THE EFFECT OF GROOTVLEI MINE WATER ON THE BLESBOKSPRUIT

by

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ABSTRACT

Gold mining activities are widespread in the Witwatersrand area of South Africa. These have significant influences, both positive and negative, on the socio-economic and bio-physical environments. In the case of South Africa's river systems and riparian zones, mining and its associated activities have negatively impacted upon these systems.

The Blesbokspruit Catchment Area and Grootvlei Mines Limited (hereafter called "Grootvlei") are located in Gauteng Province of South Africa. The chosen study area is east of the town of Springs in the Ekurhuleni Metropolitan Municipality on the East Rand of Gauteng Province. Grootvlei, which has been operating underground mining activities since 1934, is one of the last operational mines in this area. Grootvlei pumps extraneous water from its underground mine workings into the Blesbokspruit, which includes the Blesbokspruit Ramsar site. This pumping ensures that the mine workings are not flooded, which would result in the gold reserves becoming inaccessible and would shortly lead to the closure of Grootvlei. This closure would further affect at least three other marginal gold mines in the area, namely, Springs-Dagga, Droogebult-Wits and Nigel Gold Mine, all which rely on Grootvlei's pumping to keep their workings dry. Being shallower than Grootvlei, they are currently able to operate without themselves having to pump any extraneous water from their underground workings. A cessation of pumping would also cause flooding of the lower workings of the neighbouring Consolidated Modderfontein Mine. If pumping does not take place the water will eventually percolate to the surface, initially in the Nigel area and eventually throughout the entire Far East Rand, which would lead to substantial economic losses.

This study was undertaken to establish whether Grootvlei's pumping activities of extraneous water from underground mine workings into the Blesbokspruit has had, and is still having, an impact on the water quality of the Blesbokspruit and, if so, how this impact can be minimized or eliminated.

Water quality of the Blesbokspruit was analysed and trends in four selected variables, i.e. pH, Electric Conductivity, magnesium and sulphate content, are discussed in this report. These variables were analysed in relation to three categories, namely the sample point position, seasonal influences and four periods of pumping operations. The sample position immediately downstream of the discharge point of Grootvlei, where the extraneous water from their underground mine workings is pumped into the Blesbokspruit, as well as the samples collected in the dry seasons, recorded the poorest overall water quality values in

all four variables. Although the sample position and seasonal changes influenced the water quality of the Blesbokspruit, it was found that the periods of pumping had the most significant influence on the water quality, with a decrease in water quality after the huge increase in pumping volumes, which commenced in October 1995. It was also established that the Blesbokspruit wetland does not have the capacity to purify the water in the Blesbokspruit in order to maintain similar water quality conditions found upstream from the mine. This could be due to the wetland already having too many contaminants in it. The analysis concludes that the pumping of extraneous water from underground mine workings into the Blesbokspruit has had and is still having, although to a lesser degree, a major influence on the deterioration of water quality of the Blesbokspruit.

The strategic management plan of Grootvlei, as well as the feasibility study to establish the best-suited scenario for reducing water ingress into the underground mine workings were discussed. In addition, the following recommendations were made in order to assist Grootvlei in improving the water quality of the Blesbokspruit:

- Strict compliance with environmental law regarding the requirements set out in the water extraction licence of Grootvlei.
- Grootvlei should adhere to its statements and undertakings to improve the water quality pumped into the Blesbokspruit.
- Grootvlei should expand on its increased environmental awareness by ensuring that communication channels are open between Grootvlei and the community. This is essential to ensure that Grootvlei is made aware of issues and concerns of the community and that the community is aware that their issues and concerns have been heard, understood and acted upon by Grootvlei.
- Grootvlei should become actively involved in the activities and decisions of the Blesbokspruit Catchment Forum, and should be a permanent member thereof.
- The use of Phytoremediation, trees and riparian zones could be implemented as an alternative to, or in conjunction with current practices to improve the water quality of the water before it is pumped into the Blesbokspruit by Grootvlei. Phytoremediation can also be used in order to reduce the amount of water ingress into underground workings, by establishing vegetation, such as trees, to absorb and evapotranspirate water at areas where ingress occurs.
- Procedures in the reduction of the surface water ingress to the underground mine workings should also be implemented.
- Monitoring the water quality pumped into the Blesbokspruit, as well as monitoring the amount of water ingress into the underground mine workings must be continued.
- A study for the restoration of the Blesbokspruit wetland needs to be implemented urgently.

OPSOMMING

Goudontginningsaktiwiteite word wydverspreid in die Witwatersrandgebied van Suid-Afrika aangetref en het ‘n betekenisvolle invloed, beide positief en negatief, op die sosio-ekonomiese en bio-fisiese omgewing. In die geval van Suid Afrika se riviersisteme en oewersones, het mybou en die geassosieërde aktiwiteite, ‘n negatiewe impak uitgeoefen.

Die Blesbokspruit opvangsgebied en Grootvlei Myn Beperk (hierna verwys as “Grootvlei”) is geleë in die Gauteng provinsie in Suid Afrika. Die verkose studiegebied is geleë oos van Springs, in die Ekurhuleni Metropolitaanse Munisipale gebied, aan die Oosrand van Gauteng Provinsie. Grootvlei beoefen reeds vanaf 1934 ondergrondse mynbou aktiwiteite en word beskou as een van die laaste operasionele myne in die gebied. Die myn pomp oortollige water vanuit die ondergrondse mynbedrywighede na die Blesbokspruit, insluitende die Blesbokspruit Ramsargebied. Hierdie pompaktiwiteite verseker dat die myn nie oorstroom nie, wat voorkom dat goudreserwes ontoeganklik sal word en tot die uiteindelike sluiting van Grootvlei sal lei. Die sluiting sal verder ten minste drie ander marginale myne in die area beïnvloed, naamlik, Springs-Dagga, Droogebult-Wits en Nigel Goudmyn. Hierdie myne maak almal op Grootvlei staatmaak om hulle ondergrondse afbouplekke droog te hou. Aangesien hierdie myne vlakker as Grootvlei is, is dit vir hierdie myne moontlik om voort te gaan met mynbou aktiwiteite sonder om self te pomp. Die sluiting van pompaktiwiteite sal ook die oorstroming van die laer afbouplekke van die naburige Consolidated Modderfontein myn tot gevolg hê. Indien die uitpomping van die water nie plaasvind nie, sal die grondwatervlakke uiteindelik tot aan die oppervlak styg in die Nigel area en uiteindelik oor die hele verre Oosrand, wat groot ekonomiese verliese sal veroorsaak.

Hierdie studie is onderneem om vas te stel of Grootvlei se uitpompaktiwiteite van oortollige grondwater vanuit die ondergrondse mynbedrywighede in die Blesbokspruit, ‘n impak gehad en moontlik steeds het, op die waterkwaliteit van die Blesbokspruit en indien wel, tot hoe ‘n mate hierdie impak verminder of uitgeskakel kan word.

Waterkwaliteit van die Blesbokspruit is vir vier gekose veranderlikes ontleed, naamlik pH, elektriese geleiding, magnesium- en die sulfaatinhoud. Hierdie veranderlikes was geanaliseer in verhouding met drie kategorieë, naamlik, monsterligging, seisonale invloede en vier tydperke van pompaktiwiteite. Die monsterligging geleë net na die vrylating van oortollige grondwater in die Blesbokspruit, asook die monsters wat geneem

is in die droë seisoene, het deurgaans oor al vier konstituante die swakste waterkwaliteit syfers getoon. Alhoewel die monsterliggings en seisoenale veranderinge die waterkwaliteit van die Blesbokspruit beïnvloed het, was die bevinding dat die verskillende tydperke van uitpompingsaktiwiteite die mees betekenisvolle invloed op die waterkwaliteit gehad het, met 'n afname in die waterkwaliteit na die hewige toename in uitpompvolumes wat in Oktober 1995 begin het. Daar was ook bevind dat die Blesbokspruit vleiland nie die kapasiteit het om die waterkwaliteit stroomaf van Grootvlei tot so 'n mate te suiwer soos die waterkwaliteit stroomop van die myn nie. Die rede van die bevinding kan wees, dat daar alreeds te veel kontaminate in die vleiland is en om die rede die suiweringskapasiteit van die vleiland belemmer. Die gevolgtrekking uit die analise was dat die uitpomping van oortollige water 'n groot invloed op die afname in die waterkwaliteit van die Blesbokspruit gehad het en nog steeds het, alhoewel tot 'n mindere mate.

Die strategiese bestuursplan van Grootvlei, asook die uitvoerbaarheidsondersoek, om die bes-passende scenario vir die afname in waterinsyfering in die ondergrondse mynafbouplekke vas te stel, word ook bespreek. Om Grootvlei behulpsaam te wees in die verbetering van die waterkwaliteit in die Blesbokspruit is die volgende aanbevelings ook gemaak:

- Streng nakoming van omgewingswetgewing, rakende die vereistes uiteengesit, in die wateronttrekkingslisensie van Grootvlei
- Grootvlei moet getrou bly aan hul stellings en ondernemings om die waterkwaliteit, wat deur die myn in die Blesbokspruit gepomp word, te verbeter
- Grootvlei moet uitbrei in hul verhoogde omgewingsbewustheid, deur te verseker dat hulle kommunikasiekanale met die gemeenskap oop is. Dit is baie belangrik om te verseker dat Grootvlei bewus is van die kwessies en bekommernisse van die gemeenskap en dat die gemeenskap, aan die anderkant, verseker is dat daar aan hul kwessies en bekommernise, aandag gegee word.
- Grootvlei moet aktief betrokke bly by die aktiwiteite en besluitnemings van Blesbokspruit Opvangsgebied Forum , asook 'n permanente lid daarvan wees
- Die gebruik van fitoherstelling, bome en oewersones, kan as 'n alternatief, of in samewerking met huidige praktyke, geïmplimenteer word om die waterkwaliteit, voor vrylating in die Blesbokspruit, te verbeter. Fitoherstelling kan ook gebruik word om die insyfering van water in die ondergrondse mynbedrywighede te verminder, deur plantegroei te vestig op gebiede waar water insyfering

geïdentifiseer is. Die plante, byvoorbeeld bome, sal water kan absorber en evapotranspireer

- Prosedures moet ingestel word om die insyfering van water in die ondergrondse mynbedrywighede te verminder
- Monitering van die waterkwaliteit wat in die Blesbokspruit ingepomp word, asook monitering van die hoeveelheid water wat in die ondergrondse mynbedrywighede insyfer, moet volgehou word
- Maatreëls vir die herstel van die Blesbokspruitvleiland moet dringend geïmplimenteer word.

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CHAPTER 1

ORIENTATION

1.1 Introduction

South Africa is one of the richest countries in the world in terms of mineral resources. The mineral wealth is found in diverse geological formations, some of which are unique and are extensive by world standards (Department of Minerals and Energy, 2001). The country's gold reserves constitute a third of the known total world's gold reserves. In 1998, South Africa's known gold resources represented 39 percent of the world total (Tshikalange, 1999). Gold contributed 8.3 percent to the country's gross domestic product (GDP). In 1999, South Africa's contribution to the world's mining production was 17.5 percent (Department of Minerals and Energy, 2001). In 2000, South Africa's mining industry produced a sales revenue of R51.6 billion, representing 6.5 percent of the country's GDP. Although the importance of gold mining has fluctuated over the last decade with the performance of the gold price, gold mining still contributes just under four percent to the GDP. Taking into consideration the indirect contribution to the economy and the multiplier effects, gold mining's total contribution to the GDP is closer to 10 percent (Bullion, 2001). On the other side of the coin, South Africa's freshwater reserves are a limited natural resource. South Africa is a water scarce country, due to its low average annual precipitation (less than 500mm), and the unevenness of surface and groundwater distribution, which are a result of climate and topography (21 percent of the country receive less than 200mm). Only 8.6 percent of rainfall converts to useable runoff, one of the lowest portions in the world (Davies & Day, 1998).

Economics, mining operations and the environment are inextricably linked, as natural resources are the basis of production, manufacturing, and waste disposal. Mining activities cannot take place without having an effect on the environment, as the processes in which natural resources are extracted to provide for human demands ultimately affects land, water and ecosystems. It is therefore essential to keep these disturbances that affect the environment to as low a level as possible (Rio Tinto Limited, 2001).

This study focuses on the impact of Grootvlei on the water quality of the Blesbokspruit. Grootvlei is located east of the town of Springs, part of Ekurhuleni Metropolitan Municipality on the East Rand of Gauteng Province. The mine is one of the last operational mines on the East Rand (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003). One of the major problems the mine is experiencing is the increasing water ingress into the underground mine workings. In the past the East Rand mines were dewatered from the Sallies Mine (South African Land and Exploration

Company Limited), however pumping at this point ceased in 1991 (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003). As a result of the discontinuation of pumping activities from Sallies Mine, the mines in the East Rand area started to flood. It became essential for Grootvlei, in order to continue its operations, to pump large volumes of water from the underground mine workings into the Blesbokspruit (Berry, 2004; Personal Communication). This pumping activity commenced in October 1995.

The Blesbokspruit flows in a north-south direction east of Grootvlei. Its source is located north of Boksburg, from whence it flows due east following the mined out route of the Main Reef. Consequently it flows through the mined out and polluted industrialised area of the East Rand before turning south just before it reaches the Grootvlei boundary. It is a hydrologically important river as it drains a large area before joining the Suikerbosrand River, a tributary of the Vaal River. In the past the Vaal River supplied provided water to the Gauteng Province. As a result of the increased pollution load in this river, the Vaal Dam now supplies Gautengs' domestic water. The Vaal River, however, still supplies water to a vast area, ranging from Parys in the Free State to the confluence with the Orange River at Douglas in the Northern Cape Province. The Blesbokspruit was listed on the Montreux Record of the Ramsar Convention in 1996 in response to a decline in the ecological character of the site, brought about primarily by the discharge of large volumes of polluted water from Grootvlei (Dini, 1999).

1.2 Problem Statement and Aim of Study

Water availability, now and in the future, is highly dependent on water use and the management thereof. Availability of water is not only dependent on the quantity obtainable, but to a large extent, on the quality thereof. It is unlikely that the projected demand on water resources in South Africa will be available at anticipated population growth and economic development rates. Water will become an increasingly limited resource in South Africa and supply will become a major drawback in the future socio-economic development of the country, in terms of both the quantity and quality of available water.

One of South Africa's Ramsar wetlands, the Blesbokspruit, has been the subject of widespread concern, as a result of the decline in water quality. The decline in water quality has been the result of processes and activities that take place upstream of the Blesbokspruit, particularly the activities at Grootvlei. The Blesbokspruit is seen as a hydrological important river and pollution of the Blesbokspruit could ultimately have a detrimental effect on the downstream river systems and users (Dini, 1999). Regular monitoring has been conducted to test water quality conditions of the Blesbokspruit below Grootvlei.

Grootvlei commenced emergency pumping activities in October 1995, to manage the flooding of the surrounding underground mines, when Sallies Mine discontinued their pumping activities (Berry, 2004; Personal Communication). Since Grootvlei commenced pumping extraneous water from underground mine workings from their No. 3 Shaft into the Blesbokspruit, various issues and concerns have been raised by both the public and the Department of Water Affairs. These issues and concerns were raised after a red slime (ferrous oxide) was observed in the Blesbokspruit, shortly after pumping commenced. The red slime caused widespread concern for the Ramsar certified wetland within the Blesbokspruit, which was now under threat from the introduction of polluted mine water from Grootvlei. Concern was also raised for the surrounding agricultural community, which makes use of the Blesbokspruit for irrigation purposes, was also at risk (Dini, 1999).

The pumping operations of No. 3 Shaft ceased in December 1995, by order of the Department of Water Affairs, after Grootvlei's management refused to stop pumping polluted water into the Blesbokspruit. The mine management also refused to install filters to remove ferrous oxide from the mine water, as no funds were available to implement the equipment needed for such an operation. Grootvlei however, installed settling ponds, which contributed quite significantly in solving the problem of the ferrous oxide (Berry, 2004; Personal Communication). The cessation of operations placed 6000 jobs in jeopardy, and in February 1996, pumping was resumed. In 1996 the Blesbokspruit was listed on the Montreux Record of the Ramsar Convention due to the decline in ecological character of the site.

The purpose of this study is to evaluate and interpret the decline in water quality in the Blesbokspruit as a result of processes and ac tivities taking place at Grootvlei, upstream of the Blesbokspruit.

The objectives of this study are to:

- Evaluate whether Grootvlei has had a direct impact on the water quality of the Blesbokspruit.
- Evaluate how effective the Blesbokspruit wetland has been in purifying the polluted water of the Blesbokspruit.
- Focus on whether or not there has been an improvement in the water quality of the Blesbokspruit since pumping operations recommenced, after the initial cessation of pumping operations in December 1995, as a result of non-compliance by the mine.

The above objectives will be evaluated by analysing water quality data over a period of eight years. This will be done to:

- Establish how Grootvlei intends to improve the quality of the water discharged into the Blesbokspruit; and
- Provide further recommendations on the improvement of the water quality of the Blesbokspruit.

This study will be useful to industry and society at large as the intentions and activities of Grootvlei to improve the quality of the water discharged into the Blesbokspruit will be presented.

The study will highlight the importance of a balance between the socio-economic and bio-physical environment and stress the importance of water quality management.

1.3 Methodology

This study has been divided into seven chapters to present a logical and ordered sequence (Figure 1.1).

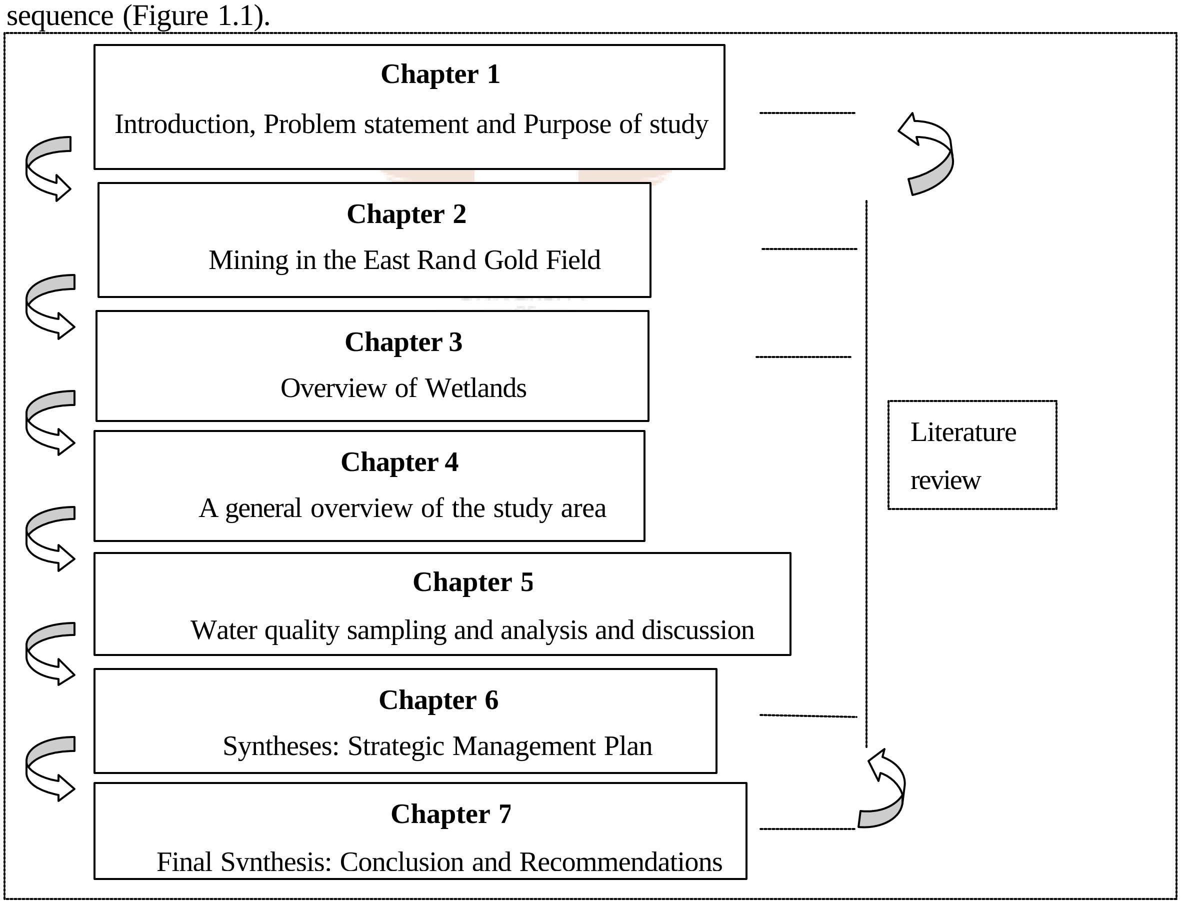


Figure 1.1: Schematic flow chart for method of investigation

In Chapter 1, the purpose of the study and the problem statement is discussed. Chapters 2 and 3 serve to introduce the importance of mining in the East Rand Gold Field as well as the importance of wetlands. These chapters also focus on problems experienced in these two areas. In Chapter 4 the study area is introduced with regard to the bio-physical and socio-economic aspects. The history of the Blesbokspruit wetland and Grootvlei are discussed individually and then the impact of the mine on the Blesbokspruit is examined. Chapters 2, 3 and 4 therefore introduce and present a meaningful understanding of the problems surrounding the study area. The description of sampling and analysis of water quality is discussed in Chapter 5. Whisker and scatter graphs are used in order to show the statistical variables and their relationship with different categor ies. Chapters 5 and 6 serve as the syntheses of the study. Chapter 5 gives an overview of the Strategic Environmental Plan of Grootvlei, wherein the mine strives to find the best suited scenario to improve the water quality pumped into the Blesbokspruit and reduce surface water ingress into the underground mine workings of Grootvlei. Chapter 6 provides an overall conclusion. Recommendations, which can be included in Grootvlei's activities and future management in order to improve the water quality of the Blesbokspruit, are presented in this Chapter. Throughout the study ongoing literature reviews were used in order to ensure that a broad overview, as well as detailed relevant information, are provided.

