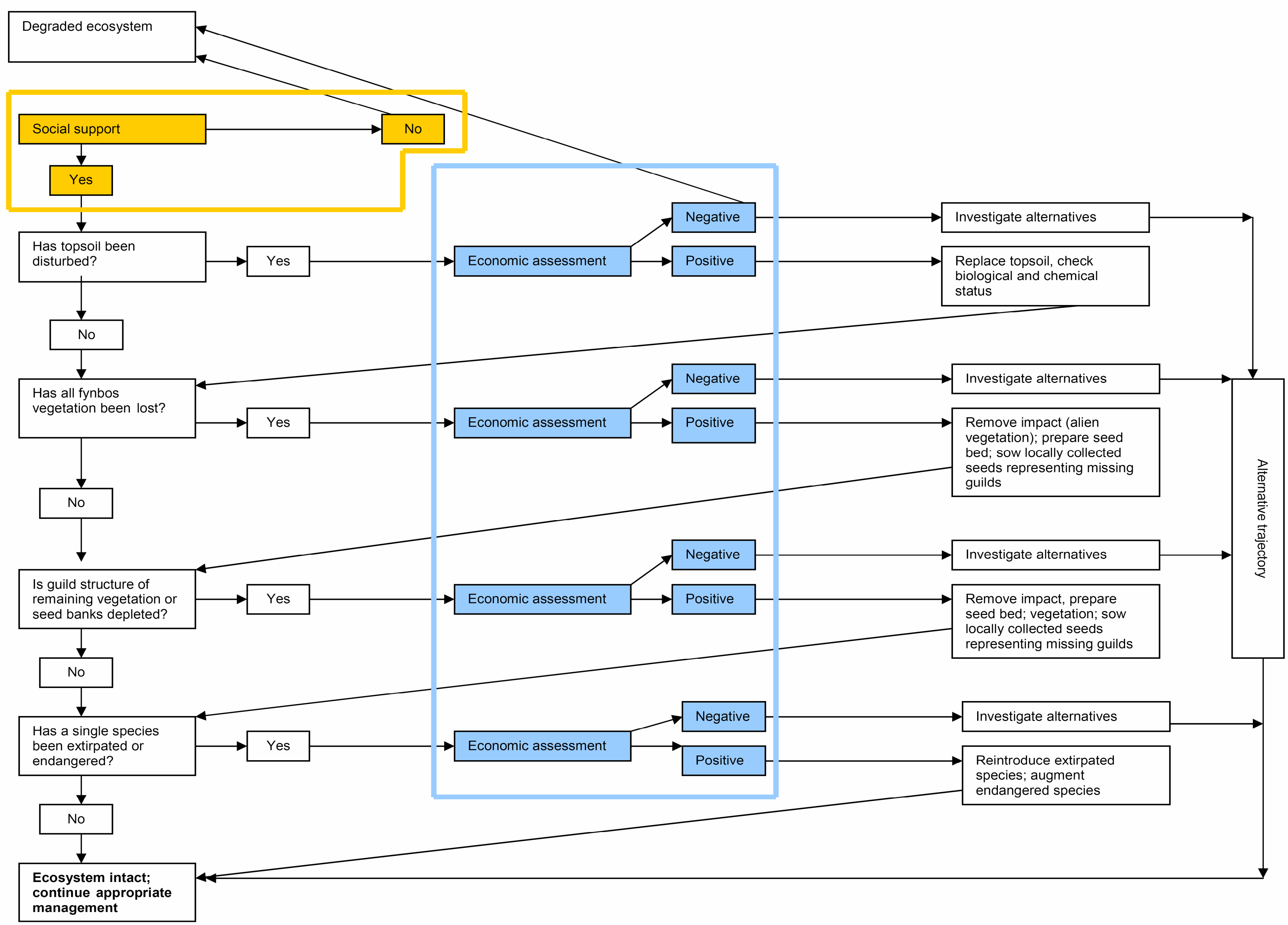

Figure 14: Social, economic and ecological flow diagram of restoration (Adapted from Holmes and Richardson,1999)

6.3 CONCLUSION

Rees et al. (2007) pointed out that without natural capital, production is not possible. Therefore, natural capital is an important means and end in economics. With the merging of the two disciplines of ecology and economics, a value can now be placed on the natural resources and ecosystem services which sustain life. In order to make sensible socio-political decisions, environmental consequences must be taken into account (Bräuer, 2003). Placing a monetary value on environmental goods and services provides a useful method of integrating environmental goods into the political decision-making process. In fact, decision makers request monetary valuations as part of their deliberations (Rees *et al.*, 2007).

It must be remembered, however, that resource economics is an emerging field in science and cost-benefit analysis has become an accepted method in the justification of conservation-orientated projects, such as the Working for Water Programme in South Africa. It is important to recognize the limitations of the cost-benefit analysis method, especially the application of the correct discount rate and time horizon. The results are based on a number of assumptions made in the analysis: for example, which values, intangible (such as the aesthetics value) or tangible (such as income derived from permit sales), have been included or excluded? An example of this would be the inclusion or exclusion of costs, such as flood damage, avoided through restoration.

Furthermore, Rees et al. (2007) commented that all the benefits the restoration of natural resources delivered were not yet known – the “cognition problem” (p. 230). Many of them are public goods ignored by markets or difficult to quantify; some are disregarded because of ignorance. Many benefits are thus basically “invisible” (p. 230) until their absence draws attention to the resulting lack of function. This is termed “functional transparency” (Rees *et al.*, 2007, p. 230).

Despite the criticisms of cost-benefit analysis, it remains one of the economic tools used to value natural resources as objectively and realistically as possible. It can promote the acceptance of conservation programmes by showing their benefits in a directly understandable way (Bräuer, 2003). This is especially pertinent in developing countries, where immediate economic growth and social issues take precedence over conservation (Van Wilgen *et al.*, 1998).

Cost-benefit analysis should be used as a decision aid only: it cannot offer a final verdict. As Rees et al. (2007) stated, restoration and conservation decisions have to be based on more than just monetary value. A balance between social, ecological and economic goals and objectives must be found if an ecological restoration project is to succeed. The broad range of goals has to be acknowledged, as do the technical challenges facing cost-benefit analysis of restoration projects.

In conclusion, it is pertinent to refer to the primary hypothesis stated in the cost-benefit analysis case study (Section 4.2 in Chapter 4). The hypothesis states that the water yield and increment of tourism benefit from the Assegaaibos mountain catchment area outweighs the costs of restoring the catchment to a condition similar in structure, function and composition to that of an undisturbed site.

Despite the high costs of restoration, the basic restoration option costs were out-weighed by the water and tourism benefits derived. This was also true of the moderate restoration option, when evaluated under the optimistic scenario and using an 8% discount rate, or a 3% discount rate under any scenario. However, this was not the case in the moderate restoration option when using an 8% discount rate in conjunction with the realistic and pessimistic scenarios. Neither was it the case when using a 12% discount rate, irrespective of the scenario.

Furthermore, under no scenario (optimistic, realistic or pessimistic) was the cost of a comprehensive restoration option outweighed by the benefits, irrespective of the discount rate used. However, had the total economic value been taken into consideration and/or a longer time horizon used, the outcome would have been different.

A further question, posed as a sub-problem, is whether or not restoration would still be considered economically viable if such restoration required alien invasive plant clearing and then, more importantly, further restoration action in the form of reseeding. Because costs of restoration sometimes far outweigh the costs of alien invasive plant removal, these costs should not be underestimated or ignored should reseeding be required. An extreme example of this is offered when the realistic scenario is applied to the Assegaaibos case study. The total costs of alien invasive plant removal were R1 359 142.91 ($194 163.27). The total costs of reseeding Assegaaibos with a comprehensive seed mix (excluding other actions, such as gully-erosion repair) amounted to R42 211 444.58 ($6 030 206.36). Thus, the costs of restoration can far outweigh the costs of alien clearing alone or, indeed, the water benefits derived from the mountain catchment.

However, the answer in terms of the calculations is that further restoration, in addition to the mere clearing of alien invasive plants, would be economically viable under certain scenarios. According to the Society of Ecological Restoration Science & Policy Working Group (2004), once the ecosystem is on the desired trajectory, further assistance to ensure its future health and integrity is not required and restoration has been achieved. The comprehensive restoration option as described in this thesis is not necessary, as the moderate restoration option will place the ecosystem on the desired trajectory. Nevertheless, it must be stated that comprehensive reseeding will promote long-term resilience of the ecosystem to disturbance and, therefore, reintroducing as many species as possible within each functional guild is most desirable (Holmes & Richardson, 1999).

