

**COST-BENEFIT ANALYSIS OF THE ENVIRONMENTAL IMPACTS OF
DARVILL WASTEWATER WORKS, PIETERMARITZBURG, KWAZULU-
NATAL**

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**Submitted in fulfillment of the academic requirements for the degree of
Master of Science
in the
Department of Geography, Faculty of Science and Agriculture
University of Natal**

Pietermaritzburg, 2001

ABSTRACT

Darvill Wastewater Works (DWWW) receives and treats both domestic and industrial wastewater from the city of Pietermaritzburg, in KwaZulu-Natal. Sludge from the wastewater treatment is sprayed onto surrounding lands, causing odour and fly problems. The plant also discharges treated effluent into the Msunduzi River, compromising water quality. This study uses several economic valuation techniques to estimate the value of the benefits of improving air and water quality to overcome these problems caused by DWWW. The benefits are then compared with the costs of upgrading DWWW to see whether or not upgrading DWWW to improve air and water quality would be worthwhile.

The Contingent Valuation Method (CVM) was used to elicit people's willingness to pay (WTP) for improvements in air quality due to the elimination of odours and flies caused by sludge deposited by DWWW. The WTP estimates reflect individual's preferences for improvements in air quality. The stated WTP amounts were positively related to household income, but negatively related to the age and gender of the respondent and the number of dependants in the household. The mean monthly WTP for the surveyed households is higher for those that are closer to the pollution source (R23.00 and R29.00 for Zones 1 and 2) and less for those further away (R14.00 for Zone 3). Sobantu residential area had the lowest mean monthly WTP (R18.00), followed by Lincoln Meade (R27.00) and Hayfields (R54.00). This is expected, as Sobantu has relatively high levels of unemployment and lower household incomes. Strategic, hypothetical and free rider bias may have led to the unexpected signs of some estimated regression coefficients in linear regression models used to estimate WTP. The mean WTP was estimated as R307.20 per annum per household, and when this is aggregated over the total population in the residential areas impacted by odours and flies (37192 households), the benefits of eliminating odours and flies are estimated as R11 425 382.00 per annum.

A hedonic price method was used to quantify the decline in property values as a result of odours and flies caused by sludge deposited by DWWW. Properties experienced a R6650.08 decline in selling price if the distance from them to DWWW is decreased by one kilometre. Properties that are closer to DWWW were worth R15953.90 less than those further away from DWWW. Aggregating these values over all estimated impacted households in the study, gives an estimated benefit of improving air quality of R28 480 518.00 per annum. The impact of water pollution was quantified by estimating the revenue (R3 744 975.00) that would be lost by Pietermaritzburg if the Duzi Canoe Marathon were to be cancelled due to incidences of diarrhoea reported during the race. A cost of illness procedure was adopted to quantify the effect of water pollution on the health of communities that use the Msunduzi River as a source of potable water supply. A value of R1 243 372.50 was estimated as the annual cost of water-related illnesses in these rural areas. This value represents the costs of the river pollution to those communities. Both of these exercises indicated that improving water quality of the Msunduzi River would be beneficial to society.

The effect of nutrient enrichment of the Msunduzi River was quantified by estimating the cost of removing water hyacinth from the Inanda Dam, treatment cost at Wiggins water treatment works and the value of recreation at Mahlabathini Park (Inanda Dam). The annual cost of removing water hyacinth was estimated from the direct costs of chemicals and labour as R47 202.15. The increased treatment costs at Wiggins attributable to DWWW were estimated as R1 104 999.20 and R956 924.15 per annum for removal of algae, and tastes and odours, respectively. The value of R706.90 per annum was estimated as the consumer surplus accruing to recreationists, and, therefore, the value of recreation at Mahlabathini Park to an individual. These annual benefits, when aggregated over the total study population (296 590) were over two hundred million rands (R209 659 470.00).

The estimated total benefits (R256 662 840.00) of eliminating odours and flies and effluent problems were compared to the actual costs of two alternative methods of upgrading DWWW using cost-benefit analysis. These alternatives were co-disposal

option (R170 473 320) and a land disposal option (R168 809 377). Benefit-cost ratios of 1.51 and 1.52 suggest that from society's standpoint, it would be beneficial to upgrade the plant in order to eliminate its adverse environmental impacts. The study results have important implications for policy makers, both the DWWW management and the Pietermaritzburg-TLC municipality. At present DWWW is operating beyond its design capacity, and this problem, together with the poor status of Pietermaritzburg's reticulation system, causes overflow of untreated or compromised final effluent into the Msunduzi River during rainy seasons. These problems also impact on the efficient operation of the plant as the sludge is not properly digested before being sprayed onto surrounding land. Thus to prevent further environmental degradation, a fundamental basis of the National Environmental Management Act, DWWW would need to address these issues. Upgrading DWWW would be a short-term solution if the problems with the storm-runoff into the plant is not addressed.

PREFACE

The research reported herein was conducted in the Department of Geography, University of Natal, Pietermaritzburg, from July 2000 to July 2001, under the supervision of Dr F.B Ahmed (Department of Geography) and Mr M.A.G Darroch (Discipline of Agricultural Economics).

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any other University. Where use has been made of the work of others it is duly acknowledged in the text.

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ACKNOWLEDGEMENTS

I owe a great many thanks to a great many people, for their help and support throughout the course of this research. Firstly, my supervisors, Dr F.B Ahmed (Department of Geography) and Mr MAG Darroch (Discipline of Agricultural Economics), I am certain I would not have managed without their constructive criticism and their unwavering support. Much gratitude also to Ms Eiman Karar and the Eastern Environmental Network of South Africa for financial assistance. I would also like to thank Celani Myeza and Babalwa Manyakanyaka for being there for me when I needed to go to the field, they acted as my drivers even though they had work of their own, I cannot thank them enough. Thanks to the Sobantu Environmental Group and the Lincoln Meade Ratepayers Association who acted as focus groups, they provided much needed guidance in the design of the questionnaires. Without the emotional support of my family and the spiritual guidance of the Almighty this study would not have been successful. Last but not least I would like to thank my friends who saw me through the frustrations when things were difficult and shared my moments of triumphs, especially: Faith, Sindi, Bongiwe and Khosi.

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CHAPTER 1

INTRODUCTION

1.1 PREAMBLE

The decline of nature and natural resources is now an ubiquitous phenomenon, which appears in all economic systems regardless of political ideology, and in both the very rich to the very poor countries. It is not only an attribute of the more advanced western industrial countries, despite the impressions given in some environmental literature, as many developing countries face acute threats from water and air pollution, water scarcity and the loss of biodiversity to name just a few (Nebel & Wright, 1996). There is no question that human societies are responsible for most of the changes in the natural environment, nor is there any question that this is occurring on a much greater scale (Swanson, 1996). The developing community has seen a dramatic acceleration in the rate of environmental deterioration, as a direct consequence of increased urbanization, high unemployment rates and poverty. These issues have resulted in a significant increase in the amount of waste and wastewater produced (Loots, Ollermann, Pearce & Saaymann, 1994). ✓

Every community produces both liquid and solid wastes. The liquid waste which is referred to as wastewater is essentially the water supply of that community after it has been fouled by a variety of uses. Thus, wastewater can be defined as a combination of liquid or water-carried wastes removed from residences, institutions, commercial and industrial establishments together with groundwater, surface water and storm water as may be present. If untreated wastewater is allowed to accumulate, foul smelling gases may be produced. Furthermore, since wastewater also contain sewage, harmful pathogens are often a problem associated with untreated wastewater. In addition, this water is usually rich in nutrients, and if it enters the watercourse of rivers, the nutrients may stimulate the proliferation of undesirable aquatic plants. The bacteria found in wastewater can also reduce the oxygen content of the water thereby rendering the water anaerobic. The immediate removal of wastewater, therefore, is imperative (Tchobanoglous & Burton, 1991).

1.2 WASTEWATER TREATMENT & IMPACTS ON THE ENVIRONMENT

The collection of wastewater can be traced back to the early 18th century in London, and its systematic treatment followed in the late 18th century (Nebel & Wright, 1996). In recent years, the treatment and disposal of wastewater have received much attention due to the nuisances and health conditions they cause. More and more demand has been placed on wastewater treatment technologies and their effectiveness. Due to the scarcity of fresh water, it is clear that the used water collected from communities and municipalities must not be viewed as a waste to be disposed of, but rather as a resource. Therefore, after treatment the wastewater must either be reused or returned to the environment. It is common practice now to discharge the treated effluent into streams, rivers, lakes, estuaries or the oceans. In order to avoid adverse environmental impacts, however, the quality of the treated and discharged effluent must be consistent with local water quality objectives. If the final effluent is not treated properly, pollution of the watercourse may occur. As noted above this may cause serious problems such as eutrophication, oxygen depletion, proliferation of aquatic weeds and introduction of disease-causing organisms (Lester, 1996).

This deterioration of water quality is further compounded by non-point sources of pollution such as discharges from various agricultural lands and settlements without proper sanitation. Polluted water has serious health impacts on the human population as well as other non-human species that use river water (Loots, Ollermann, Pearce & Saaymann, 1994). It is estimated that 50 000 people die daily world-wide due to water-related diseases (Nevondo & Cloete, 1999). In South Africa there is a serious lack of safe and clean water. More specifically, approximately 12 million people do not have an adequate supply of potable water (Department of Water Affairs and Forestry- DWAF, 1995). Most of these people live in rural areas and use water directly from available and often contaminated water sources, such as rivers, without any treatment, and areas exposed to water-related diseases is high (Nevondo & Cloete, 1999). The human costs associated with mortality and morbidity resulting from these diseases will obviously have an impact on the economic development of the affected communities and the Gross Domestic Product (GDP) (Nebel & Wright, 1996).

Recreation in polluted water is another identified route of transmission of water related diseases. Transmission can either be through direct contact, aerosol inhalation or accidental consumption of contaminated water. Water related diseases, which include water borne and water vectoral diseases, depend on the type of recreational water used. Freshwater recreation such as canoeing, river fishing and swimming has received little attention. There are no guidelines for acceptable water standards and monitoring is mostly carried out by local authorities and relevant water bodies. Polluted water often requires expensive treatment technologies to make the water adequate for potable use (Kfir, 1992).

Another environmental impact resulting from wastewater treatment technology is the odour problem that is associated with wastewater treatment plants and the surrounds. This odour may be due to the foul smelling sludge that is produced during the primary treatment. In recent years, most treatment plants have adopted technologies aimed at treating the raw sludge, the most frequently employed method being anaerobic digestion. In this procedure, bacteria are allowed to feed on the organic matter in the absence of oxygen. A major byproduct of this process is a gaseous mixture of which about two thirds is methane gas. The other third is made up of carbon dioxide and other foul smelling organic compounds that give sewage its distinctive smell. Flies, usually found at the inlet of the works, are a frequent nuisance in areas that are close to the wastewater works (Lester, 1996 & Tchobanoglous & Burton, 1991).

1.3 VALUATION OF ENVIRONMENTAL DEGRADATION

The estimation of both the value of environmental resources and changes in environmental quality is fundamental in environmental resource economics. Firstly, such values serve as reminders that environmental quality is essentially a public good, and that there is no conventional market for it. Secondly, the imbalances between quantifiable and non-quantifiable effects of environmental degradation in cost-benefit analyses can be addressed. Valuation can also provide a truer indication of economic performance if it accounts also for the external benefits and external costs of economic actions by individuals or institutions. External benefits

and costs are not experienced by the individuals performing the actions, but which are felt by individuals not related to those actions (Winpenny, 1991). For example, if air quality is improved by one person in an urban area, it is thereby improved for everybody else in that community.

The measurement of value is important in determining the optimal levels of pollution and also in cost-benefit analysis. The determination of optimal levels of pollution employs the concept of marginal abatement costs, which are the costs of reducing the quantity of residuals that are emitted into the environment. These are the costs that the polluting individual incurs in implementing activities that prevent emissions that would otherwise affect the environment. Marginal damages, however, are the result of environmental degradation, and are determined by relating human exposure to environmental pollution. The impacts - which may be health, aesthetic or recreation impacts - as a result of this exposure are measured and then valued to give an estimate of the benefits of reducing pollution (or improving air or water quality). In cost-benefit analysis the emphasis is on comparing all the estimated benefits and costs of a particular project (Dixon, Scura, Carpenter & Sherman, 1985).

The project in question may be a physical project such as upgrading of public wastewater treatment plants, or a regulatory program, which is directed at enforcing environmental laws. An example of a regulatory program could be legislation about pollution control standards, which polluters must adhere to (Field, 1994). The results of a cost-benefit study would then determine whether or not it is worthwhile to embark on a project - as is in the case of upgrading the wastewater treatment plant. If the estimated benefits exceed the estimated costs of upgrading the plant, then the project would be initiated.

In cost-benefit analysis, the direct costs of resources traded in markets can be used. However, where there are untraded resources, it is usually necessary to use other methods of valuing the costs, because direct market costs are not available. In these cases, damage cost valuation and surrogate markets can be used. Damage cost valuation refers to the reduction in income estimated from product market prices such as increased medical costs and the indirect costs from

illness (such as loss in productivity, etc). Legal liabilities have also been used to attach a value on environmental amenities. The assumption is that damage penalties paid according to law enforcement can indicate the value to society of a particular environmental good (Karmokolias, 1999).

The value attached to environmental services gives the estimate of the benefits of those services to society. The critical issue in environmental economics, therefore, is how to measure (estimate) these benefits. An individual is said to benefit from some action if he/she is being made better off than he/she was initially before that action. The benefits of an environmental good are measured in terms of what individuals are willing to pay (WTP) for that good (such as improvements in air quality and water quality or the conservation of biodiversity). The use of WTP to measure benefits is based on the notion that individuals' preferences count, in that consumers, being rational individuals, will show preferences for one good over another. These preferences are measured by some factor usually correlated to income. In consuming a particular good, individuals will obtain utility or satisfaction from that good, which means they would place a value on that good. The value will be what the individual is willing to pay for that good. The measured individual's WTP will, therefore, give an estimate of the benefits of that good being made available to that individual - for example, cleaner air (Dixon *et al.*, 1985).

1.4 RATIONALE FOR UNDERTAKING THE STUDY

Darvill Waste Water Works (DWWW) has been owned and operated by Umgeni Water since 1992. This plant is situated to the east of the Pietermaritzburg city center and is built on 78 hectares of land that is bounded by the Msunduzi River on the north and east (Umgeni Water Environmental Report, 1997-1998). Towards the west side of the plant there is a landfill site (New England Landfill). Residential areas such as Sobantu, Hollingwood and Lincoln Meade are situated to the north and south of the plant. A further 71 hectares of land is leased by Umgeni Water from the Transitional Local Council (TLC), with about 50 hectares of this land being used for sludge disposal. Agricultural holdings can be found towards the eastern region of the sludge

disposal land (GFJ, 1999).

The plant treats all domestic and industrial sewage from the city of Pietermaritzburg by employing a combination of biological filtration and activated sludge process technologies. The average dry weather flow is 60Ml/d. The treated effluent is discharged directly into the Msunduzi River while the sludge is sprayed onto land using a sprinkler irrigation system. Debris and grit removed during the preliminary step of the sewage treatment process are disposed of at the New England landfill site (GFJ, 1996). The Msunduzi River, which is a major tributary of the Umgeni River, serves as a major source of drinking water for rural communities residing in areas along the length of the river, such as those communities living in the Valley of a Thousand Hills. The Umgeni River eventually joins the Inanda Dam, which is one of Umgeni Water's major catchments, and it serves the Durban Metropolitan area with potable water. Several management and environmental issues associated with DWWW operations have prompted the need for a study of the environmental impacts of DWWW.

1.4.1 DWWW Management Issues

The management of Umgeni Water face substantial challenges in operating DWWW. Some of these challenges stem from the split responsibility of DWWW operation between Umgeni Water and the Pietermaritzburg TLC. Umgeni Water is responsible for monitoring pollution, whereas the TLC is responsible for the enforcement of environmental legislation. An example of such legislation is the "Polluter Pays Principle". According to this law any person who causes significant pollution or degradation of the environment must take reasonable measures to prevent that pollution from occurring, continuing or recurring. If pollution cannot be avoided or stopped, then that individual is required to minimize and rectify such pollution or environmental degradation (National Environmental Management Act, 1998). These Bylaws, however, are not always enforced because of the lack of proper infrastructure and the shortage of properly trained staff. Hence, some industries continue discharging their effluent down storm water drains. Another challenge is the lack of advanced sludge disposal techniques. As a result, not all of the

sludge that is produced is digested anaerobically before being sprayed over the land (Umgeni Water Environmental Report, 1997-1998).

1.4.2 Environmental Issues Associated with DWWW

- ◆ Odours and flies are a constant nuisance at DWWW, due to the under-processed sludge that is sprayed onto the land at Darvill. Numerous complaints about these problems have been received and a Residents' Forum has been established in order to address these complaints. These problems compromise the air quality, and as a result may have a detrimental impact on the value of the properties in the surrounding residential areas (Umgeni Water Environmental Report, 1997-1998). Aside from the problems of odours and flies, the spraying of the sludge onto the land also contaminates the ground water and the soil, and makes the conditions conducive for the proliferation of alien plants (GFJ, 1999).

- ◆ The stormwater attenuation dam, which has a capacity of 63Ml, was designed for emergencies such as heavy rains, floods and shutdowns. Illegal pollution of storm water drains with industrial effluent and urban runoff contributes significantly to the periodic overflows of raw effluent from this dam, as the ingress of this wastewater is sometimes twice the dam's capacity. These overflows result in a compromised final effluent that is discharged to the Msunduzi River, posing a health hazard to people using the river for recreation and as a source of drinking water. The Duzi Canoe Marathon, which is held annually on the Msunduzi River in Pietermaritzburg, has attracted attention in recent years due to the incidence of diarrhoea or "Duzi Guts" amongst competitors during and after the race. Cancellation of this race due to this problem would have a negative impact on the revenue generated by the city. The possibility of civil litigation against the authorities would also increase the costs of water pollution.

- ◆ The Msunduzi River is a tributary of the Umgeni River, and thus the nutrient enrichment

as a result of sewage effluent discharge from Darvill eventually finds its way to the Inanda Dam. The nutrient enrichment of the surface waters encourages the growth of Phytoplankton and blue green algae which cause taste and odour problems. Furthermore, some algae species are toxic to humans and this adds to the purification costs. The algae also rapidly clog filters in the water treatment plants, thus requiring expensive technology to eradicate them. Another consequence of nutrient enrichment is the proliferation of aquatic weeds such as the water hyacinth, which require an expensive herbicide-spraying programme for removal.

1.4.3 South African Environmental Legislation

With the promulgation of legislation such as the National Water Act (NWA) No 36 of 1998 and the National Environmental Management Act (NEMA) No 107 of 1998, more focus has been directed at preventing environmental degradation in order to promote sustainable development. The fulfillment of these objectives hinges on the application of some basic principles that the government has adopted in order to achieve its vision of sustainable development. One example of these principles is the “Polluter Pays Principle”, which states that those who are responsible for environmental damage are obliged to pay all of the repair costs. These costs include ‘costs to the environment, costs to human health and well-being and the costs of reducing or preventing any further environmental damage’ (White Paper, 1999). The National Environment Management Act 107 section 28(1) states that people causing, that have caused or may cause significant pollution or degradation of the environment, must take measures to prevent such pollution or degradation by implementing or installing necessary measures to minimize pollution or degradation in cases where pollution cannot be completely prevented. Costly consequences may result from failure to comply with this legislation such as the payment of a steep fine and all legal costs incurred should the case be taken to court.

The DWWW management issues, environmental impacts, and the recently enacted legislation discussed above indicate that there is an urgent need for a study that quantifies the environmental

impacts caused by DWWW. Past studies of the problems at DWWW have focused mainly on the costs of improving sludge handling and disposal techniques at DWWW. A consulting civil and environmental engineering firm, GFJ (Pty) Ltd, was commissioned by Umgeni Water Board in 1996 to investigate the financial analysis for the augmentation of the wastewater treatment infrastructure in Pietermaritzburg-Msunduzi TLC. The main issues highlighted by this study were that DWWW had reached its dry weather flow capacity and needed to be extended. Secondly, the high quantity of stormwater entering the plant from the Pietermaritzburg-Msunduzi TLC affects the performance of the works. Thirdly, as there is insufficient land within the Pietermaritzburg-Msunduzi TLC to build a new wastewater treatment plant, Darvill would need to be upgraded to increase its capacity and to build a retention dam to handle the stormwater flows. The same consultants in 1999 carried out a pre-feasibility study on the financial and environmental implications of sludge disposal at DWWW. Another study (Watermeyer, Legge, Piesold & Uhlmann Consultants and Wates, Meiring & Barnard Consultants, 1993) investigated different sludge disposal options, such as Active Sludge Pasturization (ASP), Co-disposal at the New England Landfill site and Land Disposal. Both these studies indicated that the option of using the New England Landfill site to dispose of sludge is, although not the most cost effective option, attractive. The present study undertakes a cost-benefit analysis of upgrading DWWW to eliminate or reduce the environmental impacts outlined above. In most of the past studies of DWWW operations, estimates of the cost of damages to the environment are missing. These are important in any proposed project as they provide a truer picture about the merit/s of that project (Field, 1994).

1.5 ASSUMPTIONS UNDERLYING THE STUDY

Due to time and financial resource constraints, certain assumptions had to be made regarding this study. Environmental degradation, especially pollution, is usually caused by both point and non-point sources. Most of the environmental impacts that have been identified in this study are exacerbated by pollution from other sources. The pollution of the Msunduzi River by the discharged raw effluent during overflows at DWWW is confounded by the location of

informal settlements upstream of the river. This affects the *Escherichia coli* (*E.coli*) count in the river and renders the water unsafe for consumption or any recreational activity. The industries situated upstream of DWWW have long been suspected of polluting the Baynespruit, which is a tributary of the Msunduzi River. The Umgeni water quality monitoring programme of this stretch of the river and of the Msunduzi River indicates that the treated effluent discharged from DWWW into the Msunduzi actually improves the quality of the water by diluting it (Umgeni Water Quality Monitoring Programme, 2001).

According to Archer (1999), however, the DWWW retention dam overflow has in the past introduced more than 72000 *E.coli* per 100ml into the river, whereas the effluent discharged from the plant has introduced more than 36000 *E.coli* per 100ml. These figures are very high compared to those set by the World Health Organisation, which states that the count of 100 *E.coli* per 100ml or above may cause serious health problems if the water is used for consumption, bathing, laundry or recreation. Since these overflows occur during heavy rainfall and are the result of the sewage loads exceeding design capacity, it makes sense in environmental and economic terms to address the issue of upgrading the plant.

Another environmental impact which is assumed to be a direct consequence of overflows from DWWW is that of nutrient enrichment of the water entering the Inanda Dam. This eutrophication is thought to cause the growth of hyacinth and algal blooms at this dam. However, there are other sources of pollution that are not considered in this study, such as runoff from agricultural lands and the abattoirs in Camperdown. Simpson and Pillay (1999) conducted a study on the impacts of nutrient loading in the Msunduzi River on downstream users, assessing the relative contributions from DWWW and diffuse sources at and above Pietermaritzburg. The aim was to determine the overall effect that increased phosphorus loads from DWWW would have on the Inanda Dam. The increased phosphorus loads might be the result of not upgrading DWWW and allowing it to become overloaded, thus continuing to discharge even more phosphorus into the river. The study showed that DWWW has a detrimental effect on the water quality of the Msunduzi River with respect to nutrient enrichment. The effluent from the plant was found to have raised the nutrient concentrations

in the river by 52% for nitrate, 86% for ammonia, 117% for total phosphorus and 306% for soluble phosphorus. The DWWW had also contributed 22% of the total volumetric load and it was dominant for soluble and total phosphorus loads, which were estimated at 81% and 64% of the total, respectively. The contributions of the nutrients by point and non-point sources were similar, suggesting that controlling the contribution by DWWW would be effective in reducing nutrient loading (Simpson & Pillay, 1999).

The issue of odours and flies is confounded by the sewage plant being situated next to a landfill site, which also produces air pollution as a result of odours and flies. However, as both the smell and the flies are distinct for the two polluting sources, it was assumed that the residents were able to distinguish between the two polluting sources. As a result of these assumptions it is possible that some of the estimated benefits from improving environmental quality will overestimate the value of the benefits of upgrading DWWW.

1.6 STUDY AIMS AND OBJECTIVES

The main aim of this study is to quantify the environmental impacts of the DWWW on downstream water resource users and communities surrounding DWWW, and to evaluate the benefits and costs of internalising these impacts by upgrading the plant. The environmental impacts to be assessed when estimating the benefits of improving environmental quality will include:

- i) Health impacts on rural communities relying on the Msunduzi River for recreation, potable use and bathing;
- ii) Increased water treatment costs at the Wiggins Water Works to remove tastes, odours and trihalomethanes from the water in the Inanda Dam;
- iii) Removal of the water hyacinth from the Inanda Dam;
- iv) The loss of the Duzi Canoe Marathon to the city of Pietermaritzburg;
- v) The decline in property values in the vicinity of DWWW due to odour and fly problems;

- vi) The decrease in the quality of life of residents close to DWWW due to odour and fly problems, and
- vii) Loss of recreation at Inanda Dam.

The costs to be used in the cost-benefit analysis will be estimated from the market-related costs of upgrading DWWW.

1.6.1 Study Hypotheses to be Tested

The valuation of health impacts on rural communities using the river will involve testing the hypothesis that people who use the Msunduzi River as a source for domestic and recreational water use have high incidents of water-borne diseases such as diarrhoea and dysentery. To value the increased treatment cost at Wiggins Water Works, the hypothesis is that the increase in the growth of algae in the water abstracted from Inanda Dam results in higher treatment costs. The costs of removing the water hyacinth from the water at the Inanda Dam will be estimated by testing the hypothesis that increased nutrient loadings in the Msunduzi River as a result of effluent discharge from DWWW causes proliferation of water hyacinth. The loss of the Duzi Canoe Marathon will be quantified by estimating the revenue generated by this event for the city - this value would be lost if the marathon is cancelled because of water pollution caused by DWWW.

The decline in the property values in the residential areas affected by odours and flies from DWWW will be estimated by testing the hypothesis that properties that are close to DWWW have lower market values than properties of similar characteristics but which are not affected by these impacts. The decline in the quality of life of residents impacted by odours and flies will be quantified by testing the hypothesis that people have preferences for better air quality as reflected by their willingness to pay to eliminate the odour and fly problems. The willingness to pay estimates reflect the loss in utility (well-being) of these individuals as a result of odours and flies. Lastly, the loss of recreation due to the problem of water hyacinth

will be valued by testing the hypothesis that visitation rates decline as transport costs to the site increase. The estimated costs of travelling to the site are a proxy for the value of the site to visitors. The benefits of upgrading DWWW – the value of improved air and water quality, and avoided costs of medical, algae, water hyacinth and Duzi Canoe Marathon loss – will be compared to the costs of two alternative options for upgrading DWWW in a cost-benefit analysis. The hypothesis is that the ratio of the benefits to the costs is greater than one. This would mean that the benefits of upgrading DWWW outweigh the actual costs of upgrading, implying that it would be worthwhile from society's standpoint to upgrade DWWW.

1.7 STRUCTURE OF THE THESIS

The first chapter has introduced the rationale for undertaking this study by looking at the environmental issues and challenges faced by the DWWW management. This formed a theoretical framework of why it is necessary to quantify the environmental impacts caused by DWWW in monetary terms. The chapter also familiarizes the reader with the underlying assumptions of the project. Chapter two reviews the literature on the causes and consequences of environmental degradation, with more emphasis on degradation caused by human action such as sewage treatment processes. Furthermore, the chapter gives the theoretical basis of the economic techniques used to value natural resources and improvements in environmental quality. Chapter three describes the areas affected by the environmental impacts of DWWW in terms of climate, topography, vegetation and water quality. Chapter four discusses the methodology used in this study, assumptions and the economic theory used in applying the resource valuation methods. In chapter five the results of the seven valuation exercises are presented and discussed. Chapter six summarizes the result of the cost-benefit analysis and gives recommendations about the future upgrading of DWWW.

CHAPTER 2

LITERATURE REVIEW

This chapter provides an understanding of wastewater treatment processes and how these impact on the environment. Relevant environmental economics literature is presented, with the specific aim of introducing the issues of environmental resource valuation. Environmental valuation techniques to be used in the study are reviewed, and lastly, the concept of cost- benefit analysis is discussed.

All major terrestrial biota ecosystems and humans depend on freshwater for their livelihoods. Freshwater is defined as that water that has a salt content of less than 0.01% (100ppm). The oceans and seas constitute 97% of the earth's water. Freshwater only constitutes 3%, however with 87% of this bound in glaciers and polar ice caps, only 0.4% of the earth's water is accessible. Freshwater is sometimes referred to as renewable because of the evaporation from the seas and the subsequent precipitation. Nevertheless, freshwater can be more appropriately referred to as an exhaustible resource since the natural supplies of freshwater are limited by the amounts that move through the natural system. Precipitation patterns are variable around the globe. Some regions enjoy abundant rainfall while others have minimal rainfall. Semiarid regions, such as South Africa, fall somewhere in between these two extremes (Nebel & Wright, 1996 and Jackson & Jackson, 1996).

Water shortage according to hydrologists is the limiting factor to food production, economic development and protection of natural resources. The problems of overpopulation such as the demands placed on food, resources and the environment were analysed by Erhlich & Erhlich (Cited in Gilpin, 1999) in their famous publications, *Population Bomb* (1968) and *Population, Resources, Environment: issues in Human Ecology* (1970). Water is one of these resources, which is in great demand. The demand for water has increased with the increase in human population such that some areas of the world, especially the developing communities, are facing acute water shortages (Gilpin, 1999). South Africa as a semiarid region receives an

average of 475mm of rain annually. The forecast is that South Africa is one of the countries that is likely to face shortages of water in the next 25 years because of the uneven distribution of rainfall and subsequent runoff (Loots, Ollermann, Pearce & Saaymann, 1994).

Figure 2.1 (the water cycle) shows that water rises to the atmosphere to form clouds with subsequent precipitation (rainfall). The processes of evaporation and condensation result in natural water purification. When water evaporates, salts and other solids are left behind and only water molecules leave the surface, so condensed water is essentially purified water. Sometimes, however, the water molecules pick up pollutants in the atmosphere, and hence their quality deteriorates. Water resulting from precipitation makes its way through aquifers, streams, rivers, lakes and oceans. Some of the water infiltrates the ground and may be held in the soil or drawn up by the plants in the process known as transpiration (Jackson & Jackson, 1996).

