Department of Economics

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Mini-Thesis

An Investigation into the Negative External Impact of Water Pollution, Public Policy Options and Coping Strategies – with specific reference to the Lotus River Catchment area

Submitted in partial fulfilment of the requirement for the degree of M.Com (Economics)

By

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DECLARATION

I declare that *An Investigation into the Negative External Impact of Water Pollution, Public Policy Options and Coping Strategies – with specific reference to the Lotus River Catchment area* is my own work, that it has not been submitted before for any degree or examination at any other university, and that all the sources I have used or quoted have been indicated and acknowledged as complete references.

Mariana E. Moses January 2006

Signed: ………………………………….....

DEDICATION

This thesis is dedicated to my mom and sisters who taught me the invaluable lesson of saving water at a tender age.

We never know the worth of water until the well runs dry.
Thomas Fuller: *Gnomologia*

ACKNOWLEDGEMENTS

I want to express my eternal gratitude to my Heavenly Father for granting me this opportunity in life and for having surrounded me with a strong network of support. Numbered among these are my family, mentors and friends. Thanks for all your words of encouragement over these past years, know that they never went unnoticed.

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To my family, without whom this would not have been possible THANKS! Each and every act of kindness, sacrifice and love is much appreciated.

ABSTRACT

Given the backdrop of South Africa's high population growth over the preceding decades and subsequent migration of jobseekers to urban areas, water resources have been adversely affected. Of particular significance to the Western Cape region, has been the impact of informal settlements on water quality, i.e. the quality and reliability of water for its intended use. Location of housing near and alongside riverbanks, be it formal housing structures or informal dwellings (i.e. shacks), invariably impacts upon water resources, caused by pollutants such as sewage, oils, rain, litter (plastics, metals and building rubble). These pollutants are transported by bodies of water flowing into catchment areas that provide water necessary for human consumption or usage by firms, thus necessitating added purification measures and costs. This therefore imposes a social cost on the community.

The main purpose of this study was to assess the negative external impact of water pollution upon water resources and the users thereof within urban areas. The literature provides a background to the problem and presents a theoretical framework for the analysis of water pollution as a negative externality. Based upon the theoretical analysis, the report assesses the available policy options by government to remedy these situations and to internalise the external costs. A case study analysis was conducted on the specific case of the Lotus River Catchment in the Western Cape in order to investigate the problem of water pollution in South Africa. Finally, the report investigates the various coping strategies in other countries and derives lessons for South African water managers.

The main conclusion of the study is that water pollution is present in South Africa and negatively impacts upon all users of the water resources. This externality is a form of market failure requiring intervention by government. The lessons learnt from other countries point to the fact that existing regulation needs to be complemented by other economic measures, such as taxation, abatement subsidies, property rights and effluent fees. South Africa has its own inherent problems that render traditional measures not viable. The case study indicates that water pollution in the Lotus River canal is largely attributed to a diffuse source in urban settlements, thus the provision of sanitation stands out as the most viable measure to pursue, due to the unique nature of informal settlements in South Africa.

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CHAPTER ONE: INTRODUCTION

1.1 STATEMENT OF THE PROBLEM

Water is a vital resource necessary for the survival of humankind, yet at the same time, it is a scarce commodity greatly taken for granted by many. The scarcity of water may appear at contrast with the fact that water (in liquid form) covers approximately seventy percent of the earth's surface (i.e. oceans, rivers, lakes). However, only a small proportion, "…just under 1% of the total" water supply, constitutes fresh drinking water (Davies, et al, 1998:23).

Without clean water, all life would cease to exist as plants, animals and people rely on water for survival, because it provides nourishment and facilitates the transport of oxygen within living cells. Access to piped water resources provide so much convenience to modern man, evidenced in household uses, such as bathing, sanitation, laundry and gardening; in industrial and commercial ventures, such as mining, paper mills, car washes, producing electricity and manufacturing.

Water undisputedly plays a vital role within the ecosystem, for example, by carrying dissolved chemicals, eroding hard insoluble rocks (thereby shaping the landscape), driving our weather systems; while in society, piped water aids industry in production processes and is used by households in consumption. Not only is water consumed as drinking water or used in cooking, but it is also used for recreational activities, for example swimming, windsailing, water-skiing.

The ability to obtain water at the turn of a tap has left most people unaware of the enormity of the crisis facing mankind with regard to its scarce water resources. Water pollution only compounds the problem, limiting the use of water for drinking, recreation, etc. Changing weather patterns (attributed to the depletion of the ozone layer) and the natural distribution of water resources, negatively affects the supply of fresh water worldwide. The population explosion contributes to the increased demand for natural resources, which has done little to alleviate this situation.

Yet, even confronted with potential shortage of water resources, man inconceivably is his own worst enemy. Man's innate inclinations have always been self-gratifying, often at the expense of the environment and future generations. As science and technology have improved over the past decades, so too did man's desires and needs, resulting in more and new stresses being placed on the relatively scarce resources. These expansionary changes have resulted in increased urbanisation that requires countries to construct extensive water-supply schemes to pipe water to densely populated cities located far away from rural areas, this consequently alters the ecosystem of rivers.

This disregard is engendered in the destruction of water quality (suitability of water for consumption) and thus limiting even further the supply of fresh drinking water. To this end, man has through the years, played a major role in the degradation of water resources, which is more commonly termed pollution. Water pollution can take on many forms, from the obviously visible (litter) to the less visible (organisms), but often more harmful contaminants. Water pollution implies that fresh water sources are no longer available for consumption without cost, as purification measures would be required for drinking purposes and possible medical costs incurred if polluted water were ingested during recreational activities.

The South African example sees water managers face the daunting task of supplying water to a huge population in a semi-arid region and having to design dams large enough to contend with unpredictable weather patterns, more specifically prolonged droughts. Water managers are also required to ensure that water is fit for use, by following the guidelines established by the governing authority (i.e. DWAF), a necessity due to the negative effects of water pollution. Effective management is the tool to achieving sustainable water resources by focusing both on ensuring that water is fit for use as well as allowing for use and development. This is achieved by balancing socio-economic development and environmental protection. From a regulatory point of view the "business" of water quality management entails the ongoing process of planning, development, implementation and administration of water quality management policy, the authorisation of water uses that may have, or may potentially have, an impact on water quality, as well as the monitoring and auditing of the aforementioned (http://www.dwaf.gov.za).

Water pollution arises through the behaviour of members of society and is influenced by socio-economic factors. The legacies of the past have filtered into all aspects of life, whether socially or economically. The high unemployment levels so often encountered in remote rural villages and small towns have seen an influx of job seekers to city centres. These increased migratory practices from traditionally black rural areas to urbanised cities and towns have left Provincial Authorities hard pressed to find suitable housing. The inability or lack of speed in providing housing (in formal residential areas) has resulted in informal settlements sprouting up on vacant land; this is especially prevalent in developing countries.

These situations are manifested along the banks of most of South Africa's rivers, for example, the Mzimvubu River in the old Transkei is an area characterised by a large number of small settlements where the majority of the people have no access to treated water for domestic use and sanitation infrastructure (van Niekerk, 2000:16). Similarly, informal settlements have sprouted along the Olifants River (Northern Province), Sand River (North West) and Elands River (Free State/Gauteng/Mpumulanga), to name but a few, contributing to the high pollutant levels (van Niekerk, 2000:16). As this phenomenon is of consequence on a national level and not only isolated to selected areas in South Africa, the likelihood of water sources being negatively affected is probable, especially in light of water shortages encountered in the Western Cape.

The Western Cape has just recently had water restrictions lifted, following a period of minimal rainfall that left water in reservoirs at critically low levels. This situation is amplified because Cape Town has virtually nowhere to store its rainwater and consequently relies on importing the greater part of it from rivers outside the city and environs. Other parts of the country have similarly oscillated between periods of drought and rainfall over the past decades, these include KwaZulu-Natal and the Free State in 1987, the southern and Eastern Cape and northern KwaZulu-Natal in 1993, the Western Cape in 1994 and the southern Cape in 1996 (Davies, et al, 1998:3).

Within the Cape Metropolitan area, most of the rivers (such as the Liesbeek- and Black – Rivers in Cape Town) are located in highly urbanised areas and have been canalised in parts. The canalisation of rivers was deemed necessary in order to counter the problem of flooding during heavy rainfall periods (a consequence of soil hardening due to urbanisation). Canalisation though, impacts upon the natural functioning of the river and causes it to operate more as a stormwater drain, a factor contributing towards the degradation of the river's ecosystem.

The Lotus River is another example, having undergone extensive canalisation over time, which has contributed towards its function as a stormwater drainage system. In addition, housing (both formal and informal in nature) are located along the banks of the river before flowing into Zeekoevlei, a shallow lake used for recreational activities all year round. Housing is not the sole source of pollution however, as both farming and industrial activities are major contributors.[1] Agricultural activities are heavily reliant on water; consequently, farms were established in prime locations along riverbanks in certain regions. Certain industries (such as those involved in manufacturing, mining, service and electricity) encroached even further on these natural water resources by using them in production processes, as well as for the disposal of effluent. These activities reveal the failure to consider the ecological impact on the environment and costs to future generations because of the degradation of water quality.

[1] The reaches of the Eerste- and Plankenberg -Rivers (Helderberg Municipality, Western Cape) are similarly dotted with settlements, farming operations and industries before entering the ocean.

These extenuating factors strengthen the case for considering the impact of water pollution in the Lotus River and Zeekoevlei.

1.2 OBJECTIVES OF THE RESEARCH PAPER

- To provide a theoretical framework for the analysis of water pollution as a negative externality;
- To explain the various policy options available to government to internalise the external costs;
- To investigate the problem of water pollution in South Africa and specifically in the catchment of the Lotus River in the Western Cape;
- To investigate various coping strategies in other countries in order to derive lessons for South African water managers.

1.3 METHODOLOGY AND STRUCTURE

The research methodology applied in this report is descriptive and analytical, involving qualitative reasoning. This is achieved through conducting a literature review of water pollution encountered both locally and internationally. Then, using utility maximisation theory, to theoretically model the economic impact of water pollution. Finally, constructing a case study of the Lotus River Catchment located within the Cape Metropolitan Area (CMA) (after surveying South African rivers).

The report is structured as follows: Chapter Two provides a general overview of water pollution encountered globally and focuses on aspects of identification and classification. This chapter further strives to find the link between upstream users of water bodies (i.e. rivers) and the negative spillover effects (externality) that downstream users face, achieved through analysing market failure within a theoretical framework and providing the solutions available to government in addressing the problem. In Chapter Three, the focus shifts to a general assessment of water pollution in South Africa and the Cape

Metropolitan Area, where the specific case of the Lotus River Catchment is examined; the characteristic features of the catchment is outlined, as well as the urban dynamics and pollutants affecting end users. Finally, Chapter Four provides suggestions of various economic policy options and coping strategies available to authorities after reviewing what's done in other countries. Chapter Five concludes.

CHAPTER TWO: A THEORETICAL ANALYSIS OF WATER POLLUTION, THE RESULTANT MARKET FAILURE AND THE ROLE OF GOVERNMENT

2.1 INTRODUCTION

Water pollution in essence is the altering (whether physically or chemically) of the features of water often to the detriment of its inhabitants or users, whether human, animal or plant life. As pollution is viewed differently by the natural and behavioural sciences (see Section 2.2), a clear definition of pollution is required, which may broadly encompass these views. This chapter therefore focuses on water pollution from an international perspective. It identifies and classifies water pollution by considering the sources of pollutants, as well as their causes and effects on the environment. As pollution is a negative external effect (externality), a theoretical explanation of market failure is provided and possible solutions for redress are identified.

Section 2.2 defines pollution, as well as water pollution. Then Section 2.3 highlights the sources of water pollutants by distinguishing between point-source and diffuse source pollution, while Section 2.4 focuses on the causes and effects of pollution on water quality. Section 2.5 identifies water pollution as a negative externality and discusses the possible solutions available to remedy the problem. Finally, Section 2.6 summarises and concludes.

2.2 DEFINING POLLUTION

The word pollution generally conjures up the mental picture of students busy with a clean-up campaign removing unsightly litter along riverbanks or marine life killed off by oil spills. Pollution is much more than this and depending on the angle of the research, natural -and behavioural- scientists hold different viewpoints. The natural sciences focus on the physical and chemical alteration of the environment. In the behavioural sciences, economists additionally consider the secondary impact on the well being of users and producers.

According to Chenje, et al (1996:125), "pollution is the degradation of natural systems by the addition of detrimental substances such as sewage, heavy metals, pesticides and detergents". This clearly indicates that pollution can take on many forms, from the obviously visible (litter) to the less visible (organisms), but often more harmful contaminants. A more comprehensive definition of pollution is thus necessary. One such definition as cited by Coetzee (1995:248), is "the introduction, by man, into the environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structure or amenity or interference with legitimate uses of the environment" (Mason 1990). This definition therefore identifies the role of man in generating pollution and its impact on all living organisms.

Water pollution refers to the altering of the physical or chemical properties of water resources (Pegram, et al, 2001:11). In the natural sciences, water pollution involves the discharge of foreign substances (i.e. sewage, heavy metals, pesticides, litter and oils, etc.) into lakes, rivers, etc., altering the functioning of the ecosystem. In economics, it also considers that water pollution adversely affects societies well-being or agricultural production.

2.3 THE SOURCES OF WATER POLLUTANTS

Before assessing the degree to which pollution impacts on water quality, the various sources of water pollution are identified.