6.4 RECOMMENDATIONS

Apart from the significant impact of long-term afforestation of *Pinus* species, Assegaaibos can be considered a relatively unimpacted mountain catchment, worthy of restoration. It is the source of the all-important Berg River which is a path for the transfer of water from the Theewaterskloof Dam and various other sites as part of the Riversonderend (RSE) tunnel system. Its importance as a vital element in the water-supply infrastructure in the Western Cape has also recently been increased by the R490 million ($70 million) investment in the construction of the Berg River Dam, (Department of Water Affairs and Forestry, South Africa, 1996a) located downstream of the Assegaaibos mountain catchment. The dam is designed to augment the existing water supply in the province. This water supply supports a variety of crops grown in the Western Cape, as well as supplying the industrial and domestic sectors of the Greater Cape Town Metropolitan area. Furthermore, the Berg River is an important recreational resource to the communities living along the river and surrounding areas.

This thesis outlines the variety of ways in which the long-term forestry activity of the past eighty years has significantly impacted the Assegaaibos mountain catchment. The most threatening is the loss of biodiversity and, in particular, the loss of the Proteoid over-storey component. The loss of this functional group decreases the ecosystems stability, making it more vulnerable. This threatens to reduce the value of the natural resources derived from the catchment.

The removal of the forestry impact is the first step in restoring the Assegaaibos mountain catchment. However, the removal of alien invasive plants from the catchment will not in itself restore the catchment. It does not address the re-establishment of seed beds destroyed by the extended forestry activity and the frequent and intensive fire regime. Nor does it address the existing erosion issues. Failure to restore an area properly can potentially lead to further soil erosion, declining water quality and reinvasion by alien invasive plant species (Vlok & Yeaton, 1999). Furthermore, underspending increases the problem exponentially and raises future costs considerably (Turpie, 2004).

Admittedly, restoration can be a costly exercise. This thesis illustrates the fact that reseeding a comprehensive seed mix is much more expensive than merely clearing the alien invasive plantation. Even though comprehensive reseeding of Assegaaibos is most desirable ecologically, it has been proved that this is not economically viable. However, the restoration requirement at Assegaaibos must include a reseeding component. When economic assessment shows that a project, or an aspect of a project, is not economically feasible, other alternatives should be considered. For example, comprehensive reseeding is not necessary at Assegaaibos, as only one functional group is missing. Therefore, just reseeding the missing functional group (which would cost far less than a comprehensive seed mix) will set the ecosystem on the correct trajectory. In this way, the project can be shown to be economically viable.

A further alternative, not explored in this thesis but worthy of consideration, is to sow a seed mix (comprehensive or Protea only) at a substantially reduced rate (20%, for example), aimed at establishing source populations only for further natural colonization. This would hopefully still meet the ecological requirements and substantially reduce the cost of reseeding, the most expensive operation in the restoration project. Compromises need to be made to meet the ecological, economic and social requirements. With regard to Assegaaibos, the reseeding component offers a situation where compromise can be made, meeting both ecological and economic goals.

As important as the ecological aspect is to a restoration project, economics is just as important. The valuation and attachment of a monetary value to natural resources is the only hope of proper management: "… looking at fynbos in financial terms holds the only promise for the long term conservation of this unique natural asset" (Cowling & Richardson, 1995, p. 130). Money offers the means of placing a value on natural resources and cost-benefit analysis is a useful method of determining the economic viability of a restoration project.

Until such time as further economic methods are found, the present use of cost-benefit analysis is of value. However, some of the criticisms of cost-benefit analysis are well-founded and, owing to the lack of scientific knowledge, many ecosystem functions are undervalued. Economists need to use the precautionary principle – activities which may negatively impact on the environment should not be performed until uncertainty has been resolved. Together with this principle, the save-minimum-standard approach should be adopted. The latter lays out the minimum desirable levels of environmental goods required for ecosystem function: decisions based on cost-benefit analysis will only be accepted if within these minimum levels (Bräuer, 2003).

The economics can also be examined in order to compromise. Sometimes, merely examining direct costs can offer economic justification for a project. It might not always be necessary to undertake a total-benefits analysis, which is costly in both money and time. Often, the indirect costs are most criticized for being inaccurate or biased and are considered subjective. The direct market costs are objective and, in certain scenarios, are sufficient to prove justification. However, should this not be the case, then the indirect costs should be considered and included.

Apart from the determination of input variables, two other very important areas of economic compromise are the discount rate and time horizons. The appropriate discount rate to be used is a contentious issue and not the focus of this thesis. Nonetheless, the results observed in this thesis offer support to Turpie (2004), who considered a 3% discount rate was more appropriate for social projects. This being said, the author also recognizes that decreasing the discount rate is not the solution to the discount-rate issue – it merely lowers the expected required return of projects and allows resource-intensive projects which would have shown a negative net present value. With regard to the time frames of evaluation, it would appear that a thirty-year time horizon is not long enough when performing economic evaluations of restoration projects in fynbos ecosystems. The time horizon has to be biologically relevant. Fifty-, or even one-hundred-year time lines, as used by Higgins et al*.* (1997) and the Working for Water Programme, would be more appropriate.

On a greater scale, the author agreed with Costanza (2001), who stated that economic policy had to focus on increasing the productivity of natural capital, rather than on the productivity of human-made capital. The proper valuation and pricing of the natural resources (for example, water) also have to be evaluated. This said, Daily et al. (2000) commented that the most crucial decisions were those where benefits greatly outweighed costs or vice versa. These researchers continued by observing that, in such cases, complete accuracy was not necessary and establishing rough, conservative value estimates for natural-water purification services was adequate. For example, authorities globally are coming to the conclusion that the protection or restoration of natural services was often economically preferable to the construction costs of alternative water filtration plants.

Elliman and Berry (2007) offer another example. In the late 1980s, the City of New York had to make a decision regarding the security of the future natural health of the Catskill-River watershed (this supplies 90% of the city's daily water) and the Delaware-River watershed. The city had to decide whether to devise a watershed protection plan to safeguard the quality of water supplied, at a cost of $1 billion or whether to build a filtration plant to remove impurities in the water at an initial cost of between $6 and $10 billion, with a further $300 million annual maintenance cost. The city of New York opted for the watershed protect plan, which has sustained and (arguably) improved the quality of the water supply.

In conclusion, it must be remembered that money can assist in economic analysis of natural resources, but does not provide information regarding environmental impacts or quality. This information is vital for risk assessments and management planning (Bräuer, 2003). Indeed, the actual cost-benefit analysis is but one part of the decision-making process: the social outcomes of the decision must also be taken into account to ensure fair and equitable distribution of natural resources. Costanza (2001) highlighted the goals of ecological sustainability, distributional fairness and efficient allocation of resources and stated these had to be integrated by value formation through public discussion.

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PERSONAL COMMUNICATIONS

NAME	COMPANY	POSITION	TOPIC	DATE
Fourie, K.	Stellenbosch Municipality	Water Engineer	The bulk water supply cost paid by the Stellenbosch Municipality	26 January 2007
Gerricke, B.	Mountain to Ocean	Forester	The history and general information of the La Motte Forestry Plantation	7 June 2006
Howard, G.	Berg River Baseline Monitoring Programme	Hydrologist	The volume of water passing the G1H004 gauging weir	5 April 2006
Lloyd, P.	Jonkershoek Nature Reserve, Scientific Services	Specialist scientist (Mammologist)	Map of fauna found in the Assegaaibos mountain catchment	6 June 2007
Milton, S.	Stellenbosch Percy Fitzpatrick Institute	Professor	The best comprehensive species mix to obtain Protea species list	8 December 2006
Paulsen, M.	Working for Water	Implementation Manager	Alien invasive plant removal in the Assegaaibos mountain catchment	5 July 2006
Rossouw, N.	TCTA	Environmental Manager (Berg River Project)	The cost of the alien invasive plant removal programme in the Assegaaibos mountain catchment	18 July 2006
Shone, P.	Cape Nature	Reserve Manager	General information and history of the Assegaaibos mountain catchment	5 July 2006

