A PHILOSOPHY AND METHODOLOGY FOR IMPLEMENTATION OF THE POLLUTER PAYS PRINCIPLE

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& K Clement

A PHILOSOPHY AND METHODOLOGY FOR THE IMPLEMENTATION OF THE POLLUTER PAYS PRINCIPLE

FINAL REPORT

Prepared for the

WATER RESEARCH COMMISSION

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List of symbols and abbreviations

AC	- administration charge
BAT	- best available technology economically achievable
BOD	- Biological Oxygen Demand
BPT	- best practicable control technology currently available
Co	- Water Quality Objective defined as concentration at a control point
CAC	- Command and Control (see Glossary)
CMA	- Catchment Management Authority
COD	- Chemical Oxygen Demand
CONNEPP	- Consultative National Environmental Policy Process
DEA&T	- Department of Environmental Affairs & Tourism
Dsd	- Diffuse source differential
DWAF	- Department of Water Affairs and Forestry
EC	- electrical conductivity
ECU	- European Currency Unit
EEA	- European Environmental Agency
EPA	- US Environmental Protection Agency
EPE	- Economic Project Evaluation (PTY) LTD
HPM	- hedonic pricing method
I&APs	- Interested and Affected Parties
IPC	- Integrated Pollution Control
LDO	- Land Development Objectives
MAP	- Mean Annual Precipitation
MAR	- Mean Annual Runoff
MEIs	- Million Inhabitant Equivalents
MU	- Management Unit (see Glossary)
NCC	- Non-Compliance Charge
NRA	- National River Authority

Oc	- optimisation coefficient
OECD	- Environmental Committee of the Organisation for Economic Co-operation and Development
PPMR	- Potential Pollution Mobilisation Rates
PPP	- Polluter Pays Principle
RWQO	- Receiving Water Quality Objectives
SABS	- South African Bureau of Standards
TDL	- Total Diffuse Load
TDS	- Total dissolved solids
TPMP	- Total Potential Mobilisable Pollution
WLA	- waste load allocation
WLC	- Waste Load Charge
WRC	- Water Research Commission
WTP	- willingness to pay

Glossary

Abatement cost – cost of returning water to its original or acceptable qualitative state.

Catchment (as defined in the National Water Act, Act No. 36 of 1998) - in relation to a watercourse or watercourses or part of a watercourse, means the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points.

Charge - includes a fee, price or tariff which might be imposed under the National Water Act, Act No. 36 of 1998.

Command and control – this is the term usually applied to legislative or regulatory approaches to resource management.

Compliance monitoring point – a monitoring point which is used to determine the contribution of pollution from a certain source. For a point source it is usually a point at the end of the pipe or any other point just before the point where effluent is discharged. For diffuse sources a number of compliance points are needed. These points are usually defined after negotiation with the polluter as part of the licensing procedure.

Control monitoring point - a point at a MU's downstream end for which water quality guidelines can be determined in order to ensure downstream fitness of use.

Earmarking - is the allocation of a share of public revenues for a specific range of functions or the assignment of revenues generated by specific taxes.

Externalities - activities whose full cost or benefit is not incorporated into an economic decision; hence they lead to sub-optimal social allocation. *Internalisations of externalities* thus involves fully incorporating these costs and benefits into the decision process.

Fixed cost - capital and operating costs which are unaffected by volume of production. It is also called customer cost.

Intergenerational equity – the capital (including natural resources) that should be maintained between generations.

Management Unit - a river reach with a control point at it's downstream end and a number of compliance monitoring points, for which water quality guidelines can be determined in order to ensure downstream fitness of use.

Marginal costs – (long and short run) a marginal cost is the increase in the total costs caused by increasing its output by one extra unit.

Pollution (as defined in the National Water Act, Act No. 36 of 1998) - the direct or indirect 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 -

  (i) to the welfare, health or safety of human beings;

  (ii) to any aquatic or non-aquatic organisms;

  (iii) to the resource quality; or

  (iv) to property.

Pollution charge = waste water charge = effluent charge = emission charge

Regular point source - source of pollution, which discharges a consistent amount of pollution throughout the year, such as from a sewage work. It is distinguished from a release (see below).

Release - an irregular point source, such as spillage or controlled release from a dam, or mine dewatering. Its discharge ranges from near zero during dry periods to quite high values during wet periods.

Scarcity – the situation which arises when demand for any given commodity outstrips the supply of that commodity.

Sustainability – this concept captures the view that there is a need to treat environmental protection and continuing economic growth as mutually compatible rather than as necessarily conflicting objectives.

Sustainable water resource use – occurs where, with effective management and allowing for temporal rainfall and runoff/recharge variability, the rate of resource withdrawal, consumption or depletion is always equal to or exceeded by the rate of resource replenishment, while maintaining certain selected and agreed characteristics of the resource (e.g. water quality, biological diversity, degree of resilience to external disturbance or change).

Waste water charge – a charge for three categories of water use as determined according to the section 21 of the National Water Act, Act No. 36 of 1998:

- "discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;
- disposing of waste in a manner which may detrimentally impact on a water resource;
- disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process"

EXECUTIVE SUMMARY

Introduction

The initial response of governments around the world to environmental issues relied on the Command-and-Control (CAC) approach. This generally involved prescribing to industries the technology or processes that must be used. However, after years of implementing such systems the experience of many countries began to indicate that the CAC approach often failed to provide cost effective and efficient solutions for environmental management. The problems with the CAC approach eventually gave rise to a new approach to environmental governance provided by the discipline of environmental economics. This approach suggested that it was possible for flexible, economics-based measures to achieve acceptable levels of environmental benefit with simpler administration and lower control costs. In the context of pollution control this approach became known as the "Polluter Pays Principle" or the PPP as it is referred to in this report. Numerous studies have shown that the PPP concept has been widely used to design pollution or emission charges. In the water quality management field such charges are referred to as "waste water charges". In this report the terms "pollution charge" and "waste water charge" are used interchangeably.

The use of economic measures for environmental management is particularly attractive for the South African situation, which has elements of both the first and third worlds. As a developing country South Africa cannot afford expensive environmental regulatory systems. Such systems need to be self-sufficient and so must generate their own revenue. At the same time, South Africa has a relatively well developed infrastructure and level of knowledge and skills. These two factors mean that the introduction of a waste water charges system to improve water quality, warrants consideration and investigation.

The objectives of this research programme are as follows:

- to present the philosophy for the implementation of the PPP;
- to conduct a case study for the design of a waste water charge system, determine the optimum level for pollution charges and define the extent and fate of revenues;
- to identify the most suitable institution/s to administer the pollution charges system; and
- to make recommendations regarding options for implementation.

Philosophy of the PPP

Extensive research into the philosophy and practical application of the polluter pays principle revealed that the concept is being widely used to design pollution charges and has proven to be successful in many cases.

The six philosophical pillars upon which a polluter pays system stands are:

- The **ethics** of the 'polluter pays principle' derives from the universal moral principle that, all other things being equal, we ought not to cause harm to others.
- **Sustainable economic development,** which involves an "inter-generational social contract", which requires this generation to act as the steward of

environmental resources, so that the interests and needs of future generations are met.

- Everybody has an **equal right** to use environmental resources. Pollution charges systems protect this right.
- Current generations need to optimise **economic efficiency** for future generations. PPP systems provide an opportunity to optimise the choice between emission treatment and cleaner process technologies.
- Introducing a PPP system requires an extensive **consultation** process and the participation of regulators, polluters and parties affected by pollution.
- PPP implementation encourages polluters to stay below prescribed standards, resulting in a maximisation of environmental benefits or **environmental efficiency**.

Overseas experience

There is a general trend to combine CAC based systems with systems which utilise fiscal instruments such as PPP based pollution charge systems. An extensive examination of the overseas experience is described in section 3.3 and the key lessons are summarised below:

- If polluters in developing countries do not pay for their pollution, the impact of the pollution is felt most by those who are dependent on environmental resources for their livelihoods such as the rural poor communities.
- Less developed countries which undergo structural transformation have an advantage when implementing PPP based systems because the resistance to new systems is less extreme than in more developed countries where current systems are highly entrenched.
- The implementation of a PPP system can be politically problematic if public sector enterprises have significant interests in polluting industries and are thus both referee and player.
- Experience from other developing countries indicates that the most common problem in implementing pollution charge systems is the shortage of skilled personnel. However, this problem is even more pronounced for CAC systems.
- Pollution charge systems must automatically be adjusted for inflation.
- No waste water charge system for diffuse pollution was found. However, the theoretical discussions found in the literature recommend encouraging polluters to convert their pollution discharge from non-point source to measurable point source. Higher charges for non-point than for point source discharges would provide an incentive for such an action.
- Only one waste water charge system dealing with sulphate pollution was found. This is the system utilised in Poland, where the waste water charge on saline mine effluent is the largest contributor to total revenue collected in water management. The charge has been in effect since 1970 and has been increased a few times since then. The latest charge published is 24.3 ECU/t of sulphate for 1993, which is about 60 R/t inflated to 1997 prices.

Pollution control in South Africa

South Africa has previously relied on a number of systems based on the CAC approach. While this has been effective in certain instances, there is a need for a system which relies on economic incentives rather than regulatory supervision and which is self-funding. Since 1994 South Africa's legal and policy framework has evolved such that it is now suitable for the introduction of PPP based systems.

Witank Dam catchment - the case study area

The Witbank Dam catchment and the pollutant sulphate were selected for a case study of pollution charges as they were in accordance with the objectives of the study.

As much information as possible was collected about the catchment. Some attempts were made to improve the quality of the data, however to bring all the data up to the necessary quality was far beyond the scope of this study. The monitoring and data collection systems will have to be modified at some stage to support a charge system in this catchment.

Once the information had been collected and analysed it was processed to provide the following input into the pollution charge model:

- the assessment of the monitoring data was used to determine the monitoring costs that form a part of the Administrative Charge (AC);
- the water quality status was used as an input to calculate the exceedance of the Water Quality Objective (Co) that determines the Non-Compliance Charge (NCC);
- the water use data was utilised to estimate the impact cost that determines the catchment Waste Load Charge (WLC); and
- the pollution sources were characterised to calculate the WLC for individual polluters.

The AC, WLC and NCC are the main components of the charge system that is described below.

Impact and abatement costs

The costs in this study have been calculated for two water quality regimes in the Witbank Dam catchment: the 1990/91 and the 1995/96 hydrological years. These two years represented different hydrological conditions - one of the driest and one of the wettest years in the last decade. The impact cost considered was only the direct financial cost and not the full cost to society of the impact of pollution. Another limitation was that only water users within the study area were considered. It was found that the impact costs vary widely between wet and dry years.

The abatement costs were assumed to range from cost of treatment at the source to the cost of treatment at a point of use. These values were compared with abatement cost estimated in earlier studies.

It was concluded that the direct impact cost is very small when compared to abatement costs.

Charge system model

From an examination of international experience and the case study at Witbank it is concluded that pollution charges are a viable water quality management tool for South Africa to implement.

The model that has been developed for implementing pollution charges in the Witbank Dam catchment is essentially a framework model intended to demonstrate the practical application of the system. No model is perfect, although models such as this are intended to eventually achieve a degree of 'perfection' which is acceptable to both polluter and society as they are implemented and modified with experience.

The model takes into account relevant lessons learnt from an extensive literature survey and also proposes new solutions to local problems, which are not as yet addressed elsewhere.

It is successful in satisfying all the following design objectives:

- Net revenue must be equal to or exceed local direct impact costs of pollution.
- Implementation costs should be minimised.
- A deterrent to polluters from excessive and harmful pollution is essential.
- A deterrent to non-point source pollution should be provided.
- Charges must be reasonable, justifiable and must not promote economic decline.
- The model must be simple and flexible.

The proposed system arrived at during the course of the research is a combination of cost covering charges and an incentive system. It includes the following three main components:

Administration Charges (AC) - Administration costs are incurred because polluters want to use surface water systems to dispose of waste, and society wants such actions to be monitored, controlled and paid for. These costs must be specific to the characteristics of the administered area and be paid in full by polluters in that area.

Waste Load Charge (WLC) - This applies to all effluents when the concentration at the control point exceeds the impact level (Ci). The WLC is charged per ton of pollutant load discharged based on the impact cost.

Non Compliance Charge (NCC) – the NCC is a penalty charge, which is levied on waste discharges when the concentration at the control point exceeds the Water Quality Management Objective (Co) for a particular pollutant.

The model calculates the different types of pollutant loading from each individual source and the charges payable. The calculations made in the spreadsheet model are only a demonstration of the model capabilities as they have some limitations.

This model was developed assuming that its implementation will be undertaken in phases. It provides input for the first phase and each succeeding phase should include further model development based on feedback from the previous phase.

Likely income from charge system

The proposed system is expected to generate a revenue of R3.05 million/a to R9.15 million/a for the first year of implementation. Although this revenue is less than the estimated cost of pollution for the first few phases of implementation, the full recovery could be achieved within four years. The phased approach for system implementation is suggested.

Comparison with CAC system

The implementation of the charges system to complement the old CAC approach should reduce state expenditure on water quality management because of the following:

- It might be possible for the DWAF to use some monitoring equipment installed for the charge system.
- The system should minimise monitoring costs to the regulating authority, because polluters will have a strong incentive to carry out comprehensive monitoring themselves. In particular there should be no need for compliance monitoring with only spot checks at compliance points being required.
- Use of NCC and penalties will simplify control systems and minimise enforcement costs (e.g. the cost for legislative procedures).

The charge system will definitely provide polluters with an incentive to reduce their pollution without limiting their choice of an optimum economic solution. Pollution prevention by utilising better water management practices will become a first option for the minimisation of the WLC paid by polluters. This option is the most effective and economically viable first step for improving overall water quality in the catchment. The use of a Diffuse Source Differential is an incentive that eventually will minimise non-point source contributions.

Choice of model algorithms

Extreme care was taken in developing algorithms for the charge calculations and implementation procedures to ensure that charges are reasonable and justifiable. A need to prevent charges from promoting economic decline was stressed.

Finally, the simplicity of the model was paramount. Numerous possibilities for improving the model are available, although some will make the model more complex and therefore should only be introduced at a later stage if it becomes certain that the increased complexity is justifiable and necessary.

Fate of revenues

The spending of any revenue arising from the collection of charges should be linked to reducing the impact costs of pollution and should aim for maximum impact. Where possible double or even triple dividends should be achieved.

Treating revenue from pollution charges like other taxes and returning it to the general fiscus is problematic and contravenes the transparency requirement of the PPP. It has been rejected as an option in the review of South African water laws.

One of the first priorities is the implementation of the system for pollution monitoring and control, and the administration of the charge system. Following this, revenues should be used to mitigate against negative environmental impacts, to implement measures to improve water quality management or to fund research and development and national water quality policy initiatives.

Excess revenue arising from penalties should be spent on subsidies to a number of groups, from companies needing to invest in new pollution control technologies to under-serviced communities to provide for environmentally sound sanitation. The clean up of past pollution can also be subsidised from this revenue.

A combination of uses for charge revenue is the most appropriate and is likely to yield the highest overall dividends.

Need for consultation

The success of a charge system depends on the presence of two features: an effective incentive to reduce, manage and monitor pollution by the polluter, and acceptance by the polluter of the pollution charge system, inclusive of its design and methodology. Whilst this particular model achieves the objectives of model design as described earlier, its success will also depend on consultation and understanding between the system managers and the polluters. This aspect is outside of the scope of this project, but appropriate recommendations are provided in section below.

Recommendations

Implementation of a charge system for the Witbank Dam Catchment

It is recommended that serious consideration be given to the implementation of a sulphate pollution charge system in the Witbank Dam catchment. The model proposed under this project is simple to apply and effective in achieving the design objectives. Its implementation should bring a twofold benefit of improved environmental control with reduction of implementation costs to government and society. With time it may have a further benefit, when revenues from the charge system are spent on water quality enhancing measures, which also have a welfare benefit (e.g. sanitation).

From overseas experience it was found that in introducing such a system it is better to test it in one area in order to evaluate public reaction and determinate its effectiveness. The Witbank Dam catchment seems to be a good choice for an introductory implementation.

Acceptance of a charge system for the Witbank Dam catchment

It is important that the design of a waste water charge system, the information used as an input and the underlying assumptions are accepted by all affected parties. A charge system which is open to dispute in any way is unlikely to yield any revenue whatsoever. Moreover, it would most likely burden society with additional costs such as those incurred through the appointment of specialists and lawyers.

The specific issues, which have to be considered and accepted by I&APs include, but are not restricted to the following points:

- Institutional arrangements for the effective administration of waste water charge systems must be finalised by government. It is recommended that such systems be initiated by the DWAF and that a catchment forum be used for negotiation among stakeholders. Ultimately, a catchment management authority should administer the system.

- The best method for allocating total diffuse load to known non-point sources has to be selected in consultation with the I&APs.
- The appropriate level of monitoring must be determined. The monitoring and auditing of polluters are components of the administrative cost of the waste water charge system. Hence, a decision regarding the design of control and compliance monitoring systems should be taken.
- All algorithms and all input data used in the proposed model must be discussed with I&AP's and accepted, including procedures for determining the direct financial cost of pollution.
- The more in-depth investigation of possible negative socio-economic effects of the charges on industry was suggested by the Chamber of Mines.
- This study has paid insufficient attention to the disbursement of the revenues generated by the waste water charge system. This needs to be investigated further, agreed upon by all parties, and guidelines drawn-up prior to introduction of a charge system generating a significant revenue surplus.

Monitoring of economic effects

It is essential to the successful running of the system that the economic effects and environmental effectiveness of the charges system are closely monitored during each stage. The CMA should respond quickly enough to such indicators to ensure that appropriate charge levels are maintained.

Should it be decided that a pilot waste water charge system be introduced in the Witbank Dam catchment, it is important that its introduction is gradual and closely monitored as the threshold charge (i.e. the charge at which polluters start to reduce discharges due to the cost involved) remains unknown.

Extension to other pollutants and catchments

As this study focussed on only a one single catchment and only one water quality parameter, it is imperative that further studies be conducted to extend the charge system to include other pollutants. Priorities should be set for this extension, based on the results of the classification of the water resources. The priorities for implementing the charge system for other river catchments will be an outcome from the same process.

The procedure for determining the direct financial cost of current pollution on downstream water users is still lengthy and imprecise. Clear guidelines need to be developed to streamline this procedure before the charge system is applied in other catchments.

Pollutants that have a clear economic impact, such as salinity or salinity related parameters could be the first priority for the charge system implementation. In cases when no clear economic impact cost can be determined a combination of AC and NCC charges might be utilised.

Method of dealing with old pollution sources

The control of backlog pollution was beyond the scope of this project, but it is recommended that the cost of water pollution control measures from abandoned mines be included as one of the revenue uses. This activity will relieve the government of the financial burden caused by past polluters, improve water quality for water users and provide present polluters with an additional assimilative capacity.

Pollution charges as part of the water management

Any charge system that is introduced should form part of a Water Management Plan (WMP) for the catchment. Both the charge system and the WMP should arise from the establishment of an appropriate CMA. The CMA will be responsible for determining the water quality objectives, water allocation for the catchment and other components of the WMP that are also needed for design of the charge system. The WMP must be developed in close co-operation with all I&APs.

The current project provides a basis for further development of water related legislation. The implementation of the new national water pricing proposals must be dovetailed with waster water and environmental charges so as not to undermine incentives or distort prices. It is strongly recommended that the findings of this project be used for dealing with issues such as pollution prevention and financial provisions for CMAs.

1. INTRODUCTION

1.1 Background

The initial response of governments around the world to environmental issues relied on the Command-and-Control (CAC) approach. This generally involved prescribing to industries the technology or processes that must be used. However, after years of implementing such systems the experience of many countries began to indicate that the CAC approach often failed to provide cost effective and efficient solutions for environmental management. The problems with the CAC approach eventually gave rise to a new approach to environmental governance provided by the discipline of environmental economics. This approach suggested that it was possible for flexible, economics-based measures to achieve acceptable levels of environmental benefit with simpler administration and lower control costs. In the context of pollution control this approach became known as the "Polluter Pays Principle" or the PPP as it is referred to in this report. Numerous studies have shown that the PPP concept has been widely used to design pollution or emission charges. In the water quality management field such charges are referred to as "waste water charges". In this report the terms "pollution charge" and "waste water charge" are used interchangeably.

The use of economic measures for environmental management is particularly attractive for the South African situation, which has elements of both the first and third worlds. As a developing country South Africa cannot afford expensive environmental protection systems. Such systems need to be self-sufficient and so must generate their own revenue. At the same time, South Africa has a relatively well developed infrastructure and level of knowledge and skills. These two factors mean that the introduction of a waste water charges system to improve water quality, warrants consideration and investigation.

The Water Research Commission (WRC) began to investigate the subject of economic instruments for water quality management several years ago through a project entitled "The Application of Economics to Water Management in South Africa" (WRC, 1993). A follow-up project entitled "The potential for the use of economic instruments to protect the quality of water resources in South Africa" (WRC, 1996) was completed. These studies analysed the full range of economic instruments which could be utilised and simulated an application of polluting permit trading using the Witbank Dam Catchment as a case study.

This project follows on from the past research, but specifically focuses on the philosophy of the PPP, modelling the implementation of waste water charges in a specific catchment, and examining implementation issues associated with such a system.

1.2 Objectives of the research

The objectives of this research programme were as follows:

- To present the philosophy for the implementation of the PPP.
- To conduct a case study in order to design a waste water charge system, determine the optimum level for a pollution charge and define the extent and fate of revenues.

- To identify the most suitable institution/s to administer the pollution charge systems.
- To make recommendations regarding options for implementation.

1.3 Interpretation of the objectives and approach

The authors have interpreted these objectives as to investigate the theoretical basis for the Polluter Pays Principle and to examine a hypothetical, yet realistic, South African case study of implementing a water pollution charge system. In doing so, appropriate institutions for implementation must be identified and some other implementation issues examined. The two last objectives of the research project were interpreted as pertaining primarily to the case study, although some of the institutional and implementation findings have a strong generic flavour.

The approach taken to this research has been to gather relevant material from other countries regarding the philosophy behind the PPP and where possible the experience of other countries in implementing pollution charge systems. Gathering material on the experience of other countries proved to be quite an onerous task. The reason being that very few countries have published detailed investigations into their charge systems, despite the fact that there are many such systems some of which have been in place for many years. This may be because they are unwilling to publicly acknowledge the objectives of their charge systems and thus whether the objectives are being met.

Once the philosophical basis of the PPP was established, the theoretical case study for the Witbank Dam catchment was conducted. This involved designing a set of charges and modelling them according to actual data from the Witbank Dam catchment. During this stage of the project, stakeholders in the catchment that would be affected by such a charge were informed of the project and given the opportunity to make inputs.

The final stage of the project involved identifying issues relevant to the actual implementation of such a system in the Witbank Dam catchment. Issues such as appropriate institutions to best administer such a system, the fate of revenues and the potential economic impact of the charges were examined. The identification of appropriate institutions included those organisations best able to administer a pollution charge system on an agency basis.

Throughout the research, the Steering Committee, DWAF and stakeholders in the Witbank Dam Catchment were consulted and kept informed about progress.

1.4 Structure of the report

This report is structured in the following way:

Chapter 2 presents the philosophy of the Polluter Pays Principle and provides an essential policy foundation for the introduction of pollution charges.

Chapter 3 briefly summarises the international experience with various pollution control approaches over time. More specifically it documents the move towards the PPP and the introduction of pollution charges in a number of other countries. The lessons learnt from this process are noted.