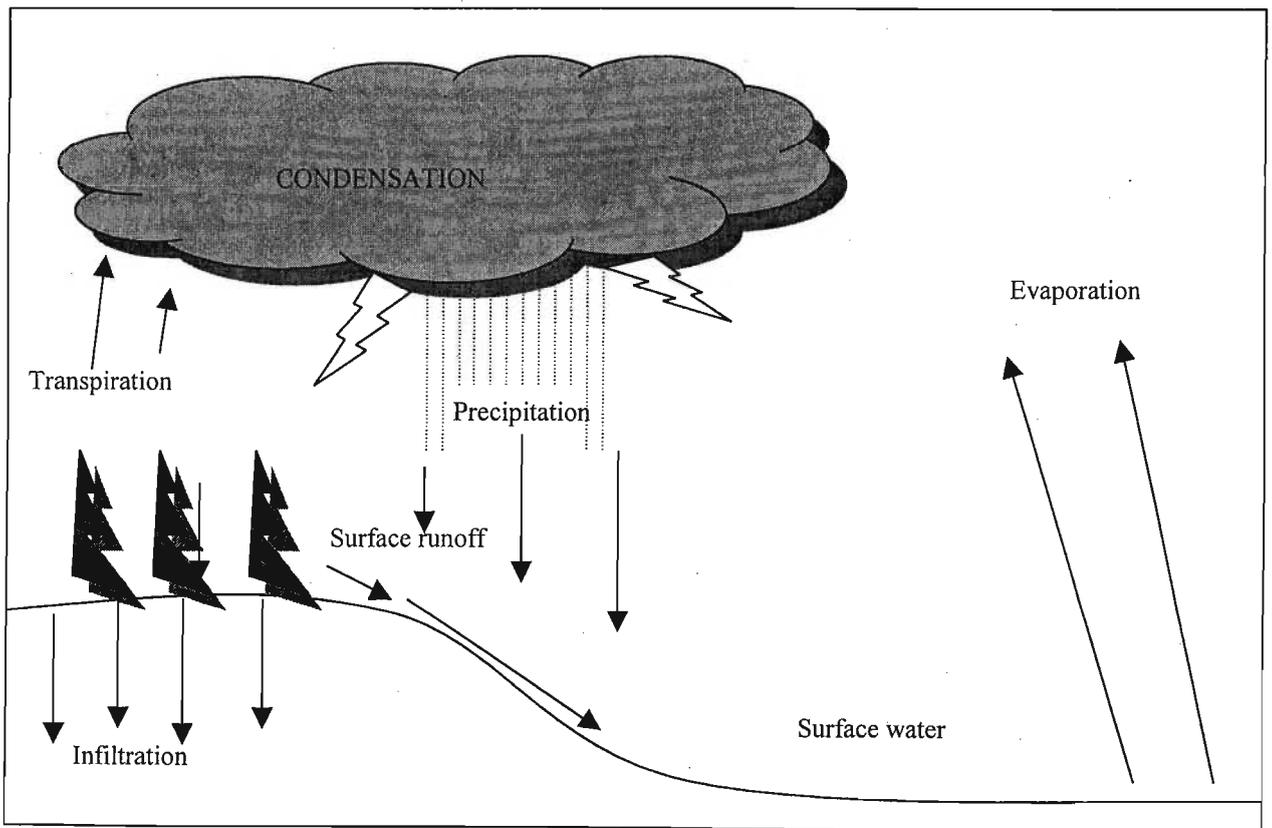


Figure 2.1 Water cycle showing the processes of evaporation, condensation and rainfall

Source: Adapted from Jackson & Jackson, 1996

2.1 ANTHROPOGENIC IMPACTS ON THE WATER CYCLE

In the natural ecosystem there is very little surface water run-off because of the vegetation cover and the porous topsoil. The water resulting from precipitation thus recharges the groundwater reservoir and is gradually released through springs and seeps into the streams and rivers. The flow of rivers and streams is maintained at uniform rates. In this state the ground water may be sufficient to maintain the flow for prolonged periods of droughts. Deforestation, overgrazing and erosion cause the pathway of the water cycle to shift from infiltration to runoff of rainwater into surface waters. Flooding, sedimentation and pollution from surface erosion are some of the consequences of this phenomenon (Jackson & Jackson, 1996).

The traditional method of managing surface runoff has been to channel the storm runoff down storm drains. This has led to use of the nearest off-site location to discharge the water such as the side of the valley or a natural streambed. Evidently this practice is not without consequences, which can include flooding, stream-bank erosion and increased pollution. The pollution results because of materials that are used by humans, which might be spilt on the ground and might find their way to the surface waters through storm water drains. In some cases this pollution results from illegal discharging of industrial waste down the storm water drains. Pollutants can be: nutrients from fertilizers, insecticides, herbicides, faecal waste pathogens, chemicals from the surfaces, trash and litter. Urban runoff is another potential source of pollution of many rivers and estuaries (Developing World Water, 1988).

Water pollution is defined as the situation where water contains one or more materials that make it unsuitable for a given use. Human concerns regarding water are both qualitative and quantitative. Quantitative refers to the amount of water available to meet the needs of the human population. Qualitative refers to the purity of water to prevent or minimize harm due to pollutants in the water. Major uses of fresh water are: domestic, industrial and agricultural. Water use is further categorized into consumptive and non-consumptive use. In non-consumptive use, the water is still available for further use after being utilized for a different

or the same use. In the consumptive category the water used for that use is no longer available for further use. Worldwide the allocation of water according to the three main uses is estimated as: 70% for agriculture; 23% for industrial activities and a mere 7 % is reserved for domestic uses (Nebel & Wright, 1996). In South Africa, agricultural water use demand is estimated at 52.2%, industrial water use at 30.5% and only about 17.3% is reserved for domestic water use (DWAF, 1995).

In developing countries there are three main modes of collecting water: rain water harvesting, collecting straight from surface waters, and commercialized water suppliers. Rural communities that do not have access to commercialized water supplies usually do rain harvesting and collection of water straight from the surface waters. However, surface waters often receive runoff which is polluted by various wastes including animal excretion, human excretion, agricultural runoff, and effluent discharges which are often polluted with pathogens (disease causing organisms). Contaminated water is responsible for 80% of the diseases in the developing world, with 4-5 million child deaths per annum (UN estimates). Usually the microorganisms that are transmitted through water are those that infect the intestinal tract such as typhoid & paratyphoid bacteria, dysentery, cholera bacteria and enteric viruses (Berk & Gunderson, 1993).

Pollution of the surface water can be due to both point and non-point sources. Point source pollution refers to pollution that may enter a waterway at a particular traceable point, such as industrial discharges and domestic effluent released from a sewage treatment plant. Non-point source pollution originates from diffuse sources such that the source of pollution is unidentifiable or non-distinguishable, such as are fertilizer runoff from various agricultural farms and sewage runoff from informal settlements (Jackson & Jackson, 1996).

There are different conceptions about the term pollution, because it can refer to sources that contaminate air, water or soil, and so a simple definition is elusive. Pollution can, however, be generally defined as the human-caused addition of any material or energy in amounts that cause undesirable alterations in the water, air or soil. Causes of pollution are usually

byproducts of otherwise worthy and essential activities such as crop production, the building of houses, providing energy and transportation. This definition of pollution clearly shows that it is practically impossible to achieve zero pollution. This would mean stopping all the essential activities just because they cause pollution. A more realistic approach would be to minimize pollution in ways that ensure that the needs of the present generations are met without compromising the needs of future generations. In environmental literature this approach is referred to as sustainability. According to Nebel & Wright (1996) it can be achieved through a three-step process:

- ◆ Identification of materials that are causing pollution;
- ◆ Identification of the sources of pollution; and
- ◆ Implementation of pollution control or avoidance strategies.

Pollution control refers to the process of preventing the pollutants from entering the environment, whereas pollution avoidance refers to the process of finding alternative means of meeting the needs, which do not produce the polluting byproducts (Nebel & Wright, 1996)

2.1.1 Eutrophication

Freshwater in its natural state is low in nutrients and has a clear colour. In this state it is able to support the growth of aquatic plants such as benthic plants - aquatic plants that grow attached or are rooted in the ground and that provide the aquatic animals with essential nourishment and dissolved oxygen. They are divided into two categories, namely the submerged vegetation and emergent vegetation. The former grows totally underwater, while the latter grows with the lower parts in water but the upper parts emerging from the water. The submerged vegetation flourish in clear waters since there is sufficient penetration of sunlight to support photosynthesis. The depth of sunlight penetration is referred to as the euphotic zone, and this zone is reduced when the water becomes turbid. Moreover, the submerged vegetation obtains nutrients from the bottom sediments and so grows well in nutrient-poor waters. There are other groups of aquatic plants beside the benthic plants,

namely the phytoplankton plants, that include many species of algae and Cyanobacteria/ blue green algae which grow as microscopic single cells or small groups or threads of cells. The growth of the phytoplankton is stimulated in nutrient rich water because they are not connected to the bottom and must obtain their nutrients from the water (Hawker & Linton, 1979, Nebel & Wright, 1996).

The term oligotrophic refers to the water that is low in nutrients and is clear enough to support the growth of benthic plants. This situation changes, however, as waterways become enriched with nutrient, and the consequence of this is eutrophication. As the nutrient content in the water increases, the phytoplankton growth is rapid and thus the turbidity of the water increases. Photosynthesis of the submerged benthic plants gets suppressed and these plants start to die off. As they die, they form a mass of organic matter on the water bottom and become a breeding ground for organisms that feed on organic matter, such as bacteria and fungi. The consequence of the dying-off of the benthic plants and proliferation of the microorganisms is depleted oxygen, which causes various species of fish to suffocate and die off. The bacterial species are able to survive in the depleted oxygen environment because they are able to switch to anaerobic respiration. Eutrophication, hence, refers to the whole sequence of events that start with the nutrient enrichment of water through the growth of phytoplankton, accumulation of organic matter, bacterial growth and eventually depletion of oxygen. Biochemical oxygen demand is used to measure the amount of organic matter in the water, in terms of how much oxygen will be required to break it down biologically and or chemically (Johnson & Morrell, 1982).

Natural eutrophication occurs in natural waters as a result of a gradual enrichment of water with nutrients, but cultural eutrophication which results from anthropogenic activities has drastic consequences. Table 2.1 overleaf summarizes the main causes of eutrophication. Sediments such as sand, silt and clay entering the waterways contribute to eutrophication as they contribute to increasing the water turbidity (Nebel & Wright, 1996).

Loss of wetlands is another result of human activity that contributes to eutrophication of

waterways, as the water filtering capability of wetlands is lost. Wetlands are land areas that are naturally covered by shallow water at certain times and are more or less covered at other times of the year. These areas aid in flood control and water filtering. In the latter the sediments settle out and the nutrients are captured and reabsorbed by plants (Hawker & Linton, 1979).

Table 2.1 Causes of cultural eutrophication

TYPE	CAUSE	SYMPTOMS
Nutrient Enrichment	Effluent discharge from sewage treatment plants, agricultural and urban runoff	Growth of phytoplankton and aquatic weeds, water turbidity, organic deposits and depletion of dissolved oxygen
Sedimentation	Erosion from farmlands, deforestation, overgrazing, construction and mining sites and stream banks	Water turbidity, organic deposits and depletion of dissolved oxygen
Loss of Wetland	Converting wetlands to agriculture, residential or commercial areas	Increased sedimentation and nutrient enrichment of water ways

Source: Adapted from Nebel & Wright, 1996.

2.1.2 Consequences of Eutrophication

Eutrophication is a serious deterrent to human activities such as swimming, fishing and boating. Eutrophic water emits odours due to the organic matter and algae that proliferate. Further, some of the bacteria that grow in the nutrient enriched water may cause diseases in humans. Some algae species also produce substances that are toxic to both human and aquatic life. In water treatment works, algae from eutrophic impoundments cause clogging of filters and odour problems. As a result, expensive treatment procedures are required to remove these nuisances. Nutrient enriched water also provides conditions that favour the growth of waterweeds such as water hyacinth and water lettuce. Water hyacinth can double its surface area covered within eleven days because it employs both sexual and asexual reproduction and thus has a very fast reproduction rate. Water hyacinth is also able to root

and this helps the plant in establishing itself. The latter property of water hyacinth makes the control and eradication of this plant difficult and costly. The seeds produced by this plant can lie dormant in the soil for up to thirty years. The control of water lettuce is not as challenging as that of water hyacinth because the plant has a slower reproduction rate, as the main form of reproduction is asexual. Moreover, reproduction requires suitable climatic conditions (Degner & Howat, 1997).

2.1.3 Solving the Problem of Eutrophication

There are two main approaches to solving the problem of eutrophication: The first is based on attacking the symptoms of eutrophication, and the second is aimed at attacking the causes of eutrophication. The symptoms of eutrophication include growth of undesirable vegetation and the lack of dissolved oxygen. The causes of eutrophication are those illustrated in Table 2.1 and they include nutrient input, sedimentation and loss of wetlands (Nebel & Wright, 1996).

2.1.3.1 Attacking the Symptoms of Eutrophication

This approach applies in situations where costs are not prohibitive and immediate remediation is the goal. The method used depends on the symptoms to be eradicated and can be: chemical treatments, aeration, harvesting of aquatic weeds and dredging. Herbicides can be sprayed to kill aquatic weeds but the phytoplankton, especially the Cyanobacteria, are the most resistant of organisms. Therefore, amounts of chemicals needed to kill them also kills all the other aquatic organisms. Further, they are the first to reappear when the herbicide is diluted sufficiently. Copper sulphate is used mostly in water reservoirs to control the growth of phytoplankton. Given that copper is toxic to almost all living organisms above trace amounts, the long-term effects of this practice are a critical issue (Johnson & Morrell, 1982).

The second method involves using artificial aeration of the water to avert the terminal stage

of eutrophication. Although this method is costly, it has an added advantage of converting phosphate into more stable compounds in the sediments and these can then be removed from the water. Harvesting of the undesirable aquatic weeds is the mechanical removal of deep-rooted plants that sprawl over the water surface. Mechanical harvesting of phytoplankton is, however, not practical due to the microscopic nature of these organisms, and filters become clogged rapidly. Another technique aimed at attacking the symptoms of eutrophication is the removal of sediments through dredging. This procedure has an undesirable effect of increasing eutrophication, since it stirs up settled material back into solution (Jackson & Jackson, 1996).

2.1.3.2 Approaches to Preventing Eutrophication

Reducing the nutrient inputs and sedimentation can prevent eutrophication. This entails identifying the major sources of nutrients and sediments and also implementing strategies for correction. Agricultural practices, urban runoff, sedimentation and sewage effluent are the major sources of nutrients and eutrophication. The first three sources can be prevented by adopting management practices that reduce their impact on water quality (Nebel & Wright, 1996).

2.2 SEWAGE TREATMENT

Raw sewage is a major public health hazard as it also contains human excrement, which contains pathogens that are harmful to humans. If these pathogens contaminate drinking water, food or water used for swimming/bathing, the pathogens gain access to, and infect, people. The pathogens survive only a few days outside the host and the infection will depend on the number of organisms entering the human host. This makes the problem more severe in densely populated areas. Microorganisms that are transmitted through water are those that cause infections of the intestinal tract such as typhoid and paratyphoid bacteria, dysentery and cholera bacteria and enteric viruses (Hawker & Linton, 1979). This problem can be

resolved by purification and disinfection of public water supplies. Sanitary collection and treatment of sewage waste before discharging into surface water are also fundamental in combating the problem of pathogens. The main aim of treating sewage waste is to remove pollutants that may have a number of consequences if they come into contact with surface water. The pollutants in the sewage might be debris/grit, particulate organic matter, colloidal and dissolved organic matter and dissolved inorganic matter (Berk & Gunderson, 1993).

The first step in sewage treatment is the preliminary treatment of sewage to remove debris and grit via the processes of screening and settling. The primary treatment of removing the particulate organic matter follows from the preliminary treatment and this is done in the primary clarifiers. In this step, the particulate organic matter settles to the bottom and the oils and fats float to the surface. The fats, oil and settled organic matter are removed and are known as raw sludge. The secondary treatment follows to remove colloidal and dissolved organic matter. This process is called biological treatment since it uses microorganisms to decompose the organic matter. Oxygen is added to the wastewater to enhance the respiration and growth of these organisms. Most sewage wastewater works use the activated sludge method, although the trickling system can also be used. At DWWW, however, a combination of biological filtration and activated sludge methods are employed to treat wastewater (Watermeyer *et.al*, 1993). The dissolved inorganic matter is removed through biological nutrient removal. Denitrifying bacteria remove the nitrogenous compounds, whereas phosphate is taken up by bacteria as food. These microorganisms are added to the raw sludge during sludge treatment to produce a nutrient rich sludge. Finally, the treated wastewater is cleansed and disinfected before discharging into the waterways. The water is filtered through a bed for cleansing and chlorine gas is used to kill the remaining pathogens (Berk & Gunderson, 1993).

Although chlorine gas is widely used for disinfection as it is inexpensive and yet effective, the disadvantage is that chlorine gets introduced into the waterways. However, even minute levels of chlorine can harm aquatic animals, and it reacts with organic compounds to form chlorinated hydrocarbons, which are toxic and non-biodegradable. Some of these chlorinated

hydrocarbons have been implicated as causes of cancer and in abnormal human body developments. Ozone gas is an alternative to using chlorine gas, and has the advantage that it also breaks down into oxygen, which improves the quality of the water. The limitation, however, is that it is very expensive as the compound is unstable. The treated water is then discharged into surface waters and may then be used a water supply source by another community (Berk & Gunderson, 1993).

The collection and treatment of sewage, although identified as one of the approaches of preventing eutrophication, has adverse impacts on the environment. The Simpson and Pillay (1999) study referred to in section 1.5 found that although the Msunduzi River was already impacted before DWWW discharge, the effluent resulted in a much poorer quality when judged against National Guidelines. The discharged effluent also caused increased nutrient enrichment of the water and this impacted on the downstream water users. The main nutrient loading was phosphorus and this was considered to be the driving force in the production of algae and associated increased treatment costs of water abstracted down stream (Inanda Dam). Activated sludge and methane gases are some of the byproducts of the treatment process. These substances emit strong odours and the disposed sludge provides a breeding ground for flies, and as a result contributes significantly to air pollution (GFJ, 1999).

2.3 AN ECONOMIC APPROACH TO ENVIRONMENTAL MANAGEMENT

Field (1994) defines economics as the study of how and why individuals, be it consumers, firms, non-profit organizations or government institutions make decisions about the use of valuable resources. This analysis when extended to environmental services is referred to as environmental economics. In broad terms, environmental economics focuses on how individuals make decisions that have environmental consequences. The economy can be divided broadly into producers and consumers. Producers convert inputs into products that are utilized by the consumers. The environment provides primary inputs, and during the production process, not all the inputs are converted into products, as some are converted into

residuals that are discharged back to the environment (Fig. 2.2). These waste products can be liquid, gas or solid and their accumulation in the environment, at a faster rate than the environment's assimilating capability, results in environmental pollution. The damages caused through economic actions are fundamental in the discipline of environmental economics as the objective is to quantify environmental degradation (Turner, Pearce & Bateman, 1994).

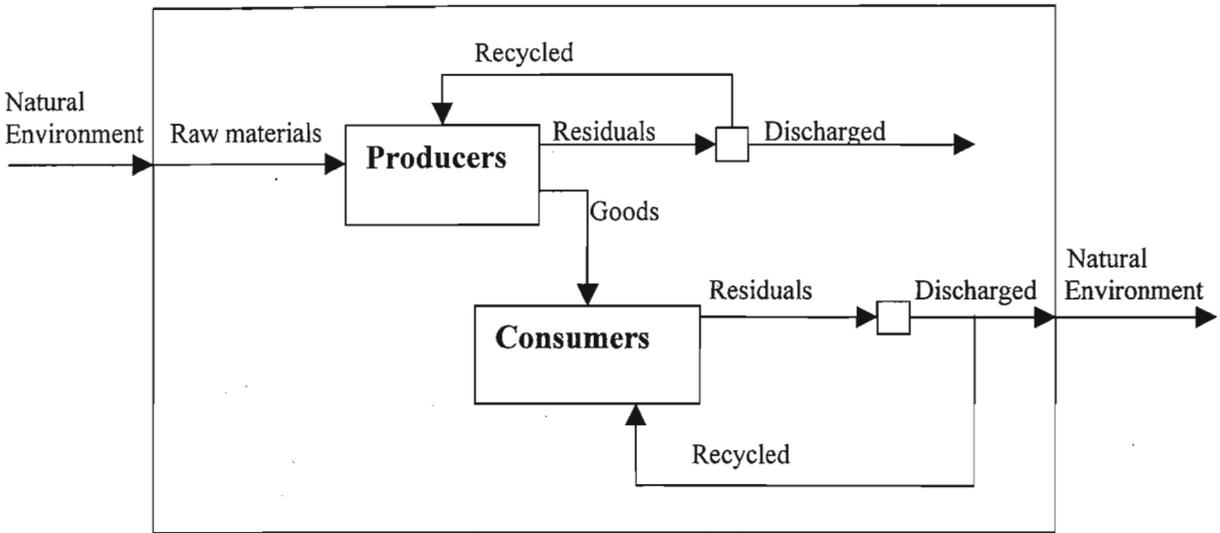


Figure 2.2. Model of economic processes and their interactions with the environment
Source: Field, 1994, page 24.

In economic terms pollution is defined on the basis of some physical effect of waste on the environment and human reaction to that effect. Usually, this pollution is due to unintentional side effects of production that may affect a third party negatively. These side effects are referred to as external costs. Some actions may affect a third party positively in that the individual benefits from them, and these are termed external benefits. Both external costs and benefits are collectively known as externalities (Pearce & Turner, 1994).

The environment provides the economy with a variety of invaluable services and so provides the life support systems that sustain economic growth. Therefore depletion of environmental

amenities through environmental degradation such as pollution will eventually have a significant impact on economic growth (Collins, 1992). It is thus important to measure what level of environmental degradation is acceptable, bearing in mind the issue of sustainable development, whereby the use of natural resources by the present generation takes into consideration the needs of the future generations (Common, 1991).

The relationship between the environment and economic systems can be analysed by adopting either a positive or a normative approach. The former is useful in describing the nature of this relationship, whereas the normative approach aims to maximize the value of an asset by creating a balance between preservation and use of that asset (Collins, 1992). The next section gives a review of valuation techniques that can be used to estimate the value of environmental resources or changes in environmental quality.

2.4 OVERVIEW OF ENVIRONMENTAL VALUATION TECHNIQUES

Economic valuation can improve the reliability of the analysis of natural resource problems and provide information to help private sector managers and public policy officials make better resource management decisions. Correctly done, it also improves the estimate of a project's development impact. It also provides managers with information on the benefits associated with specific environmental investments. Consequently, the information base that is available to public policy makers is enlarged through the estimation and identification of the benefits of environmental investments. Such benefits (e.g. water consumption) include both use and non-use benefits (e.g. knowledge that resources will be preserved for future generations). This necessitates that environmental policies be analysed, devised and implemented from a broader perspective. The omission of any relevant environmental impact from an economic analysis gives a distorted picture of the effects of any environmental investment, and a distorted estimate of a project's profitability. There are, however, limitations inherent in including environmental valuation in an economic analysis, such as an increase in expenses, scarcity of relevant data, and findings that may support claims for retroactive compensation (Karmokolias, 1999).

The main problem when estimating a value for environmental goods is that many environmental resources - such as air and water - are public goods and there is no specific market price that could be assigned to them. Public goods are characterized by non-exclusivity and joint consumption, meaning that everybody can gain utility (satisfaction) from them without necessarily diminishing other people's utility, and they are not privately owned. Thus, no person can be excluded from consuming them (Turner, Pearce & Bateman, 1994; Field, 1994). Due to this characteristic of many environmental goods, market systems are not useful in determining their value since there is no clear demarcation of property rights to the use of those resources. The context of a value of the environment, therefore, needs to be considered. The definition of what a value is in environmental terms differs between ecologists and economists. For market goods, economists conceptualize this value by extrapolating the inverse demand curves from individual preferences for these goods as reflected by the willingness to pay (WTP). The total WTP would be represented by the area under the resource demand curve from the origin to the quantity of the resource demanded (Kahn, 1998).

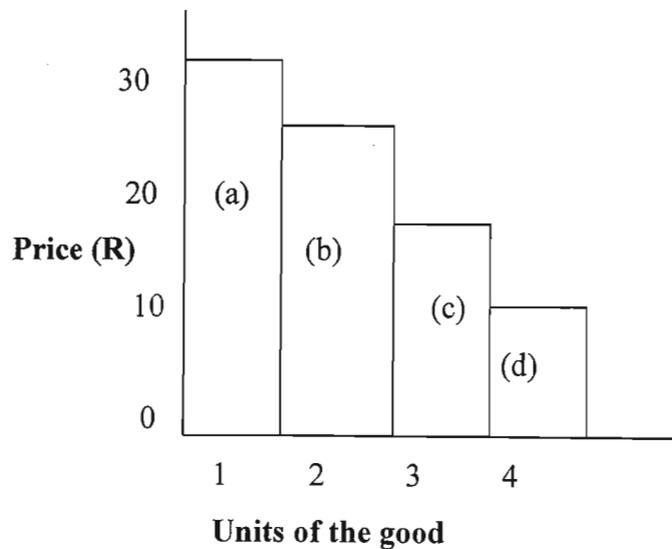


Figure 2.3 The concept of willingness to pay (WTP)

Source: Field, 1994, page 47.

Figure 2.3 shows the WTP of an individual person for a good, where initially the person had none of the good. From observations of how the person spends his/her money it can be deduced how much s/he would be willing to pay for the good. The WTP depicted in the diagram shows that a person would be willing to pay more for a single unit and that this value diminishes as the individual consumes more units of this good. This phenomenon is referred to as 'diminishing WTP – as the number of units consumed increases, the WTP for additional units of that good decreases (Field, 1994). Total WTP for 4 units by this individual would be the sum of areas (a), (b), (c) and (d). For example, the WTP for unit 1 is about R30, unit 2 about R25, unit 3 about R18 and unit 4 about R10. This implies a total WTP for 4 units of the good of about R83.

Critical assumptions are made when using the WTP with respect to individual preferences, income distribution, conditions in the supply industry and externalities. A major underlying assumption is that individual preferences remain constant enough over a long period of time such that they can be included as parameters in the valuation exercise. This may not always be the case as preferences do change, either rapidly or gradually (Laslett, 1995). The distribution of income is important because if markets are used to estimate the social value, then WTP patterns for a particular good will be determined by the prevailing distribution of income. Individuals at the lower scale of this distribution may have a lower WTP for the good as compared to their wealthier counterparts. Such imbalances between the rich and the poor mean that markets may be a poor guide as to whether the right amounts of goods are being produced, consumed or traded. Supply conditions also affect valuations, as the competitive conditions under which the markets are supplied are affected by monopolized or cartelized industries. Markets may thus not be very useful in guiding the suppliers to do the right thing for the society (Laslett, 1995).

Externalities are another important facet in environmental valuation. The external effects of a project are defined as income or income equivalent welfare changes for individuals or groups not directly affiliated with the project (Karmokolias, 1999). These costs are not taken into consideration by privately owned firms when they make decisions regarding their output

rates. An example of an externality is the costs inflicted on society through environmental degradation that may have detrimental impacts on a number of aspects such as health and loss of enjoyment of natural resources (Field, 1994).

Markets also fail when dealing with public goods that are jointly consumed and non-exclusive. Due to the nature of these goods, people's WTP for them may not reflect the true value of the good to the people because of the "free rider problem". This refers to the situation where some people may be induced to underpay for that good if they know that others are benefiting from utilizing it and not paying (Common, 1991). The value of non-market goods is not only determined by the money that people are willing to pay for them, but also by the time and opportunities forgone. Such goods can either have direct or indirect use values. Direct use values are those associated with tangible uses of an environmental resource, for example clean water when used as an input in a factory. The indirect use values represent intangible uses of environmental resources, such as the satisfaction derived from knowing about the existence of a resource, such as the black rhino (Mitchell & Carson, 1989).

Indirect use values are also referred to as non-use or passive use values. They are categorized into bequest values, altruistic values, option values, and the value of ecological services. The option value refers to the situation where an individual might not at present have a desire to use an environmental resource but might in future consider using it. These kinds of values are generally the closest to the direct use values. Bequest values are concerned with the desire by an individual to preserve the resource for his children or grandchildren. Altruistic values are associated with an individual's concern for another person, such as when a person values the opportunity for other people to enjoy an environmental resource such as clean air. The value of ecological resources are unique to indirect use values, since these refer to resources about which people are unaware that their services positively affect them, such as the presence of biodiversity (Kahn, 1998).

The valuation of environmental goods is a complex process that requires multidisciplinary

work, as the analysts need to understand both the economic implications and environmental effects of a project. The critical part in any environmental economics study is to identify what environmental impacts to include in the analysis. After the impacts have been identified a selection of impacts to be valued should be made since the analysis occurs under a specified time frame and usually within a specified budget. In identifying and selecting the environmental impacts to be valued, it is important to explicitly state the underlying assumptions, as other analysts may wish to challenge the results or make comparisons with other areas (Dixon *et.al*, 1994).

The methods that are used to estimate the value of environmental assets can be categorized as objective and subjective valuation methods (see summary of these methods in Table 2.2 overleaf). The objective methods are based on physical relationships that describe the cause and effect relationships and provide objective measures of damage resulting from various causes. Examples of these methods are: the cost of illness approach, changes in productivity, human capital loss and replacement costs. The changes in productivity approach examines the effect of an activity on the cost of production and profitability of producers, where these have impacts on the consumer surplus through changes in supplies and prices (Winpenny, 1991). Costing of illness is based on the observation that impacts on environmental quality or sustainability of renewable resources are reflected in changes of the productivity of the systems involved, and hence these are used to assign values. The systems can be natural or human, with the former encompassing buildings, fisheries and forests, and the latter health and productivity (Biswa & Agarwal, 1994). In applying these approaches, the level of environmental deterioration, such as air pollution, is related to the degree of physical damage to a natural or man-made asset or health impact. This type of approach is referred to as a damage function approach. The values obtained using objective techniques provide a measure of the total benefits of preventive or remedial actions (Field, 1994).

Subjective valuation techniques are based on a subjective assessment of possible damages as stated or revealed in real or hypothetical markets. The revealed preference methods examine the decisions made by individuals to reveal the resource value, and are generally not useful

for estimating non-use values. In the stated preference methods, the values are elicited from individuals through survey methods that are useful for both use and non-use values. Examples of subjective valuation methods given in Table 2.2 include preventive expenditure, the hedonic approaches (property or land value), travel cost and contingent valuation (Kahn, 1998).

Table 2.2 Methods used in natural resource valuation

VALUATION METHOD	EFFECTS VALUED	BASIS FOR VALUATION
<i>Objective Approaches</i>		
Changes in productivity	Productivity	(Behaviour assumed) Technical/physical
Cost of illness	Health (Morbidity)	Technical/physical
Human capital	Health (Mortality)	Technical/physical
Replacement/Restoration costs	Capital and natural resource assets	Technical/physical
<i>Subjective Approaches</i>		
Preventive expenditure	Health, productivity and assets	Behaviour revealed
Hedonic approaches		
Property/Land value	Environmental quality, productivity	Behaviour revealed
Travel cost	Natural resource assets	Behaviour revealed
Contingent valuation	Health, natural resource assets	Behaviour expressed

Source: Dixon et.al, 1994, page 30

The choice of technique used to estimate the value of a resource depends mainly on what is being measured. When deciding on which method to use it is useful to examine the primary effect of an impact. An illustration of the methods used to quantify different environmental impacts is shown in Figure 2.4 overleaf. The effects of the impacts are divided into those that produce changes in production and those that result in changes in environmental quality. The choice of a technique for the changes in production is fairly simple, as it requires the analyst to determine whether market prices for those changes are available. The analyst can use a change in productivity approach if market prices are available or a surrogate market approach if they are not available. However, choosing an appropriate technique for impacts that

involve changes in environmental quality is more complex, because there is more than one possible technique that can be used to value one impact (Dixon *et.al*, 1994). Some of these techniques, mainly the ones used in this study, are discussed in more detail below.