As Chapter 1 has already been presented, the phases of the study will follow in the sequence given above in Figure 1.1.

CHAPTER 2

MINING IN THE EAST RAND GOLD FIELD

2.1 South Africa's Geological Viability and Marginal Gold Mines

The first recorded discovery of gold in South Africa during the modern era, occurred on the farm Eersteling, near Polokwane, in Limpopo Province, in 1871. Within twenty years of that discovery, gold started to play an important role in the economy. Initially gold was mined from outcrops, but it was found that the gold ran deeper in a southward dip, which in turn forced mines to use deep mining methods. The discovery of gold in conglomerates, on the Witwatersrand, in 1886, led to the exploitation of the largest gold deposits the world has known to date (Department of Minerals and Energy, 2001). The methods of gold mining in South Africa are unique from other countries, due to the depth at which mining takes place, in some mines at more than 3000 metres below surface.

The Department of Minerals and Energy reports that the underground gold resource base of South Africa amounts to 39 percent of the total identified world gold resources. Despite this gold reserve base, most South African gold mines are now marginal mines. Disproportionate cost increases have been the primary cause for the large gold producing mines becoming marginal mines together with the depletion of high-grade ore reserves; the cooling of the work environment requiring large refrigeration plants; the hoisting of ore over long distances as development of the working places extends ever further from the shafts; and the ever increasing salaries of mine employees. In addition the gold price has, apart from the increase of 21% during 2003, remained static over the medium term. Although many gold mines are still operating in most of the gold fields, some mines have been worked out to such an extent that there are no major mining operations taking place (Tshikalange, 1999).

2.2 Gold and the Gold Mining Industry in South Africa

The most extensive occurrences of gold in South Africa are found within conglomerates in the upper division (Central Rand Group, with an age of approximately 2800 Ma) of the Witwatersrand Supergroup and the basal formation of the overlying Ventersdorp Supergroup. Within the Central Rand Group, the Kimberley Subgroup is found, with a further three economic reef horizons, the Crystalkop, Kalkoenkrans and the Kimberley Reefs. The Kimberley reef is typical of the Witwatersrand conglomerates in that as much as 50 percent of chert occurs. The average pebble assemblage in the Witwatersrand conglomerate is 85 percent vein quartz, 12 percent chert, two percent quartz porphyry and one percent metamorphic clasts. The Witwatersrand rocks were deposited over a time span of some 190 million years, commencing about 2900 million years ago. Gold is also found in the Transvaal Supergroup (2000 to 2600 million years old), notably in the Black Reef (Department of Minerals and Energy, 2001). The Black Reef is a conglomerate bed, containing basal quartzite, carbonates, cherts and banded iron formation and forms part of the Black Reef Quartzite formation at the base of the Transvaal Supergroup (Geoscience, 2001). This reef is both mineralogical and petrographically almost indistinguishable from the uraniferous and pyrite-bearing Witwatersrand reefs, except for a lower metamorphic grade (Frimmel & Minter, 2002).

The mining industry in South Africa, particularly the gold mining industry, has a long-standing economic history. Despite its decline, it remains an important sector of the economy, accounting for four percent of the GDP, six percent of the total non-agricultural formal sector employment and 19 percent of the foreign exchange earnings. Most gold mines have become marginal primarily due to the decline in the gold price and the depletion of higher-grade ore reserves. Grootvlei once a viable mining operation, had seventy-five percent of their mining operations concentrated on the high-grade Black Reef. This position has changed due to the exhaustion of the Black Reef and 75 percent of operations are now concentrated on the lower-grade Kimberly reef ore (Tshikalange, 1999).

2.3 East Rand Gold Field

The East Rand Gold Field is the mining area highlighted in this study. This field has been one of the most significant contributors to the total gold production in the Witwatersrand basin (see Section 4.3.1 for the geological description of the study area).

Gold was discovered in 1886. At the time of the discovery, most mineral rights belonged to the State. Mining development was not difficult as the private sector was expected to provide capital, management and technical expertise (Tshikalange, 1999).

Shortly after the discovery of gold, there were thirty-one gold mines operating the East Rand Gold Field. Most of these mines later merged into large mining companies. More than 9500 tonnes of gold have been extracted since the commencement of gold mining. With current technology, easily accessible ore reserves have been extensively worked out. The current production stands at no more than 20 tonnes per annum. Most of the production comes from slimes dams and small-scale underground mining activities.

The remaining rich ore bodies in the Kimberly Reef Zone, especially at the upper level, continue to minimally contribute to the viability of mines such as Grootvlei. However, since the steady decline of the gold price in 1996, all the mines along the Kimberly Reef have been declared marginal. Mines like Grootvlei have been operating under difficult conditions as a result of surface water ingress into underground mine workings and low-grade ore reserves (Tshikalange, 1999).

2.4 Pumping of Water out of Underground Mine Workings

Groundwater and surface water inflow into mines has been a problem since Roman times. The technical feasibility of mining certain deposits is dependent on the ability to control groundwater inflow, while the economic viability of mining in some cases is limited by the cost of controlling or removing groundwater inflow (Brown, 1989).

Since gold mining started on the East Rand Gold mines, excess water has been encountered, and accumulates in the East Rand Basin. To keep the underground mine workings from flooding, mines have had to install pump stations to pump water to the surface. During 1955, a total of twenty-four mines were pumping some 97Ml per day (Department of Water Affairs, 1986). From 1963 onwards, the Government began to subsidise mines on the running costs of pumping to prevent the premature closure of mines as a result of excessive pumping costs, as well as flooding.

Many mines have decommissioned their operations as a result of these difficulties. Runoff of water through closed gold mines on the East Rand eventually drains into Grootvlei, which is pumping the water out in order to keep operations going (Bourne, 2002). Grootvlei has been receiving sporadic pumping subsidy assistance from the State due to its marginality (Tshikalange, 1999).

The important role of the gold mining industry in the economy over the years has given the impetus to successive governments to provide assistance to marginal gold mines. As far back as 1918, various processes were instituted to look at possible ways of assisting gold mines faced with problems beyond their control. Recommendations of these processes culminated in the promulgation of the Gold Mines Assistance Act of 1968. The intention of the Act was to ensure that gold mines continue operations during periods of hardship. The Government, through support schemes to marginal gold mines, has been providing assistance to Grootvlei with a water-pumping subsidy for more than four years (Tshikalange, 1999). However, the subsidy falls short of the actual cost of pumping (Berry, 2004; Personal Communication).

CHAPTER 3

WETLANDS

3.1 Defining a Wetland

Wetlands are highly productive ecosystems that provide resources that are of economic and social importance. Wetlands provide significant benefits to humans in general due to their ecological functions in the global ecosystem. People may benefit directly from wetland products such as fish, rice, timber, fuel-wood, reeds and medicine or indirectly from their functions such as flood control, nutrient cycling, erosion control, storm protection, ground water recharge, and recreational activities. The most important resource from wetlands is water, which is essential for the survival of life.

“Wetland” is a relatively new term used to describe the landscape that many people have known under different names and indeed, it is used as a generic term for any ecosystem, which has an aquatic base or hydrological driving force. Wetlands occur in many different climatic zones, in many different locations from the upper reaches of a catchment, through river mouths and estuaries, as well as coral reefs, and have a wide range of soil and sediment characteristics. Because of this, wetlands have been an integral part of the landscape since earliest times. They have been given various names in a number of locations, which has added to the confusion of the term “Wetland” (Cowan & van Riet, 1998). There are a variety of definitions including:

According to the Ramsar definition “wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres. Wetlands include marshes, swamps, vleis, pans, bogs, ponds, reed beds and estuaries” (Peck, 1999).

According to Walmsley and Boomker (1988) wetlands are areas where an excess of water is the dominant factor determining the nature of soil development, as well as the type of plants and animal communities living at the soil interface. It spans a continuum of environments w here terrestrial and aquatic systems integrate.

According to the above definitions wetlands can be classified according to the interplay between the land and the water, the level of the water table, impeded drainage, soils, fauna and flora.

Many wetland areas have been lost due to ignorance and misunderstanding of their role. Direct losses are due to their conversion to intensive agricultural, industrial and residential uses, while indirect losses are due to changes in their hydrological regime (Office of International Standards and Legal Affairs, 2000).

3.2 Wetland Classifications and Types

As with definitions, there is a wide range of classifications for wetlands. Cowardin et al. (1979) proposed a classification system based on ecological functions, which has proved to be both robust and widely applicable. Dugan (1990) made an attempt to sort the Ramsar wetland types into Cowardin's classification for use with Asian wetlands. In Table 3.1 Dugan's approach is listed, but it has been adapted for sorting the Ramsar wetland types into Cowardin's broad categories in a manner more applicable to the South African situation.

Table 3.1: Classification of wetlands habitats (Cowan & van Riet, 1998).

COASTAL WETLANDS			
Marine	**subtidal**	1.	Sea bays, straits
		2.	Subtidal aquatic vegetation
		3.	Coral reefs
	intertidal	4.	Rocky marine shores, including cliffs, rocky shores
		5.	Shores of mobile stones and shingle
		6.	Intertidal mud, sand or salt flats
		7.	Intertidal salt marshes
		8.	Intertidal mangroves
Estuarine	**subtidal**	9.	Estuarine waters
		10.	Intertidal mud, sand or salt flats
		11.	Intertidal marshes
		12.	Intertidal forested wetlands
		13.	Brackish to saline lagoons
(Lagoonal)			
INTERIOR WETLANDS			
Endorheic		14.	Permanent and seasonal, brackish, saline or alkaline lakes, flats, pans and marshes
Riverine perennial		15.	Rivers and streams including waterfalls
		16.	Inland deltas
	seasonal	17.	Seasonal rivers and streams
		18.	Riverine floodplains
Lacustrine	**permanent**	19.	Permanent freshwater lakes (≥ 8ha)
		20.	Permanent freshwater ponds, pans (≤ 8ha)
	seasonal	21.	Seasonal freshwater lakes (≥ 8ha)
		22.	Seasonal freshwater ponds, pans (≤ 8ha)
Palustrine	**emergent**	23.	Permanent freshwater marshes and swamps
		24.	Permanent peat-forming freshwater swamps
		25.	Seasonal freshwater marshes
		26.	Peatlands and fens Alpine and polar wetlands
		27.	Springs and oases
		28.	Volcanic fumaroles
	forested	29.	Shrub swamps
		30.	Freshwater swamp forest
		32	Forested peatlands
MAN-MADE WETLANDS			
Aquaculture/mariculture		33.	Aquaculture ponds
Agriculture		34.	Irrigated land including rice fields
		35.	Seasonally flooded agricultural land
Salt exploitation		36.	Salt pans and evaporation pans
Urban/Industrial		37.	Excavations
		38.	Wastewater treatment areas
Water storage areas		39.	Reservoirs
		40.	Hydro-dams

South Africa has designated sixteen wetland sites to the List of Wetlands of International Importance in terms of the Ramsar Convention, of which the Blesbokspruit is one. The Blesbokspruit wetland was selected as a wetland site by South Africa in 1986. These sites all include more than one habitat type, and are a good indication of the diversity found in the wetlands. The Blesbokspruit wetland is classified by the Directory of South African Wetlands as a palustrine wetland - permanent freshwater marsh and swamp (Cowan & van Riet, 1998). Table 3.1 shows the classification of wetland habitats adapted from that approved by the Ramsar Convention 1990.

South African river systems have been severely modified by water resource management to supply water to industry, irrigation, mining, municipal and domestic use, power generation and stock watering. Gauteng, being a major industrial and mining centre has had a tremendous impact on the natural wetland landscape, through the damming of rivers. These impoundments result in the drowning of wetlands and the changing of the inherent hydrological character of the river systems (Department of Water Affairs, 1986).

3.3 Functional Values of Wetlands

The function of wetlands is determined by the landscape in which they occur. This tight relationship means that wetlands exist only as a part of a larger system and not as an independent unit. Wetlands act as the kidneys of the landscape, cleaning and detoxifying impurities from the water flowing through them. Wetlands are important components of all river systems. In addition to their significant role in hydrological functioning, they are centres of biodiversity, supporting plants, animals and insects that are specially adapted to take advantage of wetland conditions (Kotze & Breen, 1994). Figure 3.1 summarizes the important functional values of wetlands.

3.3.1 Stream flow regulation

Wetlands usually have a number of attributes such as gentle slopes, dense vegetation and outflow constrictions that impede the rate of water flow. By delaying the passage of water through the catchment, wetlands add value in that they:

- Attenuate flood peaks; and
- Store water at the wetland site providing a more sustained supply of water during periods of low flow i.e. they augment base flow (Kotze & Breen, 1994).

3.3.2 Flood attenuation

The ability of wetlands to spread and slow down floodwaters, thus attenuating and lagging flood peaks, is a well known fact (Chow, 1959; Dungan, 1990). The attributes most often cited as contributing to the effectiveness of flood peak control are:

- Topography of the wetland site (includes wetland slope and nature of the wetland outlet) (Adamus et al., 1987).
- Size. The larger the wetland the greater the area provided for flood storage and velocity reduction.
- Nature of the vegetation. Tall robust vegetation offers more frictional resistance than short softer vegetation.
- Water regime. The potential for a given wetland to attenuate flood flow is lower if it is already covered with standing water i.e. if it is flooded (Kotze & Breen, 1994).

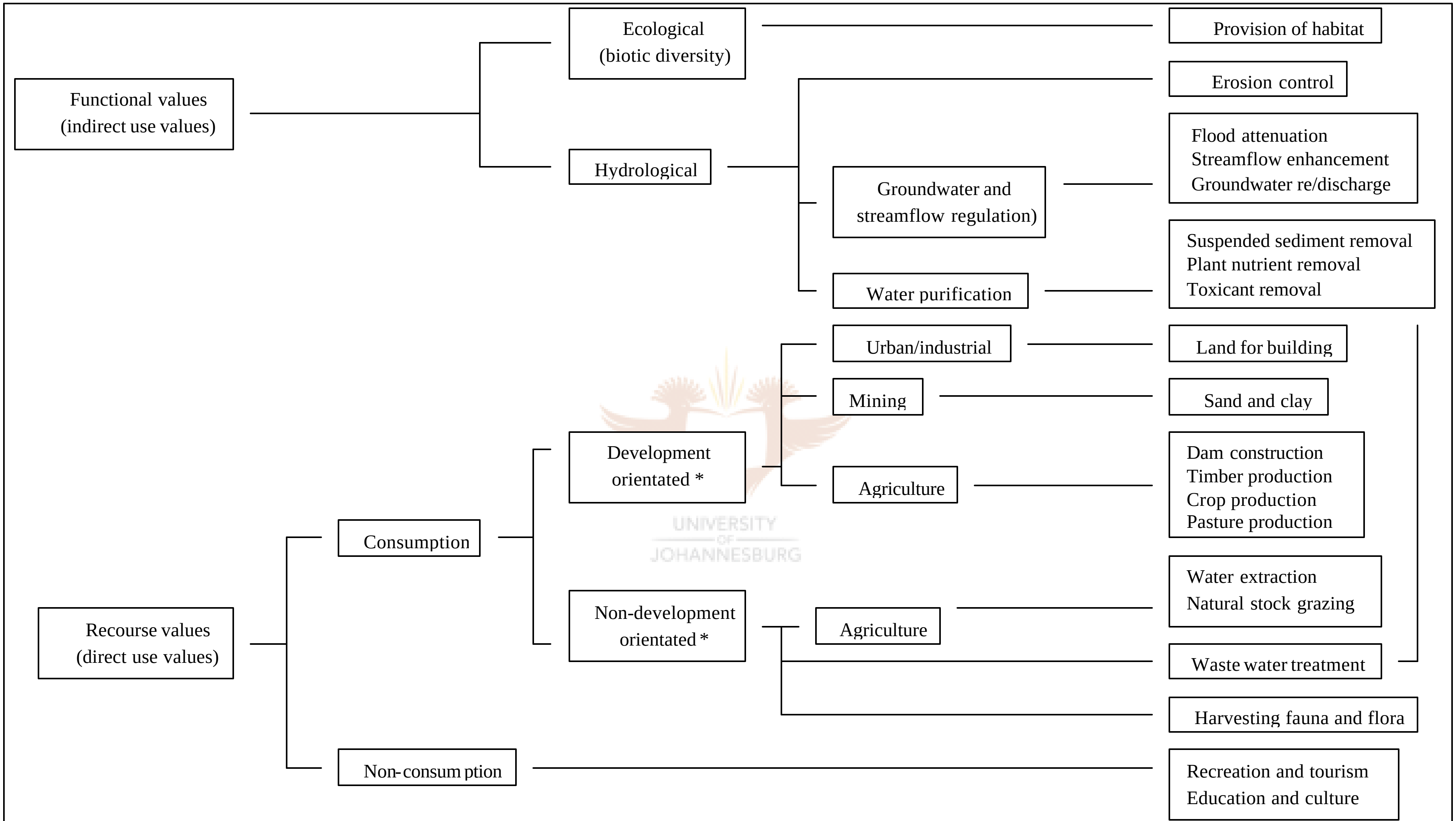
3.3.3 Water storage and enhancement of sustained stream flow

A popular belief is that wetlands increase dry season stream flows by acting as sponges, which gradually release water from wetland storage. Empirical evidence shows that the popular belief of wetlands as sponges, that are able to "squeeze themselves out" during dry periods, is untrue. Nevertheless, evidence shows that wetlands do potentially have a regulatory effect by slowing down the run-off process. This may however be offset by evapotranspirative losses if the wetland vegetation actively grows during the dry season (Kotze & Breen, 1994).

3.3.4 Groundwater recharge and discharge

The role that wetlands play in groundwater recharge and discharge is poorly understood. While it is agreed that some wetlands act as recharge areas, most occur where water is discharging to the surface (Larson, 1981). The relationship of wetlands and groundw ater is largely a function of their hydrological and topographical position as well as their underlying geology (O'Brien, 1988).

Generally speaking, wetlands perched above the main zone of saturation (the upper limit of the regional groundwater) are in a position to recharge the groundwater, while those in contact with the main groundwater zone of saturation serve as aquifer through flows or discharge areas. In addition, some wetlands may change during the course of the year from acting as a recharge area to acting as a discharge area. Even if a wetland acts as an aquifer discharge area, it may exert as much influence on the groundwater aquifers as a wetland acting as a recharge zone (Kotze & Breen, 1994).



* Development orientated values require that the wetland be modified by directly removing the indigenous vegetation and/or through hydrological manipulation. Non-development orientated values do not require that wetland be modified. However, injudicious management may cause extensive modification.

Figure 3.1: Use values provided by wetlands (Kotze & Breen, 1994)

3.3.5 Erosion control by wetland vegetation

Wetland vegetation plays three major roles in erosion control:

- It binds and stabilizes soil.
- It dissipates wave and current energy.
- It traps sediment.

Clark and Clark (1979) state that determining the erosion control value of vegetation in a given wetland is complicated by numerous factors. By way of a general summary they conclude that effectiveness depends on the particular plant species involved (e.g. its flood tolerance and resistance to undermining), the width of the vegetated shoreline band in trapping sediments, the soil composition of the bank or shore, and the elevation of the toe of the bank with respect to mean storm high water (Kotze & Breen, 1994).

3.3.6 Ecological value of wetlands

Wetlands can support an abundance and variety of plants, ranging from duckweed and orchids to black ash. These plants contribute to the earth's biodiversity and provide food and shelter for many animal species at critical times during their life cycles.

The importance of floral diversity in a particular wetland is usually related to two factors. Firstly, the more valuable wetlands usually support a greater variety of native plants (high diversity), than sites with little variety or large numbers of non-native species. Secondly, wetland communities that are regionally scarce are considered particularly valuable (Trochlell, 2002).

Some of the most valuable wetlands for fish and wildlife provide diverse plant cover and open water within large, undeveloped tracts of land. This function may be considered particularly important if the habitat is regionally scarce, such as the last remaining wetland in an urban setting (Trochlell, 2002).

3.3.7 Contribution of wetlands to biogeochemical cycling

The effect of wetlands on biogeochemical cycling on a global scale is poorly understood and often overlooked. It has only been recently that the value of wetlands as major sinks for carbon was recognized (de la Cruz, 1980). Substantial amounts of carbon are currently stored in wetlands and continue to be incorporated into storage. The oxidation of this carbon, caused by wetland drainage, is certainly of global significance (Armentano, 1980; Gorham, 1992), especially in view of rising atmospheric CO_2 levels (Kotze & Breen, 1994).

3.3.8 Aesthetics, recreational, education and science

Wetlands provide peaceful open spaces in landscapes, which are under development pressure and have rich potential for hunters and anglers, scientists and students. Wetlands provide exceptional educational and scientific research opportunities due to their unique combination of terrestrial and aquatic life and physical/chemical processes. Many species of endangered and threatened plants and animals are found in wetlands. Wetlands located within or near urban settings and those frequently visited by the public, are especially valuable for the social and educational opportunities they offer. Open water, diverse vegetation, and lack of pollution also contribute to the value of specific wetlands for recreational and educational purposes and general quality of life (Trochlell, 2002).

3.3.9 Water purification

Water purification is probably the most important function of wetlands and will be discussed in Chapter 5 of this study. The impact of Grootvlei's pumping activities on the water quality of the Blesbokspruit will be analysed and the function that the wetland plays in purifying the water will be evaluated.

Wetlands may contribute substantially to improving water quality by modifying or trapping a wide range of substances widely considered as pollutants. These include suspended sediment (such as silt and clay), excess nutrients (most importantly nitrogen and phosphorus) and toxicants (e.g. pesticides and excess heavy metals). The word "excess" in this study refers to concentrations high enough to render the water unsuitable for human consumption.