Chapter 4 examines the background to water pollution control in South Africa in the context of both water resources management and integrated environmental management. By highlighting issues such as the policy review of water tariffs and the general trend towards economic and self-financing approaches to environmental management, this chapter provides the legal foundation for the introduction of waste water charges in South Africa.

Chapter 5 broadly considers the limitations of a waste water charge system. More specifically it considers the typical problems that would be encountered with non-point pollution, the economic justification for pollution charges, and striking an acceptable balance between the need to encourage economic development and the importance of improving and protecting the quality of the nation's scarce water resources.

Chapter 6 presents the case study of the Witbank Dam catchment. It focuses on the problem of sulphate pollution, most of which enters the drainage system by way of non-point pollution from upstream coal mines. It contains a description of the available data for the study period and explains how it should be processed to prepare an input into the waste water charge system.

Chapter 7 contains an estimation of the direct cost impacts of sulphate pollution for the Witbank Dam catchment. It covers agricultural, domestic, municipal and industrial water users. It also estimates costs of abatement, including the costs of treating sulphate-rich water to acceptable standards.

Chapter 8 looks at the hypothetical design of a waste water charge system specifically for Witbank Dam. It introduces a model to simulate the application of charges and different options for estimating contribution of non-point source pollution. The modelling results for different pollution loading scenarios (wet and dry hydrological years) are also presented.

Chapter 9 considers the fate of the revenues generated by the hypothetical application of a waste water charge system in the Witbank Dam catchment, and how these might be used to indirectly compensate downstream water users, improve water quality generally in the catchment, and to reimburse the administrators of the charge system.

Chapter 10 takes the Witbank Dam Case Study further by examining the practical aspects of implementing a waste water charge system. This examination includes the possible impact on investment and considers the various institutional options. The way of phasing in of the charge system is proposed.

Chapters 11 and 12 offer some conclusions on the research study and make recommendations for further work.

2. THE PHILOSOPHY OF THE POLLUTER PAYS PRINCIPLE

2.1 Why polluters do not pay for their externalities

2.1.1 Pollution: a negative externality

By definition, the process of production involves the transformation of one good or service into another. By-products formed during the process of production that are passed on to third parties and affect their welfare are known as externalities. For example, if a house improves in value as the neighbourhood improves, and nothing specific has been done to improve the house, then the household owner has benefited from an externality.

Unfortunately, many externalities decrease the welfare of the third party. Consider the steel mill upstream of a riverside holiday resort that discharges toxic by-products into the river, thus preventing boating, angling, swimming and other recreational activity. Here a cost is imposed on the riverside holiday resort, which in the absence of contrary legislation, the steel mill is not obliged to pay, even though it is a result of its production process. In such instances pollution is a negative externality.

2.1.2 Why externalities are not internalised

At a conference on poverty and sustainable rural livelihoods held by the Land and Agriculture Policy Centre in 1997 (Ainslie A and Ntshona Z, 1997), a case study of rural livelihoods and the environment illustrated the tragedy of the commons[1]. The study looked at the usage of land formerly owned by the Ciskei government. During the transition, after the 1994 elections, land in the Ciskei was effectively not administered by any authority. The former Ciskei government had no authority and provincial government was not yet in place. During this time the land was used by local residents as commonage, with all parties using the land to graze freely. There was no form of payment or system of management and as such the land was subsequently over-grazed and has been badly damaged.

In the long run all the residents in the area have lost as a result of this situation, as over-grazing will eventually lead to soil erosion. Why then did residents pursue this policy of overgrazing and not regulate their resource? The simple answer is that the short term benefits accrued to the individuals involved, whereas the long term costs will be borne by the whole community and indeed the greater society. In other words, there was an incentive for a group of individuals to act, as individuals, in maximising the benefits to themselves without considering the costs and benefits of over-grazing to other parties.

As with the steel mill in the previous example, the mill accrues the benefits of its production, but much of the cost is passed on to another party. It can do this because the environmental resources, in this case water, are treated as free goods - as commonage, they do not have a price. Alternatively in some countries where they do have a price, the price does not reflect the true opportunity cost of the environmental resource.

If an individual benefits from a particular action by one unit, and the costs of the action are less than one unit, then in the short term it is economically rational for the

[1] In this instance commons referes to an area of open acess with no rules reulating access and usage of the area

individual to continue with that course of action. However, it is ethically indefensible for the individual to derive full benefit without bearing the cost of his actions.

2.2 The philosophical principles for a pollution charge system

There are six philosophical premises for the pollution pays principle:

Ethics: The ethics of the 'polluter pays principle' derives from the universal moral principle that, all other things being equal, we ought not to cause harm to others. At present most of the costs related to pollution are borne by society. Implementation of the PPP shifts the responsibility for environmental costs to the polluter and adjusts pricing systems to reflect more true costs of production.

Equality: Everybody has an equal right to use environmental resources. A pollution charges system can protect this right by ensuring for example that parties polluting water at the upper reach of a river are responsible for compensating, in some way, parties using polluted water lower down the river.

Sustainability: The notion of sustainable economic development requires that at any point in time the present generation has a responsibility towards meeting the likely needs of future generations. When examined in the light of environmental concerns, this requires the present generation to act as stewards of environmental resources. It is up to the current generation to institute systems and safeguards that ensures these resources are available to and able to be used by future generations.

Economic efficiency: Economic efficiency is improved when the systems of production are adjusted so that the social benefits (comprising both the benefits of economic activity and the benefits associated with a protected and functional environmental resource base) are maximised. To maintain economic efficiency, the sustainability of both the economic activity and the natural resource base on which it relies, must be ensured. PPP systems provide an opportunity to optimise the choice between economic and environmental needs and between emission treatment and cleaner process technologies.

Transparency: The PPP should be introduced via an extensive, consultative process and the participation of all affected parties, generally - regulators, polluters and parties affected by pollution (pollutees).

Environmental efficiency: Unlike the CAC approach, implementation of the PPP encourages polluters to stay below prescribed standards, resulting in the maximisation of environmental benefits (see Box 3.1)

2.3 The objectives of a pollution charges system

2.3.1 Introduction

The theory behind polluters paying pollution charges is that they must pay for the costs incurred as a result of their pollution. However, if polluters were to pay the full costs of their pollution, the impact would be severe enough to cripple many economies. The aim is thus to reach an optimal level of pollution. In practice, charges are generally levied to induce polluters to modify their behaviour (deterrent objective) and to generate revenue to cover some of the polluter's externalities (revenue objective).

2.3.2 What is the optimal level of pollution?

As indicated, the optimal level of pollution is a key feature of the PPP. Some people would argue that the optimal level of pollution should be zero, however this could have disastrous economic implications. The PPP approach requires that some kind of compromise be reached between the polluter and society (whose interests in this instance are generally represented by government). The dual objectives of this compromise are to find a level of pollution where the costs of the pollution are bearable to society and where the costs of using the resource, for example clean air or water, are bearable to the polluter. In theoretical terms this point is referred to as the optimal level of pollution. It is not an actual level of pollution that can be readily quantified, but rather a conceptual level. It is a level of pollution, which both industry and society can live with. It is represented in Figure 2.1 below.

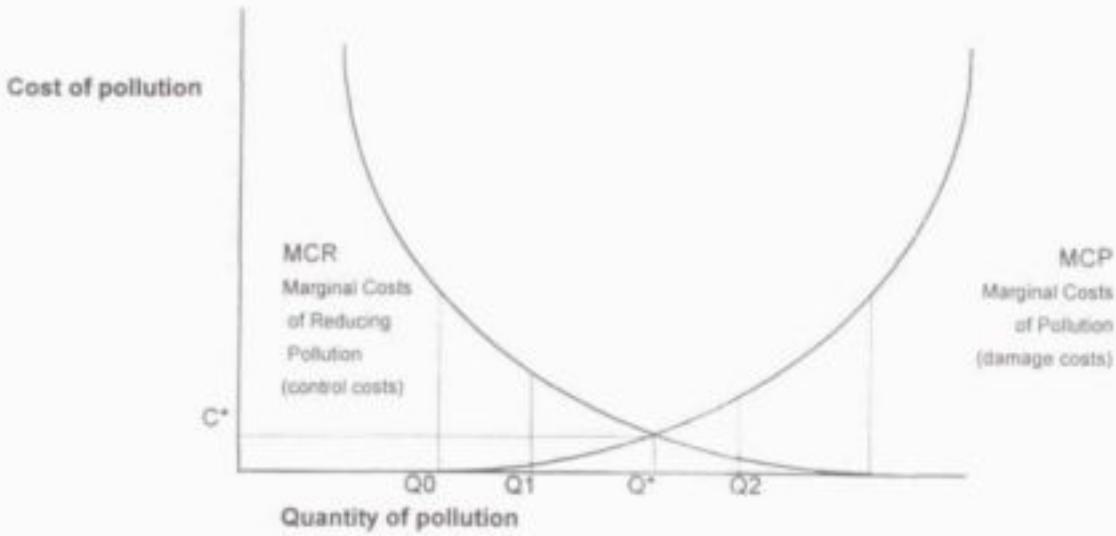

Figure 2.1: The determination of the optimal level of pollution in terms of the "polluter pays" principle.

Figure 2.1 indicates that as the quantity of pollution increases so does the Marginal Cost of that Pollution to society or damage costs. When the Marginal Cost of Reducing pollution is plotted, it can be seen that the more money spent on control the less pollution there is. Where the two curves intersect is the point where control costs are equal to damage costs, point Q*. This quantity of pollution represents the optimal level of pollution that industry can maintain if the money spent controlling pollution is to be equal to the costs of the damage caused by the pollution. At Q1 the costs of pollution control exceed the damage done by pollution. In other words the money spent is greater than the benefits gained from an improvement in environmental quality.

What is clear from this diagram is that the optimal level of pollution is not zero. It is a point at which industry can continue to produce goods and the production of those goods with a reasonable level of environmental quality, which will maximise the welfare to society. In other words this optimal point is where a country or region can afford to trade-off economic growth with levels of pollution.

2.3.3 *The deterrent objective*

In order for a system to meet a deterrent objective, a trial and error approach can be utilised. This involves starting with relatively low charges and increasing them regularly until they are high enough to provide sufficient incentive for polluters to minimise their discharges. Further details on how this can be implemented are provided in chapter 8.

2.3.4 *The revenue objective*

Pollution charges can also recover some of the costs imposed by the discharge on various parties. Revenues could be used for a range of purposes in keeping with the polluter pays principle including:

- Monitoring polluters and operating the system of charges.
- Finance for new or upgraded treatment works.
- Catchment water quality management.
- Indirect subsidisation of victims.
- Cross subsidies to assist other polluters to reduce their pollution effect.
- Cross subsidies for reducing pollution backlogs, (e.g. abandoned mines).

The state already spends some revenue on defending and preserving the integrity of its environmental assets. Part of this defensive expenditure is normally borne by the taxpayer. However, over and above this, the state requires additional funds to monitor pollution and to prosecute those polluters who break the law. This requires a guaranteed source of revenue. A charge system based on the PPP can provide this.

2.4 What must the polluter pay for?

The relationship described below indicates the costs that the polluter imposes on society as a result of water pollution.

$$C_{Total\ impact} = C_{Admin} + C_{Direct} + C_{Indirect} + C_{Opport}$$

Where:

$C_{Total\ impact}$ = Total cost impact of pollution on society.

C_{Admin} = Costs to government of monitoring and policing pollution.

C_{Direct} = Direct costs of pollution on downstream water users.

$C_{Indirect}$ = Indirect costs to the economy.

$C_{Oppport}$ = Opportunity cost of water which has been polluted, i. e. the cost of not being able to use the water for a particular purpose.

It would be nice if the victims of pollution were compensated for the complete cost of the impact. In reality, no country has a system in which polluters pay the whole value of the externality. Aside from the practical difficulties of always establishing the total value of an externality, forcing polluters to pay for the total costs of their externality would sometimes cause enormous economic upheavals. Similarly, the victims of pollution are most probably consumers of products, the manufacture of which causes pollution. Hence full compensation may not always be warranted.

Consequently, the PPP generally only aims to recover a portion of the full costs of pollution. Theoretically, this portion should correspond to the optimal level of pollution. In practice, we have no way of knowing where this is. However, the assumption is made that if all the C_{Admin} costs and a portion of the C_{Direct} costs are recovered from the polluter in order to meet the deterrent and revenue objectives of the system, then investment will not be discouraged nor economic growth affected.

3. INTERNATIONAL EXPERIENCE WITH POLLUTION CONTROL

3.1 Overview

This section presents an overview of some of the experiences of other countries with pollution control systems and draws out several lessons, which are relevant for South Africa. In terms of the command and control approach, the United States has been singled out as a case study and some key issues with the approach have been explored. In terms of the Polluter Pays Principle, the experiences of several countries, and the main lessons they learned, have been presented.

3.2 The command and control approach

3.2.1 Overview

The first attempts of most countries at controlling pollution involved direct intervention into the production processes that were generating pollution. This often involved technical prescriptions as to how a good or service should be produced. This early system of pollution control has come to be known as the 'command and control' approach. As with definitions of 'polluter pays', there are a wide variety of definitions of 'command and control'. However, the common thread in definitions is that 'command and control' regimes involve direct government (local, regional or national) intervention in the production process to reduce pollution. The history and limitations of 'command and control' are most clearly illustrated in the experience of the United States (US), largely because they have introduced one of the world's most ambitious water pollution control initiatives. The next section focuses on the history of water pollution control in the USA and it is based on extracts from Tom Tietenberg's *"Environmental and natural resource economics"* 1992.

3.2.2 The case of the United States

3.2.2.1 Initial legislation

The first federal legislation dealing with discharge into the nation's waterways occurred when Congress passed the 1899 Refuse Act. Designed primarily to protect navigation, this Act focused on preventing any discharge that interfered with using rivers as transport links. All discharges into a river were prohibited unless approved by a permit from the Chief of the US Engineers.

Most permits were issued to contractors dredging the rivers, and dealt mainly with the disposal of the removed material. This Act did not cover other pollutants until 1970, when this permit program was rediscovered and used unsuccessfully as the basis for federal enforcement actions.

3.2.2.2 The Water Pollution Control Act of 1948

The Water Pollution Control Act of 1948 represented the first attempt by the federal government to exercise some direct influence over what previously had been a state and local function. This was a hesitant move, since it reaffirmed that primary responsibility for water pollution control rested at state and not at federal level. However, it did provide federal government with the authority to conduct investigations, research and surveys.

3.2.2.3 Amendments to the Water Pollution Control Act passed in 1956

The first hints of the current approach to pollution control are found in the 1956 amendments to the Water Pollution Control Act. Two important provisions in this Act were; firstly, federal financial support for the construction of waste treatment plants, and secondly, direct federal regulation of waste discharges via a mechanism known as the Enforcement Conference.

The first of these provisions envisaged a water pollution control strategy based on subsidising the construction of waste treatment plants. Municipalities could receive federal grants to cover up to 55% of the construction cost of sewage treatment plants. This lowered the cost to the local governments of constructing these facilities, and the cost to users since the federal government contribution was a grant, rather than a loan. The fees charged to users did not reflect the federally subsidised construction portion of the cost. The user fees were set at a low rate, but high enough to cover the unsubsidised portion of the construction cost, as well as the operating and maintenance cost.

The mechanism created by the 1956 amendments to enforce the regulation of discharges was the Enforcement Conference. Under this approach, the designated federal control authority could call for a conference to deal with any interstate water pollution problem, or it could be requested to do so by the governor of an affected state. The fact that this authority was discretionary, not mandatory, and that the control authority had little means of enforcing any decisions reached, meant that the conferences simply did not achieve the intended results.

The 1956 amendments initially envisaged a relatively narrow federal role in the regulation of discharges. Only polluters contributing to interstate pollution were included but subsequent laws broadened the coverage. By 1961, discharges into all navigable water were covered by the Act.

3.2.2.4 The Water Quality Act of 1965

The Water Quality Act of 1965 attempted to improve this process by establishing ambient water quality standards for interstate watercourses and by requiring states to file implementation plans. The plans forthcoming from states in response to the 1965 Act were vague and did not attempt to link specific pollution standards on discharges to the ambient standards. The fact that these standards bore no relationship to local ambient levels made them difficult to enforce in the courts.

3.2.2.5 Recent Legislation

An air of frustration regarding pollution control pervaded Washington in the 1970s. As with air pollution legislation, this frustration led to the enactment of a very tough water pollution control law. The 1972 Act called for the achievement of two goals: "that the discharge of pollution into navigable waters be eliminated by 1985"; and "that wherever attainable, an interim goal of water quality, which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by June 1, 1983." The stringency of these goals represented a major policy departure.

This Act introduced new procedures for implementing the law. Permits were required for all discharges (replacing the 1899 Refuse Act, which, because of its navigation focus, was difficult to enforce). Permits would be granted only when the discharges met certain technology-based pollution standards. The ambient standards were completely bypassed as these pollution standards were uniformly imposed and ignored local water conditions.

According to the 1972 amendments, the pollution standards were to be implemented in two stages. By 1977 industrial discharges were required to meet pollution limitations, based on the "best practicable control technology currently available" (BPT). In setting these national standards, the US Environmental Protection Agency

(EPA) was required to consider the total costs of these technologies and their relation to the benefits received, but not to consider the conditions of the particular waters into which it was discharged. In addition, all publicly owned treatment plants were to have achieved secondary treatment by 1977. By 1983 industrial discharges were required to meet pollution limitations based on the presumably more stringent "best available technology economically achievable" (BAT), while publicly owned treatment plants were required to meet pollution limitations which depended on the "best practicable waste treatment technology."

3.2.2.6 Subsidies

The system of subsidising municipal water treatment plants, introduced in 1956, was continued in a slightly modified form by the 1972 Act. Whereas the 1965 Act allowed the federal government to subsidise up to 55% of the cost of construction of waste treatment plants, the 1972 Act raised the ceiling to 75%. The 1972 Act also increased the funds available for this program. The 1977 amendments continued this regulatory approach, but with some major modifications. This legislation drew a more careful distinction between conventional and toxic pollutants, with more stringent requirements placed on the latter, and extended virtually all of the deadlines in the 1972 Act.

For conventional pollutants a new treatment standard was created to replace the BAT standards. The pollution limitations were to be based on the "best conventional technology," and the deadline for attaining these standards was set at July 1, 1984. In setting these standards, the EPA was required to consider whether the costs of adding the pollution control equipment were reasonable when compared with the improvement in water quality. For unconventional pollutants and toxic wastes (any pollutant not specifically included in the list of conventional pollutants), the BAT requirement was retained but the deadline was extended to 1984.

The date for municipalities to meet the secondary treatment deadline moved from 1977 to 1983. Industrial compliance with BPT standards were delayed until 1983 or whenever the contemplated system had the potential to be applied throughout the industry.

The final modification in the 1977 amendments involved the introduction of pre-treatment standards for waste being sent to a publicly owned treatment system. These standards were designed to prevent discharges that could inhibit the treatment process and to prevent the introduction of toxic pollutants that would not be treated by the waste treatment facility. Existing facilities were required to meet the standards within three years of publication, while facilities constructed later would be required to meet the pre-treatment regulations upon commencement of operations.

3.2.2.7 Conclusion

US water pollution control policy relied on permits that were based upon meeting certain technology based pollution standards.

The 1972 Act based the pollution standards on the technologies of pollution control available to each industry. The enforcement of this proved to be a monumental task for the EPA. The EPA was required to take into account

> *"the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various control techniques, process changes, non water quality environmental impact (including energy requirements) and such factors as the Administrator deems appropriate"* (Tietenberg, 1992).

Studying the technology of each and every polluting industry's technology as well as the available water pollution control technology was an enormous task. Setting standards could not be completed and the deadlines for publication were continually shifted. As soon as they were published they were challenged in court.

The standards were also set without regard for specific ambient pollution levels at particular sources. In other words, pollution standards were set without regard for the specific tolerance of the water body into which they were disposed. Establishing the specific tolerances of each water body was an immense undertaking.

The US policy of "command and control" focused on technology requirements rather than the ultimate aim of achieving clean water. Ironically, CAC retarded the development and adoption of new water pollution control technology. When faced with a range of possible technologies, industry in the US often chose the specific equipment cited by the EPA (Tietenberg, 1992). If anything went wrong and the industry was taken to court, they would argue that they used the same technology as that specified by the EPA when it determined the standards.

Industry also tended to keep the same technology until the standards were revised. The US technology based water pollution control legislation actually provided an incentive for the maintenance of obsolete water pollution control technology.

3.2.3 Limitations of 'command and control' regimes

3.2.3.1 Enforcement

Properly enforced 'command and control' regimes are expensive for both regulator and regulated. Regulators require a large number of highly trained staff with knowledge of the different types of pollution, industry-specific technology, and production processes. Industrialists are required to adopt technology stipulated by the regulator, irrespective of the cost implications.

In terms of enforcement, "Command and Control" regimes require the constant monitoring of industry to ensure that state stipulations are being followed. When the legislation stipulates regular maintenance of pollution control or other pollution causing equipment, the regulator is forced to gain an understanding of that piece or range of equipment in order to ensure that it is well maintained.

It is the regulator more than the polluter, which must pay to keep abreast of industry developments. Stipulating technology requirements also holds the inherent danger of exposing the legislator to litigation arising from claims made by down stream users.

3.2.3.2 Hampers competitiveness

There are numerous aspects of the command and control approach which hamper the competitiveness of firms. Prescribing technology is likely to reduce the competitiveness of a firm as regulators are concerned with pollution control, and not the needs of particular industrial operation or plant.

There is generally a time lag between recognising appropriate technology and incorporating it into legislation and regulations. Often technology has changed by the time legislation is amended. Entrepreneurs know their production process and technological requirements better than a regulator as they are constantly working with it. As such, they are usually in the best position to select the most appropriate technology. The correct incentive will encourage them to decide on technology which is environmentally sound and most appropriate for their business.

A further inefficiency of the system is that regulators are open to corruption, as suppliers vie to have their technologies specified.

3.2.3.3 No incentive to reduce pollution levels to below the minimum standard

"Command and Control" systems do not provide any incentive to reduce pollution levels *below* a prescribed standard. Box 3.1 provides an example of how the imposition of command and control approaches can actually result in an increase in pollution.

3.2.4 Conclusion

The 'Command and Control' approach was a useful step in the evolution of water quality management that showed the potential to solve a range of problems. In the case of toxic pollutants, 'Command and Control' approaches are the only viable methods of pollution control. However, 'Command and Control' methods tend to be cumbersome, inefficient and not always just. The deficiencies of the 'Command and Control' approach has fuelled the development of economic incentives such as pollution charges based on the 'polluter pays principle'.

3.3 International experience with the PPP

3.3.1 Overview

This section examines the history of the development of PPP and the international experience with the implementation of water quality management systems based on the polluter pays principle. While the study is not primarily concerned with sewage treatment facilities, some experience with such systems has been included. Unfortunately, there is limited information relating to the implementation of polluter pays based systems. Specific details about the strengths and weaknesses of systems in China, Eastern Europe, France, Germany, Korea, Netherlands and the UK are presented followed by key lessons from international experience.

3.3.2 Historical background

Environmental degradation has been recognised as a threat to humanity for several decades. The Polluter Pays Principal (PPP) was developed in response to an increased awareness of the need for environmental management. It also fits soundly within a philosophical framework of justice, equality, environmental sustainability and protection (see section 2.2).

In 1964 A.Kneese in his publication "The economics of regional water quality management" stressed the advantages of an approach to pollution control which used economic incentives and the PPP. The Environmental Committee of the Organisation for Economic Co-operation and Development (OECD), also recognised the importance of the PPP and started to promote it. In 1975 the OECD's research culminated in the publication - "The Polluter Pays Principle: definition, analysis and implementation". Its guiding principles are set out in Box 3.2. According to this publication the PPP was defined in the following way - "Polluters should bear the expenses of preventing and controlling pollution to ensure that the environment is in an acceptable state".