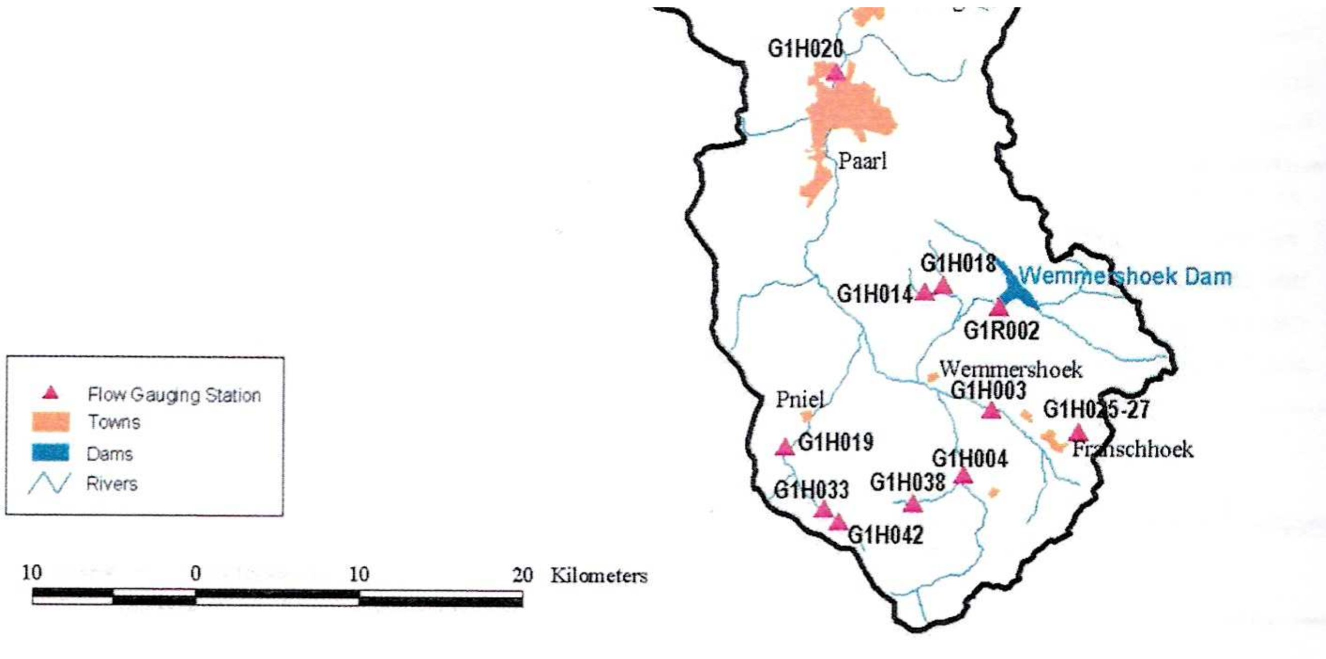
NAME	COMPANY	POSITION	TOPIC	DATE
Shone, P.	Cape Nature	Reserve Manager	General area management costs for Jonkershoek Nature Reserve	8 June 2007
Van Eeden, D.	Vula Environmental Services	Director	The costs of reseeding and gully erosion in the Assegaaibos mountain catchment	8 December 2006

Annexure 1

Satalite image of the Assegaaibos mountain catchment.
(Source: www.google.com 2006)

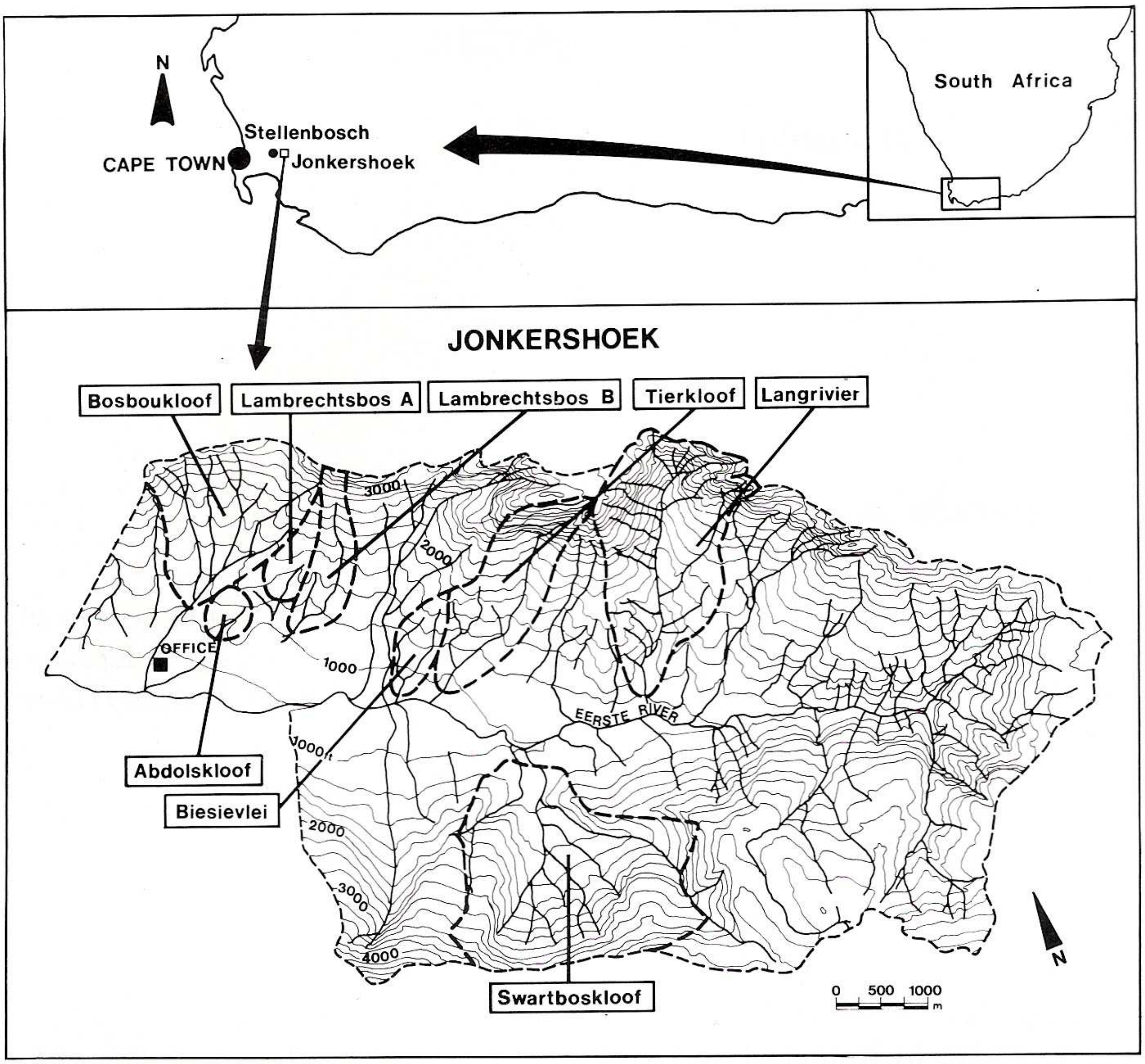
Annexure 2

Map indicating the location of the G1H004 gauging weir.
(Source: Ractliffe, G. and Dallas, H. 2004. Berg River Baseline Monitoring Programme. Initialisation report – volume 1: Introduction to the Berg River Catchment ; Groundwater and riverine environment.)