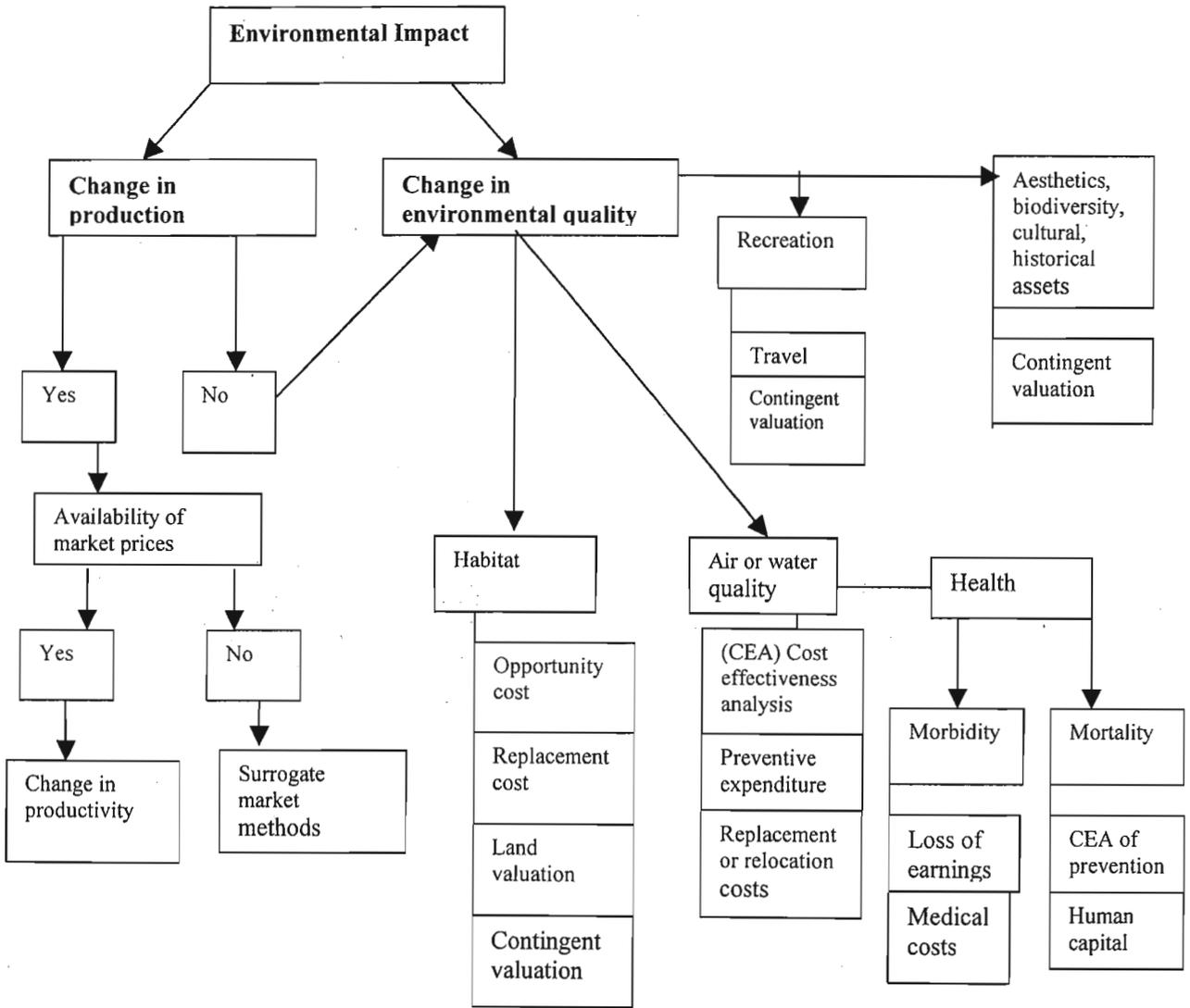


Figure 2.4 Environmental valuation flowchart

Source: Adapted from Dixon et.al, 1994, page, 33

Some of these techniques, mainly the ones used in this study are discussed in more detail below.

2.4.1 Revealed Preference Methods

These methods use a surrogate market as a substitute for the real market for non-market goods such as clean air (Kahn, 1998). They estimate an implicit value from actual market prices paid for another good. Their applications are most commonly concerned with valuing the removal of air pollution, and public recreational sites. Property valuation (hedonic pricing method) is mostly employed in valuing the cost of air pollution, whereas the travel cost method is used to assign a value to a recreational area (Winpenny, 1991). These methods are described in more detail in sections 2.4.1.1 and 2.4.1.2, respectively.

2.4.1.1 The Hedonic Pricing Method

This technique is based on the premise that people value a good because they value the characteristics of that good rather than the good itself. For example, a person might value a car because of its safety, its comfort, and operating cost per mile among other attributes. In order to estimate the price of these attributes, one would need to examine how the price of the car changes as the level of these characteristics changes. In an environmental context, these characteristics would be represented by the attributes of the environment, such as improvements in air quality. Regression analysis can be used to analyze the relationship between, say, house prices and air quality. From this analysis, individuals' WTP for air quality improvements is estimated (Winpenny, 1991), using a function like equation (1):

$$\text{Price} = f(\text{Air Quality}) \quad (1)$$

Equation (1) must be expanded to account for other factors that determine the housing price, such as the size of the house. Equation (2), therefore, would better explain the variation in housing prices as:

$$\text{Price} = f(\text{Air Quality}; \text{House Size}; Z_n) \quad (2)$$

where Z_n represents n other structural, neighbourhood and environmental characteristics (Freeman, 1995). Equation (2) represents a regression analysis in three-dimensional space. A non-linear relationship among variables could also occur, where housing price increases with an increase in air quality at either an increasing or decreasing rate (Kahn, 1998). The most serious limitation of this method is the large volume of data that is required, such as a range of different representative environments, information regarding all the principal attributes of the properties and relevant socio-economic data. The environmental variables must also be specified and calibrated, such as the degree of air pollution from a specific agent (Winpenny, 1991).

2.4.1.2 The Travel Cost Method

This method is usually applicable when estimating the benefits associated with using publicly-owned recreation resources. The main problem with such resources is that visitors are usually only charged nominal entrance fees, which do not reflect the true value that people place on the use benefits. Recreational benefits, therefore, cannot be calculated from the recreational demand curves. The theory behind this method is that the determination of the travel cost to a recreational site can give an estimate of (proxy for) the price of access to the site (Kahn, 1998; Biswa & Agarwal, 1994). A number of assumptions are made when using this method to determine the value of a recreational service. Firstly, individuals can be grouped into zones surrounding the site where they would have similar preferences, because of similar socio-economic characteristics. Secondly, people are assumed to react the same way to increasing travel cost as they would to increased entrance charges to the site. This means that there would be a point where people would not be willing to visit the site because it is too expensive for them. Empirical studies using this method involve determining the number of trips to the site, the cost of travelling to the site and relevant economic and demographic information (such as income levels, age and education levels). From these measurements, a demand curve can be estimated using regression analysis to relate visitation rates to the cost of travel. The value of the site to the individual is given by the consumer surplus for each individual. Figure 2.5 illustrates the concept of consumer surplus. The

demand (D) and supply (S) curves are simply WTP and cost curves, respectively. The consumer surplus is given by the area under the demand curve but above the price line, namely area **a** (Field, 1994). The concept of consumer surplus is explored further in section 2.7.1 below.

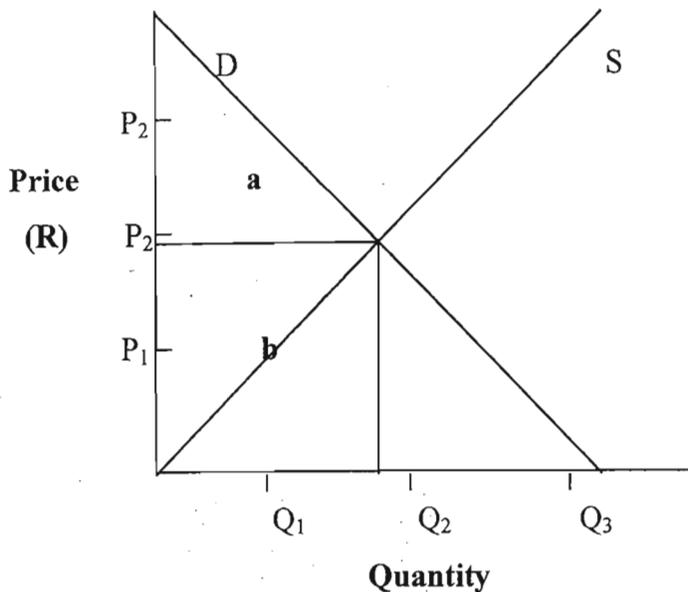


Figure 2.5 The concept of consumer surplus (CS).

[CS = a], where D is the demand curve of quantities demanded by the consumer and S is the supply curve of quantities supplied by the producer Source: Adapted from Field, 1994, page 66.

In order to find the aggregated value of the site, the average consumer surplus is multiplied by the estimated the number of people who visit the site. The value thus obtained is only an estimate, as travel cost is not necessarily equal to the value of the site. Furthermore, the existence of other sites influences the approach to a certain extent (Biswa & Agarwal, 1994). The limitation of this method is that it is only applicable in situations where there is no congestion at the site. Congestion may reduce the demand artificially, and so estimated demand would lead to underestimation of the site benefits. Another difficulty is the inability to forecast how the recreational benefits would change over time (Kahn, 1998).

2.4.2 Stated Preference Methods

These methods involve eliciting the estimated values of environmental amenities directly from individuals by means of hypothetical questions. Such methods are mostly applicable in quantifying the benefits of pollution control. The issue of estimating pollution control benefits is compounded by the search for efficient levels of pollution control. These benefits are quantified by estimating the environmental damages that would be prevented by pollution control. The damage caused by pollution can be in various forms such as the effect on human health, loss of enjoyment from outdoor activities, or damage to flora and fauna (Kahn, 1998).

To assess the magnitude of this damage, the affected categories would need to be identified. Secondly, the physical relationship between pollution and the damage caused to the affected categories needs to be estimated. Moreover, the affected peoples' responses toward avoiding or combating some damage also need to be estimated, while the physical damages must be quantified and assigned a monetary value. All of these requirements are difficult to meet, but the most difficult aspect is assigning a monetary value to the physical damage caused by pollution. The Contingent Valuation Method (CVM) and conjoint analysis are examples of stated preference methods. The former can involve bidding games, take it or leave it experiments, costless choice trade-off games and the delphi technique (Biswa & Agarwal, 1994).

2.4.2.1 The Contingent Valuation Method

In the CVM the value of an amenity is estimated by directly asking the respondents their WTP for a change in the level of environmental quality, or their willingness to accept compensation for the proposed reduction in environmental quality. The value thus obtained gives a measure of an individual's preference for a public good, like cleaner air. The hypothetical questions can be either of two formats - open-ended questions where respondents are asked to state their maximum WTP, or close-ended questions, where

individuals state whether or not they would be willing to pay a particular amount. The CVM must also specify the mechanism by which payment would be made and also convey that whoever collected the money would bring about the necessary change in environmental quality (Mitchell & Carson 1989).

The main objective of a contingent valuation survey is to elicit WTP amounts from individuals. Many of these surveys have used an open-ended question format, but it has been frequently observed that this format results in a large proportion of protest responses and non-responses. This has been attributed to the difficulty facing the respondents in picking a value for a good that is not usually traded in markets. As a means of resolving this issue, different variations of the open-ended question formats are used. These aim to facilitate the elicitation process by offering the context in which to value the good, and include bidding games, the payment card method, and take it or leave it experiments (Mitchell & Carson 1989).

Bidding games are the oldest and most widely used CVM techniques, and they are based on real life situations in which individuals are asked to state a price for a good in an auction. The respondents are asked whether they would be willing to pay a particular amount for the provision of a certain good, and the responses are either yes or no. The interviewer increases the bids and the process is repeated until a no response is obtained. This technique offers the possibility of capturing the highest price consumers would be willing to pay, and thus measures the full consumer surplus. Another advantage is that the respondents are able to consider more fully the value of the good. The disadvantage of the bidding game is a potential "starting point bias", where the respondents may take the initial bid as the true value of the good in question. The payment card method, developed by Mitchell and Carson in 1981, is an alternative to the bidding games. The technique maintains the properties of the open-ended question, while increasing the response rate. It presents respondents with a visual aid that has a large selection of WTP amounts, ranging from zero to some appropriate amount. This is an advantage over the bidding games and other methods as it provokes a greater proportion of respondents into making reasonable trade-offs between money and

environmental improvement (Garrod & Willis, 1999). Although there is less of the anchoring problem that is observed in the bidding games around a particular value, the method is also vulnerable to the biases associated with the ranges used on the cards (Mitchell & Carson 1989). The payment card method is mostly appropriate in studies where there is a large proportion of non-use value. The other methods require familiarity with the environmental good in order for the respondents to give meaningful WTP estimates (Garrod & Willis, 1999).

The take it or leave it experiments simplify the respondents' task in the sense that the respondent makes a judgment on whether s/he prefers the stated situation or not. The respondent is presented with scenarios where different levels of an environmental good are presented at a specified cost. This method is suitable even for mail surveys although it also suffers from biases mentioned above (Mitchell & Carson 1989).

In order to elicit the WTP from the respondents, a survey method is used which presents hypothetical market situations (e.g. for cleaner air), with the WTP elicited being dependant on the type of hypothetical market used. The questionnaire design has three steps: Firstly, a very detailed description of the good that is going to be valued and the hypothetical circumstance under which the good is going to be delivered is presented to the respondents. During this process the interviewer may read out the hypothetical scenario to the respondents. The main objective of this step is to describe the environmental goods, the baseline level of provision, the structure under which the goods are to be delivered, the range of alternatives and the method of payment. By asking the respondents to value several levels of provision of, say, cleaner air, a demand curve for a particular good can be constructed (Biswa & Agarwal, 1994).

The second step deals with how the questions to obtain the respondents' WTP for a particular good are presented – bidding games, the payment card method, take it or leave it experiments etc. As outlined above, this step is important in that it must not bias the respondents' WTP. The third step is to collect data about the respondents' characteristics (for example age,

income and gender), their preferences relevant to the valued goods, and their use of the good. Usually this step is performed at the beginning of the survey process before the interviewer reads out the hypothetical situation. However it can also be done towards the end of the interview, and the results obtained can be used in a regression equation to estimate the individual's valuation function for the good. The WTP amounts thus obtained are used to estimate the benefit of that good, in that they reflect individual preferences for those benefits (Biswa & Agarwal, 1994).

The CVM survey can be done via face-to-face interviews, telephonic interviews or postal surveys. Each of these has advantages and disadvantages and the surveyor chooses the one that would best suit his/her purposes. The choice of the method used is determined by three characteristics of a CVM: Firstly, the hypothetical markets that are described to the respondents are often very complex, and as such they require careful explanation. This process can best be facilitated by person-to-person interviews, whereby the interviewer is able to use visual aids and control the pace and sequence of the interview. Secondly, it may be necessary to motivate the respondents such that they put an extra effort into assigning a monetary value to the good in question. Furthermore, once the WTP amounts have been obtained for the chosen sample, the estimates will need to be extrapolated for the target population (Mitchell & Carson, 1989).

The CVM studies vary according to the nature of the goods being valued, the methodological and theoretical constraints, the population being surveyed and the researchers' ingenuity and imagination (Mitchell & Carson, 1989). Some of these variations can best be described by looking at the history of the CVM. It was developed in the early 1960's by the economist Robert K. Davies (cited in Mitchell & Carson, 1989), after earlier suggestions that direct interview methods be used to measure values that people place on natural resources (Ciriacy-Wantrup, 1947). The main aim of using the CVM is to estimate the benefits and costs of a change in provision of a good, like cleaner air, in order to perform a cost-benefit analysis. As such the survey must meet the requirements of economic theory, implying that the respondents must find the hypothetical scenario both understandable and meaningful.

Furthermore, it must be free of incentives, which might bias the results. For example, people may bid low WTP values if they know that people who do not pay for that environmental improvement may still use the improved site. The fulfillment of the requirements of the economic theory is best achieved by obtaining the correct benefit measures for the good in question, in the context of an appropriate hypothetical market (Mitchell & Carson 1993). This technique also assumes that economic agents, be it individuals, households, consumers or firms, if confronted with a possible choice between two or more bundles of goods, would prefer one bundle of goods over the other. Secondly, that an economic agent will choose in such a way that his/her utility (satisfaction) is maximized. These assumptions have direct implications for the CVM as outlined in section (i) below.

(i) Contingent Valuation Issues

Traditional economic theory states that there must be physical consumption of a good for an individual to get utility from it. In the case of environmental goods, individuals can obtain utility from them without physical use. For example, individuals may gain satisfaction from knowing that water quality in a particular area is being improved, even though they may never visit that area (passive-use value). Considerable controversy has resulted from including passive use values in cost-benefit studies. Much of the debate concerns the biases associated with their quantification. The nature and origin of these biases differ and they are categorized into information biases, hypothetical biases, strategic biases, starting point biases, embedding biases, and protest biases. Information bias arises when the respondents are not familiar with the good being valued. To correct for this it is suggested that the respondents be presented with adequate information regarding the good being valued, and visual aids. Hypothetical bias, can, according to Brent (1997), arise when the respondents do not take the questions seriously, since they are hypothetical. This train of thought might result in the respondents giving answers that are random and unrelated to household characteristics and preferences. Strategic biases arise when respondents think that they can influence the outcome of the policy decision by not answering truthfully (Brent, 1997; Mitchell & Carson, 1989; Kahn, 1998).

The argument for including passive-use values has largely focused on the need to estimate *all* of the benefits of environmental goods. If passive-use values are excluded from a cost-benefit analysis, the benefits associated with pure public goods may be significantly underestimated. The rationale behind this observation is that the traditional economic approaches which examine the changes in the level of a good consumed as a function of the changes in prices is not appropriate for public goods, due to their joint consumption and non-exclusive nature. Thus, a market-based system fails because one individual's consumption of the good does not necessarily result in the decrease in the level available for the next person (Mitchell, Draft 1999).

Those who argue against the inclusion of passive use values have focused on the limitations of the CVM, such as the embedding phenomenon. This refers to the inability of respondents to proportionally value environmental goods, as they may assign the same value to one environmental good as well as to a package of a number of environmental goods (Pasour Jr, Nieuwoudt & Hoag, 1993). Embedding can, however, be successfully resolved through adequate questionnaire design by, for example, stressing to respondents that they check whether the stated values are within their budget constraints and reminding them to consider outlays on other environmental goods (Garrod and Willis, 1999). Traditionally, the Marshallian consumer surplus has been used to measure the benefits to individuals of environmental resources as the area under the demand curve but above the price line (Johansson, 1987). However, the main criticism of this measure is that the levels of utility are not constant and this measure holds income constant. Due to this limitation, the Hicksian consumer surplus is proposed as the measure of benefits. Compensating variation and surplus hold utility constant at an initial level, whereas equivalence variation and surplus hold utility constant at specified alternative levels. These measures involve either payment or compensation to maintain the utility constant at specified levels (Mitchell & Carson 1989; Johansson, 1987). The variation measures are used when consumers are able to vary the quantity of the good, whereas the surplus measures are used when the consumers are constrained to buy fixed quantities. The compensating surplus is defined as the area under the compensated demand curve for initial utility levels. Equivalence surplus is defined as the

area under the compensated curve for specified alternative utility levels (Johansson, 1987).

The benefit measures obtained from the CVM are equal to the difference between two expenditure functions. These are the changes in the income and level of the public good that will not alter the utility level. The expenditure function is one of the four equivalent ways to represent the constrained utility maximization problem, and it can be expressed mathematically as: -

$$e^{(P, Q, U)} = Y \quad (3)$$

where P is the price of the public good, Q is the quantity of the fixed public good, U is the level of utility and Y is the minimum income required to maintain the utility level U at a given price and fixed public good. Initial levels can be represented by P_0, Q_0, U_0 and Y_0 , and subsequent levels by P_1, Q_1, U_1 and Y_1 . Thus the mathematical representation of the compensating surplus (CMS) is:-

$$\begin{aligned} \text{CMS} &= [e^{(P_0, Q_0, U_0)} = Y_0] - [e^{(P_1, Q_1, U_1)} = Y_1] \\ &= Y_0 - Y_1 \end{aligned} \quad (4)$$

If the compensating surplus is positive, then Q_1 is preferred to Q_0 - the consumer would be willing to pay up to the point where the utility level was the same as in the initial situation.

The equivalent surplus (ES) can be mathematically represented as:-

$$\begin{aligned} \text{ES} &= [e^{(P_0, Q_0, U_0)} = Y_0^*] - [e^{(P_1, Q_1, U_1)} = Y_1^*] \\ &= Y_0^* - Y_1^* \end{aligned} \quad (5)$$

If Q_1 is preferred to Q_0 , then the consumer would be willing to accept compensation to compensate for the foregone utility. If Q_0 is preferred, then the consumer would be willing to pay some amount to restore the initial utility level (Mitchell & Carson, 1989).

(ii) Willingness to Pay vs Willingness to Accept

The CVM can use either the WTP or willingness to accept (WTA) compensation in estimating the value of the benefits that individuals derive from environmental goods. The choice depends upon which Hicksian consumer surplus is desired, and also upon the allocation of property rights - that is whether the economic agent has the right to the particular good. In the context of public goods this question is not easy to answer. In most empirical studies, the WTA measure has been inconsistent with economic theory in that it is usually significantly larger than WTP. Respondents may give higher WTA estimates because they reject the property rights associated with WTA compensation. This rejection is characterized by large number (50% or more) of protest bids, which can be in the form of 'refuse to sell' or 'want an infinite amount for compensation' (Mitchell & Carson, 1989). Consumers may have high WTA as they lack information, or time, to optimize the decision about the good. Giving the respondents the opportunity to become familiar with making value judgments can circumvent this problem. This usually leads to decreased WTA, whereas WTP remains stable (Hoehn & Randall, 1983 cited in Mitchell & Carson, 1989). The higher WTA may also be explained by the lack of a budget constraint, since the respondent does not face his/her own income constraint when offered compensation (Field, 1994). Choosing between WTP and WTA is still a dilemma for CVM surveyors. The WTA is not appropriate for valuing the degradation in the quantity or quality of the public good, while WTP is appropriate in cases where theory specifies that a WTA may bias the results. The WTP is usually used for valuing a decrease in the level of provision of a large class of public goods (Mitchell & Carson, 1989).

2.4.3 The Cost of Illness Approach

Costing of illness is an approach for valuing the cost of pollution-related morbidity and mortality. It is based on an underlying damage function, whereby the level of pollution is related to the degree of health effect. The main limitation of this method in developing

countries is that the dose response function of pollutants and health effect is inapplicable, as very few epidemiological studies have been done in this regard. Moreover, extrapolating the dose response function from developed countries tends to bias the results, since the concentration of pollutants and the general health status vary significantly. Benefits are measured as an estimate of the costs incurred from the preventive actions that prevent the damage from occurring. The costs that are usually included are any loss of income resulting from being ill, medical costs and any related out-of-pocket expenses. The main criticism of this method is that it disregards individuals who are not employed but who might be affected as the result of water pollution. And, non-market losses, such as the pain and suffering of individuals, are not easy to quantify (Biswa & Agarwal, 1994).

The cost of illness approach is easier to use when the illness studied is short, discrete and does not have negative long-term impacts. Most empirical work using this approach has been related to the evaluation of potable water supply projects, which are aimed at reducing the incidence of diarrhoea. In most cases, the link between contaminated drinking water supply and diarrhoea can be clearly established, although it is also important that other transmission (e.g. contaminated food) links be considered. Waste disposal project valuation is also another likely candidate for the cost of illness approach as there is a distinct possibility of the improvement of human health and productivity (Biswa & Agarwal, 1994).

Margulis (1991) applied the cost of illness approach to estimate air pollution costs in Mexico, using a three-step approach: Firstly, determining the ambient concentrations of different pollutants. Secondly, using the dose response function to determine the incremental incidence of disease. Thirdly, estimating the costs of the increase in morbidity and mortality based on treatment costs, loss of income and loss of life. This study, however, did not include indirect costs such as discomfort, suffering and the opportunity cost of time.

Verma and Srivastava (1990) estimated the personal cost of illness due to water-related diseases in Uttar Pradesh, a rural area of India, to assess the losses in productivity and treatment costs. Losses in productivity were estimated from the number of days lost due to

illness in a year. This approach, however, excluded people who are not earning any income, and so understated the costs. In most empirical studies using the cost of illness approach, social costs and overall costs to the economy are not included, mainly because of time, financial, and data constraints. The social costs resulting from an illness may include both short- and long-term reductions in the quality of life, which are associated with pain or suffering and death. Overall costs to the economy reflect the effect of an illness on the gross national product as a result of reductions in productivity and allocation of resources in health care (Pelgram, Rollins & Espey, 1998).

2.5 AGGREGATION OF ENVIRONMENTAL BENEFITS

Once individual demand curves for a resource have been analysed, the next critical issue is how to aggregate these individual demand curves in order to estimate the total benefits of the good being valued. This requires that the target group of people affected by the change in the state of that resource be defined. A further problem is whether or not this group is sufficiently large, and representative, for study results to be accepted (Bishop, Champ and Mullarkey, 1995).

2.6 COSTS OF IMPROVING ENVIRONMENTAL QUALITY

The production of goods or services requires expenditure on inputs. In market economics, costs can be quantified by using the market prices of the raw inputs. However, environmental amenities and services are different from most market-based goods, as they are not traded. The quantification of their costs is usually considered in terms of what could have been produced with these environmental inputs had they not been used in that particular production. This concept is referred to as an opportunity cost, and it is the maximum value of the alternative output that could have been obtained had the resources been used differently. It is not practical to measure the opportunity cost in terms of the other physical items that could have been produced. There is also not enough information to measure the value of the next best output that could have been produced. Therefore it is best to measure the

opportunity cost in terms of the value of inputs used up in production. Thus the correct value of the inputs is needed, and the cost curves would give the geometric representation of the production costs. The costs increase with increase in output and the shape differs from one situation to the other. The key determinants of the costs are the technology used, price of input and time (Collins, 1992).

2.7 COST-BENEFIT ANALYSIS ISSUES

In cost-benefit analysis the emphasis is on attributing a social value to all aspects of a proposed project. This analysis considers both the total benefits and the total costs associated with a project. Some aspects may be valued as costs whilst others may be valued as benefits, depending on whether they are negatively or positively affected by the project. If the benefits exceed the costs then the project is said to be worth considering (Laslett, 1995). This procedure determines whether a potential Pareto improvement is possible but will not determine the Pareto optimality. Assumptions are made in order to obtain the correct estimate of aggregate individual WTP amounts or the aggregate valuation function. Then a weighing scheme for the costs and benefits is chosen, but since WTP involves an income constraint, the standard weighing scheme is to assume that the current distribution of income is acceptable from society's standpoint. Cost-benefit analyses are applicable in selecting efficient policies, justifying a proposed project or stopping new regulations or weakening old ones (Field, 1994).

The cost-benefit analysis is a form of applied modern welfare economics which is based on the Pareto criterion, in that it attempts to put monetary value on the losses and gains to those affected by the change in the level of the provision of a public good. The net gains and losses are determined on whether the proposed change is potentially Pareto improving or not (Mitchell & Carson, 1989). Positive economic theory is the basis of two of the main characteristics of cost-benefit analyses. The first is the acceptance of consumer sovereignty, which means that the consumer is a better judge of what gives him/her utility. Secondly,

cost-benefit analyses tend to emphasize economic efficiency rather than distributional issues. Economic efficiency in this context refers to the concept that the resources are put to their most productive use and its measurement follows from positive economics theory. Economic efficiency is more difficult to analyze because the data is usually of poor quality and most measurement techniques are not well suited to clarify the distributional outcomes (Kahn, 1998). In welfare economics the Pareto criterion is employed to judge policies as it allows those who gain from the change to compensate the losers. However, in reality compensation is rarely paid, and hence the more realistic concept of *potential* Pareto improvement is used. This emphasizes that projects should be selected on the basis of strict economic efficiency. The Pareto criterion has been criticized as implying that the government, scientist or the elite group knows best what should be done to increase an individual's utility (Kahn, 1998). ✓

2.7.1 Willingness to Pay and Consumer Surplus in Cost-Benefit Analysis

Paretian value judgments are at the core of social cost-benefit analysis, because society's welfare depends on the satisfaction or utility of all the individuals of that society. This statement is represented mathematically as:

$$W = U_1 + U_2 + \dots + U_n \quad (6)$$

where W represents social welfare and is obtained by adding the utility (U) of all the society's n individuals. Using income (Y) as proxy for utility, equation (6) becomes:

$$W = Y_1 + Y_2 + \dots + Y_n \quad (7)$$

Using income to measure social welfare poses a problem, since income is dependent on market values. As a result it is possible, if demand is inelastic (unresponsive to price changes), to reduce output even when market income (revenue) rises. To overcome this problem a WTP measure is used to calculate welfare. A demand curve, which reflects prices that consumers would pay for additional units of a good, is used to define WTP, which is

defined as the whole area under the demand curve (Brent, 1997).

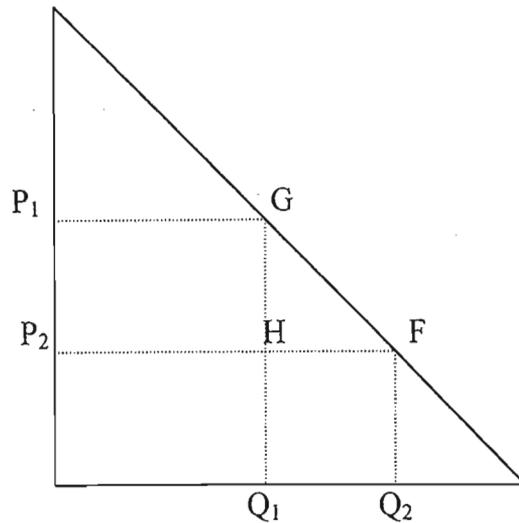


Figure 2.6 The Willingness to pay concept

Source: Reproduced from Curry & Weiss, 1993, page 165

Figure 2.6 shows consumer demand for a particular good, where output expands from Q_1 to Q_2 , and this additional supply lowers the price of the good from P_1 to P_2 . The WTP for the additional output is the area GHQ_1Q_2F . At output Q_1 , consumers are willing to pay a price of P_1 per unit, which is higher than when quantity is increased to Q_2 . The reason for this is that initially consumers have none of this good, so they would attain more satisfaction from consuming one unit of this good. However, for additional units of this good the utility obtained from consumption has decreased, since they already have the good. This phenomenon reflects diminishing WTP (Field, 1994; Curry & Weiss, 1993). Using WTP as a measure for social welfare, the total satisfaction from consuming all units of the good that are available is estimated mathematically as (Brent, 1997):

$$\text{WTP} = \text{WTP}_1 + \text{WTP}_2 + \dots + \text{WTP}_n \quad (8)$$

The concept of willingness to pay is used to explain consumer surplus, which is defined as the difference between the willingness to pay and what the individual actually pays for a

particular good (market price). This is given by the area under the demand curve, but above the price line (shown in figure 2.7).