Although the PPP had been accepted as a general principle, for a long time it played a very minor role in environmental management and legislation, which was dominated by a Command and Control (CAC) approach.

Box 3.1 - Environmental Regulations, Cost of Abatement, and Regional Growth

Could the USA's Clean Air Act be causing an increase in pollution? Does it affect the location of industries in the United States? These are questions addressed by economist, Robert Crandall, in a study done for the Brookings Institute. The non-degradation policies of the Clean Air Act require all new industrial and electrical utilities to install stack gas scrubbers to prevent sulphur oxide emissions from being discharged into the atmosphere. No new plant is allowed to enter an area if it decreases the air quality there. These regulations add to the capital and operating costs of new concerns and may influence their location decisions.

Other regulations in the Act require all fossil-fuel burning facilities to reduce the percentage of their emissions to the maximum amount possible. Each plant must remove the same percentage of emissions regardless of the initial level of discharge. These regulations may make air pollution worse over much of the country.

The major sources of sulphur oxide emissions in the United States are coal and oil-burning plants, especially electric power plants. The United States produces two types of coal - coal with a high sulphur content in the East (Appalachia), and low-sulphur coal in the West (Colorado and Montana). Power plants and other facilities located in the East burn eastern coal for the obvious reason that it is cheaper than western coal (largely due to transportation costs). Plants located in the East are typically old, and are thus exempt from the requirement that they must install scrubbers.

Crandall argues that air quality, and firms attempting to locate in the West, are the losers from the Clean Air Act. First, requiring scrubbers of all facilities means that fewer will be built than if these concerns were able to use cost-minimising methods of meeting air pollution standards. Scrubbers are expensive to construct and to operate. They are prone to malfunction if not maintained in top condition. Fewer new plants will be built because of the high costs, and old plants will be discouraged from installing scrubbers. Because old plants emit a lot of sulphur oxides, aggregate emissions may rise. However, even if new plants are built, the overall air quality will decline unless the old plants increase their abatement or shut down. Then there is the high-sulphur coal problem. New plants will have an incentive to use high-sulphur coal because it is cheaper than low-sulphur coal. They are required to install scrubbers and effectively prevented from using low-sulphur coal to meet the standards without having to use scrubbers. However, if an absolute standard were in effect - so many tons per day of emissions must be reduced as it would provide an incentive to shift to the low-sulphur coal to meet the standard

Crandall argues that the Clean Air Act represents more than just a desire on the part of Congress to reduce pollution. It may be a means of protecting Eastern coal producers at the expense of the Western producers. Whatever the case, the economic incentives provided by the regulations are clear - requiring firms to install scrubbers increases the fixed costs to new or relocating firms. Fixed costs can be a barrier to entry. Requiring equal percentage abatement and the installation of scrubbers regardless of the amount of emissions that would be generated inhibit firms from seeking cost-minimising methods of abating pollution. If existing firms face less restrictive environmental regulation than new entrants, markets may become less competitive and pollution emissions may rise.

Robert Crandall in "Clean Air and Regional Protectionism", the *Brookings Review*, pp 17 – 20.

Box 3.2 - OECD 'polluter pays' principles

1. Environmental resources are in general limited and their use in production and consumption activities may lead to their deterioration. When the cost of this deterioration is not adequately taken into account in the price system, the market fails to reflect the scarcity of such resources both at the national and international levels. Public measures are necessary to reduce pollution and to reach a better allocation of resources by ensuring that prices of goods depending on the quality and/or quantity of environmental resources reflect more closely their relative scarcity and that economic agents react accordingly.
2. In many circumstances, in order to ensure that the environment is in an acceptable state, the reduction of pollution beyond a certain level will not be practical or even necessary in view of the costs involved.
3. The principles to be used for allocating costs of pollution prevention and control measures to encourage rational use of scarce environmental resources and to avoid distortions in international trade and investment is the so called "'polluter pays' principle". This principle means that the environment is in an acceptable state. In other words, the costs of these measures should be reflected in the costs of goods and services, which cause pollution in production and/or consumption. Such measures should not be accompanied by subsidies that would create significant distortions in international trade and investment.
4. The principle should be the objective of all member countries; however, there may be exceptions or special arrangements, particularly for the transitional periods, provided that they do not lead to significant distortions in international trade and investment.

Almost two decades later, at the UN Earth Summit in Rio, 1992 an international declaration on the environment was made. Principle 16 of the declaration accepted the PPP and stated:

"National authorities should endeavour to promote the internalisation of environmental costs and the use of economic instruments by taking into account that in principle the polluter should bear the costs of pollution with due regard to the public interest and without distorting international trade and investment".

The wording of this principle was very similar to one stated in the OECD publication in 1975.

In similar fashion the European Community Council adopted "The Euroregion Environmental Chapter" in 1993, which stated six major principles.

The fourth principle pertained to the PPP and read as follows:

> *"organisations or individuals responsible for threats or damage to the environment should bear cost of prevention or cleaning up"*

By the 1990's the PPP was accepted as a principle, and most governments had realised that the use of economic and fiscal instruments had to constitute an increasingly important part of an overall environmental management approach.

The initial implementation of the PPP in water management was quite limited. It was first used to recover some of the costs for sewage treatment in the USA. The Federal Water Pollution Control Act amendments of 1972 required agencies receiving Federal construction grants to establish a system of user charges. It was designed to ensure that each discharger paid a proportionate share relative to the amount of the pollution discharged. Similarly, in 1983 the European Economic Community ratified the use of the PPP for cost allocation (prevention and carrying out of pollution control measures) by local authorities. More serious implementation has only started in the 90s.

3.3.3 China

3.3.3.1 Description

China introduced a system of pollution charges in 1979. (O'Connor, 1996). The charge is levied on both the quantity and the concentration of discharges. The system was initially introduced on an experimental basis in Suzhou city and was gradually extended nation-wide. In principle, the charges are to be set at a level slightly above the average operating costs (including a depreciation factor) of pollution control facilities, to encourage broad compliance with standards. The charges cover a range of parameters, with higher charges levied on more toxic pollutants.

Until 1988 revenues were largely allocated as grants to subsidize pollution control measures, but since then there has been a shift towards a greater reliance on loans. The revenues are deposited in an earmarked, local, environmental fund, managed by a designated bank. Roughly 80 per cent of the revenues are then lent or given to enterprises for pollution control investments. The loans are extended only to those enterprises that have paid charges.

The remainder of the revenue goes to environmental agencies to finance the capital and operating costs of the charge program, e.g. the purchase of monitoring equipment and analytical instruments and the hiring and training of additional staff. Charge revenues were a major source of financing for pollution control investments: from 1982 to 1986, they accounted for almost 30 percent of pollution control expenditures in the steel industry. During that period the industry's rate of compliance with discharge standards rose from one-third to 60 percent.

Charges however, are not corrected with inflation, which is a weak point of the system. In addition, environmental officials at the local level are often amenable to influence by industrialists intent on avoiding the charge. According to O'Connor (1996), one of the greatest weaknesses of the scheme is that state enterprises are permitted to pass on the charge costs in higher prices or entitled to a tax rebate to offset the charge. Consequently, they have little incentive to improve efficiency. A strength of the system is a fourfold system of penalties for serious violations of standards.

The charges described above are for non-compliance. Additionally, Shanghai Water Board introduced a constant waste water charge based on the volume of the effluent (WRC, 1996). This charge is the same for all types of effluent and the revenue is used for the operation, maintenance and renovation of the sewage system.

3.3.3.2 Features of the system

- There is a fourfold system of penalties for serious violations of standards.
- Charges are not corrected for inflation.
- At the local level, environmental officials are amenable to influence by industrialists intent on avoiding the charge.

- State enterprises have little incentive to improve efficiency as they are permitted to pass on the charge costs in higher prices or entitled to a tax rebate to offset the charge.

3.3.4 Eastern Europe

3.3.4.1 Description

Eastern European countries have recently begun a transformation process of both political and economic structures. They face a myriad of complex and often conflicting priorities between social and economic reforms, privatisation activities and environmental protection. In order for their goods and services to be accepted by the European Union and the USA they need to harmonise their legislative and institutional frameworks with those of their main trading partners. Consequently, they are presently investing heavily in the development of a system of environmental management. In 1993 their environmental spending exceeded $2.4 billion.

Bulgaria, the Czech Republic, Hungary, Poland and the Slovak Republic have had charges for sewage treatment for decades. Bulgaria has had them since 1951 and from 1991, these charges were significantly increased, and it is expected they will increase further. The Czech Republic, Hungary, Poland and Slovak Republic have implemented waste-water charges on a limited base.

Table 3.1 provides a summary of available information about pollution charges in some Eastern European countries.

Although most of the charges are quite low (in the Czech Republic they represent about 30% of the abatement cost), only part of the imposed charges are collected. In Romania, an essential part of the imposed charges is not being paid, due to insolvency among enterprises. The charges are not adjusted for inflation and do not have strong political support. The Czech Republic and Slovak Republic have a charge for TDS (Dissolved inorganic salts), but no further data is available.

Poland is an exception to this. It collects significant pollution fees estimated to be almost 0.5% of GDP. Fees for atmospheric sulphur dioxide emissions account for most of this. The largest contributor to waste water charges revenue in Poland is the charge on saline coal mining water. Poland was the only country, found to charge for this type of pollution.

In Hungary there are plans to introduce a water effluent charge. However, draft legislation is only in an early stage of preparation at present.

3.3.4.2 Features of the system

- Introduction of pollution charges system can be done as part of social and economic reform;
- Sulphate and chloride pollution from coal mines can be controlled by pollution charges;
- Revenue is distributed between national, regional and local funds.

3.3.5 France

3.3.5.1 Description

Waste-water charges were introduced in 1970 (RIZA, 1995). From 1993 the following pollution parameters were considered: suspended solids, organic matter (BOD and COD), soluble salts, acute toxicity (calculated on the basis of LD50 experiments on

Daphnia), reduced nitrogen, oxidised nitrogen, total phosphorus, halogenated hydrocarbons and heavy metals (arsenic, lead, nickel, chromium, copper, zinc, cadmium and mercury).

Table 3.1: Water Effluent Charges for Eastern Europe (source: REC, 1995).

Country	Charge Base and Rate	Revenue	Revenue Spending
Czech Republic	• BOD5 • Undissolvable substances • Crude oil substances • Evident alkalinity and acidity • Dissolved inorganic salts The charge can be levied on enterprises.	1993: 37.8 Million ECU *	Revenue goes to SEF, a National Fund, which supports projects related to water protection.
Poland	• BOD5 •1993: 428.5 ECU/t • COD •1993: 244.8 ECU/t • Suspended solids •1993:38.4 ECU/t • Heavy metals *(total mass)* •1993: 4411.1 ECU/t • Chloride and sulphate ions •1993: 24.3 ECU/t	1993: 59.9 Million ECU	36% to National Fund 54% to Regional Fund 10% to Local Fund For charges on saline coal mining waters *(chlorides and sulphates)*: 90% to National Fund 10% to Local Fund
Romania	Suspension + substances in solution 0.46 ECU/t Oxygen consuming substances 1.86 ECU/t The charge can be levied on enterprises.	1993 : n.a.	5% to Water Funds 95% to WIA**
Slovak Republic	• BOD5 • Undissolvable substances • Crude oil substances • Alkalinity and acidity • Dissolved inorganic salts	1993: 7.79 Million ECU	Revenue goes to SEF, a National Fund, from where projects are being supported with respect to water protection.
Slovenia	2.40 ECU/E *(for 1994)* Emissions are calculated through some elements on the basis of calculating the factor E *(population equivalent)*.	1993: 4.9 Million ECU	Revenue goes to the general state budget.

*ECU: European Currency Unit

** WIA: no description of this fund was available

The values for pollution parameters are determined from a table of sector specific coefficients, which relate pollution to economic variables such as input, output and number of employees. The discharger may demand that actual pollution loads be measured. If the actual pollution load is equal to or higher than estimated, then the cost of measurement is born by the discharger, otherwise by the Agency.

When a waste treatment plant has been installed the industry is awarded a purification bonus, which is deducted from the gross pollution fee (World Bank, 1995).

Revenues are spent on grants for water pollution control investment (50%), loans to finance water pollution control (30%) and bonuses for communal waste water treatment (20%).

3.3.5.2 Features of the system

- Some of the revenues from charges are used to subsidise the building of treatment works. The number of treatment works has increased substantially since the system was implemented.
- There has been a significant improvement in water quality since the system was introduced.
- The system became more effective when charges were increased and the level of organic pollution has subsequently decreased.

3.3.6 Germany

3.3.6.1 Description

Before 1990, East Germany used a system that combined wastewater charges with effluent standards (the charge was levied on a discharge exceeding fixed effluent limits). However there is no information on the wastewater charge system after unification.

The charging system for the former West Germany has been effective since 1981 (RIZA, 1995). It is the only known system with a clearly stated incentive purpose. The following pollution parameters are considered for direct discharges: organic matter (as COD), toxicity to fish, inorganic nitrogen, phosphorus, halogenated hydrocarbons and heavy metals (lead, nickel, chromium, copper, cadmium, mercury and their compounds).

Similar to Belgium and France, unit pollution is calculated based on pollution loads of the above parameters and multiplied by a tariff to obtain the waste water charge. When the concentration in an effluent exceeds the value declared by the discharger the charge is raised proportionally. If the concentration of pollutants is lower than the minimum standards specified by federal authorities then the charge is reduced by half. It can also be reduced by 75% if the discharger uses a treatment plant that meets the requirements of the federal authority for a particular economic sector. Furthermore, the payment of charges is waived for three years prior to a planned extension of wastewater treatment equipment with a discharge reduction of at least 20%. A hardship clause provides the possibility of exemption if considerable adverse economic effects are expected (OECD, 1989).

The municipal user charge for discharge into sewerage is based on costs for collection and treatment and no general rules for their calculation are available.

Both direct waste water charges and user charges are used for financing water pollution control and for the construction and management of treatment plants.

3.3.6.2 Features of the system

- There is a system of discounts for reducing effluents by more than the minimum standard. For example there is a 100% discount on the charges if the discharge is lower than half the minimum effluent standard.

- The incentive effect for most firms is still low because the current average treatment cost is still around four times the cost of the average charge burden. Thus there is little real incentive to reduce pollution discharges.

3.3.7 South Korea

3.3.7.1 Description

A non-compliance emission charge system was introduced in the early 1980s (O'Connor, 1996). Initially, the charge could be levied only if the polluter continued to violate standards after having been issued an improvement order. Since 1986 the levy has been automatic, once emissions exceed the permitted level. The charge is based only on pollutant concentrations. It varies with the location of the facility, the duration of excess discharges and the number of previous violations.

The weakness of the system is that the charge rate has historically been set rather low, in some instances falling below the operating costs of a pollution treatment facility. Therefore polluters often do not operate their treatment plants to their full potential as to do so is sometimes more expensive than the charge. If non-compliance fees are set at proper levels they do discourage the violation of standards. However, they do not reward the minimisation of emissions. Moreover, the use of pollutant concentration alone as the basis for the fee can encourage dilution without any reduction in total pollution load. Thus, there have been discussions in Korea on shifting to a straight emission charge that would tax all emissions, not just those above the standard, and would combine concentration with pollutant quantity in the charge formula.

3.3.7.2 Features of the system

- The charge was introduced by an administrative act, and as such could be implemented with a minimum of delay.
- The charge rate has historically been set rather low, in some instances falling below the operating costs of a pollution treatment facility. Polluters therefore make no effort to minimise emissions.
- The use of concentration alone as the basis for the fee can encourage dilution without any reduction in total pollution load.

3.3.8 Malaysia

3.3.8.1 Description

In the mid-1970s the government introduced a permitting system for palm-oil mills which incorporated features of an effluent charge in that the licensing fee could be varied according to the quantity of waste discharged (O'Connor, 1996). The rapid expansion of palm-oil production during the 1970s, caused this industry to be the largest source of water pollution in the country. The system was built on effluent standards which were phased in over four years. The gradual phase-in was designed to give industry time to construct treatment facilities and acquire experience in operating them. The government also reserved the right to grant a partial or full waiver of the effluent-related portion of the fee to those mills conducting research on new treatment methods. By 1989 the pollution load was less than one per cent of its level at the inception of the programme, despite the fact that palm-oil production was at a record high. The costs to industry were mostly internalized, since they could not be passed on to consumers in a highly competitive world market whereas individual mills exerted considerable market power over neighbouring growers.

In practice, the licensing fee consisted of two parts: a flat administrative fee and a variable effluent-related fee.

3.3.8.2 Features of the system

- Gradual phasing in of the system.
- Waiver of charges for research contribution.
- Use of two-tier fee: flat administrative charge and a variable effluent-related fee.
- Internalisation of pollution costs without impact on consumer costs.

3.3.9 The Netherlands

3.3.9.1 Description

The Netherlands has one of the oldest and most complex pollution charge system (RIZA, 1995) which was introduced in 1970.

The following pollution parameters were originally considered: organic matter (BOD and COD), reduced nitrogen and heavy metals (lead, nickel, chromium, copper, cadmium, mercury and arsenic). The government planned to include chlorinated hydrocarbons as of 1 January 1996.

The charge is equal to the number of pollution units multiplied by the tariff and is applied for direct and indirect discharges. Different tariffs are used for discharge into state and non–state controlled water bodies and sewers. For State controlled water there are two levels of charge: a lower charge for discharge into saline water and a higher one for discharge into fresh water.

Charges for medium size industrial discharges differ from the charges imposed on large industries and communal treatment plants. For medium size plants the charge is calculated using coefficients related to the use of raw materials by a particular industry, the number of employees, and the volume of effluent. For large discharges, monitoring is compulsory for determining pollution loads and calculating charges. Discharges from communal treatment plants to state water are given a 15% charge reduction (30% in 1995 and 50% in 1996). Communal plant discharges into non-state water are free.

The charge revenues are sufficient for the construction and operation of communal and inter-communal sewage treatment plants, with a smaller share being used to finance water quality programs and subsidise pollution control initiatives by industry.

3.3.9.2 Features of the system

- The system appears to have had a strong incentive effect. Pollution decreased by 50% between 1969 and 1975 and another 20% by 1980.
- The initial charges were comparatively the highest in Europe. This level of charges may not be appropriate for all situations, particularly not in countries with significant development needs.

3.3.10 UK: England and Wales

3.3.10.1 Description

The first pollution charge system was introduced for trade effluent and implemented by regional water authorities (RIZA, 1995). In 1990 the water sector was privatised and private water companies levy the charges. They also started to charge households via the water bills. A charging system for direct discharge was introduced in 1992 in England and Wales (Scotland and Ireland only have systems for charging for discharges into sewers). It was formerly administered by the National River

Authority (WRA) of the State, which has since been incorporated into the National Environment Agency.

Charges are calculated to cover administrative costs. The annual charge for each source is calculated based on criteria, (volume, content and type of receiving water) that have been put into bands to which factors are assigned. Volume is divided into 8 bands from 5 m^3/d to 150,000 m^3/d with factors from 0.3 to 14.0. The receiving water is divided into ground, coastal, surface and estuarial with factors from 0.5 to 1.5. The contents division is quite complex and depends on both the type of effluent and the presence of a large number of pollutants.

Industrial effluent charges for discharge into sewers are based on treatment and conveyance costs, and are calculated from volume, COD and suspended solids concentrations. Households are charged according to a rateable value, except a minority of houses with metered water consumption.

It is interesting to note that revenue from households was £2.3 billion for 1992/3 compared to revenue from industry of £146 million for 1992/3 and the revenues of the then National River Authorities of £40 million (1994/5).

The biggest weakness of the NRA charge system is that charges are not related to actual pollution load or to the concentration of pollutants in the discharge. The charges are also too low to provide an incentive for pollution reduction.

3.3.10.2 Features of the system

- There is a high charge collection rate from households, this may be because the water service is privatised and households pay a pollution charge along with their regular water service payment.
- NRA charges are not related to actual pollution load, or to concentration of pollutants in the discharge.

3.4 Key lessons from international experience with pollution control

3.4.1 Minimisation of Government intervention

The US experience with the CAC approach for pollution reduction, which involved prescribing technology, is generally acknowledged as a case study in government inefficiency and ineffectiveness. This is not to say that all CAC type programmes are the same. However, a key factor in whether the system is effective is the role that government plays. As long as government is regulatory and facilitative and not prescriptive the system has a good chance of being efficient. As soon as government begins to take on responsibilities for which it has no competence or mandate and which it is the job of the private sector to do, problems arise. The business of government should be regulation and enforcement, which is their mandate and what they are best suited to do. Their business should not be trying to make decisions for business about what technology or process is most appropriate in manufacturing or production; this should be left to the private sector. This same premise can be applied to numerous sectors and the shortcomings of the CAC approach highlight how important it is to pollution control.

On the other hand, economic instruments on their own are insufficient for the control of pollution and they should complement and not replace CAC. An example is a case involving highly toxic pollutants that should be banned. In this instance it has been shown that it is necessary for government to play more of an interventionist role, in order to avoid endangering the public. In such instances the CAC is usually a more appropriate control mechanism.

3.4.2 Efficiency of pollution charges

International experience began to prove that the introduction of emission charges did not discourage industry or reduce industrial output and growth, but in many cases encouraged efficiency which in turn can improve competitiveness as well as provide a source of revenue. In Germany for example pollution charges raised a modest ECU 135 million per year. In most cases it also resulted in an improvement in receiving water quality. In the Netherlands, oxygen-demanding waste decreased from 25 MEIs (Million of Inhabitant Equivalents) in 1975 to 8.7 MEIs in 1990. In France in the Artois-Picardie Basin industrial water pollution fell by 45% between 1974 and 1984 as a result of the introduction of emission charges. In both countries manufacturing output grew during the same period. In France between 1975-1986 organic pollution decreased by 35% and toxic discharges by 50%, while industrial output increased by 20%. Similarly in Germany the volume of industrial discharges declined by 14% between 1977 to 1987, while industrial production grew by 14%. (Renzetti and Dupont, 1995). These achievements are not limited to developed countries. Malaysia also had success in the effective implementation of pollution charges (see section 3.3.8).

From experience with effluent charges, it was generally found that in order to make charges effective in pollution control, at least 60 to 80% of the total charge should be related to the quality/quantity of the discharge (Katko, 1992), ie that administrative fees should never exceed 40% of the total charge.

A review of studies comparing costs of pollution reduction via regulation or via economic instruments concluded that "these studies generally show that there are substantial economic gains from using a policy instrument which would efficently allocate emission reduction between polluters rather than the type of 'equal abatement' rule which frequently results from command and control regulation" (EEA, 1996).

3.4.3 Designing charges

In order to meet the principles of a polluter pays system the charge should provide an incentive for polluters to change their behaviour. There are a number of positive changes that a system can encourage including: polluters reducing their discharge from previous levels, polluters reducing their discharges to below standard levels and/or pre-treating waste before discharging it. The following features offer incentives for polluters to take such actions:

- Charges related to the quality and quantity of discharges.
- Charges that are higher than the cost of treatment or abatement.
- Discounts on charges for discharging less than the standard.

In the introductory phase, it is better to keep charges relatively low to give firms time to adjust. A maximum time limit for this period should be set, communicated to affected firms and adhered to. Local experimentation provides a less risky way of testing public reaction to the effectiveness of the system. In this way it can be fine-tuned before an attempt is made to replicate it at the national level.

Many of the systems make distinctions between different pollutants according to their toxicity. The charges are higher for more toxic pollutants.