Wetlands have several attributes that enhance their capacity for improving water quality (Kadlec & Kadlec, 1979; Mitsch & Gosselink, 1986; Hart, 1995) including:

- A high capacity for reducing the velocity of water flow, which results in suspended particles being more readily deposited;
- Considerable contact between water and sediments (because of the shallow nature of the water column, leading to high levels of sediment/soil-water exchanges);
- A variety of anaerobic and aerobic processes, such as denitrification and chemical precipitation, that remove pollutants from the water;
- The high plant productivity of many wetlands, leading to high rates of mineral uptake by vegetation;
- High soil organic matter contents, which favour the retention of elements such as heavy metals; and
- Microbial decomposition of certain organic substances (such as those introduced through sewage addition). Wetland plants provide substantial surface area for the attachment of microbes, both above- and below-ground, due to the aerobic rhizosphere around roots.

- Wetlands that filter or store sediments or nutrients for extended periods may undergo fundamental changes. Sediments will eventually fill in wetlands and nutrients will eventually modify the vegetation. Such changes may result in the loss of this function over time (Trochlell, 2002).

3.4 Wetland Driving Forces

South Africa's freshwater environments, such as wetlands, are being affected by three main driving forces. Firstly, the natural conditions, particularly the climate, which combines low rainfall with high evaporation rates that together create low availability of run-off. Secondly, the rapid population growth, and need for development through economic activities is leading to greater water demand and increased pollution of available resources (Department of Environmental Affairs and Tourism, 1999). An example of such a situation is the negative impact of mining in the East Rand Basin, with specific regard to Grootvlei, which is pumping mine water into the Blesbokspruit wetland, polluting the ecological character of the wetland. In Chapter 5 the impact of Grootvlei on the functional value of the wetland will be briefly looked at. The third driving force is the policy pertaining to management of water resources, which determines the approach taken by relevant authorities at all levels in the government, to managing the resource and directly impacts other driving forces and pressures. Figure 3.2 shows the main influences that these driving forces have on the aquatic environment and their impacts.

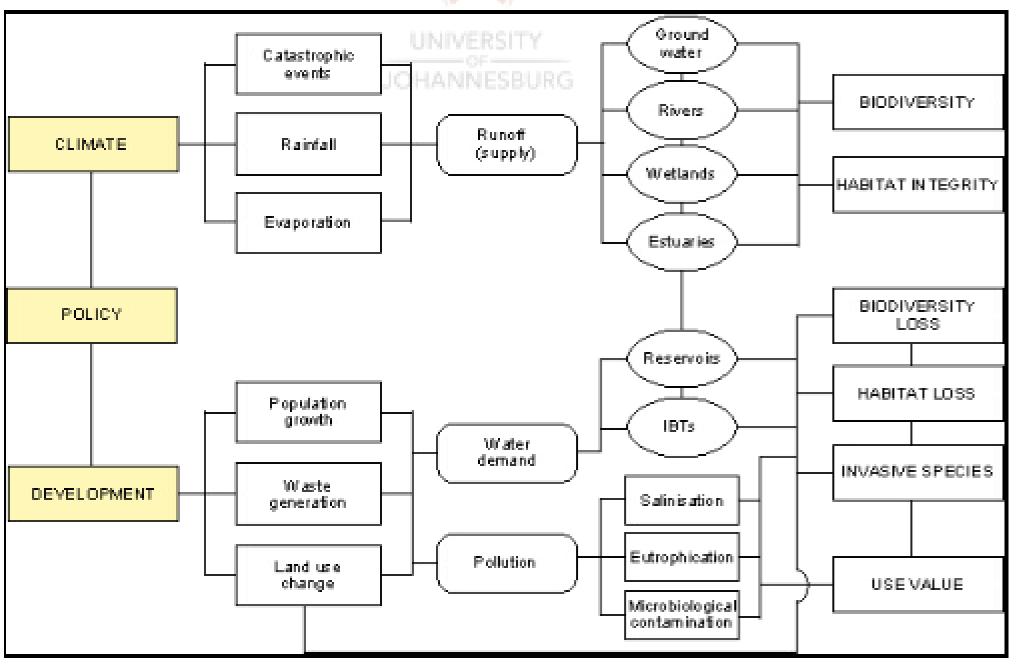


Figure 3.2: The three main driving forces of freshwater in South Africa (Walmsley, 1999)

In the following chapter a general overview will be given of the Blesbokspruit and its main driving force, Grootvlei, which is the major contributor to the poor water quality within the river system and the resulting negative impact on its ecological character.

CHAPTER 4

GENERAL OVERVIEW OF THE STUDY AREA

4.1 Location

The Blesbokspruit wetland and Grootvlei are located in Gauteng Province of South Africa (Figure 4.1). These sites are approximately 3km east of the town of Springs on the East Rand of Gauteng Province.

Figure 4.1: Regional location of Blesbokspruit and Grootvlei Mine (Africa Travel Magazine, 2004)

The Blesbokspruit flows in a southerly direction through the Grootvlei area into the Marievale Bird Sanctuary, which is contained within the mining lease area of Marievale Gold Mining Company Limited. Half of the site, which is protected, is within the Marievale Bird Sanctuary (Figure 4.2). The other half is owned by the Anglo American Group who maintains a private waterfowl sanctuary.

The Blesbokspruit system was a small, non-perennial spruit prior to mining and industrial development on the East Rand (Dini, 1999). The current permanent flooded status is due to artificial inputs of water (e.g. from mines and sewage treatment works) and the creation of a weir over across the river, originally as a water storage facility for the mine. Since the early 1930's, the area has become exposed to a variety of industrial water discharge, mainly from gold mining activities. Due to industrial water discharge from a number of industries, including Grootvlei, the river and wetland have expanded substantially and now form a significant Reed and Bulrush Phragmitis/Typha wetland.

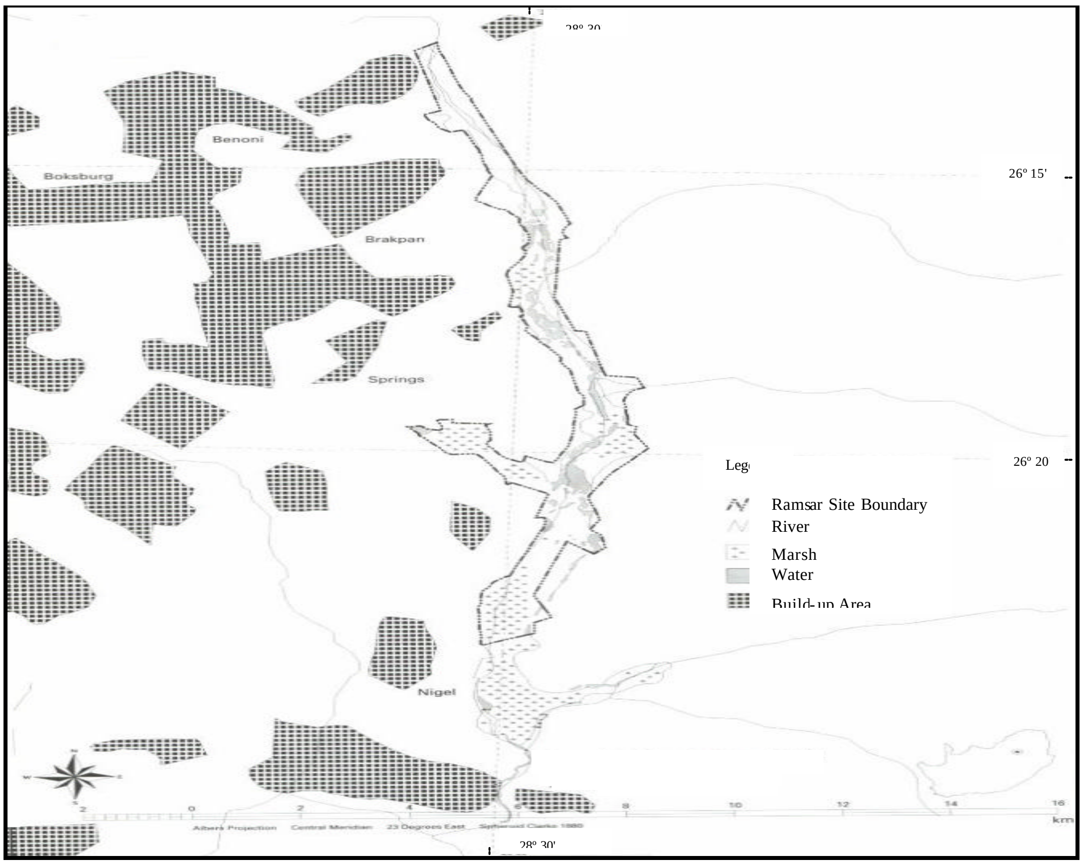


Figure 4.2: Location of Blesbokspruit Wetland (Cowan & Marneweck, 1996b)

By the time the Blesbokspr uit was designated as a Ramsar site (Department of Water Affairs, 1986), the landscape had been transformed into a permanent wetland that was valued for the variety and abundance of bird species, which it contains. The wetland is currently maintained in its artificially inundated state by daily inputs of several megalitres of eutrophic water from sewage works, mines and industries (Haskins, 1998).

4.2 Bio-Physical Characteristics of the Study Area

4.2.1 Geology and related water ingression

The geology of the area is fairly simple with flat lying sedimentary rocks of Karoo and Transvaal age (250 Ma and 2200 Ma respectively) overlying older formations of gold bearing Witwatersrand (2500 Ma) (Dini, 1999). The gold bearing reefs of the Witwatersrand Supergroup and Transvaal Sequence sub-outcrop and outcrop along an arc in the East Rand Basin (Appendix 1), which stretches from Benoni eastwards towards Springs and then southward to Nigel (Barradas & Loggenberg, 1996).

Surface exposures, i.e. outcrops of the Witwatersrand Reef, occur in some areas within the East Rand Basin, but none are present in the study area. The Main Reef outcrops occur east of Benoni and again in the Nigel area; usually in the near vicinity of the Blesbokspruit Valley where the thin cover of Karoo sediments have been denuded by weathering. In the Springs area, the Witwatersrand reefs sub-outcrop against Transvaal Sediments. The Black Reef Quartzite Formation and the Malmani dolomites form a part of the Transvaal sequence. The Black Reef Quartzite Formation overlies the Witwatersrand strata unconformable and is in turn overlain by Malmani dolomites of the Chuniespoort Group (2500 Ma old), which form an important natural water reservoir, especially in zones of broken ground as a result of post- Transvaal faulting and weathering. The Karoo sediments overlay the basin. Extensive erosion took place prior to the deposition of the Karoo sequence (Barradas & Loggenberg, 1996) (Appendix 2).

Major east-west striking tear faults occur within the Basin area, with lateral movement in the order of some 1000 metres. These faults have been active throughout the history of the Witwatersrand deposition and indications are that this activity continued through the Transvaal depositional period. This created br oken ground conditions in the dolomites. Where stooping occurs near the Black Reef sub-outcrop, water seeps from the dolomite into the mine workings (see Section 4.5) at a higher rate via hanging wall cracks (Barradas & Loggenberg, 1996).

Grootvlei is exploiting the Kimberly Reef of the Witwatersrand Supergroup and the Black Reef of the Transvaal Formation for gold and other precious metals. The mine started its mining operations on the Main Reef, but this reef horizon has now been depleted and is flooded. The primary product is gold, plus secondary metals such as silver, osmium, rhodium, ruthenium, iridium and platinum (Digby Wells & Associates, 1996).

The sub-outcrop of the Black Reef occurs at a depth of approximately 200 metres. Both the Black and underlying Kimberley Reefs have been mined at depths in excess of 200 metres. In 1996 the mine used 6Ml of water per day for its underground mining operations whilst its pumping rate per day varied between 65 to 70 Ml. In July 1996 the water level was recorded at 48 metres above the No. 3 Shaft pump station elevation. Some of the Kimberley Reef workings were at that time already flooded (Barradas & Loggenberg, 1996).

Many surface collapses, resulting from shallow coal undermining, are present in the vic inity of the defunct Largo Colliery, which is north, and in close proximity, of the Blesbokspruit (Figure 4.3 and Figure 4.4). In view of the shallow coal undermining below the Blesbokspruit and visible occurrence of numerous ground collapses in this area, it is concluded that ground collapsing has also occurred in the Blesbokspruit itself (Barradas & Loggenberg, 1996), resulting in the ingress of water into the old colliery workings themselves, which in turn causes acid water pollution (Berry, 2004; Personal Communication).

Figure 4.3: Typical ground collapses on the surface of Largo Colliery (Barradas & Loggenberg, 1996)

Figure 4.4: A sealed defunct shaft of Largo Colliery with accumulated water (Barradas & Loggenberg, 1996)

4.2.2 Soil

Approximately one third of the land within two kilometres of the Blesbokspruit (from Grootvlei to the confluence of the Blesbokspruit and the Suikerbosrand River) consists of deep well drained red loamy soils and deep imperfectly drained yellow–brown loamy soils, suited to irrigation with water of high to moderate quality (Digby Wells and Associates, 1996) (Table 4.1).

Table 4.1: Soils within the Blesbokspruit area (After Institute for Soil, Climate and Water, 1993)

Soil Description	Dominant Soil Form	Subdominant Soil Form
Mainly deep, well drained red loamy soils	Hutton	Shortlands Swartland Oakleaf
Predominantly deep to moderately deep imperfectly drained yellow brown loamy soils	Avalon	Clovelly Glencoe Tukulu
Shallow imperfectly drained yellow brown loamy soils	Avalon Glencoe	Westleigh
Other soils	Rensburg Mispah Glenrosa Estcourt Groondal	Katspruit Willowbrook

Since pumping on a far greater scale started in 1995, as a result of the discontinued pumping activities by Sallies Mine, there has been more water available for irrigation purposes. However, a blend of mine water and river water may lead to extensive salination of the soil. The soils along the Blesbokspruit are not particularly suited to irrigation with saline water – in 1996 there were already signs of soil salination. Heavy metals in the mine water are unlikely to become a problem unless the soil pH drops significantly to below 5.5 (Digby Wells and Associates, 1996).

With a decrease in the water quality of the Blesbokspruit due to the pumping of extraneous water from Grootvlei, a potential for soil degradation exists if the Blesbokspruit is used for irrigation purposes. Proper mitigation by good management practices, future water treatment, use of assistance from agricultural consultants for the mine's expense, as well as financial assistance from the government, could reduce the potential problem of soil degradation.

4.2.3 Climate

The study area falls within the summer rainfall area (Land Type Survey Staff, 1985). The average annual rainfall is 670 mm recorded over a period of 31 years. Hailstorms are not uncommon during summer. Snow falls on rare occasions. One of the heaviest snowfalls was recorded in July 1964 when a depth of 200 mm was measured and the area was blanketed with snow for three days. Temperatures vary from -10° C in winter to 35° C in summer. On a regional basis frost is for 115 days of the year between mid-April and mid-September (Digby Wells and Associates, 1996).

4.2.4 Hydrology

The Blesbokspruit is a hydrologically important river in the Gauteng Province, since it drains a large area before joining the Suikerbosrand River, which ultimately flows into the Vaal River. The topography of the immediate catchment is gradual, so that the increase in flow volumes has resulted in the formation and lateral expansion of the Blesbokspruit wetland. The natural hydrology of the stream has been suppressed by artificial inputs of eutrophic water (from mines, sewage works and various industries). Seasonal fluctuations in water level and depth are largely masked by the artificial water inputs. The wetland is thus permanently flooded. Before the 1930's the wetland would have been temporarily filled and associated with a small non-perennial stream (Dini, 1999). The site was designated as a Ramsar site in it's permanently flooded (i.e. artificially supported) state.

Water from the Blesbokspruit eventually flows into the Vaal River, which supplies water for a large region, ranging from Parys in the Free State to where it meets with the Orange River at Douglas in Northern Cape Province. Maintaining good quality water in the Blesbokspruit is therefore important. Although the wetland does have a natural purification capacity, it is not regarded as the primary purifier of effluents entering the catchment, as effluents are required to be treated to Department of Water Affairs standards. Since this ideal is not always realized, the Blesbokspruit wetland undoubtedly assists in purification.

4.2.5 Vegetation and animal life

The original vegetation of Blesbokspruit wetland has been completely replaced by a modified system. The changes that have taken place in the wetland are a consequence of increasing development in the area resulting in a number of embankments and causeways carrying roads and railway lines across the stream which cause the flow to spread out over the valley (Dini, 1999). In addition to these artificial impoundments of water, the following human-related inputs have shaped, and continue to shape, the present day ecological character of the system:

- Sewage discharges from five treatment plants, which enrich the system and foster the growth of reed beds.
- Discharges of industrial effluent, which maintain water chemistry at levels, which differ from ancestral levels.
- Siltation from mine dumps.
- Water abstraction, which changes flow patterns and nutrient levels.
- Causeways, which result in modified flow depths (Digby Wells and Associates, 1996).
- With respect to the natural vegetation these factors have increased the extent of the reedbeds especially *Phragmites australis* (Common Reed) and *Typha*

latifolia (Bulrush), which account individually for approximately 53 and 19.51 percent of the reedbeds. Other reedbeds include *Spirogyra spp* (Green Alga), *Azolla filliculoides* (Red Fern), *Ceratophyllum demersum* (Hornwort), *Potamogeton pectinatus* (Fennel-leved Pondweed) and *Potmogeton crispus* (Curly Pondweed).

The Blesbokspruit is situated in the Cymbopogon-Themeda veld (Acocks veld type no. 48). This veld type merges with the Bankenveld and is a spare, tufted sourveld.

Some other species found in the area include:

- *Cunodon dactylon*
- *Enyda fluctuans*
- *Jancus effusus*
- *Eragrostis spp*
- *Themeda triandra* (Acocks, 1988).

Undisturbed, this area would consist of sparse, tufted veld with several grass species, including *Themeda trianda*. The area is however highly developed and little, if any, of the original grassland remains (Table 4.2).

Table 4.2: Dominant vegetation species of Blesbokspruit and Grootvlei Mine (Digby Wells and Associates, 1996)

Blesbokspruit	Grootvlei Mine
Cunodon dactylon	*Chymbogopon plurinoides*
Enyda fluctuans	*Themeda triandra*
Jancus effusus	*Hyparrhenia hirta*
Eragrostis spp	*Cynodon dactylon*
Themeda triandra	*Digitaria argyrogrpta*
	Gazania krebsiana
	Crinum bulbispermum
	Erythrina zeyheri
	Cyrtanthus tuckii
	Phragmited australis
	Typha latifolia
	Polygonum lapathifolium
	Alisma plantago-aquatica
	Imperata cylindrica
	Falkia oblonga
	Homeria pallida
	Aloe ecklonis

Due to the considerable disturbance in the area of Grootvlei and surrounding areas, animal life is limited to mammals, birds, reptiles and insects common to developed areas. The Blesbokspruit supports a variety of fish, amphibians, reptiles, crustaceans and rodents. The Spotted Necked Otter, Water Mongoose and many of the larger birds depend on these animals for their food supply (Digby Wells and Associates, 1996).

4.3 Land Uses

Before mining started in the area the Blesbokspruit flowed unrestricted through a broad, grassy valley. By the mid-1940's, mining activities in the area were in full production. Residential areas had been established for mine employees and many trees and shrubs were planted. Several roads were built on embankments crossing the spruit, which have dammed up large areas of shallow open water, which has provided a natural habitat for beds of *Phragmites* and *Typha* species (Dini, 1999).

In 1971, an area of about 500 Ha of mainly vlei and grassland, at the southern end of the vlei, was donated by Marievale Consolidated Mines Limited to the Transvaal Division of Nature Conservation (now called Gauteng Nature Conservation) to be managed as a Bird Sanctuary. A further 385 Ha was donated in 1976. Today approximately 1000 Ha of the designated site, which is approximately 7.4 kilometres long and approximately 500 metres wide (varying in different locations), falls within a proclaimed provincial nature reserve, Marievale Bird Sanctuary (Madden, 2002). Since the Sanctuary was officially proclaimed in 1978, further areas of 860 ha of the farm Grootvaley, at the northern end have been protected by the Anglo American Group and the Nature Conservation Division. The total length of the Blesbokspruit now under protection is roughly 20 kilometres (approximately 1858 Ha) (Dini, 1999).

The Blesbokspruit catchment, in its entirety, covers approximately 60 km^2, of which approximately 45% of the catchment is urbanized while the remaining land is utilized for agricultural, sewage treatment works and mining and industrial activities (Dini, 1999).

Agricultural activities include maize, vegetable, lucerne, kikuyu (lawn grass), fodder and flower production. Water from the Blesbokspruit is used to irrigate these crops. The irrigation and fertilizers used for these activities are negatively impacting on the water quality of the Blesbokspruit.

Several sewage treatment works (including ERWAT works) are located along the Blesbokspruit and the treated sewage is discharged into the Blesbokspruit. These discharges have contributed to the eutrophic status of the wetland. Continued urban growth in the catchment area has necessitated the upgrading of existing, and the creation of new, sewage treatment works. The impact of sewage discharges into the Blesbokspruit is likely to increase, unless more efficient treatment technologies are introduced (Dini, 1999).

Urban expansion is a major problem. Settlements have occurred well within the 1:50 year floodline in many places. Urban expansion is especially a problem with regard to the run-off and the sewage treatment works. The greater urban expansion becomes, the greater the demand for land adjacent to the site. This will result in more run-off and discharge of effluent into the Blesbokspruit system by sewage treatment works.

Mainly industrial (including Sappi) and gold mining activities take place in the Blesbokspruit area (Appendix 3). Dewatering of underground mine workings contribute large quantities of poor quality water to the Blesbokspruit, with Grootvlei being the main contributor in this regard. Settling ponds and a pilot desalination plant have been introduced to reduce the pollution to the wetland. Lack of funds to treat extraneous water discharged from underground mine workings adjacent to the Blesbokspruit means that the quality of water discharged into the Blesbokspruit will deteriorate (Dini, 1999).