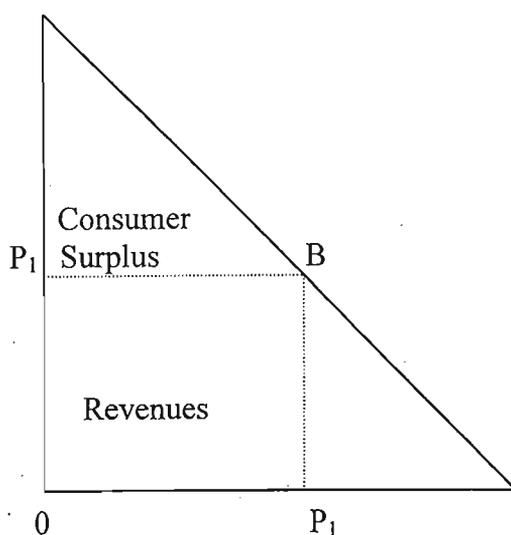


Figure 2.7 **The consumer surplus concept**

Source: Reproduced from Brent, 1997, page 169

In cost-benefit analysis the consumer surplus plays a very important role, as it provides social justification for providing goods that would otherwise be rejected by the market. Dupuit introduced the notion of consumer surplus in 1844, as a guide when making decisions that involve public investments (cited in Brent, 1997). The three alternative measures discussed in section (i) can be used to estimate consumer surplus. These measures are: the Marshallian measure, the compensating variation and the equivalent variation. The Marshallian measure is defined as the excess of the price which an individual would be willing to pay rather than forego consumption of that good, over that which an individual would actually pay. With the compensating consumer surplus the emphasis is on measuring the amount of compensation that one can take away from an individual and leave them just as well off as they were before (utility is held constant). The equivalent consumer surplus is defined as the amount of compensation that has to be given in order that an individual forego the change and yet be as well off as before (Blaug, 1999). According to Brent (1997), the Marshallian measure is the one that is mostly used in empirical studies.

2.8 SUMMARY

This chapter has described the economic theory underlying, and the issues associated with, the economic valuation methods used in this study. The next chapter describes the study area from which the empirical data for applying the valuation methods were obtained.

CHAPTER 3

THE STUDY AREA

3.1 DESCRIPTION OF THE STUDY AREA

Darvill Waste Water Works (DWWW) is located to the east of the Pietermaritzburg Central Business District. Umgeni Water has managed this works since 1992, after taking over from the Pietermaritzburg-Msunduzi Transitional Local Council (TLC). The works is built on 78 hectares of land, while a further 71 hectares is leased from the TLC, 50 hectares of which is used for sludge disposal. Residential areas such as Glenwood, Eastwood and Sobantu are to the North and North West of DWWW, with Lincoln Meade, Hayfields and Hollingwood to the South and South East. Most of the Northern region comprises of agricultural land. The DWWW plant receives all the domestic and industrial wastewater from the sewered regions of Pietermaritzburg. After treatment, the final effluent is discharged directly into the Msunduzi River, which bounds the plant from the South West to the North and South East.

With respect to proximity to DWWW, a third of the Sobantu area lies within a 0-1Km radius of DWWW (Zone 1) and the other two thirds lie within the 1-2Km radius (Zone 2). Eastwood and Glenwood are within a 3Km radius of DWWW (Zone 3). Glenwood has both formal and informal settlements, the latter being very close to the Msunduzi River which is occasionally used as a source of water supply. The informal settlements do not have proper sanitation and human excrement sometimes pollutes the watercourse. The residential areas Lincoln Meade and Hayfields are also close to DWWW as they fall within the 3Km radius. Part of Lincoln Meade falls within the 1Km radius of DWWW, while the rest is within the 2-3Km radius. Hayfields is found in the 2-3Km and 3Km radii around DWWW. Another residential area on the South Eastern side of DWWW is Hollingwood, an informal settlement adjacent to Lincoln Meade. This area falls within the 1-2Km radius of DWWW.

Tables 3.1, 3.2 and 3.3 present the socioeconomic characteristics of these residential areas, excluding Hollingwood. The data were obtained from the 1996 census data for these areas,

and the information for Hollingwood was not available. Table 3.1 compares the percentages of the people that are employed against those that are unemployed in the five residential areas. Eastwood and Sobantu have relatively high unemployment levels of over 60%. Sobantu is a predominantly black township with an estimated population of 9020, whereas Eastwood is a coloured area with an estimated population of 14982.

Glenwood, Lincoln Meade and Hayfields have higher employment levels than Sobantu and Eastwood. In Glenwood approximately 57% of people are employed, while over half of the total population in Lincoln Meade and Hayfields are employed (59% and 60%, respectively). Lincoln Meade and Hayfields are predominantly white suburbs and as such are characterized by low unemployment rates and relatively smaller families (three to four persons per household). Sobantu, Eastwood and Glenwood, which are black and coloured residential areas, have larger families, between five and seven individuals per household (Hirschowitz and Orkin, 1995).

Table 3.1 Population and employment statistics for the residential areas surrounding DWWW

	Eastwood	Glenwood	Hayfields	Lincoln Meade	Sobantu
Population	14982	4645	6369	2176	9020
Unemployed	68.35%	42.84%	39.99%	40.99%	62.28%
Employed	31.65%	57.16%	60.01%	59.01%	37.72%

Source: Census Data, 1996

Table 3.2 shows the distribution of household income as indicated by the percentage of people in different income groups. Eastwood and Sobantu can be categorized as low-income areas, since more than half of their populations have a total monthly income of less than five hundred rands per household. Some 41% of people in Glenwood earn between R500 and R2500 per month. Lincoln Meade and Hayfields are at the upper end of the income scale as more than one third of their populations earn more than R4500 per month.

Table 3.2 Household monthly income in the residential areas surrounding DWWW

Income	Eastwood	Glenwood	Hayfields	Lincoln Meade	Sobantu
None	60.28%	29.00%	15.14%	15.65%	47.37%
<R500	10.26%	8.60%	7.83%	7.80%	10.40%
R500-R2500	16.70%	41.43%	27.54%	15.93%	19.27%
R2501-R4500	5.86%	8.48%	17.26%	25.80%	11.28%
R4501-R6000	3.65%	5.04%	18.79%	17.25%	9.40%
>R6001	3.25%	7.45%	13.44%	17.57%	9.28%

Source: Census Data, 1996

Education levels reported in Table 3.3 show that just under 45% of the total population in Sobantu, and some 41% of the people in Eastwood have only a primary education or below. Approximately 31% in Sobantu and 34% in Eastwood have a secondary education, and 21% and 15%, respectively, of their populations have a matric certificate. An estimated 3% of the total population, in both areas, has a tertiary qualification. In Lincoln Meade and Hayfields the largest education level is matric, with 36.39% in the former and 44.29% in the latter. The number of individuals with tertiary qualification is higher in these areas at 15.40% and 18.02%, respectively. Glenwood has the lowest levels of illiteracy when compared to the other residential areas (6.89%), while its proportions of individuals with a matric certificate and those with tertiary qualifications are just below that shown for Hayfields.

Table 3.3 Education levels in the residential areas surrounding DWWW

Education	Eastwood	Glenwood	Hayfields	Lincoln Meade	Sobantu
None	22.31%	6.89%	7.78%	12.02%	13.73%
Primary	25.68%	10.78%	13.40%	18.33%	31.07%
Secondary	34.03%	25.93%	16.51%	17.86%	31.44%
Matric	15.36%	38.64%	44.29%	36.39%	20.58%
Tertiary	2.62%	17.76%	18.02%	15.40%	3.17%

Source: Census Data, 1996

To the North of DWWW there are agricultural lands that are also scattered across the length of the Msunduzi River. Owners of these lands abstract water from the river for irrigation purposes. Agricultural runoff exacerbates the pollution of the river. The Msunduzi River also runs through the rural areas of Cato Ridge and Table Mountain. It then joins the Mgeni River, which runs through rural areas of the Valley of the Thousand Hills before the water enters the Inanda Dam. The Table Mountain and Valley of the Thousand Hills areas are characterized by nucleated rural settlements, which have poor infrastructure in terms of sanitation and water supply. Although most of these rural areas have a potable water supply, residents still use river water for washing, and sometimes children use it for swimming.

The Mgeni River eventually enters the Inanda Dam that serves as a source of water supply for the Durban Metropolitan area. The water from the Inanda Dam is treated at the Wiggins Water Works before being distributed for domestic and industrial use. The Inanda Dam is relatively new, having been completed in 1989. This dam is drained by the Mgeni River and its major tributary, the Msunduzi River. Significant nutrient loadings at this dam are thought to be due to extensive agriculture, urban development and informal settlements in the catchment area. DWWW and the Cato Ridge Abattoir, however, are recognized as major point sources of nutrient loadings at this dam (Graham, Dickens & Mbowa, 1998). Inanda Dam has been classified as eutrophic because of high initial loads of phosphates (which can be as high as 80 tons per year) and the retention of 80% of this load. High concentrations of algae apparently persist throughout the year. The dam is also described as a warm monomictic system with summer stratification, an autumn turnover and uniform conditions during winter (Graham *et al.*, 1998).

The Wiggins Water Works draws water mainly from the Inanda Dam, and occasionally from the Nagle Dam, for purification. Occasional algal blooms are observed at the Inanda Dam with a maximum of 6310 cells/ml of *Anabaena* recorded during the period January 1990 to March 1997. These algal blooms impart bad taste and odours to the water entering Wiggins Water Works and often expensive and specialized treatment procedures have to be adopted to eradicate these problems (Graham *et al.*, 1998). ✓

3.2 TOPOGRAPHY AND CLIMATE

The study area encompasses those parts of Pietermaritzburg, Cato Ridge and Durban that experience the environmental impacts that are associated with DWWW (Figure 3.1). These areas lie within the Pietermaritzburg-Msunduzi TLC and the Durban Metropolitan TLC. The Pietermaritzburg-Msunduzi TLC lies in a flat-bottomed valley in the Msunduzi catchment basin, which is well defined on the three sides by an escarpment that is a prominent topographic feature that forms the watershed between the Msunduzi and the Mgeni Rivers (Table Mountain area).

Rainfall is a critical factor that affects the present volumes of sewage entering DWWW. Stormwater runoff entering the sewer lines periodically increases the volumes entering the works due to a poor reticulation system in the city. Pietermaritzburg has rainfall peaks during the summer months and this causes overload of the present capabilities of DWWW. As a result, raw sewage overflows into the Msunduzi River. High intensity thunderstorms in the city also cause environmental degradation as a result of the runoff of the human wastes and other contaminants from land areas without adequate sanitation and solid waste disposal facilities into the local rivers. The high temperatures during the summer months also increase health risks, especially in the valley bottoms, due to the acceleration of the growth and spreading of pathogens. Wind is another important climatic factor in the vicinity of DWWW. Areas that are impacted by odours originating from the wastewater works are determined by wind direction and wind speed. The predominant wind direction at DWWW is North Easterly and the windiest periods are between September and October.

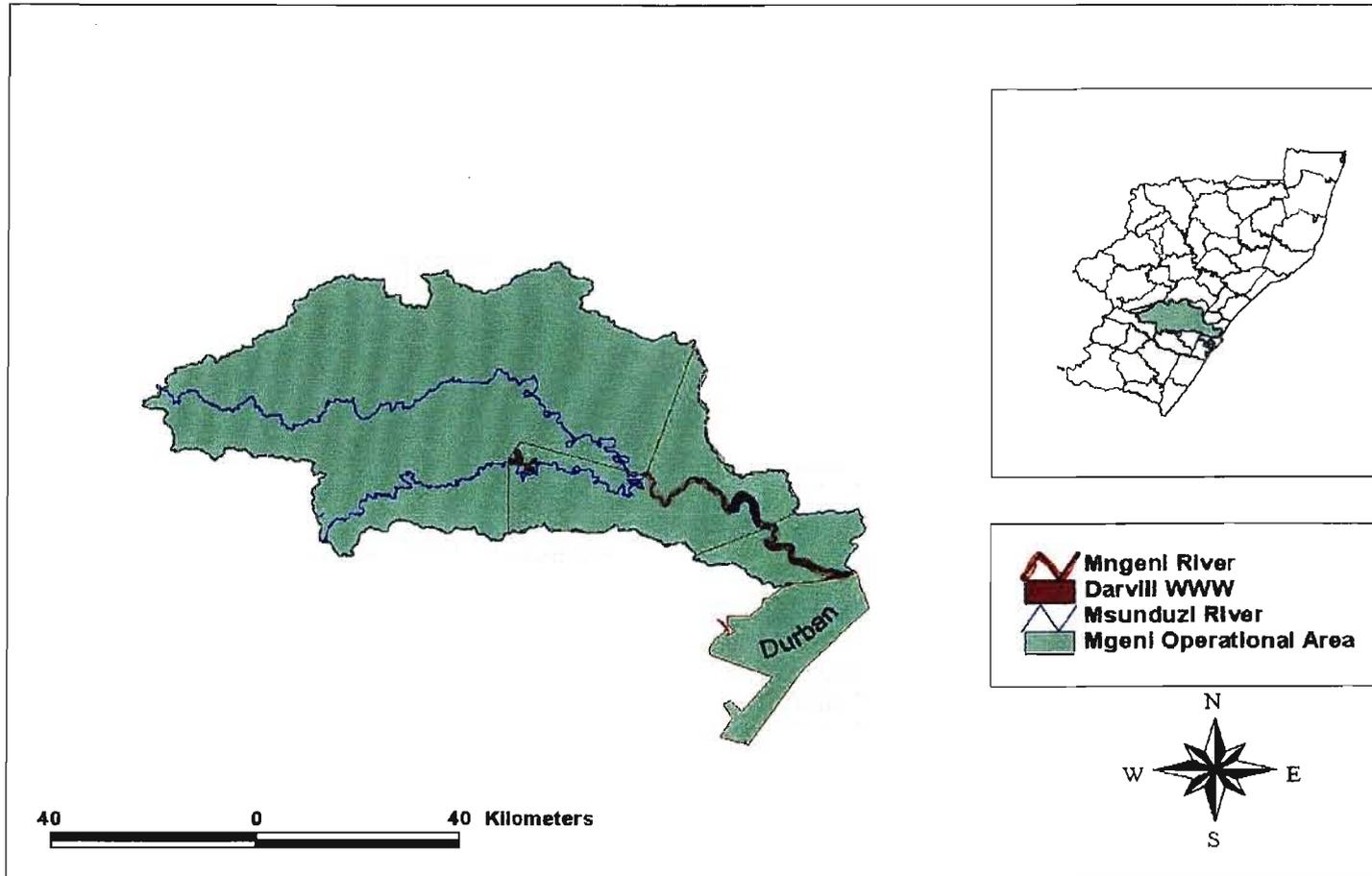


Figure 3.1 Map of the study area

3.3 WATER QUALITY

Lack of adequate and appropriate sanitation, mainly in rural areas and informal settlements, causes a marked deterioration in water quality. This has adverse impacts on both human and animal health as well as the natural environment, aesthetics, recreation, and the suitability of water for industrial purposes. All of these impacts have a high economic cost associated with them, while poor quality water requires expensive treatment, which adds to costs. According to A'Bear (1991 cited in GFJ, 1996), Pietermaritzburg gives rise to the worst bacteriological water quality in the Msunduzi-Mgeni River system, and the Msunduzi River is a major contributor to the deterioration of bacterial quality of the Umgeni River below the Msunduzi River and Mgeni River confluence. However, even though DWWW contributes significantly to the poor quality of the Msunduzi River, there has been a pronounced improvement in the quality of final effluent that is discharged to the river since 1992, after Umgeni Water Board took over the management of DWWW. Pollution of the Msunduzi River is also exacerbated by the diffusion of non-point sources of pollution, such as agricultural runoff and runoff from the informal settlements.

According to the Umgeni Water Environmental Report (1998-1999), non-compliance at DWWW has been observed with respect to the effluent discharge and the sludge disposal.

The non-compliance of the effluent discharge observations were as follows:

- 15% in *E. coli* non-compliance;
- 30% in Soluble Phosphate (SRP) non-compliance;
- More than 50% non-compliance in soap, oil and grease;
- 80% *E. coli* compliance with working limits only; and
- Less than 5% *E. coli* compliance with DWAF's General Standard & Special Phosphate Standard.

The presented figures indicate instances, in terms of overall performance of DWWW, when the final effluent discharged into the watercourse compromised the water quality of the Msunduzi River.

Overall, only 3% of the final effluent showed non-compliance, 4% compliance with working limits and 93% compliance with DWAF's General Standard & Special Phosphate Standard. In terms of the sludge disposal, 64% non-compliance has been observed and areas requiring improvements were identified as storm water control, access control, sludge distribution, pollutant load monitoring and formal complaints resolution procedure. The latter is important, as several complaints from the neighbouring residential areas have been directed at DWWW due to problems with odours and flies. These result from the treatment of wastewater and the disposal of the sludge which emit odorous gases and create conditions for flies to breed at the inlet of the wastewater works (Graham, Dickens & Mbowa, 1998).

Umgeni Water has an extensive water quality monitoring network as shown in Figure 3.2 & 3.3. Figure 3.2 shows the suitability of the rivers and dams for swimming based on the *E. coli* count. The Msunduzi River upstream of DWWW has an *E. coli* count between 201 and 400 - a figure considered as some risk that is not significant. After the DWWW discharge, however, the *E. coli* count rises above 400 - a figure that is considered significant risk. At the Mgeni and Msunduzi confluence, the Msunduzi River (some risk - yellow in colour) corrupts the Mgeni River (low risk - strong blue in colour) and the *E. coli* count increases to a slight risk figure (131-200). The water that eventually enters the Inanda Dam thus has an *E. coli* count in the 131-200 range. Pollution from other contaminated streams joining the Mgeni River also contributes to the increased *E. coli* count, as is evident from Figure 3.2.

Figure 3.3 shows water quality and river health using three indicators - the biotic index, habitat quality and river and impoundment quality. The biotic index is derived from the presence or absence of aquatic organisms. If these are present, the biotic index is considered good. The habitat quality is based on the physical nature of the river including riparian vegetation, bank stability, presence/absence of rocks, flow and river morphology. For both the biotic index and the habitat quality, the blue colour denotes good, green shows medium and red indicates poor index or quality.

The third indicator (river and impoundment quality) is based on the Umgeni Water water quality index (WQ index) which includes calculating the Algal counts, Chlorophyll A, *E. coli*, turbidity, conductivity, Nitrate, Ammonia, Total phosphate (TP), Soluble phosphate (SRP) and Suspended Solids. In Map 2 the Msunduzi River after DWWW discharge is considered poor in terms of both the habitat quality and the river and impoundment quality. The water after the Msunduzi/Mgeni confluence is satisfactory only in river and impoundment quality and the biotic index. However, it is poor in habitat quality. The water at the Inanda Dam is satisfactory in all three aspects. Changes in river water quality for 1998 to 1999 in Map 2 show a significant decrease from unsatisfactory status to poor status for the Msunduzi River. An approximate 10% decline from a good status to satisfactory status is observed with the Mgeni River.

3.4 VEGETATION

The study area is situated at the edge of the subtropics and is both biologically and visually diverse, consisting of three different veld types: The low-lying areas along the Mgeni and the Msunduzi Rivers are characterized by the Valley Bushveld. The vegetation towards the South East (Ashburton area) is Southern Tall Grassveld. The Ngongoni Veld occurs in the cooler Northern and Western slopes. This biodiversity is important as it contributes to the cultural heritage of this area and therefore adverse impacts of the DWWW must be minimised in order to conserve this biodiversity. The DWWW has a pond and a bird sanctuary illustrating the waterworks management's concern for nature conservation.

CHAPTER 4

MATERIALS AND METHODS

4.1 INTRODUCTION

Different economic valuation techniques were used to quantify the impacts of DWWW, in terms of estimating the benefits and costs associated with upgrading DWWW. The estimated benefits and costs were required for the cost benefit analysis, which was the focal point of the study. The benefits were estimated using a demand function approach that involves quantifying the damages that would be prevented by pollution control. Geographic information systems (GIS) were also used in some stages of the study to identify areas impacted by DWWW. Market related costs of upgrading DWWW were extrapolated from similar studies. Lastly the estimated costs and benefits were compared in a cost benefit analysis to evaluate whether upgrading DWWW was worth considering.

4.2 COSTING THE DECREASE IN THE QUALITY OF LIFE OF HOUSEHOLDS IN THE RESIDENTIAL AREAS SURROUNDING DWWW

The contingent valuation method was used to elicit what people living around the DWWW were WTP for improvements in air quality due to the eradication of odours and flies. Contingent valuation is a technique for individuals to reveal their preferences for the benefits they get from non-market goods such as improvements in air quality.

4.2.1 CVM Model Of Factors Affecting WTP Estimates

Economic valuation of the decrease in the quality of life involved estimating individual preferences for improving air quality in the areas surrounding DWWW. These preferences are likely to compete with preferences for the consumption of other marketed and non-marketed goods and services. The value of improved air quality to the individual is what

that person is willing and able to pay for it. The WTP is dependant upon several factors as outlined in the following model:

$$\text{WTP} = f(\text{Income, Age, Education, Dependants, Marital Status, Proximity to DWWW}) \quad (9)$$

Equation (9) hypothesizes that WTP is a function of total household income, respondent's age and education level, the number of dependants in the household, the respondent's marital status and proximity to DWWW. Since each respondent is likely to face a budget constraint, stated WTP will probably increase with increasing income (Field, 1994). The income variable is a proxy for budgetary constraints faced by the household. Individuals with more education may have more information about the effects of sludge emissions on air quality and thus have a higher WTP. Older respondents may perceive that they have smaller time horizons to recoup outlays for improving air quality, and so may make lower WTP bids. Households with more dependants are likely to have less disposable income for non-family expenditure, and, therefore, have lower WTP for air quality improvements. Women principal decision-makers are likely to see expenditure on family needs as a priority, leading to lower WTP values. Finally, respondents that are single may have proportionately less disposable income committed to family expenditure, and thus report higher WTP values. These *a priori* expectations will serve as checking points for any biases that are inherent to the CVM.

4.2.2 Research Methodology

The residential areas that are close to DWWW were identified as Glenwood, Eastwood, Sobantu, Hayfields, Scottsville, Lincoln Meade and Hollingwood. Due to limited time and financial resources, however, it was not possible to include all of these areas in the study. Prevailing wind speed and direction information obtained from the Darvill Weather Station was used to locate and map out the air pollution locus from DWWW using GIS in order to delineate those areas that are frequently impacted by odours and flies. It was determined that the prevailing wind was a North Easterly one affecting Sobantu, Lincoln Meade, Hollingwood and Hayfields. Hollingwood had to be dropped from the study because of the

political instability in the area. Using the graphics function in ArcView the identified residential areas were further divided into three buffer zones of a kilometer apart, and classified as: Within one kilometer (Zone 1), between 1-2 kilometers (Zone 2) and between 2-3 kilometers (Zone 3) from DWWW (Figure 4.1).

4.2.2.1 Questionnaire Design

The study also required the design of a questionnaire that was going to be used as a survey instrument to interview people selected in the study areas to indicate their WTP for improvement in air quality. The CVM questionnaire used was designed by following procedures adopted by Mitchell & Carson (1989). An open-ended question format was used, and the questionnaire was divided into three main sections. The first section was aimed at eliciting the monthly WTP amount that the respondents would be prepared to bid to remove the odour and fly problems. Photographs A, B, C & D on pages 140 and 141 of Appendix A were used to present the CVM scenarios. Photograph A showed the Darvill WWW and the respondents were informed that the plant treats all of the industrial and domestic effluent from the city of Pietermaritzburg. The respondents were further informed that the treated effluent is discharged directly into the Msunduzi River (Photograph B). Photograph C showed respondents that people were using the Msunduzi River as a source of water supply. Finally, Photograph D showed the sludge – responsible for odour and fly problems – that is produced during the wastewater treatment process being sprayed over the land near the works. The photographs were used to familiarize the respondents with the good being valued and, hence, to try and eliminate biases in responses due to lack of information about the problems that compromised air quality. Before asking the respondent's to estimate their WTP, interviewers reminded them to check that these estimates were affordable, given the respondents' competing needs and respective budgetary constraints. Respondents were also asked to state why they bid a particular WTP amount, in order to identify potential biases in the stated monthly WTP. For example, a respondent might state a zero WTP for improvements in air quality even though s/he has funds available because s/he believes that it is not his/her responsibility to pay for improvements in air quality.

The second section collected demographic information about the respondents' gender, age, marital status, number of dependants in a household, education and total household income each month before taxes. These questions are used in the statistical analysis of the survey results, and the respondents were assured that this information would remain confidential. This section also included questions about property characteristics that would be used in the hedonic price approach (Section 4.3, below). The third and last section was completed by interviewers and showed the extent to which they felt that the respondents understood the survey questions and whether they made any effort in answering the questions. This was important in order to eliminate biases in the respondents' answers. English and Zulu versions of the questionnaire were created, with the Zulu version being used during the surveys in Sobantu because most of the people there are Zulu speaking (see Appendix A for the copy of the questionnaire).

4.2.2.2 Questionnaire Pretesting

The questionnaires were pre-tested on three focus groups to assess the clarity of the questions and whether the length of the interview was acceptable. The focus groups used were representatives of the Sobantu environmental group and representatives from the Ratepayer's Association from Lincoln Meade and Hayfields. The pre-testing was administered using face-to-face interviews. These groups were chosen because they are actively involved with the environmental management issues in their communities. In addition, it was thought that they would have ideas about the level of information required by the members of the general public. Problems identified during this exercise were corrected and the questionnaire modified as described in section 5.1 of Chapter 5, which presents the study results.

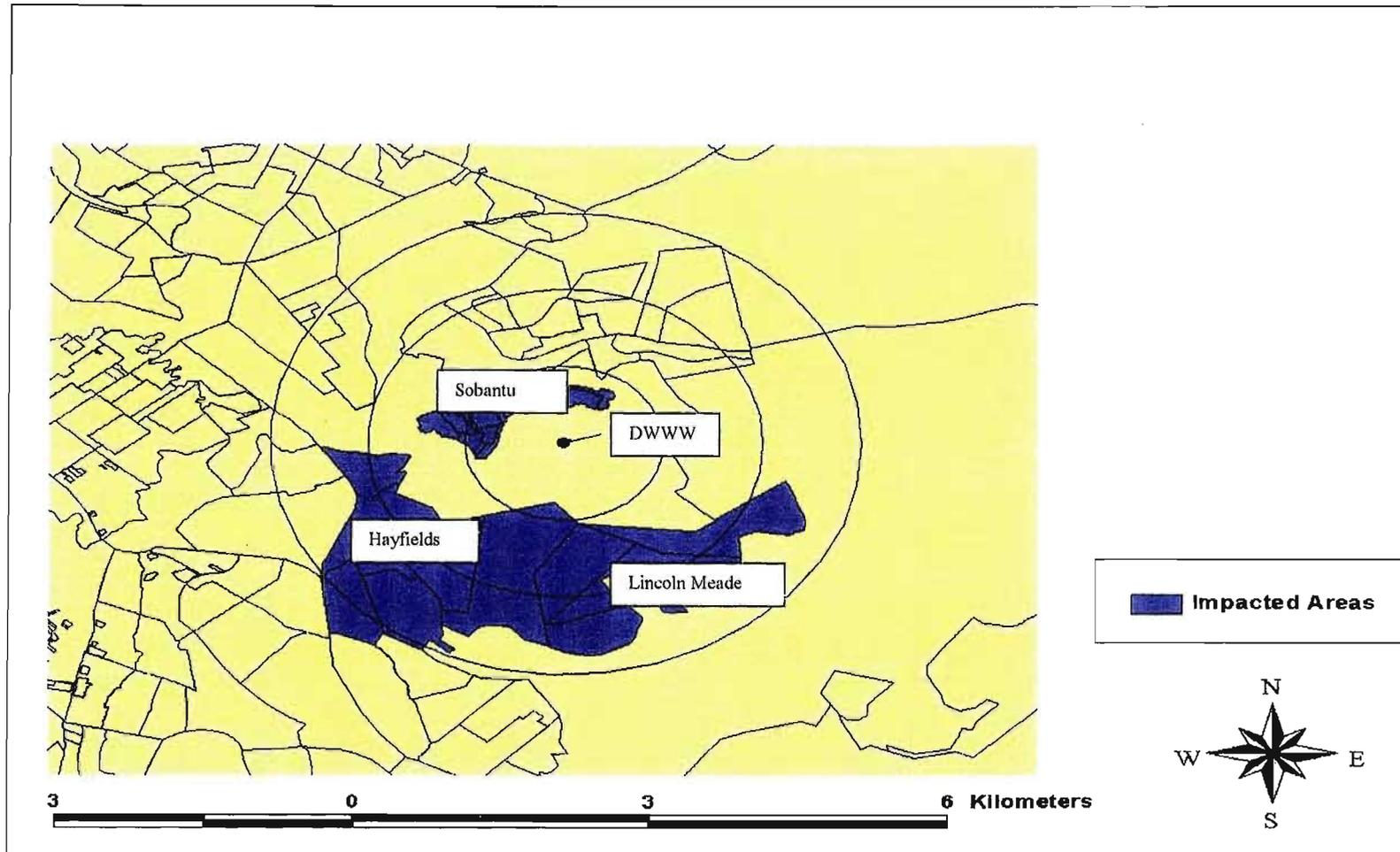


Figure 4.1 Map of residential areas impacted by odours and flies due to DWWW sludge

4.2.2.3 Interviewer Training

Five first-year students from the University of Natal, Pietermaritzburg were selected to assist with the pilot project and the field survey. These students were first given background information by taking them on a field trip to DWWW and the surrounding residential areas. They were then given copies of the questionnaires to familiarize them with the content, and some pointers on how to fill in the questionnaires, stressing that it was important that respondents answer all questions. At the end of each interviewing day, the submitted questionnaires were checked for any inconsistencies such as missing information or cases where more than one answer for a question was supplied and these were corrected where possible.