Automatic penalties make the system more effective and efficient. It also minimises legal procedures and makes the system more cost effective. One of the ways of using penalties is to include two components in the charge system – an effluent charge and a non-compliance charge.

Use of concentration in the effluent charge determination could encourage effluent dilution. To avoid this the charge should take into account the total load of effluent and the price of water in the area.

A final important feature of a charge system is that it should keep pace with inflation. Without this, the incentive effect is reduced each year as inflation effectively discounts the charge. The inflation adjustment should be built into the system so that such increases do not require changes to legislation and regulations.

3.4.4 Revenue distribution

All of the international pollution charge systems examined are self-financing. A system that does not place a strain on the general fiscus is an attractive feature of any pollution control system, particularly in South Africa, where there are many priorities competing for central government finance. In addition, a system that is self-financing is more likely to operate efficiently as there is a very small loop between revenue generation and spending, and thus fewer opportunities for funding to be spent on alternate and remote functions and administration. Interested parties, such as polluters, are also able to monitor expenditure and ensure accountability.

An important lesson from international experience was that revenue collected should be earmarked only for activities related to water quality management and should be distributed through appropriate local, provincial and national funds. In several cases, attempts were made to make the pollution charges system more revenue neutral by subsidising pollution control investments. In such systems only enterprises that pay pollution charges may be subsidised.

3.4.5 Applicability of overseas experience for the case study

- The experience of other countries, particularly less developed nations, has been that **the shortage of skilled personnel is a major issue**. This holds true despite the fact that pollution charges usually require staff with less technical skills than the CAC approaches that involve the prescription of technology or technological requirements. These types of CAC systems tend to require staff at the level of chemical engineers, while pollution charges systems tend to require technicians with some economic skills. It is envisaged that it will be possible to find personnel with the appropriate skills to run a pollution charges system in South Africa.
- **Developing countries undergoing structural transformation have an advantage**, because the resistance to a new system is not as extreme as in developed countries where previous control systems can be highly entrenched. On the other hand there is more danger of problems related to transparency and the inappropriate diversion of funds.
- Implementation of **the system could be politically problematic** if public sector enterprises represent a significant presence in the polluting industry. This can cause a conflict of interest and it is not as efficient as for private enterprises. Political transparency is essential as it is a commitment to the true internalisation of costs as opposed passing it on to the consumer.

- It was also found that **government research institutions play a major role** in collecting and disseminating information on pollution control technologies to local developing industry.

- Although non-point pollution is significant in South Africa, **there are few charge systems for diffuse source water pollution**. *??SF, what charge systems for diffuse pollution are available, you mentioned nothing in previous sections. Please add references mentioned by Dr Backeberg.* However, theoretical discussions in the literature recommend that polluters be encouraged to convert their pollution discharge from non-point source to measurable point source. Higher charges for non-point than for point source discharges provide an incentive for such action.

- Only **one waste water charge system dealing with sulphate pollution was found**. This is the system utilised in Poland, where the waste water charge on saline mine effluent is the largest contributor to the total revenue collected in water management. This charge has been in effect since 1970 and has been increased a few times since then. The latest published charge is 24.3 ECU/t of sulphate for 1993, which is about R60/t adjusted to 1997 prices.

- The **possible consequences of polluters not paying fully for pollution, particularly in less developed countries should be noted**. In developing countries those who are dependent on the environment for their livelihoods (e.g. the rural poor) tend to be most affected by polluters not paying for the damage of their pollution. When livelihoods are threatened drastic action is often taken. Box 3.3 examines such a scenario in Papua New Guinea (DEAT 1994b).

Box 3.3: What happened when the polluter didn't pay in Papua New Guinea

Bougainville is one of the largest copper mines in the world, which had been managed by the Australian CPA Ltd. for 17 years before its closure in 1991. The mine is situated in the North Solomons Province, where the first rebellions started in 1988. Prior to these rebellions there had been serious land conflicts in the area between the local people, the miners and the government.

Between 1978 and 1987, the national government received 57.5% of all cash benefits of the Bougainville mine. Provincial government received 4.8% and landowners received 1.4%. Although the national government spent these revenues for the benefit of the nation in general, it was actually the local people who suffered the social costs of the mining. According to a consultancy report, the land surrounding the mine was totally devastated, the watercourses were heavily polluted and forests were damaged. In addition, the pollution affected the health of the local people. The miners paid the province (95%) and/or landowners (5%) an average of 5 million kina per year in compensation and royalties. However, neither charge revenues nor these compensation payments were distributed fairly.

In 1979, local people set up the Panguna Landowners' Association (PLA) and created a fund to finance compensations. CPA was to put money into the fund. After years of turbulent management, the PLA escalated their demands. In 1988 they insisted that the national government turn over to the landlords its 20% share ownership in the mine as well as 10 billion kina in compensation for past damage. No one took these demands seriously. This led to a rebellion, which resulted in the destruction of property, the closing of the mine and the deaths of at least one hundred Papua New Guineans. The country lost the source of 40% of its foreign exchange earnings and local people had to go back to agriculture on damaged land.

This event was not the result of a rebellious spirit but that of economic hardship. The government refused to recognise that the local people were enduring serious hardship as a result of environmental degradation and pollution from the mine and that they needed to be compensated for their loss.

4. POLLUTION CONTROL IN SOUTH AFRICA

4.1 History of pollution control

4.1.1 Introduction

Like many countries at the turn of the century, South Africa had no legislation in place to combat pollution, and prevailing surface water quality probably did not warrant such measures. The first legislation with a pollution control component was the Public Health Act of 1919, which prohibited the discharge of sewage into public streams (DWAF, 1986). Ironically it was not problems with pollution *per se* that promoted this first major piece of South African anti-pollution legislation, but the fear of water shortages caused by unusable water.

The Water Act of 1956 made provision for the compulsory purification of pollution by the user to specified standards in a manner that would make it available for reuse. The anti-pollution component of the 1956 Act was motivated by concern over the re-use of water, rather than the costs of pollution.

4.1.2 The Water Act of 1956

The Water Act of 1956 sought to control pollution through a number of mechanisms. It made provision for the:

> *" Purification of pollution resulting from the use of any water for industrial purposes, which does not meet prescribed standards"*

and the development of defined standards.

Section 21 of the Act introduced pollution standards for different pollutants. It required all polluters to return water to streams with levels of pollutants not exceeding the standards determined by the South African Bureau of Standards.

Section 23 of the Act allows for pollution levels to exceed the prescribed standards under certain conditions, but obtaining permission for this is a lengthy process. It requires consultation with the SABS and Department of National Health, and ultimately depends upon the issue of a permit by the Minister of Water Affairs. Without this permit, the discharge of pollution is a criminal offence.

4.1.3 The 'command and control' aspects of the Water Act

In keeping with the early pollution control regulation world-wide, Sections 12 and 24 of the Act seek to control the production process in order to reduce discharges of pollution into water courses (solid waste disposal sites are controlled by the Environment Conservation Act). Section 12 of the Act requires any industrialist considering establishing a water intensive industry to obtain permission from the Department of Water Affairs. In effect this gives the Department the right to veto the use of specific technology.

Section 24 makes provision for the Minister to

> *"prohibit or restrict the manufacture, marketing or use of any substance that in his opinion might cause water pollution, or subject such manufacture, marketing or use to such conditions as he may deem fit" (DWAF, 1986)".*

4.1.4 *Providing subsidies for pollution control*

In order to assist with the cost of water treatment, the 1956 Act makes provision for subsidies to be granted to anyone in respect of the costs incurred in the construction of water works, including sewerage treatment works. At the Minister's discretion the subsidy can amount to as much as one third of the total cost of the construction. In 1982, the Browne Committee recommended that subsidies be paid to local authorities for the construction and improvement of sewage works. However, this was of little assistance to poorer local authorities because in order to obtain a subsidy the authority had to contract a plethora of consultants to assist it in making a submission - the cost of which was often prohibitive. As such, the subsidy tended to go to more wealthy municipalities that did not necessarily need the subsidy. The subsidy represents a radical difference to the notion of 'polluter pays', as it comes from the general fiscus, at the expense of the taxpayer.

4.1.5 *Later amendments of the 1956 Act*

Prompted by concern over deteriorating water quality, the Act was further amended in 1982. This amendment dealt with issues of eutrophication resulting from rapid urbanisation and the attendant solid waste problem. Despite these changes, the Act retained its 'command and control' approach.

At the time of the 1984 amendments concern was expressed over the poor effluent quality emerging from those municipal treatment works which had received subsidies for upgrades. This raises questions about the effectiveness of subsidies and indicates weaknesses in the 'command and control' approach.

4.1.6 *PPP implementation in South Africa*

PPP has been partially implemented in South Africa in the form of municipal sewage effluent charges. The first charge recorded was in 1920. By 1952 the Industrial Effluent by-laws were gazetted (Kardachi, 1997a). Since then a wide variety of formulae have been developed and implemented by different local authorities around the country. Unfortunately many are "illogically designed, have no sound basis and totally inadequate in meeting PPP" (Kardachi, 1997b). At the moment the WRC has funded a project, the "Review of industrial effluent tariff structures in South Africa and guidelines on the formulation of an equitable effluent tariff structure". It suggests that the unit charge should never be less than the cost of water purchased from the authorities. This principle may be useful in the calculation of pollution charges.

4.1.7 *The Receiving Water Quality Objectives (RWQO) approach*

The 1956 Water Act introduced pollution standards for different pollutants. Section 21 required all polluters to return waste water to the stream of origin of the water supply, with levels of pollutants not exceeding the standards determined by the South African Bureau of Standards.

Officials recognised that while the setting of general and special standards was relatively simple to apply, and to audit administratively, it was too inflexible. As a result some water resources may not be sufficiently protected, while others could be over-protected. Hence, the DWAF moved towards the Receiving Water Quality Objectives (RWQO) approach as a means of managing water quality. The Department also embraced the Polluter Pays Principle as a key concept in its policy. However, to date the problem of reconciling this principle with the RWQO approach has not been resolved.

The first goal in the RWQO approach tried to achieve reductions in the concentration of problematic effluent quality variables to the levels at which there would be no adverse impact on water users or the environment. The realisation of this ideal is practically and economically unattainable. The second goal was to limit the impact while, the third goal was to ensure that acceptable water quality limits were not exceeded. This last goal is achieved by the application of strict penalties for non-compliance. The degree of application of the 'polluter pays principle' lies in the area between the ideal and the maximum allowable limits, where pollution taxes or emission charges provide an incentive to reduce impacts.

The application of RWQO involves determining the water quality needs of each and every downstream user. This allows for the calculation of threshold criteria, beyond which any further discharge of pollution will impact negatively on downstream users. These limits are converted into specific pollution loads and allocated to polluters by means of a Waste Load Allocation (WLA) in such a way that the total discharge does not exceed the RWQO. In theory, this approach ascertains the point at which the impact ceases to be negligible.

This approach assumes that no impact whatsoever is a reasonable goal and this does not take into account the prevailing economic conditions. Additionally, once the RWQOs have been set and a permit issued, the polluters have a free right to use the environment for waste disposal up to a specified level. There is no incentive for them to further reduce their pollution or to optimise their pollution discharge in terms of costs and benefits. In short, the current RWQO approach conflicts with the PPP.

Implementation of the pollution charges system resolves this problem and provides the necessary incentive to reduce pollution. In addition, it may also allow for a higher WLA, where it is proved to be cost effective, rather than reduce the WLA to the levels required by the RWQO. It also offers the advantage of providing revenue that can be used for funding water quality control activities, for minimising the impact of deteriorating water quality and for indirectly compensating the victims of pollution.

The pollution charges system fits well within the general principles of the DWAF's policy of RWQO because it provides a flexible way of catering for different water quality conditions and user needs in individual catchments.

4.2 The direction of South African water pollution control

4.2.1 Background

The political transition in South Africa has spurred a transformation of the policies of many government departments. The Department of Water Affairs and Forestry has embarked upon a process of reviewing many of its policies and guidelines. There are a number of relevant policy initiatives underway - the water tariff policy, the water law review and the water quality policy formulation. This project only cover the application of waste water charges to point and non-point pollution discharges into the stream.

4.2.2 The DEA&T initiatives and the IPC & CONNEPP processes

In recent years, South Africa has recognised the potential for the use of economic incentives for environmental management. The President's Council Report on a National Environmental Management System (1991), devoted just a few sentences to the subject, and the conclusion was that "*in theory the combination of incentives and standards is better than standards alone, but in practice there are still major difficulties to resolve*". It was also mentioned in the national report prepared by the Department of Environmental Affairs & Tourism (DEA&T, 1992) to the UNCED conference in Rio de Janero. Alongside many of other recommendations, a suggestion was made to investigate the use of economic incentives.

From 1993, the DEA&T started to publish a series of reports on Environmental Resource Economics and also began to organise workshops and seminars to disseminate knowledge and promote participation. This research investigated the need for a new economic approach and provided a list of requirements for its application. Several aspects of environmental economics in South Africa have been investigated, particularly the application of emission charges (see DEA&T, 1993 and DEA&T, 1994a).

A report by the EPE in 1995 concluded that the likely market for tradeable pollution permits in South African catchments was probably too "thin", ie. too few traders and too few transactions to result in market-related prices, and that the most appropriate economic instrument was pollution charges.

A national holistic policy on Integrated Pollution Control (IPC) was initiated by the DEA&T in 1994, in co-operation with other departments and a broad range of industrial and other role players. The Water Quality team of the IPC considered economic instruments and concluded that polluters should pay for the right to use the waste assimilative capacity of the stream and that the revenue should be retained by an authority or agency to be used to fund other environmental actions and projects.

In 1995, the DEA&T launched a wider process entitled the "Consultative National Environmental Policy Process (CONNEPP) designed to develop a new Environmental Policy. The IPC and CONNEPP were thus linked and from then on worked in parallel. A Green Paper was published in October 1996, followed by a White Paper in July of 1997. Environmental charges and incentives are included as one of the pro-active regulatory measures, but no further details are provided.

4.2.3 The water law review process

A process of legal reform in the water sector has been under way since 1994. Its aim is to replace existing legislation with a new Act, which incorporates the policy objectives of a basic water supply to all and central government stewardship of water resources. The water law review process developed a range of fundamental principles for managing South African water resources. In April 1996 a set of draft principles was released, which have since been accepted through a process of public consultation. Principle D5 provides clear support for the polluter pays principle. It states that:

> *" Water quality management options should include the use of economic incentives and penalties to reduce pollution. In the case of waste disposal, this may be achieved through the 'polluter pays' policy."*

The report of the Control & Enforcement Team (DWAF, 1997f), which formed a part of the Water Law Review process, also discarded the option of tradeable pollution permits and concentrated on pollution charges.

Several important water Acts have been published recently. These included the National Water Act, which was signed by the Pesident on the 20 August 1998. It states the following with regard to charging for waste discharges:

4.2.4 The water tariff policy review process

Water tariffs in South Africa are presently being reviewed by a team established by the Minister. The tariff review process is not yet complete, but it is important that the authority charged with implementing pollution charges take cognisance of water tariffs because of the potential for conflict.

Box 4.1 - Pricing strategy for water use charges (source: National Water Act, Act No.36 of 1998)

56. (1) The Minister may, with the concurrence of the Ministry of Finance, from time to time by notice in the *Gazette*, establish a pricing strategy for charges for any water use within the framework of existing relevant government policy.

(2) The pricing strategy may contain a strategy for setting water use charges -

(a) for funding water resource management, including the related costs of -

(ii) gathering information;

(iii) monitoring water resources and their use;

(iv) controlling water resources;

(v) water resource protection, including the discharge of waste and the protection of the Reserve; and

(vi) water conservation.

(5) The pricing strategy may provide for a differential rate for waste discharges, taking into account -

(a) the characteristics of the waste discharged;

(b) the amount and quality of the waste discharged;

(c) the nature and extent of the impact on a water resource caused by the waste discharged;

(d) the extent of permitted deviation from prescribed waste standards or management practices; and

(e) the required extent and nature of monitoring the water use.

For example, if municipalities are given a credit for returning clean water to its source and then charged for the pollution load in the water, they will have an incentive to offset the credit against the waste charge. This may have unanticipated outcomes for water quality as the incentive to reduce pollution is compromised.

5. LIMITATIONS OF WASTE CHARGE SYSTEMS

5.1 Introduction

Before one can institute a system of waste charges the relevant authority must be able to identify who caused the pollution and precisely how much of it. This is a necessary condition for any charge system based upon the PPP - if it cannot be demonstrated that an organisation or individual is discharging pollution, then they can not be asked to pay for it. So the proof of causality is one of the main limitations of the waste charge system.

The second major limitation is related to the problem of valuation (in particular the placing of monetary value on environmental goods or the impacts of environmental quality changes). Although valuation techniques are theoretically well founded there are limitations to the economic measurements of sustainability, the valuation of human life, biodiversity and cultural, historical and aesthetic resources.

The last limitation is the perceived conflict between environmental and developmental needs. However, this limitation applies to any environmental regulation.

5.2 Charges for non-point discharges

5.2.1 Problems with establishing causality for non-point sources

In order to establish who caused the pollution, it is important to understand the mechanisms of pollution discharge. Pollution is discharged either through point or non-point sources. Point source discharge refers to pollution that is a measurable discharge through a specific discrete pollution: for example - the discharging of sewage into the sea through a single pipe. Non-point discharge, on the other hand, refers to pollution that is not discharged at a specific point and thus cannot be measured with reasonable accuracy; an example of which is nitrate, which leaches through the soil and into water as a result of the use of fertiliser. Pollution from non-point sources is also referred to as diffuse source pollution.

Activities that often lead to non-point source pollution, include:

- agriculture;
- mining;
- commercial forestry;
- construction;
- land-fill sites;
- urban development;
- industries where wastes are discharged through evaporation, irrigation and other methods, which may cause diffuse pollution; and
- atmospheric emissions leading to the deposition of pollutants.

Attributing causality is usually simpler in the case of a point source discharge. However, a point source discharge may consist of the discharges of more than one polluter: for example, shared pollution pipelines and storm water outlets. In these cases attributing specific causality is problematic unless factory edge monitoring exists.

Ideally a pollution charge system must place the onus for accurate measurement of discharge on the polluter. As long as there are regular audits of systems, this encourages polluters to ensure that their equipment is accurate, lest they pay too much. Chapter 8 explores possible mechanisms that can achieve this.

One pollutant that demonstrates the problem with non-point source pollution is organo-phosphate pollution resulting from agricultural activity. A catchment will usually have hundreds of farmers, all using organo-phosphate pesticides. While it is possible to establish the quantity of organo-phosphates in a particular water body, it may be difficult to determine and agree on the contribution of each individual farm. In this case, the level of pollution is closely associated with the input choices and management practices of individual farmers. Thus in order to establish how much a particular farmer is polluting the following information will be required:

- the brand of pesticide the farmer bought and its chemical characteristics;
- land preparation methods employed;
- the types of crop grown;
- how the pesticide was mixed and applied;
- the timing of the applications;
- where it was applied, i.e. proximity to drainage systems;
- what the weather conditions were at the time of application, i.e. wind speed, rainfall and temperature; and
- the specific physical endowments of the farm, the geology, hydrology and soil types.

Even with this supposedly "perfect" set of information, the process of estimation is still complex, uncertain and controversial. Therefore, estimating an individual farmer's contribution to the organo-phosphate levels is virtually an impossible task even for highly developed, wealthy countries. This problem could be partially solved by levying a charge on organo-phosphate pesticide. However, this may not provide sufficient incentive to reduce usage.

In Britain this problem also caused a heated debate around who was causing nitrate pollution, which finally degenerated into political controversy. Because the process of nitrate leaching in the soil was so under-researched, scientific data was mustered by all sides to bolster their claim that they were not the polluters.

5.2.2 Incentives to convert non-point discharges to point discharges

A charge system needs to apply to both point and non-point sources simultaneously in order to discourage the polluter from converting point to non-point and *vice versa*. If a charge is placed only on point sources, without a concomitant charge on non-point sources, the polluter may have an incentive to convert the discharge to non-point.

Typical examples of the conversion of point source discharges to non-point source discharges can be found in situations where:

- effluent is irrigated on pasture, giving rise to a diffuse return flow comprising concentrated pollution;

- effluent is led into evaporation ponds but the evaporate residue is allowed to dry and be dispersed by the wind; and
- the poor control of pollution streams (pipelines, dumps and dams) resulting in significant pollution leakage into the environment.

In most cases (except in the case of atmospheric pollution), when the locality and the size of a non-point source are known it is possible to determine its contribution by monitoring the stream upstream and downstream of the diffuse source. The difference in the measured loads would be the contribution of this source. This methodology is applicable only when one polluter is responsible for an activity along particular stretch of the river, as often happens in mining. However, if a number of polluters share the land draining to the same stretch of river, it would be impossible to separate the contribution of each polluter using this approach. Furthermore it is not always possible to separate the contribution of non-conservative pollutants that decay in the environment. Then the only way to estimate an individual contribution is by relating production, consumption, spatial extent of activity or other relevant combination of source characteristics to total pollution load measured.

5.3 Establishing the total value of the pollution damage

While it is feasible to establish the cost of cleaning up pollution, it is much more difficult to assess the cost of its damage to the environment. This problem is closely related to the problem of giving a monetary value to the environment.

Methods for valuing the environment have only begun to evolve in the last 30 years. Two broad approaches to evaluation exist (Turner *et. al.*, 1994)[2]; demand curve approaches and non-demand curve approaches.

Demand curve approaches value the environment in terms of people's preferences for environmental goods and services. Non-demand curve approaches are more variable and look at the actual cost of potential damage, the cost of restoring damage etc. The methods for valuing the environment are outlined in Box 5.1.

There are myriad assumptions that go into valuing the environment. Given the assumptions that underpin the various valuation techniques, different techniques will yield different values. There is no local or globally accepted best method of valuing the environment.

Aside from problems with the practical process of attributing a monetary value to the environment, some theorists would argue that the entire process is flawed and that in attempting to place monetary values on the environment we are making a category error. A category error is an error made when one uses the wrong yardstick to measure, compare or evaluate.

Sagoff in his book "*The economy of the earth*" (1988) argued that questions surrounding the value of the environment are of an ethical and political nature and are appropriately sorted out through a process of public debate.

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[2] With the exception of the human capital approach, all the examples of techniques are excerpted from Turner *et al* 1994 pp. 114 to 1273.

Box 5.1 - Environmental valuation techniques

There are two broad methods of valuing the environment. We can either place a value on environmental goods and services directly, or we can infer a value for environmental goods by assessing demand for those goods and services. The former approach is referred to as a non-demand curve approach, and the latter as a demand curve approach.

1. Non Demand curve approaches

The **dose response approach** seeks to quantify the increased risk of illness or death to plants or animals due to pollution.

The **replacement cost method** looks at the cost of restoring an asset to its pre-pollution state.

The **mitigating behaviour approach** quantifies the cost of remedial actions taken by victims of pollution.

The **opportunity cost method** is a technique, which does not attempt to give an environmental evaluation, but is a useful method for setting a benefit benchmark.

2. Demand curve approaches

There are two basic kinds of demand curve approaches. The first approach attempts to **elicit** consumers stated preferences for environmental goods for example through the use of a questionnaire. The second approach attempts to **reveal** the demand for environmental goods by looking at what goods individuals purchase which are necessary to enjoy associated environmental goods - these are also termed revealed preference methods.

Revealing consumer preferences

The assumption underlying the **travel cost method** is that the amount of money that an individual would be willing to pay to visit a site e.g. petrol costs, entrance fees, would be indicative of the value they attach to that site.