Industrial, mining and sewage works contribute more water to the system than would be expected in ideal conditions. This volume of water is likely to increase in the future, due to urban expansion in the catchment area.

All of the abovementioned land uses have impacted on the Blesbokspruit in one way or another. The Blesbokspruit wetland has been listed on the Montreux Record due to upstream and adjacent activities, which threaten the ecological nature of the site. Due to the linearity of the system and the fact that the site is located downstream of potentially harmful industries, mines and sewage works, these threats are difficult to control. The lack of an integrated catchment management plan may also contribute to the difficulties experienced with the site. It has been proposed that the Department of Water Affairs and Forestry, in conjunction with a Catchment Management Agency, develop such a plan.

4.4 Grootvlei Mine Ltd.

4.4.1 Location and function

Grootvlei is a subsidiary of Petrex (Pty) Ltd and is situated along the eastern boundary of the East Rand Basin, within the municipal area of Springs (Ekurhuleni Metro Council) (Appendix 3 and Appendix 4) (Oryx Environmental and Jones and Wagener Consulting Engineers, 2003). Grootvlei is exploiting the Kimberley Reef, and the Black Reef for gold, using underground mining methods, which are taking place at the depth of 700 metres (Tshikalange, 1999).

Initial shaft sinking operations commenced in 1906, but were abandoned the following year when water was intersected in the shaft. Mining activities started again from the neighbouring East Gedult Mine in 1934, and gold was first produced in 1938 in close proximity to the Blesbokspruit (Digby Wells and Associates, 1996).

As discussed in Section 4.3.2, Grootvlei is currently one of the last gold mines operating in the Springs area of the East Rand mining basin (Tshikalange, 1999).

4.4.2 Pumping of mine water into Blesbokspruit wetland

The East Rand mines were dewatered from the Sallies Mine into the Withokspruit until 1991. During 1991, Sallies Mine ceased operations. The water level in the flooded mine workings was monitored from two observation point, Sallies No. 1 Shaft and Grootvlei No. 4 Shaft. Realising that the closure of Sallies was going to affect productive operations, Grootvlei applied for pumping assistance from the state. Temporary measures were provided for three months before the full assistance proposal was assessed. Based on the 1962 guideline of the Cabinet, which provided for any assistance to marginal gold mine to be approved, a mine must be threatened within five years with inflow of extraneous water. It was envisaged that the water problem was going to threaten Grootvlei within a period of two years. Because this did not happen within suc h a period, pumping assistance by the state was not considered within a period of five years. The threatening water level was only experience in 1995 and it was then that the state decided to assist Grootvlei with pumping costs (Tshikalange, 1999). Grootvlei was asked by the South African Government to establish a pump station at No. 3 Shaft (Appendix 4 and Appendix 5) to pump extraneous water from the East Rand Basin (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

Groundwater, which has accumulated in the East Rand Basin, is being discharged into the Blesbokspruit from the adjacent Grootvlei. This water is derived from various sources. Grootvlei pumps on average 75 mega litres of water per day from the mining basin (Appendix 6). (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003). The balance of the water enters the mine in a polluted state from underground workings (see Section 4.1.2). A number of potential sources of water inflow to the East Rand Basin and subsequently Groovlei exist:

- Groundwater seeps from dolomites;
- Water inflow from surface via shallow reef zones;
- Inflow from geological structures underlying the Spruit;
- Inflow via shafts and subsided mining areas (Figure 3.3); and
- Seepage under dams (Oryx Envir onmental and Jones & Wagener Consulting Engineers, 2003).

The Blesbokspruit wetland is situated down-stream of the discharge point and has been declared a Ramsar site, which gives the wetland international importance. The Blesbokspruit was however placed on the Montreux Record in response to contamination by large quantities of polluted water discharged into the Spruit (Dini, 1998). On the other hand, the pumping of the water out of the underground workings is essential for Grootvlei's continual operation. Predictions that the mine will flood, if the mine does not pump the water out of the mine workings have been made, which will result in inaccessibility to the gold reserves (Cowan & Marneweck, 1996a). Flooding of the underground mine workings will also ultimately affect at least three other marginal mines in the area and the water will eventually rise to the surface, firstly in the Nigel area. As a result Grootvlei continuously pumps water from its underground workings to ensure safe mining conditions.

In terms of the Minerals Act, 1991 (Act 50 of 1991), an Environmental Management Programme Report (EMPR) was submitted in which permission was requested to pump between 40 000 m^3 and 65 000 m^3 of this floodwater daily from the mine into the listed site, the Blesbokspruit (Cowan and Marneweck, 1996b). The Department of Water Affairs and Forestry granted permission for continued pumping on condition that measures to improve the quality of the water were installed and a permanent solution to the problem, in the form of a desalination plant, was investigated (Cowan and Marneweck, 1996b).

In August 1995 an Environmental Impact Assessment, commissioned by the Department of Minerals and Energy, concluded that the proposed quantity and quality of mining effluent to be discharged from Grootvlei into the Blesbokspruit would have a limited detrimental effect on the relevant receiving water bodies (Foundation for Water Research, 2000).

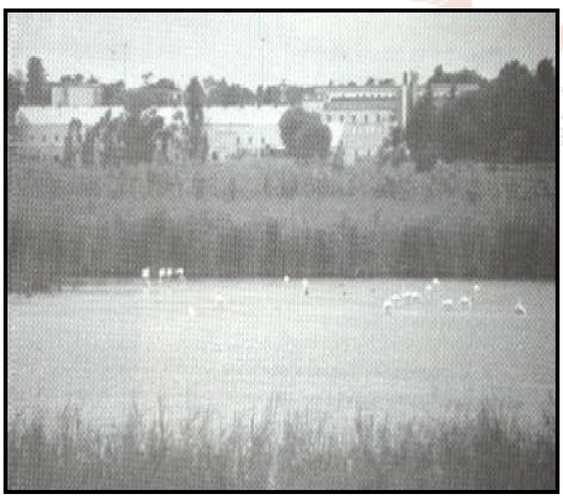


Figure 4.5: Blesbokspruit showing the proximit Grootvlei (Cowan & Marneweck, 1996b)

Figure 4.6: The No. 3 Shaft of Grootvlei Mine (Barradas and Loggenberg, 1996)

Pumping of the extraneous water from underground mine workings into the Blesbokspruit commenced in October 1995 from the No. 3 Shaft of Grootvlei (Figure 4.6, 4.7 and Figure 4.8). Some months later a red slime was observed in the Blesbokspruit. This caused widespread concern that the Ramsar certified wetland within the Blesbokspruit was under threat from the introduction of polluted mine water.

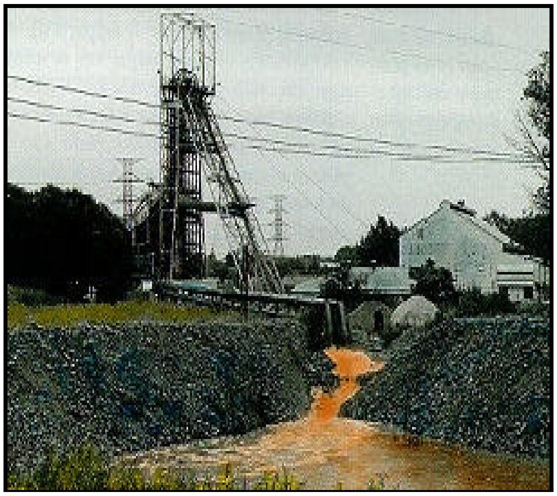


Figure 4.7: Discharge of highly polluted water i the wetland by Grootvlei Mine, December 1995 (Dini, 1998)

Figure 4.8: Discharge water pumped at Grootvlei Mine No. 3 Shaft (Barradas and Loggenberg, 1996)

In December 1995 the South African government ordered Grootvlei to switch off pumps draining the gold mine, after the mine refused to stop pumping polluted water into the Blesbokspruit wetland, and also refused to install filters to remove iron dioxide from the water (Figure 4.7). The problem with this action was that 6000 jobs were put in jeopardy, and because of this, pumping resumed in February 1996 (U.S Water News, 1996).

4.4.3 Water treatment

A High Density Separation (HDS) plant has been constructed at Grootvlei to deal with the contaminated underground water. This treatment plant is situated on the banks of the Blesboksprui below No. 3 Shaft. The plant has been constructed on a waste rock foundation. This raises the level of the plant to higher than the natural ground level. The reason for this is to ensure that the plant can act under gravity (Digby Wells and Associates, 1996). The undergr ound water is brought to the surface and is treated in the HDS (Appendix D). The plant removes some of the iron oxide pollutant from the water before it is discharged into the Blesbokspruit. The HDS process produces a more dense precipitate. It undoubtedly improves effluent quality, however it still produces water with a high dissolved salt content (Wren Technologies, 2001).

The sludge from the plant is discharged into paddocks on top of a tailings dam, and thereafter the water flows into settling tanks before being discharged directly into the Blesbokspruit (Figure 4.9 and Appendix B).

Figure 4.9: Dams into which the water is released before flowing into the Blesbokspruit, showing a high degree of pollution (1996) (Barradas and Loggenberg, 1996).

Rainwater, which may be contaminated in the plant, is pumped into the plant flow system. The effect of this additional water is that it has a diluting effect on the slimes pumped to the slimes dams (Oryx Environmental & Jones and Wagener Consulting Engineers, 2003). Any spillage from the mixing tanks and clarifier falls onto a paved block area.

4.4.4 Impact of discharging extraneous water from underground mine workings into the Blesbokspruit wetland

Despite the measures mentioned above, the impact of the discharge on the ecological character of the Ramsar site has been severe. The high concentration of dissolved solids, and large volumes of water being discharged, have impacted on the hydrology and ecology of the wetland to the extent that it no longer fulfils the criteria under which it was designated as a Ramsar site in 1986 (Dini, 1999).

The impacts are primarily manifested in two ways. Firstly, water quality has deteriorated, resulting in a decline in the abundance and diversity of aquatic animal species. Secondly, the seasonal fluctuation in water levels in the wetland has been replaced by permanently flooded conditions. As the region is characterised by summer rainfall, the system originally displayed a natural regime of high summer flows and reduced water levels in winter. This dynamic fluctuation in water levels maintained habitat diversity and ecosystem productivity. The result of high stable water levels, together with large concentrations of nutrients derived from domestic and industrial discharges upstream of the wetland, has produced a severe reed encroachment problem, that has brought about a decline in habitat diversity. This loss of the dynamic habitat mosaic has induced a corresponding decline in diversity of birds and other species, which depend on the wetland for feeding, roosting and breeding sites (Dini, 1998).

4.5 Functional Importance of Blesbokspruit

The issue of the discharge of water by Grootvlei has proved to be highly complex, and involves social, economic and political elements. The threat of job and revenue losses following the closure of Grootvlei, should it no longer be permitted to discharge mine water into the wetland, has been effectively used at a political level to motivate the need to continue pumping water. It is clearly an issue that cannot be easily resolved. Grootvlei is continuing to discharge polluted water into the wetland. As a result, there has been no improvement in the ecological character of the site, and there is therefore no reason to consider the removal of Blesbokspruit from the Montreux Record at this time (Dini, 1998).

The Blesbokspruit has a functional importance within the agricultural community of the surrounding area. A number of agricultural activities take place around it and landowners living adjacent to it use the water from the Blesbokspruit for irrigation purposes.

The Blesbokspruit is also of hydrological importance as previously mentioned. It eventually flows into the Vaal River, which provides water to a large region.

In part 2.3 the functional importance of wetlands was discussed. The Blesbokspruit wetlands exhibit these functional characteristics. There is however one main function which needs to be highlighted to illustrate the importance of the Blesbokspruit wetland in this study.

The wetland serves as a purifier for industrial effluent entering the spruit from local industries, sewage works and mines, before it joins the Suikerbosrand River downstream. Below Vanderbijlpark, the Suikerbosrand River flows into the Vaal River Barrage. The Blesbokspruit is thus a sub-catchment of the Vaal River catchment.

With the increase in development in the Blesbokspruit catchment, it is becoming clear that only an integrated approach to the management of the wetland, which takes into account all major stakeholders, will succeed in restoring and maintaining the ecological character of the wetland. The survival of the Blesbokspruit Ramsar site will depend on the sound management of its catchment area.

CHAPTER 5

WATER QUALITY SAMPLING AND ANALYSIS

5.1 Water Quality

The term water quality is used to describe the microbiological, physical and chemical properties of water that determines its fitness for use. Many of these properties are controlled or influenced by substances, which are either dissolved or suspended in the water.

- Microbiological quality refers to the presence of organisms that cannot be seen by the naked eye, such as protozoa, bacteria and viruses.
- Physical quality refers to water quality properties that may be determined by physical methods such as conductivity, pH and turbidity measurements.
- Chemical quality refers to the nature and concentration of dissolved substances such as salts, metals and organic chemicals (Water Research Commission, 1999).

In this study no focus will be placed on biological water quality.

5.2 Important Chemical Water Quality Variables

Water quality in the Blesbokspruit is generally poor due to artificial inputs from mines, sewage treatment works and other industrial activities (i.e. point source discha rges). The quality of the water is mainly influenced by total dissolved salts. The "fingerprint" of the water chemistry is similar throughout the area (high sulphate, phosphate, nitrite/nitrate and ammonia concentrations).

The chemical characteristics of water in abandoned underground workings are essentially identical to the chemical properties of parent infiltrated water, together with the oxidation products of pyrite. Abandoned mine water contains iron and other sulphates. Low concentrations of H_2S and dissolved sulphates remain in water indefinitely (Singh, 1989).

After consultation with the Environmental Manager of Grootvlei, personnel from Rand Water, as well as Academics from Rand Afrikaans University, it was decided to use four variables for the purpose of this study. These were chosen to represent the impact of mining activities on the water quality of a water resource. The following variables are associated with mining activities and are analysed and discussed in this study.

- pH
- Electrical Conductivity (EC)
- Magnesium (Mg)
- Sulphate (SO_4)

The iron content of the water was taken into consideration as one of the variables, but was disregarded when statistical analysis showed that the iron concentrations have remained constant over the years and over the distribution of the sample points (Appendix 8).

pH is the measure of the acidity or alkalinity of the water on a scale from 1-14 (1 being very acidic, 7 being neutral and 14 being very alkaline). The pH of natural water is determined largely by geological and atmospheric influences. Freshwater resources in South Africa are relatively well buffered.

However, human induced acidification, from industrial effluents, mine drainage and acid precipitation, can cause a lowering of the pH, leading to mobilisation of elements such as iron, aluminium, cadmium, cobalt, copper, mercury, manganese, nickel, lead and zinc. This may impact the biota, as well as mining, domestic, industrial and agricultural users.

Electric Conductivity (EC) is a measure of the ability of water to pass an electrical current and reflects the levels of dissolved salts present in the water. EC is therefore directly linked to total dissolved solids (TDS). TDS gives an indication of the salinity or salt content of the water. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulphate and phosphate anions or sodium, magnesium, calcium, iron and aluminium cations (Environmental Protection Agency, 2003).

Electric Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity as granite is composed of more inert materials that do not ionise when washed into the water. On the other hand, streams that run through areas with clay soils (such as the area under study) tend to have higher conductivity due to the presence of materials that ionise when washed into the water. Ground water inflows can have the same effects, depending on the bedrock they flow through (American Public Health Association, 1992) such as the case of Grootvlei wastewater. Electric Conductivity gives a good indication of water pollution or the deterioration in water quality of a water body.

An increase in EC and therefore TDS indicates an increase in salinity. Salinity refers to the total dissolved inorganic compounds in the water and is measured by TDS. Effects of increased salinity include salinisation of irrigation soils; reduction in crop yields; increased scale formation and corrosion in domestic and industrial water conveyance systems; increased requirement for pre-treatment of selected industrial water uses; and changes in biota (Environmental Protection Agency, 2003).

In most natural waters, sulphate ions tend to occur in lower concentrations than bicarbonate or chloride ions. Sulphates are not toxic. In excess however, they form sulphuric acid, which is a strong acid that reduces pH and can have devastating effects on aquatic ecosystems. This is particularly problematic in water seeping from mines, where sulphate levels can be extremely high.

Magnesium enters the freshwater system through the weathering of rocks, especially limestone, and from the soil through seepage, leaching and run-off. As a contributor to the total hardness, magnesium can have detrimental effects on drinking water quality (Day, 1963). Total hardness of water impacts on the taste of the water.

5.3 Groundwater Composition of Grootvlei Mine

The raw groundwater composition of Grootvlei before being pumped into the Blesbokspruit is listed in Table 5.1. More variables are presented within Table 5.1, Table 5.2 and Table 5.3 to give an extended overview of the problem, but only the four chosen for the study (Refer to p.32) will be further discussed.

Table 5.1: Raw water composition (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003)

Variable	Unit	Minimum	Maximum	Average
pH		**6.0**	**6.8**	**6.4**
Temp	°C	25	28	26.7
Dissolved Oxygen	mg/l	2.0	3.5	2.5
EC	mS/m	**294.0**	**347.0**	**321.8**
TDS	mg/l	1928	3138	2879
Cl	mg/l	170	198	183.8
F	mg/l	Na	Na	<0.2*
SO4	mg/l	**930**	**2065**	**1383**
Na	mg/l	187	458	240
Ca	mg/l	385	493	422
Mg	mg/l	**170**	**251**	**197**
Al	mg/l	0.1	0.9	0.3
Fe	mg/l	82	210	135
Mn	mg/l	2.4	5.4	4.1
Zn	mg/l	NA	NA	0.01
Ba	mg/l	NA	NA	0.001*
Ni	mg/l	NA	NA	0.003*
COD	mg/l	12	80	35.480
Suspended Solids	mg/l	NA	NA	NA
Turbidity	NTU	NA	NA	NA

Bold printed figures are the variables of importance for this study

NA: Not Available

Additional variables are included for comparison with the water quality standards illustrated in Table 5.2, Table 5.3 and Table 5.4.

Presently, all mine water is passed through the HDS plant, producing a treated water quality (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003) as shown in Table 5. 2. When comparing the water quality of the water treated by the HDS plant (Table 5.2) with the raw water composition (Table 5.1) it is can be seen that of all four variables (pH, conductivity, magnesium and sulphate) chosen for this study, conductivity and magnesium levels have improved in quality after being treated by the HDS plant. However the sulphate levels show an increase in the average concentration before being discharged into the Blesbokspruit. pH levels were not available for this study.

Table 5.2: HDS treated water (As discharged into Blesbokspruit in 2002) (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003)

Variable	Unit	Minimum	Maximum	Average
pH		**NA**	**NA**	**NA**
Temp	°C	25	28	26.7
Dissolved Oxygen	mg/l	NA	NA	NA
EC	mS/m	**294**	**333**	**315**
TDS	mg/l	2472	2653	2518
Cl	mg/l	179	184	181.2
F	mg/l	NA	NA	NA
SO4	mg/l	**1386**	**1478**	**1431**
Na	mg/l	230	244	239
Ca	mg/l	310	360	341
Mg	mg/l	**108**	**123**	**117**
Al	mg/l	NA	NA	NA
Fe	mg/l	0.32	1.88	0.92
Mn	mg/l	0.8	1.1	1.1
Zn	mg/l	NA	NA	NA
Ba	mg/l	NA	NA	NA
Ni	mg/l	0.02	0.035	0.025
COD	mg/l	NA	NA	NA
Total Hardness	mg/l $CaCO_3$	1098	1228	1165
Total Alkalinity	mg/l $CaCO_3$	120	146	137
Suspended Solids	mg/l	4	31	21
Turbidity	NTU	NA	NA	NA

Bold printed figures are components of importance for this study

NA: Not Available

Table 5.3 illustrates the target ranges for water quality discharged into the Blesbokspruit according to the Department of Water Affairs and Forestry. Note that no objective is stipulated for magnesium levels.

Table 5.3: Current objectives for water quality discharged into the Blesbokspruit (Department of Water Affairs and Forestry, 2002)

Variable	Unit	Target range
EC	mS/m	400
pH		6.5-8.5
Suspended Solids	mg/l	25
Dissolved Oxygen	mg/l	>9
COD	mg/l	35
Na	mg/l	290
SO_4	mg/l	220
Cl	mg/l	210
Fe	mg/l	1.0
Mn	mg/l	1.0
Al	mg/l	0.5

Comparing the water quality of the water treated by the HDS plant and the current target ranges for water quality discharged into the Blesbokspruit (Table 5.5) it can be seen that the water quality discharged by Grootvlei into the Blesbokspruit, is within the water quality target ranges given to the mine. However, when comparing Grootvlei's Current Water Quality Guidelines to the South African Water Quality Guidelines for Domestic Use and the Blesbokspruit Catchment Water Quality Guidelines, it seems that some of the water quality target ranges (EC, sodium, chloride, and sulphates) of Grootvlei are more lenient and achievable than those of the South African Water Quality Guidelines for Domestic Use (Table 5.4) and the Blesbokspruit Catchment Water Quality Guidelines (Table 5.5).

5.4 Water Quality Standards

The Department of Water Affairs and Forestry (1996) has compiled the South African Water Quality Standards for Domestic Use to serve as a standard or objective for the water qualities of different catchments, which are used for domestic use (Table 5.1). Two water quality guidelines, the Domestic Use guideline and the Aquatic System guideline, were considered to serve as water quality guidelines for this study. This Domestic Use guideline was decided upon for mainly two reasons. Firstly, due to the fact that the Blesbokspruit is a hydrologically important river supplying a vast area with drinking water. Secondly, the Domestic Use guidelines are considered to be more comprehensive than the aquatic system guidelines. For example, no magnesium target range value (which will be analysed in this study) is available within the aquatic system guideline.

Table 5.1: South African Water Quality Standards for Domestic Use (Department of Water Affairs and Forestry, 1996)

		South African Water Quality Guidelines
Variable	**Unit**	**Drinking water target range**
PH		**6.0-9.0**
Conductivity (mS/m)	mS/m	**0-70**
Mg	mg/l	**30.00**
Na	mg/l	100.00
Cl	mg/l	100.00
Sulphate	mg/l	**200.00**
Aluminium	mg/l	-
Manganese	mg/l	-
Total Iron	mg/l	0.10

Bold printed figures are variables of importance for this study

The water quality variables in this study have been evaluated according to the Blesbokspruit Catchment Water Quality Guidelines (Table 5.2).