4.2.2.4 Pilot Survey

A pilot survey was undertaken in Sobantu using 33 households to answer the questionnaire. The main reason for this was to test whether typical respondents could understand the questionnaire content. Moreover, this pilot survey would help to indicate the non-response rate that could be expected and to observe whether the interviewers were adequately prepared. Prior to this a pre-testing exercise was performed to identify any problems with the questionnaire that would have hindered the success of the survey. Two focus groups were used, namely an environmental group from Sobantu and the Ratepayers Association from Lincoln Meade. Both groups were under the impression that they were required to value the benefits of improved air *and* water quality.

The members of the Lincoln Meade focus group were not happy about stating WTP in the pre-testing exercise, as they felt that they were already paying too much in the form of rates. In their opinion, they were subsidizing surrounding low-income areas and, therefore, it was the local municipality's responsibility to improve the air quality. The Sobantu focus group, on the other hand, were confused with the issue of the vehicle of payment. They indicated

that the WTP question did not clearly convey to them how they would be paying for cleaner air.

These issues were resolved when modifying the questionnaire. Firstly, the paragraph on background information was carefully reworded in order to eliminate any confusion, and to clarify that the respondents were required to value the benefits of improved air quality only. The WTP question made no mention of improving water quality. Secondly, the respondents were assured that their valuation of the benefits of less air pollution did not mean that their municipal rates would be increased. If they still did not want to state a WTP amount, they were asked to indicate how much, from what they were already paying in municipal rates, they would like to contribute towards improving air quality. The sequence of these steps was important in order to avoid introducing a ceiling price on any respondent's WTP.

4.2.2.5 Sampling Frame

Due to time and financial constraints, a 100% coverage of the residential areas that are affected by the odour and flies from DWWW was not possible. Instead only the residential areas of Sobantu, Hayfields and Lincoln Meade were considered. These households are directly impacted by odours and flies, and improvements in air quality would probably be of direct benefit to them. A stratified random sampling procedure was then adopted, whereby 40% of the total population in Zone 1, 30% of the total population in Zone 2 and 20 % of the total population in Zone 3 were interviewed. Out of a total of 2496 households, 700 were selected to be interviewed, making the sample 30% of the total population affected by odour and fly problems in Sobantu, Lincoln Meade and Hayfields.

4.2.2.6 Interview Process

Before the final survey took place, notices were placed in the local Natal Witness newspaper and on the community notice boards at Lincoln Meade and Hayfields. The purpose was to

inform people in the identified residential areas that this study was going to be conducted and, thereby, to reduce the number of non-responses. This was not done in Sobantu because the Sobantu Environmental Group indicated that most principal decision makers are available on weekends. Face-to-face interviews were conducted with the principal decision makers in all three areas.

4.2.3 Treatment Of Data

Descriptive and one-way analysis of variance statistics were estimated for each of the variables specified as determinants of WTP in equation (9), section 4.1.2 above. The descriptive statistics procedure aimed to identify inconsistencies such as outlying and protest WTP values, and to investigate whether the data contained any missing information. The relationship between WTP and the different variables specified in equation (9) was then estimated by multiple regression using the SPSS statistical programme.

4.3 ESTIMATING THE COSTS OF AIR POLLUTION

A hedonic pricing approach was used to quantify the costs associated with odours and flies from DWWW in terms of the estimated decline in property values in surrounding areas as a result of this air pollution. This method is based on the principle that goods with market prices, such as houses, can be thought of as a collection of various attributes and amenities. The term 'hedonic' refers to a situation where a complex commodity is divided into a sum of the values of its various components. The combination of these components make up the value of that good and defines what the prospective buyer is willing to pay for that good. Using the hedonic price function, the implicit prices for these characteristics can be quantified from the observed market prices for the good as a whole (Fridgen & Shultz, 1999). In the case of air quality, the implicit value of improvements in this resource can be quantified from the reduction in the market values of the houses in the study area described below.

4.3.1 Sources and Description of Data

The study was performed for Lincoln Meade and Hayfields plus eight other residential areas not impacted by odours and flies from DWW, namely Athlone, Bellevue, Bisley, Blackridge, Epworth, Richmond Crest, Scottsville and Wembley, to check for any significant decline in the property values. The eight residential areas were included in order to compare their property values with those from the impacted residential areas. Property values for Sobantu were not available, therefore this area is not included in the analysis. Information about the relevant properties was obtained from the Residential Property Price index (RPPI) files made available by Natal Property estate agents. This information described the properties in terms of their attributes such as asking and selling prices, area of the property, municipal property value, age of the house and size of the property. Additional data described the structural dimensions of the house such as the number of bedrooms and bathrooms, presence or absence of a swimming pool, number of garages, and presence or absence of outbuildings. A total of 1232 records of property values over the period July 1998 to October 2000 were included in the analysis.

4.3.2 Hedonic Price Model Specification

Michaels and Smith (1990) indicated that the hedonic price function describes how prices must relate to characteristics for an equilibrium matching to be realized. The function is a modeling strategy that alters the definition of market equilibrium in order to describe an economic agent's choice among different commodities. The conceptual framework of the hedonic model maintains that the attributes of the commodities can be identified and that they provide the motivation for the individual's choice. Thus the hedonic price function can be used to infer the implicit price for air pollution. The hedonic price function, when used in property valuation, tests the theoretical propositions regarding relationships among variables affecting property values and estimate the degree to which one variable influences property values (Ridker & Henning, 1992). The form and content of this study was determined mainly by time limitation and availability of data. Economic theory provides little direction on the

functional form of the hedonic model, but the most commonly used functional forms are the linear and the semi-log models (Ridker & Henning, 1992). These forms were used in this study as specified below:

$$\text{Price} = a_0 + a_1X_i + a_2Z_i + a_3Y_i \text{ (Linear model)} \quad (10)$$

$$\text{LnPrice} = b_0 + b_1X_i + b_2Z_i + b_3Y_i \text{ (Semi-log model)} \quad (11)$$

where, X_i represents the collection of structural variables (size of property, age of house, number of bedrooms, condition of house, number of bathrooms, presence of swimming pool, covered parking and outside buildings such as maid's room or flat), Z_i represents the collection of neighbourhood and environmental characteristics. Y_i is the distance to DWWW (the pollution source), Ln represents natural log, and Price is the housing price obtained from the estate agent records.

4.3.3 Variables Used in the Hedonic Price Model

The data for the property valuation exercise was collected from the record of sales of properties in the city of Pietermaritzburg. These records had information on the market prices and characteristics specific to the properties. The data about the neighbourhood and environmental characteristics of the suburbs included in the study was obtained from the 1996 census, Pietermaritzburg cadastral map and a hard copy map of Pietermaritzburg. The dependant variables (Price and LnPrice) were the selling prices and the natural logarithm of the selling price of properties in the selected residential areas sold between July 1998 and October 2000. The structural housing variables (X_i) in the model are expected to be linearly related to the prices. The neighbourhood and environmental variables (Z_i) in the models include distance to the Pietermaritzburg city center, major shopping centers, number of recreational facilities (parks, caravan parks, rivers, sports fields or race course), and presence of historical monuments or places of interest (such as airport). The dependant variables used in the study and the signs of their expected coefficients, are presented in Table 4.1 overleaf.

Table 4.1 Description and expected signs of the variables used in the hedonic price models

Variables	Description	Expected sign
Structural		
SIZE	Total area of the property in km ²	+
AGE	Number of years since the house was built	-
COND	Condition of the house (good, poor or satisfactory)	+
BED	Number of bedrooms	+
BATH	Total number of bathrooms in the house	+
STUDY	Presence or absence of study rooms	+
REC	Number of reception areas (Kitchen and lounge)	+
POOL	=1 if swimming pool is present	+
FLAT	=1 if outbuilding is present	+
GAR	Number of garages	+
CPOR	Number of carports	+
MAID	=1 if maid's room is present	+
Neighbourhood & Environmental		
DCBD	Distance to the city center in km	-
ENVD	Major shopping centers, schools, number of recreation facilities, historical monuments or places of interest are present	+
Distance DWWW	Distance to DWWW in kilometers	+

4.3.4 Treatment of Data

Descriptive statistics were performed on data for Hayfields and Lincoln Meade and the three zones using the asking price of the seller of the property (Askprice), the price at which the property was sold (Sellprice) and the municipal value of the property (Munvalue). An analysis of variance was also performed using the same variables for the three zones and the two suburbs impacted by odour and flies, to determine whether the mean values of the three variables were significantly different for the three zones and the two suburbs.

Correlations between the selling price and the structural variables of the properties were also analyzed to determine the strength and the direction of the relationship between the selling price and the different explanatory variable. This involved calculating Pearson's Product Moment Correlation coefficient (Pearson's r) to measure correlation between the dependant and the explanatory variables. This measure was used because scatter diagrams indicated linear relationships between the dependant and the explanatory variables (Bryman & Cramer, 1999).

The first step in quantifying the influence of odours and flies on property values involved regressing the price at which the property was sold against the structural characteristics of the property (X_i), the neighbouring and environmental characteristics (Z_i) of the ten residential areas (Hayfields, Lincoln Meade, Athlone, Bisley, Bellevue, Blackridge, Epworth, Richmond Crest, Scottsville and Wembley) and the air quality variable (Y_i). Linear and semi-log hedonic models were estimated in the regression analysis. In a semi-log model the relative change in the value of the properties that is associated with an absolute change in the value of explanatory variables was calculated by using the semi-elasticities, given by:

$$b_i = \text{Relative change in regressand} / \text{Absolute change in regressor} \quad (12)$$

where B_i is the regression coefficient (semi-elasticity) of the characteristic being valued. For linear models, the elasticity is defined as the percentage change in the sale price of the

property for every percentage change in each explanatory variable, holding all other variables constant. This value is estimated from each regression coefficient in a linear model as:

$$E = b_i * X_i / Price \quad (13)$$

where E is the housing value elasticity for an amenity X, and b_i and Price are as defined previously.

4.4 QUANTIFYING THE LOSS OF THE MSUNDUZI CANOE MARATHON

This loss was estimated as the total amount of revenue that would be lost by the City of Pietermaritzburg if the Duzi Canoe Marathon was not held. The first step was to determine the average percentage of annual contenders who are not residents of Pietermaritzburg, the rationale being that they would contribute to the revenue generated by the City through paying for accommodation, food and entertainment. The average family size and the average number of companions for the contenders were also determined from estimates provided by the Duzi Canoe Club. The revenue generated from using restaurants, petrol, cinemas and parks was estimated from interviews conducted with the Pietermaritzburg Publicity Association, providers of local accommodation facilities and contenders. Limited research time meant that employment opportunities created, and revenue generated, through the manufacturing and marketing of canoeing equipment due to the Marathon could not be estimated. The estimated revenue generated by the Duzi Canoe Marathon organizers, however, is approximately thirty million rands (R30 000 000) annually.

4.5 ESTIMATION OF TREATMENT COSTS AT WIGGINS WATER WORKS

A detailed estimation of water treatment costs in the Umgeni Water operational area as a result of algae (Graham, Dickens & Mbowa, 1998) was used to infer the increase in water

treatment cost estimates at Wiggins as a result of the pollution of water from Inanda Dam.

4.6 ESTIMATION OF COSTS ASSOCIATED WITH THE REMOVAL OF WATER HYACINTH FROM INANDA DAM

The objective of this exercise was to estimate the costs of removing and monitoring future reoccurrences of water hyacinth at the Inanda Dam. Discussions held with the dam's management staff revealed the plant's reoccurrence patterns and its management programme. A study on the effect of phosphorous rich DWWW effluent on algal production at Inanda Dam was used to relate algal blooms at the dam with effluent discharged from DWWW (Simpson & Pillay, 1999). The costs of removing water hyacinth from the Inanda Dam were obtained from a similar study conducted by Degner & Howat (1997).

4.7 QUANTIFYING THE HEALTH IMPACTS OF THE MSUNDUZI RIVER ON RURAL COMMUNITIES

A full valuation of the cost of illness was not conducted due to financial and time constraints. Only the core costs of illness were estimated, namely the direct costs of medical resources used in the treatment of water borne diseases, and the indirect costs for households with lost short-term economic opportunities caused by illness. The cost of illness method used was that formulated by Pelgram *et.al* (1998) which consists of six steps for assessing the impacts of diarrhoea:

- ◆ Estimating the demographic distribution of people within the different age groups associated with levels of water supply and sanitation services that are below SA's reconstruction and development (RDP) recommended levels;
- ◆ Estimating mortality and morbidity associated with the level of water supply and sanitation infrastructure;

- ◆ Estimating an impact of an infection of each level of severity on productivity, health services and transportation to health facilities;
- ◆ Estimating the unit cost with each infection identified;
- ◆ Collation of demographic information with the incidence of disease, their impacts and cost estimates to calculate the direct health and transport costs, and
- ◆ Estimating short-term indirect (lost opportunity) costs incurred from being unable to go to work.

The rural communities that are affected by DWWW were identified by determining the die-off rate of the *E.coli* in order to map out what stretch of the river is contaminated by the effluent discharged from DWWW using GIS. Secondly, GIS was used to delineate the demographic distribution of people who are below the RDP recommended water supply and sanitation service levels. The demographic information was obtained from census 1996 data from the Statistics South Africa, and included the level of services, age distribution and occupation. From this exercise the relevant clinics that treat affected people were identified and the personnel contacted to obtain health records that were used to estimate the number of people afflicted by diarrhoea and dysentery each year, transport costs to and from the medical facilities, and direct costs of medical resources used to treat these diseases.

Appropriate health records were obtained from the Msunduzi clinic in Table Mountain, and they provided information about the number of people afflicted by diarrhoea and dysentery and their place of origin. The distance travelled to and from the clinic was used to calculate transport costs using a value of R1.50 per kilometer. The costs of medical resources were estimated from the study conducted by Pelgram *et.al* (1998). Loss of productivity was estimated using the number of inactive days for both the patient and the caregiver, and the Gross Domestic Product (GDP) to cater for individuals who are not employed. An assumption made when using the GDP as an income proxy for unemployed caregivers is that the average GDP per adult indicates their contribution to the economy annually.

4.8 ESTIMATING THE LOSS OF RECREATION AT INANDA DAM

The travel cost method (TCM) was used to estimate the loss of recreation at Inanda Dam's Mahlabathini Park. This method involves using direct transportation costs to and from a recreational site as a surrogate market price for the value of that site. It is assumed that visitors to a park treat travelling and other visit-related costs the same as they treat prices for marketed goods. A visit to a recreation site involves allocation of scarce resources such as time and transport services to produce a recreation experience with maximum utility level. Another assumption of the TCM is that the visit occurs as a result of a single destination trip, thus all travel costs borne by visitors from their destination can be attributed to the cost of recreation (Hackett, 2000).

4.8.1 Sources of Data

The average number of visitors per day and their place of departure was obtained from the Mahlabathini Park site records for the period November 2000 to January 2001. Visitors to the park came from Durban, Pinetown, Pietermaritzburg, Howick, and Inanda. It was assumed that the visit to the park of visitors who had travelled more than 200Km was not the sole destination. These cases were grouped under Durban visitors, as they were probably holidaymakers who were in Durban for the holiday season. The distance travelled by the recreationist to the park was calculated from hard copy maps of Inanda, Pietermaritzburg and Durban, and this information was used to calculate transport costs at a value of R1.50 per kilometer travelled by car. Assuming that there are four passengers in the car, transport costs would be distributed evenly among passengers. Data on the duration of visit and other demographic attributes were not available.

4.8.2 Recreation Demand Function

The adopted demand function uses visitation rates as a function of the cost of travel. Visitation rates and direct transport costs were calculated for each area of origin for each visitor to the park. Albert Falls Dam was included as a substitute visit site in the estimation of the demand curve. The functional form of the model was:

$$V_i = f(C_1, C_2) \quad (14)$$

where V_i represents visitation rates per year and C_1 and C_2 represent the cost of travel to the Mahlabathini Park and Albert Falls Dam, respectively. Since a visit to the recreation site involves allocation of scarce resources, the demand curve for trips per year would show this resource allocation as the fall in the number of visits to the site as the distance travelled and the transport costs increase. Thus, *a priori* it is expected that when V_i is regressed against C_t , the regression coefficient will be negative.

4.8.3 Treatment of Data

Visitors to Mahlabathini Park were grouped according to their place of origin, and the visitation rate per month. The visitation rate per month was then converted to visitation rates per year. The distance from the place of origin to the site was multiplied by R1.50 to obtain direct transport cost by car. Visitors that had to pass through tollgates accrued a further cost. This was added to their respective transport cost, with the value obtained being further divided by the number of passengers per car. Visitation rates per year were then regressed against the transport costs of visiting the park. From the estimated demand curve, visitation rates were then forecasted by substituting higher travel costs. It was assumed that any explicit charge that is made is treated like an increased travel cost. This means that the visitation rate for an area facing a particular positive price is the one that corresponds to an area with travel costs similar to the former's travel cost plus price increase (Brent, 1997).

4.9 COSTS OF UPGRADING DWWW

The main environmental issues considered in the study are air and water pollution caused by DWWW. Air quality problems caused by odours and flies originate at the inlet of the works and from the under-processed sludge that is disposed on the land. Pollution of the Msunduzi River is caused by the overflow of wastewater from the storm water attenuation dam. This overflow, mainly the result of stormwater infiltration of the city's sewerage reticulation system, occurs when the capacity of DWWW is exceeded. Thus one of the identified areas at DWWW that requires attention is the upgrading of the attenuation dam to accommodate larger volumes of wastewater entering the plant. A long-term strategy would be to repair or upgrade the city's reticulation system to prevent stormwater infiltration of this system. The latter option was beyond the scope of this study.

Market-related direct cost estimates for upgrading DWWW are available, except for those related to removing odours at the head of the works, from the studies conducted by Geustyn, Forsyth and Joubert Consulting Engineers (GFJ,1996; 1999). A 10% annual inflation rate was used to calculate the current value of these cost estimates to account for average annual nominal increase in these costs since 1998.

4.10 ANALYSIS OF COSTS AND BENEFITS OF UPGRADING DWWW

Benefits estimated in the study were aggregated to obtain the total benefits of upgrading DWWW. The estimated upgrade costs were then compared to the benefits, and a benefit-cost ratio was calculated. This ratio shows the Rand benefits that will be produced by upgrading DWWW per Rand of costs.

4.11 SUMMARY

In this chapter the methodology that was used during the course of this research is outlined. The methodological frameworks and the economic models for the techniques used in this study were presented and any assumptions made when adopting and employing the different valuation techniques were stated in this chapter. Lastly, the chapter also gives information about the sources of data and the eventual treatment of data for the analysis of results.

CHAPTER 5

RESULTS & DISCUSSION

5.1 INTRODUCTION

This chapter presents and discusses the results for: the CVM analysis of the value of improving air quality; the hedonic price analysis; the revenue generated by the Duzi Canoe Marathon; water treatment costs at Wiggins; the costs of removing water hyacinth from Inanda Dam; the health impacts of effluent in the Msunduzi River; and the recreation value of Mahlabathini Park.

5.2 CONTINGENT VALUATION OF IMPROVING AIR QUALITY AROUND DWWW

5.2.1 Pilot Survey Results

The questionnaire was first tested in a pilot survey using 33 households in Sobantu. These households were selected at random and they included both those that are affected by the odours and flies, and those that are not. The main problems that were highlighted in this exercise were the low WTP amounts and a large number of zero WTP bids. These results can probably be explained by the high unemployment rate in Sobantu, which would suggest relatively lower household incomes and, hence, tighter budget constraints.

Tables 5.1 and 5.2 show the analysis of variance and descriptive statistics for the pilot survey data. The variables used were the respondent's monthly WTP, total household income per month (INCGRP), education status for the principal decision maker (EDUGRP), age of the respondent (AGEGRP) and the number of dependants in the household (DEPS). Table 5.1 shows that the average amount that the respondents were willing to pay for improvements in the quality of air is R21.21 per month. Although relatively low, this is plausible considering

the socio-economic profile of Sobantu i.e. high unemployment rate and large families. The mean total income per month per household ranged between R2001 and R2500. Most respondents were within the 50 to 60 years age group and had a secondary education, and there were approximately six dependants per household.

Table 5.1 Descriptive statistics for the pilot survey of Sobantu households, 2000 (n=33)

Variables	Observations (n)	Min	Max	Mean	SD
WTP (Rands)	33	0	250	21.21	44.91
INCGRP(Income, Rands)	33	No answer	>10 000	2 001-2 500	7.31
EDUGRP (Education Level)	33	None	University	Secondary	1.25
AGEGRP (Age, Years)	33	20-29	>69	40 - 49	1.50
DEPS (Dependants)	33	1	14	5.87	3.18

Note: SD = standard deviation.

Table 5.2 indicates that there is no significant difference in the amounts that respondents in the different income groups in Sobantu are willing to pay. This could also be explained by the socio-economic profile of Sobantu - households with relatively higher total income per month might have a larger number of dependants and therefore the larger income would not be a factor in determining the stated WTP. Furthermore, expenditure priorities might not be towards environmental improvements as the respondents probably perceive necessities like food, clothing and shelter as relatively more highly valued.

Table 5.2 One-way analysis of variance for the pilot survey of Sobantu households, 2000 (n=33)

INCGRP *WTP	Sum of Squares	DF	Mean Square	F-Statistic	Significance
Between Groups	7237.348	9	804.150	0.323	0.95
Within Groups	57314.167	23	2491.920		
Total	64551.515	32			

Note: DF = degrees of freedom.

5.2.2 Main Survey Results

5.2.2.1 Descriptive Statistics and Analysis of Variance

A 100% response rate was obtained (700 questionnaires), although there were some outlier and protest bids. Following Markandya & Richardson (1992), outlier bids are those WTP amounts that are significantly different from the mean WTP of the whole sample and which do not take into account the budgetary constraints of the household. Protest bids are zero WTP amounts that are reported even though the individual may have funds available to spend on improving air quality. Outlier bids may have resulted from respondents overstating their WTP in order to increase the likelihood that steps will be taken to improve air quality around DWWW (strategic bias).

Most of the protest bids were from respondents who felt it was not their responsibility to pay for the elimination of odour and fly problems that they did not cause (62%). Another large source of protest bids (18%) was respondents who felt they were paying too much already in the form of municipal rates, whereas 9% were respondents who said they were not impacted by the odour and flies problem. The remaining protest bids (11%) could not be adequately explained. Table 5.3 shows that the mean WTP stated by the respondents in the main survey was R25.60 per month or R307.20 per annum. This value does not differ greatly from the average WTP per month stated in the pilot project, the difference being less than R5.00 per month.

Table 5.3 Descriptive statistics showing the minimum, maximum, mean and the standard deviation values for final survey, 2000 (n=700)

Variables	Observations (n)	Min	Max	Mean	SD
WTP (Rands)	700	0	500	25.60	52.71
INCGRP(Income, Rands)	700	No answer	>10 000	2 001-2500	1.39
EDUGRP (Education Level)	700	Primary	University	Matric	3.18
AGEGRP (Age, Years)	700	10-19	>69	40-49	1.31
DEPS (Dependants)	700	1	21	4.87	5.88

Note: SD = standard deviation.

The analysis of variance was done for WTP and the different variables, and these results are presented in Table 5.4 and Figures 5.1 to 5.8 in Appendix B. Table 5.4 shows that there are significant differences at the 1% confidence level in the mean WTP within the groups of all the variables, except for marital status, for which the difference was significant at the 5% confidence level. The statistical analysis of the WTP by different income groups indicates that higher income groups are willing to pay more than the lower income groups. However there were exceptions such as income groups 21 (R9 501-R10 000) and 22 (>R10 000), which had lower mean WTP than lower income groups 18 (R 8 001-R8 500), 17 (R7 501-R8 000), 14 (R6 001-R6 500) and 8 (R3 001-R3 500). The overall mean monthly WTP when analysing by income groups was R25.00 (see Fig. 5.1, Appendix B). There were also significant differences between the WTP in the different zones around DWWW. The people in zones 1 and 2, within a two-kilometer radius, had a higher WTP than people who are more than two kilometers away from DWWW. The mean monthly WTP in the one-kilometer and the two-kilometer radii was R23.00 and R29.00, respectively. In the three-kilometer radius the mean monthly WTP was R14.00 (Fig. 5.2, Appendix B). Further analysis revealed differences in mean monthly WTP among the different residential areas, Sobantu having the lowest at R18.00, followed by Lincoln Meade (R27.00) and Hayfields (R54.00) (Fig.5.3, Appendix B).

Table 5.4 **One-way analysis of variance between WTP and explanatory variables for final survey, 2000 (n=700).**

Analysis	DF	F-Statistic	Significance
INCGRP*WTP	18	19.766	0.000
EDUGRP*WTP	4	5.395	0.000
DEPS*WTP	17	2.712	0.000
AGEGRP*WTP	6	5.577	0.000
GENDER*WTP	1	10.795	0.001
MSTAT*WTP	2	3.651	0.026
ZONE*WTP	2	17.161	0.000
SUBURB*WTP	2	17.566	0.000

Note: DF = degrees of freedom.

When WTP was analysed according to the number of dependants in each household, the mean monthly WTP decreased as the number of dependants increased (Fig. 5.4, Appendix B). However, the educational status had a similar effect as income, in that the higher the educational status, the higher the mean monthly WTP (Fig. 5.5, Appendix B). Different age groups were willing to pay different amounts, with the mean monthly WTP amounts starting very low in the under twenty-age group (R12.50), rising for the 20 to 30 years age group (R41.00), and then falling to R8.00 by age group 60 to 69 years (Fig. 5.6, Appendix B).

The analysis also showed that males were willing to pay more than the females (Fig. 5.8, Appendix B), while married and widowed or divorced individuals were WTP less than their single counterparts (Fig. 5.8). The variations in the mean monthly WTP by different income groups were also analysed within the different zones and within the three residential areas. The WTP values that were thought to be outliers- very high and very low as compared to the rest of the values- were excluded from this analysis. The income distribution in the three residential areas showed that Sobantu was at the bottom of the scale, with an average monthly income of less than R750.00. In Lincoln Meade and Hayfields there was an even distribution of income but in the former, the majority of households earned between R1501.00 and R2000.00 per month. In Hayfields most respondent households earned between R2501.00 and R3000.00 per month (Fig 5.9).

The descriptive and analysis of variance results indicate that the survey results agree with *a priori* economic theory as the stated WTP was affected by the household's budgetary constraint. Stated WTP also decreased as the number of dependants increased and this reflects that larger households have relatively less disposable income for non-family expenditure. Respondents with higher education level usually stated a higher WTP when compared to their counterparts. These observations indicate that although the CVM has biases associated with it, the results obtained are acceptable.

5.2.2.2 Estimated WTP Regression Equations

Regression models for estimating factors that affect mean monthly household WTP used the following explanatory variables to represent the theoretical framework outlined in section 4.1.1: Monthly household income (INC) which accounts for budgetary constraints; respondent's age (AGE) and education level (EDU); number of household dependants (DEPS); gender of the respondent (GEN), equal to 1 if male, and 2 if female; and the principal decision-maker's marital status (MSTAT), equal to 1 if single, 2 if married, and 3 if divorced or widowed. The regression equations estimated to predict monthly WTP to eliminate odours and flies are shown in Table 5.5.

Table 5.5 Estimated WTP regression models

Item	Regression coefficient estimates and statistics						
	Total sample	Zone 1	Zone 2	Zone 3	Sobantu	Lincoln Meade	Hayfields
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	37.24***	56.21***	40.19***	14.73	28.29***	41.73***	87.57*
INC	0.184***	0.100	0.210***	0.172**	0.196***	0.221***	-0.007
AGE	-0.129***	-0.184 ^a	-0.102*	-0.192**	-0.150**	-0.186***	-0.110
EDU	0.004	-0.950	0.022	0.081	-0.023	-0.010	-0.024
DEPS	-0.078**	-0.218**	-0.058	-0.024	-0.122**	0.032	-0.187**
GEN	-0.080**	-0.930	-0.100**	-0.015**	-0.016	-0.117**	-0.127
MSTAT	0.007**	-0.002	-0.033	-0.116	-0.025	-0.014	0.090
Adjusted ²	80%	19%	95%	58%	76%	84%	36%
F value	11.020	1.283	8.992	2.453	5.551	5.451	0.645
N	689	90	456	143	334	292	63

Note: ^a, *, ** and *** indicate significance at the 0.15, 0.10, 0.05 and 0.01 levels, respectively.

Equations (1) to (7) are regression models for households in the whole sample, Zone 1, Zone 2, Zone 3, Sobantu, Lincoln Meade and Hayfields, respectively. Equations (1), (3) and (4) agree with *a priori* expectations - INC and EDU are positively related to WTP, while the

number of dependants (DEPS) is negatively related to WTP. These equations estimate that for every R100 increase in monthly household INC, the WTP to eliminate odours and flies will increase by R18.40, R21.00 and R17.00, respectively. Equations (2), (5) and (6) also show that an increase in INC will increase WTP, but that the increase in education level causes a decline in WTP. Furthermore, the INC coefficient in equation (2) is much lower than those in equations (3) and (4). Since equation (2) estimates the WTP by Zone 1 households (that are closer to the pollution source), it was expected that the estimated WTP would be larger. However, the estimated intercept values were larger for Zone 1, followed by Zone 2 and then Zone 3.

The estimated WTP regression models had larger intercept values for Hayfields (7), followed by Lincoln Meade (6) and then Sobantu (5). This can be explained by the socio-economic characteristics of the three areas. Sobantu has the highest level of unemployment, with the principal decision maker in most households being a pensioner. In Hayfields and Lincoln Meade there is a relatively low rate of unemployment amongst the respondents. Sobantu also has the highest average number of dependants per household (5.75) compared to Lincoln Meade (3.57) and Hayfields (3.25). The F-value and the regression coefficient estimates for INC were statistically significant at either the 0.05 or 0.01 levels, except in equations (2) and (7). The monthly WTP values reported above, and results in Table 5.5, exclude outlier WTP values (only monthly WTP values greater than R200.00 were included). The adjusted R^2 estimates show that between 19% and 95% of the total variation in monthly WTP values for improved air quality was explained by the variables in equations (1) to (7).

The results that do not confirm with *a priori* expectations and the unexpected signs of some regression coefficients may be due to biases associated with the CVM, such as strategic bias, starting point bias, hypothetical bias and free rider bias. According to Brent (1997), strategic bias occurs due to respondents' desire to influence the outcome of the study, and this may cause under- or over-bidding. Overbidding may result if respondents think that they would not be paying for the service, and in the case of this study respondents may have thought that the local municipality or the plant management would finance the project. Respondents thus

may have realised that they would not be expected to extend their expenditure to accommodate rectifying the problem of odours and flies. Under-bidding would arise if respondents thought a decision had been taken to eliminate the pollution problem and the purpose of the study was to decide how much individuals would pay for the service.

Starting point bias, which occurs when respondents focus on the initial bid made by the interviewer, was avoided in this study by asking respondents an open-ended question about their mean monthly WTP. The issue of ceiling price (possibility that respondents would think that they could not state a WTP amount higher than a certain value) was avoided by reminding respondents that any amount within budgetary constraints was acceptable. Hypothetical bias, which may have arisen due to lack of understanding of the commodity (improved air quality) being valued, was avoided by giving respondents background information relating to the problem. Another form of hypothetical bias, which may result if respondents do not take the questions seriously, may have resulted in random answers that are unrelated to household characteristics and preferences (Whittington, Lauria, Mu & Mu, 1994).