The **hedonic pricing method (HPM)** looks at the way in which the price of a resource, usually housing, is affected by the presence of an environmental resource e.g. a park.

The final method of revealing environmental values indirectly is known as **the human capital approach** (Winpenny 1991: 51). This approach looks at the cost in human terms of environmental degradation.

Eliciting consumer preferences

Perhaps the best known of all evaluation techniques is the **willingness to pay (WTP)** technique, which involves asking people how much they are willing to pay to preserve an environmental asset.

Cornerstones of environmental policy in US (Clean Air Act, 1970 and Clean Water Act, 1972) explicitly prohibited the weighting of costs against benefits in the setting of environmental standards (Copper & Oates, 1992).

Even if we were to accept the validity of environmental valuation techniques, valuing the environment takes considerable time, effort and skill. The techniques are new and still evolving, and very few South Africans are trained in them. All the techniques require some degree of estimation, and as a consequence lay themselves open to contestation by polluters. In general, it is very difficult to quantify the total cost of pollution; in South Africa, with its low levels of human capital, it will prove extremely difficult.

5.4 Finding a balance between developmental and environmental needs

Most industries and many government authorities perceive PPP as a danger to the economy in general and to development in particular. Experience from other countries does not support this perception (see section 3.4.2).

The communication between the research team and the polluters during this project culminated in the following positive statement made by the South African Chamber of Mines after a draft of the report was distributed in September 1998:

"The mining industry supports the use of an optimal mix of regulatory mechanisms to achieve sound environmental management, and consequently supports the Polluter Pays Principle as one of these mechanisms. Internalising costs related to environmental management is an important approach in placing a real value on limited natural resources, and this is promoted by the implementation of the Polluter Pays Principle. It could also serve as a viable decision-making tool for industry on regulatory authorities."

Furthermore, the Chamber of Mines calls for caution:

"The implementation methodology is therefore of the utmost importance, and needs to take into account the current economic realities within which industry in South Africa is operating. The possibility of job losses and other negative socio-economic effects cannot be discounted, should excessive financial burdens be placed on industry. The report does not adequately address these realities and the necessary influence of these on the model."

This recommendation was incorporated in the chapter 12 of the final report. Implementation of pollution charges should support the principle of sustainability, but in countries with development needs like South Africa, the competition for resources is very intense. As a result political decisions can be influenced by development needs before environmental needs. According to Maines, 1995 "there is no chance that humans will put their interest on a par with the interest of animal and non-sentient things".

6. CASE STUDY CATCHMENT

6.1 Selection of case study

6.1.1 Selection of study catchment

Witbank Dam catchment was selected as a case study for the following reasons:

- It is a heavily polluted catchment where novel approaches to water quality management are worth considering.
- It is located at the headwaters of the intensively utilised Olifants River catchment. Since it is a headwater catchment, it is possible to distinguish between the contribution of natural background salts and the contribution of local pollution.
- This catchment is one of the largest sources of sulphate and chloride pollution in South Africa.
- There are many pollution sources with varying characteristics in the Witbank Dam catchment.
- More importantly, this catchment has been extensively studied and this information is available for use in developing different options for waste water charges.

6.1.2 Selection of pollutant of interest

Sulphate was selected as an ideal pollutant for waste water charge system simulation for the following reasons:

- It is one of the more significant pollutants in the catchment.
- Most of the monitoring performed in the catchment includes sulphate measurements.
- Sulphate pollution emanates from both point and diffuse sources.
- A management programme with water quality objectives for sulphate has already been developed and accepted.
- Sulphate is a relatively conservative pollutant which responds favourably to mass balance modelling.

Sulphate is consistently proportional to salinity and the linear regression parameters for this relationship were estimated, while salinity impacts were studied in-depth and have the most measurable economic effects. Therefore, both salinity and sulphate pollution are the most suitable candidates for waste water charges, provided the link between pollutant and economic impact can be clearly defined. Consequently, charge calculated for sulphate was based on the economic impacts estimated for sulphate's contribution to salinity.

6.1.3 Selection of study period

Water quality varies with seasonal and long term hydrological changes. As hydrology variations can be quite extreme and the resulting pollution loads have similar wide variations, it is important to take them into account in the calculation of waste water charges. Fortunately the most comprehensive monitoring programs for the Witbank Dam catchment were carried out in the 1990/91 and 1995/6 hydrological years which represent one of the driest and one of the wettest years respectively in the last decade. This is advantageous because it provides us with the opportunity to test the charge system design for a wide range of hydrological conditions.

6.2 Catchment description

The Witbank Dam catchment is described in more than 20 reports (see TPG&P reports and WMB reports in Appendix B). Summarised relevant information from these is provided in the following sections.

The main streams of the Witbank Dam catchment are the Upper Olifants River and its tributary the Steenkoolspruit (see map in Appendix A.1). For the purpose of water quality management, the catchment was divided into nine Management Units (MUs). Their characteristics are given in Table 6.1. According to WMB (1995c), a MU *"is a river reach with a control point at it's downstream end and a number of compliance monitoring points (preferably not exceeding seven), for which water quality guidelines can be determined in order to ensure downstream fitness of use"*.

Table 6.1: Management Units description (source: Table 2.1,WMB, 1997c)

Management Unit	River	Monitoring Points	Area (km²)	MAR (million m³)
1	Trichardtspruit	B1H006	107.54	3.98
2	Rietspruit	B1H028	394.33	14.58
3	Koringspruit	B1H020	137.78	5.09
4	Boesmanskransspruit	B1H030	124.93	4.62
5	Saalwaterspruit	B1H029	342.33	12.66
6	Noupoortspruit	B1H019	90.65	3.35
7	Lower Steenkoolspruit	B1H021	805.59	29.78
	Upper Steenkoolspruit	B1H017		
8	Upper Olifants River	B1H018	1260.46	46.6
9	Olifants River	B1H005		
	Witbank Dam	B1R001	38.92	1.44
	Tweefonteinspruit	B1H031		
TOTAL			3302.53	122.10

These stations are presented on the map in Appendix A.2. Note that the station number appearing on the map is only the last two digits of the DWAF's code (e.g. station B1H019 is marked as "19").

To fit the above definition more accurately, the boundaries of some MUs were redefined in 1995 (WMB, 1995c) by increasing the size of MU5 and MU8, and subsequently reducing the size of MU9. In this way the Tweefonteinspruit monitoring station, B1H031, became part of MU5. The map in Appendix A-1 shows the corrected new MUs.

It must be observed that the WMB reports, from which the information used in this chapter was derived, were written for a different purpose. For this reason the information derived does not always fully meet the needs for developing the pollution charge system. In particular such system requires that water quality data is available and sampled at the bottom of every defined MU. This was not always found to be the case, which might be due to the inability to find suitable weir sites. Some of the problems encountering in this regard are described below.

Some post-1995 reports, still refer to the old MU boundaries (see Table 6.1 above which was extracted from the report published in 1997). Even with the new boundaries, there are no control points for MU5, MU7 and MU8. The map in Appendix A-1 indicates that station B1H021 shown in Table 6.1 as the monitoring point for MU7, can not measure total pollution in this MU as there are sources of pollution between this station and the downstream boundary of the MU7. Similarly, B1H031 does not represent the full load at MU5, and station B1H018, which is the control point for MU8, represents only background conditions and does not monitor any pollution occurring in this MU.

There are some inter-basin water transfer schemes, which deliver water to the catchment, but only one of those, the Usutu-Vaal Government Water Scheme, affects the river flow (see section 6.7.3). Other schemes provide water directly to large water users, without any discharge into the river system.

The water quality requirements of, and the water quality status for each MU are described in the following sections.

6.3 Monitoring data

As the calculation of waste water charges is based on the results of monitoring, it was extremely important to assess what data is available and its associated quality.

Only the monitoring data from the stations registered by the DWAF was examined. The data available in the Hydrobank at the Directorate of Hydrology, DWAF is summarised in Table 6.2.

Table 6.2: Availability of continuous flow and water quality grab samples data from DWAF.

Station	Flow	Water Quality
B1H005	1972/11-present	1979/11 – present
B1H006	No data	1982/10 - present
B1H017	1989/11 – present	1990/1 - present
B1H018	1989/11 – present	1991/5 - present
B1H019	1990/3 – present	1990/5 - present
B1H020	1990/3 – present	1990/5 - present
B1H021	1990/11 – present	1990/7 - present
B1H022	1991/3 – present	1990/4 - present
B1H028	No data	1990/4 – present
B1H029	No data	1995/10 - 1996/7
B1H030	No data	1995/10 - 1996/7
B1H031	No data	1990/4 - 1996/9
B1R001W	1953 – present	1972/1 - present

Comparison of Tables 6.1 and 6.2 demonstrates that pollution loads could not be estimated for MU1, MU2, MU4, MU5 and MU6 as no flow data is available for the monitoring stations of these MUs. There is a Crump weir at B1H006, which was calibrated, but the DWAF does not record regularly water level at this point. The weir is only used on certain occasions when data is collected to estimate how much water Majuba Power Station releases for abstraction.

In addition to the DWAF data, two reports were used extensively as a source of data:

- WMB, 1992a: "Olifants River Catchment Region B100 - Water quality status on the basis of 1990/91 monitoring" Report No. 1503/511/1/W to DWAF, Directorate of Water Quality Management.
- DWAF, 1997c: "Upper Olifants River Basin: Description of the water quality monitoring program for the 1995/6 hydrological year", Report No. WQM B100/00/0297.

These reports were prepared by WMB for the DWAF.

The **first report** describes the most comprehensive monitoring program ever executed in the Witbank Dam catchment. Three types of monitoring stations were operated during the 1990/91 hydrological year:

- existing weirs where the DWAF measured flow continuously, and water quality by means of grab samples (see Table 6.2); and
- six continuous conductivity monitoring stations which were installed at B1H005, B1H017, B1H018, B1H019, B1H020 and B1H021 (see Appendix A.2); and
- weekly flow estimates and water quality samples which were collected at 56 locations for each identifiable point of effluent discharge and in each natural drainage course upstream and downstream of the discharge point.

It was found that the annual load calculated from continuous data differs significantly form the annual sulphate loads calculated from weekly grab samples. According to Table 6.1 (WMB, 1992a) the differences were about 85% for two out of the five stations (B1H017 and B1H005). This illustrates the importance of using high frequency flow and water quality sampling to calculate loads at river stations.

Most of the available data for loads is based on weekly sample data. Hence, it was decided to use weekly data for all stations and exclude continuos data, to obtain a valid comparison between different stations and between the two study periods.

The **second report** concentrated only on the major monitoring points and unfortunately no measurements were repeated for the estimation of pollution source contributions. Two points were added as control points for MU4 (B1H030) and MU5 (B1H029) from the beginning of hydrological year 1995. The data collected at these major points was used to provide a comparison between the water quality during the dry and wet years of the study period.

Adequate monitoring data for point sources could not be extracted from either report. Nor was the monitoring data found to be sufficient for estimating the contribution of diffuse pollution sources and loads for each MU for the study period.

Therefore most of the analysis carried out in this study refers to station B1H005, controlling the biggest part of the catchment. This station was chosen because it has most comprehensive data available. Most of the data processing for this station was done by WMB, but some additional calculations were done by the authors.

It must be stressed that all the calculations made as part of this project are only for the demonstration of the proposed charge system and should not be interpreted as an accurate assessment of the catchment situation. More comprehensive monitoring data will have to be utilised for the implementation of a waste water charge system, and a more detailed study is necessary to optimise this monitoring system. However, for the introduction of the charge system the total monthly catchment pollution loads can be calculated with reasonable accuracy from a mass balance of Witbank Dam.

6.4 Water quality status

The water quality situation in the catchment has been assessed regularly and compared with the water quality management program objectives. The management objectives consist of 50 percentile and 95 percentile values which are based on the results of the WITSIM model simulation and guideline sulphate concentrations (see Table 6.3).

Table 6.3: Water Quality Management Objectives (source: table 7.3, WMB, 1993)

MU	River	Water Quality Control Point	Guideline Concentration (mg SO_4/l)	Management Objectives (mg SO_4/l)	
				50 percentile	95 percentile
1	Trichardtspruit	B1H006	30	24	34
2	Rietspruit	B1H028	200	70	120
3	Koringspruit	B1H020	—	620	1200
4	Boesmanspruit	B1H030	—	830	1450
5	Saaiwaterspruit	B1H029	200	220	390
6	Naauwpoortspruit	B1H019	—	260	380
7	Steenkoolspruit	B1H021	200	70	90
8	Upper Olifants	B1H005	200	110	170
9	Olifants	B1R001	200	84	155

The sulphate pollution in the catchment changes the water quality composition drastically from the headwaters of the catchment to its downstream point (see Figure 6.1). The sulphate contribution increases from 8% of TDS to the most dominant ion with a contribution of 57%. The salinity increases threefold between B1H018 and B1H005.

Figure 6.2 indicates the changes in sulphate concentrations for all major stations. The concentrations of the 50 and 95 percentiles are similar to the 1990/91 and 1995/96 hydrological years respectively. The change in concentration through the system is so dramatic that in order to present it graphically two scales were used – one with lighter colours for low pollution (below 280 mg/l) and one with darker colours for high pollution (below 2400 mg/l). It is interesting to note that even for the background stations, B1H017 and B1H006, the sulphate concentrations on occasions exceed the water quality management objectives.

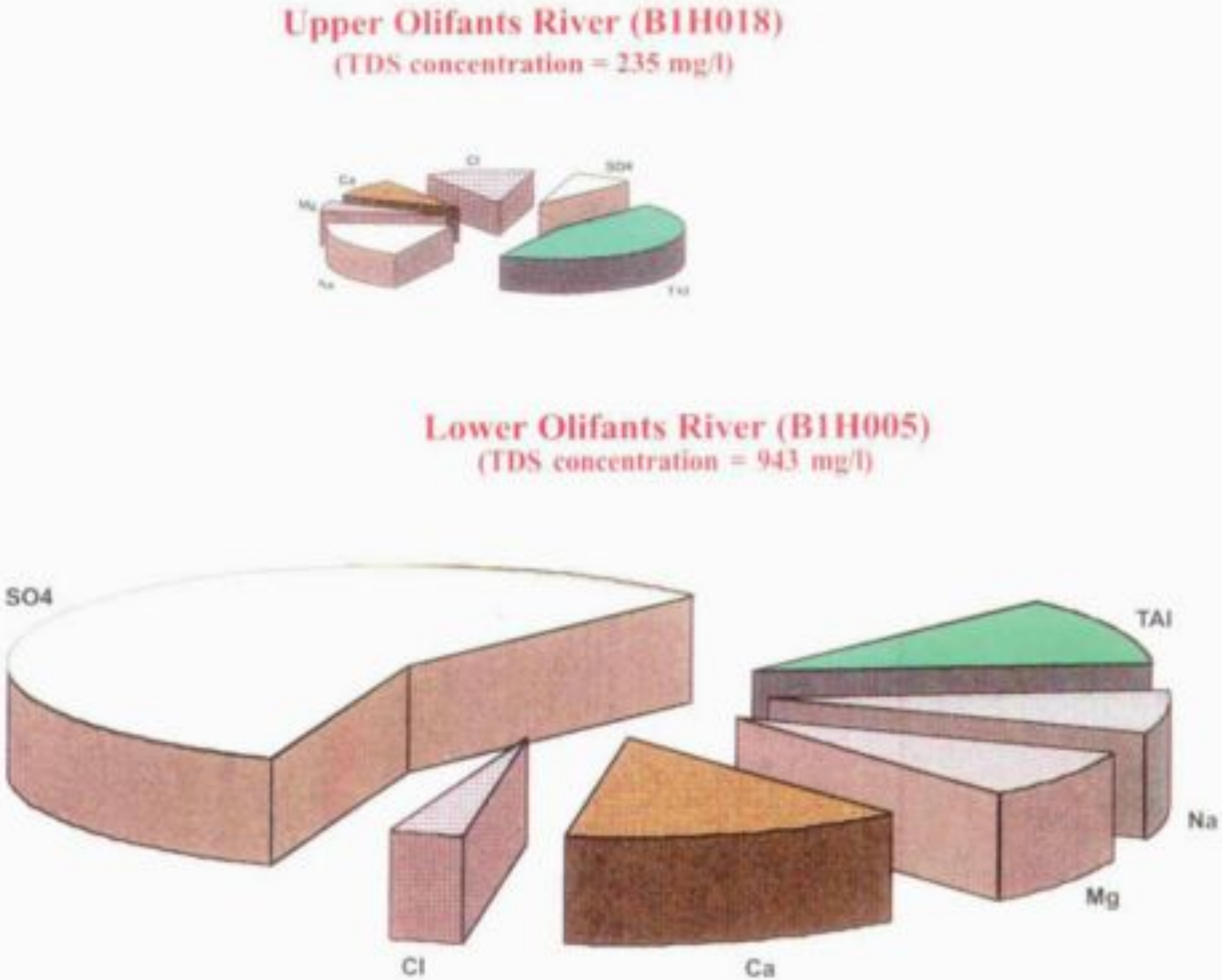

Figure 6.1: Ionic composition at the B1H018 and B1H005 stations in milliequivalents/l (source: Figure 4 form DWAF, 1997c)

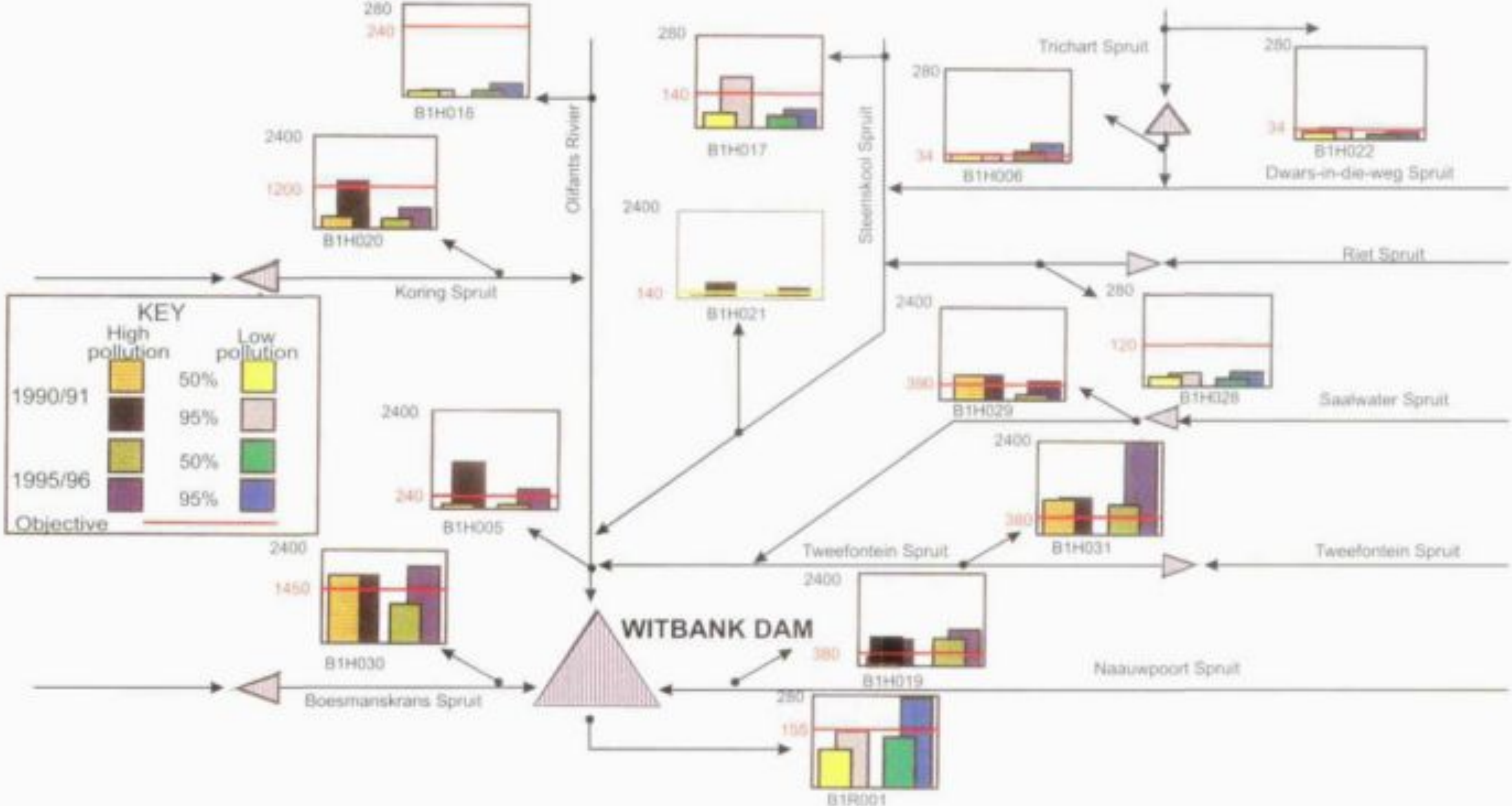

Figure 6.2: Sulphate concentrations in the catchment (1990/91 and 1995/96 hydrological years)

The catchments that are heavily affected by pollution are Tweefontein, Boesmankransspruit, Naawpoortspruit and Koringspruit. For all of these the 95 percentiles for both years exceeded the management objective (except for the Koringspruit where the situation improved in 1995/96). Although the concentrations just below Witbank Dam (at B1H005) are not as high as in the upstream tributaries, they also exceed the objective for both years. The situation at this point improves in 1995/96, but concentrations in the dam are still increasing as a result of the higher contribution from the Boesmankansspruit and the Naawpoortspruit in 1995/96.

When annual sulphate loads are compared (see Table 6.4) it is clear that during the wet year of 1995/96 the sulphate loads were significantly higher at all the stations than during the dry year of 1990/91.

Table 6.4: Comparison of annual sulphate loads for 1990/91 and 1995/96 hydrological years (source: Table 9b,DWAF, 1997c).

Monitoring	1990/1991	1995/1996
Olifants River at Wolwekrans (B1H005)	10232	72106
Boesmankransspruit (B1H030)	—	21549
Upper Steenkoolspruit (B1H017)	546	2019
Lower Steenkoolspruit (B1H021)	—	9671
Noupoortspruit (B1H019)	1526	6855
Olifants River at Middelkraal (B1H018)	963	3985
Koringspruit (B1H020)	932	2696

A closer look at these data reveal that for all of the stations except the Noupoortspruit, more than 90% of this load is exported during the wet summer conditions (see Table 6.5). The seasonal variation in the Noupoortspruit is different because this catchment has a relatively low natural runoff and flows are dominated by effluents.

Another way of looking at the pollution impact is to present loads in terms of t/km^2 (see Table 6.5). From this comparison it is obvious that the most polluted catchment is the Boesmankransspruit which exports 187 t/km^2 of sulphate, followed by the Noupoortspruit, while background conditions contribute only 4 to 5 t/km^2 of sulphate. During the drier 1990/91 hydrological year, the pollution loads dropped significantly and the background contribution ranged between 0.95 to 1.05 t/km^2 of sulphate.

6.5 Water uses

Present and future water uses are described in detail by WMB (1993a). The water uses considered are irrigation, domestic and industrial. Natural or environmental use is not addressed. However, for this particular study there is no need to take it into account, as sulphate in these concentrations is not a limiting factor for environmental water use. It must be stressed that sulphate pollution can have an indirect impact on environmental use by decreasing pH, therefore acidity must be considered as an ecological limiting factor where high sulphate pollution exists. Salinity as such and its other ionic components (in particular sodium and chloride) may also pose problems for certain environmental use.

Table 6.5: Annual and seasonal sulphate loads for 1995/96 conditions(source: Table 9a,DWAF, 1997c).