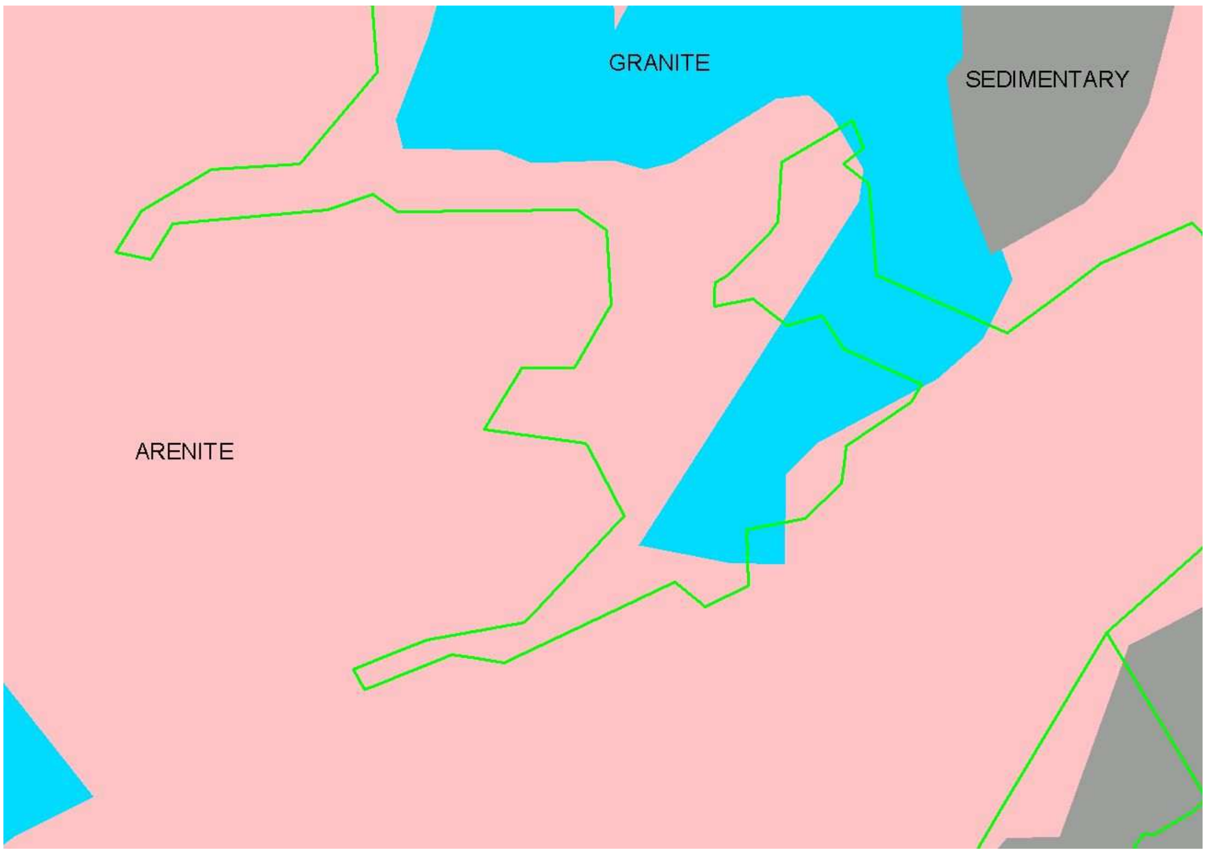
Annexure 3

Map indicating the location of Swartboskloof mountain catchment.
(Source: van Wilgen, B.W., Richardson, D.M., Kruger, F.J., and van Hensbergen, H.J. (Eds). 1992. Fire in South African Mountain Fynbos. Ecosystem, community and species response at Swartboskloof. Springer-Verlag. Germany.)



Annexure 4

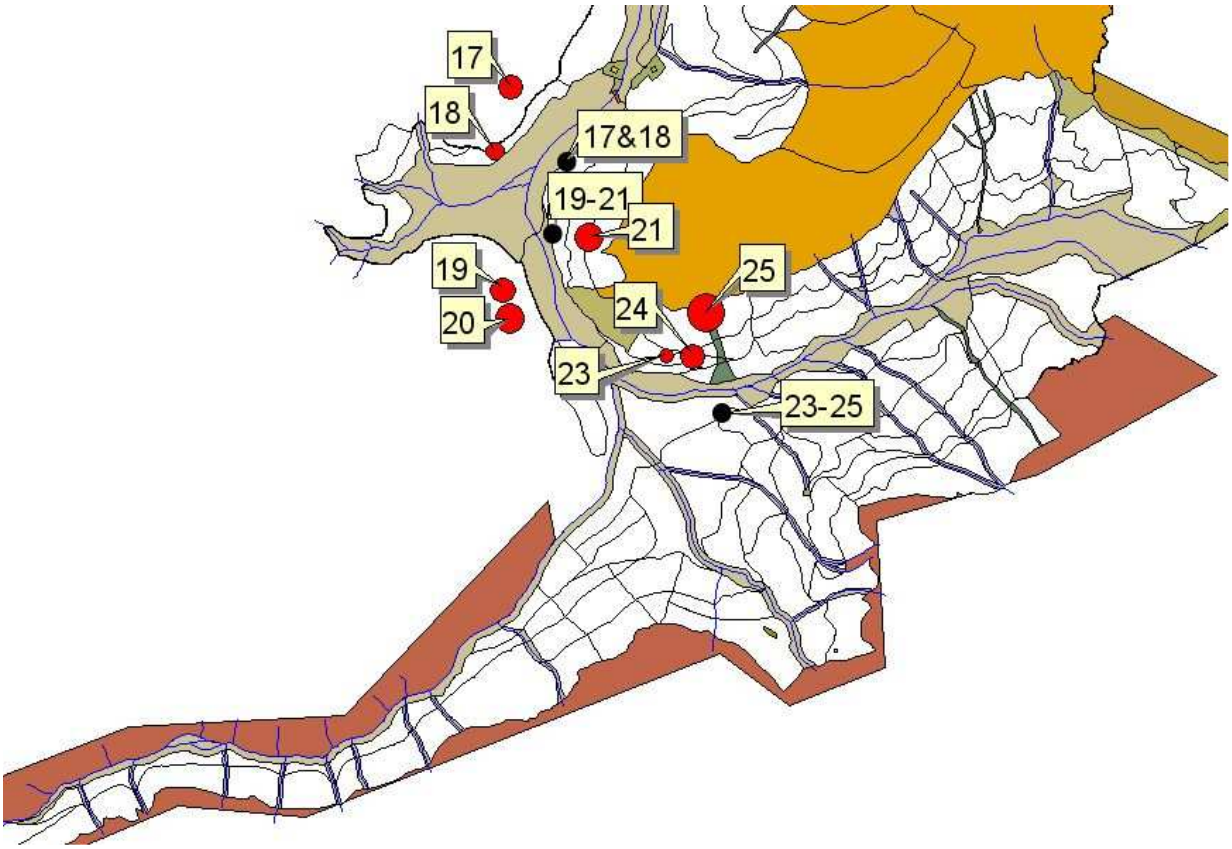
Dominant geology of the Assegaaibos mountain catchment.
(Source: Cape Nature, Patrick Shone, Conservation Manager, Jonkershoek Nature Reserve 2006).



Annexure 5

Soil erosion sites being monitored by Cape Nature in the Assegaaibos mountain catchment.
(Source: Mountain to Ocean (MTO), Barend Gerricke, La Motte Plantation Manager. 2006).

Note: The Red dots are the erosion sites, the black dots are points for fixed photographic reference.



Annexure 6

Erosion gully specifications at Assegaaibos mountain catchment

The data herewith has been sourced from Gerricke (2006) and the erosion gullies found at Assegaaibos are numbered according to the MTO (Mountain to Ocean) system of observation. Their extent, aspect and slope is reflected in the following table. The information was obtained from a GIS system managed by MTO.

Assegaaibos Erosion Site Specs			
Erosion site	**Size (Sqm)**	**Aspect**	**Slope (º)**
17	277	East facing	36 -40
18	93	East facing	
19	120	Soth west facing	36 -40
20	120	South west facing	36 -40
21	800	South west facing	36 -40
23,24,25	13286	South facing	31 -40

Annexure 7

Alien invasive plant species found in Swartboskloof mountain catchment.

(Source: van Wilgen, B.W., Richardson, D.M., Kruger, F.J., and van Hensbergen, H.J. 1992. Fire in South African Mountain Fynbos. Ecosystem community and species response at Swartboskloof. Springer – Verlag. Germany)

Acacia longifolia
Hakea sericea
Pinus halepensis
Pinus pinaster
Pinus raidata
Pittosporum undulatum
Pasiflora
Conyza bonariensis
Hypochoeris radicata
Briza maxima

Annexure 8

Faunal list giving the species recorded in Assegaaibos mountain catchment sourced from Lloyd (2007).