Table 5.2: Blesbokspruit Catchment Water Quality Guidelines (Blesbokspruit Forum, 2003a)

		Blesbokspruit Catchment Water Quality Guidelines			
Variable	**Units**	**Ideal Catchment Background**	**Acceptable Management Target**	**Tolerable Interim Target**	**Unacceptable**
pH		**6.5-8.5**			**<6.5->8.5**
Conductivity	mS/m	**<45**	**45-70**	**70-120**	**>120**
Magnesium	mg/l	**<8**	**8-30**	**30-70**	**>70**
Sodium	mg/l	<70	70-100	100-150	>150
Chloride	mg/l	<80	80-150	150-200	>200
Sulphate	mg/l	**<150**	**150-300**	**300-500**	**>500**
Aluminium	mg/l		<0.3	0-0.5	>0.5
Manganese	mg/l	<0.2	0.2-0.5	0.5-1.0	>0.1
Total Iron	mg/l	<0.1	0.1-0.5	0.5-1	>1

Bold printed figures are variables of importance for this study

5.5 Water quality sampling

Surface water quality sampling is carried out by Rand Water. Water sampling is undertaken twice a month (every two weeks, and not at any scheduled time of the day or week) by Rand Water for all the sample points depicted in Figure 5.1 and Figure 5.2, except for Sample Point C-B10 (downstream of the Blesbokspruit wetland), which is sampled on a weekly basis. Three categories were chosen for this study to identify whether or not Grootvlei has an impact on the water quality of the Blesbokspruit, as well as to identify temporal tendencies of each variable in relation to three categories being:

- The distribution of sample points over the area;
- Seasonal influence; and
- Temporal variation

The monitoring points chosen for this study were:

- Sample Point C-B5

This point is situated upstream of the discharge point of Grootvlei (depicted as GD on Figure 5.1). It was selected to act as the baseline against which the other two monitoring points were measured.

- Sample Point C-B15

This point is situated downstream of the discharge point of Grootvlei (Figure 5.1). It was selected to see whether or not the discharge of extraneous water from underground mine workings by Grootvlei has an effect on the water quality of the Blesbokspruit.

- Sample Point C-B10

This point is situated downstream of the Blesbokspruit wetland (Figure 5.2). It was selected to see whether or not the wetland has an effect on the water quality of the Blesbokspruit.

The study covers an eight-year sampling period from November 1993 to September 2002, the latter, which is the latest water quality data available. These periods and subsequent analysis of the water quality of these periods were selected as a result of the increase in pollution of the water resources from the pre-pumping environment to the current situation. These temporal categories were established in approximately two year periods, with the aim of establishing if the pumping of extraneous water from underground mine workings by Grootvlei has affected the water quality of the Blesbokspruit:

These temporal categories are grouped into four main groups:

- November 1993 to September 1995

This period was selected as a category to establish a baseline to compare the water quality from the period before Grootvlei commenced pumping larger volumes of extraneous water from underground mine workings into the Blesbokspruit, to the years following, when pumping of extraneous water from underground mine workings into the Blesbokspruit commenced.

- October 1995 to December 1997

In October 1995, Grootvlei started pumping extraneous water from underground mine workings into the Blesbokspruit. This period selected as a category to illustrate the change in water quality directly after pumping of extraneous water from underground mine workings into the Blesbokspruit.

- January 1998 to December 1999

This period was selected as a category to illustrate how the water quality of the Blesbokspruit has been affected from the continuation of underground water pumping into the Blesbokspruit.

- January 2002 to September 2002.

Water quality of the Blesbokspruit is only available until September 2002. This period was therefore selected as a category to illustrate the most current water quality condition of the Blesbokspruit, as the result of continued pumping of the underground water into the Blesbokspruit.

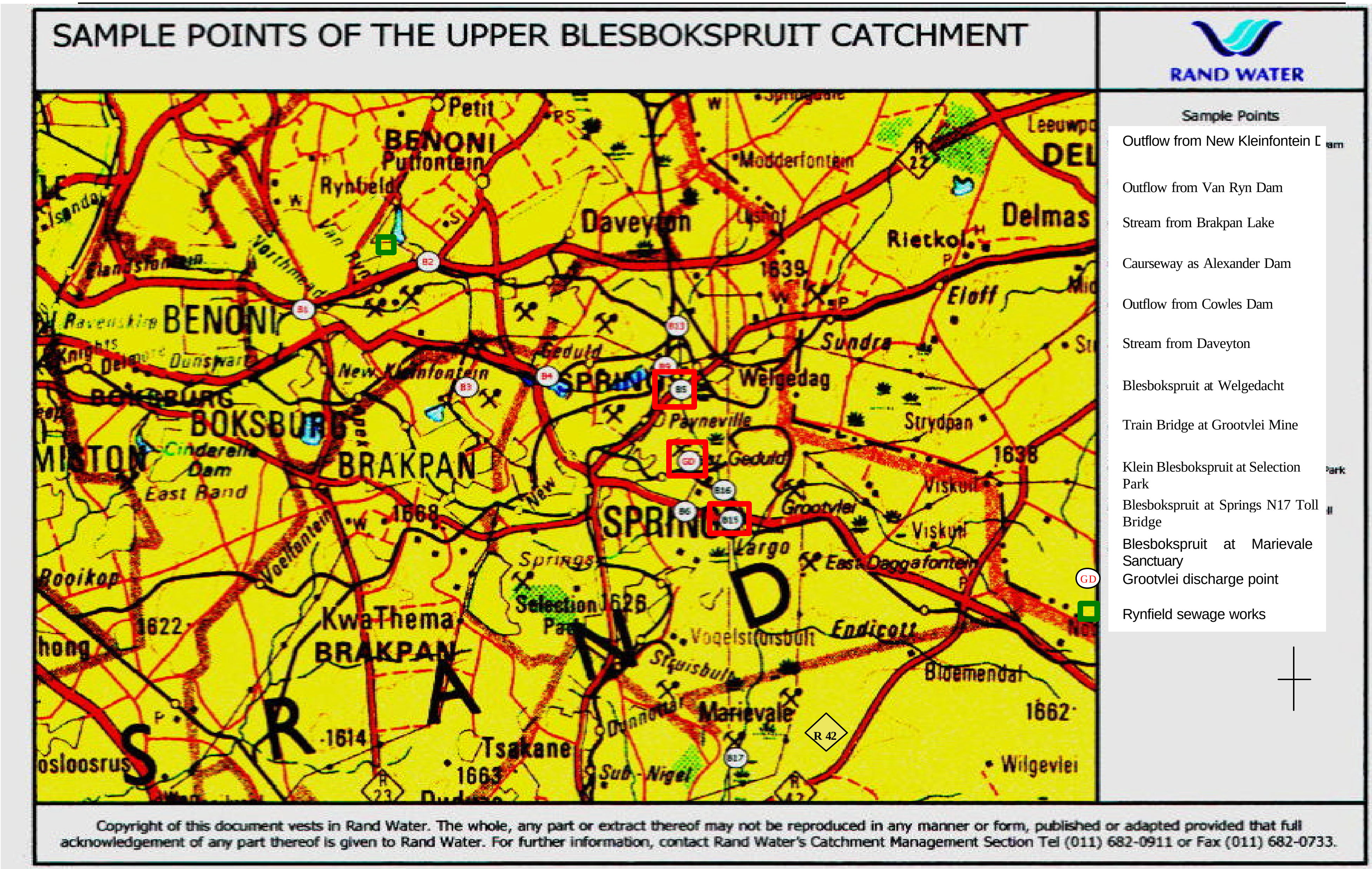


Figure 5.1: Sampling points of the Upper Blesbokspruit Catchment (Blesbokspruit Forum, 2003b)

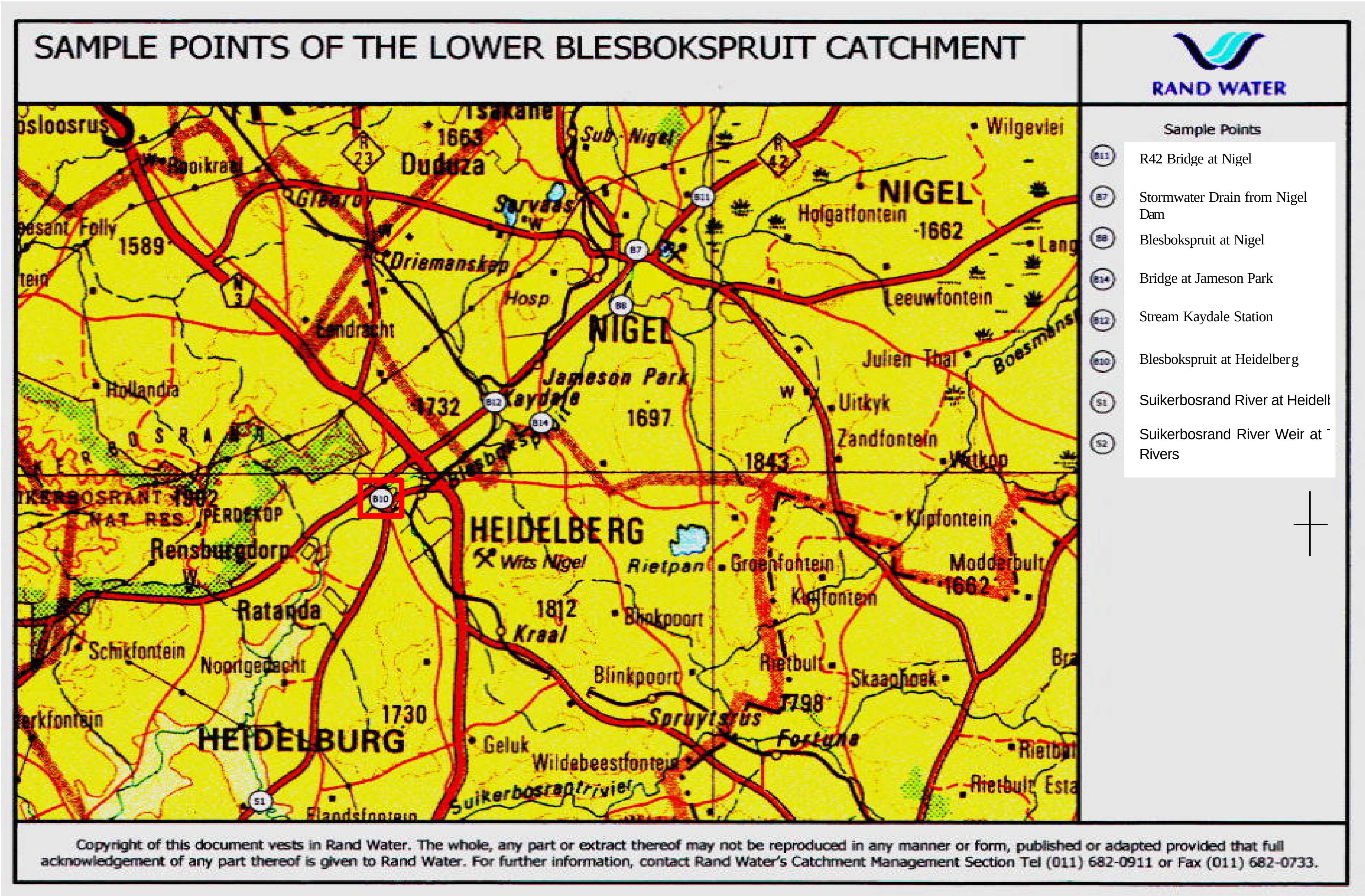


Figure 5.2: Sampling points of the Lower Blesbokspruit Catchment (Blesbokspruit Forum, 2003b)

Seasons were also taken into account when the data were evaluated for trends. Rainfall data were provided by the Weather Bureau. The data were used to evaluate whether the rainfall during different time periods of the year has had an impact on the water quality of the Blesbokspruit.

The rainfall periods were grouped into the following quadrants:

- January to March

Over the whole study period, the period between January and March was the period with the highest rainfall.

- April to June

The period between April and June was the period with the second lowest rainfall.

- July to September

The period between July and September had the overall lowest average rainfall.

- October to December

The period between October and December was the period with the second highest average rainfall (Figure 5.3).

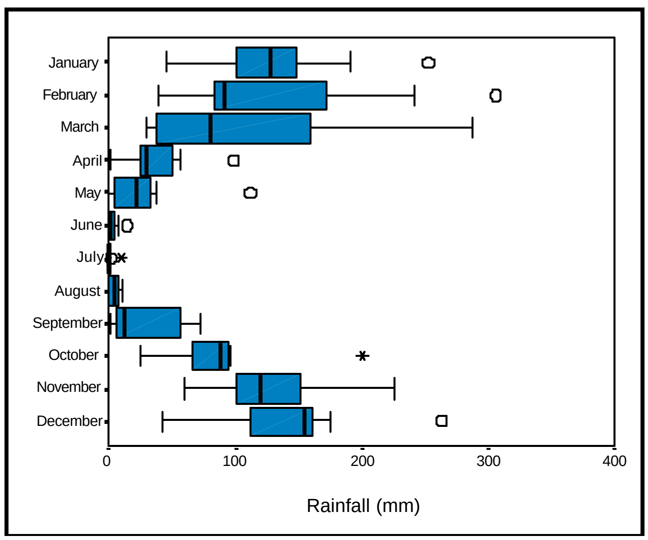


Figure 5.3: Rainfall averages from 1994 to 2001 in the Blesbokspruit Area

5.6 Reliability and Shortcoming of the Data

The water quality data provided by Rand Water contained various gaps and inconsistencies in the form of extreme values. This could be the result of errors occurring during the period of sampling or the fact that some of the variables for a specific sample point were measured and tested on different dates and times during the week of sampling. However, extreme values could represent periods where Grootvlei experienced possible problems (i.e. leaking pipes etc.). As a result of the limited scope of the study, the extreme values of the variables were ignored during the analysis. For the purpose of analysing and interpolation, the received data were analysed by Rand Afrikaans University Statistical Consultation Service (Statcon). Statcon reworked the data into monthly averages and filled gaps in the data by means of linear interpretation to establish meaningful data. This provided 321 water quality samples from which the analysis and interpretation are based (Appendix 7).

5.7 Water Quality Analysis

To determine whether Grootvlei has a direct influence on the water quality of the Blesbokspruit, the variables are examined and judged according to the three different categories namely, distribution of sample points over the area, the influence of the monthly rainfall on the water quality in the study area and the water quality temporal trends (see Section 5.4).

The deterioration of water quality in the Blesbokspruit over the three categories will be clearly illustrated by means of graphs indicating the 25, 50 and 75 percentile values, which will illustrate where the majority of concentrations of each variable lie in relation to the average concentration of that analysis. This will make it possible to visualize the temporal tendencies of each water quality variable at each category over the period in question. On each graph the guideline for the Blesbokspruit Catchment (Table 5.2) will be indicated and compared with the variable's concentrations depicted on that specific graph. This will be done in order to examine where this guideline has been exceeded and therefore where problems exist in the water quality of the study area. The tendencies for each water quality variables in relation with the three categories will be ascertained, making it possible to identify a possible upward or downward trend. Scatter graphs will be used to summarize the interpreted results.

5.8 Discussion of Results

The water quality variables will now be discussed individually. The water quality data at the different sample points are illustrated as averages over the whole sampling period. This was done to examine whether there is an overall trend in the water quality from upstream of No. 3 Shaft to downstream of the Blesbokspruit wetland (Refer to Appendix 8 for the exact water quality values). The result of the water quality analysis in this section will be compared to the Blesbokspruit Catchment Water Quality Guidelines in order to determine whether the water quality observed conforms to the set standards determined by these guidelines (Table 5.2). This will be done by indicating the ideal catchment background and the unacceptable catchment background target ranges on the graphs with vertical lines.

5.8.1 pH

The average pH values measured over the three sample points over the eight years of sampling data show that a definite change in pH levels occurred over the total area from upstream of No. 3 Shaft to downstream of the Blesbokspruit wetland. This is clearly illustrated in Figure 5.3.

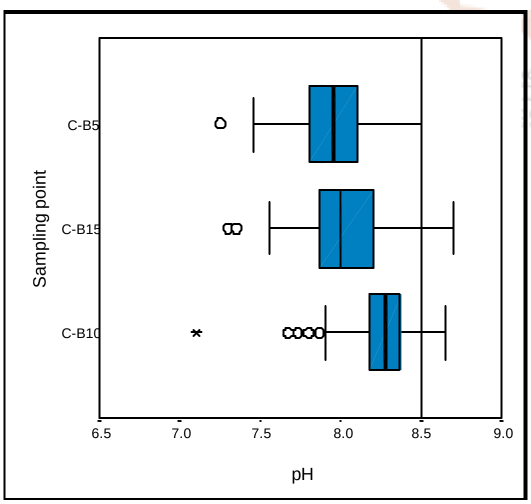


Figure 5.3: pH values over sample points

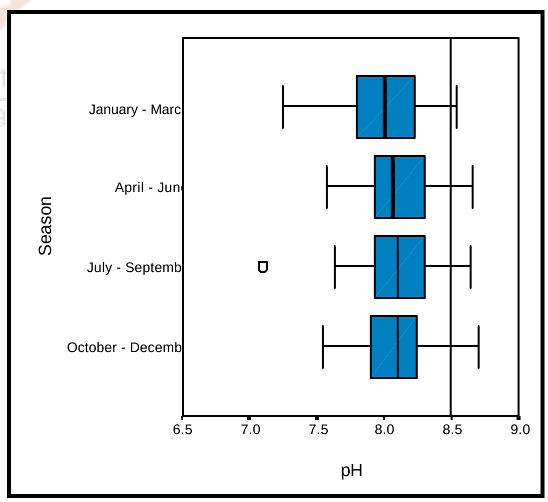


Figure 5.4: pH values with seasonal influence

The pH values measured in the area, show that all of the values were within the target water quality ranges given by the Blesbokspruit Catchment Water Quality Guidelines. However, a definite increase is indicated in Figure 5.3 from the sample point before No. 3 Shaft (C-B5) towards downstream of the Blesbokspruit wetland (C-B10). Within the sample point upstream of No. 3 Shaft average pH values were between 7.80 (25 percentile) and 8.10 (75 percentile), with the median value at 7.95 (50 percentile). These levels increased slightly downstream of No. 3 Shaft with pH levels ranging between 7.85 and 8.20, with the median pH value increasing to 8.00. The levels increased more sharply below the Blesbokspruit wetland, with values ranging between 8.18 and 8.38.

The increase in pH values may be affected by an increase in the biological activity in the river and wetland system over the years. Another possible reason could be that an increase in the intense photosynthetic activity of algae and higher plants may have caused an increase in the pH values (Hellawell, 1986). It is expected that lower pH values occur downstream of No. 3 Shaft as a result of the pumping of the mine water into the Blesbokspruit. However the higher levels of eutrophication due to a possible increase in plant nutrient and silt from mining activities could have been a major contributing factor to increased pH values.

Figure 5.4 illustrates that the seasonal rainfall pattern has a slight influence on the levels of pH values in the overall study area over the eight years of sampling data.

The periods of high rainfall (January to March) showed average pH values ranging from 7.80 (25 percentile) to 8.24 (75 percentile) with the median at 8.00 (50 percentile). The period between April and June, when rainfall is lower, shows the pH values increasing slightly, ranging between 7.92 and 8.30 with the median at 8.07. During the driest periods (July to September) the pH levels increased further to ranges between 7.92 and 8.30 with the median at 8.10 and this median value remained stable for the period where rainfall increased again, although the pH values decreased slightly to between 7.90 and 8.25. This can be explained as a continuous circle where, with periods of more intense rainfall, the dilution factor of the river system is much higher and therefore pH levels in the Blesbokspruit will appear to be lower than in the drier seasons. The opposite scenario takes place in the drier seasons. From the above figures it can be concluded that the seasonal rainfall pattern influences the level of pH values encountered in the Blesbokspruit, but only to a limited extent. This could either be the result of the pH value of the rainfall itself, or a dilution effect within the Blesbokspruit due to increased water volumes within the river system.

Figure 5.5 illustrates the temporal variation of the average pH values over the eight years of data collected, i.e. in the period before pumping of extraneous water from underground mine workings into the Blesbokspruit commenced, until the more recent pumping periods.

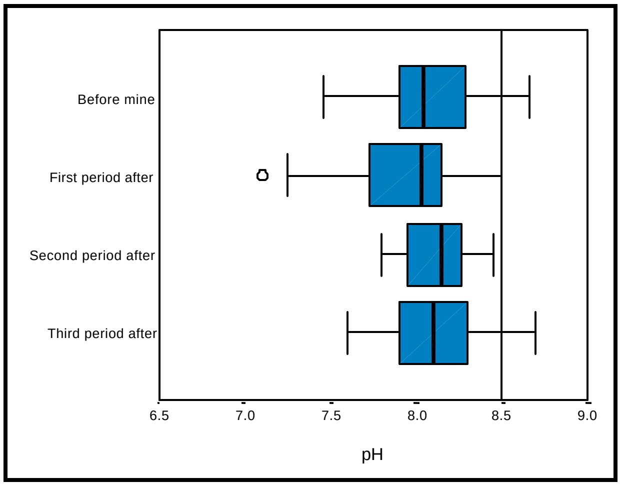


Figure 5.5: pH values over Grootvlei pumping period

As mentioned before, the overall pH values are within the recommended target ranges. However, a definite variation in the pH values is illustrated in Figure 5.5. The period before Grootvlei commenced pumping underground water into the Blesbokspruit showed average pH values ranging between 7.90 (25 percentile) and 8.29 (75 percentile) with the median value at 8.04 (50 percentile). After the commencement of pumping in October 1995 the pH levels decreased to ranges between 7.73 and 8.15 with a median value of 8.03. This can typically be expected from pumping mine water into a river system, as well as the high levels of sulphate in the water form sulphuric acid, which reduces pH levels. The third period after pumping commenced, illustrates an increase in the pH values ranging between 7.95 and 8.27 with a median value of 8.14. This increase could have been the result of sewage workings in the area. However, in more recent periods (January 2000 to September 2002) the pH values are moving towards the pre-pumping period with an average value ranging from 7.90 to 8.30, with a median of 8.10.