Monitoring Point	Total SO_4 Load	Sulphate export (ton/km²)	Summer SO_4 Load (ton)	Winter SO_4 Load (ton)
Lower Olifants River upstream of Witbank Dam (B1H005)	72 106	18	65 415	6 691
Boesmankransspruit (B1H030)	21 549	187	20 531	1 017
Upper Steenkoolspruit (B1H017)	2 019	5	1 833	186
Lower Steenkoolspruit (B1H021)	9 671	7	8 778	966
Noupoortspruit (B1H019)	6 855	78	4 590	2 431
Upper Oliftans River (B1H018)	3 985	4	3 868	116
Koringspruit (B1H020)	2 696	20	2 424	288
Total	118 881	-	107 439	11 695

Note: the sum of totals for summer and winter differs from the annual total, but no explanation for this could be found in the report.

6.5.1 Irrigation

The Witbank Dam catchment is part of a highly productive dry land agricultural region. Maize is the most common crop cultivated in the area and its cultivation is practised on 82 500 ha (24% of catchment area). However only 0.6% of the catchment area is under irrigation. An estimated 2040 ha are irrigated at the headwaters of the Olifants River and its tributaries (see Appendix A.3). Irrigation water is drawn from river and farm dams. The irrigation abstractions for each MU are given in Table 6.6.

Table 6.6: Irrigation abstractions from Management Units (source: Table 5.1, WMB, 1993).

MU	River	Irrigation abstraction (10^6 m^3 p.a)	
		1990	2000
1	Trichardtspruit & Rietfontein Dam	0.00	0.19
2	Rietspruit & Rietspruit Dam	3.18	1.18
3	Koringspruit & Blinkpan Dam	0.00	0.38
4	Boesmanskransspruit & Douglas Dam	0.00	0.77
5	Saaiwaterspruit & Phoenix Dam	0.98	1.08
6	Naauwpoortspruit	0.00	0.46

MU	River	Irrigation abstraction (10^6 m^3 p.a)	
		1990	2000
7	Steenkoolspruit & Dwars-in-die-Wegspruit	5.28	3.95
8	Olifantsrivier & Springbokspruit	0.82	0.96
9	Upper Olifants	0.00	0.00
TOTAL		10.26	8.97

The area exploited by agriculture continues to shrink as coal mining expands. A recent project by BKS (BKS,1997) identified irrigated area by satellite images and showed that the earlier WMB estimates are probably overestimating the actual areas.

6.5.2 Domestic and industrial water use

There are several towns in the case study catchment, but only Witbank abstracts water from the catchment river system (from Witbank Dam). The water abstracted is purified before supply for domestic and industrial use. Table 6.7 provides information on the amount of water delivered to the purification plant for calendar years 1994 to 1996.

Table 6.7: Raw water supply to Witbank purification plant (Ml) (source: Witbank City Council, private communication)

Parameter	*1994*	*1995*	*1996*
Annual average	22582	23696	25939
Monthly max	2245	2230	2563
Monthly min	1456	1842	1771

For hydrological year 1995/96, 24.5 Mm^3 was abstracted for purification and about 4.4 Mm^3 of this was supplied for industrial use. Domestic use for this year was 20.1 Mm^3.

A pipeline to supplement Middelburg's water supply from Witbank Dam was constructed in 1997. It is planned to pump 8.2 Mm^3 /a for the next 10 years after which the allocation will be increased. However, during the study period under consideration, 1990/91 and 1995/96, this pipeline did not yet exist.

The biggest industrial complex in the Witbank area, the Highveld Steel and Vanadium Corporation, abstracts water from Witbank Dam. For hydrological year 1995/96 about 5.94 Mm^3 of water was abstracted directly. The minimum monthly abstraction was 0.41 Mm^3 and the maximum monthly abstraction was 0.6 Mm^3.

Many coal mines abstract water directly from the river or dams for domestic and industrial use. This data is available in the earlier report (WMB, 1990) and is summarised in Table 6.8. About half of this water was utilised for domestic use, which was about 4.1 Mm^3 /a. The values provided seem to be high considering the number of the people working on the mine. This was queried with WMB who confirmed that these earlier figures are an overestimation and that abstractions by coal mines could be neglected. No better data could be obtained. Furthermore, the reported information conflicts with the latest data provided by the Witbank City Council, which gave the amount of water delivered to the Landau mine as 4700 m^3/d. This is more than double the value given for 1990 (see Table 6.8). These values require checking before they are used in any water management system.

6.6 Pollution sources

Considerable effort was made to compile the most comprehensive description of pollution sources in the catchment for the two years considered (1990/91 and 1995/96). The same two reports, which were used for examining monitoring data (i.e. WMB, 1992a and DWAF, 1997c - see section 6.3) were utilised for this purpose.

The known pollution sources are presented on the catchment map in Appendix A.4.

Table 6.8: Raw water abstracted by mines (m^3/d) (source: WMB, 1990).

MU	Colliery	Abstraction Point	Abstraction (m^3/d)	Domestic Use (m^3/d)
MU2	Rietspruit	Rietspruit Dam	2740	1970
MU4	Douglas (Douglas Section)	Douglas Dam	506	0
MU5	Phoenix	Phoenix Dam	1100	783
	Phoenix	Marietta Dam (Steenkool Spruit)	2880	1600
	Tweefontein	Tweefontein Dam or Olifants River of springs	500	492
	Kleinkopje	Olifants River	2170	1302
	Witbank Consolidated	Saaiwater Dam	345	305
MU6	Greenside	Witbank Dam	1800	1290
	SA Coal Estates Landau	Witbank Dam	1800*	
MU8	Transvaal Navigation	Olifants River	564	564
	New Clydesdale	Olifants River	460	288
MU9	Duhva Opencast Services	Olifants River	80	—
	Douglas (van Dyks Section)	Olifants River	2773	1973
	Douglas (van Dyks Section)	Steenkool Spruit	2882	—

MU	Colliery	Abstraction Point	Abstraction (m^3/d)	Domestic Use (m^3/d)
MU9	Douglas (Wolwekrans Section)	Olifants River	1173	768
	Riverside	Olifants River	745	—
TOTAL			22518	11335

* this value is excluded as water for this mine is provided by Witbank City Council and was included in Table 6.7.

In this study point sources are defined as being effluent from a regular source of pollution, which discharges throughout the year, such as a sewage works. This is distinguished from discrete releases, which are irregular point sources, such as the spillage or controlled release from a dam, or from mine dewatering.

As expected in a study of this nature, there were contradictions in the data extracted from the different reports. An attempt was made to find explanations for these, but stopped short of more in depth investigation. This study's objective is to design a waste water charges system and therefore exact values of pollution loads are not that important, as they are only used to demonstrate how the system works. However, all significant problems related to the data were noted by the researchers and, where pertinent, they are discussed in the report.

6.6.1 Point sources

A summary of the pollution load from point sources is given in Table 6.9. The information for 1990/91 was available for all the sewage works of municipalities, mines and power stations. For 1995/96 only the data for municipal sewage works was available. Unfortunately, this data is not based on measured results, but had to be interpolated from predictions made for the year 2000, and seems inaccurate. The biggest point source is the effluent from Witbank Sewage Works, which contributes almost half of the total load emanating from point sources. The sulphate concentration in its effluent was given as 108 mg/l (see Table 5.2, WMB, 1993), which is significantly lower than the concentration in the raw water supply. Therefore this value was replaced by the average sulphate concentration measured in Witbank Dam during the 1995/96 hydrological year, i.e. 160 mg/l. For the sewage works, where the estimate for 1995/96 was lower than the value measured for 1990/91, the 1990/91 value was accepted for 1995/96. No further attempt to improve the accuracy of the data was made as the sewage works contribute a relatively small part of the total pollution load. The reason for this is that sulphate concentration in sewage effluent is usually much lower than in mine releases, and effluent volumes are relatively low too.

As suggested by WMB (WMB, personal communication, 1997), it was assumed that sewage works for mines and power stations contributed the same load in 1995/96 as in 1990/91, except for Blinkpan Colliery, which closed down. Although it was felt that this assumption is inaccurate, a more in-depth investigation is clearly beyond this study brief.

6.6.2 Releases

Reasonable data on pollution loads from releases was only available for the 1990/91 hydrological year (see Table 6.9) . The data available for the 1995/96 hydrological year consisted of just two figures provided in by the DWAF (1997d). These figures were based on the analysis of the available mine water discharge records. However these records were not presented in the DWAF report. The information provided was as follows:

- Release from Kleinkopje Colliery – 6922 t/a.
- Release from other mining operations – 15604 t/a.

Therefore, it was decided to use information collected during the program of controlled releases conducted during the summer of 1996/97 (DWAF, 1997d). This information is summarised in Table 6.9.

One of the releases during 1990/91 was extremely large (i.e. the release from Landau Colliery into the Noupoortspruit). This load was estimated at 11842 tons of sulphate, while the rest of the releases during that year were only 3167 tons. This looks very high when compared to the controlled releases during the summer of 1996/97. This release was evidently a result of the dewatering of Landau Colliery. The sulphate concentration of this underground water was very high, with a 50 percentile of 2000 mg/l (see Table 5.9 in WMB, 1993).

The 1995/96 hydrolocical year was one of the wettest years on record and mines accumulated large volumes of polluted water. As a result, the available storage facilities were not able to contain all this water and uncontrolled seepage and decanting occurred during the summer and the following winter season.

This caused a progressive deterioration of water quality in Witbank Dam, and the salinity level reached an all time high in October 1996. Therefore an experimental scheme of controlled releases during high flow conditions over the period December 1996 to March 1997 was implemented. The monitoring of these releases included daily measurements of the electrical conductivity (EC) and water levels at B1H005, B1H019 and B1H030. Additional weekly grab samples were collected at regular sampling sites (see section 6.3). During the1996/97 summer the biggest contributor to sulphate load was Kleinkopje Colliery, which released 3680 t of sulphate, followed by Middelburg Mining Services, which released 1023 t.

6.6.3 Diffuse sources

The only data available on diffuse sources was that collected during the monitoring program of 1990/91 (see Table 6.9). In general, the estimation of pollution loads from diffuse sources is quite complicated, as it can not be measured directly. In this area it is particularly complex, because some mines are located so close to each other that it is possible that seepage from one mine can go through the area of the other mine before reaching the stream. Some of the mines discharge to several streams, which are located in more than one MU, and this makes estimation of pollution loads more complicated.

Research was done to examine the pollution generation potential from different types of coal mines for the Middelburg catchment (WMB, 1995b). As no such research is available for the study area and the Middelburg catchment is quite similar to the Witbank Dam catchment, it was decided to utilise the above results for this project.

Table 6.9: Summary of pollution source loads (tons/annum).

MU	Monitoring Points	Pollutant Sources	Short names	Point sources (regular)[*1/*2]		Releases [*1/*3]		Diffuse sources[*1]
				1990/1	1995/6	1990/1	1996/7	1990/1
1	Trichardtspruit (B1H006)	Trichardt Town, Syferfontein	Tsw	47.3	47.3[*8]			
		Colliery	Sy				133	
2	Rietspruit (B1H028)	Matla 1,2,3 Colliery,	M1,			134.0	77	
			M2 & M3	5.8	5.8[*6]		(all)	
		Rietspruit Opencast Mine +	R			549	3271	
		Sewage works	Rsw	18.1	25.0[*6]			
		Kriel Colliery (p)	K			102	53+75	
		Matla Power Station (p)	M					
		Kriel Power Station(p)	K			265.2		
3	Koringspruit (B1H020)	Komati Power Station	Ko(ps)	21.2	21.2[*8]	448.9		
		Douglas Colliery[*5]	D				353.5	167.3
		(partially)+sewage works	Dsw	32.8	32.8[*8]			
		Koornfontein Colliery	Ko				253.0	
		Goedehoop Colliery	G				336.0	790
		Blinkpan Colliery	Bl			41.2		
		(defunct)+sewage works	Blsw	14.9	0.0			
4	Boesmanskransspruit (B1H030)	Douglas Colliery[*5]	D				353.5	167.3
		Middelburg Mining Services	Mi				1023	
		Duhva Power Station	Dps			60.5		
		Duhva Opencast	DO					1208
		Speekfontein Colliery	Sp					
5	Saaiwaterspruit (B1H029)	South Witbank Colliery[*4]	SW				72[*4]	
		Arthur Taylor Colliery[*4]	AT					
	Tweefonteinspruit (B1H031)	Phoenix Colliery[*4]	P			1468		2379
		(partially)+sewage plant	Psw	34.6[*7]	34.6[*8]			
		Tweefontein Colliery	T			98.7	105	
		Kleinkopje (partially)	Kl				3680	
		Sondagsvlei Colliery	So					
		Witbank Cons. Colliery	WC					
6	Noupoortspruit (B1H019)	Witbank Town	Wsw	218.9	349.44			
		Greenside Colliery	Gr				119.8	682
		Landau Colliery	L			11842		829

MU	Monitoring Points	Pollutant Sources	Short names	Point sources (regular)[*1/*2]		Releases [*1/*3]		Diffuse sources[*1]
				1990/1	1995/6	1990/1	1996/7	1990/1
7	Lower Steenkoolspruit (B1H021)	Kinross town	Knsw	72.2	72.2[*8]			
	Upper Steenkoolspruit (B1H017)	Kriel Town+	Ksw	48.2	48.2[*8]			
		Kriel Township	Ktsw	0	32.85			
		Albion Colliery	Al					
		Kriel Colliery	K					
		Phoenix Colliery (partially)	P					
		ATCOM Colliery	A					
8	Upper Olifants River (B1H018)	Transvaal Navigation Colliery +	TN					1750
		sewage works	TNsw	38.4	38.4[*8]			
		New Clydesdale Colliery	NC				479.2	
		Kleinfontein Colliery	Kf					
		Sealby Colliery (defunct)	Se					
9	Olifants River (B1H005)	Vandyksdrift Colliery	V					
	Witbank Dam (B1R001)	Wolwekrans Colliery	W					
		Riverside Colliery	Ri					
		Springbok Colliery +	Sp					623
		Sewage Works	Spsw	35.1	35.1[*8]			
	Total			587.5	742.9	15009.5	10384	8595.6

[*1] From WMB, report, No 1503/511/1/W, Table 5.10 pp. 30-32 (WMB, 1992).
[*2] From WMB, report No. WQ B100/000/01/93 ,Table 5.2, p.46 (WMB, 1993).
[*3] From WMB, report No: WMB 3608/1498/1/W, Table 5.2(d), (WMB, 1997d).
[*4] All belong to Tavistock group (diffuse source given for the group).
[*5] Douglas mine contributes 50% to MU3 & 50% to MU4 (A van Nierkerk, private communication).
[*6] According to Rietspruit mine EMPR, Ch2, p.56.
[*7] From WMB, report, No 1503/511/1/W, p.41, (WMB, 1992).
[*8] Assume that sewage plants did not change (except Blinkpan which closed).

The above study concluded that the pollution load can be estimated if at least three factors are taken into account, namely:

- mining technique;
- mined area; and
- pollution control measures implemented.

The last factor is the most complex, and it was decided to use it in a very simple way and only for open-cast mining. The decision was to divide collieries into three categories: poorly rehabilitated; adequately rehabilitated and well rehabilitated. It was found that the management of open-cast mining changed considerably over a period of time.

If no information on rehabilitation levels is available, it can be assumed that the above three categories can be divided according to the age of the mine. So, mines that started to operate before March 1982 fall into the first category, between April 1982 and December 1993 – into the second category, and after December 1993 – into the third category. The pollution potential factors are summarised in Table 6.10.

Table 6.10: Potential Pollution Mobilisation Rates (PPMR) for coal mines.

Type of mining	Control measure	Pollution potential ($t\ SO_4/ha/a$)
Board & pillar		0.15
High extraction		0.7
Opencast mining	Poorly rehabilitated	5.0
	Adequately rehabilitated	3.6
	Well rehabilitated	1.5

These factors were used to share the available assimilative capacity during the Controlled Releases Scheme in 1996/97. Although most of the mines had started operation before December 1993, and some of them even before March 1982, it was decided (without explaining the reasons) to apply a uniform factor of 1.5 t/ha/a for all open-cast mines. In order to verify the applicability of this estimate, the calculated pollution potential loads were compared with the monitoring results (see Figure 6.3).

In the first instance Figure 6.3 shows that the data base is deficient, with only Tavistock mine having data for all three release and diffuse pollution conditions under consideration. Moreover, estimates of diffuse source contributions are available only for the dry 1990/91 hydrological year. Secondly, the potential pollution contribution is often lower than that from the sum of observed releases and diffuse inputs. The reason for this could be that the average potential pollution load represents the pollution during average climatic conditions, and therefore would underestimate the load during a wet year. Also a mine could accumulate polluted water for more than a year before releasing it.

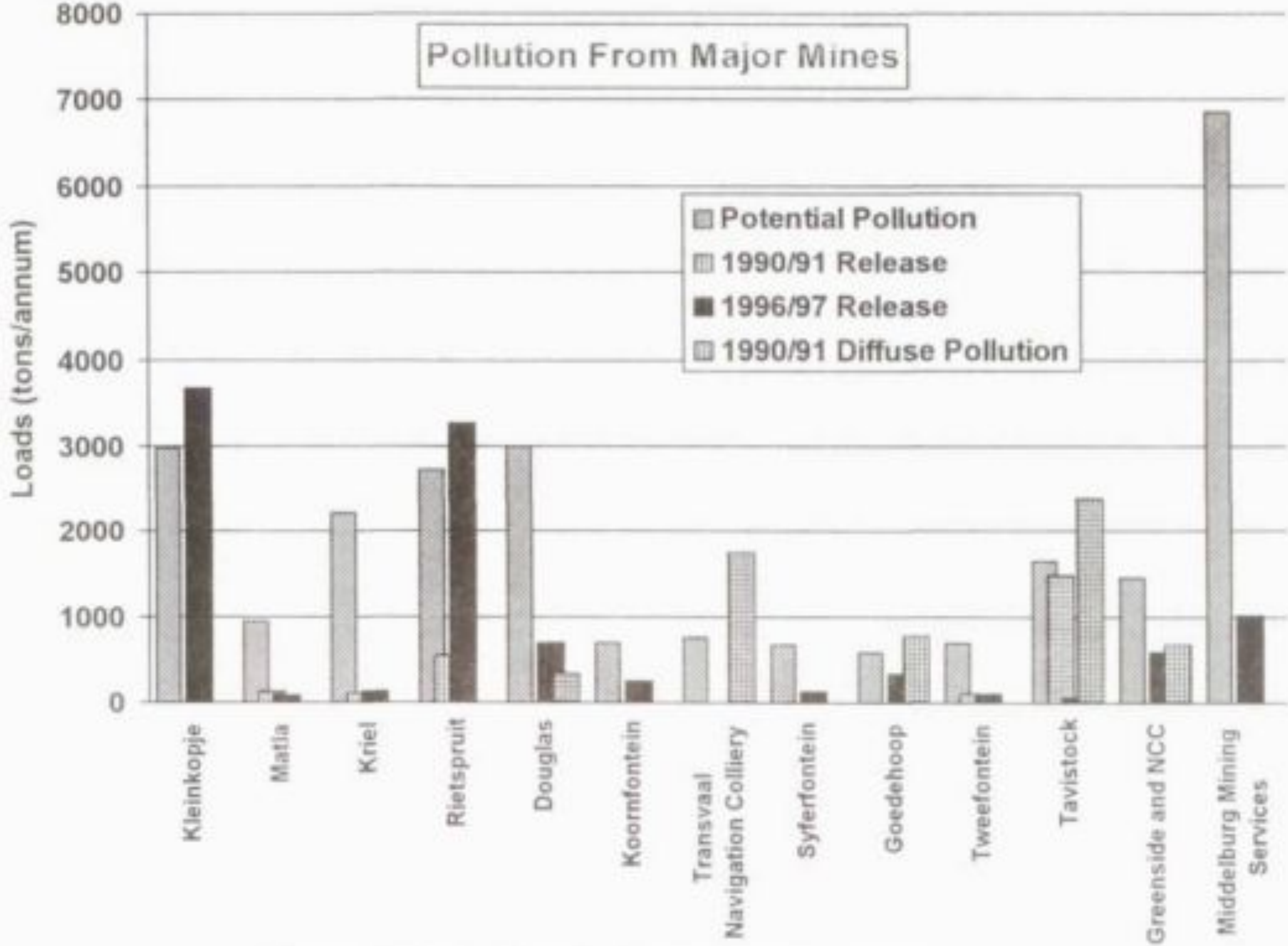

Figure 6.3: Estimation of diffuse pollution from mines.

An examination of the data for controlled releases revealed some further conflicts. For example, the open-cast area of Rietspruit mine used for calculations of the potential load was 2519 ha, while according to the latest information from the mine it is only 1700 ha (Rietspruit Mine Services, personal communication, 1997).

The potential pollution loads were also compared with excess mine water accumulated during 1995/96 (see Table 3a in DWAF, 1997d). This comparison demonstrated that during wet years the calculated loads are underestimated for the larger mines, but overestimated for the smaller mines.

The overestimation is acceptable, because excess water is only part of the polluted water generated by a mine. Unfortunately, for three mines, which accumulated the largest excess – Kleinkopje, Middelburg Mine Services and Matla, the potential pollution loads were underestimated. This underestimation was quite significant, i.e. 569% and 191% for Kleinkopje and Matla mines respectively.

Again, no attempt to improve the quality of the data was made as it is beyond the scope of this study. Taking into account the above-mentioned considerations it is suggested that the calculated potential pollution loads may not be suitable for estimating diffuse loads from each mine directly. But they could be used for allocating the total diffuse load estimated from the monitoring at control points to individual mines.

The estimate of total diffuse source contributions was made for 1995/96. According to the DWAF, (1997d) the sum of background and diffuse source pollution contributed by the Upper Olifants River (at B1H005) was 49 047 t of SO_4. After subtracting the background contribution, estimated in section 6.7, the total catchment diffuse source load was calculated to be 32 339 t of sulphate. As the releases during that year were also very high (22 526 t - see section 6.6.2), it explains why the sulphate concentration in Witbank Dam reached it highest ever level in the 1995/96 hydrological year.

6.7 Background pollution and interbasin water transfer

6.7.1 Introduction

As background load contribution could be higher than 20% of the total load (see section 6.8) it is important to estimate it as accurately as possible. Unfortunately this estimate was only available for the 1990/91 year, so additional data processing had to be done in order to determine this contribution for 1995/96. To confirm our calculation the estimation for 1990/91 was repeated using the same type of data and the same method of calculation as was used to calculate 1995/96 values. Our estimate for 1990/91 (2 130t) was close to but slightly lower than the WMB estimate (2 440 t).

6.7.2 Background sulphate loads

During the extensive monitoring of 1990/91 the total sulphate load entering Witbank Dam from the Upper Olifants River was estimated to be equal to 10 232 t. Most of it was contributed by major pollution sources such as mines, power stations and sewage works, while 23% of the load was defined as the background contribution. This contribution consisted of the following:

- natural weathering;
- atmospheric deposition; and

* agricultural pollution.

It was believed that atmospheric deposition was probably the biggest of these (WMB, 1992a, p.44). To check this statement the atmospheric deposition over the catchment was estimated using recent measurements of SO_2 concentrations in the air and SO_4 concentrations in the rain. The result was 15 874 t of sulphate for a year with average climatic conditions. At first sight this seems high compared to a total background contribution of only 2 440 t/a. However, most of the atmospheric deposition is transported through the soil profile and is thus partly adsorbed. There is a lag effect of a few decades before the deposited pollution reaches the surface water (see WRC, 1997). Consequently, only a relatively small part of deposited sulphate is thought to be contributing to current pollution in the surface water. However, in view of its potential large long term contribution, further investigation of the impact of atmospheric deposition on this catchment is recommended.