5.2.2.3 Estimated Benefits of Eliminating Odours and Flies

The objective of this exercise was to estimate the value of people's preferences for the benefits of improving air quality, by eliminating odours and flies, in the residential areas surrounding the DWWW. The mean WTP was estimated as R307.20 per annum, and when this is aggregated over the total population in the residential areas impacted by odours and flies (37192 households), the benefits are estimated as just over R11 million per annum.

5.3 PROPERTY VALUATION USING THE HEDONIC PRICING METHOD

The underlying hypothesis for this study was that odours and flies cause a decline in the property values of houses surrounding the DWWW. A one-way analysis of variance was performed for the three zones using asking price (Askprice), selling price (Sellprice) and the

municipal value (Munvalue) of the properties, the results are presented in Table 5.6. The mean asking price, mean selling price and mean municipal values fall the further away the properties are from the pollution source. Furthermore, the mean values for zone 1 are greater than for zone 2 and also greater than for zone 3.

Table 5.6 Minimum, maximum, mean and the standard deviation values for asking price, selling price and the municipal value for houses in zones 1, 2 and 3.

Variable	Observations (n)	Min. (Rands)	Max. (Rands)	Mean (Rands)	SD
Askprice 1	18	212795.61	279204.39	246000.00	66770.90
2	143	222327.06	240938.67	231632.87	56293.31
3	229	175808.19	190505.35	183156.79	56436.73
Total	390	197665.31	20998.28	203831.79	61939.60
Sellprice 1	18	199990.62	259898.27	229944.44	60234.32
2	144	211483.30	229266.70	220375.00	53979.29
3	231	164509.82	201004.81	182757.31	1400448.70
Total	392	187358.34	210127.28	198742.81	1146446.64
Munvalue 1	12	154943.42	302473.25	228708.33	116097.63
2	96	204889.44	230195.98	217542.71	62448.62
3	111	174877.96	216304.03	195590.99	110116.66
Total	219	194649.45	219407.17	207028.31	92947.34

Note: SD = standard deviation.

The analysis of variance for the three test variables for the different zones in Table 5.7 shows that for both asking price and selling price, the mean values are significantly different among the three zones at the 95% confidence level. However the mean value for the municipal value (Munvalue) was not statistically significantly different.

Table 5.7 Analysis of variance between asking price, selling price, and municipal values for houses in zones 1, 2 and 3.

Variable	DF	F-Statistic	Significance
Askprice Between Groups	2	37.158	0.000*
Within Groups	387		
Sellprice Between Groups	2	5.594	0.004*
Within Groups	389		
Munvalue Between Groups	2	1.794	0.169
Within Groups	216		

Note: DF = degrees of freedom.

The Levene’s test of homogeneity of variances in Table 5.8 between the three variables and the three zones show that the variances are not significantly different. Levene’s test was employed to investigate whether it was appropriate to use the analysis of variance to test mean differences in the three zones (Bryman & Cramer, 1999).

Table 5.8 Test of homogeneity of variances between asking price, selling price and municipal values for houses in zones 1, 2 and 3.

Variable	Levene Statistic	DF1	DF2	Significance
Askprice	0.65	2	387	0.522
Sellprice	0.223	2	389	0.800
Munvalue	1.426	2	216	0.242

Note: DF1 and DF2 = degrees of freedom for between and within groups, respectively.

Property values were further compared for the three years 1998, 1999 and 2000. The results for this analysis are presented in Table 5.9 and show that the pattern of decline in property values the further away properties are from DWWW is similar for these three years. Values

for 1998 in Zone 3, and for 1999 in Zone 2, however, go against this trend.

Table 5.9 Mean asking price, mean selling price and mean municipal value for 1998, 1999 and 2000.

Variable	1998	1999	2000
Askprice 1	240875.00	225166.67	287500.00
2	218629.63	227737.29	241509.43
3	176750.00	184873.42	185977.01
Sellprice 1	222625.00	208833.33	276250.00
2	210184.19	21591.67	230311.32
3	170654.70	173687.00	199695.40
Munvalue 1	219116.67	164600.00	312000.00
2	192044.44	200648.94	249715.15
3	199313.33	168248.94	229506.25

The results in Table 5.9 were contrary to expectations that property values closer to DWWW would be adversely affected by odours and flies. The initial hypothesis was that properties that are within a one-kilometer radius of DWWW have less value than those that are within a two- and a three-kilometer radius, and the study area was divided into three zones of a kilometer apart. The results of the analysis show that it is possible all three zones are impacted by odours and flies from DWWW. Further analysis was, therefore, undertaken to compare the residential areas impacted by odours and flies with the residential areas that are not impacted. The results in Tables 5.10 and 5.11, overleaf, show that both the mean asking price and mean selling price are greater for the residential areas that are not impacted by odours and flies, and less for areas that are impacted.

Table 5.10 Mean asking price and mean selling price for houses in impacted (I) and non-impacted (NI) residential areas, 1998 to 2000

Variable	Observations (n)	Min.	Max.	Mean	SD
Askprice NI	839	43000.00	155000.00	217864.40	142381.12
I	392	99900.00	890000.00	209248.50	75383.88
Sellprice NI	839	20000.00	2142000.00	209276.80	148184.76
I	392	16300.00	1950000.00	198742.80	117818.18

Note: SD = standard deviation.

One-way analysis of variance in Table 5.11 shows that these mean values are not statistically significantly different for both variables (non-significant F ratios and probabilities greater than 0.05).

Table 5.11 Results for the analysis of variance between asking and selling price for the two groups (impacted and non-impacted residential areas), 1998 to 2000

Variable	DF	F Statistic	Significance level
Askprice: Between Groups	1	0.382	0.537
Within Groups	1229		
Sellprice: Between Groups	1	1.306	0.253
Within Groups	1228		

Note: DF = degrees of freedom.

Table 5.12 gives the correlation analysis between the selling price (Price) or natural logarithm of selling price (LnPrice) and the physical attributes of the properties and neighbourhood and environmental characteristics. Pearson's correlation coefficients between Price and LnPrice with the Age and Condition of the house are not statistically significant. However, as correlation coefficients are affected by the size of the sample, Condition and

Age might have more missing values than the other variables. All of the variables have a positive relationship with the dependant variable. The environmental attributes variable used in the hedonic model is a collection of recreational facilities such as parks, rivers, sports fields or race course and/or the presence of historical monuments in the residential areas. A value of one was assigned to the residential area if only one of these attributes was present, and the values were increased according to the number of attributes. These coefficients indicate that the number of bathrooms, presence of reception room, number of garages, and a study or maid room on the property are most highly correlated with Price or LnPrice. Note that Price and LnPrice are significantly positively correlated to Distance to DWWW as expected.

Table 5.12 **Pearson's *r* correlation coefficients for variables in the hedonic price model**

Variable	Price	Ln Price
Size	0.217**	0.232**
Age	0.039	0.040
Condition	0.008	0.014
Bedrooms	0.263**	0.338**
Bathrooms	0.484**	0.548**
Study room	0.335**	0.328**
Reception	0.453**	0.478**
Swimming pool	0.253**	0.324**
Flat	0.199**	0.229**
Garage	0.375**	0.496**
Carport	0.117**	0.111**
Maid room	0.321**	0.375**
Distance to CBD	0.165**	0.189**
Environmental attributes	0.092**	0.022**
Distance to DWWW	0.167**	0.156**

Note: ** indicates statistically significant at 0.01 confidence level

These coefficients indicate that the number of bathrooms, presence of a reception room, number of garages, and a study or maid room on the property are most highly correlated with

Price or LnPrice.

5.3.1 Statistical Interpretation of the Models

Both linear and semi-log regression models with selling price as the dependant variable and the house attributes as explanatory variables were estimated for properties in the residential areas impacted, and the areas not impacted by odours and flies. Tables 5.13, 5.14 and 5.15, in the following pages, present these regression results. The statistical significance of the explanatory variables improved when the log-linear model was used for both impacted and non-impacted residential areas. The log-linear model estimated for the impacted areas in Table 5.13 indicates that proximity to CBD, covered parking (car port or garage), the number of bedrooms, the presence of a swimming pool and house condition are key determinants of house prices. The linear model estimated for the same group was similar but excluded covered parking, and had less statistically significant coefficients. Most of the structural variables, neighbourhood and environmental attributes impact on house price. The linear model identifies only the number of bedrooms, presence of a pool and distance to the CBD as factors affecting house price. Due to multicollinearity, as indicated by a zero tolerance value, the environmental characteristics variable was excluded from the impacted areas regression model.

Table 5.13 Regression results for impacted residential areas, 2000 (n=156)

Impacted Areas	Linear			Log-Linear		
	Coefficient	Standard Error (SE)	t-Value	Coefficient	Standard Error (SE)	t-Value
Constant	237199.509	157793.212	1.503	11.271	0.005	82.820 ^{***}
Size (X ₁)	-3.865	11.299	-0.342	1.088E-06	0.036	0.067
Age (X ₂)	77.312	1732.573	0.045	-1.191E-03	0.146	-0.489
Condition (X ₃)	23869.376	25975.713	0.919	8.883E-02	0.152	2.378 ^{**}
Bedrooms (X ₄)	51926.492	26904.032	1.930 [*]	8.770E-02	0.088	2.284 ^{**}
Bathrooms (X ₅)	-529.156	34544.657	-0.015	6.171E-02	0.027	1.243
Study room (X ₆)	-16502.796	31972.037	-0.516	2.114E-02	0.007	0.461
Reception area (X ₇)	-18183.774	22946.907	-0.792	3.083E-03	0.231	0.093
Pool (X ₈)	48262.593	28896.292	1.670 [*]	0.146	0.071	3.539 ^{***}
Flat (X ₉)	3444.459	41452.881	0.083	6.420E-02	0.250	1.078
Garages (X ₁₀)	19676.940	20780.180	0.947	0.108	0.101	3.664 ^{***}
Carport (X ₁₁)	19494.096	16516.250	1.180	3.640E-02	0.088	1.533 ^a
Maid room (X ₁₂)	24387.021	33420.338	0.730	5.579E-02	0.055	1.193
Distance to CBD (Z ₁)	-80134.100	37967.464	-2.11 ^{**}	-0.245	0.039	-4.475 ^{***}
Environmental Attributes (Z ₂)	Excluded			1.253E-02	0.041	0.319
Distance to DWWW (Z ₃)	32856.608	27231.541	0.230	-0.170	0.328	-4.836 ^{***}
	Adjusted R ² = 0.076 n = 156 SE = 157221.2631 F-Ratio = 1.920			Adjusted R ² = 0.49 n = 156 SE = 0.2263 F-Ratio = 12.526		

Note: ^a, ^{*}, ^{**}, ^{***} indicate significance at 20%, 10%, 5% and 1% respectively

A correlation matrix for all the variables used to estimate the regression equation for impacted areas is shown in Table 5.15. There are perfect linear relationships between the distance to CBD (Z₁), environmental characteristics (Z₂) and distance to DWWW (Z₃), as indicated by the correlation coefficients equal to one. This introduces multicollinearity, which may cause difficulties in the estimation of regression coefficients, such as signs of the estimated regression coefficients that differ from expectations. The consequences of

multicollinearity in the impacted areas data set is shown by the exclusion of the environmental attributes coefficients (Z_2) in the linear model, and also by the unexpected sign of the regression coefficient for Z_3 . Property values that are closer to DWWW were expected to be lower than those of properties that are further away. However, the estimated coefficient is negative suggesting that properties that are closer to DWWW have relatively high values.

Table 5.14 Correlation matrix for all variables included in the hedonic model for impacted areas

	P	X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	X ₇	X ₈	X ₉	X ₁₀	X ₁₁	X ₁₂	Z ₁	Z ₂	Z ₃
P	1.000															
(X₁)	-0.01	1.000														
(X₂)	0.091	0.401	1.000													
(X₃)	0.093	-0.300	0.218	1.000												
(X₄)	0.242	0.157	0.267	-0.071	1.000											
(X₅)	0.161	0.026	0.100	0.012	0.374	1.000										
(X₆)	0.039	-0.010	0.129	0.025	0.051	0.098	1.000									
(X₇)	0.123	0.195	0.302	0.007	0.368	0.418	0.070	1.000								
(X₈)	0.229	0.106	0.137	-0.060	0.295	0.305	0.089	0.386	1.000							
(X₉)	0.036	0.029	0.289	-0.080	0.098	0.182	0.081	0.157	0.097	1.000						
(X₁₀)	0.132	-0.050	0.088	0.019	0.146	0.270	0.007	0.226	0.114	-0.149	1.000					
(X₁₁)	0.150	0.105	0.186	-0.020	0.205	0.235	0.055	0.158	0.203	0.197	-0.231	1.000				
(X₁₂)	0.216	0.265	0.296	-0.030	0.200	0.159	0.126	0.396	0.308	-0.094	0.297	0.160	1.000			
(Z₁)	-0.230	0.062	0.300	-0.040	-0.200	-0.190	-0.234	-0.161	-0.100	-0.200	-0.201	0.014	-0.307	1.000		
(Z₂)	0.230	-0.060	0.300	-0.040	0.200	0.190	0.234	0.161	0.100	0.200	0.201	-0.014	0.307	- 1.000	1.000	
(Z₃)	0.230	-0.060	0.300	-0.040	0.200	0.190	0.234	0.161	0.100	0.200	0.201	-0.014	0.307	- 1.000	1.000	1.000

In Table 5.15, the log-linear model for non-impacted areas estimates house size, house condition, number of bathrooms, presence of a swimming pool, flat and maid room, number of garages, distance to the CBD, environmental attributes and distance to DWWW as key determinants of house price. The linear model for these areas has similar variables, although it excludes environmental attributes and the presence of a flat, and rather includes the number

of bedrooms and the presence of a reception area.

Table 5.15 Regression results for non-impacted residential areas, 2000 (n=438)

Non-Impacted Areas Variables	Linear			Log-Linear		
	Coefficient	Standard Error (SE)	t-Value	Coefficient	Standard Error (SE)	t-Value
Constant	-99903.06	42046.830	-2.38**	10.952	0.130	83.975***
Size (X ₁)	3.732	3.140**	1.188	1.329E-05	0.000	1.378 ^a
Age (X ₂)	13.140	94.447	0.139	-2.240E-05	0.000	-0.079
Condition (X ₃)	14761.675	10866.281	-1.358 ^a	0.101	0.033	3.077**
Bedrooms (X ₄)	3059.833	3106.201	0.985**	1.029E-02	0.009	1.098
Bathrooms (X ₅)	47780.832	13979.810	3.418***	0.218	0.042	5.181***
Study room (X ₆)	-4434.304	13970.622	-0.317	3.579E-02	0.042	0.850
Reception area (X ₇)	16938.167	9813.279	1.726 [*]	7.982E-03	0.030	0.270
Swimming Pool (X ₈)	45288.173	13320.858	3.400***	0.147	0.040	3.650***
Flat (X ₉)	16299.072	17598.573	0.926	0.157	0.053	2.965**
Garages (X ₁₀)	21311.139	9680.939	2.201**	0.120	0.029	4.105***
Carport (X ₁₁)	-1702.196	7225.594	-0.236	1.999E-02	0.022	0.917
Maid room (X ₁₂)	34956.740	13946.489	2.506**	1.188E-07	0.042	4.435***
Distance to CBD (Z ₁)	21712.899	6346.445	3.421***	0.137	0.025	5.410***
Environmental Attributes (Z ₂)				4.848E-02	0.008	5.762***
Distance to DWW (Z ₃)	11562.091	2630.321	4.396***	3.204E-02	0.017	1.837 [*]
	Adjusted R ² = 0.272 n = 438 SE = 125451.5435 F-Ratio = 12.666			Adjusted R ² = 0.457 n = 438 SE = 0.3791 F-Ratio = 27.384		

Note: ^a, *, **, *** indicate significance at 20%, 10%, 5% and 1% respectively

The adjusted R² values were much larger for the log-linear models for both the areas impacted and not impacted by odours and flies. For the impacted areas, it shows that the linear model explains 7.6 % of the variability in house selling price, whereas the log-linear model explains about 49% of the variability. For non-impacted areas, the variability

explained is only 27% for the linear model, against 46% for the log-linear model. Thus it appears that the log-linear model - due to its higher adjusted R^2 and more significant coefficients - is the more appropriate functional form. The critical F-values in all of the estimated models were below the calculated F-Ratios, suggesting that the estimated variables together significantly influence house price. Regression analysis was also performed for the total sample using the natural log of selling price as a dependant variable and this gave results comparable to the other log-linear models (Table 5.16).

Table 5.16 Log-Linear regression estimates for all residential areas, 2000 (n=595)

Variables	Coefficient	STD Error (SE)	t-Value
Constant	11.045	0.104	106.525 ^{***}
Size (X ₁)	0.00001125	0	1.385 ^a
Age (X ₂)	-0.0000614	0	-0.234
Condition (X ₃)	0.109	0.026	4.130 ^{***}
Bedrooms (X ₄)	0.0131	0.09	1.54 ^a
Bathrooms (X ₅)	0.207	0.034	6.058 ^{***}
Study room (X ₆)	0.04911	0.034	1.459
Reception area (X ₇)	0.00554	0.024	0.232
Swimming Pool (X ₈)	0.141	0.032	4.44 ^{***}
Flat (X ₉)	0.147	0.042	3.45 ^{***}
Garages (X ₁₀)	0.125	0.023	5.448 ^{***}
Carport (X ₁₁)	0.01945	0.018	1.111
Maid room (X ₁₂)	0.167	0.034	4.953 ^{***}
Distance to CBD (Z ₁)	0.124	0.021	5.949 ^{***}
Environmental attributes (Z ₂)	0.0427	0.008	6.134 ^{***}
Distance to DWWW (Z ₃)	0.0305	0.009	3.443 ^{***}
	Adjusted R ² = 0.448		
	n = 595 SE = 0.3498		
	F-Ratio = 33.237		

Note: ^a, *, **, *** indicate significance at 20%, 10%, 5% and 1% respectively

Table 5.16, in the previous page, shows the regression results using all selected residential areas. The estimated model agrees with *a priori* expectations, as the coefficients have the expected signs. As the distance to DWWW decreases, property values decline, while property values increase with increasing distance from the city centre. The latter might be caused by the presence of major shopping centres in most residential areas that act as substitutes for shopping in the CBD. With the exception of age of the house, presence or absence of a study room and reception area, all coefficients are significant at either the 1% or 20% confidence level.

Table 5.17 shows the change in property price for a unit change in the explanatory variable (ΔP for 1 unit ΔX or Z) that was calculated using the anti-log of the regression coefficient and the mean price. These semi-elasticities were then used to calculate elasticities for each explanatory variable.

Table 5.17 Semi-elasticities of log-linear coefficients

Variable	Total Sample		Impacted		Non-Impacted	
	Mean	ΔP per ΔX (or Z)	Mean	ΔP per ΔX (or Z)	Mean	ΔP per ΔX (or Z)
Price (P)	214727.20		203831.80		219785.7	
Size (X ₁)	1317.71	R2.42	1061.12	R0.022	1278.77	R2.90
Age (X ₂)	29.33	-R13.18	14.59	-R2413.24	32.49	-R4.92
Condition (X ₃)	1.33	R24728.49	1.29	R18750.10	1.46	R23358.09
Bedrooms (X ₄)	3.22	R2831.43	3.05	R18683.34	3.099	R2273.27
Bathrooms (X ₅)	1.83	R49383.51	1.81	R12972.51	1.733	R53536.95
Study room (X ₆)	0.28	R10808.48	0.17	R4346.55	0.29	R8008.59
Reception area (X ₇)	2.21	R1192.89	2.08	R623.25	2.11	R1761.35
Swimming Pool (X ₈)	0.46	R32514.99	0.42	R32041.58	0.44	R34803.94
Flat (X ₉)	0.16	R34002.90	0.11	R13515.20	0.16	R37362.61
Garages (X ₁₀)	1.18	R28590.59	1.17	R23246.56	1.08	R28021.99
Carport (X ₁₁)	0.70	R4217.32	0.57	R7556.17	0.48	R4437.72
Maid room (X ₁₂)	0.52	R39027.58	0.32	R11694.97	0.71	R45459.05
Distance to CBD (Z ₁)	3.52	R28347.40	3.30	R54771.48	3.522	R32270.73
Environmental attributes (Z ₂)	4.32	R10393.88	2.29	R2549.44	6.1856	R10971.72
Distance to DWWW (Z ₃)	5.2741	R6650.08	3.11	R37771.02	4.87	R7155.96

Elasticities given in Table 5.18 show the percentage change in the sale price of the house for each percentage change in the explanatory variable, other things held constant. In the total sample, Distance to CBD (Z₁) has the most influence on the price of the property because a 1% change in the value of this variable will bring about a 0.465 % change in the selling price of the property. Bathrooms (X₅) is the second most important variable followed by Environmental Attributes (Z₂) and Distance to DWWW (Z₃). The presence of a garage, the condition of the house and the presence of the maid room are also important determinants of property price. In all three samples, Distance to CBD has the most influence on the property price and the Distance to DWWW is also an important determinant of property price as it is

the second highest in the impacted sample and the fourth highest in both the total and the non-impacted samples.

Table 5.18 Elasticities of log-linear coefficients

Variable	Total Sample	Impacted Areas	Non-Impacted Areas
X ₁	0.015 (11)	0.0001 (15)	0.017 (11)
X ₂	0.002 (14)	-0.172 (4)	-0.0007 (14)
X ₃	0.153 (6)	0.119 (6)	0.155 (5)
X ₄	0.042 (9)	0.279 (3)	0.032 (9)
X ₅	0.421 (2)	0.115 (7)	0.422 (2)
X ₆	0.014 (12)	0.004 (14)	0.011 (12)
X ₇	0.012 (13)	0.006 (13)	0.017 (11)
X ₈	0.070 (8)	0.066 (8)	0.070 (8)
X ₉	0.025 (10)	0.007 (12)	0.027 (10)
X ₁₀	0.155 (5)	0.133 (5)	0.138 (7)
X ₁₁	0.014 (12)	0.021 (10)	0.0097 (13)
X ₁₂	0.095 (7)	0.018 (11)	0.147 (6)
Z ₁	0.465 (1)	0.886 (1)	0.517 (1)
Z ₂	0.209 (3)	0.029 (9)	0.309 (3)
Z ₃	0.163 (4)	0.576 (2)	0.159 (4)

Note: Numbers in brackets represent the order of influence of each of the variables on housing price, where 1 has the most influence and 15 has the least influence.

One aim of the study was to investigate the hypothesis that properties closer to DWWW are lower in value when compared to those further away. The coefficient of distance to DWWW (Z₃) in impacted areas has a negative sign, suggesting that houses closer to DWWW have a higher property value than those further away, which is contrary to *a priori* expectations. This unexpected result can be explained by considering that the sample comprises of properties within a five-kilometre radius, and that all of the properties might be impacted. Wind direction also determines which properties will be affected - due to time constraints the physical location of the different properties was not determined and so it was not possible to identify which properties lay on which side of DWWW.

The non-impacted and whole sample regressions have similar results. In both instances, distance from DWWW has a positive sign, and in terms of magnitude it has a significant influence on property values. This observation indicates that homebuyers have a preference for improved air quality. All the structural characteristics of the properties had positive coefficients, except for Age of the house which had a negative influence on property value (albeit a minor one as reflected by its size relative to the other coefficients - in all regressions Age had the lowest semi-elasticity). These two samples differ from the impacted sample with respect to the influence of the distance to CBD (Z_1). In the impacted areas, property values increase as one gets closer to the city centre, while in the non-impacted areas property values increase for the properties further away. Most residential areas in the non-impacted sample have major shopping centres, which serve as substitute for CBD shopping. In the impacted sample, however, only one of the two areas has a shopping centre.

Numerous empirical studies confirm a significant negative relationship between air pollution and property values (Chay & Greenstone, 1998; Krumm, 1980 and Cobb, 1984). Properties in the impacted residential areas experienced a R15953.9 decline in their mean selling price when compared to those in the non-impacted areas. Moreover, using the results for the total sample, properties experienced a R6650.08 decline in their selling price if the distance to DWWW is decreased by one kilometre. Thus the benefit that would result from improving air quality in the areas impacted by compromised air quality is obtained by aggregating R6650.08 over the total population in the impacted areas, which is R28 480 518.00. In using the predicted changes in property values as a measure of aggregate benefits it is assumed that all surpluses resulting from air quality improvements are eliminated by the land market, and that there are no induced changes in the prices of other goods. This zero surplus assumption holds when land is used for residential and private recreational purposes rather than for production for the market (Freeman, 1979).

5.3.2 Testing the Functional Form of Regression

The MacKinnon, White and Davidson (MWD) test was used to choose the appropriate hedonic price model for the study. This test, tested the null hypothesis that house selling price is a linear function of the explanatory variables. The test involved estimation of the linear and log-linear models and obtaining the estimated selling price values (y) and the estimated log-selling price ($\ln y$). A new variable (Q) was obtained by taking the log of the estimated selling price and subtracting it from the estimated log-selling price as per equation (15):

$$Q = \ln y - \ln y \quad (15)$$

Regression was then performed using selling price as a dependant variable and the original explanatory variables as well as the calculated Q (Gujarati, 1995). Regression coefficients for Q for the impacted and non-impacted areas were:

Impacted areas: Q Coefficient = -37655.9 t = 5.137 (0.000)

Non-Impacted areas: Q Coefficient = -0.114 t = 5.476 (0.000)

In both groups the coefficient estimated for Q is highly statistically significant, so the null hypothesis that the dependant variable is a linear function of the explanatory variables is rejected. This implies that the true model is a log-linear model.

5.3.3 Economic Interpretation of the Model

Regression coefficients or elasticities produced using a linear model do not agree with expectations nor can they be rationalised using economic theory. The MWD test also concludes that the appropriate hedonic price model for this study is a semi-log model. The focus, therefore, will be on the results of the log-linear models. The coefficients in the log-linear model represent semi-elasticities since they measure the relative change in the dependant variable given an absolute change in the independent variable.

The coefficients for both groups of residential areas have the expected signs except for the distance to CBD (Z_1) in the non-impacted group and the distance to DWWW (Z_3) in the impacted group (Tables 5.14 & 5.15). However, the unexpected sign in the former might be because some homebuyers might prefer properties further away from the CBD as long as there are other satisfactory environmental and neighbourhood characteristics. The coefficients for most of the structural characteristics had positive coefficients, this was as expected since prospective homeowners usually have in mind what sort of structural attributes their properties would have. The estimated coefficients agree with expectations and are consistent for both groups, and this indicates that the log-linear model is robust. (Blades, 1993). The elasticities calculated from the log-linear coefficients show the relative influence of each of the explanatory variables on property selling price, and in all the regressions, Distance to CBD is ranked as the variable with the most influence on property selling price. Most of the results obtained in this exercise agree with economic theory, for example, proximity to the CBD has a major positive most influence on property selling price, and as the CBD is the center for economic activity, homebuyers would want to be closer and thus save on transport costs.

5.4 ESTIMATED REVENUE LOSS FOR THE DUZI CANOE MARATHON

The statistics for different aspects of the Duzi Canoe Marathon collected from the marathon organisers, the Pietermaritzburg Publicity Association and interviews with the contenders in 2000 are presented in Table 5.19. A total of 2300 contenders participated, with 1725 contenders coming from outside Pietermaritzburg. The figures for the number of contenders coming from outside the city, average family size and the number of friends to visit by the contenders were used to estimate the total revenue generated by the marathon for Pietermaritzburg. The figure of 1725 contenders was first multiplied by the number of people to visit contenders - since the visitors are from out of town, this figure would indicate the revenue generated from accommodation facilities, food and transportation for the visitors.

A figure of close to R4 million was estimated as being the revenue generated by the Duzi Canoe Marathon to the city of Pietermaritzburg. However, due to the threat of high *E.coli* in the Msunduzi River, the race could be cancelled, as the organisers would be liable to be sued for damages by contenders that fall ill. This figure thus represents revenue that would be lost should this sport be cancelled, and is a proxy for the benefits of improving the quality of water in the river. The estimated figure is a conservative estimate of the revenue generated by the race, since the study did not consider the value of employment opportunities created by the race or the levies paid to enter the race. Manufacturing and marketing of canoeing equipment is another important generator of revenue that was not considered. The estimates of the revenue generated calculated by the race organisers is about of R30 million, which is seven times more than this study's estimate.

Table 5.19 Estimated total revenue generated during the Duzi Canoe Marathon from using accommodation facilities, restaurants, petrol stations and cinemas, 2000

Total number of contenders	2300
% Contenders from outside Pietermaritzburg	75
Average family size	3.5
Average no. of family friends to visit	2
Average cost of accommodation/night/person	R134.00
Revenue generated from using restaurants, petrol and cinemas/person	R200.00
TOTAL REVENUE GENERATED	R3744975

5.5. ESTIMATION OF TREATMENT COSTS AT WIGGINS WATER WORKS

Table 5.20 shows the estimated model developed by Graham *et al* (1998) to predict factors affecting water treatment costs at Wiggins Water Works (WWW). It explains 79% of the variability in water treatment costs at WWW and shows that treatment costs increase with turbidity, total aluminium, iron, suspended solids, nitrate, total organic carbon, dissolved solids, silicon, number of coliforms, conductivity, water hardness, potassium, nitrates and *Anabaena*. Such costs, however, decrease with increasing pH and dissolved oxygen in water. All of these factors are directly related to water pollution of both natural and anthropogenic origin.

Table 5.21 Estimated regression coefficients for factors affecting water treatment costs at Wiggins Water Works (before and after removing the multicollinearity problem)

Variable	Original coefficients	Original t-value	Final coefficients	Final t-value
Constant	-34.288	-0.77	34.087	1.96*
Turbidity	0.303	6.21***	0.091	13.88***
Total Aluminium	0.020	1.35	0.016	6.96**
Iron	4.432	1.55	4.253	4.67***
Suspended solids	-0.015	-0.19	0.104	3.76***
Nitrate	-3.77	-1.45	3.156	4.33***
Total Organic Carbon	-0.327	-0.30	1.196	5.15***
Dissolved solids	-0.011	-0.47	0.024	3.90***
PH	4.497	0.79	-5.279	-2.32**
Silicon	0.654	1.18	0.486	3.23***
Trend variable	0.084	1.87*	0.032	2.25**
Coliforms	0.006	2.34**	0.009	3.79***
Sulphates	0.404	2.14**	0.090	1.78*
Temperature	-0.051	-0.18	0.465	2.42**
Anabaena	0.001	1.71*	0.001	2.01*
	Adjusted R ² = 85%		Adjusted R ² = 77%	

Note: *, **, *** indicate significance at 10%, 5% and 1% respectively

Source: Graham, *et.al.*, 1998.