5.8.2 Electric Conductivity

The average concentration Electric Conductivity over the three sample points, for the overall study area, showed that there was a significant variation in the EC concentration upstream of No. 3 Shaft towards downstream of the Blesbokspruit, as well as the concentrations occurring within the sample point over the eight years.

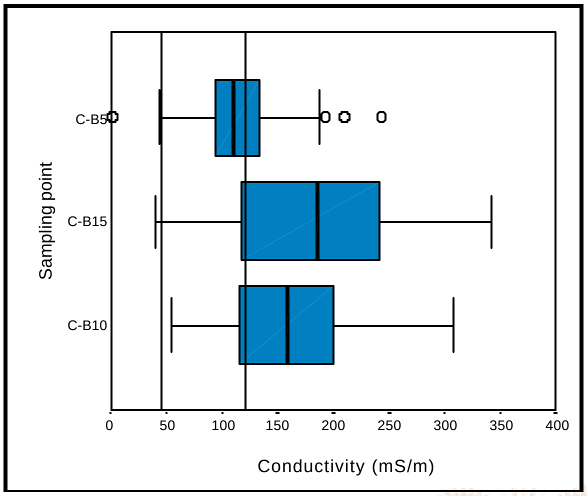


Figure 5.6: Conductivity concentrations over sample points

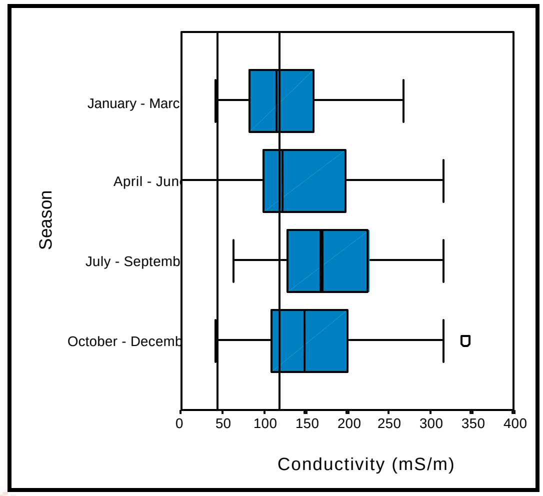


Figure 5.7: Conductivity concentration with seasonal influence

From Figure 5.6 it is illustrated that the EC concentrations for the sample point upstream of No. 3 Shaft have been the best quality in relation to the other two sample points, with average concentrations ranging between 94.25 mS/m (25 percentile) and 132.50 mS/m (50 percentile) with a median concentration of 109.67 mS/m (50 percentile). The greatest percentage of these values was below unacceptable target ranges (greater than 120 mS/m). The sampling position downstream of No. 3 Shaft showed a dramatic increase in EC concentrations with average ranges between 115.75 mS/m and 240.75 mS/m with a median of 184.00 mS/m, with the majority of levels above the unacceptable target ranges. The variation within this sampling point is much wider than the other two sampling positions. This could be the result of different volumes of extraneous water from underground mine workings pumped into the river system during different time periods. As the EC concentration is a good indicator of the quality of a river system, it seems that the water quality of the study area, with special reference to this sample point, has not been ideal. In Figure 5.6 it is shown that the EC levels were lower downstream of the wetland system. The wetland system therefore has the ability of absorbing the EC levels. However, the greatest percentage of concentrations were above the unacceptable target ranges. The average EC concentrations ranged between 114.77 mS/m and 199.25 mS/m with a median of 156.38 mS/m.

The increase in EC could have been the result of a continuous adding of salts through natural and man-made processes, e.g. the pumping activities.

As with pH, a definite seasonal trend is illustrated by Figure 5.7. The period of the highest rainfall was associated with the lowest EC concentrations ranging between 82.75 mS/m and 160.00mS/m with a median value of 115.00 mS/m. This could be the result of the dilution of total dissolved solids in the system, which consequently resulted in lower EC. Approximately 50 percent of the concentrations were within target ranges. The period when rainfall decreased was associated with concentrations ranging between 100.75 mS/m and 198.75 mS/m with a median value of 126.50 mS/m. The period with the least rainfall showed EC concentrations ranging between 123.00 mS/m and 231.06 mS/m, with a median of 167.50 mS/m. All of these concentrations were above the unacceptable target ranges. With the start of the rainy season, the EC concentrations lowered in range from 108.50 mS/m to 195.00 mS/m, with a median of 143.33 mS/m.

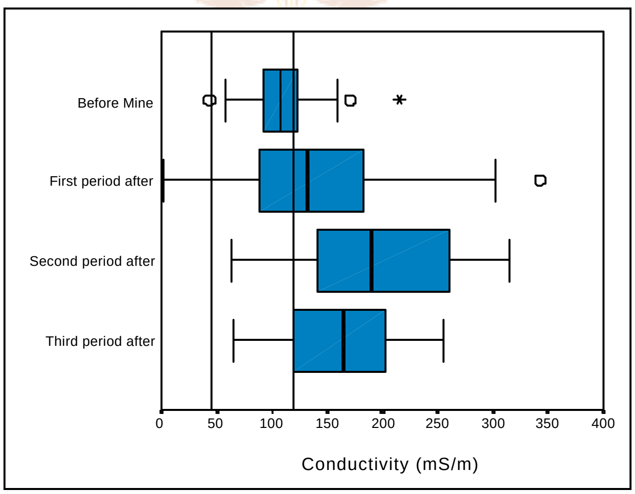


Figure 5.8: Conductivity concentration over Grootvlei Mine pumping period

Figure 5.8 illustrates a clear variation in the average EC concentrations over the pumping history of Grootvlei. In the period before pumping of underground water into the river system commenced, the majority EC concentrations fell within the accepted target ranges. The EC concentration ranged from 91.50 mS/m to 121.88 mS/m with the median of 106.88 mS/m. With the commencement of pumping operations the EC concentrations showed an overall increase to ranges between 89.00 mS/m and 183.75 mS/m with the median at 128.75 mS/m. In the third period after pumping operations commenced these levels showed a continued increase to ranges between 140.00 mS/m and 263.13 mS/m, with a median of 185.00 mS/m. All these concentrations were well above unacceptable target ranges. Figure 5.8 shows that in the more recent period the EC levels are slowly recovering and ranges between 118.00 mS/m and 204.00 mS/m occur with a median value of 165.00 mS/m.

5.8.3 Magnesium

Figure 5.9 illustrates the average concentration of magnesium over the three sample points, and as with the previous variable, a variation is seen in the magnesium concentrations between the sample points as well as within each sample point. At the sample point upstream of No. 3 Shaft the magnesium concentrations were well within the acceptable target ranges (between 8mg/l and 70 mg/l) w ith concentrations ranging between 18.50 mg/l (25 percentile) and 26.00 mg/l (75 percentile) with the median at 21.50 mg/l (50 percentile). The sample point after water is pumped into the river system showed a steep increase in magnesium concentration with ranges between 23.00 mg/l and 72.50mg/l with the median at 48.80 mg/l. These concentrations were however mostly within the acceptable target ranges. The variation within this sample point was much wider than the other two sample points, which can, as for conductivity, be the result of different volumes of underground water being pumped into the river system at different periods. The sample point downstream of the wetland showed a slight improvement in the magnesium concentrations with ranges between 27.00 mg/l and 63.67 mg/l, with the median at 45.00 mg/l.

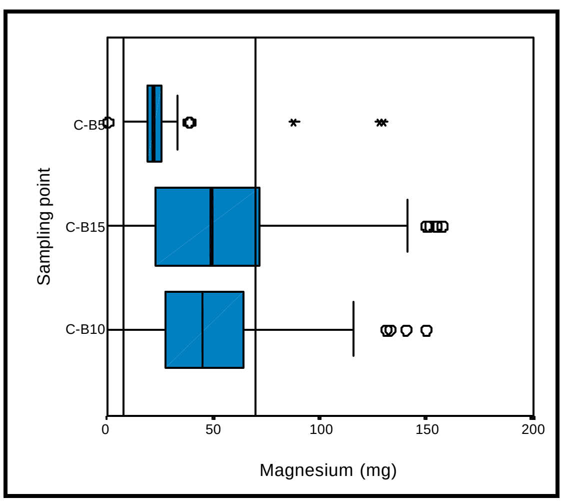


Figure 5.9: Magnesium concentrations over sample points

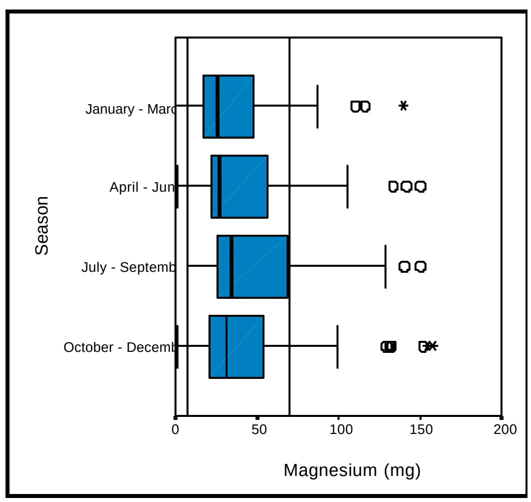


Figure 5.10: Magnesium concentration with seasonal influence

A possible reason for an increase in the average magnesium concentration in the Blesbokspruit, as a result of pumping activities, is that the geological region in which Grootvlei is operating, falls within the Transvaal sequence. The Lower strata of the Transvaal consists of a large amount of dolomite. The Malmani Dolomite is the thickest and most important series of dolomites in the sequence (see Section 4.2.1). Dolomite consists largely of calcium and magnesium carbonate and is therefore vulnerable to solution, especially by carbonic acid found in rainwater percolating downwards. The ingress of water into underground workings of Grootvlei may result in the solution of magnesium, which contributes to the concentrations found in the water.

As for pH and conductivity, Figure 5.10 illustrates a seasonal influence on the magnesium concentrations. The periods of the highest rainfall were associated with the lowest magnesium concentrations, which ranged between 18.00 mg/l (25 percentile) and 48.40 mg/l (75 percentile) with the median at 26.00 mg/l (50 percentile). These concentrations were well within the acceptable target ranges. With the drier seasons the magnesium concentrations increased to ranges between 22.42 mg/l and 57.50 mg/l with the median at 26.67 mg/l. These figures are also within acceptable target ranges. In the driest season the magnesium concentration increased sharply and the variation within this period was much higher than the other three periods, with average ranges between 25.47 mg/l and 69.00 mg/l with the median at 34.40 mg/l. A large amount of these concentrations were above the acceptable target ranges for the Blesbokspruit catchment. With the increase in rainfall the magnesium concentrations reduced and were close to the period associated with the highest rainfall ranging between 20.75 mg/l and 54.08 mg/l with the median at 31.25 mg/l.

Figure 5.11 illustrates a definite variation as with the previous variables discussed, in the magnesium concentration associated with the temporal variation. The period before the commencement of pumping extraneous water from underground mine workings into the Blesbokspruit is associated with average magnesium concentrations much lower than those of the other three periods. The magnesium concentrations for this period ranged between 16.75 mg/l and 26.38 mg/l with the median at 21.75 mg/l. The period of two years after pumping commenced illustrates an increase in the average magnesium concentrations ranging between 20.92 mg/l and 47.00 mg/l with the median at 27.33. A further increase is illustrated in the third period after pumping commenced with ranges between 26.63 mg/l and 53.50 mg/l with the median at 97.63 mg/l. The most current pumping period is associated with the average magnesium concentrations decreasing with ranges between 24.00 mg/l and 65.00 mg/l, with the median at 48.00 mg/l.

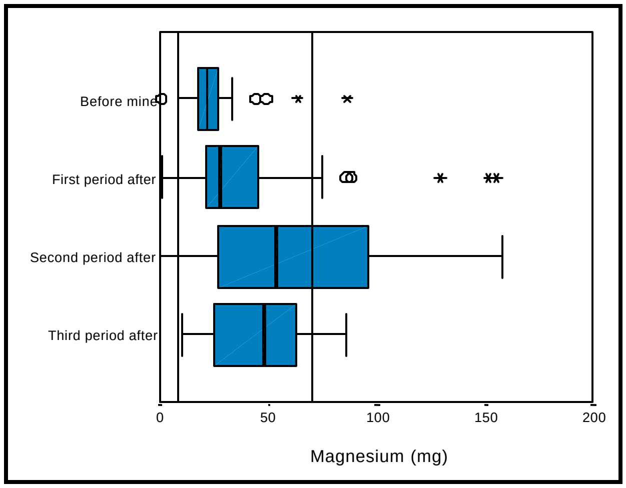


Figure 5.11: Magnesium concentration over Grootvlei pumping period

5.8.4 Sulphates

The water quality of the Blesbokspruit and the wetland consists of high sulphate concentrations (Dini, 1999).

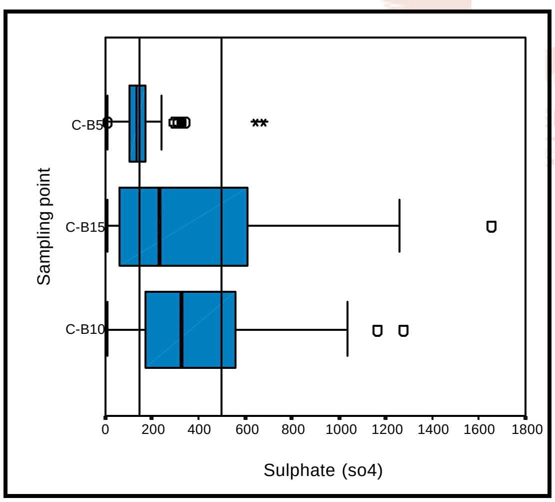


Figure 5.12: Sulphate concentrations over sample points

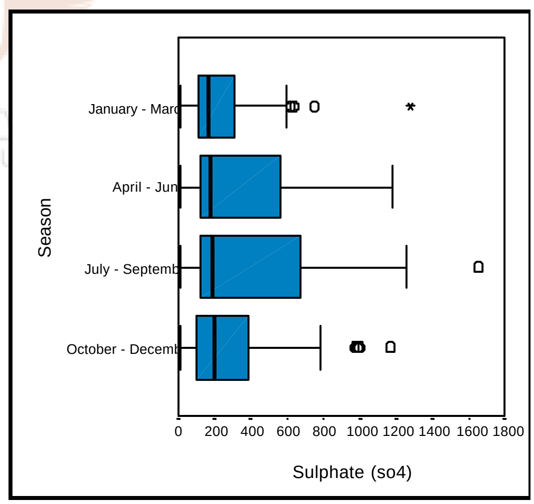


Figure 5.13: Sulphate concentration with seasonal influence

Figure 5.12 illustrates that there is a very strong variation between the sulphate concentrations over the three sample points. The sample points associated with the area before No. 3 Shaft has by far the lowest average sulphate concentration over the eight years of water quality data within that area. The variation within the sample point is also very small, which illustrates that these concentrations were very stable. The sulphate concentrations at this sample point ranged between 105.00 mg/l (25 percentile) and 170.00

mg/l (75 percentile) with the median at 132.50 mg/l (50 percentile). The lowest concentrations were below the acceptable target ranges (below 150 mg/l), but none occurred above the unacceptable target ranges (greater than 500 mg/l). At the sample point downstream of No. 3 Shaft the average sulphate concentrations showed a dramatic increase with concentration ranging between 53.00 mg/l and 615.00 mg/l and the median at 235.50 mg/l. The increase in the sulphate concentrations is expected as a result of the mining activities. The variation within this sample point was much wider than the other two sample points. The sample points downstream of the wetland system showed a reduction in the average sulphate concentrations with ranges between 176.00 mg/l and 562.50 mg/l and the median at 328.00 mg/l. These concentrations were however still much higher than the sulphate concentration samples before No. 3 Shaft.

Figure 5.13 illustrates the same seasonal trends as the other variables. During the period of the highest rainfall the sulphate concentrations ranged between 111.50 mg/l and 313.75 mg/l and the median was 161.25 mg/l. With the decrease in rainfall the sulphate concentrations increased to ranges between 125.50 mg/l and 560.65 mg/l with the median at 175.00 mg/l. The sulphate concentrations were highest in the driest period, with concentration ranges between 120.13 mg/l and 679.00 mg/l with the median at 185.00 mg/l. With the increase in rainfall in the fourth period a reduction in the sulphate concentrations occurred to ranges between 100.00 mg/l and 385.87 mg/l with the median at 198.75 mg/l.

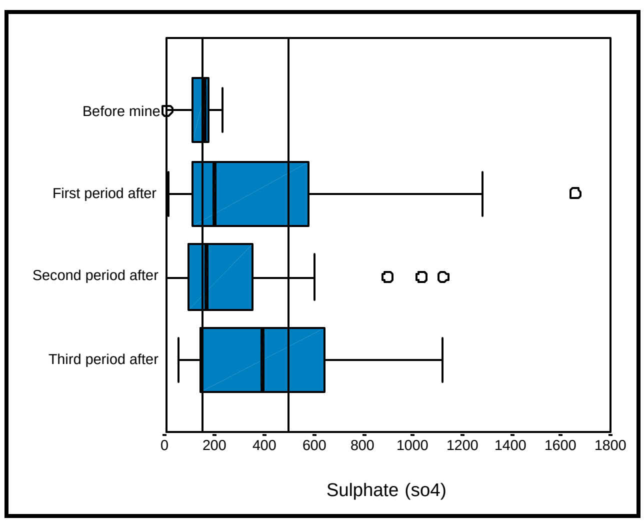


Figure 5.14: Sulphate concentration over Grootvlei pumping period

From Figure 5.14 it is clear that the period before pumping activities commenced was associated with much lower sulphate concentrations than the other three periods with average ranges in the sulphate concentrations between 106.00 mg/l and 175.50 mg/l with the median at 153.75 mg/l. With the commencement of pumping activities into the Blesbokspruit a drastic increase in sulphate concentration occurred with ranges between 104.56 mg/l and 586.88 mg/l with the median at 197.50 mg/l. In the third period after pumping commenced the sulphate concentrations decreased to ranges between 96.00 mg/l and 363.96 mg/l and the median at 166.25 mg/l. The most current period is associated with even higher concentrations of sulphate than the period right after pumping commenced, with average concentrations ranging between 140 mg/l and 650.00 mg/l and the median at 389.00 mg/l. One reason for this may be that the wetland is losing its capacity to remove sulphate out of the river. Figure 5.12 shows that the sulphate concentrations did not show a significant decrease in concentrations from the sample points downstream of No. 3 Shaft to the sample point downstream of the wetland.

5.8.5 Summary of results

In the previous section each variable's concentrations were discussed individually in relation to the three categories. It was established that the categories do have an influence on the water quality of the Blesbokspruit. In this section scatter graphs will be used to give an overall summary of each variable. This will be done by comparing the sample point and seasonal influence with the temporal variation for each of the variables. Using this relationship, it will be established whether or not Grootvlei has had a direct influence on the reduction in water quality of the Blesbokspruit.

In the previous section it was established that the sample points had an influence on the pH, Electric Conductivity, magnesium and sulphate concentrations. With the sample point upstream of No. 3 Shaft as the baseline it was illustrated that the pH concentrations became lower directly downstream of No. 3 Shaft, which could have been the result of the pumping activities of Grootvlei. It was also illustrated that there was an increase in pH levels after the Blesbokspruit wetland, which could have been a result of increased biological activity. The Electric Conductivity concentrations showed an increase in concentration downstream of No. 3 Shaft, which could have been the result of an increase in salt loads due to mining activities. A decrease in concentrations was found downstream of the Blesbokspruit wetland. This could be the result of the wetland absorbing salt loads. The same trends were found for magnesium and sulphate concentrations. It should be noted that although there was a decrease in the overall concentrations of the variables at the sample point downstream of the wetland, the decrease was on an overall scale, very slight, and the wetland does not have the capacity to purify the water to the same conditions before No. 3 Shaft.

Figure 5.15 illustrates that although it was established that the sample points had a direct influence on the pH levels of the Blesbokspruit, the temporal variations are the major influence.

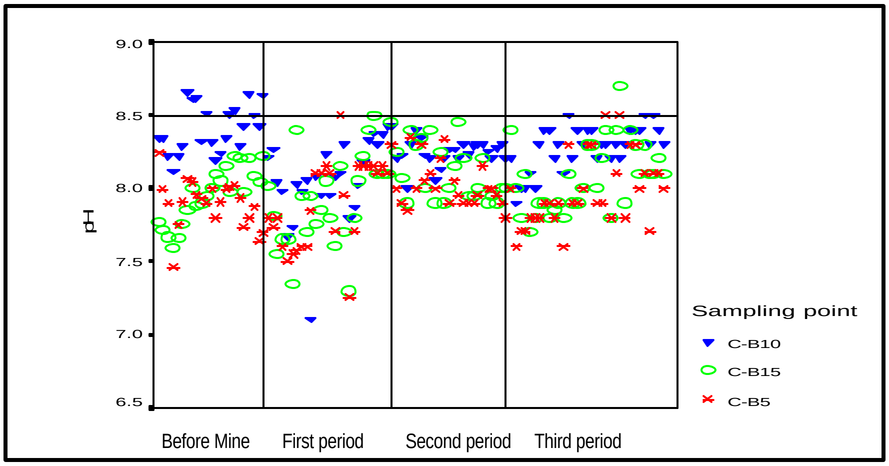


Figure 5.15: pH concentration with sample point in relation with periods of pumping

The sample point upstream of No. 3 Shaft (C-B5) was associated with fairly constant pH levels. The sample point downstream of No. 3 Shaft (C-B15) showed a decrease in pH levels in the first period after pumping commenced. However it can be established from the figure that the pH concentrations stabilize towards the pre-pumping periods and therefore improve in quality. Most of the pH levels have remained within acceptable target ranges throughout the pumping periods.