No other estimates of the background contribution of sulphate could be found in the available literature. Therefore, it was necessary to estimate it for the purpose of this project.

There are two monitoring stations that appear to represent background conditions – B1H018 on the Upper Olifants River and B1H017 on the upper reaches of the Steekoolspruit. Examination of the measured water quality revealed significant differences between these stations, with sulphate concentrations being consistently higher at B1H017. Another unexplained phenomenon is that although sulphate concentrations increased slightly between 1990/91 and 1995/96 at B1H018, they dropped drastically in the same period for B1H017. The above findings render the data questionable, but further investigation was beyond the scope of this project, so the data was used without any correction.

The first step in estimating the total background contribution involved calculation of, monthly flow-weighted average sulphate concentrations using flow and water quality data at these two stations. These concentrations are depicted in Figure 6.4.

Although the maximum monthly value looked unrealistically high in 1990/91 (141.2 mg/l), the rest of the values seem to be reasonable as are the annual averages of 18.2 mg/l for 1990/91 and 21.0 mg/l for 1995/96. Therefore these results were accepted without further correction. The monthly concentrations were multiplied by monthly flows coming from the Upper Olifants River to the Witbank Dam (through station B1H005), and the resulting annual loads were 1 975 t and 16 494 t respectively. It is clear from these figures that the most important factor affecting the background load is the runoff, which can change the load by an order of magnitude. The unrealistically high maximum monthly concentration in 1990/91, mentioned earlier, did not have any significant effect on the annual load.

Another way of estimating the background contribution is to determine the likely variation in the Witbank Dam water quality assuming that there are no pollution sources in the catchment and that the variation in the sulphate concentration is a function of the hydrological variation only. This estimate was necessary in order to evaluate the impact on those water users who are affected by the deterioration of water quality in Witbank Dam. It was used in estimating the cost of damage given in Chapter 7. The deterioration could be expressed as the difference between the above hypothetical background conditions and present conditions in Witbank Dam.

The measured water quality variation in Witbank Dam was expressed as a ratio between the average and 95 percentile value.

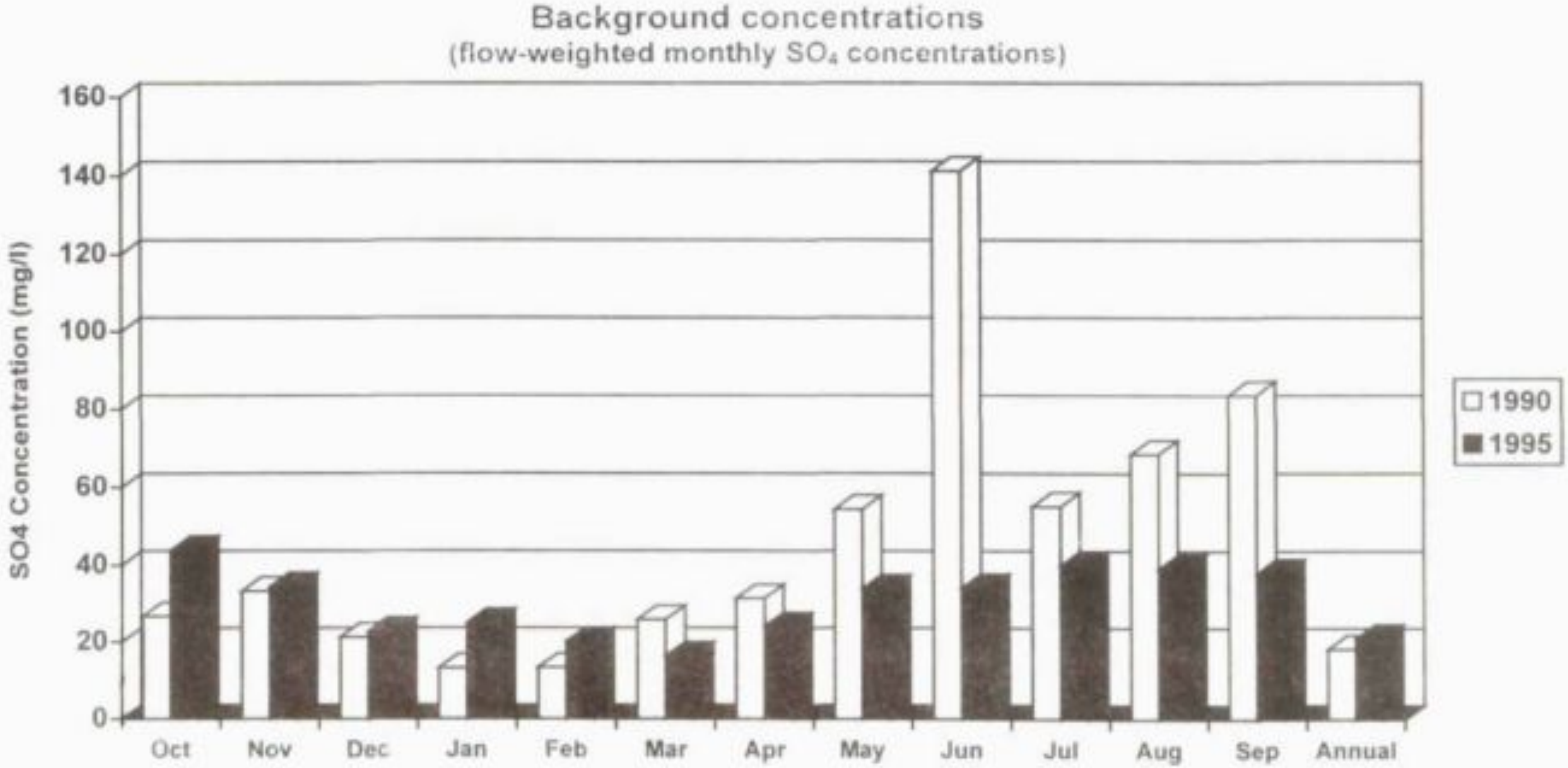

Figure 6.4: Flow-weighted background sulphate concentrations.

A slightly lower variation was assumed for hypothetical background concentrations (part of the measured variation is attributable to changes in pollution contribution).

The ratio between sulphate to TDS at both stations (B1H017 and B1H018) was calculated and found to be very similar. The average of these ratios was applied to estimate the variation in hypothetical TDS concentrations in the dam. The results of the calculations are presented in Table 6.11 [SS(L12]

Table 6.11: Variation in hypothetical sulphate and TDS concentrations in Witbank Dam (assuming zero pollution).

Hydrological years	Average		95 percentile	
	SO_4	TDS	SO_4	TDS
1990/91 (dry)	18.2	158.3	26.7	208.9
1995/6 (wet)	21.0	182.6	30.9	241.0

6.7.3 Inter-basin water transfer

Of those inter-basin water transfer schemes which deliver water to the study catchment, only the Usutu-Vaal Government Water Scheme affects the catchment flow pattern. The objective of this water scheme is to provide high quality water to Matla power station. This transfer scheme delivers water from Grootdraai Dam in the Upper Vaal catchment to Trichardsfontein Dam. From there it is released to Rietfontein Dam and then pumped to Matla. Although this transfer affects mainly the river reach between Trichardsfontein Dam to Rietfontein Dam, some of the Grootdraai Dam water spills and therefore affects the rest of the Witbank Dam catchment (see Appendix A.1).

Unfortunately, no estimate of this impact was found in the literature and an attempt had to be made to calculate it.

Accurate calculation of the sulphate load contributed by the water transfer scheme requires a proper mass balance of all incoming and outgoing flows from Trichardsfontein to Rietfontein Dam. This mass balance should include the balance of both dams, releases from the Trichard sewage works and releases and diffuse source contribution from Syferfontein colliery. However, such detailed information was unavailable. The only data that could be used was extracted from the DWAF's Hydrobank database on flows and water quality at B1H022 (Trichardsfontein Dam) and a few values for 1990/91 at Trichardsfontein Dam and Rietfontein Dam WMB, (1992a).

The above data was used to calculate monthly and annual loads leaving Trichardsfontein Dam for the study period. As most of this water is released to be delivered to Matla power station it was assumed that only 25% of this load is spilled downstream from Rietfontein Dam. Final estimates of the contribution of the inter-basin water transfer were 155 t/a and 214 t/a of sulphate, which are quite small, but still a noticeable addition to the total load.

6.8 Comparison of pollution sources

All of the above information was put into perspective by graphically presenting it as a pie chart (see Figure 6.5). It is important to note that the background contribution to total load grew from 13.6% in a dry year to 22.8 % in a wet year. The diffuse source contribution to the total load decreased from 59.4% in the dry 1990/91 to 44.7% in

1995/96. However, in absolute terms the diffuse load increased almost 4 times - from 8 596 t/a in the dry year of 1990/91 to 32 339 t/a in the wet year of 1995/96. This demonstrates the pollution generating and loading potential of rainfall-runoff processes. The observed increase in the percentage background sulphate contribution during the wet year could in part be attributable to the nature of sulphate. Sulphate is known to behave differently from TDS, in that background concentrations tend to rise during wet years, when TDS concentrations fall (WRC, 1997). The sparse quality data could also reduce the accuracy with which sulphate loads were calculated from the two background stations.

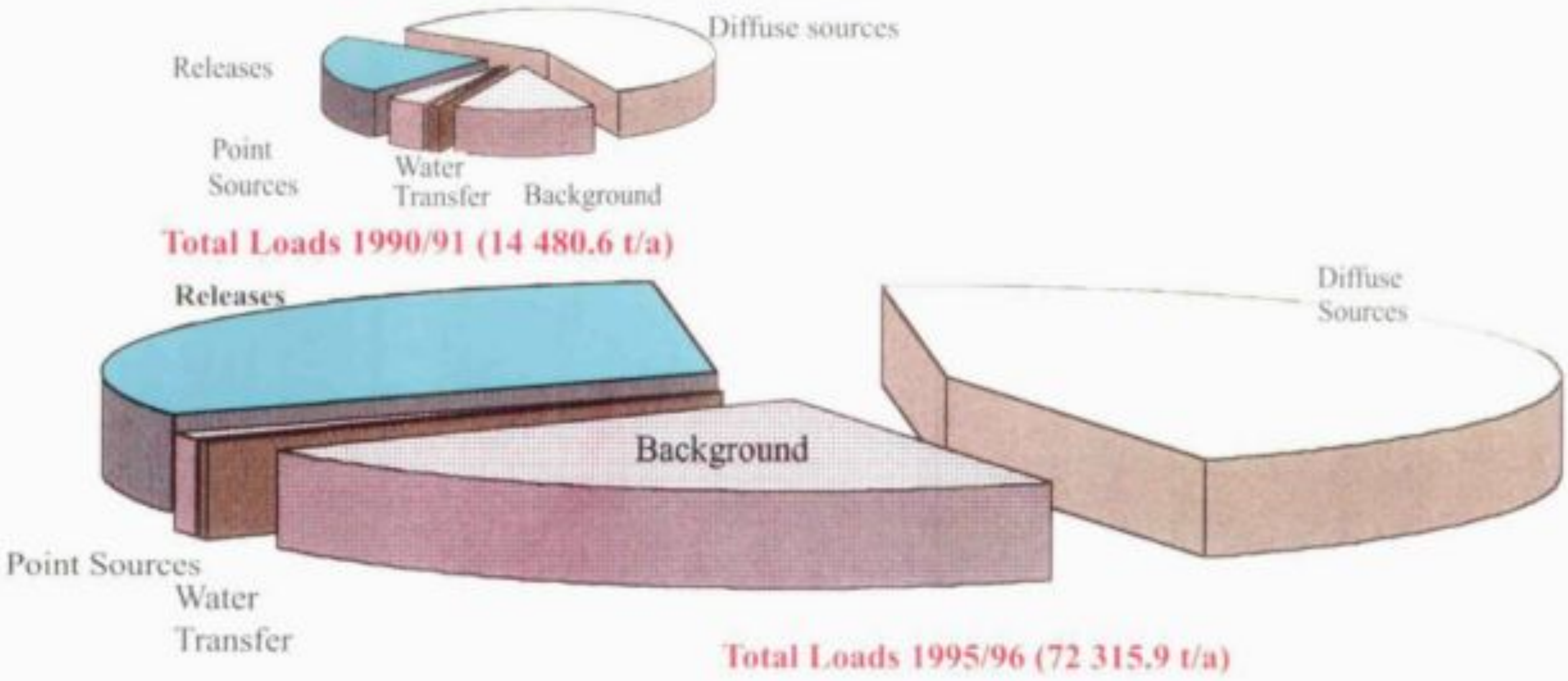

Figure 6.5: Pie chart of total load distribution at station B1H005.

7. ESTIMATION OF THE EXTERNALITIES OF POLLUTION IN THE WITBANK DAM CATCHMENT

7.1 Overview

It is essential to consider impact and abatement costs as they are measures of the externalities associated with pollution. Impact costs measure externalities from the perspective of water users, while abatement costs measure externalities from the perspective of water polluters. The cost of water pollution control measures to minimise or to prevent pollution could not be estimated. This cost depends on the management practices and specific characteristics of mining and auxiliary activities as well as on geohydrological properties of a mined area. This cost can only be estimated by the mines and it is usually lower than the treatment cost. Therefore for the purpose of estimating the upper range of abatements costs the treatment cost has been used.

The costs were estimated for sulphate's contribution to salinity. Most of the data for the impact cost is only available for TDS or EC. Thus the costs were adjusted for sulphate concentrations, assuming a linear relationship between TDS and sulphate values, as suggested by WMB (DWAF, 1997d).

The methodology utilised to estimate the direct financial cost of impact and the total catchment cost for the study area are presented in this chapter. This cost estimate is used in Chapter 8 to demonstrate the capabilities of the proposed model for calculation of the pollution charge. The estimated abatement cost is used to determine the upper range of this charge.

7.2 Estimation of the cost of impacts on water users

7.2.1 Background

It was originally intended to use the impact costs estimated by Wates, Meiring and Barnard (DWAF, 1997b). However, these costs were found to be inappropriate as:

- they were estimated for a hypothetical level of sulphate concentration, while in this project it has to be done for a more realistic situation during the study period;
- better ways of determining some of the costs have been identified;
- more accurate data has been collected for this study; and
- certain assumptions had to be replaced.

The costs in this study have been calculated for two water quality regimes in the Witbank Dam catchment: the 1990/91 and the 1995/96 hydrological year. These two years represented different hydrological conditions - one of the driest and one of the wettest years in the last decade respectively. The water use for both scenarios was assumed to be the same as that estimated for 1995/96. This was done in order to compare the impact cost of different water qualities on consumers using a constant level of consumption. The more recent year (1995/96) was selected because most of the required information was available for that year and represents recent conditions quite accurately.

All calculations were corrected to 1997 prices. The water use for each type of user is described in section 6.5.

7.2.2 Agriculture

The aforementioned report (DWAF, 1997b), did not include the cost impact on irrigators in the Witbank Dam catchment. Although these impacts are relatively minor, for the sake of completeness, agricultural impacts have been included in the present analysis of costs.

When considering the impacts on agriculture of a decrease in water quality there are two possible courses of action – either an attempt can be made by the irrigator to restore crop yields, or a loss of yield can be accepted. Later in this section these are referred to as scenario (i) and (ii) respectively. Both courses of action incur costs. The acceptance of a loss of yield with subsequent compensation is undesirable and should not be encouraged, since it might serve as a subsidy and lead to low productivity.

A better alternative may to try to improve the overall productivity of the affected farms. There are a number of measures, which can be implemented to achieve this, includes increasing the leaching fraction, providing artificial drainage, using higher yielding cultivators and improving general management. Some improvement to water management can probably also be achieved via education. Other measures may require some indirect subsidies.

Irrigators demanding direct compensation from polluters would have to prove and quantify the impact, identify the cause and culprit. In this regard it must be noted that the payment of a waste water charge by a polluter may not protect that polluter from legal damage claims brought by the victims of pollution. Payment of the waste water charge is not a licence or permit allowing polluters to impose direct negative financial impacts on downstream users with impunity. However such a charge system should create the opportunity for introducing mitigation measures rather than opting for lengthy, expensive and possibly inconclusive litigation. If claims are made by victims of pollution, managers of charge systems would be faced with three options:

increase charges to reduce pollution levels;

provide financial assistance to the polluter to reduce pollution levels; or

provide financial assistance to the irrigator to help him/her cope with a poorer water quality.

The impact on irrigation farming becomes noticeable when TDS concentrations rise above 600 mg/l. From sections 6.4 and 6.5.1 and from the map of irrigated land distribution in Appendix A.3 it can be deduced that the only affected irrigated areas in the Witbank Dam catchment are in the lower reaches of MU7. According to a recent BKS project (BKS, 1997) the irrigated land in MU7 is 1305 ha. As no better data could be found an assumption was made that 80% of irrigated land is located in the Lower Steenkoolspruit (conservative estimation from the map). Then the affected area should not be more than 1044 ha. Information of the typical crop distribution in this area was provided by BKS.

For the purposes of these calculations, cost factors for irrigating with poor water quality have been extracted from the Lower Vet River study (DWAF, 1997j). It has been assumed that the cost factors for water quality with a TDS of 600 mg/l can be used for both years (1990/91 & 1995/96) as concentrations above 600 occur for both years in this area.

Table 7.1: Cost factor (R/ha) (source: Table F.4, DWAF, 1997j).

Scenario	Potatoes	Maize	Lucerne	Pasture
i	404	266	272	0
ii	613	95	56	0
Crop distribution(%)	30	8	3	59

Impact costs for the present range of crops were calculated for scenarios (i) and (ii) and were estimated, using above mentioned cost factors, to be R0.16 million/a and R0.20 million/a respectively. For both scenarios, irrigating potatoes accounted for most of the cost (for scenario (ii) about 95% of total cost). The rounded value of R0.2 million/a is used for further calculations.

7.2.3Household consumers

The impact on household users was calculated by using cost factors determined in the latest report by Urban-Econ (WRC, 1996b). It assumes that the cost is zero to the householders when the TDS concentration is equal or lower to 200 mg/l. Unit costs in R/month/household are provided for three types of households: suburban, township and informal at a TDS concentration equal to 500 mg/l. It was suggested in the report that for TDS concentrations above 200 mg/l, the cost changes linearly with TDS, and can be calculated by the following equation:

$$C_T = C_0 \frac{(T-200)}{(500-200)}$$

where: T - the TDS concentration;

C_T - the cost at TDS =T; and

C_0 - the cost at TDS = 500 mg/l.

The sources of the data used in the calculation were as follows:

- The number of households for the above dwelling types provided by the Department of the Witbank City Council (personal communication) were 14 100, 50 000 and 9 000 respectively.
- The C_0 values derived from the above-mentioned WRC report for each type of dwelling were 49.4, 64.0 and 30.7 R/month/household respectively.
- The monthly TDS concentrations at Witbank Dam were calculated from DWAF Hydrobank data.

The impact cost to offices and the large prison in the Witbank area were calculated using different approach and added to the cost to household consumers. Application of the above mentioned unit costs for the mix of households for the Lower Vet River (DWAF, 1997j) resulted in an average unit cost of 0.2494 c/m^3 per 1 mg/l increase in TDS above 200 mg/l (adjusted to 1997 prices). This factor and the values of consumption by the main users provided by Witbank City Council were used to calculate the impact cost for offices and the prison.

The final costs (after adjustment to 1997 prices) were R3.06 million for 1990/91 and R7.26 million for 1995/96 water quality conditions.

7.2.4 Industrial consumers

Three types of industrial consumer were considered: sensitive wet industries, intensive wet industries and dry industries which are affected only as consumers of water for human consumption. The cost to Eskom (Duvha Power Station) is discussed separately.

- The first group includes Highveld Steel and Vanadium (HS&V). HS&V's water use was 5.936 Mm^3 for 1995/96. The unit cost determined for the Iscor Steel Works at Vanderbijlpark (see Heynike, 1987) was used. After adjusting to 1997 costs and assuming that additional costs would start to be incurred after TDS concentrations rose above 200 mg/l (original Heynike calculations were based on 300 mg/l), the unit costs come to 0.371 c/m^3 per 1mg/l increase in TDS. This is almost 49% higher than the unit cost for the domestic consumer, which seems reasonable.

  The total cost to HS&V was calculated at R1.40 million for the 1990/91 water quality scenario and R3.32 million for the 1995/96 water quality scenario.

  Examining the costs of water treatment can test the accuracy of the estimate above. HS&V use certain chemicals for its water treatment. The one that is most directly related to sulphate problems in the water supply is a corrosion inhibitor. From sketchy information provided by HS&V, it seems that the use of this chemical escalated quicker than the water consumption. The cost of the use of this chemical increased from R 1.17 million in 1992 to R2.01 million in 1995. The quantity of anti-scalants required is also dependent on the water quality of the feed water. The cost of their use by HS&V in 1995 exceeded R3 million. Although these figures do not represent the direct cost of the water quality impact on HS&V, they suggest that the proposed estimates are of the correct order of magnitude.

- The second group includes the remainder of the industries in the Witbank area. As no information was available for them it was assumed that their unit cost was equal to an average between the unit cost for domestic users and for sensitive wet industries. The water use for this group was 4.455 Mm^3 for 1995/96. The total cost to this group was calculated to be R0.88 million for the 1990/91 water quality scenario and R2.08 million for the 1995/96 water quality scenario.

- The third group included coal mines, which use most of their water for offices, change houses and hostels. Some of the water is used for coal washing, but this use is not sensitive to salinity level and was therefore ignored. The quantity of water used for domestic purposes was extracted from the water system diagrams provided in WMB, 1990. Difficulties related to utilising this information for this purpose are detailed in section 6.5.2.

No information on the quality of the abstracted water could be obtained. Therefore the water quality at the nearest upstream monitoring station was used. The total cost to coal mines was calculated to be R1.32 million for the 1990/91 water quality scenario and R1.48 million for 1995/96 water quality scenario.

The cost of increasing the salinity of the water supply to Duvha Power Station was estimated by WMB (DWAF, 1997b) as R150 million for both scenarios. This is the capital cost of providing water from Rietfontein Dam rather than the Witbank Dam. Eskom was approached several times and requested to provide relevant information regarding their costs as a result of low quality of the water in Witbank Dam but no response was received.

Due to the complexity of the situation, an additional case study was conducted and presented in section 7.5. To represent the situation in the study area for 1995/966 the cost of the blending option was adjusted to 1997 prices, which resulted in a value of R0.63 million. As no data was available on the impact of the water quality in Witbank Dam on the cost of the blending option, the same cost was used for both the 1990/91 and 1995/96 water quality scenarios. It must be stressed that this cost is not truly representative of the full cost to Eskom and it may increase in the future if there is insufficient water for Duvha from the Komati system.

7.2.5Summary of the costs to water users

Although the costs of pollution to water users were calculated independently to the WMB study, and different assumptions and input data were used, the overall results were very similar (DWAF, 1997b). The estimate of the impact cost on the municipal water distribution network calculated by WMB was therefore accepted for this study. In any case, this cost is the lowest of all and any variation arising because of different methods of calculation is likely to be insignificant. The 1995 WMB estimates for municipal use were adjusted to 1997 prices. This resulted in values of R0.23 million for the 1990/91 scenario and R0.47 million for 1995/96.

A summary of impact costs is provided in Table 7.2. The impact cost to the domestic water users is significantly higher than the cost for any other water user group. This conclusion is identical to the conclusion reached by the Urban-Econ (WRC, 1996b) and the WMB studies (DWAF, 1997b).

Table 7.2: Summary of impact costs.