ASSEGAAIBOS MAMMAL LIST				
Source: Jonkershoek Nature Reserve, Scientific Services (Mr. Pieter Lloyd) (06/06/2007)				
Family	**Taxon**	**English Name**	**SARDB Status**	**IUCN Status**
Bathyergidae	Cryptomys hottentotus	Common molerat	Least Concern	NULL
Bathyergidae	Georychus capensis	Cape molerat	Least Concern	Least Concern
Bovidae	Oreotragus oreotragus	Klipspringer	Least Concern	NULL
Bovidae	Raphicerus melanotis	Grysbok	Least Concern	Least Concern
Bovidae	Sylvicapra grimmia	Common duiker	Least Concern	NULL
Cercopithecidae	Papio hamadryas	Chacma baboon	Least Concern	Least Concern
Chrysochloridae	Amblysomus corriae	Fynbos golden mole	Near Threatened	Near Threatened
Chrysochloridae	Amblysomus hottentotus	Hottentot golden mole	Data Deficient	Data Deficient
Chrysochloridae	Chrysochloris asiatica	Cape golden mole	Data Deficient	Data Deficient
Felidae	Caracal caracal	Caracal	Least Concern	NULL
Felidae	Felis silvestris	African Wild Cat	Least Concern	NULL
Felidae	Panthera pardus	Leopard	Least Concern	NULL
Herpestidae	Atilax paludinosus	Water mongoose	Least Concern	NULL
Herpestidae	Galerella pulverulenta	Cape grey mongoose	Least Concern	NULL
Herpestidae	Herpestes ichneumon	Large grey mongoose	Least Concern	NULL
Hystricidae	Hystrix africaeaustralis	Porcupine	Least Concern	NULL
Leporidae	Lepus saxatilis	Scrub hare	Least Concern	NULL
Molossidae	Tadarida aegyptiaca	Egyptian free-tailed bat	Least Concern	NULL
Muridae	Acomys subspinosus	Cape spiny mouse	Least Concern	Least Concern
Muridae	Aethomys namaquensis	Namaqua rock mouse	Least Concern	NULL
Muridae	Dendromus mesomelas	Brants' climbing mouse	Least Concern	NULL
Muridae	Mus minutoides	Pygmy mouse	Least Concern	NULL
Muridae	Mus musculus	House mouse	NULL	NULL
Muridae	Myomyscus verreauxi	Verreaux's mouse	Least Concern	Least Concern
Muridae	Otomys irroratus	Vlei rat	Least Concern	NULL
Muridae	Otomys saundersiae	Saunders' vlei rat	Least Concern	Least Concern
Muridae	Rattus norvegicus	Brown rat	NULL	NULL
Muridae	Rattus rattus	House rat	NULL	NULL
Muridae	Rhabdomys pumilio	Striped mouse	Least Concern	NULL
Mustelidae	Aonyx capensis	African clawless otter	Least Concern	NULL
Mustelidae	Mellivora capensis	Honey badger	Near Threatened	NULL

Nycteridae	Nycteris thebaica	Egyptian slit-faced bat	Least Concern	NULL
Procavidae	Procavia capensis	Rock dassie	Least Concern	NULL
Pteropodidae	Rousettus aegyptiacus	Egyptian fruit bat	Least Concern	NULL
Rhinolophidae	Rhinolophus capensis	Cape horseshoe bat	Near Threatened	Near Threatened
Sciuridae	Sciurus carolinensis	Grey squirrel	NULL	NULL
Soricidae	Crocidura cyanea	Reddish-grey musk shrew	Data Deficient	NULL
Soricidae	Crocidura flavescens	Greater red musk shrew	Data Deficient	NULL
Soricidae	Myosorex varius	Forest shrew	Data Deficient	NULL
Vespertilionidae	Miniopterus schreibersii	Schreiber's long-fingered bat	Near Threatened	NULL
Vespertilionidae	Myotis tricolor	Temminck's hairy bat	Near Threatened	NULL
Vespertilionidae	Neoromicia capensis	Cape serotine bat	Least Concern	NULL
Viverridae	Genetta genetta	Small-spotted genet	Least Concern	NULL
Viverridae	Genetta tigrina	Large-spotted genet	Least Concern	NULL
	= Alien species			

Annexure 9

List of Interested and Affected Parties identified during the planning of the Berg River Dam project, sourced from Department of Water Affairs and Forestry (1996b).

African Farmers Union
Armanjo Investments
Ashton Municipality
Avontuur Plaas
Berg River Valley Development Forum
Bergrivier Besproeingsraad
Boesmansrug Farm Trust
Boland Chamber of Commerce
Boland Traders Association
Botanical Society of South Africa
Botmansdrif
Bradpak Orchards Trust / Bradfontein (Pty) Ltd
Breede River Water Conservation Board
Breerivier Streeksdiensteraad
Breerivier Waterbewaringsraad
Bush Radio
Cape Metropolitan Council
Caledon Municipality
Cape Bird Club
Cape Chamber of Commerce and Industry
Cape Natural History Club
Cape Nature Conservation
Cape Piscatorial Society
Cape Town Ecology Group
Cape Town Water Undertaking
Cape Wetlands Trust
Cape Whitewater Club
Captour
CAPTRUST
Chiltern Farms (Pty) Ltd
Citi News and Citi Vision
Community Newspapers
COSATU
Crookes Brothers Ltd
CSIR – Ematek
Dal Jasaphat Besproeiingsraad
Dal Josafat Gemeenskapvereniging
Damar Boedery
Darling Municipality
Darling RDP Forum

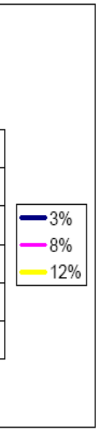
Dennesbos Farm
Dennehof Recreational Resort
Department van Landbou
Departement van Waterwese en Bosbou
Department of Agriculture
Department of Economic Affairs
Department of Health
Department of Mineral and Energy Affairs
Department of Public Works
Department of Regional and Land Affairs
Department of Water Affairs and Forestry
Department of Environmental Affairs and Tourism
Dewdale Farms
Die Burger
Die Tyger-Burger
Die Weslander
District Mail
Dwarsrivier Besproeiingsraad
Earthlife Africa
Eco programme
Eikstadnuus
Elandskloof Besproeiingsraad
Elandskloof Irrigation Board
Elgin Grabouw Vyeboom Farmers Association
Elgin Irrigation Services (Pty) Ltd
Environmental Monitoring Group
Fine Music Radio
Fortuin Boerdery
Franschhoek Belastingsbetalersvereniging
Franschhoek Boerevereniging
Franschhoek Civic Association
Franschhoek environmental Society
Franschhoek Farmers Association
Franschhoek Municipality
Franschhoek Ratepayers Association
Franschhoek RDP Forum
Franschhoek Tourism Association
Franschhoek Trust / Environmental Society
Franschhoek / Wemmershoek Municipality
Freshwater Research Unit
Friends of Hangklip
Glenalric Trust
Goedgegun Farm
Gouda Municipality
Goudini Boerevereniging
Greyton Municipality
Groenberg Besproeiingsraad

Grooteiland Klipdrif Irrigation Board
Helderberg Community Radio
Hexvallei Besproeiingsraad
Holsloot Besproeiingsraad
Houtveld Agrisouth Orchards
Islamore Estates
Kirsten Boedery
Kontrei Landboudienste CC
Krom River Irrigation Board
KWV
La Motte Besproeiingsraad
La Motte Wynlandgoed
La Roche Farm
Lakeview Farm / Elandskloof Irrigation Board
Langebaan Municipality
Little Oaks Farm
Mail and Guardian
MBB Consulting Eng. Inc.
Mbekweni Civic
Mbekweni Traders Association
McGregor Municipality
Melsetter Trust – Brandwag Farm
The Metaplan Team
Mondi Timber Products
Montague Municipality
Dennis Moss Partnership
Mountain Club of SA (Paarl / Wellington Branch)
Newton Ratepayers Association
Noord Agter Paarl Besproeiingsraad
North Argus
Northlands News
Oak Valley Estates (Pty) Ltd
Oewerbewoners Villiersdorp Boerevereniging
OUTOL
Ovenstone Farms
Overberg Regional Services Council
Paarl Boerevereniging
Paarl Business Forum
Paarl Chamber of Commerce
Paarl Civic Association
Paarl East Ratepayers Association
Paarl Farmers Association
Paarl Municipality
Paarl Munisipale Wernemersvereniging
Paarl Post
Paarl Publicity Association
Paarl Ratepayers Association

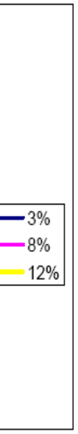
Paarl RDP Forum
Paarl Rural Council
Paarl Sakekamer
Paarl Small Business Trust
Paarl Small Scale Farmers Association
Paarl Town Council
Paarlse Boerevereniging
Paper Printing Wood & Allied Workers Union
Peninsula Times
Peoples Express
Perdeberg Besproeiingsraad
Piketberg Local Council
PLOEG
Pniel Local Council
Pniel RDP Forum
Provincial Development Council
Queen Anne Trust
Radio 786
Radio Atlantis
Radio C Flat
Radio Fish Hoek (CCFM)
Radio Matie FM
Radio Tygerberg
Rapport
Rapport Metro
Rawsonville Municipality
Rawsonville RDP Forum
Riebeeck Wes Municipality
Riviersonderend Municipality
Robertson Municipality
AD Roux and Sons
Rural Foundation
S.A. Institute of Town and Regional Planners
SA Apple and Pear Producers Association
SAAME (Paarl Branch)
SAAPAWU
SABC (Radio)
SABC (Television)
SAFCOL
SAFCOL La Motte Plantation
SAPA
Saron Local Council
Saron Municipality
Saron RDP Forum
Smalblaar Besproeiingsraad
Smalblaarrivier Besproeiingsraad
H Snipelisky and Company