2.3.1 Point-Source Pollution

Point-source pollution according to Spulber, et al (1998:80) is pollutants that "…enter pollution transport routes at discrete, identifiable locations…" while Hanley, et al

(2001:239), identifies it as "…emissions, which enter waterbodies from an easy-to-identify single source…" Thus, if the source discharges through a storm-water drain at a single known location, such as an industry or water treatment works, then it is a point source. Actual emissions into water bodies are therefore more easily measurable as they emanate from a single point of entry. Examples include the disposal of effluent into lakes or rivers by factories, the emission of fluids and sewage by waste treatment plants, the spillage of toxic chemicals by manufacturing industries such as pulp-and-paper mills and textile factories, and oil leaks or spills arising from production or its transportation and use.

2.3.2 Non-point/Diffuse Source Pollution

Non-point sources of pollution "…enters waterbodies in a diffuse manner…" (Hanley, et al, 2001:239), also therefore identified as "diffuse sources" and refers to those discharges from flows "…distributed over or through the land surface" (Huber, 1993 as cited in Grobicki, et al, 2001:108), such as surface runoff (farming or household effluent), drainage, atmospheric pollution and seepage from mining. The diffuse nature of emissions into water bodies makes measurement extremely difficult, as they are not emanating from a single point of entry. Examples include, surface runoff originating from households such as washings from vegetable and animal products, swimming pool discharges, oils and fuel, building rubble; agricultural runoff such as fertilizers and pesticides, which also contaminates groundwater aquifers; atmospheric pollution in the form of acid rain; and chemically toxic seepage water from mines.

2.4 THE CAUSES AND EFFECTS OF POLLUTION ON WATER QUALITY

The term 'water quality' is technically of human origin and considers the suitability of water for the functioning of the aquatic environment and human uses, i.e. its fitness for use as drinking water, as well as for agricultural and industrial purposes. Water pollution alters the quality of water therefore the ensuing discussion focuses on the causes of some of these contaminants, whether organic or inorganic in nature.[2] The contamination of freshwater bodies can mainly be attributed to industrial effluent, agricultural run-off, and the discharge of untreated waste, consequences of industrial expansion and urbanisation. The quality of surface waters (dams, lakes, rivers, etc.) not only influences human consumption in the form of ingestion (by drinking water), but also its use for recreational purposes. Polluted water consequently can have disastrous effects on human health, aquatic life and economic sectors (such as agriculture, industry, etc.), because deteriorating water quality necessitates increased treatment costs to make water fit for use, and potentially decreases agricultural yields. This therefore emphasises the importance of considering the effects water pollution has upon aquatic ecosystems and all life forms. The next section provides a more detailed discussion on the causes and impact of water pollutants in waterbodies.

2.4.1 Temperature:

Industries and nuclear power plants discharge heated water into the ecosystem causing thermal pollution. Scientifically, this discharge of heated water into dams or rivers raises the temperature levels of the water, thereby reducing the dissolved oxygen content, while promoting faster growth of organisms. This potentially influences the animals and plant life living within close proximity to the polluted water; for example, animals with relatively short life cycles will grow more quickly, possibly affecting the food chain (Davies, et al, 1998:180). Temperature may thus significantly impact on aquatic biota (living organisms) and other contaminants, such as ammonia (Pegram, et al, 2001:14). The latter turns toxic to aquatic organisms when exposed to high temperatures (Ecobe EMS, 2001:9).

Alternatively, occurrences such as afforestation, stream regulation by dams or alterations in vegetation cover along the banks of streams and rivers may conversely, lower temperatures (Davies, et al, 1998:180; Pegram, et al, 2001:14). By contrast, these lowered

[2] Organic compounds are products of living things, while inorganic compounds are produced by non-living natural processes or by human intervention in the laboratory (Berger, 2000).

temperatures (even though better facilitating absorption of oxygen) result in lower metabolic rates, which reduce the speed of animal movement, while slowing down the rate of growth of organisms (i.e. increased time to maturity and rate of egg production) (Davies, et al, 1998:179). The impact upon human use is unknown and thus rules out economic quantification.

2.4.2 Sediment:

"Sediment is mineral and organic matter that is eroded and washed off the land surface by storms and wind" (Pegram, et al, 2001:12), which gives rise to suspended sand and silt particles at the bottom of lakes. Sedimentation is a diffuse source of pollution occurring in surface water that negatively affects most water users. Increased erosion occurs when the vegetation cover is disturbed, such as agricultural crops and construction sites in urban areas, uncontrolled fires and dredging of harbours or rivers. These sediments may carry adsorbed pesticides, fertilisers, heavy metals and toxic matter into rivers or lakes.

Sediments in suspension "contribute to turbidity", the "murky appearance of water" (Davies, et al, 1998:180) and affect the functioning and productivity of aquatic systems by decreasing the light penetration for aquatic plants dependent on photosynthesis, interfering with feeding habits and smothering aquatic organisms. Sedimentation of lakes and rivers decreases the lake's storage capacity and increases the flooding of riverbanks (Pegram, et al, 2001:12). Chenje, et al (1996:139) cites the Malawian example, where "…increasing silt loads have caused rivers to meander more than usual and to flood their banks more often, washing away riverbank crops". Turbidity and sedimentation also reduces the recreational opportunities available to society and raises the economic costs (loss of revenue, clean-up costs) when these facilities are utilised for swimming and other water-based sports. The presence of toxins and pesticides in sediment also negatively impacts upon health (for a more detailed discussion on health impacts, see Appendix A2.1).

2.4.3 Nutrients:

Nutrients are those chemicals required for plant growth and reproduction, (Davies, et al, 1998:191). Nitrogen and phosphorus are two such nutrients that strongly encourage growth in freshwater ecosystems. Generally, high concentrations of nutrients are not toxic to organisms; the exceptions are nitrates, these are "…end products of the aerobic stabilization of organic nitrogen…" nitrite, "…a naturally occurring anion…" and ammonia, a gas, chemically found in "…free, un-ionized form (NH3) or as ammonium ions (NH4+)…" (Ecobe EMS, 2001:9). Ammonia is a common pollutant associated with sewage and industrial effluents. Fertilisers used by farmers and manure from livestock operations are nutrient rich and the excess nutrients either leach into groundwater or wash off during rainfall (i.e. surface runoff) into rivers or lakes. According to Jeffries & Mills, (1990) as cited by Coetzee, (1995:252) "many domestic and industrial detergents contain significant levels of nutrients, specifically phosphorus".

Nutrient loads such as excessive phosphorus levels stimulate plant production and "…contribute to excessive algal blooms"; therefore, regarded as the "limiting nutrient" of "fresh water systems" (Pegram, et al, 2001:12). Fertilisers affect surface water by causing "…nutrient enrichment (i.e. eutrophication)…" (Davies, et al, 1998:191), which has a myriad of impacts, arising from divergent views. The aesthetic impacts are based on the external (for example, disagreeable tastes and odours in drinking water, unsightly scum); where recreational impacts on users may for example result in decreased recreational use, limited access to waterways so limiting sports such as skiing and yachting. The ecological impacts of eutrophication include decaying algae that release toxins causing mortality in animals; impact on human health (e.g. morbidity and mortality if water treatment is inadequate) (see Appendix A2.1); and economic impacts (e.g. increased water treatment costs, livestock losses and corrective action costs from health impacts) (DWAF, unknown-a: 9-10).

2.4.4 Pathogens:

Pathogens (i.e. agents causing disease) such as E.coli (faecal coliforms) attach to particulate matter and are so transported through the environment (much like sediments), (Pegram, et al, 2001:12). The die-off rate varies from less than a day to a couple of weeks, depending on external factors such as higher temperatures and solar radiation. These contaminants arise from human and animal activities near and around water bodies, from sources such as urban runoff, inadequate sanitation infrastructure or treatment of municipal sewage, and livestock grazing and waste disposal sites.

Pathogenic bacteria in surface waters pose a health risk to people using the resource for recreation or domestic purposes (Pegram, et al, 2001:12). For example, Stevenson (1953) and Cheung, et al, (1991) notes, "swimmers in polluted water are exposed to significantly higher risks of contracting swimming-associated ear, eye, skin and gastro-intestinal illness" (Harding, 1994:235). It also renders water unsuitable for use in the irrigation of crops for consumption and irrigation of land for dairy cow grazing. Exposure to these bacteria has health impacts (e.g. diarrhoea, dysentery, cholera and typhoid) (see Appendix A2.1), recreational impacts (e.g. reduced recreational use such as swimming and water sports) and economic impacts (e.g. potential loss of revenue, clean-up costs and medical costs incurred to remedy health effects).

2.4.5 Litter:

Urban litter such as tin cans, newspapers, plastic bags, discarded batteries (containing chemicals and metals), car parts and construction rubble accumulates in roads, parking lots, vacant fields, etc., where it remains until removed or dispersed by the wind or stormwater runoff into the drainage system (Armitage, et al, 2000:181). Littering arises from refuse bin spillovers, dumping grounds and a lack of sanitation facilities.

Litter (visible rubble) when left unattended may be transported along via conduits, rivers and lakes until it reaches the open sea. Entanglement with the vegetation along the banks of these water bodies occurs, necessitating costly clean-up operations (i.e. economic impacts). Other impacts on society include aesthetic impacts (e.g. unsightly dumps) and health impacts (e.g. decaying contents of discarded cans and bottles, pathogens attached to discarded hypodermic needles) (Armitage, et al, 2000:181). Scientific impacts include for example, impaired functioning of the aquatic environment, because litter "does not biodegrade easily and is potentially harmful to fish and birds if mistakenly ingested and/or animals become entrapped" (Ecobe EMS, 2001:12). Most of these impacts are quantifiable in terms of economic costs (e.g. loss in property valuations, medical costs to regain health, and measures for litter removal).

Having identified the contaminants of water pollution and their resultant impact on water quality and the environment, the subsequent section links the harmful effects of water pollution to the economic concept of externalities (spill-over effects).

2.5 WATER POLLUTION AS A NEGATIVE EXTERNALITY

The expression, 'no man is an island', holds true in that not only is man incapable of surviving alone, but also its actions have far-reaching effects. Engaging in the consumption of goods and services and alternatively, the production processes to produce goods, results in contamination of water resources (see Section 2.4). For example, farmers cultivating crops upstream, make use of fertilisers that are nutrient-rich. During heavy rainfall periods agricultural runoff occurs raising the pollutant load of the rivers or streams. This water pollution negatively impacts upon all users of these vital resources, therefore it is likely that the actions of inhabitants living or working further upstream in densely populated areas, negatively impacts on the usage of the river by downstream users. In technical terms, these spillover effects of consumption and production activities by individuals or society as a whole, on others, are called externalities.

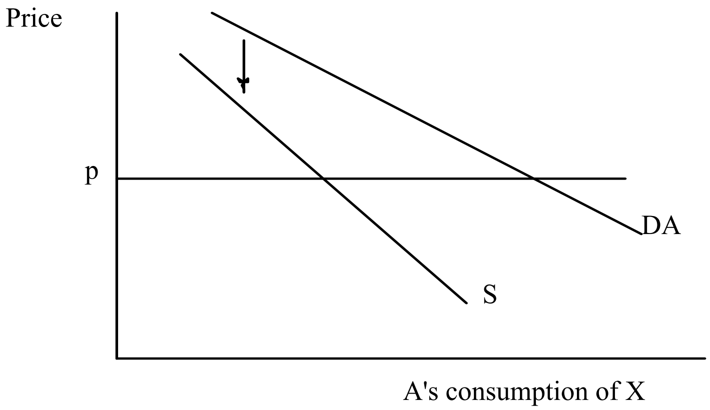
2.5.1 Market Failure

According to economic theory, when the actions of the individual consumer or producer affect not only himself/herself but others as well, this spillover effect is called an externality. Some citations include those subsequently recorded by Brown and Jackson (unknown:31), which notes that "an externality arises when the production or consumption activities of one party enters directly as an argument into the production or utility function of another party". Arrow (1969), as cited by Hanley, et al, (1997:29) states, "the externality is the classic special case of incomplete markets for an environmental asset". This points to the fact that markets fail due to a lack of acknowledging the impact of external effects on society, rendering the markets incomplete. These external effects can be either negative or positive in nature, imposing unintentional costs or benefits on other parties. They are technological when they have a direct effect on the level of production or consumption of the other party and pecuniary when they change the demand and supply conditions, hence the market prices facing the other party, while not altering the technical possibilities of production or consumption (Black, et al., 2005:37; Brown and Jackson, unknown:31).

An externality exists when the market price or cost of production excludes its social impact, cost or benefit (Hanley, et al., 2001:17), driving a wedge between private and social (i.e. the sum of private and external) costs and benefits, resulting in inefficiency (Connolly and Munro, 1999:73). From a societal point of view if these external effects are not taken into consideration, the distribution of consumption among individuals will not be optimally achieved, resulting in market failure because too much is produced or consumed at too low a price. In principle, one should be able to calculate how much the affected individuals would be willing to pay to have others reduce their consumption of those goods and/or services that caused negative externalities. However, these are not always possible, practically.

The ensuing focus utilises graphical analysis as the necessary tool to examine the negative externalities arising from consumption and production activities.