The annual water treatment costs at WWW were estimated as R22/Ml and 44% of this cost (R9.70/Ml) is attributed to the removal of *algal genera* (coagulant), while the cost of disinfecting the water constitutes 38% (R8.40/Ml). These treatments are necessary to remove tastes and odours from the water at Wiggins (Graham *et.al.*, 1998). Using a 10% annual inflation rate for the period 1998 to 2001, the current annual value of the estimated treatment costs was calculated by multiplying the estimated treatment costs by the compound factor $[1+(1/10)]^3$ as:

- ◆ Removal of algae = $R9.70 (1+0.1)^3 = R12.91M/l$
- ◆ Removal of tastes and odours = $R8.40 (1+0.1)^3 = R11.18M/l$

Wiggins has a design capacity to treat up to 350 Ml per day, therefore the cost of removing algae from water is R1 649 252.50 per annum and that of removing tastes and odours is R1 428 245.00 per annum. The plant treats water abstracted primarily from Inanda Dam, and DWWW has been identified as a major point-source of nutrient loading at this dam, contributing 67% of total nutrient loading. Thus the treatment costs per annum attributable to DWWW can be estimated as R1 104 999.20 and R956 924.15 for removal of algae, and tastes and odours ,respectively.

5.6 COSTS OF REMOVING WATER HYACINTH FROM INANDA DAM

The problem of water hyacinth started a year after Inanda Dam was built (1990), and by 1996 there were major infestations within the impoundment (Degner & Howat, 1997). Regular water quality monitoring conducted by Umgeni Water in the whole Umgeni operational area shows no significant nutrient enrichment before the Nagle and Msunduzi River confluence, upstream of DWWW. The nutrients that contribute to algal production at the dam result from the Msunduzi River down stream of DWWW and diffuse sources in the catchment. Although the direct cause of water hyacinth has never been ascertained, the consensus is that nutrient enriched water creates conditions that are conducive to the growth of this waterweed. Thus, even though DWWW is not a cause of hyacinth reoccurrences, it makes conditions favourable for the germination of this plant's seeds. To effectively control the growth of water hyacinth it is necessary to prevent the weed from entering the impoundment, which requires monitoring of the whole Msunduzi-Umgeni catchment area (Oliffant, Pers.Com). Summer rains also provide conditions that are favourable to the growth of water hyacinth, and reoccurrence of this plant is usually during the summer months (Degner & Howat, 1997). Management of water hyacinth, usually by chemical spraying, is done as frequently as once every second week to prevent its growth (Oliffant, Pers.Com).

Table 5.21 gives a summary of total phosphorous loads from DWWW and phosphorous flows at Inanda Dam, where TP stands for total phosphorous, SRP is soluble phosphorous (primarily drives production of algae) and PP refers to suspended Phosphorous. According to

these results, the water flow at DWWW contributed 26% of the total inflow at Inanda. The proportionate contribution of DWWW SRP to Inanda Dam inflows, when compared with diffuse sources, is estimated as 67%. Moreover, algal counts at the dam were found to increase by twice the amount of SRP load (Simpson & Pillay, 1999). These results imply that, since DWWW contributes more than two-thirds of the nutrient entering the impoundment, upgrading DWWW to eliminate nutrient enrichment of Msunduzi River would substantially reduce hyacinth reoccurrence at the dam.

Table 5.21 Phosphorous inflow loads to Inanda Dam and total loads at DWWW

	Inanda Dam	DWWW	DWWW as a % of load/flow at Inanda
TP (kg)	42606	48137	113
SRP (kg)	11863	17943	151
PP (kg)	30743	30194	98
Flow (Mm ³)	524	135	26

Source: Simpson & Pillay, 1999, pages 2-4

The costs associated with the removal and control of water hyacinth from Inanda Dam includes the costs of chemicals, labour and equipment. Two types of chemicals are used to control water hyacinth - Midstream and tumbleweed - and a wetting agent (ADD2). During major hyacinth infestations manual removal of plants from the shoreline in addition to chemical removal is necessary. Chemical removal is either done by means of a boat or knapsack spraying. Table 5.22 presents the costs of removing water hyacinth at Inanda Dam during 1996-1997 (Degner & Howat, 1997), when the programme of water hyacinth control was initiated, and the costs of controlling it. Effective management and regular monitoring of the catchment area ensures that major infestations are avoided.

Table 5.22 Annual costs of removing and controlling water hyacinth from Inanda Dam

Description	1996-1997 costs (Rands)	Annual costs (Rands)
Equipment	32397.81	14 567.74
Chemicals	57643.91	7 283.23
Labour	97740.00	48 600.00
Total	^b 187 781.72	70 450.97

Source: Degner & Howat, 1997, pages 33-34

At the beginning of the hyacinth control programme almost the whole surface of the impoundment was covered by hyacinth, and the cost of removing it was about two hundred thousand rands. Every year a total amount of R70 450.97 is required to effectively control water hyacinth at Inanda Dam. Approximately 67% of the total costs of removing hyacinth can be attributed to DWWW, and thus the value of R47 202.15 per annum reflects some of the benefits of upgrading DWWW to receive and adequately treat increased flows and loads.

5.7 QUANTIFYING THE HEALTH IMPACTS OF SEWAGE EFFLUENT IN THE MSUNDUZI RIVER ON RURAL COMMUNITIES

The first step in quantifying the health impacts associated with contamination of the Msunduzi River with sewage effluent was to identify the rural communities that use the river as a source of potable water supply. This was achieved by using GIS to determine the die-off rate of the *E. coli* in order to map out the stretch of the river that is contaminated by the effluent discharged from DWWW. Due to limited time, a scientific bacterial die-off rate investigation was not conducted, as this would have required taking into consideration the hydraulics of the river. However, personal communication with Ian Bailey from Umgeni Water's scientific services confirmed that the whole stretch of the river up until the Inanda Dam would be compromised by the raw effluent discharged from DWWW. Secondly, GIS was used to delineate the demographic distribution of people who are below the RDP recommended levels of water supply and sanitation services. From this exercise the relevant clinics were identified and the personnel contacted to get the health records. Figure 5.9 and

Table 5.23 present these results. Six clinics are mobile points, which at the time of the study did not have a regular operating timetable, and thus it was not possible to obtain their records. The Pietermaritzburg Community Health Department, however, indicated that it would be acceptable to work with the Msunduze Clinic, as people visit it when the mobile clinics are closed.

Table 5.23. Table of clinics in areas with below RDP recommended water supply and sanitation service levels, 2000

CLINIC	TYPE
Cuphalaka	Mobile Clinic
Emvini	Mobile Clinic
Msunduze	Clinic
Nkanyezini	Mobile Clinic
Nqwadolo	Mobile Clinic
Sikhelekeheni	Mobile Clinic
The Ferns	Mobile Clinic

Health records provided data about the incidence of diarrhoea and dysentery, and the study only considered cases of mild illnesses, since moderate to severe cases of diarrhoea and dysentery usually require hospitalization not provided by clinics. Approximately 60% of the patients seen at this clinic suffer from diarrhoea, whereas only 5% percent suffer from dysentery. In Table 5.24 a large percentage of people suffering from diarrhoea (54% of the total sample) were over 16 years of age, and were considered adults. The incidence of diarrhoea in children below five years of age was 23%, while the incidence in children between five and sixteen years of age was 21.2%. Only 1.8% of the sample was afflicted by dysentery, and the incidents were distributed equally between children under five years of age and adults. These results differ from what Pelgram *et.al* (1998) found in KwaZulu-Natal and South Africa, where children under the age of five had the highest incidence rates for diarrhoea, and adults had the lowest. The diarrhoeal incidents in the present study might be

caused by other factors not accounted for in this study such as HIV/AIDS, which usually has diarrhoea as an opportunistic disease (Zungu, Pers.Comm). All diarrhoea incidents were attributed to the use of contaminated river water and this might explain the observed discrepancies between the two studies.

Table 5.24 Diarrhoeal and dysentery incidence rates for different age groups in the identified clinics, 2000

Age (years)	Diarrhoea (Incidents per 1000 people)	Dysentery (Incidents per 1000 people)
< 5	138	45
> 5	451	45

Findings from the study conducted by Pelgram *et.al* (1998) were used to estimate unit costs of diarrhoea and dysentery. Table 5.25 shows the impacts of an incident for different age groups on productivity, health services and transport to health services. Impacts on productivity are measured in terms of effective impact on economic activity due to illness, for both the patient and the caregiver.

Table 5.25 Impacts of diarrhoea and dysentery incidence on productivity, health and transport

Age	Diarrhoea		Dysentery	
	Lost Productivity (Days)	Health and Transport Impacts (clinic visits)	Lost Productivity (Days)	Health and Transport Impacts (clinic visits)
<5 Patient	0.9	0.7	2	0.5
Care-giver	1		2	
>5 Patient	0.3	0.1	1.3	0.5
Caregiver	0		0.2	

Source: Pelgram *et.al*, 1998

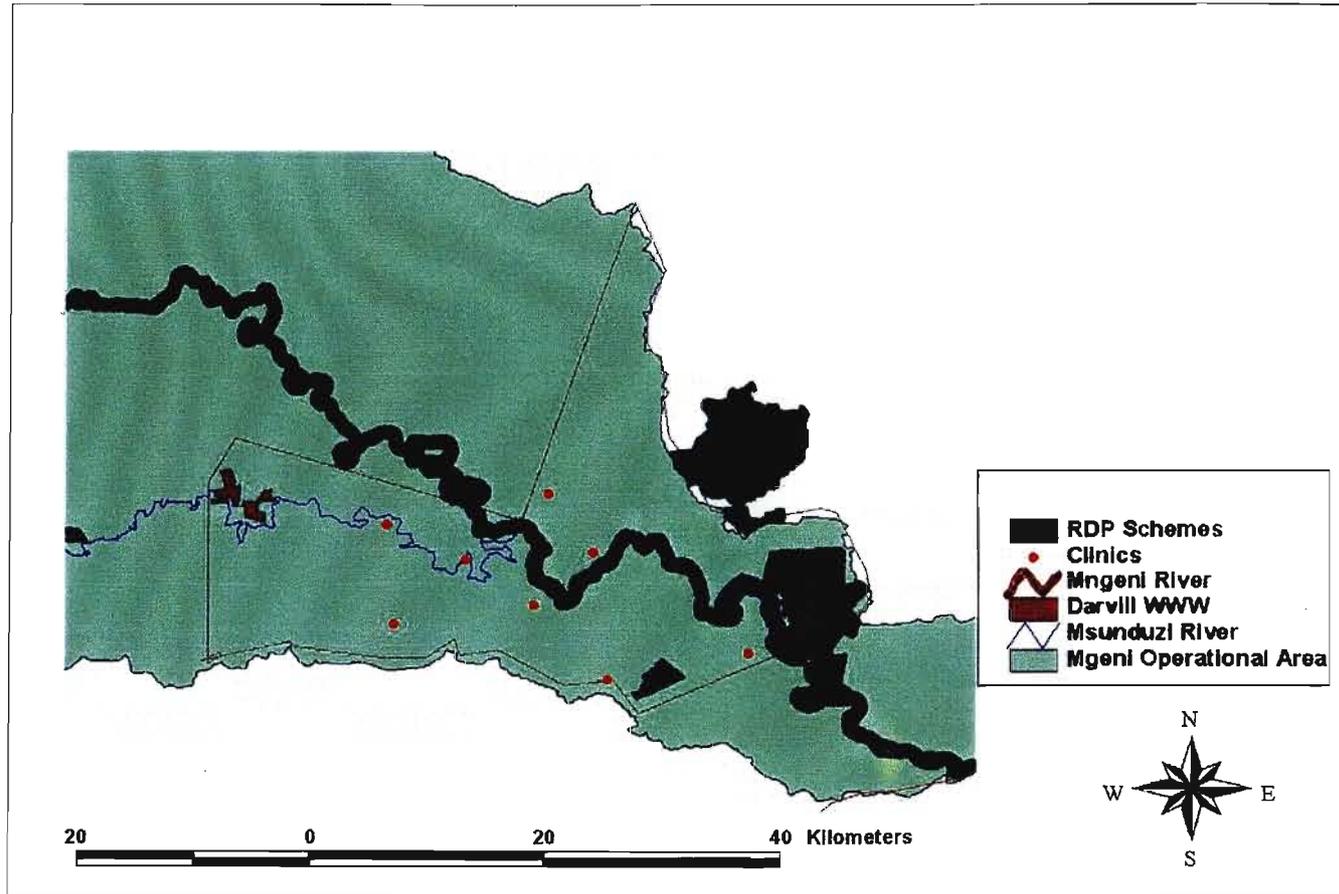


Figure 5.6 Map of clinics without RDP schemes

In costing the loss of productivity, it was assumed that the average income per adult represents the lost income to a household, and that the average gross domestic product (GDP) per adult reflects their contribution to the economy. According to Pelgram *et.al*, 1998 this cost is estimated as R30 per day for an adult patient, and R15 per day for a caregiver. The current value of these costs is estimated by using a 10% annual inflation rate, and multiplying the above costs by this rate compounded over three years – 1998 to 2001 – by the compound factor $[1+(1/10)]^3$. The costs are estimated as R39.93 and R19.97 per day, respectively. The argument for the smaller cost associated with the caregiver's time is that this value reflects household choice of a less productive caregiver. This value is multiplied by the number of restricted activity days to obtain the cost of lost productivity. The cost of health care is obtained from a mean charge for non-subsidised patients by clinics, which is R26.62 per visit to a clinic, plus costs of medical supplies which are R13.31 and R39.93 per incident for diarrhoea and dysentery respectively, and the value is multiplied by the number of clinic visits.

Transport costs were estimated from the average distance travelled in kilometres to the clinic, multiplied by R1.50 per kilometer. Using a mean distance of 5.97km, transport costs were estimated at R9 per visit. Total costs were estimated by aggregating the costs of lost productivity, health and transport costs using the incidence rates as shown in Table 5.26.

Table 5.26 Costs of diarrhoea and dysentery for the total population per annum

Cost Item	Diarrhoea Cost (Rands)	Dysentery Cost (Rands)
Loss of productivity	569 066.39	342 950.78
Health resources	245 469.68	12 990.60
Transportation	55 327.00	17568.00
Total	869 863.07	373 509.38

A value of just over one million rands (R1 243 372.50) is estimated as the cost of water-related illnesses in the rural areas that use the Msunduzi River as a source of potable water supply, recreation and other uses. This value represents the costs of the river pollution to

those communities. Hence, assuming that all bacterial contamination is due to compromised effluent discharged from DWWW, this figure reflects the social benefits that would accrue to the affected rural communities if the plant is upgraded to prevent overflows of raw effluent.

5.8 RECREATION VALUATION

5.8.1 Statistical Analysis

The aim of this exercise was to test the hypothesis that visitation rates decline as transport costs to the site increase, and the estimated travel costs are a proxy for the value of the site to visitors. Eight zones were identified according to the places of origin of the site visitors to Mahlabathini Park. The demand function was then estimated using visitation rates per annum for each zone (V_i) as a dependant variable and travel costs to Mahlabathini Park (C_1) and Albert Falls (C_2) as explanatory variables. Three functional forms of the model (linear-linear, log-linear and log-log models) were estimated using ordinary least squares regression.

Pearson's correlation coefficients between the variables in the recreation demand model given in Table 5.27 for all variables of the linear regression model were not statistically significant. Correlation coefficients between visitation rates and Mahlabathini Park travel cost (C_1) and Albert Falls travel cost (C_2) had negative signs – visitation rates decrease with increasing travel costs for both sites. The sign for Albert Falls was, however, expected to be positive as this site serves a substitute for Mahlabathini Park (if travel costs to the latter increase, visitation rates to Albert Falls may increase). The correlation coefficients indicate a negative relationship between travel costs for Mahlabathini Park and Albert Falls- as the costs to and from Mahlabathini Park increase those for Albert Falls decrease.

Table 5.27 Pearson's r correlation coefficients for variables in the recreation demand model

Variable	Visitation Rates (V_i)	Mahlabathini Park (C_1)	Albert Falls (C_2)
Visitation Rates (V_i)	1.000	-0.174	-0.124
Mahlabathini Park (C_1)	-0.174	1.000	-0.014
Albert Falls (C_2)	-0.124	-0.014	1.000

5.8.2 Demand Function Estimation

Regression results in Table 5.28 show that both the log-linear and log-log models had F-ratios that are not statistically significant, so the null hypothesis that all the coefficients are zero is not rejected. The F-ratio for the linear model, however, was significant at the 5% level. The adjusted R^2 was lower for the log models and they explain less than 20% of the variation in annual valuation rates. The linear model explains 53% of the variation in these rates. Loomis and Walsh (1997) recommend an adjusted R^2 value of 50% as a benchmark for accepting a model. The Durbin-Watson statistic was greater than 2 for all three models confirming that there was no first-order autocorrelation.

Further evidence that the linear model is the appropriate model for this study is provided by the estimated coefficients. The coefficient for travel cost is negative and significant at the 10% confidence level, which follows expectations and suggests that there will be a decline in visitation rates as travel costs increase. The sign of the estimated C_2 coefficient is also negative which is inconsistent with economic theory. All else being equal, zones that are further away from a site and are thus associated with a higher travel cost component have lower visitation rates to the alternative site (Hackett, 2000). The estimated demand function forecast 4048.9 annual visits, whereas the actual number of visits to the eight zones was 4038. The forecasted visits were only 0.2% above the actual visits, which is within the 20% under- or over- forecasting bracket suggested by Loomis and Walsh (1997).

Table 5.28 Regression results for Travel Demand Function, 2000

Linear			Log-linear			Log-log		
Variable	Coefficient	t-Value	Variable	Coefficient	t-Value	Variable	Coefficient	t-Value
Constant	949.98	1.3012 ^a	Constant	5.240	2.660 ^{**}	Constant	10.14	1.325
C ₁	-5.23	-1.417 [*]	C ₁	0.0048	0.199	lnC ₁	-1.15	-1.02
C ₂	-0.0834	-0.289	C ₂	-0.0052	-0.981	lnC ₂	0.0277	0.033
Adjusted R ² = 0.536 F- Ratio = 4.74 ^{**} SE = 1280.37 n = 8 D-statistic = 2.615			Adjusted R ² = -0.165 F- Ratio = 0.503 SE = 2.3527 n = 8 d-statistic = 2.725			Adjusted R ² = -0.121 F- Ratio = 0.623 SE = 2.3073 n = 8 d-statistic = 2.613		

Note: ^a, ^{*} and ^{**} indicate significance at 20%, 5% and 1% respectively

5.8.3 Resource Demand Curve

The resource demand curve was estimated by using higher travel costs and the estimated demand function. The average travel cost to Mahlabathini Park by car was calculated from site records as R40.37. Costs were then increased by R20.00 increments, and visitation rates estimated for each value as shown in Figure 5.10. The benefits for visitors to Mahlabathini Park are estimated as the area under the demand curve but above the price line (R40.37). This area is estimated by using the formulae for area (rectangle = length times breadth, and triangle = half breadth times height):

$$\begin{aligned} \text{Total Area} &= [1.5 * (R181.75 - R40.37)] + [(8.3-1.5)/2 * (R181.75 - R40.37)] \\ &= R706.90 \end{aligned}$$

The value of R706.90 is the consumer surplus accruing to recreationists and thus estimates the value of Mahlabathini Park to an individual. These benefits, when aggregated over the total population (296 590) are over two hundred million rands per annum (R209 659 470.00). This figure estimates the annual value of this site to its visitors. However, the problems of algal blooms and growth of water hyacinth pose a serious threat to recreational activities at

the dam. Therefore the problem of nutrient enrichment of the Inanda Dam is of paramount importance, as the estimated value indicates social benefits that would be lost if the hyacinth problem is not controlled.

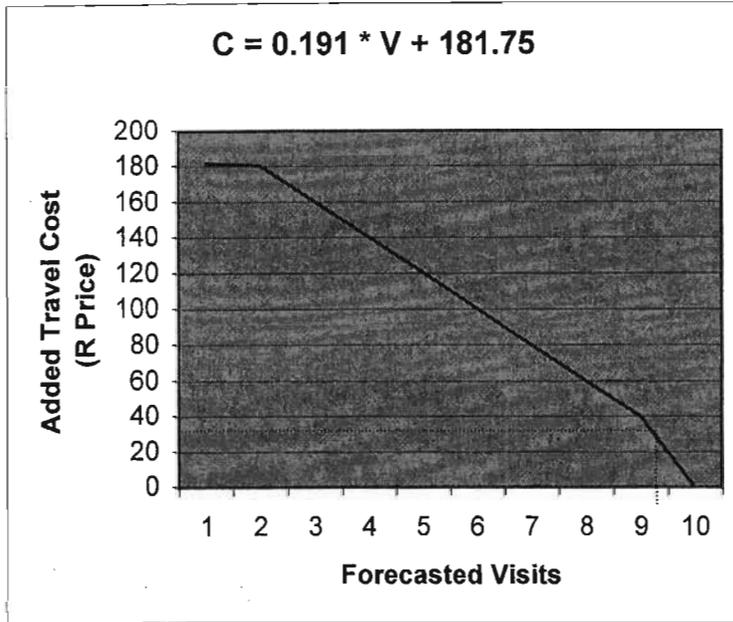


Figure 5.10 Estimated demand curve for Mahlabathini Park

5.9 COSTS OF UPGRADING DWWW

The upgrading of DWWW to address the identified environmental issues would involve upgrading the inlet works, upgrading the existing stormwater attenuation dam and proper sludge treatment facilities. Consultants GFJ (1996 & 1999) estimated the cost of upgrading DWWW and the current value of these estimates is presented in Tables 5.29 and 5.30. The current value of the cost estimates was calculated using a 10% annual inflation rate to increase the 1996 and 1999 cost estimates provided by consultants GFJ to current (2001) values.

Table 5.29 Estimated costs of upgrading sludge disposal at DWWW

Description	Co-Disposal Option		Land Disposal Option	
	Cost (R)	Current Value	Cost (R)	Current Value
Capital	16 496 802.00	19 961 130.00	16 479 742.00	19 940 488.00
Operational	2 739 000.00	3 314 190.00	1 380 900.00	1 670 889.00
Total	19 235 802.00	23 275320.00	17 860 642.00	21 611 377.00

Source: GFJ, 1999, Appendices E and F

Table 5.30 Estimated costs of upgrading DWWW to increase capacity and prevent overflow of effluent.

Description (Duration of activity)	Cost (R)	Current value (R)
40 Ml Stormwater Retention Dam	2 882 812.90	4 642 799.00
Additional Clarifier	1 932 612.00	3 112 491.00
25 Ml/d module	72 472 950.00	116 718 410.00
Eastern corridor trunk sewer	7 810 000.00	12 578 083.00
Pump station and rising main	4 540 000.00	7 311 715.40
Extension to the sludge de-watering facility	1 760 000.00	2 834 497.60
Total	91 398 374.00	147 198 000.00

Source: GFJ, 1996, page 57

The estimated cost of upgrading DWWW and disposal of sludge at the New England Landfill site (Co-disposal) is R170 473 320.00. The upgrade cost and the disposal of sludge at DWWW (Land-disposal) is estimated as R168 809 377.00. Land disposal of sludge is the method that is currently employed at DWWW, where a sprinkler system is used to irrigate treated sludge over land. The limitation of this method at present is the problem of spraying improperly treated sludge which causes odours, and the sludge itself provides conditions that encourage the breeding of flies. The cost estimates for the land disposal option have taken these factors into consideration and include costs of improving sludge treatment processes. Another option in trying to eliminate the odour and fly problems that result from spraying of

sludge over land is to dispose of this sludge at the New England Landfill site adjacent to DWWW. The cost of upgrading DWWW is more for the co-disposal option when compared to the land disposal option. The land disposal option might be cheaper because of existing infrastructure which only needs improving in order to address the fly and odour problems. The cost estimates of upgrading the inlet of the DWWW were not available. These costs might underestimate of the true costs.

5.10 COST-BENEFIT ANALYSIS OF UPGRADING DWWW

Table 5.31 presents the estimated social benefits of upgrading the DWWW plant as R256 662 840. A benefit-cost ratio (BCR) rule is used in this study to determine whether it is worthwhile to upgrade DWWW. The BCR is the ratio of the discounted benefits to be realised from a project contrasted with the discounted costs, and it uses the criterion that the ratio must be greater than unity for the project to be considered worthwhile (Curry & Weiss, 1993). Given the R170 473 320 upgrading costs for the co-disposal option and R168 809 377 for the land disposal option, the estimated BCR in Table 5.32 for the DWWW upgrading options is 1.51 and 1.52, respectively. These BCRs suggest that the social benefits of upgrading DWWW for both options far outweigh the costs of upgrading the plant (R1.51 and R1.52 of benefits per R1.00 of upgrading costs).

Table 5.31 Estimated benefits of upgrading DWWW

Benefit	Value (Rands)
Recreation (Inanda Dam)	209 659 470.00
Cost of Illness	1 243 372.50
Eutrophication (Water hyacinth)	47 202.15
Treatment Costs (Wiggins)	2 061 923.40
Duzi Canoe Marathon Revenue	3 744 975.00
Property Valuation	28 480 518.00
Contingent Valuation (Improved air quality)	11 425 382.00
Total	256 662 840.00

Table 5.32 Estimated benefit-cost ratios (BCR's) for the two upgrade options for DWWW

Option	Estimated Benefits (R)	Estimated costs (R)	Benefit-Cost Ratio
Co-Disposal	256 662 840	170 473 320	1.51
Land Disposal	256 662 840	168 809 377	1.52

5.11 SUMMARY

This chapter presented the monetary value of the benefits associated with improving or upgrading DWWW by estimating the benefits of eliminating pollution in the Msunduzi River on the downstream rural communities and on the Duzi Canoe marathon. Furthermore, it estimated the benefits of improving air quality in the vicinity of DWWW, reducing the nutrient enrichment at Inanda Dam and reducing treatment costs at WWW. These benefits were then compared to the costs of upgrading DWWW by calculating the benefit-cost ratios (BCR). The BCR's for both options of upgrading DWWW were greater than one, suggesting that upgrading is a preferable option from society's standpoint.

CHAPTER 6

CONCLUSION

6.1 SUMMARY

Economic valuation techniques were used to estimate the value of improving the quality of air and water that is improved by the operations of the Darvill Wastewater Works (DWWW) in Pietermaritzburg. Environmental goods like air and water are public goods due to their joint consumption and non-exclusivity characteristics. Environmental valuation centres on estimating people's willingness to pay (WTP) for environmental improvements, with the explicit assumption that individual preferences remain constant for long periods of time such that they can be included as parameters in the analysis (Laslett, 1995). Environmental valuation is usually a multidisciplinary process requiring knowledge about both the economic and environmental underpinnings of the problem. The main objective of the study was to quantify the benefits of overcoming air and water quality problems caused by DWWW and compare these benefit estimates to the costs of upgrading DWWW using a cost-benefit analysis approach. This approach provides essential information to decision makers, who may, on the basis of this exercise, decide to encourage or discourage proposed investments. The results of this research indicate strong support for upgrading DWWW, as the estimated benefits associated with the project far outweigh the costs, indicated by benefit-cost ratios of 1.51 and 1.52 for two alternative upgrade options.

The decrease in the quality of life of residents living close to DWWW was quantified using the contingent valuation method (CVM). The CVM involves asking individuals to state their preferences (WTP) for environmental improvements using a hypothetical market. Residents from the Sobantu, Lincoln Meade and Hayfields residential areas indicated positive preferences (positive WTP values) for improved air quality (elimination of flies and odours caused by sludge deposited by DWWW). The stated WTP was affected by the socio-economic characteristics of the surveyed household, with Sobantu residents stating the lowest mean monthly WTP (R19.00), followed by Hayfields (R28.50) and Lincoln Meade (R52.00).

Sobantu has the highest unemployment rate, and in many households the principal decision maker is a state pensioner. Furthermore, as in many black townships, the family size was larger than in the other residential areas. These factors affected the household expenditure that was available for non-family needs. The issue of income inequality is important when assessing WTP as a measure of the value of environmental services. People in the lower income scale might place a lower value on environmental services not because they value it less than their wealthier counterparts but because of budgetary constraints.

The study identified possible strategic, hypothetical and free-rider biases that may have led to some unexpected signs on coefficients for the determinants of WTP in linear regression models. Stated monthly WTP amounts which did not seem plausible given the household's budgetary constraints were ascribed to those individuals' desire to influence the outcome of the study (strategic bias). Some respondents presented with a hypothetical market may not take the problem (compromised air quality) seriously (hypothetical bias). Free-rider bias is the most common phenomenon in environmental valuation and it arises because of the non-exclusivity and joint consumption nature of environmental services. Individuals may perceive that others who do not pay for environmental improvements will also benefit.

Despite the methodological issues surrounding the CVM, the method is widely used in the valuation of environmental goods that are not traded in markets. The reliability of this method is often under considerable scrutiny. However, many empirical studies have produced results that are replicable and consistent with demand theory and with other valuation procedures (Smith, 1996). The aggregate annual WTP for cleaner air in the vicinity of DWWW was estimated from this study at R11 425 382.00, indicating that people living close to DWWW place a higher value on cleaner air. This is not surprising considering the complaints that have been raised as the result of odours and flies in these areas arising from sludge disposal at DWWW.

A hedonic price method was used to try and quantify the influence of odours and flies on property values around DWWW by regressing the selling price of the properties against their

structural, environmental and neighbourhood characteristics. Proximity to DWWW had an adverse impact on property values since a one kilometre decrease in the distance between a property and DWWW caused a reduction of R6650.08 in the value of that property. Properties that are impacted by odours and flies were also worth R15953.90 less than those that are non-impacted. Annual net benefits (decline in property values avoided) that would be realised from the elimination of air pollution were estimated as R28 480 518.00.

The revenue generated by the Duzi Canoe Marathon to the city of Pietermaritzburg was estimated in order to infer the cost of the loss of this race. The estimate of R3 744 975.00 represents the annual benefits that would be lost by the city if the pollution of the Msunduzi River is allowed to continue. A conservative valuation of water-related illnesses, such as diarrhoea and dysentery, indicates that these diseases have an adverse annual economic impact of R1 243 372.50 on the rural communities that use this river as a source of potable water supply. Water quality monitoring of the river indicates that the quality of the river upstream of DWWW is much worse than downstream, and DWWW activities are thought to improve the quality of the river. However, as Archer (1999) noted, “the lack of an annual polluting effect of DWWW on the river disguises the effect of peak discharge events, which result in an acute health impact on downstream communities”. Therefore, although these estimates might seem to overestimate the actual benefits that will result from upgrading DWWW, they do provide decision makers with insight as to the importance of reducing or eliminating water pollution. Controlling point-sources of pollution is a first step towards the rehabilitation of the environment.

Water quality data for the final effluent discharged from DWWW show that the effluent is not compliant with DWAF Phosphate Standards. This nutrient enrichment has been shown to contribute significantly to nutrient loadings at Inanda Dam (Simpson & Pillay, 1999). The growth of water hyacinth and algal blooms are some of the consequences of this nutrient loading. The annual cost of removing water hyacinth was estimated from the direct cost of chemicals and labour as R47 202.15, and this value gives the estimated benefits that would result from upgrading DWWW to eliminate nutrient enrichment of the Msunduzi River.