Sonderend Besproeiingsraad
SouthAfrican Association of Municipal Employees
South African Forestry Company Ltd
South African Municipal Workers Union – COSATU
South African Police Services
Southern Argus
Suid Agter Paarl Besproeiingsraad
Sunday Times Metro
Swartstomp Landgoed
Swartland Monitor
Willem Thonie Boerdery
The Argus
The Cape Times
Tulbagh RDP Forum
UCT Radio
Unicorn Publishing
Veldrif Municipality
Verenigde Breederivier Ontwillelingsvereniging
Vignerons De Franschhoek Tourism
Vilko Handelstak
Villiersboom Farmers Association
Villiersdorp Boerevereniging
Villiersdorp Botanical Society
Villiersdorp Civic
Villiersdorp Co-op
Villiersdorp Farmers Union
Villiersdorp Municipality
Villiersdorp RDP Forum
Villiersdorp Rural Foundation
Villiersdorp Squatters
Vredenhof Trust
Vyeboom Besproeiingsraad
Vyeboom Co-op
Vyeboom Irrigation Board
Vyeboom Kooperasie
Waterval Sawmills
Welgelegen Farm
Wellington Boerevereneging
Wellington Civic Association
Wellington Development Trust
Wellington Kamer van Koophandel
Wellington Municipality
Winelands Regional Services Council
Wellington Publicity Association
Wellington Ratepayers Association
Wellington RDP Forum
Wellington Trust for Housing and Community Development

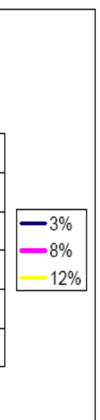
Wemmershoek Sawmill
Wes Kaapse Landbou unie
West Coast Farmers Association
Western Cape Agricultural Union
Wildlife Society of South Africa
Wine Route
Winelands District Concil
Wolseley Municpality
Wooden Posts Investments
Worcester Farmers Association
Worcester Municipality
Worcester RDP Forum
Worcester Standard & Advertiser
Worcester Oos Hoofbesproeiingsraad
WP Canoe Union
Zonderendrivier Bespoeiingsraad



0	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
3	-1,708,054	165,863	231,117	287,572	288,109	288,700	289,351	290,066	290,853	291,719	292,671	293,718	294,870	296,137	297,532	299,065	300,752	302,607	304,648	306,893	309,363	312,079	315,068	318,355	321,971	325,948	-41,754,586
2	-46,945,680	-46,810,818	-46,628,372	-46,407,972	-46,193,592	-45,985,028	-45,782,084	-45,584,563	-45,392,275	-45,205,031	-45,022,649	-44,844,944	-44,671,739	-44,502,856	-44,338,120	-44,177,358	-44,020,398	-43,867,069	-43,717,203	-43,570,629	-43,427,179	-43,286,684	-43,148,975	-43,013,883	-42,881,235	-42,750,860	
5	-43,847,119	-43,750,339	-43,625,474	-43,481,616	-43,348,166	-43,224,347	-43,109,442	-43,002,785	-42,903,761	-42,811,799	-42,726,372	-42,646,989	-42,573,198	-42,504,579	-42,440,744	-42,381,333	-42,326,013	-42,274,474	-42,226,431	-42,181,619	-42,139,793	-42,100,725	-42,064,204	-42,030,036	-41,998,039	-41,968,047	
1	-41,691,724	-41,616,696	-41,523,352	-41,419,650	-41,326,887	-41,243,892	-41,169,623	-41,103,148	-41,043,633	-40,990,337	-40,942,597	-40,899,818	-40,861,473	-40,827,090	-40,796,246	-40,768,564	-40,743,709	-40,721,381	-40,701,310	-40,683,257	-40,667,009	-40,652,375	-40,639,183	-40,627,282	-40,616,535	-40,606,822	



0	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
8	-1,960,406	110,684	182,717	245,017	245,503	246,038	246,627	247,274	247,986	248,769	249,631	250,578	251,621	252,767	254,028	255,416	256,942	258,621	260,467	262,499	264,733	267,191	269,894	272,868	276,140	279,738	-48,459,094
5	-52,273,305	-52,183,308	-52,039,069	-51,851,284	-51,668,606	-51,490,863	-51,317,884	-51,149,502	-50,985,554	-50,825,879	-50,670,318	-50,518,714	-50,370,913	-50,226,764	-50,086,114	-49,948,816	-49,814,720	-49,683,679	-49,555,546	-49,430,175	-49,307,420	-49,187,134	-49,069,169	-48,953,378	-48,839,612	-48,727,721	
8	-48,791,327	-48,726,743	-48,628,027	-48,505,457	-48,391,742	-48,286,220	-48,188,281	-48,097,359	-48,012,930	-47,934,507	-47,861,642	-47,793,919	-47,730,951	-47,672,382	-47,617,881	-47,567,141	-47,519,879	-47,475,832	-47,434,756	-47,396,427	-47,360,634	-47,327,186	-47,295,901	-47,266,615	-47,239,173	-47,213,432	
9	-46,372,212	-46,322,144	-46,248,348	-46,159,992	-46,080,946	-46,010,216	-45,946,913	-45,890,244	-45,839,502	-45,794,052	-45,753,332	-45,716,837	-45,684,116	-45,654,768	-45,628,434	-45,604,793	-45,583,559	-45,564,476	-45,547,315	-45,531,874	-45,517,970	-45,505,441	-45,494,141	-45,483,940	-45,474,723	-45,466,386	



,513	361,880	362,283	362,728	363,216	363,754	364,345	364,995	365,711	366,497	367,363	368,315	369,363	370,515	371,782	373,176	374,709	376,396	378,252	380,293	382,538	385,007	387,724	390,712	393,999	397,615	401,592	11,517,579
,083	327,415	327,780	328,182	328,624	329,110	329,645	330,234	330,881	331,593	332,376	333,238	334,185	335,228	336,374	337,635	339,023	340,549	342,228	344,074	346,106	348,340	350,798	353,501	356,475	359,747	363,345	10,420,667
5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
,298	344,647	345,032	345,455	345,920	346,432	346,995	347,614	348,296	349,045	349,870	350,776	351,774	352,871	354,078	355,406	356,866	358,473	360,240	362,183	364,322	366,674	369,261	372,107	375,237	378,681	382,469	25,606,227
79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	
,454	325,784	326,148	326,548	326,988	327,471	328,004	328,589	329,233	329,942	330,721	331,578	332,521	333,558	334,699	335,954	337,334	338,853	340,523	342,361	344,382	346,605	349,051	351,741	354,700	357,955	361,536	10,385,902
,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	9,975,219
,305	3,635	3,999	4,399	4,839	5,322	5,855	6,440	7,084	7,792	8,572	9,429	10,372	11,409	12,550	13,805	15,185	16,704	18,374	20,212	22,233	24,456	26,902	29,592	32,551	35,806	39,387	410,683

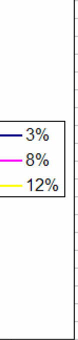
2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
,775	2,069,933	196,420	131,611	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	75,644	53,272,165
,331	2,287,821	217,096	145,465	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	83,607	58,879,761
5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
,553	2,178,877	206,758	138,538	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	79,626	56,075,963
79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	
,483	2,059,625	195,442	130,956	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	55,363,487
,863	123,651	110,278	103,197	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	2,690,630
,141	239,538	84,876	27,573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,506,800
171	128	288	185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12,644
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19,901
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	176,352
,850	7,850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39,251
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61,564
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,050
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61,564
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42,211,445
,458	1,688,458	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8,442,289