Figure 2.1 Negative Consumption Externality



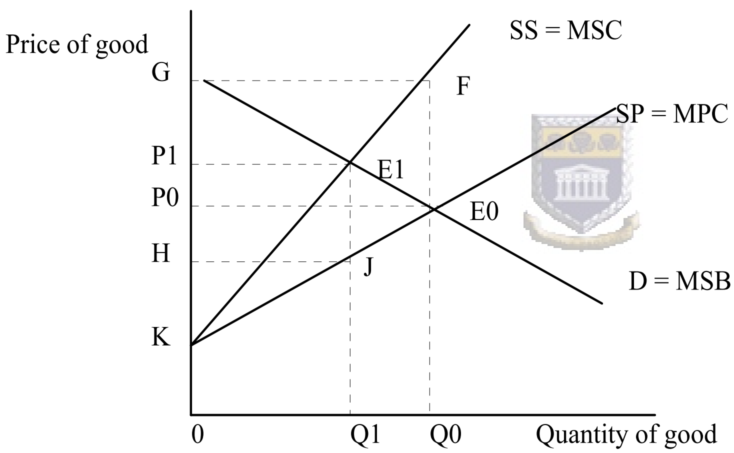
(Source: Bohm, 1991:30:2.6)

Figure 2.1, above, provides a graphical depiction of the case in which individual A's consumption of a good creates a negative external effect. As a result, the societal valuation by all consumers (S) of the marginal increase in A's consumption of the good is less than A's evaluation (which does not take cognisance of its impact on others); therefore S lies below A's demand curve (D_A), (Bohm, 1991:29). The consumption activities of consumers therefore having a negative external effect, where marginal external benefits are less than zero and marginal private benefit (private demand) is greater than the marginal social benefit (social demand) (Black, et al, 2005:37). This implies that the volume of consumption will exceed the social optimum under negative external effects. In other words, this leads to over-provision and over-pricing of goods and services when negative externalities arise within competitive markets.

Linking water pollution to this negative consumption externality is best described through the following example. Residents of urban settlements (whether formal or informal) engage in consumption of goods and services daily. Their actions produce pollutants into the river, such as litter discarded in the streets, grey water from bathing, nutrients from washing powders, etc. These pollutants impact on other parties using the water body, therefore satisfying the definition of externalities.

In Figure 2.2 below, a graphical depiction of a negative externality arising from production processes is provided. In the absence of externalities the market optimum would occur at Q_0 where the private demand- and supply -curves intersect at E_0, as motivated by profit-maximising principles. Capturing the negative externality, raises the marginal social costs (MSC) above the marginal private costs (MPC), where MSC is MPC plus marginal damage, consequently the social optimum occurs at Q_1 (Rosen, 1995:94). This is because society holds the view that efficient production occurs where marginal social benefit (MSB) exceeds MSC. From a social perspective, "the presence of a negative production externality in a competitive market causes inefficiency in the form of over-provision and under-pricing of the good in question" (Black, et al, 2005:38).

Figure 2.2 Negative Production Externality



(Source: Black, et al, 2005:38:3.3 (adapted))

Externalities thus influence the decisions of producers and consumers, delivering a level of resource allocation that differs from that which the perfectly competitive market would have produced in the absence of external effects (Brown and Jackson, unknown:31; Bohm, 1991:25).

Water pollution can also be likened to a production externality, as the production processes engaged in by industries produces effluent containing toxins and acids. These alter the quality of water so that other parties using the resource are negatively impacted upon. In other words, the actions of the producer influence the consumption of another party.

Alternatively, negative externalities can be expressed algebraically, where use will be made of the assumptions upheld within utility maximisation theory. This viewpoint is based upon the notion that utility is derived from gaining pleasure and avoiding pain, which translates into the fact that there are benefits to be derived from gaining positive external effects and avoiding the negative ones. A revised definition of externality, as cited by Hanley, et al (1997:29) states that an external effect exists “if the consumption or production activities of one individual or firm affect another person’s utility or firm’s production function so that the conditions of a Pareto optimal resource allocation are violated”. This violation of efficiency conditions is shown in the discussion where a consumption model is constructed for the catchment (See Appendix A2.2).

2.5.2 Public Solutions to the Externality Problem

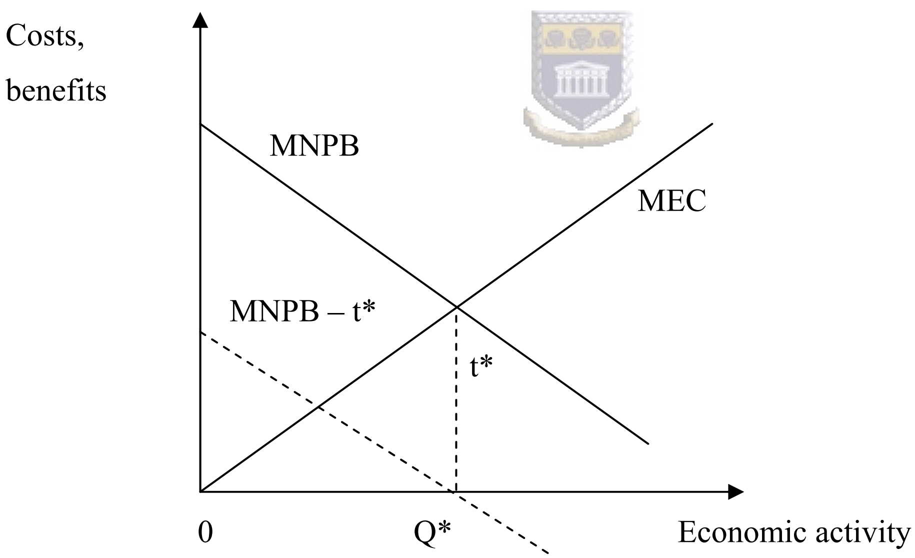
It is unlikely that the externality will be captured within the perfectly competitive market, except where mergers between polluter- and pollutee -firms arise or social conventions influence consumer behaviour. As a consequence, this market failure needs to be addressed by the public sector. Governments can intervene in order to address these allocative inefficiencies by using the following measures at their disposal, namely taxation, subsidies, regulation, the establishment of property rights and creation of markets.

2.5.2.1 Taxation

Taxation operates through a modification of relative prices and may be imposed on the level of inputs or on levels of emissions. A tax on emissions eliminates the wedge (created by pollution) between the private and socially optimal prices. Use is made of Pigouvian taxes as the necessary means of internalising the externality, which forces “…parties to include the external effects of their actions in their cost and benefit calculations" (Black, et al, 2005:40), thus establishing a suitable manner of equating private and social costs.

As previously stated, a negative production externality leads to the over-provision and under-pricing of the good in question. Thus, by levying a Pigouvian tax on the polluter it enables government to align the marginal private costs with the marginal social costs, i.e. increasing private costs to the level of social costs (Connolly and Munro, 1999:79; Rosen, 1995:99). With reference to Figure 2.2 in Section 2.5.1, a tax equivalent to E_0F at Q_0 is levied on the price charged; this raises MPC by the level of external damage to MSC. Equilibrium is re-established at E_1 where MSC equals MSB. At Q_1 the ad valorem tax equals JE_1, which is also the marginal external cost, internalising the externality to KJE_1. The net effect, a large portion of the original externality is eliminated.[3]

Figure 2.3 The Optimal Pollution Tax.



(Source: Pearce, et al, 1990:86:6.1)

As per Figure 2.3, a Pigouvian tax (t*) is imposed on each unit of the level of activity creating pollution, shifting the Marginal Net Private Benefit (MNPB) curve towards the

[3] The analysis is based upon the discussion outlined in Black, et al (2004).

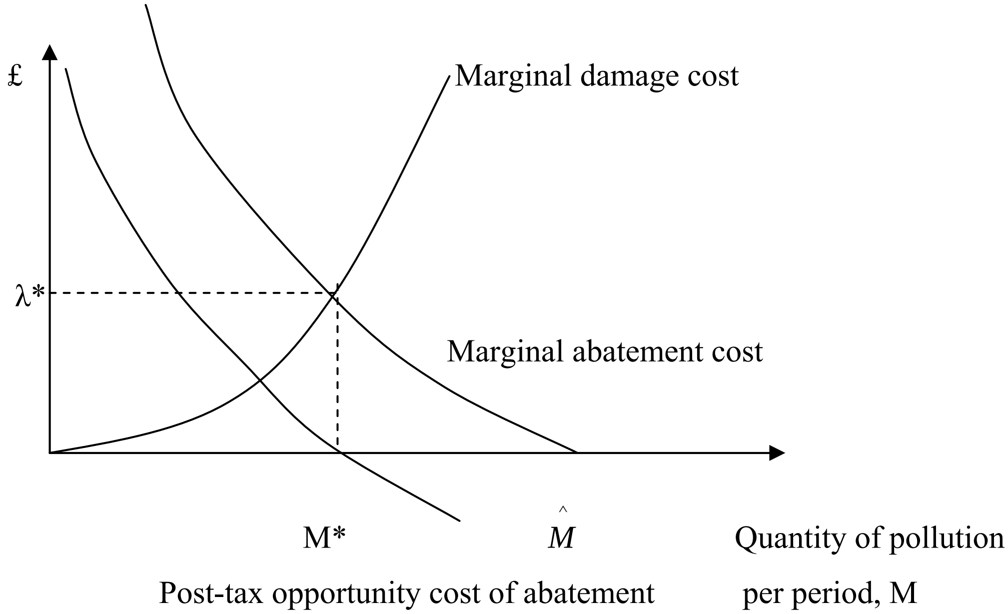
left (MNPB - t*). The post-tax marginal benefit schedule differs from its pre-tax counterpart by the value of marginal damage (also known as the Marginal Economic Cost (MEC)). Maximising net private benefits subject to the tax occurs at Q*. Tax t* is thus an optimal Pigouvian tax equal to the MEC at the optimal level of pollution (Pearce, et al 1990:85).

From a theoretical perspective Pigouvian taxes are an efficient tool towards achieving socially efficient optimality, should all external damages be known. However, Hanley, et al, (2001:30) states that taxes have been set too low, thus failing to induce people to significantly increase pollution abatement or environmental protection. Information gathering to achieve the desired effect is a costly exercise and this then paved the way for the establishment of property rights and negotiations as an alternative measure (see discussion on Coase Theorem in Section 2.5.2.4).

2.5.2.2 Abatement subsidies

Subsidies (in the form of grants, loans and tax allowances) may be offered to polluters as an incentive to reduce pollution through lower effluent discharges or "…to mitigate the economic impact of regulations by helping firms meet compliance costs" (Hanley, et al, 1997:72). Here the analysis changes in terms of viewing the problem from the perspective of abatement rather than level of pollution. It achieves much the same outcome as taxation, "this is because a subsidy for not polluting is simply another method of raising the polluter's effective production cost" (Rosen, 1995:101). According to Pearce, et al, (1990:108), this results in raising the marginal cost, because "as the firm expands output, it foregoes a subsidy which it could get by pollution reduction".

Figure 2.4 The Effect of an Emissions Tax on Marginal Abatement Costs.



(Source: Perman, et al, 1999:308:12.4)

In Figure 2.4, in the absence of an abatement subsidy, firms lack incentive to abate pollution. Satisfying profit-maximising behaviour, zero abatement is recorded at pollution level $\hat{M}$. This changes when an abatement subsidy is made available, as an incentive to abate exists by gaining the subsidy, which is considered, as long as it remains profitable (i.e. Marginal abatement costs being less than the subsidy per unit of emission abated). If the subsidy is granted at level of λ*, then a pollution level of M* is attained, lower than the initial level of $\hat{M}$.[4]

2.5.2.3 Regulation

Regulation, as a policy measure, focuses on the use of legislation to achieve desired pollution levels. This is where for example, each polluter is commanded to reduce their pollution to certain levels to avoid legal sanctions or specific production processes may

[4] Analysis based on Perman, et al (1999).

be banned. Using Figure 2.4, this implies that government will prohibit the polluter, via the setting of standards, from producing at any other level exceeding M*, the socially efficient output (Black, et al, 2005:40; Rosen, 1995:106; Pearce, et al, 1990:103). However, the socially efficient outcome may not be guaranteed as standard setting implies full knowledge of cost and benefit information, as well as requiring the institution of a monitoring agency to oversee polluters' activities and enforce penalties.

2.5.2.4 Property Rights

Property rights are those legal rights of ownership assigned to individuals, granting them the right to exclude others from enjoying the benefits that the commodity (property) provides. The lack of adequately defined property rights, according to Ronald Coase, is the main reason for divergence between marginal private cost and marginal social cost. The Coase theorem, as cited by Black, et al (2005:42) states, "market incentives will generate a mutually beneficial exchange of property rights through which externalities can be fully internalised, provided that property rights are well defined and enforceable and transaction costs are negligible".

If transactions costs are minimal then a bargaining solution will produce an efficient outcome. However, in the case of non-depletable externalities (where one person's consumption of the externality does not diminish another agent's ability to suffer from the externality) the bargaining costs are likely to be high because of the large number of people involved needing to reach an agreement and the possibility of free-riding by consumers (Connolly and Munro, 1999:77). The role of government is therefore primarily limited to the judicial system by virtue of defining and enforcing property rights, as well as creating a market for lowering transactions costs.

2.5.2.5 Creation of markets

Governments can create markets for the relevant resource experiencing inefficiencies in the form of externalities, by enhancing efficiency through the sale of pollution permits. This implies that markets for clean resources (water, air) are created that would not otherwise have existed. Via a bidding process, the highest bidding firm procures the right to pollute. The fee charged is set at the market-clearing level, in other words "…so the amount of pollution equals the level set by the government" (Rosen, 1995:103; Hanley, et al, 2001:30). These pollution permits are also known as effluent fees.

With reference to Figure 2.2, the area KJE_1 reflects the efficient level of pollution identified by government. A limited number of pollution permits would be sold to the highest bidder. These effluent fees equal to JE_1, is set at the level, which clears the market (output Q_1). The unwillingness of producers to pay effluent fees, only leaves them recourse to shift to cleaner technologies or lower output (Black, et al, 2005:42)

2.6 SUMMARY AND CONCLUSIONS

In summary, water pollution by definition alters the quality of surface waters, negatively impacting upon the environment and all users, whether plant, animal or human. It originates from different sources, ranging from a stipulated, fixed point to diffuse sources over the land surface. The causes of water pollution are attributed to the direct or indirect actions of individuals, which affect all life forms using the resources. This impact on others resulting from the actions of producers and consumers is likened to the economic problem of externalities, a form of market failure. The analysis reinforces the need for addressing this environmental problem within society, with solutions to the water pollution problem being sought within the ambit of economics, suggesting measures such as taxation, subsidies, regulation, etc.