As for pH, Figure 5.16 illustrates that the periods of pumping were the major influence over the sample points. However the periods of pumping had a much larger influence on the Electric Conductivity concentrations than the pH levels.

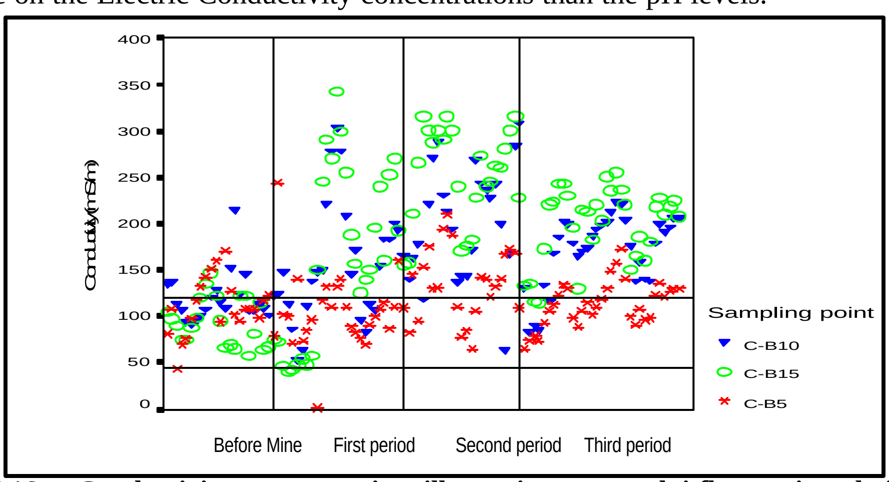


Figure 5.16: Conductivity concentration illustrating seasonal influence in relation with periods of pumping

The period before pumping commenced should again be used as the baseline to establish whether or not the mine has had an influence on the Electric Conductivity concentrations. This period was again associated with constant concentrations during the four periods. The first period after pumping commenced was associated with an increase in Electric Conductivity concentrations and this continued into the second period of pumping. However the third period after pumping commenced (more recent) shows that the Electric Conductivity concentrations are decreasing, however slightly. The periods after pumping commenced resulted in a large amount of the Electric Conductivity concentrations above unacceptable target ranges. Again, it should be stated that Electric Conductivity is a good indicator of the quality of water in a river system, and therefore it can be concluded in Figure 5.16 that the first and second periods after pumping commenced were associated with the poorest water quality and that the water quality has improved during more recent periods.

Figure 5.17 again illustrates the same trends for magnesium as for pH and Electric Conductivity.

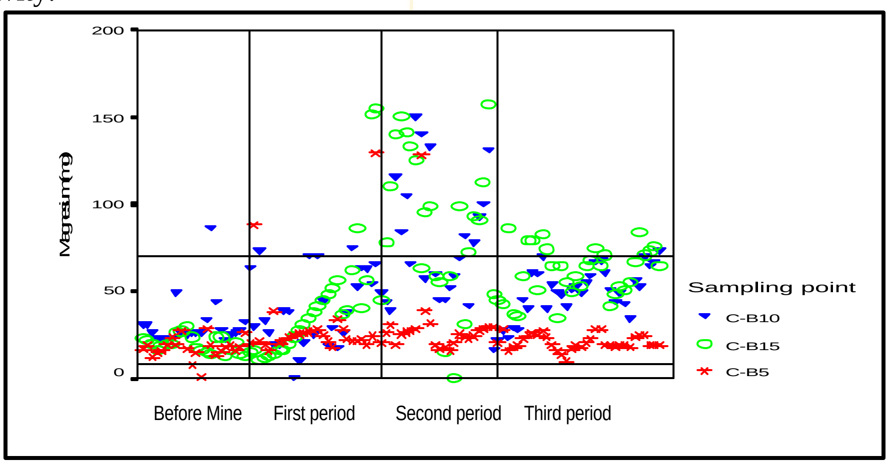


Figure 5.17: Magnesium concentration illustrating sample points in relation with periods of pumping

The sample point before No. 3 Shaft showed an overall constant magnesium concentration over the four periods of pumping. In the first and second periods after pumping commenced an increase in concentrations was found, with a large amount of the concentrations, especially in the second period after pumping commenced, above the unacceptable target ranges. However, as for the two variables discussed above, the magnesium concentrations show an improvement in quality (decrease in concentration) in the more recent period.

Figure 5.18 illustrates that the periods of pumping had a major influence on the sulphate concentrations.

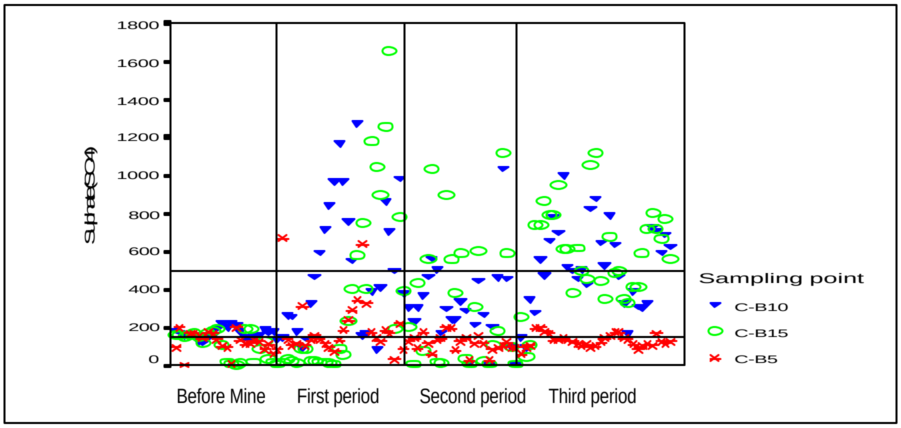


Figure 5.18: Sulphate concentration with sample point in relation with periods of pumping

The sulphate concentrations of the sample point before No. 3 Shaft showed stable concentrations throughout the period of pumping, however the other two sample points showed great variations. The first period after pumping commenced showed high levels of sulphate concentrations. The second and third periods after pumping commenced showed lower sulphate concentrations. The periods after pumping commenced were associated with a large amount of the concentrations being above unacceptable target ranges. Although these concentrations were not associated with concentrations before pumping activities commenced, the concentrations improved after the concentrations of the first period after the commencement of pumping.

In the previous section it was illustrated that the sample point positions had an influence on the concentrations of the variables. From the above discussion it is clear that Grootvlei has had a direct influence on all four variables discussed over and above the sample point positions influences. After pumping commenced, a large amount of the concentrations, except for pH levels, were above unacceptable target ranges. The overall water quality of the variables has started to show a slight improvement, however, a large amount of the concentrations are still above the unacceptable target ranges. The improvement in water quality could be the result of the increasing environmental awareness of Grootvlei, which will be discussed, in the next chapters.

In the previous section a direct influence of the seasons on all the variables' concentrations was found, with the wettest periods having the lowest concentrations and the driest periods, the highest concentrations.

Figure 5.19 illustrates that although the seasons have an influence on the pH levels in the Blesbokspruit, the periods of pumping had a major influence on the levels.

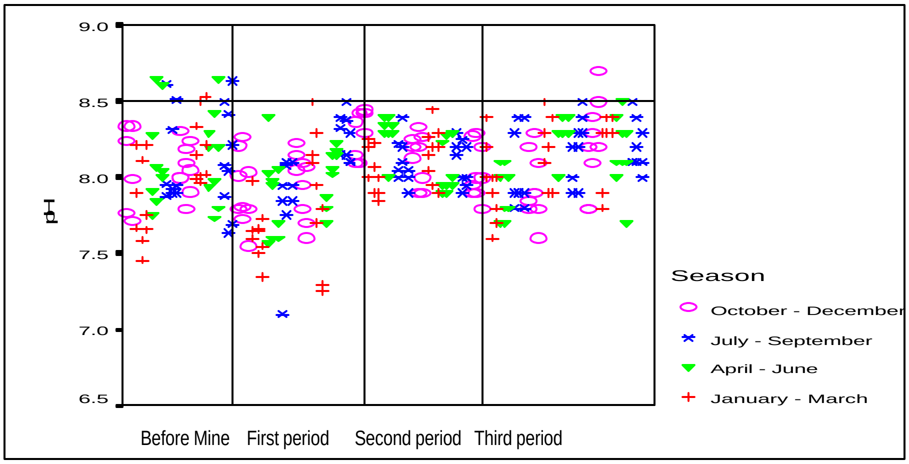


Figure 5.19: pH concentration illustrating seasonal influence in relation with periods of pumping

The period before pumping commenced should be taken as the baseline for the pH levels. The first period after pumping commenced showed a decrease in the pH levels. The second and third periods showed increases in the pH again, with the third period associated with pH levels close to the pre-pumping period and the fourth period with slightly higher levels. Most of the pH levels have remained below unacceptable target ranges.

Figure 5.20 illustrates that, although seasonal influence did occur, the periods of pumping had the greatest influence on the Electric Conductivity concentrations.

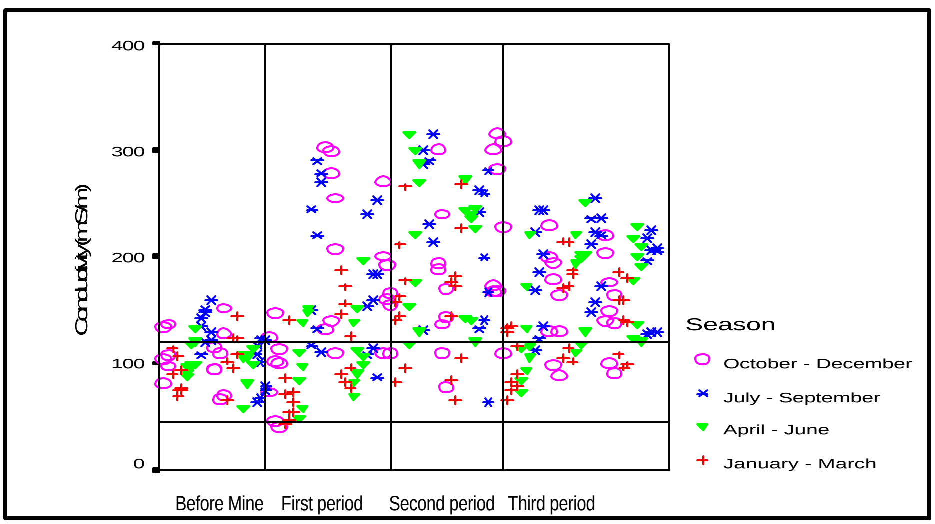


Figure 5.20: Electric Conductivity concentration illustrating seasonal influence in relation with periods of pumping

With the period before pumping as the baseline, it is shown that after the first and second periods after pumping commenced, a significant increase in concentrations occurred. The third period is associated with a decrease in concentrations and therefore improvement in water quality. However, since the commencement of pumping the greater amount of concentrations were above the unacceptable target ranges.

Figure 5.21 shows the same trends as Electric Conductivity.

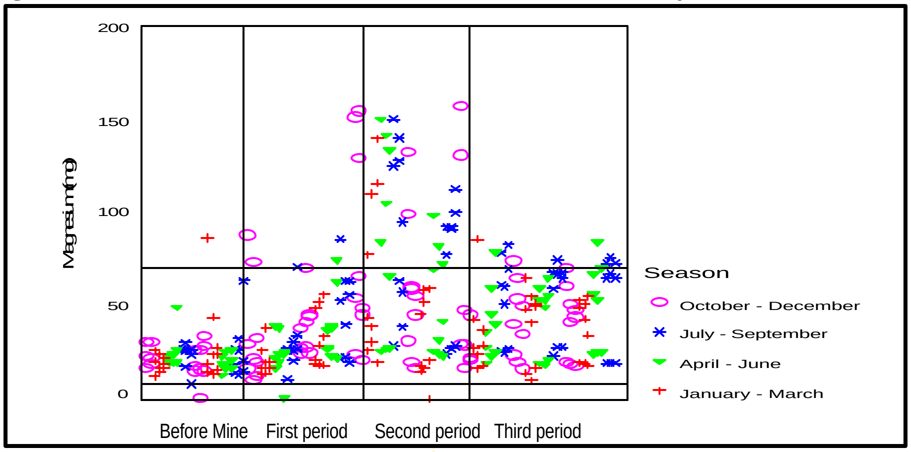


Figure 5.21: Magnesium concentration illustrating seasonal influence in relation with periods of pumping

An increase in the magnesium concentrations occurred in the first period after pumping commenced. This increase continued sharply in the second period after pumping commenced. The magnesium concentrations for the first and second periods, after pumping commenced, indicated that a large amount of the concentrations were above the unacceptable target ranges, especially in the second period after pumping commenced.

In more recent periods the magnesium concentrations have decreased and are now mostly within acceptable target ranges, although they are still much higher than the pre-pumping concentrations.

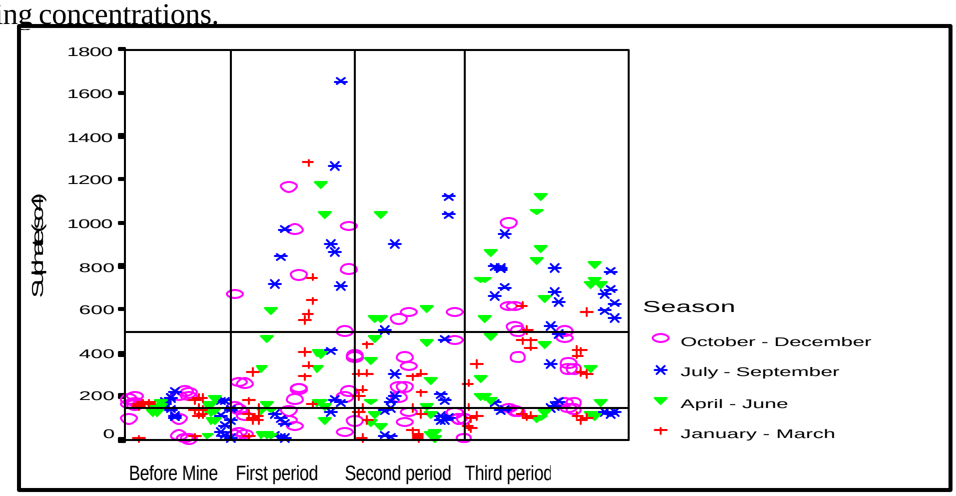


Figure 5.22: Sulphate concentration illustrating seasonal influence in relation with periods of pumping

Figure 5.22 illustrates that the first period after pumping commenced was associated with low sulphate concentrations, with a large amount of the concentrations being lower than the ideal target ranges. After the period when pumping commenced, there was a significant increase in sulphate concentrations. The second period after pumping commenced was associated with a decrease in sulphate concentrations, although these were still much higher than the pre-pumping period concentrations. In the third period the sulphate concentrations increased again, but were lower than the concentrations of the first period after pumping commenced. The periods after pumping commenced were associated with a large amount of the concentrations being above the unacceptable target ranges.

In the previous section it was illustrated that the seasonal changes had an influence on the concentrations of the variables. From the above discussion it is clear that Grootvlei has had a direct influence on all four variables discussed, over and above the seasonal influences. In the above figures it is illustrated that the period before pumping commenced was not associated with a wide variation in concentrations as a result of the seasonal influences. Since the commencement of pumping activities, it was the mine, rather than seasonal changes, that have had the greatest influence on the figures, resulting in wide variations in the concentrations of the variables.

From the above discussions it is clear that since October 1995, with the commencement of pumping extraneous water from underground mine workings into the Blesbokspruit by Grootvlei, there has been a direct decrease in water quality of the Blesbokspruit as a result of this activity. However, a slight improvement in more recent periods has occurred, which may be the result of greater environmental awareness by Grootvlei, the reduced volumes of water pumped, or the improvement of water pumped into the Blesbokspruit. These aspects will be discussed in the following chapters.

CHAPTER 6

A STRATEGIC MANAGEMENT PLAN OF GROOTVLEI MINE

6.1 Strategic Water Management Plan of Grootvlei Mine

In 2002, Grootvlei undertook an investigation into the development of a strategic water management plan to improve underground water handling. As part of this process the mine applied to the Department of Water Affairs and Forestry for the renewal of its Water Use Licence in terms of the new National Water Act (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

The Water Use Licence was granted in September 2002, with a set of conditions designed to meet the water quality objectives of the Blesbokspruit. Grootvlei has undertaken to meet these objectives in a phased approach. A plan of scoping was approved in April 2003. The scoping exercise began in parallel with two feasibility studies. One study was to determine appropriate technologies to treat the mine water, while the other study looked at means to reduce ground and surface water influx to the underground workings.

During these studies the assumptions, that form the basis for the current water use license will be tested and verified together with a number of possible alternative methods to reduce inflow into the underground workings. The impact on the Blesbokspruit is a key consideration in these studies (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.1 Additional water treatment

In 1999, the construction of a pilot desalination plant was proposed. Grootvlei was the target for the proposed project. The total initial cost was expected to be around R200 million, therefore the high cost required government and Rand Water support, who was not forthcoming and the project collapsed (Berry, 2004; Personal Communication).

According to Irene Lea (2003; Personal Communication), Environmental Manager of Grootvlei, the mine is again in the process of evaluating additional water treatment methods, including full desalination, using reverse osmosis, partial desalination using biological sulphate removal, or a combination of the two methods. This will result in a substantial, systematic improvement of the water discharge to the Blesbokspruit.

However, financial assistance, as with the 1999 scenario, will be required to get this project off the ground.

By 2005 the mine will treat 10 Ml/day and present a plan to the Department of Water Affairs and Forestry that will address how the total water volume will be treated (Lea, 2003; Personal Communication). This will be a substantial start in improving the water quality in the Blesbokspruit, which has been negatively impacted on, as a result of the pumping activities of the mine. However, reducing the amount of water treated by the mine and therefore reducing the amount of water being pumped into the Blesbokspruit, only sweeps the problem under the carpet. The main and overall problem, being the water level in the underground workings, will still rise until it percolates to the surface. Therefore, studies in reducing the amount of water ingress into the underground workings is essential in reducing the water problem (quality and quantity) in this area (see Section 6.1.2).

Grootvlei has been given the approval for a water licence, according to the National Water Act (Act. 36 of 1998), with certain requirements that need to be implemented. This licence states that the mine should by no later than 1 September 2005, submit a plan of action in order to treat the total volume of extraneous water from underground mine workings being discharged to meet the objectives given in Table 6.1 (Department of Water Affairs and Forestry, 2002).

Table 6.1: Future objectives for water quality discharged into the Blesbokspruit (2005) (Department of Water Affairs and Forestry, 2002)

Variable	Unit	Target Ranges
EC	mS/m	<45
pH		6.5-8.5
Suspended Solids	mg/l	<15
Dissolved Oxygen	mg/l	>9
COD	mg/l	<30
Na	mg/l	<70
SO_4	mg/l	<150
Cl	mg/l	<80
Fe	mg/l	<0.1
Mn	mg/l	<0.2
Al	mg/l	<0.5

Table 6.1 illustrates that the water quality targets set for 2005 are far more stringent than the current water quality objectives shown in Table 5.5. This will ensure that water of

an improved quality will be pumped into the Blesbokspruit, which will then impact on the water quality of the Blesbokspruit over time.

6.1.2 Reducing water ingress

In Section 4.5.1 the potential sources of water inflow to the Grootvlei was discussed. Grootvlei has formulated a Water Ingress Project, which aims to reduce the volume of water that will be pumped and thus treated in the long-term.

Sealing these areas, creating bypasses for existing flows over these zones or reducing the wetted area over these areas are all ways of achieving the objective of reducing inflows to the East Rand Basin. While a canal could be part of such a strategy, it may not be the only or most effective method of achieving the objectives and further alternatives need to be considered (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

Grootvlei will explore the feasibility of such options, by determining the actual volume of influx from each area, estimate the effectiveness and cost of remedial measures and evaluate potential environmental impacts predicted for each option, in a feasibility study, as part of their Environmental Impact Assessment (Table 6.2).

Table 6.2: Environmental assessment process and time frame (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003)

February 2003	Feasibility Study (Range of alternatives)	Scoping (Identify issues)
March 2003		
April 2003		
May 2003	Selection of alternatives	Scoping Report
June 2003	Detailed Design	Specialist Studies and Impact Assessment
July 2003 August 2003		
September 2003		
October 2003		
November 2003		Reporting
December 2003		Review
January 2003		

6.1.2.1 Alternatives excluded from the Scope of the Present Environmental Impact Assessment

The following alternatives were excluded from the scope of the Environmental Assessment as the feasibility study (see Section 7.1.2.1) found:

- That they would not cost effectively prevent ingress to the East Rand Mining Basin; or
- That other parties were liable for the implementation of remediation measures (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.2.1.1 Springs-Nigel canal

A canal from Springs to Nigel was proposed to prevent ingress into underground mine workings. The proposed canal would take all industrial discharge past the section of the Blesbokspruit that flows over the underground workings of the East Rand Basin.

After research, it was found that the construction of a 35 kilometre long unlined canal along the Blesbokspruit would not effectively minimize water seepage into the underground workings, as the largest volume of manageable underground seepage occurs at specific points within the mining basin and is not diffused along the flow of the river (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.2.1.2 Remediation of the subsided defunct workings of Largo Collieries

The Largo Mine is a defunct, flooded coal mine situated to the east of Grootvlei and adjacent to the Blesbokspruit (Appendix 9). The area is characterised by surface subsidence, which increases recharge to the underlying aquifers. Based on the water levels in the areas of subsidence, the water level in the coal mine appears to be in equilibrium with that of the Blesbokspruit. The proximity of the river to the subsided areas makes the source of inflow very possible, particularly as the old mining plans appear to indicate that mining occurred into the wetland area and not only next to it.