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
165,863	**231,117**	**287,572**	**288,109**	**288,700**	**289,351**	**290,066**	**290,853**	**291,719**	**292,671**	**293,718**	**294,870**	**296,137**	**297,532**	**299,065**	**300,752**	**302,607**	**304,648**	**306,893**	**309,363**	**312,079**	**315,068**	**318,355**	**321,971**	**325,948**	**5,522,099**
-1,627,064	-1,395,947	-1,108,375	-820,266	-531,566	-242,215	47,851	338,704	630,423	923,094	1,216,812	1,511,682	1,807,819	2,105,351	2,404,416	2,705,168	3,007,775	3,312,423	3,619,316	3,928,679	4,240,759	4,555,826	4,874,181	5,196,152	5,522,099	
-1,515,664	-1,390,799	-1,246,942	-1,113,491	-989,673	-874,767	-768,111	-669,087	-577,125	-491,697	-412,314	-338,523	-269,904	-206,070	-146,659	-91,338	-39,800	8,243	53,055	94,882	133,950	170,471	204,639	236,635	266,628	
-1,462,327	-1,368,983	-1,265,282	-1,172,519	-1,089,524	-1,015,255	-948,779	-889,265	-835,969	-788,228	-745,450	-707,105	-672,721	-641,877	-614,196	-589,341	-567,012	-546,941	-528,889	-512,641	-498,006	-484,815	-472,914	-462,167	-452,453	

2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
110,684	**182,717**	**245,017**	**245,503**	**246,038**	**246,627**	**247,274**	**247,986**	**248,769**	**249,631**	**250,578**	**251,621**	**252,767**	**254,028**	**255,416**	**256,942**	**258,621**	**260,467**	**262,499**	**264,733**	**267,191**	**269,894**	**272,868**	**276,140**	**279,738**	**17,898,846**
-2,196,764	-2,052,526	-1,864,740	-1,682,063	-1,504,319	-1,331,340	-1,162,959	-999,011	-839,335	-683,774	-532,170	-384,370	-240,220	-99,571	37,728	171,824	302,865	430,998	556,368	679,124	799,410	917,375	1,033,165	1,146,931	1,258,823	
-2,046,314	-1,947,597	-1,825,027	-1,711,312	-1,605,790	-1,507,851	-1,416,929	-1,332,500	-1,254,077	-1,181,213	-1,113,489	-1,050,521	-991,952	-937,451	-886,711	-839,449	-795,402	-754,326	-715,997	-680,204	-646,756	-615,471	-586,185	-558,743	-533,002	
-1,941,000	-1,867,204	-1,778,848	-1,699,802	-1,629,072	-1,565,769	-1,509,101	-1,458,358	-1,412,908	-1,372,188	-1,335,693	-1,302,972	-1,273,624	-1,247,290	-1,223,649	-1,202,415	-1,183,332	-1,166,171	-1,150,730	-1,136,826	-1,124,297	-1,112,997	-1,102,796	-1,093,579	-1,085,242	

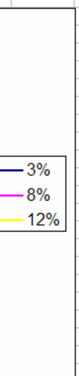
5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
298	**344,647**	**345,032**	**345,455**	**345,920**	**346,432**	**346,995**	**347,614**	**348,296**	**349,045**	**349,870**	**350,776**	**351,774**	**352,871**	**354,078**	**355,406**	**356,866**	**358,473**	**360,240**	**362,183**	**364,322**	**366,674**	**369,261**	**372,107**	**375,237**	**378,681**	**382,469**	**25,606,227**
9%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	
454	**325,784**	**326,148**	**326,548**	**326,988**	**327,471**	**328,004**	**328,589**	**329,233**	**329,942**	**330,721**	**331,578**	**332,521**	**333,558**	**334,699**	**335,954**	**337,334**	**338,853**	**340,523**	**342,361**	**344,382**	**346,605**	**349,051**	**351,741**	**354,700**	**357,955**	**361,536**	**10,385,902**
149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	9,975,219
.77	3,635.24	3,998.77	4,398.64	4,838.51	5,322.36	5,854.60	6,440.06	7,084.06	7,792.47	8,571.71	9,428.88	10,371.77	11,408.95	12,549.85	13,804.83	15,185.31	16,703.84	18,374.23	20,211.65	22,232.82	24,456.10	26,901.71	29,591.88	32,551.07	35,806.17	39,386.79	410,683

010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
576	**418,734**	**196,420**	**131,611**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**5,995,480**
321	**462,811**	**217,096**	**145,465**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**6,626,583**
5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
448	**440,773**	**206,758**	**138,538**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**6,311,031**
9%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	
506	**416,649**	**195,442**	**130,956**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**6,074,197**
363	123,651	110,278	103,197	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	2,690,630
141	239,538	84,876	27,573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,506,800
171	128	288	185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12,644
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19,901
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	176,352
350	7,850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39,251
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61,564
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,050
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61,564
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,137,036
481	45,481	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	227,407



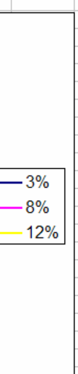
11	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
33	**165,863**	**231,117**	**287,572**	**288,109**	**288,700**	**289,351**	**290,066**	**290,853**	**291,719**	**292,671**	**293,718**	**294,870**	**296,137**
95	-122,433	60,013	280,413	494,793	703,357	906,301	1,103,822	1,296,110	1,483,354	1,665,736	1,843,441	2,016,646	2,185,529
30	-148,800	-23,935	119,922	253,373	377,191	492,096	598,753	697,777	789,739	875,167	954,550	1,028,341	1,096,959
35	-162,056	-68,712	34,989	127,752	210,747	285,016	351,492	411,006	464,302	512,043	554,821	593,166	627,550

11	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
33	**297,532**	**299,065**	**300,752**	**302,607**	**304,648**	**306,893**	**309,363**	**312,079**	**315,068**	**318,355**	**321,971**	**325,948**	**24,964,235**
95	2,350,265	2,511,027	2,667,987	2,821,316	2,971,182	3,117,756	3,261,206	3,401,701	3,539,410	3,674,502	3,807,150	3,937,525	
30	1,160,794	1,220,205	1,275,526	1,327,064	1,375,107	1,419,919	1,461,745	1,500,814	1,537,334	1,571,503	1,603,499	1,633,492	
35	658,394	686,075	710,930	733,259	753,330	771,382	787,630	802,265	815,456	827,357	838,104	847,818	



11	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
72	**R 110,684**	**R 182,717**	**R 245,017**	**R 245,503**	**R 246,038**	**R 246,627**	**R 247,274**	**R 247,986**	**R 248,769**	**R 249,631**	**R 250,578**	**R 251,621**	**R 252,767**
53	R -580,356	R -436,117	R -248,332	R -65,654	R 112,089	R 285,068	R 453,449	R 617,397	R 777,073	R 932,634	R 1,084,238	R 1,232,039	R 1,376,188
53	R -535,569	R -436,853	R -314,283	R -200,568	R -95,046	R 2,893	R 93,815	R 178,245	R 256,667	R 329,532	R 397,255	R 460,223	R 518,792
26	R -503,858	R -430,062	R -341,706	R -262,661	R -191,931	R -128,628	R -71,959	R -21,216	R 24,233	R 64,953	R 101,449	R 134,169	R 163,517

11	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
72	**R 254,028**	**R 255,416**	**R 256,942**	**R 258,621**	**R 260,467**	**R 262,499**	**R 264,733**	**R 267,191**	**R 269,894**	**R 272,868**	**R 276,140**	**R 279,738**	**R 22,007,778**
53	R 1,516,838	R 1,654,136	R 1,788,232	R 1,919,273	R 2,047,406	R 2,172,777	R 2,295,532	R 2,415,818	R 2,533,783	R 2,649,574	R 2,763,340	R 2,875,231	
53	R 573,294	R 624,033	R 671,295	R 715,342	R 756,418	R 794,747	R 830,540	R 863,989	R 895,273	R 924,559	R 952,001	R 977,742	
26	R 189,852	R 213,493	R 234,727	R 253,810	R 270,970	R 286,411	R 300,315	R 312,845	R 324,145	R 334,346	R 343,563	R 351,900	