The need for effective management of scarce water resources is amplified, due to the negative impact of water pollution on the environment and consumptive uses.

Taking into account the significance of the water pollution problem, the following chapter assesses the situation in South Africa and specifically focuses on the Lotus River Catchment in the CMA.

APPENDIX 2

A2.1 Health Impacts of Water Pollution

"Water-borne diseases are infectious diseases spread primarily through contaminated water. Though these diseases are spread either directly or through flies or filth, water is the chief medium for spread of these diseases and hence they are termed as water-borne diseases.

Most intestinal (enteric) diseases are infectious and are transmitted through faecal waste. Pathogens - which include virus, bacteria, protozoa, and parasitic worms - are disease-producing agents found in the faeces of infected persons. These diseases are more prevalent in areas with poor sanitary conditions. These pathogens travel through water sources and interfuses directly through persons handling food and water. Since these diseases are highly infectious, extreme care and hygiene should be maintained by people looking after an infected patient. Hepatitis, cholera, dysentery, and typhoid are the more common water-borne diseases that affect large populations in the tropical regions.

A large number of chemicals that either exist naturally in the land or are added due to human activity dissolve in the water, thereby contaminating it and leading to various diseases.

Pesticides. The organophosphates and the carbonates present in pesticides affect and damage the nervous system and can cause cancer. Some of the pesticides contain carcinogens that exceed recommended levels. They contain chlorides that cause reproductive and endocrinal damage.

Lead. Lead is hazardous to health as it accumulates in the body and affects the central nervous system. Children and pregnant women are most at risk.

Fluoride. Excess fluorides can cause yellowing of the teeth and damage to the spinal cord and other crippling diseases.

Nitrates. Drinking water that gets contaminated with nitrates can prove fatal especially to infants that drink formula milk as it restricts the amount of oxygen that reaches the brain causing the 'blue baby' syndrome. It is also linked to digestive tract cancers. It causes algae to bloom resulting in eutrophication in surface water.

Petrochemicals. Benzene and other petrochemicals can cause cancer even at low exposure levels.

Chlorinated solvents. These are linked to reproduction disorders and to some cancers.

Arsenic. Arsenic poisoning through water can cause liver and nervous system damage, vascular diseases and also skin cancer.

Other heavy metals. Heavy metals cause damage to the nervous system and the kidney, and other metabolic disruptions.

Salts. It makes the fresh water unusable for drinking and irrigation purposes.

Exposure to polluted water can cause diarrhoea, skin irritation, respiratory problems, and other diseases, depending on the pollutant that is in the water body. Stagnant water and other untreated water provide a habitat for the mosquito and a host of other parasites and insects that cause a large number of diseases."

(Source: http://edugreen.teri.res.in/explore/water/health.htm)

A2.2 A Consumption Model with specific reference to the Lotus River Catchment

In this section, the researcher attempts to illustrate the implications for an efficient outcome if negative consumption externalities are not considered. A theoretical model is used to demonstrate the impact on efficiency when consumers maximise utility but only consider their private benefits and costs. The model construct is based on the specific externality problem experienced in the Lotus River catchment, as outlined in section 3.3.

A. Assumptions of the model

To make the analysis easier, some simplifying assumptions are needed:

- There are two consumers (A and B) and two goods, Q_1 (all goods not contributing to waste) and Q_2 (waste producing goods).
- There is also a constant total supply of each of the two goods.
- The third good included in the analysis is recreation (Q_3).
- Both consumers consume all three goods.
- There is also a functional relationship between recreation (Q_3) and the waste producing goods (Q_2).

Incorporating an assumed unidirectional negative consumption externality (i.e. pollution - Ψ) into the utility functions of our two individuals, implies that the utility of consumer B (the downstream user), is influenced by the consumption of waste producing goods by consumer A (an upstream user), while consumer A's utility is only affected by his own consumption. It is acknowledged that an externality arises from both individuals' consumption of these waste producing goods, but that individual B's externality by assumption is negligible, i.e. having no impact on other users and is therefore not included as part of the mathematical analysis.

B. Deriving the necessary conditions for Pareto Optimality

The utility functions of the two individuals are as follows:

$$U^A = U^A \quad (Q_1^A, \quad Q_2^A, \quad Q_3^A) \tag{1}$$

$$U^B = U^B \quad (Q_1^B, \quad Q_2^B, \quad Q_3^B) \qquad (2)$$

The socially efficient level of consumption is obtained by maximising the utility of consumer B for a constant level of utility of consumer A. The necessary conditions for Pareto optimality in consumption can be derived as follows:

MAXIMISE $$U^B \; / \; U^A = \overline{U}^A$$

Subject to the following constraints:

$$Q_1^A + Q_1^B = Q_1^0$$

$$Q_2^A + Q_2^B = Q_2^0$$

$$Q_3^A + Q_3^B = Q_3$$

Where $Q^O{}_1$ and $Q^O{}_2$ are the given total supply of the two commodities and Q_3 the total supply of recreation.

Also: $$\Psi = \Psi \quad (Q_2^A) \quad \text{and} \quad \left[\frac{\partial \Psi}{\partial Q_2^A}\right] > 0$$

$$Q_3 = Q_3 \quad (\Psi) \quad \text{and} \quad \left[\frac{\partial Q_3}{\partial \Psi}\right] < 0$$

The latter two equations represent, (i) the functional relationship between pollution and the consumption of waste producing goods by consumer A, and (ii) the relationship between recreation (Q_3) and pollution, respectively. The assumption made, is that as consumer A consumes more of good Q_2, pollution will increase. The increase in pollution however, decreases recreational activities.

This behaviour can be linked to the Lotus River catchment case study. As people increase their consumption of waste-producing goods, they litter in the Lotus Rivers, which causes pollution problems. This in due course affects the recreational activities of individuals further along the river, as well as at Zeekoevlei.

Setting up this constrained maximisation problem by means of the Lagrange function, yields:

$$\begin{aligned} L = U^B(Q_1^B, Q_2^B, Q_3^B) - \lambda_1 (U^A(Q_1^A, Q_2^A, Q_3^A) - \overline{U^A}) - \lambda_2 (Q_3 - Q_3(\Psi)) \\ -\lambda_3 (Q_1^A + Q_1^B - Q_1^O) - \lambda_4 (Q_2^A + Q_2^B - Q_2^O) - \lambda_5 (Q_3^A + Q_3^B - Q_3) \\ -\lambda_6 (\Psi - \Psi(Q_2^A)) \end{aligned} \quad (3)$$

where λ is an unknown so-called Lagrange multiplier.

Differentiating this function with respect to all variables ($Q^B{}_1, Q^B{}_2, Q^B{}_3, Q^A{}_1, Q^A{}_2, Q^A{}_3, Q_3,$ Ψ) and setting these partial derivatives equal to zero, we obtain the necessary conditions for Pareto Optimality.

The First Order Conditions of the maximisation problem are:

$$\frac{\partial L}{\partial Q_1^B} = \frac{\partial U^B}{\partial Q_1^B} - \lambda_3 = 0 \quad \Rightarrow \quad \lambda_3 = \frac{\partial U^B}{\partial Q_1^B} \quad (4)$$

$$\frac{\partial L}{\partial Q_2^B} = \frac{\partial U^B}{\partial Q_2^B} - \lambda_4 = 0 \qquad \Rightarrow \qquad \lambda_4 = \frac{\partial U^B}{\partial Q_2^B} \tag{5}$$

$$\frac{\partial L}{\partial Q_3^B} = \frac{\partial U^B}{\partial Q_3^B} - \lambda_5 = 0 \qquad \Rightarrow \qquad \lambda_5 = \frac{\partial U^B}{\partial Q_3^B} \tag{6}$$

$$\frac{\partial L}{\partial Q_1^A} = -\lambda_1 \frac{\partial U^A}{\partial Q_1^A} - \lambda_3 = 0 \tag{7}$$

$$\frac{\partial L}{\partial Q_2^A} = -\lambda_1 \frac{\partial U^A}{\partial Q_2^A} - \lambda_4 + \lambda_6 \frac{\partial \Psi}{\partial Q_2^A} = 0 \tag{8}$$

$$\frac{\partial L}{\partial Q_3^A} = -\lambda_1 \frac{\partial U^A}{\partial Q_3^A} - \lambda_5 = 0 \tag{9}$$

$$\frac{\partial L}{\partial Q_3} = -\lambda_2 - \lambda_5 = 0 \tag{10}$$

$$\frac{\partial L}{\partial \Psi} = +\lambda_2 \frac{\partial Q_3}{\partial \Psi} - \lambda_6 = 0 \tag{11}$$

Substituting equation (6) into (10),

$$\lambda_2 = \frac{\partial U^B}{\partial Q_3^B} \tag{12}$$

Substituting equation (4) into (7),

$$-\lambda_1 \frac{\partial U^A}{\partial Q_1^A} = \frac{\partial U^B}{\partial Q_1^B} \tag{13}$$

Substituting equation (6) into (9),

$$-\lambda_1 \frac{\partial U^A}{\partial Q_3^A} = \frac{\partial U^B}{\partial Q_3^B} \tag{14}$$

Substituting equation (12) into (11),

$$\lambda_6 = \frac{\partial U^B}{\partial Q_3^B} \times \frac{\partial Q_3}{\partial \Psi} \tag{15}$$

Substituting equations (5) and (15) into (8),

$$-\lambda_1 \frac{\partial U^A}{\partial Q_2^A} = \frac{\partial U^B}{\partial Q_2^B} - \left[\frac{\partial U^B}{\partial Q_3^B} \times \frac{\partial Q_3}{\partial \Psi} \times \frac{\partial \Psi}{\partial Q_2^A} \right] \tag{16}$$

Dividing equation (13) by (14) yields one necessary condition for Pareto Optimality: (by eliminating the lambdas - λ)

$$\frac{\delta U^A / \delta Q_1^A}{\delta U^A / \delta Q_3^A} = \frac{\delta U^B / \delta Q_1^B}{\delta U^B / \delta Q_3^B} \tag{17}$$

Equation (17) reflects the Market Solution under perfect competition, when the externality is not considered. In addition, it reveals the Market Efficiency Model of consumption, where both individuals have maximised their utility for a given income and prices; this too is expressed in equation (17a), which is an abridged version of equation (18) excluding the externality.

$$\frac{\delta U^{A} / \delta Q_1^{A}}{\delta U^{A} / \delta Q_2^{A}} = \frac{\delta U^{B} / \delta Q_1^{B}}{\delta U^{B} / \delta Q_2^{B}} \qquad (17a)$$

By dividing equation (13) by (16) the model yields yet another necessary condition for Pareto Optimality: (by eliminating the lambdas - λ)

$$\frac{\delta U^{A} / \delta Q_1^{A}}{\delta U^{A} / \delta Q_2^{A}} = \frac{\delta U^{B} / \delta Q_1^{B}}{\delta U^{B} / \delta Q_2^{B} - \left[\delta U^{B} / \delta Q_3^{B} \times \delta Q_3 / \delta \psi \times \delta \psi / \delta Q_2^{A} \right]} \qquad (18)$$

However, equation (18) is the Socially Efficient Solution, incorporating the negative externality imposed by individual A's consumption on individual B.

C. Results

In analysing the results of the model it is observed that the utility maximisation of consumer B (users of the recreational facilities in Zeekoevlei) occurs subject to the constant utility of consumer A (consumers of waste producing goods in urban settlements). Core constraints influencing behaviour are found in the constant supply of the two goods in question, namely goods contributing to waste ($Q^{O}{}_{2}$) and those that are not ($Q^{O}{}_{1}$). It is assumed that both consumers enjoy the benefits of recreation (Q_3), but that it is functionally related to the waste producing goods. This indicates that consumption of certain goods give rise to pollution (the externality), which in turn impacts on consumption of other parties (in the form of recreational use). Both consumer A and B consume the waste producing goods, however consumer B is more negatively impacted upon as the downstream user of the vlei.

Comparing the conditions as provided in equations 17 and 18, it is noted that the private market optimum does not equate to the socially optimal solution. The difference is observed in the negative externality being absent from the private market solution. In order to achieve the social efficient solution, we must adjust the market so that the ratio of $U^A{}_1$ / $U^A{}_2$ gets smaller. This implies that the Marginal Utility of Individual A for $Q^A{}_2$ must be increased relative to $Q^A{}_1$. To achieve this, $Q^A{}_2$ (the waste producing goods flowing into the river, due to a lack of sanitation) has to be reduced. It is advocated, that as reducing the use of these goods may not be possible; the alternative option would be achieved via the provision of sanitation as abatement of the pollution.

CHAPTER THREE: WATER POLLUTION IN SOUTH AFRICA IN GENERAL AND IN THE LOTUS RIVER CATCHMENT SPECIFICALLY

3.1 INTRODUCTION

Investigating the problem of water pollution in South African rivers, the enormity of the situation was discovered particularly within urban areas, therefore the researcher decided to focus on the specific case of the Lotus River Catchment in the CMA. The reason for this is that the Lotus River Catchment extends over three municipal areas and is a reflection of urban development within South Africa, which covers a vast array of settlements. A case study analysis is therefore conducted on the Lotus River Catchment in order to evaluate the impact of water pollution.

This chapter focuses on the extent of water pollution in South Africa and the Lotus River Catchment specifically. Section 3.2 outlines the water pollution problem encountered in the country, by considering not only the causes and effects of pollution, but also the extent of the problem. Then, Section 3.3 provides a case study analysis of water pollution in the Lotus River Catchment, where following a brief description of the area, the extent of the problem and its causes are identified. Finally, Section 3.4 summarises and concludes.