Largo Colliery is not considered the responsibility of Grootvlei, since the area has been mined historically by other mining companies. However, as there is a concern that the old coal mine is adding to the overall water make, drilling has been undertaken by Grootvlei to assess this aspect.

Currently, it appears that the mine may overlay directly onto dolomites, and could thus be a significant source of inflow given the extent of surface instability above the mine, and its proximity to the Blesbokspruit. This issue will be further investigated, and if necessary, will need to be followed up by the relevant Government Authorities to facilitate the remediation of this area (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.2.2 Alternatives included in the Scope of the Present Environmental Impact Assessment

The feasibility study conducted by Grootvlei found higher rates of surface water ingress to the East Rand Mining Basin in areas of shallow undermining (i.e. less than 300m below surface) of the reef sub-outcrop, especially where such areas are overlain by Witwatersrand rocks or occur at the base of the dolomite. Such areas were also found to be associated with increased fracturing and, in some cases, subsidence where mining has occurred very close to the surface in the northern part of the study area.

On the northern and north-western margin of the East Rand Basin mining of the Main Reef outcrop extends all the way to the surface, which results in significant surface inflows from direct rainfall or at watercourses that cross the outcrop (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.2.2.1 Eliminating surface ponding over Northern Reef outcrop

Surface water influx to the East Rand Basin via this area is estimated to be in the order of 42 Ml/day of a total wet season recharge of about 108 Ml/day and 7Ml/day of a total dry season recharge of 71 Ml/day. The cost of this remediation option is estimated at between R3 to R5 million.

A number of remediation options were considered for this area including:

- Constructing a low flow channel from the culvert under the N12 freeway past the shallow mining areas to the point where the drainage changes to a southerly direction. Backfill obvious ponds (i.e. borrow pits) where they are found to be overlying shallow mining. Weirs may be required upstream and downstream of culverts along the altered section due to the flat ground, and the channel would required ongoing maintenance, primarily reed reduction;
- Enhance flow within a channel along this section by means of reed control;
- Construct a pipeline from the Rynfield sewage works near Benoni (Figure 5.1) past this area, together with localised backfilling as for the other alternatives;
- Seal shafts and canals in the area that are believed to be losing water to the underground workings.

The preferred strategy is a pipeline from the Rynfield sewage works to just past the area of shallow mining or to where the stream turns towards the south since this option is likely to have the lowest maintenance risk (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.2.2.2 Sealing dry land surface subsidence or holdings on Northern Reef outcrop

Direct rainfall recharge via such (Appendix 10**)** areas is estimated to be in the order of 2.53 Ml/day of a total wet season recharge of about 108 Ml/day. During the dry season there is no recharge due to the absence of rain. The cost of the remediation option is estimated at between R2 to R3 million.

The following remediation options were considered for this area:

- In areas where prospecting indicates that viable reserves exist, the area will be mined and rehabilitated as part of the surface mining process;
- Where mining is not economic or cannot be undertaken, the subsidence will be backfilled and rehabilitated to ensure free drainage. These measures will prevent direct surface water recharge to these areas although a little groundwater infiltration will still occur (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.2.2.3 Grouting the fault in the vicinity of Cowles Dam

Surface water influx to the East Rand Basin via this fault is estimated to be a constant 10.83 Ml/day of a total wet season recharge of about 108 Ml/day and a total dry season recharge of 71 Ml/day. The cost of this remediation option is estimated at about R12.5 million.

International Trade and Commodities (ITC – a gold mining company), in consultation with Sappi is proposing to drain Cowles Dam in order to remove the gold bearing sludge that has collected in the dam and restore it. This will result in:

- The inspection of the basin of the Cowls Dam;
- The exact location of the geological feature can be determined and the cover and potential recharge mechanism investigated in more detail;
- The flows underground can be measured to assess the change in groundwater ingress;
- Remediation strategies can be more accurately targeted on the basis of the above information (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.2.2.4 Eliminating surface ponding over areas of shallow undermining adjacent to West Pit

Surface water influx to the East Rand Basin via this area will be some proportion of the total influx due to all shallow undermining which is estimated to be a constant 24.29 Ml/day of a total wet season recharge of about 108 Ml/day and a total dry season recharge of 71 Ml/day. The cost of this remediation option is estimated at between R6 to R8.5 million.

A combination of road structure and sedimentation has caused water to dam up over this area. Remedial measures are aimed at recreating a defined channel and a seasonal wetland instead of a permanent pond of water (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.2.2.5 Reducing surface ponding over areas of shallow undermining in the Southern Basin

Grootvlei layouts indicate that there are areas in the Southern East Rand Basin where undermining could be shallow (Appendix 11). Surface water influx to the East Rand Basin via this area will be some proportion of the total influx due to all shallow undermining which is estimated to be a constant 24.29 Ml/day of a total wet season recharge of about 108 Ml/day and a total dry season recharge of 71 Ml/day. The cost of remediation at the Marievale Bird Sanctuary is estimated at R3 million. Remedial measures for the shallow undermining below Aston Woods Dam and Nigel Dam have not yet been addressed. They appear to be outside of the main water flow, and have been flagged as areas for consideration in the future.

The following remediation options have been considered for this area:

- Dredge the immediate area above the bridge on the R42 (Figure 5.1) and remove reeds to allow the water to flow over the entire bridge invert. New culverts would also be installed through the R42 at a lower level, since it appears that there is a step in the water levels from upstream to downstream of the bridge;
- Dredge from the R42 up to the area of concern, potentially to a depth of approximately 1 meter below current levels and probably within a channel on the one side of the area only;
- Relocate pipes under roads immediately upstream of the area of concern and provide a low flow channel on the eastern bank of the wetland.

The preferred strategy includes improving the drainage through the R42 by the installation of additional culverts on the overbank and dredging immediately in front of the bridge. Additional reed control would be instituted as and when required (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.2.2.6 Reducing surface ponding over shallow undermining at Geduld and Alexander Dam

Further work is required to establish what the nature of ingress is in this area and what exact measures would be effective in preventing such ingress (Appendix 9). However, it is expected that such measures would be similar in extent to those proposed for the area in the vicinity of west pit and Cowles Dam. The principle would be to keep ponding off the areas of shallow undermining (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

6.1.2.2.7 A clean water capture system in shallow underground areas in the Northern Basin

This option was identified late in the feasibility study and further work is required to establish how effective such measures would be and how they would be implemented. In principle a system of underground catchment dams would be installed at the shallowest levels of the mine in the northern part of the East Rand Basin (Appendix 9). The water would then be pumped to the surface at one of the shafts and discharged into the Blesbokspruit. The point of discharge would be located downstream of any areas of remediation proposed in the abovementioned management measures and may require a pipeline from the shaft to the preferred point of discharge (Oryx Environmental and Jones & Wagener Consulting Engineers, 2003).

CHAPTER 7

SYNTHESES: CONCLUSION AND RECOMMENDATIONS

7.1 Conclusion

This study examined whether or not Grootvlei's pumping activities of extraneous water from underground mine workings into the Blesbokspruit has had, and is still having, an influence on the water quality of the Blesbokspruit.

Four important variables, pH, Electric Conductivity, magnesium and sulphates were discussed in relation to three categories, namely the sample positions (before pumping of extraneous water from underground mine workings into the Blesbokspruit, just after extraneous water fom underground mine workings is discharged into the Blesbokspruit and just after the Blesbokspruit wetland), seasonal influences and the temporal variation (before pumping commenced until September 2002). The sample point just after the discharge of extraneous water from underground mine workings into the Blesbokspruit as well as the periods of the driest seasons were associated with the worst overall water quality in all four variables. It was found that although the sample point positions and seasonal changes had an influence on the water quality of the Blesbokspruit, the temporal variation had the greatest influence, with a decrease in water quality after pumping commenced in October 1995. It was also found that the Blesbokspruit wetland does not have the capacity to purify the water in the Blesbokspruit to that of the same quality as the water upstream of the mine. This could be the result of too many contaminants already in the wetland.

The conclusion of the analysis was that the pumping of the extraneous water from underground mine workings into the Blesbokspruit had and still has, although in lesser amounts, a major impact on the deterioration of water quality of the Blesbokspruit.

The problem of pumping extraneous water into the Blesbokspruit could result in two possible end results:

- Continued pumping or
- Decommissioning of Grootvlei's pumping activities.

Landowners living adjacent to the Blesbokspruit use the water in the Blesbokspruit for irrigation purposes. According to the impact study conducted before pumping started, there was a risk of long-term soil salination of large areas of the lands currently being irrigated if pumping without mitigatory measures was implemented. This would result in financial losses to the farmers. On the other hand a decision to withdraw the pumping permit and stop the pumping operations would ultimately have resulted in the closure of Grootvlei.

Pumping from Grootvlei will cease sooner or later, as a result of the financial burden of pumping the extraneous water in order to keep the underground workings dry. The mine nearly closed three times in the last nine years (Berry, 2004; Personal Communication). Without government funding, closure of Grootvlei is unavoidable. Closure of Grootvlei will result in extensive job losses. It should also be remembered that the Blesbokspruit wetland formed as a result of the mining activities in the area. Closure of Grootvlei will result in the decommissioning of pumping activities. As a result, the wetland will have to rely solely on seasonable flows. Less water will be available for agricultural usages, for which permits have been issued, which will have to be revised if these were based on the pumping assumption of the mine.

Restoration and maintenance of ecological integrity is now being advanced as a primary goal of water resource management. In this study the importance of Grootvlei for economic reasons, as well as the importance of the Blesbokspruit and the Blesbokspruit wetland for the environment, have been highlighted. All of these issues are very important in terms of the socio-economic and bio-physical environment and a harmony between them is imperative. This will require new management approaches with an emphasis on the assessment of a wide range of ecological impacts (Davis & Simson, 1995). It is generally accepted that a healthy environment is intrinsic to sustainable development. However moving beyond mere recognition is more difficult. This includes understanding of the dynamics and myriad environmental, economic and social relationships. Greater insight into the interactions between the macro-economy and the environment is critical (Foundation for Water Research, 2000).

7.2 Recommendations

7.2.1 Environmental law and compliance

South Africa is a signatory to numerous international environmental treaties that promote the protection and wise use of the natural environment (e.g. Ramsar Convention, the convention on Biological Diversity etc.) In addition, there are several laws and regulations that are aimed at protecting the environment to the benefit of South African society (the South African Constitution, the National Water Act, the National Environmental Management Act etc.). A Wetland Bill was tabled in Parliament during 1995 and it is anticipated that there will be a Wetland Act within the next 18 months. There is therefore both a legal and moral obligation to manage wetlands in a wise and sustainable way (Walmsley & Mzuri Consultants, 1999).

The question of whether Grootvlei has complied with the environmental law since 1995, becomes a complicated one by taking into account all the associated parties, which includes the mining sector, the environmental sector and the government. However, political pressure has allowed the mine to continue pumping operations. If Grootvlei stops its pumping operations, the Department of Water Affairs and Forestry will inherit the problem. This will lead to further problems as Grootvlei operates a gold mine and has gold sales to subsidise its pumping costs, which the Department of Water Affairs and Forestry does not have (Berry, 2004; Personal Communication).

Grootvlei has been granted a water licence in terms of the National Water Act (Act. 36 of 1998), Chapter 4. However, the mine has to comply with certain requirements to improve the underground water quality before discharge into the Blesbokspruit (see Section 5.3). The mine is currently compiling a Feasibility Study in order to comply with these requirements. This is discussed in Chapter 7.

It is recommended that the mine compile the feasibility study according to environmental law to achieve the best suited scenario to comply with the water quality target set by the Department of Water Affairs and Forestry, as well as to comply with the statements and intentions made in the final decisions to improve the water quality pumped into the Blesbokspruit (see Section 6.1.1). An Environmental Management plan should be compiled to ensure that environmental management activities take place. This plan should be a combination of a programme, scope, specifications to manage (through mitigation avoidance), environmental impacts associated with a particular operation and process. An Environmental Management System should be in place to ensure that the mine complies with the Environmental Management Plan and with all regulations and statements made to reach their objectives and target to ensure that the water quality pumped into the Blesbokspruit is improved.

7.2.3 Environmental and community awareness

It is essential to ensure that any plan is sustainable in the long term. There should be commitment and understanding from all relevant parties that management will be a continual and ongoing process requiring appropriate resources (human, financial, technical) for its operation (Walmsley & Mzuri Consultants, 1999). Successful management cannot be done without the commitment of parties other than Grootvlei.

Grootvlei should therefore become actively involved in improving community relationships. A channel of communication should be available between Grootvlei and the local community, for the mine to become aware of the local people's issues and concerns regarding the state of the Blesbokspruit as a result of Grootvlei's activities. Grootvlei should take these concerns seriously and establish programmes to address these issues and concerns. Meetings should be held to inform and assure the community and all interested and affected parties of the steps taken and progress made with regards to their issues and concerns.

A Canadian company (Petrex) took over Grootvlei from Petmin in 2002. An Environmental Manager has been appointed and all environmental policies are in the process of being revised. The mine is also in the process of investigating various programmes to ensure an improvement in the current water quality being pumped into the Blesbokspruit (see Section 6.1.4).

7.2.3 Catchment forums

The promulgation of the National Water Act (Act 36 of 1998) has resulted in the establishment of nineteen Water Management Areas (WMA's) in South Africa, which will be managed by Catchment Management Agencies (CMA's). The process to establish a CMA for the Upper Vaal WMA has been initiated and considerable progress has been made. The success of the Upper Vaal CMA, once established, will depend largely on effective communication with all stakeholders in the WMA to formulate and implement a Catchment Management Strategy (CMS). This can only be effectively accomplished through the establishment of Catchment Forums.

A Catchment Forum is a group of concerned people who agree, on a voluntary basis, to represent the different perspectives of society. It is a formal structure, which is related to the Catchment Management Agencies, where co-operative and consultative water resource management can take place. A Catchment Forum vision is to promote a healthy, safe and sustainable environment that is fit for all uses through interactive stakeholder participation within the Blesbokspruit Catchment and thereby to provide a platform to assist in the development of an Integrated Environmental Management Strategy for the Blesbokspruit Catchment through stakeholder participation.

As mentioned in Chapter 4, the Blesbokspruit wetland within the Blesbokspruit catchment's ecological character has been dramatically changed by large amounts of pollutants being discharged into the system, with Grootvlei as one of the main sources of discharge directly into the system. It is therefore extremely important to manage all the sources contributing to the decrease in quality of the wetland.

The Upper Vaal WMA comprises of thirteen Catchment Forums, of which the Forum (BF) is one. The Forum was established in 1996 and is regularly attended by mines, industries, farms, local authorities, non-governmental organizations, water service providers and the general public. The Forum also has a well-established Forum Management Committee (FMC), which coordinates and manages activities on behalf of the Forum. Various Task Teams have also been formed focusing on specific water resource related issues. The participation of all people in the protection, use, development, conservation, management and control of the water resources of the Catchment can be promoted through the Forum.

The objectives of the Blesbokspruit Forum are:

- To promote the protection, use, development, conservation and management of the environment of the Blesbokspruit Catchment;
- To develop and implement short, medium and long term goals of an Integrated Environmental Management Strategy of the Blesbokspruit Catchment;
- To effectively communicate and inform the goals of an Integrated Environmental Management Strategy of the Blesbokspruit Catchment; and
- To provide the opportunity for all role -players to participate in a forum that is transparent and representative of the Blesbokspruit Catchment.

Functions to be performed by the Forum:

- Ensure that the membership of the Blesbokspruit Forum reflects a broad range of perspectives from different sectors of society and a wide range of interests;
- Ensure that consultation with the broader base of interested and affected parties is maintained and that they be given the opportunity to comment on the Blesbokspruit Forum's deliberations and recommendations;

- Convene regular meetings and inform Forum members timeously of such arrangements; and
- Start, maintain and promote a program to raise awareness on Water Resource Management and strategies.

The Blesbokspruit Forum shall elect a Forum Management Committee, which will represent the relevant water use sectors within the Blesbokspruit Catchment. The Monitoring Committee (MC) functions is to manage all activities related to water resource monitoring within the Blesbokspruit Catchment, including surface and groundwater quality monitoring, as well as hydrological and biological monitoring (Blesbokspruit Forum, 2003c).

It is essential that developments in the catchment, that could have an impact on the wetland, be reviewed according to accepted integrated environmental management. The process of integrated environmental management is a procedure that is advocated for sound environmental management. The wetland must be viewed as being a key receiving system within the Blesbokspruit catchment. The management of the Blesbokspruit Ramsar site should also form part and parcel of any integrated catchment management activities as outlined in the new National Water Act 1998. By managing the catchment strategically it would contribute to the improvement of the wetland as well as the surrounding agricultural land. The Blesbokspruit Forum, which shall manage the catchment and activities impacting on the catchment, will ensure that this management take place.

It is recommended that the Catchment Forum initiate the development of an Integrated Catchment Management Plan. It is also recommended that Grootvlei become actively involved in the activities and decisions of the Blesbokspruit Forum. This has been initiated by the Environmental Manager of Grootvlei participating in the Forum.

7.2.4 Phytoremediation and the use of trees and riparian zones

Phytoremediation is the use of plants to remediate contaminated soil or groundwater. This technique can be used for the remediation of inorganic, as well as organic contaminants. Plant species can be selected to extract and assimilate or extract and chemically decompose target contaminants. Heavy metals can be taken up and bioaccumulated in plant tissues. Many inorganic compounds considered to be contaminants are, in fact, vital plant nutrients that can be absorbed through the root system for use in growth and development.

The advantages of Phytoremediation are the low capital cost, aesthetic benefits, minimization of leaching of contaminants, and soil stabilization. The limitations of Phytoremediation are that the contaminants present below rooting depth will not be extracted and that the plant or tree may not be able to grow in the soil at every contaminated site due to toxicity. In addition, the remediation process can take years for contaminant concentrations to reach regulatory levels and thus requires a long term commitment to maintain the system (Suthersan, 1999).

Vegetation also plays a key role in the interactions between groundwater and surface water systems, because of its direct and indirect influence on recharge and because of the dependence of vegetation communities on groundwater. Despite this, groundwater and surface water have traditionally been treated as separate legal entities in South Africa and scientific disciplines have also tended to view them as separate, or at least sepa rable, hydrological systems. This situation is beginning to change as South Africa's Water Act recognises them both as inseparable elements of the hydrological cycle (Le Maitre et al., 1999).

Trees can decrease recharge by extracting water from the soil profile to transpire through their leaves (Le Maitre et al., 1999). Trees can also be planted in surface seeps and thereby be used to intercept polluted water that will infiltrate into and degrade aquifers. Eucalyptus in South African plantations may extract water to considerable depths. Studies have proven that three-year-old *Eucalyptus grandis* trees can extract water from depths of 8m, while 10-year-old trees, cut off from rainfall, abstracted water largely from below the maximum measured depth of 8m (Dye, 1996). The Council for Scientific and Industrial Research (CSIR) have also been involved in the development of a forestry management plan as a part-solution to the ingress of unwanted water into mines for a major colliery in the Mpumalanga. In these studies trees were the main driving force in controlling the water balance, where agro-forestry, wetland systems, wildlife conservation and recreational aspects were also investigated (Button, 1993).

Plants have been used for remediation in the past. A num ber of free-floating aquatic and aquatic emergent plant species and their associated micro-organisms have been used for more than a decade in constructed wetlands for municipal and industrial wastewater treatment. The relationship between riparian vegetation and groundwater is frequently complex. Plants may tap water stored in riverbanks or in alluvial aquifers, which may be dependent on periodic flooding for their recharge; or may tap groundwater that is discharging into streams. Studies have indicated that riparian trees may be essentially independent of water in the stream channel (Dawson & Ehleringer, 1991), but in other cases, trees may switch between a separate deeper, groundwater source and the stream water.

Plants that are riparian specialists (also called obligate phreatophytes) are species adapted to fluctuating water tables and their roots typically remain in, or in contact with, the saturated soil layers. These species are sensitive to sudden water stress such as a sudden lowering of the water table (Rood and Mahoney, 1990) or changes in the duration of floods, which results in changes in the soil moisture balance and water tables (Smith et al., 1991).

This management strategy can be implemented at Grootvlei in reducing the water that is currently in the underground workings as well as water recharging this water. This will also contribute to the cleaning or treating of the underground water.

7.2.5 Regular monitoring

Underground mining operations below the groundwater table may often experience seepage or inflow of water and consequently the mine workings, like those of Grootvlei are likely to be wet and may flood. Under these circumstances, it is necessary to have a contingency plan in place (Dam Safety Committee, 2004). It is important for Grootvle i to adopt a range of control measures in order to carry out mining operations in an efficient and safe manner. It is necessary to regularly monitor the quantity of mine water inflow and the chemistry of the mine water in order to determine its source. These measures will ensure that the rate of inflow can be estimated and therefore the danger of inundation and the extent of water danger can be assessed. This process has started at Grootvlei by means of the present Scoping Report.

Thus, by judiciously following the abovementioned procedures, a mine operator or the environmental manager of the mine can obtain the correct forecast for any water problems and adopt effective remedial measures.

7.2.6 Improving the quality of the Blesbokspruit wetland

Where possible, restoration of wetlands is essential to recover the historical quality of the remaining part of the wetland. Restoration may be required as part of a permitting process, but restoration efforts may also be prompted by environmental resource management goals for habitat or water quality improvement. Degraded wetlands present restoration opportunities for improvements to water quality, habitat, water storage and other functions.

Wetland creation and restoration projects have been conducted at a number of mining areas, especially in the United States. Some of these projects include creation or restoration of riparian wetlands.

The improvement of the Blesbokspruit wetlands and therefore the improvement of the functional importance of the wetland, should be highly considered as an incentive to improve the water quality of the Blesbokspruit.

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APPENDICES