5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
4,298	**344,647**	**345,032**	**345,455**	**345,920**	**346,432**	**346,995**	**347,614**	**348,296**	**349,045**	**349,870**	**350,776**	**351,774**	**352,871**	**354,078**	**355,406**	**356,866**	**358,473**	**360,240**	**362,183**	**364,322**	**366,674**	**369,261**	**372,107**	**375,237**	**378,681**	**382,469**	**25,606,227**
.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	
5,454	**325,784**	**326,148**	**326,548**	**326,988**	**327,471**	**328,004**	**328,589**	**329,233**	**329,942**	**330,721**	**331,578**	**332,521**	**333,558**	**334,699**	**335,954**	**337,334**	**338,853**	**340,523**	**342,361**	**344,382**	**346,605**	**349,051**	**351,741**	**354,700**	**357,955**	**361,536**	**10,385,902**
2,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	322,149	9,975,219
3,305	3,635	3,999	4,399	4,839	5,322	5,855	6,440	7,084	7,792	8,572	9,429	10,372	11,409	12,550	13,805	15,185	16,704	18,374	20,212	22,233	24,456	26,902	29,592	32,551	35,806	39,387	410,683

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	
4,254	**367,412**	**196,420**	**131,611**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**75,644**	**R 4,467,570.97**
2,597	**406,087**	**217,096**	**145,465**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**83,607**	**R 4,937,841.60**
5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	
3,426	**386,750**	**206,758**	**138,538**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**79,626**	**4,702,706**
.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	5.79%	
2,440	**365,583**	**195,442**	**130,956**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**75,268**	**4,480,656**
3,863	123,651	110,278	103,197	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	75,268	2,690,630
6,141	239,538	84,876	27,573	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,506,800
171	128	288	185	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12,644
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19,901
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36,740
2,266	2,266	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11,328
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61,564
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141,050

08	10911.13	10819.51	5167.66	2181.92	**74003.82**
00	R 1,418,447.00	R 1,406,796.00	R 672,446.00	R 283,650.00	**R 9,621,409.00**
00	R 0.00	R 0.00	R 0.00	R 0.00	**R 1,293,150.00**
00	R 125,000.00	R 125,000.00	R 125,000.00	R 125,000.00	**R 1,000,000.00**
00	R 141,845.00	R 140,680.00	R 67,245.00	R 28,365.00	**R 962,142.00**
00	**R 1,685,292.00**	**R 1,672,476.00**	**R 864,691.00**	**R 437,015.00**	**R 12,876,701.00**
46	R 220.58	R 218.90	R 113.17	R 7,640.32	**R 1,685.36**
17	R 177,883.50	R 176,530.77	R 91,268.61	R 6,161,459.66	**R 1,359,142.91**

	Year 5	Year 6	Year 7	Year 8	Total cost
00	R 125,000.00	R 125,000.00	R 125,000.00	R 125,000.00	R 1,000,000.00
00	R 141,845.00	R 140,680.00	R 67,245.00	R 28,365.00	R 962,142.00
00	R 266,845.00	R 265,680.00	R 192,245.00	R 153,365.00	R 1,962,142.00
28	R 34.93	R 34.77	R 25.16	R 20.07	R 256.81
40	**R 28,165.64**	**R 28,042.67**	**R 20,291.57**	**R 16,187.76**	**R 207,105.17**

	Year 5	Year 6	Year 7	Year 8	Total cost
40	R 28,165.64	R 28,042.67	R 20,291.57	R 16,187.76	R 207,105.17
45	R 30,587.88	R 30,454.34	R 22,036.64	R 17,579.91	R 224,916.22
39	R 32,692.33	R 32,549.60	R 23,552.76	R 18,789.41	R 240,390.45
19	R 34,425.02	R 34,274.73	R 24,801.06	R 19,785.24	R 253,131.15
37	R 36,249.55	R 36,091.29	R 26,115.51	R 20,833.86	R 266,547.10
61	R 38,315.77	R 38,148.49	R 27,604.10	R 22,021.39	R 281,740.28
38	R 41,802.51	R 41,620.00	R 30,116.07	R 24,025.34	R 307,378.65
66	R 44,310.66	R 44,117.21	R 31,923.04	R 25,466.86	R 325,821.37
03	R 44,931.01	R 44,734.85	R 32,369.96	R 25,823.40	R 330,382.87
35	R 46,458.66	R 46,255.83	R 33,470.54	R 26,701.39	R 341,615.88
71	**R 48,595.76**	**R 48,383.60**	**R 35,010.18**	**R 27,929.65**	**R 357,330.21**

TS

	Year 5	Year 6	Year 7	Year 8	Total cost
32	1,017.50	1,831.08	0.00	0.00	8,696.39
95	7,851.24	7,066.19	2,991.63	922.74	37,745.65
91	1,105.69	1,220.66	593.47	241.92	17,204.21
18	9,974.43	10,117.93	3,585.10	1,164.66	63,646.25
40	1,296,675.90	1,315,330.90	466,063.00	151,405.80	8,274,012.50
74	169.71	172.16	61.00	19.82	1,082.94
44	**136,864.86**	**138,833.90**	**49,193.21**	**15,980.97**	**873,326.59**
44	136,864.86	138,833.90	49,193.21	15,980.97	873,326.59
20	148,635.24	150,773.62	53,423.82	17,355.33	948,432.68
02	158,861.34	161,146.84	57,099.38	18,549.38	1,013,684.85
52	167,280.99	169,687.63	60,125.65	19,532.49	1,067,410.15
35	176,146.88	178,681.07	63,312.31	20,567.71	1,123,982.88
54	186,187.26	188,865.89	66,921.11	21,740.07	1,188,049.91
73	203,130.30	206,052.69	73,010.93	23,718.42	1,296,162.45
34	215,318.11	218,415.85	77,391.59	25,141.53	1,373,932.20
34	218,332.57	221,473.67	78,475.07	25,493.51	1,393,167.25
35	225,755.88	229,003.78	81,143.22	26,360.29	1,440,534.93
61	**236,140.65**	**239,537.95**	**84,875.81**	**27,572.86**	**1,506,799.54**

	Year 5	Year 6	Year 7	Year 8	Total cost
90	936.70	701.58	1,582.56	1,017.26	10,357.57
00	121,771.00	91,205.40	205,732.80	132,243.80	1,346,484.10
20	0.12	0.09	0.21	0.13	9.09
79	**98.87**	**74.05**	**167.04**	**107.37**	**7,328.16**
79	98.87	74.05	167.04	107.37	7,328.16
36	107.37	80.42	181.41	116.61	7,958.38
15	114.76	85.95	193.89	124.63	8,505.92
35	120.84	90.51	204.16	131.23	8,956.73
07	127.25	95.31	214.98	138.19	9,431.44
65	134.50	100.74	227.24	146.07	9,969.03
18	146.74	109.91	247.92	159.36	10,876.21
23	155.54	116.50	262.79	168.92	11,528.78
71	157.72	118.13	266.47	171.28	11,690.19
27	163.08	122.15	275.53	177.11	12,087.65
24	**170.58**	**127.77**	**288.20**	**185.26**	**12,643.69**

Man days required (8 hrs per day)	Labour rate	Total labour cost
153	R 130.00	R 19,900.83
Total M required		**Total material cost**
7348		R 36,740.00
		R 56,640.83

IG EX SITU MATERIALS		
Man days required	**Labour rate**	**Total labour cost**
153	R 130.00	R 19,900.83
Total M required		
7348		R 176,352.00
		R 196,252.83

Total cost of Bed preparation
R 5,143.60
R 56,420.00
R 61,563.60
Total cost of road scarification
R 141,050.00
Total cost of mulch application
R 5,143.60
R 56,420.00
R 61,563.60
R 264,177.20

T PRE AND POST ALIEN INVASIVE PLANT REMOVAL

	Million litres	DWAF bulk water cost / 1000l	Total water benefit	VAT	Amount exclusive of VAT
0	109000	R 3.25	R 354,250.00	R 43,504.39	**R 310,745.61**
0	113000	R 3.25	R 367,250.00	R 45,100.88	**R 322,149.12**

R 0.00	R 900.00	R 4,070.00		
R 0.00	R 150.00	R 4,820.00		
R 0.00	R 0.00	R 2,052.00	R 15,388.00	**R 3,077.60**
R 0.00	R 0.00	R 180.00	R 15,568.00	R 2,594.67

ng 2001 and 2005
ing 2001
ing 2001 and 2005

Hectares
Square meters
Hectares

Quantity
Day permit
Annual permit
Day permit
Annual permit
Day permit
Annual permit

Quantity
Per 1000 litres

TE

Quantity
meters per hour
Per meter
Per meter

quantity
Per hectare
Per Kilometer
per hectare

Quantity
Per kilogram
Per hectare

Quantity
Per day

SPECIFICATIONS

Aspect	Slope (°)
East facing	36 -40
East facing	
Soth west facing	36 -40
South west facing	36 -40
South west facing	36 -40
South facing	31 -40