3.2 WATER POLLUTION IN SOUTH AFRICA

South Africa is in no way immune to the problems of water pollution, which has negatively impacted on water resources necessary for consumption and production activities. Given the increasing demand for potable water to satisfy a growing population, water demand management has become crucially vital, and by extension, the need to focus on addressing causes of water pollution.

The National Water Act of South Africa (Act 36 of 1998: 1xv) defines water 'pollution' as (Pegram, et al, 2001:7):

> "alteration of the physical, chemical or biological properties of a water resource so as to make it: -
> (a) less fit for any beneficial purpose for which it may reasonably be expected to be used; or
> (b) harmful or potentially harmful –
> (aa) to the welfare, health or safety of human beings;
> (bb) to any aquatic or non-aquatic organism;
> (cc) to the resource quality; or
> (dd) to property."

This implies that the water quality has been altered so that consumers and producers cannot use it for drinking, production or swimming, because it may be harmful to their health, causing water-borne diseases (see Section 2.4.4 and Appendix A2.1). Fishes and other living organisms may not survive in polluted waters or have their life cycles altered (see Section 2.4.1).

The National Water Act of South Africa therefore strives to provide an all-encompassing view of pollution that negatively affects people, animals, plants and organisms alike. The definition also embraces the essence of views held by both the natural- and behavioural - sciences, by not only focusing on the physical, chemical and biological changes due to pollution, but also on the impact on users. In so doing, the impact of pollution can be assessed and quantified from diverse viewpoints, viz. health, aesthetics, economics, ecology and recreation. Given these measures for evaluating the impact of water pollution, it is observed that water pollution has far-reaching consequences and every means possible should be utilised to limit its effects on the environment. To achieve this, the sources of pollution should be identified; therefore the origins of water pollution in South Africa are identified in the subsequent section.

3.2.1 The Sources of Pollutants in South Africa

As stated by Pegram, et al (2001:7), The National Water Act of South Africa (Act 36 of 1998), even though not directly providing a definition for point sources of pollution, identifies it as "discernable and confined sources of pollution that discharge from a single (point) conveyance, such as a pipe, ditch, channel, tunnel or conduit"; thus non-point sources are "all sources of pollution that are not defined as point sources", (see Section 2.3).

Examples of point sources of water pollution are effluents discharged from industries, sewage treatment plants and mines. These are present in South Africa as expressed by Davies, et al, (1998), such as acidic effluent from coal mines in Witbank, toxins from steel mills run by ISCOR and sewage effluent from wastewater treatment plants in the Eastern Cape.

Non-point sources of water pollution are presented in the form of surface runoff (caused by rainfall), drainage from agricultural and urban areas, mines, landfills, industrial sites and sewage treatment plants. Some South African examples of diffuse source water pollution include, dairy and sugar industries that release high pollutant loads containing phosphorus; the South African landscape, which is susceptible to water erosion causing sedimentation, and high salt loads present in mine drainage influencing the Vaal River system (Coetzee, 1995).

Identifying the sources of pollutants is significant in light of the water shortages experienced within the South African borders in the recent past, as it enables the implementation of appropriate actions to manage water resources.

3.2.2 The Causes and Impact of Water Pollution in South Africa

The historical legacy of apartheid has served to amplify the total effects of water pollution on the water resources in South Africa. These are attributed to occurrences such as negative labour practices, unemployment, migration, housing, and sanitation services.

3.2.2.1 The Causes of Water Pollution in South Africa

In South Africa water pollution arises not only from changes to the environment as discussed in Section 2.4, but also due to external factors influencing the society. Prior to 1994, negative labour practices such as the use of migrant workers on mines and farms, meant that these individuals were offered low-wage employment far from their residences. This was particularly amplified for black people, in that they were relegated to 'created homelands' in rural areas, yet the institution of poll taxes forced them to earn livelihoods on the mines. They were then accommodated in hostels constructed near the mines, but given the apartheid policies of racial segregation, forced to leave their families to struggle on their own. Similarly on farms, people of colour were forced into a life of indentured servitude, where they were housed on the property but provided with little else in order to improve their station in life.

These situations resulted in unemployment for those who equally remained behind, as well as those previously employed on the farms and mines, as the former group had no real source of income, while the latter lacked education and skills to find alternative employment opportunities. After the influx control laws were abolished, the general desire for increased well being gave impetus to the mass migration of job seekers from rural, impoverished areas to the city limits.

This increased the demand for housing, which resulted in more densely populated settlements being established, comprising of both formal- and informal -housing structures. The presence of informal settlements was relatively unknown until the late 1980's, but increased in number after the abolition of the influx control policy (Grobicki, et al, 2001). The ecological dynamics of the region changed as a result. Soil hardening occurred (due to the construction of housing, roads, parking lots, etc.), which hampered the natural seasonal (winter or summer rainfall) seepage of water into the groundwater aquifers (Davies, et al, 1998). Consequently, the runoff from these settlements ended in the drainage system.

In the period preceding 1994, "limited or no services were available in the former 'black' urban areas and rural areas, and in particular farm dwellers and farm schools had no sanitation services" (DWAF, 2002:2). This meant that informal settlement dwellers (largely black and coloured communities located along riverbanks), lacked adequate provision of sanitation and waste removal services, which resulted in diffuse source pollution that contributed towards the low quality levels of water bodies. Failure to report leaking sewage pipes (a non-point source), contributes to the lack of maintenance and repairs, which would then end up flowing into the storm water drains and rivers.

Informal settlements are not the only polluters responsible for the water pollution problem in South Africa. Mining operations produce effluent containing sulphuric- and nitric -acids, a point source of pollution. Another point source, refers to the Olifantsvlei and Natalspruit wetlands both receiving water from sewage disposal sites to the south of Johannesburg and the Mhlangane Swamps receiving eutrophic water from Durban's northern sewage works (Coetzee, 1995).

Chenje, et al, 1996 cites cases of non-point sources of pollution, such as fertiliser runoff from vegetable farmers in the Cape area and pesticides used by commercial farmers in KwaZulu/Natal. Agricultural runoff (erosion) further contribute to sedimentation with an estimated average yield ranging from less than 10 to more than 1000 tonnes/km2/annum being recorded in South African catchments (http://www.dwaf.gov.za). Households are non-point sources of pollutants, where municipal sewage rich in organic matter, nutrients and micro-organisms (bacteria, viruses) are discharged directly into the ocean (Chenje, et al, 1996). Leaking sewage pipes (a non-point source) should not however be excluded, or their impact on rivers.

Beachgoers and fishermen alike discard litter (a diffuse source), inclusive of plastics and nylons. The severity of this problem recorded in a 1991 report to the South African President's Council, which states that "more than 3,000 pieces of plastic are found in every square kilometre of coastal water, most of it dropped from fishing and pleasure boats" (Chenje, et al, 1996:139). Other forms of litter are also present in rivers and canals across the country, either due to a lack of sanitation infrastructure or gross littering by individuals. Armitage, et al, (2000:181) similarly cites from the President's Council Report of 1991, "nearly all solid waste pollution in the river systems of South Africa is derived from the urban areas although they comprise only 5.6% (6 m.ha) of the land area."

Van Niekerk (2000) cites cases of faecal pollution, because of lacking sanitation infrastructure to settlements surrounding the following rivers, namely Mzimvubu, Olifants, Sand, Tswane, Elands, Klein Letaba, Namahadi, Buffels, Wit Mfolozi and Nsikazi; considered the ten highest risk areas at the time of this report. High levels of faecal pollution are recorded in Zandvlei, Zeekoevlei and Princess vlei, three shallow lakes situated in the CMA (http://www.cmc.gov.za).

Harding (1993) identifies the sources of pollutants as originating from urban runoff, agriculture, and informal settlements and occasionally sewage overflows. The ensuing discussion focuses on the impact of water pollution in South Africa.

3.2.2.2 The Impact of Water Pollution in South Africa

South Africa is definitely not exempt from the negative impact of water pollution, experiencing income losses (i.e. increased medical costs, wage losses) due to ill-health, loss of recreational value, incurring purification costs, lowered property valuations, etc. due to degraded water resources.

The cycle of poverty is perpetuated, as rivers flowing through poverty-stricken communities are nothing more than cesspools of pollution, resulting in ill health and the spread of diseases such as cholera, typhoid and diarrhoea. This ill health (and fatally worse mortality) contributes to income losses as a result of increased medical expenses and absences from work, keeping the impoverished poor. A lack of education (or access to information), housing and general displacement has left impoverished communities unaware of the health impacts of polluted rivers and their role in contributing to the problem. As a result, Davies, et al (1998:5) cites, "…every day some 30 or so South

African children die of diarrhoeal infections caused by exposure to insanitary conditions", because caring for the environment is inconsequential when mere survival is at stake.

According to Davies, et al (1998:199), "pH values as low as 2.9 (as acid as vinegar) have been recorded in the polluted headwaters of the Olifants and Limpopo rivers…" arising from mining effluent, which killed off all living organisms. Nutrients from agricultural runoff, results in eutrophication in lakes and estuaries, killing off fish and other organisms, as well as being hazardous to health. Pesticides used have caused fertility problems in dolphins, as most pesticides contain toxic substances, which are harmful to animals.

Sewage from households causes marine pollution around coastal regions, resulting in the eggs of bilharzias-causing flatworms being discovered at the mouth of the Mbokodweni River in Durban (Chenje, 1996). Litter is harmful to animal life, having serious ecological implications (see Section 2.4.5).

Zandvlei, Zeekoevlei and Princess vlei are used for recreational activities throughout the year and hold potentially hazardous health risks to users. The State of the Environment (http://www.cmc.gov.za) reveals that these pollution levels, and notably the lakes that receive them limit the recreational potential of rivers in the CMA. These negative or harmful effects hold consequences for the users of the river and vlei, such as using piped water for irrigation of farms because clean-up costs in terms of purification measures are exorbitant or medical costs incurred in treating illnesses due to exposure to pollution.

The subsequent focus shifts to the specific case of the Lotus River Catchment, in the CMA, where the Lotus Rivers flow through urban areas in the region. In assessing the particular case, the extent of the water pollution problem encountered is identified and its causes.

3.3 CASE STUDY ANALYSIS - WATER POLLUTION IN THE LOTUS RIVER CATCHMENT

3.3.1 A Description of the Lotus River Catchment

A description of the Lotus River Catchment is provided in order to highlight the dynamics of the area through which the Lotus River flows. This section reveals that the Catchment encompasses a mix of light industrial areas, vacant lots, commercial farms, formal- and informal -settlements, all of which contribute to the pollutant loading of the Lotus River and Zeekoevlei.[5]

The Lotus River Catchment, comprising of both the Great- and Little -Lotus Rivers, extends over a large area of the Cape Flats, a flat sandy region, connecting the Cape Peninsula to the rest of mainland South Africa. From a geographical perspective, area demarcations are obscured and largely "…artificially defined" (Grobicki, et al, 2001:iii) by local government, as no clear distinction exists by which to separate suburbs (e.g. two suburbs separated by a road). Therefore the Lotus River Catchment spans across three municipal structures, namely the Tygerberg, Cape Town and South Peninsula Municipalities (Grobicki, et al, 1997).

As the Lotus River canal serves the purpose of providing a stormwater conduit to the area, the existing river is largely a concrete-lined channel. Both the Great- and Little – Lotus Rivers drain southwards, with the Great Lotus River starting off at Borcherd's Quarry in the Airport Industria and flowing through the Nyanga - Gugulethu region, Philippi East - Brown's Farm region, the Philippi horticultural area, and the Lotus River

[5] Limited research has been conducted on the Lotus River Catchment, thus this case study strongly relies upon the findings of reports conducted by Abbott Grobicki (in 1997 and 2001), Ecobe EMS (2001) and Ninham Shand (2001). See References for full details.

region into Zeekoevlei, before entering False Bay (Grobicki, et al, 2001). The Little Lotus River starts off near the Royal Cape Golf Course flowing through Grassy Park into Zeekoevlei, before discharging into False Bay (Grobicki, et al, 1997).

The combined effects of canalisation and urbanisation along the river contribute to the problem of pollution, as the natural functioning of the river is hampered. This is seen by the regional characteristics exhibited by both the Great- and Little -Lotus Rivers from their source of origin to entry into False Bay. This brief description of the surrounding geographical areas serves to provide a backdrop for identifying the sources of pollution impacting upon the Lotus River Catchment, which are discussed in Section 2.3.

According to reports conducted by Ecobe EMS (2001), Ninham Shand (2001) and Abbott Grobicki (1997; 2001) on the Lotus River, the research revealed that the Great Lotus River "rises in a stormwater detention pond in Boquinar South…" (Borcherd's Quarry) to "facilitate drainage for agriculture and in order to reduce the high water table" (Ninham Shand, 2001:4). It originates in an area adjacent to the Cape Town International Airport and therefore falls under the Tygerberg Municipality. The land use is characterised by light industrial and commercial activity, and despite the open spaces, the region is conspicuously absent of both formal and informal settlements.

The river then flows through the Nyanga - Gugulethu region, which is comprised of five sub-catchments, forming part of the City of Cape Town. The land use distribution varies with location, as the northernmost areas reflect informal, vegetated and non-vegetated open spaces, while the southern sub-catchments are mainly comprised of formal residential areas. For example, the Lotus River canal "travels through the informal settlements of Kanana and Barcelona," situated on a "disused waste disposal site," as well as through "…high-density low-income residential areas" (Ninham Shand, 2001:8). Adequate sanitation and sewer/stormwater infrastructure is lacking in both formal- and informal -areas, with residents of informal settlements only having access to the water supply from standpipes. The water quality of the canal is therefore negatively impacted upon, as this has increased its usage as a waste removal system and an open sewer, with high faecal pollution levels (Grobicki, et al, 2001).