Some species of algae are a nuisance at impoundments because they produce pungent, bad tasting and often toxic substances. As a result, water purification works use expensive treatment processes to remove these substances from potable water. The cost of removing these substances from the water abstracted from Inanda Dam thus infers benefits (costs saved) that would result from upgrading DWWW, and this annual cost is estimated as R2 061 923.40, which is 67% (the percentage contribution of DWWW to nutrient loading at Inanda Dam) of the total treatment cost.

The value of recreation at Inanda Dam was estimated by using a travel cost method. The demand for the site was estimated by specifying travel costs as a proxy for the price of visiting the Dam. Visitation rates decreased with an increase in travel cost, and the annual consumer surplus was estimated as R209 659 470.00. This figure represents the social benefits that will be lost as the result of eutrophication of the dam. All the estimated benefits were summed (R256 662 840) and compared to the market related costs of the two alternative options for upgrading DWWW in a cost-benefit analysis. From society's standpoint, it is desirable to upgrade DWWW in order to reduce or eliminate its environmental impacts as the estimated benefits were R1.51 or R1.52 per R1.00 of upgrading costs for the co-disposal and land disposal upgrading options, respectively.

6.2 POLICY AND DWWW MANAGEMENT IMPLICATIONS

The study results have important implications for policy makers, both the DWWW management and the municipality. At present DWWW employs a land disposal of sludge method, where a sprinkler system is used to irrigate the anaerobically digested sludge over land. However, sometimes the sludge is not digested properly before being sprayed over land, causing unpleasant odours and flies as a constant nuisance. The main reason why the sludge is not treated properly is that DWWW is currently operating very close to its design capacity, and during heavy rains the inflow loads exceed this capacity, and compromises the operating efficiency of the plant. This problem is confounded by the poor status of the

reticulation system of the city and illegal discharging of industrial effluent down the stormwater drains. The benefits of improving air quality that were estimated in this study indicate that the problem of flies and odours has a significant impact on property values and on the quality of life of residents living close to DWWW. Therefore, it would be in the DWWW management and the local municipality's best interest to address these issues in order to avoid further damage to the environment. Prevention and rehabilitation of environmental degradation is the core of the National Environmental Management Act, and so the implementation and enforcement of this legislation would be a sound investment towards the goal of sustainable development. The DWWW management needs either to consider other means of disposing of sludge or upgrading the plant to increase its capacity and invest in efficient wastewater treatment technologies. Co-disposal of sludge at the New England Landfill site is one option that would eliminate the problems currently experienced at DWWW with regards to the disposal of sludge. This, however, would require preliminary investigations as to the standards required to be met in order to use the landfill site for sludge disposal.

Upgrading DWWW to increase its capacity would prevent the pollution of the Msunduzi River with disease causing organisms. This upgrade would include construction of a maturation dam where wastewater could be channeled when DWWW overflows. Addressing the problem of raw effluent into the river would benefit the rural communities that use the river as a source of disposable water supply and also the recreationists such as the Duzi Canoe Marathon participants. The DWWW management would eliminate the threat of civil litigation as the result of this upgrade. Usually before the commencement of this marathon Umgeni Water releases water from the Henley Dam to dilute the Msunduzi River, this increases the costs incurred by Umgeni Water and this cost would be saved if pollution of the Msunduzi River is prevented by upgrading the plant. The direct cause of the growth of water hyacinth at Inanda Dam has never been determined, although DWWW has been implicated in creating conditions favourable to the growth of this weed due to nutrient enrichment of the Msunduzi River. The growth of algae, which is also directly attributed to nutrient enrichment, increases the treatment costs at the Wiggins plant. These are also some of the

problems that would be prevented if DWWW were upgraded.

The large annual value of estimated health benefits that would accrue to the rural communities using the Msunduzi River as a source of water supply indicates an urgent need not only to prevent the pollution of the river but to provide basic services such as treated water supply to these communities. The provision of these services, although in progress, has been slow. In the meantime rural communities could be educated about precautions to be taken if they use rivers as a source of water supply. The recent outbreak of cholera mainly in KwaZulu-Natal reinforces the urgency with which the issue of the provision of clean water supply must be addressed. The upgrade of DWWW would certainly be a costly exercise, and since the Pietermaritzburg-TLC owns the plant, the financial responsibility would be borne by the municipality and the ratepayers. It is perhaps unreasonable to expect the local municipality to have sufficient infrastructure to carry out such an enormous project. However, funds may be sourced from the national departments that are affected by the impacts of DWWW such as DWAF, Department of Health and the Department of Environmental Affairs and Tourism.

6.3 CONCLUSION

Cost-benefit analysis, referred to as social cost benefit analysis in the environmental management sphere, relates to any public decision that has an implication for the use of resources (Brent, 1997). The large social benefits estimated in the study due to upgrading of the DWWW indicate that there is awareness of the importance of environmental issues and it is unlikely that society will not take active measures to realise the benefits of environmental improvements. Sustainable development, which is concerned with meeting the needs of the present generation and those of future generations, is a fundamental criterion of social cost-benefit. Appropriately employed, this technique has an important role to play in providing information for making decisions about the allocation of scarce environmental resources.

Achieving the air and water quality control objectives as stipulated by National Water Act No 36 of 1998 and the National Environmental Management Act No 107, of 1998 requires considerable expenditures from both the public and the private sectors. If the main goal of environmental management is in promoting better use of environmental resources, then cost-benefit analysis becomes a set of rules for optimum environmental management.

Although the estimation of both the benefits and costs of upgrading DWWW was constrained by research time and financial limitations, the study results provide a decision making tool, to show the extent of the environmental impact of DWWW. As regards future research, it is suggested that further investigations would need to isolate the environmental impacts of DWWW from other sources. The cost of illness approach could not accurately estimate the benefits of improving water quality as some cases of diarrhoea are not attributed to water-borne disease causing organisms. Furthermore, it was not possible to state with conviction that the costs of illness obtained were as the result only of pollution from DWWW because of a confluence of non-point sources of pollution.

6.4 RECOMMENDATIONS

Based on the findings and conclusions of this study, the following recommendations are made:

- ◆ Upgrading DWWW to increase its capacity must be given the highest priority as this would prevent most of the environmental impacts caused by this plant. This upgrade would be a short-term solution if the reticulation system of the city of Pietermaritzburg is not addressed soon, since most of the environmental problems currently experienced at DWWW are a direct consequence of this;
- ◆ Management at DWWW could either continue to dispose of sludge by irrigating it over land, but ensure that the sludge is digested anaerobically and

properly before spraying onto the land, or the co-disposal option could be adopted;

- ◆ The inlet of the works also needs to be upgraded to eliminate the problem of flies and odours;
- ◆ Rural communities need to be educated about precautionary measures to be adopted to prevent illnesses from the use of river water; and
- ◆ The provision of clean water supply to the rural communities needs to be given more priority.
- ◆ Due to the large costs associated with upgrading of DWWW, the local municipality might not have the liquidity to carry out such a project, thus the municipality might need to approach the other stakeholders (Department of Water Affairs and Forestry, Department of Health and Department of Environmental Affairs and Tourism) for financial assistance.

APPENDIX A

Contingent Valuation Method Questionnaire

SURVEY INSTRUMENT FOR A STUDY OF THE BENEFITS OF AIR QUALITY IMPROVEMENT IN AREAS SURROUNDING THE DARVILL WATER Waste Water WORKS, PIETERMARITZBURG.

INSTRUCTIONS TO THE INTERVIEWER:

In the following questionnaire, the text in bold gives the instructions that you need to carry out yourself. Read the following passage to the interviewee (who should be one of the principal decision makers in the household), and remind her/him that the interview is completely confidential and that there are no right or wrong answers. The abbreviation WTP stands for willingness to pay.

PLEASE REMEMBER TO FILL IN ALL THE QUESTIONS!

A. BACKGROUND INFORMATION

QUESTION 1

The photograph for you to consider shows the Darvill Waste Water Works that treats all the industrial and domestic effluent from the city of Pietermaritzburg (Photograph A). The treated effluent is discharged directly into the Msunduzi River (Photograph B). As you might be aware the Msunduzi River is a source of water supply for several rural communities in Table Mountain and the Valley of the Thousand Hills (Photograph C). Darvill Waste Water Works produces waste that is known as sludge, which is sprayed over the land near the works (Photograph D). This produces odours and provides a breeding ground for flies, both of these are a constant nuisance in residential areas surrounding the plant.

We would like to know much you would be willing to pay each month in order to eliminate the odour and fly problems and improve air quality? When considering this, please also bear in mind that your household income is used to purchase other goods and services. Therefore, is your stated willingness to pay (WTP) realistic given these restrictions?

Stated WTP:.....per month

If the respondent says that she/he would be willing to pay nothing, please go to QUESTION 2a, otherwise go to QUESTION 3.

QUESTION 2a

(Ask this question if the respondent indicated a zero WTP in QUESTION 1).

You are already paying some amount towards air pollution control in your municipal rates. It is very important to us to learn what value you place on eliminating the odour and fly problems. The value you give us would help policy makers to make informed decisions about improving air quality, and this would be beneficial to you. The value you give does not necessarily have to be more than what you are currently paying in rates; however, it must be the highest amount that you or your household will be willing to pay to eliminate the odour and fly problems.

Do you want to revise your answer to Question 1? **(If yes, ask QUESTION 1 , if no go to QUESTION 2b).**

QUESTION 2b

What was the main reason you said you would pay a zero amount?**(Please tick only the appropriate answer):**

1. The elimination of the odour and fly problems is not worth anything to me.
2. I cannot afford to pay at this time.

3. I did not realize I am currently paying for it. I thought my WTP amount would be in addition to what I am paying now.
 4. I think the government should pay the costs.
 5. Other reasons (please explain): _____
-
-

QUESTION 3

(Ask this question if the respondent indicated a WTP amount greater than zero for QUESTION 1, and tick the appropriate answer).

Why would you pay the amount you have stated? **(Please tick only the most important reason):**

1. This is what better air quality is worth to me/my household.
 2. I would benefit from a cleaner and healthier environment.
 3. To pay my fair share for better air quality.
 4. Other reason (Please explain): _____
-
-

B. DEMOGRAPHIC INFORMATION

These questions will help us to understand how well our sample represents the communities directly affected by the odour and fly problems caused by the Darvill Waste Water Works. Your answers are strictly confidential and will only be used for statistical purposes. You will not be identified in any way.

QUESTION 4

What gender are you?

1. Male
2. Female

QUESTION 5

What is your marital status?

1. Married
2. Single
3. Widowed

QUESTION 6

What is your age?

- | | |
|-------------|---------------|
| 1. Under 20 | 5. 50-59 |
| 2. 20-29 | 6. 60-69 |
| 3. 30-39 | 7. 70 or over |
| 4. 40-49 | |

QUESTION 7

What is the highest level of education that you have completed?

1. Primary school (SSA-STD5 or Grade 1-7)
2. Secondary School (STD 6-8 or Grade 8-11)
3. Matric (STD 10 or Grade 12)
4. College
5. Technikon or University

QUESTION 8

How many dependants, both adults and children (you included) live in your household?

Number:.....

QUESTION 9

How much is your household monthly income before taxes? Please include all forms of income generated by individuals contributing to the household.

- | | |
|----------------------|-------------------|
| 1. Refused to answer | 12. R5 001-R5 500 |
| 2. Under R500 | 13. R5 501-R6 000 |
| 3. R500-R1 000 | 14. R6 001-R6 500 |
| 4. R1 001-R1 500 | 15. R6 501-R7 000 |
| 5. R1 501-R2 000 | 16. R7 001-R7 500 |
| 6. R2 001- R2 500 | 17. R7 501-R8 000 |
| 7. R2 501-R3 000 | 18. R8 001-R8 500 |
| 8. R3 001-R3 500 | 19. R8501-R9 000 |

9. R3 501-R4 000

10. R4 001-R4 500

11. R4 501-R5 000

20. R9 001-R9 500

21. R9 501-R10 000

22. Over R10 000

QUESTION 10

How far is the household situated from the Darvill Waste Water Works? **(Please tick only the appropriate answer)**

1. Within 1Km

2. Between 1-2Km

3. Between 2-3Km

QUESTION 11

Do you own or rent this property? **(If the respondent owns the property ask QUESTIONS 12,13 &14, otherwise go to question 15).**

1. Own

2. Rent

QUESTION 12

How long have you owned it?

1. Less than a year

2. 1-5 years

3. 5-10 years

4. 10-15 years

5. 15-20 years
6. More than 20 years.

QUESTION 13

What is the area of the property? Hectares:.....

QUESTION 14

If you own the property, how much did you buy it for? R:..... When?.....

QUESTION 15

What attributes does your property have?

- | | |
|------------------------------------|----------------------|
| 1. Number of rooms | 6. Swimming pool |
| 2. Double or single storey | 7. Garden |
| 3. Outbuildings other than garages | 8. Fenced/Walled |
| 4. Duplex or Simplex | 9. Number of garages |
| 5. Number of bathrooms | 10. Separate showers |

QUESTION 16

Do you think that current property values in this area are

1. Declining?
2. Increasing?
3. Do not know.

QUESTION 17

Do you have any additional comments?

THANK YOU VERY MUCH FOR YOUR TIME.

C. INTERVIEWER=S EVALUATION

INTERVIEWER: Please complete these questions as soon as possible after the interview.

(These two questions are only concerned with how the respondent answered the questions that asked her/him to value improved air quality).

QUESTION 19

Irrespective of whether or not the respondent gave a non-zero WTP value for improved air quality, how well did the respondent understand what he or she was asked to do in these questions?

1. Understood completely
2. Understood a great deal
3. Understood somewhat
4. Did not understand very much
5. Did not understand at all
6. Other (Please specify): _____

QUESTION 20

Which of the following descriptions best describe the degree of effort that the respondent made to arrive at a value for better air quality?

1. Gave the questions prolonged consideration in an effort to arrive at the value
2. Gave the questions careful consideration, but the effort was not prolonged
3. Gave the questions some consideration

4. Gave the questions very little consideration

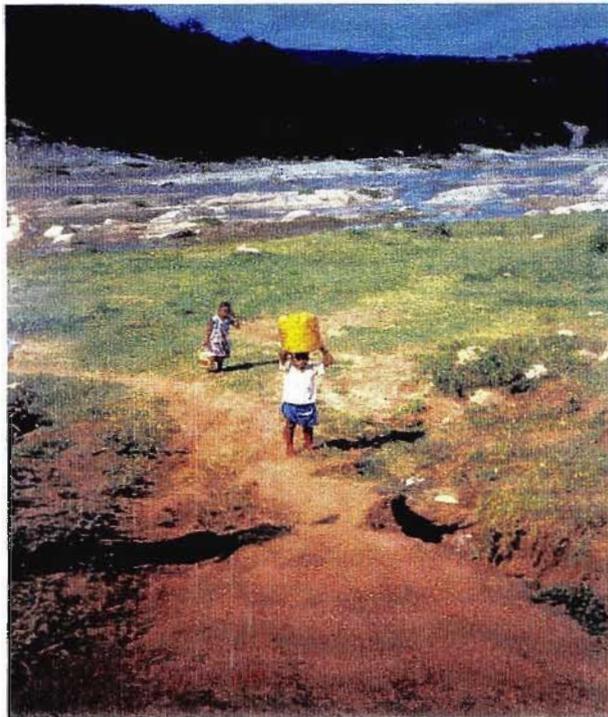
5. Other (Please specify): _____



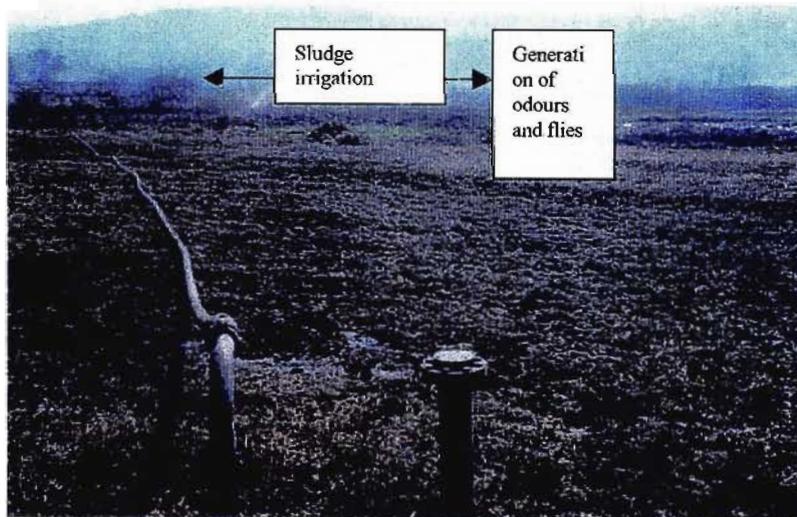
Photograph A: Darvill WasteWater Works



Photograph B: Discharging of effluent into the Msunduzi River



Photograph C: Msunduzi River: A source of potable water supply for rural Communities



Photograph D: Sludge disposal using a sprinkler system

APPENDIX B

GRAPHS OF MEAN WTP BY DIFFERENT HOUSEHOLDS

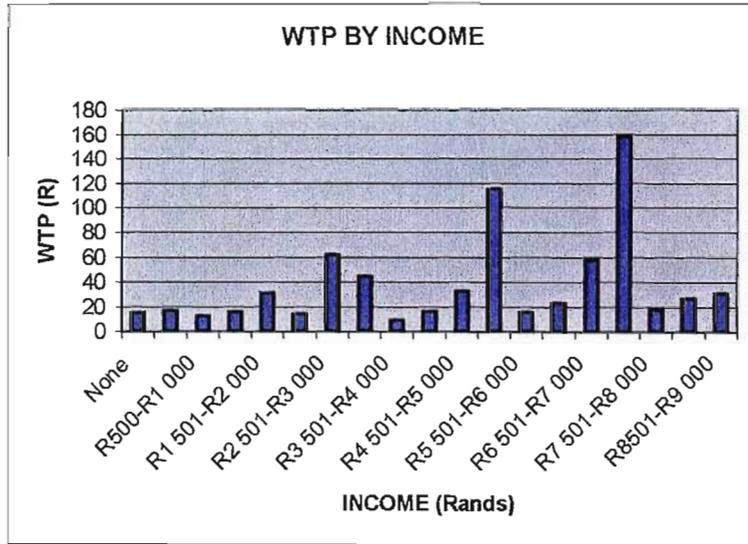


Figure 5.1 Variation of mean WTP with income

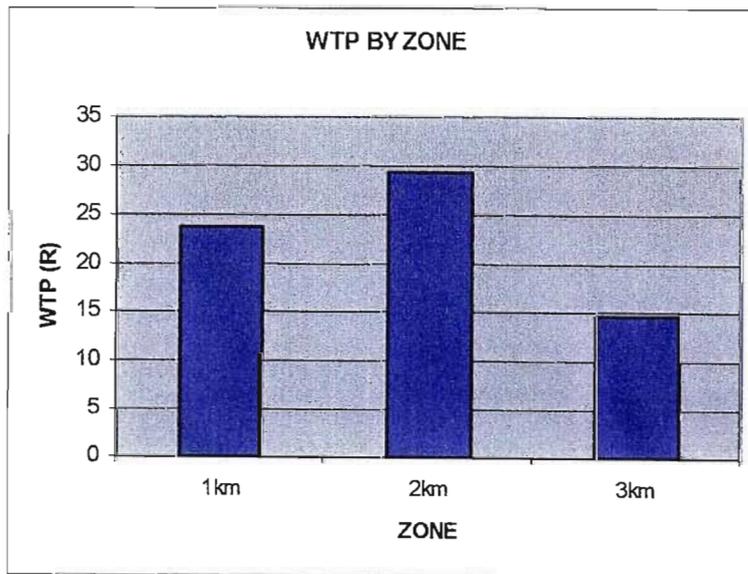


Figure 5.2 Variation of mean WTP with zone

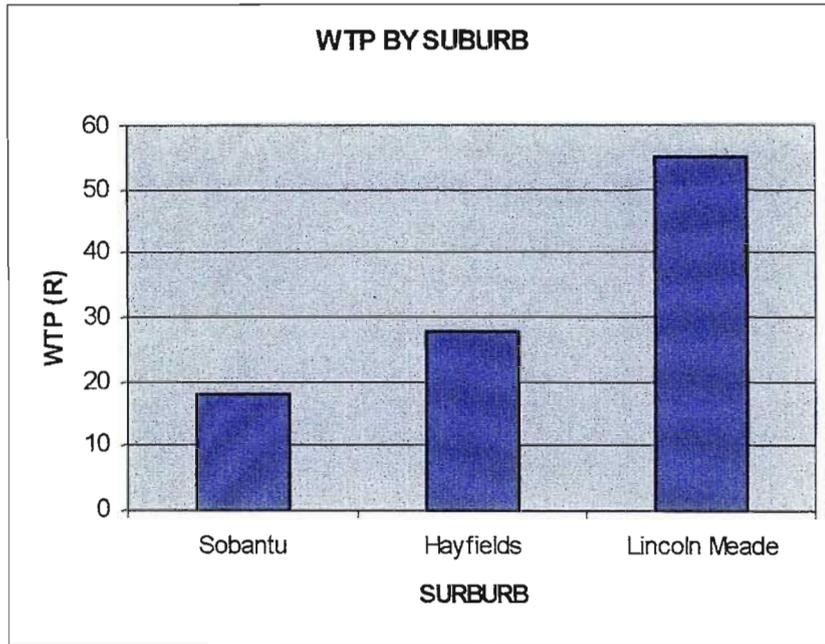


Figure 5. 3 Variation in mean WTP with residential areas

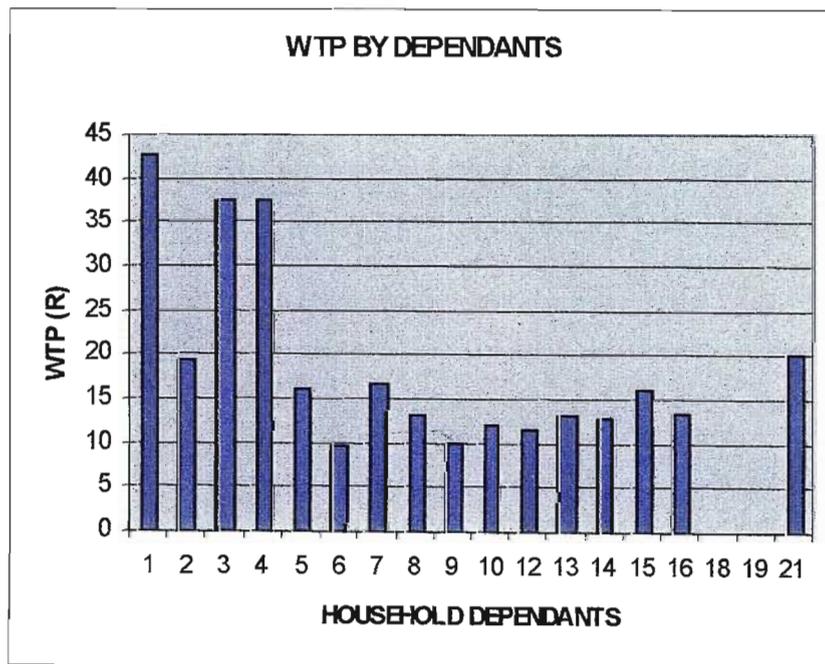


Figure 5. 4 Variation in mean WTP with households

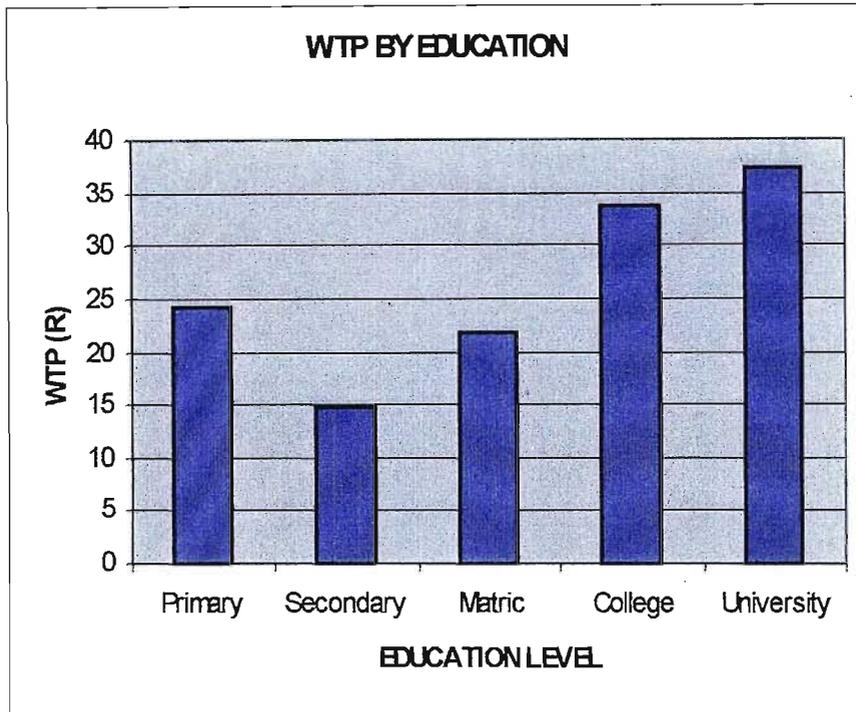


Figure 5.5 Variation in mean WTP with education level

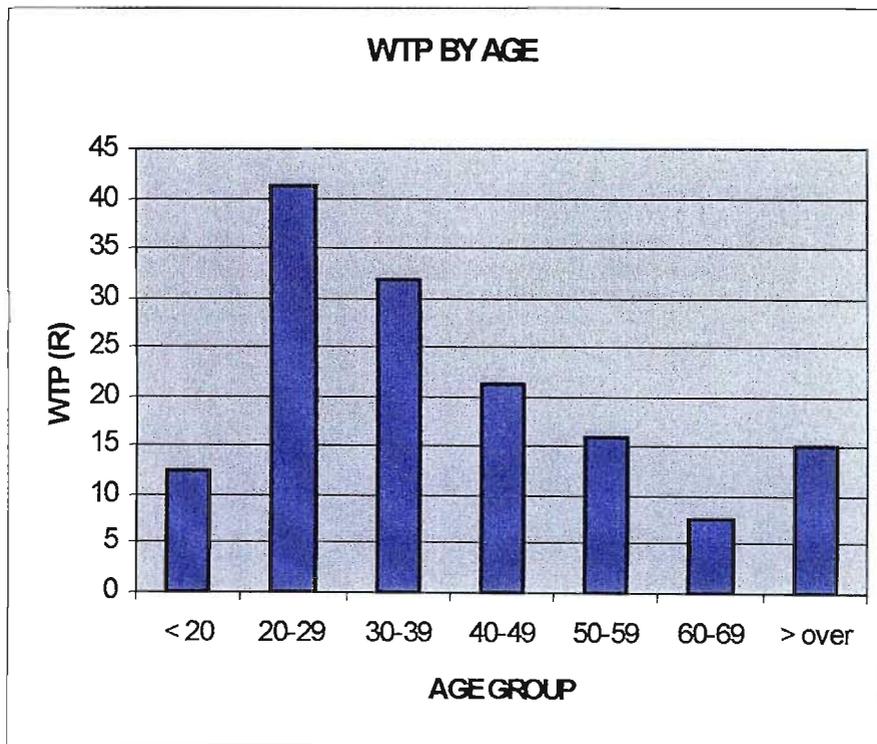


Figure 5.6 Variation in mean WTP with age group

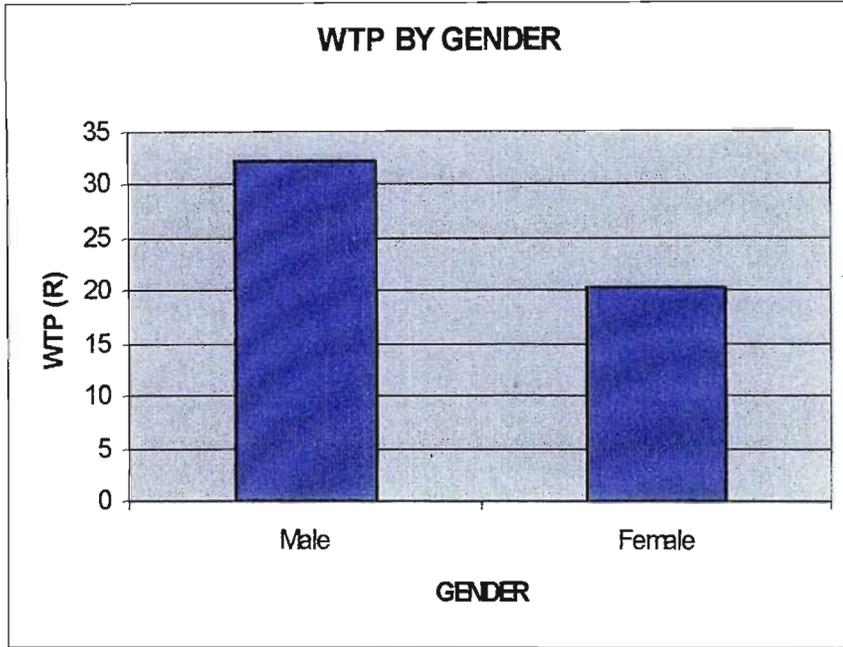


Figure 5.7 Mean WTP for males and females

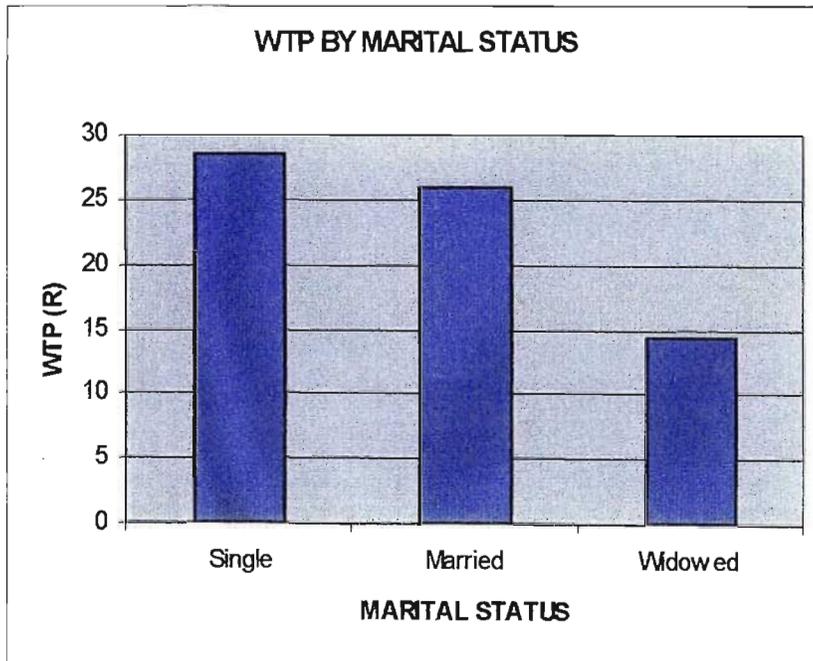


Figure 5.8 Variation in mean WTP with marital status

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