The river continues along the Philippi East – Brown's Farm region located in the eastern part of the catchment and is comprised of seven sub-catchments, falling within the municipal control of the City of Cape Town. Its land use is characterised by informal settlement areas and open spaces, reflecting the most rapid urbanisation of the catchment (Griffin, et al, 2000). Growth in informal settlement areas and serviced sites have increased the population densities of certain sub-catchments, with the Philippi East - Brown's Farm region holding 55% of the total informal settlement population in the catchment (Grobicki, et al, 2001).

From here the river flows through the Philippi Horticultural Area located in the central part of the catchment and is comprised of twelve sub-catchments. The land use is predominantly characterised by cultivated land and agricultural buildings, as well as open vegetated areas. Population densities are generally low, but marginal sub-catchments have undergone higher degrees of urbanisation by growth in informal settlements. This "…area of intense market gardening" contributes to the pollutant loading of the river as it "receives organically enriched runoff" (Ecobe EMS, 2001:5).

Finally, "the river runs within an earth canal as far as New Ottery Road, Grassy Park, where it is channelled into a concrete canal" (Ecobe EMS, 2001:5), and passes through the Grassy Park / Lotus River / Ottery region before entering Zeekoevlei. This region is located in the western part of the catchment and is comprised of sixteen sub-catchments, administered by the South Peninsula Municipality. Its land use is predominantly characterised by formal residential housing, industrial and commercial areas, as well as vegetated areas. High population densities occur in formal housing areas and low levels for those sub-catchments made up of open vegetated areas. Less than 1 % of the total informal settlement population of the catchment resides in the Lotus River region (Grobicki, et al, 2001).

The Little Lotus River rises in the "vicinity of the Royal Cape Golf Course, and flows in a southerly direction, towards Zeekoevlei" (Ecobe EMS, 2001:5). The area is located in the western part of the Lotus River catchment, which is predominantly comprised of formal settlements interspersed with open vegetated and industrial areas. High degree of urbanisation has occurred, but this is not inclusive of informal settlements as in other parts of the Lotus River catchment; rather land use changes from vegetated land to formal settlement areas (Grobicki, et al, 2001).

A brief description of the extent of canalisation along the Great Lotus River is provided.[6] According to Grobicki, et al, (1997:1) the use of controlled canalisation "…has resulted in these streams becoming stormwater drains transporting waste in various forms, and reduced their assimilatory capacity for water quality improvement". Initially the river is unlined as it flows through the informal settlement of Barcelona and a waste disposal site upstream of Klipfontein Road; then it is concrete lined within the reaches of Nyanga-Gugulethu, where the informal settlement of Phola Park has sprouted along its grassy

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6 The Little Lotus River is less polluted and therefore not a major area of focus.

banks; this occurs intermittently, with canalisation recorded within the Philippi-East and Grassy Park/Lotus River/Ottery areas (Grobicki, et al, 2001).

Finally the Lotus Rivers flow into Zeekoevlei before being discharged into False Bay. Zeekoevlei is a shallow coastal lake on the Cape Flats, receiving water from the Great- and Little -Lotus Rivers. It is utilised for recreational sports that was made possible by a "…variety of modifications, which drastically altered the natural functioning of the wetland" (Ecobe EMS, 2001:5). These modifications included the construction of a weir that controls the water levels in the vlei, enabling year-round recreation, such as sailing (Ecobe EMS, 2001).

3.3.2 An Assessment of Water Pollution in the Lotus River Catchment

The water pollution experienced in the Lotus River Catchment is in no way unique when evaluated from a scientific perspective, even though there are socio-economic issues such as poverty and inadequate provision of sanitation services within informal settlements that compounds the influences from agriculture and industries. The following discussion therefore assesses the extent of the water pollution problem in the catchment and the causes thereof.

3.3.2.1 The Extent of the Problem

The magnitude of the water pollution problem in the Lotus River Catchment is outlined below through the use of data supplied by the Scientific Services Branch of the Cape Metropolitan Council (CMC) in 2001. The sampling program is conducted on a monthly basis (with frequent gaps and omissions) and highlights the variables of concern within the system, i.e. those deviating from the water quality guidelines as put forward by the Department of Water Affairs and Forestry (DWAF).

Grobicki, et al, (2001:97,99) provides a comparison of the Great Lotus River to the DWAF water quality guidelines (see Appendix 3.1). Table A3.1 points to the fact that the

Lotus River canal is nutrient rich in nitrogen and phosphorus, falling within the eutrophic and hypertrophic (above eutrophic) ranges respectively; where trend analysis in ammonia samples are lacking, it is noted that levels increased post-1994 due to expansionary growth in informal settlements and industrial development. Table A3.2 reveals that the canal bears significantly higher levels of indicator organisms (i.e. faecal coliforms and E-coli) than the accepted guideline; where these levels can be equated to raw sewerage that hold health risk. These results raise concern as Zeekoevlei, the receiving water body, is used for a variety of recreational activities, including boating, skiing, windsurfing and competitive angling. It is estimated that Zeekoevlei receives 34 000 kg of phosphorous on average per year (Southern Waters, 2000). The eutrophic status of the vlei as cited by Davies, et al, (1998) holds serious repercussions to health, recreation and economic costs.

According to the sample analysis, variables of concern in the Great Lotus River include Total Nitrogen (TN), Total Phosphorus (TP), and Indicator organisms (Faecal coliforms, E-coli), as these have consistently exceeded the water quality guidelines. Ammonia is not considered in isolation, as it is included in the TN count.

Samples of the water were taken at various monitoring points along the Lotus River (as shown in Table 3.1 below), enabling an assessment of the trends in water quality and the areas or role players that contribute to the problem.

Table 3.1: Water Quality Monitoring Points

Code name	Description
LR01	Lotus River on Airport Approach Road (Opposite Borcherd's Quarry final effluent ponds)
LR02	Lotus River on Settler's Way (N2), about 500m from Airport Approach Road
LR03	Lotus River at corner Duinefontein and Lansdowne Roads
LR04	Lotus River at Lansdowne Road
LR05	Lotus River at Plantation Road (near Hillstar Traffic Department)
LR06	Lotus River at New Ottery Road (near Ottery Hypermarket)
LR07	Lotus River at Klip Road
LR08	Lotus River at Fisherman's Walk bridge (just above vlei body)
LR09	Little Lotus River at Klip Road (near Montagues Gift Road)
LR10	Little Lotus River at Eighth Avenue
LR11	Little Lotus River at Fifth Avenue, Grassy Park
LR12	Lotus River at Fifth Avenue, Lotus River

(Scientific Services (CMC), 1997 - 2001)

A. Total Nitrogen

Total Nitrogen is a compound of organic nitrogen, nitrates, nitrites and ammonia (Grobicki, et al 2001), discussed in Section 2.4.3. Based on seasonal changes, higher loadings are reflected in winter rainfall periods when compared to the drier summer periods. Regardless of the low and high flow situations, the sample points within the Airport Industria (LR01) and beyond the Nyanga - Gugulethu region (LR03) show significantly high concentrations, originating from industrial effluents and the diffuse source of informal settlements and residential areas, respectively. This is possibly due to inadequate sanitation and cleansing services offered to these areas and a disregard by businesses to find alternative means for discarding their waste, other than via stormwater drainage (see Section 3.2.2.1). Contributions decrease beyond this point arising from mainly diffuse sources, such as agricultural runoff in the Philippi Horticultural area (LR05) and residential sub-catchments (LR07 and LR08).

B. Total Phosphorus

Total Phosphorus includes dissolved and particulate varieties, each with organic and inorganic components; the soluble reactive phosphorus (SRP) component reflecting the only available biological form of Phosphorus (Grobicki, et al, 2001). The flow trends noted in seasonal changes for TN are once again prevalent. Both the low and high flow situations, reveal that the sample points within the Airport Industria (LR01) and beyond the Nyanga - Gugulethu region (LR03) show high concentrations, arising from cleared aquatic vegetation not being removed and urban stormwater drainage (sewer overflows and inadequate sanitation), respectively. A decrease in concentration then follows, influenced by canalisation, with peaks arising after the Philippi Horticultural area (LR05) and within the predominantly residential area of Lotus River (LR07). This may be attributed to the agricultural runoff containing nutrient-rich organic- and inorganic - fertilisers and the waste waters from urban settlements containing phosphorus detergents; not forgetting the influence of groundwater absorption over the course of this unlined section of the canal.

C. Indicator Organisms

Microbial data reveal excessively high concentrations of faecal coliforms and E-coli in the Great Lotus River. Once again sample point LR03, beyond the Nyanga - Gugulethu region, registers the highest levels. This possibly indicates, as suggested before, that a number of reasons exist, including raw sewerage effluent overflows from blocked or deteriorated sewers into stormwater drains and inadequate or non-existent sanitation delivery.

3.3.2.2 Causes of the Problem

The literature overview reveals that co-contributors, in varying proportions, influence water pollution in the catchment, with no single polluter solely responsible; these contributing factors are subsequently discussed.

A. Urban Settlements

The Cape Metropolitan Area (CMA) is a densely populated region characterised by both formal as well as informal settlements, contributing towards the general perception of a highly urbanised area. This is particularly noticeable when moving to outlying districts that are more rural in nature, as land use is far more concentrated around vegetated and non-vegetated spaces.

Due to the CMA experiencing growth in its population over the past decades (influenced in part, as a result of removing influx control policy and therefore the limitations to in-migration, as well as natural birth rates), formerly open, non-vegetated spaces have been used for development within the industrial and housing sectors.[7]

The CMA, under the auspices of the local government, is thus charged with the added burden of not only addressing existing housing backlogs, but also additional housing needs due to rapid population growth and migration into the area. Housing provision is also impeded by the lack of infrastructure to provide basic services, of which water and sanitation are key factors; and the high levels of poverty and unemployment within certain racial groups, which renders the provision of formal housing unaffordable to the majority of its residents. Based on public opinion, the pace at which housing shortages are being addressed, is regarded as too slow, therefore the homeless have taken it upon themselves to find accommodation, albeit within the informal settlement, closer to locations of employment. Occupation of private and state owned land has resulted in the gradual depletion of viable development sites.

A migration study conducted in the Western Cape in 2001 show gains of some 48 000 new residents per annum, representing "an increase due to in-migration of more than one per cent of the total population" (Bekker, 2002:iv). The majority of the migrants originate from the provinces of the Northern and Eastern Cape. The main reasons for migration to

[7] For a more detailed assessment of population growth, refer to subsequent discussion in Section 3.3.2.2.A or Bekker (2002).

the Western Cape revolves around perceptions of the availability of better job opportunities, better quality of life and more accessible and effective infrastructure (Bekker, 2002). This migration influx poses significant challenges to provincial and local authorities in addressing not only housing and infrastructural backlogs, but also meeting the increased demand for social services due to population growth.

The Lotus River Catchment in the Western Cape is representative of South Africa's urban development. This can be observed by the range of communities, varying from the desperately poor informal settlement dwellers, through crime-ridden low and middle-income communities, the economically important horticultural area of Philippi, to high-income communities around the shores of the lake (Grobicki, et al, 2001).

Acknowledging that alternative solutions needs to be found in addressing the housing problem, a report was commissioned on behalf of the Housing Department within the Directorate of Planning, Environment and Housing in the CMA (Abbott, et al, 1999). The aim of the report was to quantify the extent of growth within the informal sector over the period extending from January 1993 to May 1998, as well as measuring the trends within these designated settlements. It should be noted that where reference is made to informal settlements within the CMA, Abbott, et al, (1999:1) defines free-standing informal settlements by virtue that:

- there is no title deed linking the residents to the land;
- the land is occupied without municipal planning permission;
- a line can be drawn around the settlement, which does not include formal dwellings, and which allows the site to be geographically defined;
- in the large majority of cases the site is unserviced, or provided with emergency level services only.

This implies for example that shacks around hostel areas in Phola Park (part of the Nyanga – Gugulethu region) are excluded, as well as areas where title deeds have been granted to deed-owners who either set up shacks on the sites themselves, or allow other shack dwellers onto their sites in the form of back-yard shacks.

The reason why this report is of significance to the case study is the fact that the Lotus River Catchment is peppered with informal settlements, which are co-contributors to the pollution problem. Trends revealed in the report highlight the extent of the problem encountered, as "the total number of shacks in the informal settlements of the CMA (i.e. that area which lies within the CMC boundary) was 28300 in January 1993, 59854 in May 1996, and 72140 in May 1998" (Abbott, et al, 1999:2). After numerous requests the researcher was unable to procure the updated report conducted in 2002, from the CMC, but the statistics they provided indicates a shack count increase of 1115, a minimal 1.6% increase over the period from 1998 to 2000.

Within the Lotus River catchment, the 1999 report indicated that only the South Peninsula Municipality achieved a net decrease in shack counts, all the other municipalities experienced a net increase, indicating growth in shacks outweighed the provision of new houses; where a total of 8000 shacks were relocated to newly serviced sites across the CMA. Further trends revealed in other municipalities indicate movements within the area (voluntary relocations), most likely due to persons moving closer to places of employment. The full impact is unknown, for example Mahobe Drive (Nyanga - Gugulethu region) is an anomaly in that even though the area was intended for relocation, "…there is no record of where almost half of these shacks might have gone" (Abbott, et al, 1999:15).

According to the findings of the World Bank (1995:17) on South Africa, "a third of the poor live in shacks or traditional dwellings," having no access to electricity, piped water and modern sanitation. Even though the living conditions of the poor may not improve in relocation, the perceived employment opportunities render the CMA as a viable destination for migration. Recent protests are proof that the poor are dissatisfied with their current situation and want the Government to deliver most urgently on housing, employment, electrification, piped water, sanitation and food aid.

Sewer overflows into the stormwater system occurs at two point sources within the

Nyanga - Gugulethu region, possibly arising from sewer pump stations and/or pipes, due to blockages caused by litter and sediment, or overloading of the existing infrastructure. "An additional source of faecal coliform bacteria in the canal is the poor sanitation conditions characteristic of the Nyanga - Gugulethu informal settlement areas" (Grobicki, et al, 2001:75). When local residents cannot access sanitation via the "bucket" system, they utilise the canal for lack of suitable alternatives, contributing towards a diffuse source of coliforms into the canal. The canal finally empties into Zeekoevlei, which has shown high levels of faecal pollution that holds potential health risks to users of the lake for recreational activities, and should therefore be contained to manageable levels (Southern Waters, 2000).

B. Agricultural Sector

The agricultural sector is located in the Philippi Horticultural area, where the commercial farming of vegetables occurs, as well as the exploitation and refining of sand by the glass industry (Grobicki, et al, 2001:60).[8] Given the areas' rural nature (mainly smallholdings with horticulture being the primary land use), no stormwater drainage and waterborne sewerage system exists, with limited access to piped water.

The proportion of land use for vegetable farming has diminished, and has not resultantly caused produce output levels to fall, suggesting a substantial increase in productivity, due to more intensive farming practices and the use of organic- and inorganic -fertilisers (Grobicki, et al, 2001). Alternative land uses include nurseries (the cultivation of plants, seeds and flowers) and the increasing popularity of raising livestock (horse breeding and stabling).

The farming area "contributes significantly to the nutrient load of the stormwater drained

[8] This section and the next, relies particularly strongly on the findings of Grobicki, et al, (2001).

by the Lotus River canal and Zeekoevlei" (Grobicki, et al, 2001:63). This is evidenced by the use of organic- and inorganic –fertilisers, applied by the vegetable farmers in the area. Nutrient-rich fertiliser runoff, results in eutrophication in lakes and estuaries, particularly Zeekoevlei, killing off fish and other organisms, as well as being hazardous to health (Chenje, et al, 1996). The hypertrophic state of Zeekoevlei has not only limited its recreational potential, but probably the residential valuation of property levels surrounding the vlei and adjacent areas (Southern Waters, 2000). The transition to horse breeding is potentially hazardous, serving to increase the pollutant load, as livestock manure may pollute drainage channels and increase phosphate concentrations.

C. Industries

Industrial concerns (such as warehousing, manufacturing and printers) dominate the area surrounding the Cape Town International Airport, from where the Great Lotus River rises. Due to the increase in land use for light industrial and commercial activity, the subsequent growth in parking lots indicates the use of previously open, non-vegetated spaces.

The recent expansion of the airport can only serve to increase the load of stormwater runoff into the canal and consequently the pollutant loading, possibly arising due to the use of detergents and other ammonia based products by industries and households. Increases in industrial development are recorded in the Nyanga - Gugulethu region, Philippi East - Crossroads region and the Grassy Park/Lotus river/Ottery region (Grobicki, et al, 2001).

3.4 SUMMARY AND CONCLUSIONS

In summary, water pollution has not evaded the surface waters of South Africa. The extent of the problem encountered warrants attention, in light of water shortages experienced, hence the National Water Act of South Africa has outlined a number of guidelines revolving around water quality. Specifically focussing on the Lotus River Catchment within the CMA, a description of the catchment served to highlight the degree of urbanisation and population densities influencing land use, as well as the proportion of canalisation of the river. This enabled identification of the sources of pollution within the Lotus River Catchment, where the role played by urban settlements, industries and the agricultural sector was determined, when considering the magnitude of the deviation from water quality guidelines.

The Lotus River canal, if left unmanaged will be nothing more than a sewer outlet, given the extent of water pollution levels recorded along its pathways. The water quality specifications indicated the presence of high levels of faecal coliforms and other organisms, identified as originating from these settlements, where inadequate or non-existent provision of sanitation occurred. Its impact on Zeekoevlei and their users (of recreational facilities) cannot be ignored and in fact necessitates some form of intervention.

The following chapter provides economic policy options and coping mechanisms that can be implemented by governing authorities to reduce (if not eliminate) the extent of the water pollution problem.

APPENDIX 3

TABLE A3.1 DWAF water quality guidelines for aquatic systems compared to Great Lotus River long term average

Parameter	DWAF TWQR (mg/*l*)	Great Lotus (5^{th} Ave) (mg/*l*)
Ammonia	≤ 0.007	Min = 0.0039 95 percentile = 0.0112 Mean = 0.77 Max = 5.42
Total Nitrogen (Inorganic)	< 0.5 (oligotrophic)	Min = 1.25 95 percentile = 1.346 Mean = 6.49 Max = 21.7
	0.5 - 2.5 (mesotrophic)	
	2.5 – 10 (eutrophic)	
	>10 (hypertrophic)	
Total Phosphorus (Inorganic)	< 0.005 (oligotrophic)	Min = 0.14 95 percentile = 0.2114 Mean = 0.703 Max = 2.31
	0.005 - 0.025 (mesotrophic)	
	0.025 - 0.25 (eutrophic)	
	>0.25 (hypertrophic)	
Total Suspended Solids	< 100	Min = 1 95 percentile = 0.0112 Mean = 32 Max = 400

(Source: Grobicki, et al, 2001:97:4.1)

TABLE A3.2 Bacteriological counts of the Great Lotus River as compared to DWAF guidelines

Organism	TWQR (counts/100ml)		Great Lotus
	Domestic Use[a]	Recreational Use[b]	
Faecal coliform	0	0 - 1000	Mean = 1.78 e 06 Min = 3 e 03 Max = 47 e 06

(Source: Grobicki, et al, 2001:99:4.2)

CHAPTER FOUR: THE ECONOMIC POLICY OPTIONS AND COPING STRATEGIES

4.1 INTRODUCTION

Water pollution influences the quality of water, rendering it unsuitable for use by producers and consumers in South Africa. Given the relative scarcity of freshwater resources (see Section 1.1), water pollution purely compounds the problem and therefore should be addressed. It cannot be disputed that water pollution exists within the micro-example of the Lotus River Catchment, but the question arises as to the availability of alternatives in addressing the problem. This chapter therefore seeks to address this issue by examining case studies of solutions adopted by governments worldwide and considering the alternatives available to South African authorities.

Thus, Section 4.2 reviews the case studies of solutions implemented globally, while Section 4.3 outlines the existing policies adopted by South Africa. Then, Section 4.4 focuses on the relevance in the South African context and Section 4.5 evaluates the impact of adopting the economic policy options and coping strategies implemented worldwide. Finally Section 4.6 summarises and concludes.

4.2 CASE STUDIES OF SOLUTIONS ADOPTED TO ADDRESS WATER POLLUTION

According to Hanley, et al, (2001) an assessment of the international situation reveals that water pollution policy is dominated by regulatory options, with the use of economic instruments showing signs of increase.[9] This section focuses on policies by different governments to internalise the negative impact of water pollution on the quality of water.

[9] The text provides detailed case studies of the presence of water pollution and solutions implemented globally, which serves as the basis for this discussion.

4.2.1 Germany

Germany operates a dual system of pollution taxes (see Section 2.5.2.1) and discharge permits (performance standards) (see Section 2.5.2.3), where charges are levied on direct discharges to waterways. This implies that direct or point-source polluters (see Section 2.3.1), such as industries and municipal waste treatment plants, are taxed on emission levels at the point of entry into the watercourses. These were aimed at providing incentives to improve water quality, upgrade technology, recover costs of environmental pollution control and to align with the polluter pays principle.

Hanley, et al, (2001:248) further notes that the charges are 'firm-specific' and that a "uniform charge is levied per pollution unit, but different pollutants attract different implicit charge rates." Thus, to reduce their tax liabilities, firms are compelled to lower their emissions, providing proof thereof when seeking lower consented levels of discharge. Alternatively, charges can be avoided when new technology meeting the appropriate guidelines is met. Hanley, et al, (2001:248) also cites "a report in 1990 suggested that the introduction of the charge scheme had resulted in a significant reduction in BOD (biological oxygen demand), especially from municipal sewage-treatment works". But, on a cautionary note, it should be acknowledged that other pollution control laws are in place, and therefore cannot solely be ascribed to tax charges.

4.2.2 United Kingdom (UK)

In the UK, water pollution is controlled through regulatory legislation, where use is made of both performance- and design –standards (Hanley, et al, 2001). The former revolves around the granting of 'consents' for direct discharges into surface waters (by setting controls on how much pollution the firm emits), while design standards control the manner of production and technology used. Additionally, there are also European Union directives impacting on water quality management; to meet these goals, regulation mainly proceeds through the system of consents, but recent use of design standards in dealing with municipal sewage works have transpired (Hanley, et al, 2001).[10]

Water pollution control in the UK is therefore reliant on legislated regulation, where the earliest forms of legislation is captured within the 1951 and 1961 Rivers (Prevention of Pollution) Acts, and water quality guidelines for each river in the region established by the River Quality Objectives in 1989. Even though not widely implemented, the use of economic instruments is being investigated within recent discussion papers. According to Hanley, et al, (2001:249), "these included the way in which taxes are calculated for point-source dischargers… the use of product charges for non-point pollutants, and the introduction of TPP markets for BOD emissions to the River Thames…"

Nonetheless, the River Thames is cited as one of the success stories; it was polluted for centuries and particularly in the 19th century due to the industrial revolution (Kraemer, 2001). Based upon the environmental quality guidelines, gradual success was achieved in improving water quality levels through major investments in wastewater treatment plants and cleaner production processes. Kraemer, (2001:22), referring to a World Bank study (1998), claims: "Even the salmon returned to the river, and the case of the Thames "clean-up" is often quoted as an example of what can be achieved with consistent effort over a long period by setting water quality objectives and clear goals". This is a conclusion that policy-makers cannot ignore.

4.2.3 United States of America (USA)

The USA mainly uses regulatory options; initially these were state-based performance standards for direct discharges, enabled through the 1948 Water Pollution Act (that made possible, loans to municipalities for sewage treatment) and the Water Quality Act of 1965 (Hanley, et al, 2001). Later, control fell under federal government who replaced the system with design standards set at overly ambitious targets (such as, elimination of all pollution into navigable rivers by 1985); but was subsequently forced to amend their

[10] Examples of these directives include, Urban Waste Water Treatment Directive, the Nitrates Directive and the Bathing Waters Directive (Hanley, et al, 2001).

goals, addressed through amendments in the available Acts.

The results from these regulatory systems are mixed, since firms failing to comply with discharge permits, increased in number, while at the same time though, water quality levels improved. Hanley, et al, (2001:250) cites two cases where tradable pollution permits have been used "…to allow trading of phosphate 'allowances' between point and non-point sources;" this follows the encouragement of government in 1996, to use these measures for improving water quality. These measures have not yielded large benefits, but emission levels have fallen, even though no actual trades have occurred between point and non-point sources.

4.2.4 Other Countries

An overview of the available literature provides other interesting examples. For instance, Hanley, et al, (2001) cites cases where only regulation (i.e. government enforcing firms to apply design and performance standards) was imposed in Hungary and India. In the former case, it was noted that a lack of access to water supply and a sewage system existed, creating pollution in the Danube River. This was addressed via the signing of the Danube River protection convention that obliged member countries to reduce pollution. Hungary has further undertaken to provide wastewater treatment facilities to communities in excess of 2000 inhabitants by the year 2010.

The Indian example sees deforestation in the Himalayas that resulted in soil erosion and consequent nutrient rich sedimentation. This is amplified by industrial use of chemical fertilisers and pesticides, which contaminates the waters of the Ganges river basin. According to Pargal, et al, (1997) "industrial plants now face pressure to abate water pollution from many sources, national and local, through formal government regulation and through more informal pressure from consumer groups and concern for a firm's reputation" (Hanley, et al, 2001:243).

As early as 1980, effluent charges (see Section 2.5.2.5) were imposed on three industrial plants in Sao Paulo, Brazil (Larsen, et al, 2000). The companies responded to this by changing their production processes, substituting inputs, using more efficient equipment and mechanical washing, which led to lowered to lowered effluent levels. The imposition of these pollution charges strongly motivated the concerned industries to amend their production processes or face increased costs.

Lessons can also be learnt from countries like China, Canada and Australia. The case of China (Kraemer, et al, 2001) reveals a levelling off of industrial wastewater, as industries operate under a market-based pollution control system, which uses emission charges and abatement subsidies. This has contributed to firms investing in wastewater treatment facilities and the use of pollution levies has improved investment in abatement. Canada, on the other hand, uses a pollution control program combining traditional enforcement and public disclosure. The latter measure of naming and shaming polluters has proven to be far more successful than fines and penalties. Australia has achieved success with tradable permits (see Section 2.5.2.5) in "…pre-existing regulatory regimes that include sanctions on individuals for overall failure in pollution abatement," (Kraemer, et al, 2001:25).

A report by O'Connor (1998), notes, "…as of 1992, a total of 169 Economic instruments (EIs) were being used in 23 OECD countries". The use of product charges and deposit-refund schemes being more frequently used, but did not replace regulation. Similarly, newly industrialised countries in Asia and Latin America have frequently applied effluent charges and product charges. Comparisons to developing countries were not available, as no surveys had been conducted.

In conclusion, in adopting water pollution control measures, it is noteworthy that globally, few countries have solely relied upon economic policy measures such as taxation, subsidies, effluent fees, and property rights, but rather merged these with existing regulation. As the trend is toward considering market-based economic alternatives, Section 4.4 will focus on the relevance in the South African context.

However, Section 4.3 firstly presents a brief overview of the existing control measures in the country.

4.3 WATER POLLUTION CONTROL MEASURES IN SOUTH AFRICA

The South African government makes use of regulatory legislature, based on Roman-Dutch law, in order to establish guidelines for water management. The earliest recorded legislation was the Public Health Act of the Union of South Africa (Act No 36 of 1919), which gave the Public Health Department the responsibility of controlling pollution revolving around sewage disposal (http://www.dwaf.gov.za). This was later transferred to the Department of Irrigation, now the Department of Water Affairs and Forestry (DWAF).

The management of water resources is governed by the National Water Act (Act No 36 of 1998), while the provision of water, is regulated by the Water Services Act (Act No 108 of 1997). This distinction is noted in Sterner, (2003:353) which states, "although the Water Act promotes the role of the state as custodian of water related to basic human needs and ecological needs, the Water Services Act of 1997 strives for efficiency and makes provision for privatisation and competition at various levels along the water supply chain." The South African Water Quality Guidelines establishes the necessary framework when determining water quality requirements of users.

As per discussion on water quality management (see http://www.dwaf.gov.za), "The following prominent principles form the basis of water quality management policies and practices in South Africa.

- The management of water quality must be carried out in an integrated and holistic manner, acknowledging that all elements of the environment are interrelated.
- Decision-making must ensure that the best practicable environmental option is adopted by taking account of all aspects of the environment including all the people in the environment.

- The precautionary approach to water quality management applies, in which active measures are taken to avert or minimise potential risk of undesirable impacts on the environment.
- In general the Polluter Pays, applies. In accordance with this principle, the cost of remedying pollution, degradation of resource quality and consequent adverse health effects, and of preventing, minimising or controlling pollution, is the responsibility of the polluter.
- Participative management in the management of water quality must be advocated, ensuring that all interested and affected parties, and previously disadvantaged persons have an equal opportunity to participate.
- Transparency and openness must underlie all decision-making processes, and all information must be made accessible in accordance with the law."

The government department at the helm of control is DWAF, who is tasked with managing the nation's water resources, such as ensuring equitable access to water and its sustainable use for future generations (WQMS, 1999). The environmental management instruments employed by water quality management are namely, regulatory, market-based, self-regulatory and civil management instruments (http://www.dwaf.gov.za).

The regulatory measures refer to Acts regulating water use and impacts on quality, which may be facilitated in co-operation with other government departments. These are current examples of regulatory Acts enforced (http://www.dwaf.gov.za), namely:

- Licensing of water use that may have, or may potentially have an impact on water quality in terms of Section 40 of the National Water Act, 1998 (Act No. 36 of 1998);
- Issuing of disposal site permits in terms of Section 20 of the Environment Conservation Act, 1989 (Act No.73 of 1989);
- Recommendation for approval of Environmental Management Programmes (EMPs) in terms of Section 39 of the Minerals Act, 1991 (Act No. 50 of 1991) to the Department of Minerals and Energy; and
- Recommendation for approval of Environmental Impact Assessments (EIAs) in terms of Sections 21, 26 and 28 of the Environmental Conservation Act, 1989 (Act No. 73 of 1989) to the Department of Environmental Affairs and Tourism.

The market-based instruments use pricing strategies (waste discharge charges), while self-regulatory management can be utilised by industries after complying with legal requirements. Civil management refers to the delegation of management functions to regional or catchment level.

South Africa's water pollution control measures are still primarily based upon regulatory legislation. This a major drawback however, as these regulations may serve to establish the necessary guidelines revolving around water quality, but fail to ensure that the polluters responsible are held accountable for their actions. The use of pricing strategies (waste discharge charges) may be suitable where a known polluting industry is identifiable, but fails as a measure for non-point sources of pollutants. Self-regulation by industries runs the risk of mismanagement, as polluters may not honestly record activities. Civil management can only function properly if the necessary rights and funding are afforded to local government.

4.4 RELEVANCE IN THE SOUTH AFRICAN CONTEXT

Given the existing water management instruments available, the water pollution problem encountered in the Lotus River Catchment specifically, would not be expeditiously resolved, thus alternative economic solutions are sought by evaluating whether the measures adopted globally have any relevance to the South African case.

The economic policies adopted internationally, provide lessons for South African authorities. These are revealed by the fact that they have effectively combined existing regulation (either performance- or design -standards) with economic measures such as taxation, abatement subsidies and pollution permits (see Section 4.2), which South Africa would do well to investigate.

The successes achieved by these countries in controlling water pollution levels provide South Africa with the necessary guidelines in pursuing their objective. The UK example of the River Thames, points to what can be achieved over the long-term by setting water quality objectives and goals, which indicates that far more stringent laws should be adopted in South Africa.

However, each country is unique and faces its own particular challenges. A distinguishing feature is that South Africa is a developing economy influenced by its historical past, which might produce different outcomes to their international counterparts. Each of these economic measures should therefore be evaluated on their own merit, taking into account the South African situation and the difficulties of dealing with diffuse source pollution.

4.5 ECONOMIC POLICY OPTIONS AND COPING STRATEGIES

As the preceding discussion highlights, poor water quality and visible pollution contributes toward the loss of aesthetic appeal and recreational value, as well as environmental degradation within the reaches of the canal and vlei. This serves to warrant the need for practical solutions to be found in aiming to eradicate the water pollution problem within the catchment area.

Focussing on the role of urban settlements and the substantial contribution made by informal settlements and residential areas in the Nyanga - Gugulethu region to the pollutant loading, there is an urgent need to address the housing shortages and/or servicing of the sites being utilised. Attending to these issues will go a long way to controlling the effects of pollution. The provision of waterborne sanitation to informal settlements will improve the quality of water in the canal and reduce the concomitant health risks. Existing sewerage infrastructure should be upgraded and frequently maintained.

Better regulation and enforcement thereof should be considered in order to reduce industrial effluent, especially considering the expansion opportunities to the areas surrounding the Airport Industria and the impact this has on the stormwater drainage system. This is also applicable to the Philippi Horticultural area, as they lack the necessary sewage infrastructure and enforcement of existing regulation concerning livestock breeding.

The policy options available within economics that can be used as the necessary coping mechanisms in dealing with the abatement of the water pollution problem in the Lotus River and Zeekoevlei, include taxation, subsidies, regulation, effluent fees (pollution permits) and property rights (see Section 2.5.2). Using the theoretical solutions discussed in Section 2.5.2 as a basis, the ensuing discussion assesses the feasibility of these options, given the situation prevailing in the Lotus River Catchment.

4.5.1 Taxation

Realistically though, the relevance of Pigouvian taxes are limited by a lack of knowledge of the external cost function and concern with regard to compatibility between regulatory taxes and the existing legal system. In the context of the Lotus River Catchment, taxation of polluters (the source of waste-producing goods or inputs) who dwell in poor areas would not be viable and definitely not quantifiable, as these contributions arise from a diffuse source. Even if one could tax the polluters, further complications arise in the form of measuring the marginal damage. Success would be achieved in the taxing of environmentally damaging goods used by agriculture, causing farmers to use alternatives when the price of agrochemicals used increases. This results in reduced pollution levels because of the decreased demand for these chemically engineered fertilisers.

4.5.2 Abatement subsidies

At the outset, it appears as if the provision of abatement subsidies yields the same incentives for lowering the pollutant load as effluent charges. But, government fails to recognise that polluters may alter their consumption of the good so as to procure the subsidy itself, or receive higher values of subsidies. If this option is adopted for the Lotus River case, how does one identify the parties responsible for this non-point source of pollution? Furthermore, due to the poverty levels experienced by residents in the catchment, this measure may well lead to increased pollution levels in order to gain access to these subsidies.

4.5.3 Property Rights

The Coase theorem is bound by its assumptions of well-defined and enforceable property rights and minimal transactions costs. However, these assumptions may not be upheld in the Lotus River example. The principal polluter within the catchment is urban settlements and more specifically informal settlement dwellers, which do not own the land they reside on and are widely dispersed over large areas, contributing to the diffuse source of pollution. Unless property rights can be assigned to these settlement dwellers, the first assumption is nullified. Addressing the housing backlogs is an issue of concern, but rarely is accommodated on occupied land. This renders the bargaining process void and particularly as the specific polluters and consumers cannot be identified. The Coase theorem is more relevant where few parties are involved, which is not the case in this densely populated region.

4.5.4 Creation of Markets

The sale of pollution permits (effluent fees) to producers' yields a socially efficient outcome, but implementation thereof requires knowledge of who is polluting and in what quantities. Application to the Lotus River Catchment implies that industries and the farming concerns engaged in production would be offered the rights to pollute via effluent fees. Though, the case study in Section 3.3 supports the identification of these producers, it cannot specify the individual polluters and determine the optimal pollution levels. The writer agrees with Rosen (1995) who mentions that this could potentially result in incumbent firms buying pollution licenses in excess of the firms' cost-minimising requirements, in order to deter other firms from entering the market.

4.5.5 Regulation

With application to the Lotus River Catchment, emission levels may be regulated or residential areas controlled by zoning laws. Setting a performance standard, implies that the optimal pollution level can be measured and so establish the accurate level of emissions by polluters. Even if quantifiable, only the industries and horticultural concerns could be regulated, not the informal settlement dwellers. The use of zoning laws may be feasible, but given the legacies of the past and subsequent housing shortages, this economic measure adds another blow to humanity.

The provision of sanitation stems from legislation being developed around poverty eradication and economic development; where hygiene and sanitation are regarded as key issues. A number of statutes have already been promulgated in South Africa, with regard to the provision of water and sanitation services being granted to all. According to the DWAF draft paper (2002:3), "…the national backlog of persons without access to adequate sanitation facilities was estimated to be 18 million or 3 million households;" the majority living in rural areas, peri-urban areas and informal settlements. The funding of sanitation services is generated via inter-governmental transfers like the Equitable Share, own revenue of Local Authorities and subsidies to the poor. The draft paper further reveals that the National Sanitation Programme had only impacted upon half a million people by early 2002 (DWAF, 2002).

Water pollution arising from urban settlements is addressed through tackling the problems of inadequate or poorly functioning services, whether it be regular refuse bin removals to eliminate litter dispersion, providing sanitation where non-existent, improving existing but inadequate stormwater and sewer infrastructure, preventing sewer blockages and providing facilities for grey water disposal.

If sanitation is addressed within the Lotus River Catchment, this will positively impact upon the pollution loadings entering the canal and Zeekoevlei.

4.6 SUMMARY AND CONCLUSIONS

In summary, there were lessons to be learnt from countries worldwide, with regard to water pollution control measures. The international situation reveals a tendency toward regulation mixed with economic policy instruments, which are employed to address their water pollution problems with varying degrees of success. The policy measures adopted in South Africa indicated a heavy reliance on regulatory legislation, with moves toward market-based, civil and self-regulatory management instruments. The latter measures have yet to prove effective, therefore economic options and coping strategies were assessed in terms of their effectiveness with regard to the Lotus River Catchment.

The distinguishing measure being regulation, given the fact that water pollution in the canal was attributed to a diffuse source in urban settlements. The provision of sanitation stands out as the most viable measure to pursue, due to the unique nature of informal settlements.

CHAPTER FIVE: GENERAL CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Water pollution alters the physical quality of surface waters, thus it no longer can be used for production and consumption activities, without cost. It originates from a fixed point (i.e. point-source) or spread over the land surface (i.e. non-point/diffuse source). The actions of individuals cause water pollution, which affects plant, animals and humans alike.

This impact on others resulting from the actions of producers and consumers is likened to the economic problem of externalities, a form of market failure requiring government intervention. Suggested solutions to the water pollution problem include economic measures such as taxation, subsidies, regulation, etc.

Water pollution is present in South African waterbodies. The specific case of the Lotus River Catchment within the CMA highlights the degree of urbanisation and population densities influencing land use, as well as the proportion of canalisation of the river. The sources of pollution within the Lotus River Catchment are urban settlements, industries and the agricultural sector.

High pollution levels were recorded along The Lotus River canal, where the water quality specifications indicated the presence of high levels of faecal coliforms and other organisms. These were identified as originating from the settlements, where inadequate or non-existent provision of sanitation occurred.

Water pollution is an environmental issue that needs addressing, viewed in terms of the loss of recreational value by consumers in Zeekoevlei. Users of surface waters like

Zeekoevlei has been negatively impacted upon, as a consequence of deteriorated water quality caused by the inadequate delivery of sanitation within informal settlements and historically poor residential areas.

Lessons were learnt from countries worldwide, with regard to water pollution control measures. The international situation reveals a tendency toward regulation mixed with economic policy instruments. The policy measures adopted in South Africa indicated a heavy reliance on regulatory legislation, with moves toward market-based, civil and self-regulatory management instruments. The latter measures have yet to prove effective, therefore economic options and coping strategies were assessed in terms of their effectiveness with regard to the Lotus River Catchment. South African urban dynamics has its own inherent problems that render traditional measures not viable.

Water pollution in the canal was largely attributed to a diffuse source in urban settlements. The provision of sanitation stands out as the most viable measure to pursue, due to the unique nature of informal settlements.

5.2 RECOMMENDATIONS

- Water quality guidelines as established by DWAF have to be more stringently enforced to ensure safer water, whether for direct consumption or recreational use. The society can only be assured of safe water when issues such as accessibility, sustainability and equity are addressed.
- Timeous intervention is required within the Philippi Horticultural area to ensure that regulations are not bypassed, namely with reference to growth in livestock breeding. This would render all other interventions null and void.
- The diffuse nature of pollutants has contributed its own set of difficulties. Cheaper ways of monitoring and enforcing pollution reduction schemes should be sought, enabling more targeted measures.
- The provision of proper sanitation stands out as the most viable measure to pursue,

not only due to the unique nature of informal settlements, but in order to address far-reaching social norms.

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