Water users	**Cost (in R million 1997 prices)**	
Water quality scenario	1990/91	1995/96
Irrigation	0.20	0.20
Domestic	3.06	7.26
HS&V	1.40	3.32
Other industries	0.88	2.08
Coal mines	1.32	1.48
Municipal network	0.23	0.47
Eskom	0.63	0.63
Total	7.72	**15.44**

7.2.6Limitations of the cost estimate

In the above section only the direct financial costs were considered and not the full cost to society of the impact of pollution, which can be estimated from the following relationship (see explanation in section 2.4):

$$C_{total} = C_{admin} + C_{dir} + C_{indir} + C_{env} + C_{ops}$$

For some of the impacts the available data is insufficient to determine even the direct financial cost. In particular, the cost for Eskom could be an underestimation.

The calculation of the indirect economic costs is very complex and although attempts were made to estimate them (WRC, 1996) their estimation was beyond the scope of this project. However, what is clear is that the full economic cost will generally be significantly higher than the direct cost.

Certain types of impacts on the environment, such as biodiversity, are virtually impossible to express in agreed, financial terms and were therefore excluded from the calculations. The estimation of the opportunity cost (i.e. the cost of not being able to use good quality water), which is extremely complex, was also excluded.

A further limitation is that only water users within the study area were considered. Upon examining the available information it became clear that a more detailed study would be necessary to investigate the impact of polluters in the Witbank Dam catchment on water users downstream. Other consultants are presently carrying out this investigation for the area downstream of Loskop Dam, but the results are not as yet available. The additional impact on users, such as Kruger National Park and farmers in Mozambique, may in fact be considerably higher than the impact cost estimated for the study area.

7.3 Estimation of pollution abatement costs

7.3.1 Introduction

There are several different ways that the abatement of pollution costs can be calculated. This study focuses on estimating costs ranging from treatment at the source to the point of use, as a proxy.

The cost estimates provided in the following sections are ball-park values. They are only an indication of the likely abatement costs. In most cases, both capital and operational costs are provided, but to facilitate comparison, the capital costs were converted into capital recovery costs and added to the operational costs. A net discount rate of 10% and twenty years working life were assumed for the calculation of capital recovery cost. All the costs were adjusted to 1997 prices.

7.3.2 WMB estimate of abatement costs

According to WMB (DWAF, 1997b) to achieve a water quality objective (Co) of a sulphate concentration of 300 mg/l in Witbank Dam would require the mines in the area to spend about R56 million (capital and operating cost for 1995). This is equivalent to R65.4 million in 1997 prices.

No explanation was provided on how this cost was derived. Furthermore, the Co for Witbank Dam in the 1993 report is 155 mg/l (see Table 6.3). Hence, WMB's estimate base on a hypothetical objective of 300 mg/l should be construed as a conservative estimate of abatement costs.

7.3.3 Treatment costs as a proxy of abatement costs

Treatment costs are the costs of the treatment of all polluted water contributed by mines. A particular example investigated for the purposes of this study was the treatment of the pollution from abandoned mines, which is the responsibility of the DWAF. The Brugspruit Pollution Control Works were built in 1996 near Witbank to collect and neutralise acid mine drainage. The capital investment was R26 million and operating costs are R1.476 million/a. Every 3 to 6 years new sludge lagoons have to be built which cost another R2 million. If capital costs are converted into capital recovery costs and the operating costs added, the total annual cost comes to R5.16 million. This expense is only for the collection and neutralising of acidity. It does not include reduction of TDS or sulphate concentrations.

The removal of sulphate is more expensive than the neutralising of acidity. According to the latest estimate (WRC, 1998) the minimum cost of desalination is R5.7/m^3 of polluter water. This includes the cost of brine disposal and it combines operational and capital costs. The unit cost can also be expressed in R per unit of load (t of sulphate). The resulting unit cost is about R3585 per ton of sulphate. This cost is based on a sulphate concentration of 1590 mg/l in the polluted water. If the feed water has a lower sulphate concentration then to process one ton of sulphate a larger quantity of the polluted water has to be treated. This would cost more since the total volume treated affects the price. Since the assumed concentration of 1590 mg/l represents the upper part of the range of possible values, the aforementioned treatment cost will be considered to be a minimum unit cost.

For the 1995/96 hydrological year, total annual treatment cost for mine releases, calculated from the above unit cost, was found to be R80.7 million/a and R196.7 million/a for all non-point load (releases + diffuse. During that year, the total load contributed by releases and diffuse sources was 54 865t, while annual waste load allocation estimated for mines for 2000 is 8945t (see WMB, 1993). Assuming that all diffuse pollution was contributed by mines and that the waste load allocation is enforced, the mines would have to treat all surplus discharge of 45 920t of sulphate. This would cost them R164.6million/a (excluding the cost of converting the diffuse pollution into point source so it can be treated). This value is assumed to represent the upper range of potential cost of treating pollution at source.

The cost of treating all water, which was released by mines during summer 1996/97, comes to R37.2 million (assuming that 6.531 Mm^3 of water was released – see DWAF, 1997d). This means that the mining industry effectively saved at least R37.2 million, when the DWAF approved to release the polluted water. According to the Chamber of Mines (personal communication, 1998) the implementation of the controlled release scheme had a triple benefit:

- industry achieved significant cost savings, whilst at the same time the water quality objectives for the catchment were achieved;
- the cost savings were passed on to the shareholders, government (in the form of taxes) and to electricity users;
- the cost savings enabled South Africa to remain competitive in the international market and to earn foreign exchange. To a certain extent, this offsets some of the effects of the current harsh economic situation.

7.3.4 The cost of on site stream desalinisation

This method of abatement cost estimation involved identifying control points where the water quality exceeded the management objectives and then estimating the costs of diverting part of the stream, treating it and discharging the higher quality water back into the stream to achieve the desired water quality.

Numerous assumptions were made to arrive at estimates. An attempt was made to take into account the water quality and management objective at the relevant point, the monthly flows and the optimisation of the desalination plant. However, because such a significant amount of data processing was necessary and some data from 1990/91 was not available, only the costs for 1995/96 conditions were estimated.

Calculations were based on data from four points:– three main monitoring stations upstream of Witbank Dam (B1H019, B1H030 and B1H005) and one at the dam. It was assumed that water, which was abstracted from the dam by Witbank treatment plant, is treated to meet the required Co. The annual costs (sum of capital recovery costs and operational costs), calculated using the unit cost of R5.7/m^3 are presented in Table 7.3.

Table 7.3: Treatment costs necessary to achieve water quality objectives.

Station	**Cost**(R million/a)
B1H019	59.8
B1H030	140.9
B1H005	309.5
B1R001	10.8

In order to achieve adherence to the water quality objective at three main control points - B1H019, B1H030 and B1H005, controlling inflow into Witbank Dam, the total annual cost of side stream desalinisation was estimated as R510.2 million. This would implicitly result in achieving the Co at Witbank Dam. The option of accepting the high sulphate concentrations at the upstream control points and treating a portion of the Witbank Dam water, sufficient to guarantee that the average sulphate concentration does not exceed 155 mg/l would only cost R10.8 million.

7.4 Conclusion

It is clear from the data presented in this section that treating water after discharge is much more expensive than treating it before it is discharged. The cost of treating all water entering Witbank Dam to the level determined by Co would cost R510.2 million/a compared to the cost of R164.6 million for treating the mine's polluted water so that the waste load allocation is enforced.

The cost of treating water abstracted from Witbank Dam (R10.8 million/a) could be compared to the cost of pollution to water users. The impact cost includes cost to domestic users, municipal network and industries others than HS&V. This impact cost of R9.8 million/a (see Table 7.2) is close to the R10.8 million of treatment cost. It should be noted that even by achieving the Co at Witbank Dam, some economic costs will still be incurred by users. This is because the management objective of 155 mg/l of sulphate is equivalent to a salinity of 328 mg/l TDS (using the linear relationship between sulphate and TDS as suggested by WMB (DWAF, 1997d)), while the impact cost begins at a TDS of 200 mg/l.

Some of the costs discussed above are presented in Figure 7.1. It can be concluded that the direct impact cost is very small when compared to abatement costs.

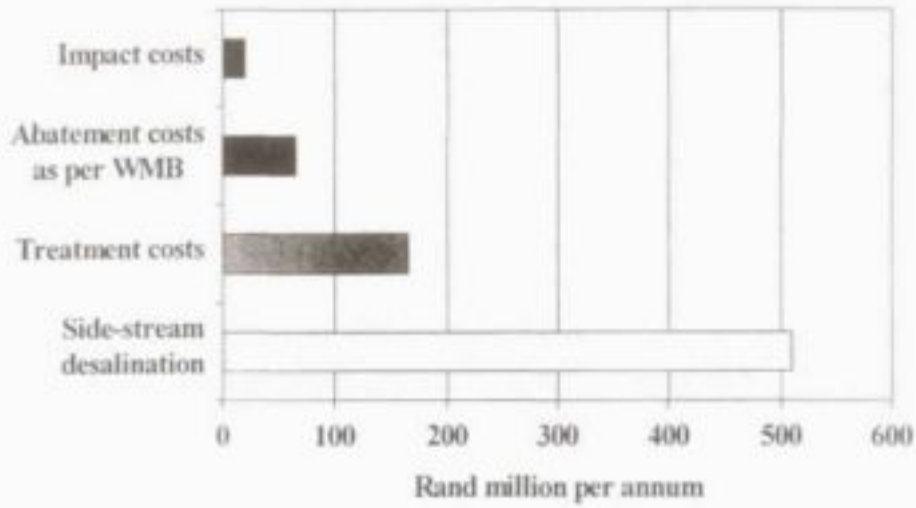

Figure 7.1: Comparison of total catchment costs (R million/a).

7.5 Eskom's sensitivity to poor water quality in the Witbank Dam: a comment

7.5.1 Historical background

The sensitivity of Eskom to poor water quality in Witbank Dam can be traced to a number of factors, the most significant of which is the vulnerability of its 'flagship' power station - Duvha, to elevated TDS levels in the Dam. Ostensibly, the station was designed around a water quality, which prevailed prior to the current level of mining and mine-related pollution that exists today in the Witbank Dam catchment. Moreover, the current level of coal mining in the catchment is to an extent a product of the construction of the station and its subsequent demand for local coal. Indeed, it is understood that some of these mines were 'tied' mines in which Eskom had a stake. Prior to the mothballing of Komati Power Station, in the upper part of the Olifant's catchment, mine water discharge from the adjacent Blinkpan Colliery (where the power station practised underground wet ash disposal), also contributed to elevated TDS and sulphate levels in surface water.

The design of Duvha Power Station was also somewhat inflexible to variations in intake cooling water quality, if the zero-effluent discharge status of the station was to be maintained. In other words the station could accept a poorer water quality but this would result in fewer cycles of concentration in the cooling water system, more frequent blowdowns, more frequent make-ups and surplus effluent that could only be discharged to the surface water system. Thus the 'no action' consequence of poorer water quality in Witbank Dam, assuming the integrity of Duvha was not to be infringed in any way, was increased cooling water demand and a quantity of saline effluent which was beyond the absorption capacity of the power station's ashing facility. The station would also incur additional costs in the treatment of comparatively smaller quantities of demineralised boiler feed water as a result of higher TDS concentrations in the intake water.

In the late 1980's a series of options to resolve Duvha's water supply problem were investigated by a joint working group of both Eskom and DWAF. The options included:

- Blending Witbank Dam water with Komati River water drawn from Eskom's dedicated water reticulation system in the area; (capital cost: R2million at 1989 prices).
- Modifying Duvha's cooling water system to render it more resilient to poor cooling water quality; (capital cost: between R23.7 and R47.6million at 1989 prices depending on modifications to all or half of the cooling water system).
- A dedicated pipeline supply of better quality Grootdrai Dam water taken from the Rietfontein Dam in the upper Olifants catchment; (capital cost: R35.8 million at 1989 prices).
- The desalination and subsequent re-use of surplus blowdown water from Duvha; (capital cost: R40.8million at 1989 prices).

The costs were calculated assuming the worst case scenario for water quality in Witbank Dam of sulphate concentrations of 150 mg/l. In the last few years the water quality was significantly worse than this (the average for July to December 1996 was 267 mg/l).

Due to the mothballing of Camden and Komati power stations, surplus Komati River water became available in Eskom's pipeline distribution system. Consequently, it was decided to proceed with the blending option and to introduce one of the remaining options only when blending proved no longer adequate. Eskom paid for the blending option whilst DWAF wrote-off a portion of the unrecoverable costs of the Nauwpoort Pumping Station (built by DWAF to supply Duvha with water from the Witbank Dam), due to the reduction in its use.

7.5.2 Determining the impact costs of pollution

The first question that needs to be examined is whether the anticipated impact costs at Duhva, regardless of how unlikely it would be for such impacts to be permitted, should be used as a basis for determining how much the polluter should pay. In other words, what would be the 'no-action' impact costs of Duvha Power Station using polluted water from Witbank Dam as was originally intended? Such costs could be considered in two ways: the cost of operating the cooling water system without any surplus blowdown and the cost of operating it with surplus blowdown.

Presumably, the cost of not producing surplus blowdown and allowing the lifespan and effectiveness of the cooling system to be negatively impacted, together with the ability of the station to produce electricity, would be extremely high. However, this is not a cost that is likely to be incurred given the responsible management that exists at Duvha, the value of the assets at stake, and the cost of reduced power supplies to the nation.

The alternative 'no-action' option for Duvha Power Station would be to protect the assets of the power station and maintain power supplies by producing surplus blowdown to be discharged to the Olifants River. Assuming that the discharge occurs downstream of Witbank Dam (it would be self-defeating for Eskom to discharge effluent into the dam from where its water supply is drawn) the following costs could be expected:

- The cost to Eskom of a pipeline from Duvha to a point where the effluent would flow to the river below the dam.
- The incremental cost of additional make up water.

- The cost to downstream water users of the additional pollution.

The combination of these three costs may represent a more realistic impact cost of Eskom abstracting more polluted water from Witbank Dam.

7.5.3 Impact costs versus abatement costs

The next question that must be answered is whether abatement costs can be used as a proxy for pollution impact costs in this instance. In other words, if the victim of pollution decides to treat their water supply to a level where they can use it without any pollution impacts, can the cost of abatement be used as an indicator of the impact of pollution? This is a common practice in other countries and is often adopted as a more practical method of estimating impact costs given the complexities associated with direct and indirect impact assessment. However, in a developing economy it is suggested that abatement costs can only be used as a substitute for impact costs in situations where the victim has the capacity and resources to implement abatement measures.

In situations where both impact costs and abatement costs can be calculated, usually the lowest cost should be used for pollution charge calculations. In Eskom's case it is probable that the impact costs of pollution are far higher than the abatement costs that might be incurred by Eskom to combat the effects of pollution regardless of whether surplus blow down is generated or not. Whilst it is not always the case that abatement costs are lower than impact costs it is nevertheless important to know which to use when both are available.

Guidance on this issue can be found in macro-economic policy. As economies develop and grow, resources are placed under increasing pressure - thus requiring that resource utilisation becomes more efficient. If pollution charges were based exclusively on impact costs and the compensation of the victims of pollution via direct or indirect means, a constant efficiency in the use of resources would be entrenched and any incentive on the part of the victim to increase that efficiency would be undermined. In the case of irrigated agriculture, it is preferable, for both the farmer and the national economy, if the farmer learns to produce the same yield with poorer quality water, rather than compensating him/her for a reduction in yield. Similarly, it is better for Eskom to adapt to the poorer quality water of Witbank Dam rather than receive compensation for having to use it. This does not mean that the victim cannot be compensated in some way for introducing adaptation systems, but rather that compensation should not be a reward for reduced, efficiency or productivity, regardless of the reasons for such a reduction.

Adaptation also brings with it a number of other benefits, most notably increased resilience to changes in the resource base and sometimes reduced consumption of resources. In the case of Duvha, several of the adaptation measures result in a reduction in the net demand for water. It is therefore reasonable to expect the State to require the victims of pollution to base their impact costs on the least cost of abatement assuming that abatement measures are viable, feasible and less than the direct impact costs.

7.5.4 Consequences of the victim of pollution becoming a polluter

Most water users are also water polluters. Thus the situation can arise whereby a victim of water pollution might claim some form of direct or indirect compensation from polluters and at the same time also pay pollution charges for their own waste water return flows. The creation of excess blowdown would make Eskom a polluter and liable for paying a pollution charge. However, Eskom may be inclined to point out that their status as a polluter has been imposed on them by other polluters and the failure of the State to adequately control such pollution. They may also point out that their effluent discharge comprises excess pollution from the mines which they are merely routing more quickly through their cooling system so as not to incur any damage, and then returning it to the Olifants River from whence it came. They may even point out that the pollution load abstracted is far less than that which is discharged back to the river, the difference being the salts that are 'locked' into the ashing system. In other words, as a net reducer of pollution in the catchment they may claim that they are entitled to a rebate and not a charge.

How does an economist deal with such a convoluted situation? The answer is to keep the pollution charge system simple and not complicate it with other issues, but rather deal with the other issues through dedicated pricing systems. For example, in the event of Duvha discharging an effluent, they must pay the required charge irrespective of what circumstances led them to discharging that effluent. If they feel financially disadvantaged as a result of the poor quality of the water supply then they must seek compensation from upstream polluters, possibly via the system through which they purchase water. For example, they might seek a discount on the price of the water as a result of a reduction in its quality - as with any impaired goods that are purchased. If the supplier of the goods (in this case DWAF) is not in a position to afford a reduction in the price of water it supplies to Eskom, then it must in turn seek compensation via the pollution charge system. Thus a situation could arise whereby the DWAF seeks to subsidise the discounted cost of supplying poor quality water in the catchment from pollution charges, thereby establishing a market for water which incorporates a quality component.

Although this may seem an ideal solution, it should be realised that it only works insofar as the demand for water does not exceed supply under the prevailing pricing system. Once, water becomes scarce in the catchment users will be prepared to pay more for it regardless of the quality. The cost of purchasing scarce water and of treating it to the required quality represents the willingness of each water user to pay for water in the area. Once that threshold is exceeded the user must consider relocating to a place where water is more affordable in terms of the viability of the business.

7.5.5Consequences of a victim being indirectly responsible for the pollution

It could be argued that Eskom is partially responsible for the pollution in Witbank Dam by virtue of the fact that their demand for local coal has a profound effect on the development of mines in the area and that they even have a stake in certain mines in order to ensure the supply of coal to the power stations. In such circumstances some might argue that Eskom automatically forfeits its status as a victim of pollution and that any costs of pollution incurred by them should be met internally.

Resource economists would be unlikely to agree with this viewpoint and once again would prefer to reduce the complexity of Eskom's relationship to the causes of pollution to more simplistic cascading pricing mechanisms. For example, if a coal mine is required to pay a charge for the pollution it discharges, then the price of its coal to Eskom should reflect that additional cost regardless of whether Eskom owns all, a part, or none of the mine in question. Eskom would then be expected to pass that price increase on to the consumer as a better reflection of the true price of electricity inclusive of the externalities associated with its production.

Similarly, investments by Eskom, which stimulate local mining development, cannot be held responsible for the externalities associated with that development. Such externalities are the responsibility of government who need to create a regulatory environment (either through command and control systems or market based instruments) which ensures the adequate internalisation of the externalities.

It must be remembered that it is not Eskom's responsibility to internalise the externalities associated with the life cycle costs of a unit of electricity. It is Eskom's job to produce electricity at the lowest possible cost within the prevailing regulatory system, be it a national or an international system. If the degree of that internalisation is inadequate to meet national environmental objectives, or the criteria laid down by overseas governments for the importation of SA's goods, or the emissions targets of global warming agencies, then it is the regulatory system that is at fault and not Eskom.

7.5.6Lessons

The above case study highlights a number of lessons concerning the imposition of pollution charges in a complex multi-polluter system, which though alluded to in the previous sections of this report, were discussed here in terms of the actual situation in the Witbank Dam catchment. These lessons are summarised below for the sake of brevity and understanding:

1. Pollution charge systems must be kept simple and confined exclusively to the act of polluting. No attempt should be made to complicate the system or introduce mitigation measures on behalf of polluters who maintain that their situation is different. In such instances financial relief should be sought through alternate mechanisms. No one other than the polluter can be held responsible for their pollution and thus the pollution charge.

2. The estimation of the impact costs of pollution, assuming a 'no-action' scenario is an unrealistic method of assessing impact costs for pollution charge setting purposes and one which can unfairly prejudice the polluter.

3. If the impact costs of pollution are difficult to estimate or unacceptably imprecise, then abatement costs should be used in those situations where abatement is feasible and viable.

4. Abatement costs should not be used as an estimate of the impact of pollution in situations where the victims have neither the capacity nor the resources to implement abatement measures.

Where both abatement costs and impact costs exist, the lessor of the two should be used for pollution charge calculations provided a significant difference exists between them. However, it is preferable to use abatement costs wherever possible as this encourages adaptation.

8. DESIGN OF A POLLUTION CHARGE SYSTEM

8.1 Objectives of the system

In addition to adhering to the Polluter Pays Principal, any model for implementing pollution charges must be practical and fair. Mindful of this, the following objectives were set for the modelling of a pollution charge system:

1. **Net revenue-generating potential.** In keeping with the Polluter Pays Principal, pollution charges should not impose a cost upon society. Indeed, the charges should alleviate at least all of the costs the society currently incurs for the management of water quality and the control of pollution in the area of application (i.e. defensive expenditure in the Witbank Dam catchment).

2. **Net revenue must be related to the direct impact costs of pollution.** According to the PPP there should be a direct link between revenue generated and direct impact costs. Although it will not always be desirable to directly compensate water users for the costs associated with pollution, it has been demonstrated that it is important for the economy to be adequately reimbursed for the costs imposed by the pollution through indirect means.

3. **Minimised implementation costs.** There is always the risk with self-funding bureaucratic systems that implementation costs will be uncontrolled and that that such costs are met via progressive tariff increases. Three factors will generally help to minimise the implementation costs of a charge systems: a simple design, minimal opportunities for disputes and challenges, and effective deterrents against abusing the system and dishonesty in the provision of information. The latter, (i.e. penalties) are not a part of the model but are discussed later in the report.

4. **Deter polluters from excessive and harmful pollution.** As indicated earlier, it is neither feasible nor economically wise to attempt to eradicate all pollution. However, the charge system must be capable of being used to encourage a gradual reduction of pollution to achieve agreed water quality goals.

5. **Discourage non-point source pollution**. The charge system must possess clear and effective incentives for converting non-point source pollution to point source pollution by means of improved on-site management of waste water and intensified monitoring of the quality and quantity of all point and non-point source discharges.

6. **Charges must be reasonable, justifiable and must not promote economic decline.** It is the purpose of the charges to provide an economic offset, which is proportional to the costs imposed by pollution. It is not the intention of a charge system to affect the viability of industry - except in situations where the external social costs of the industry clearly exceed the economic benefits. Hence, when increasing pollution charges to achieve a significant deterrent effect it must be remembered that polluters may only be able to achieve a portion of the desired reduction demanded and that further reductions may only be possible through the partial or full closure of the industry. This is where the economic optimal level of pollution becomes an issue in determining pollution charges, and where it is important for polluters to have recourse to an independent adjudicator should they feel the charges are unfair or economically harmful (see section 10.3.2).

7. **Flexibility.** The charge system must be flexible enough to take into account all of the above objectives, but still be simple to manage. Possible variations should be taken into account upfront and catered for in the basic structure.

8.2 The design of a generic charge system

8.2.1 Overview

The proposed charge system is a combination of cost covering charges and an incentive system, because both factors are essential. It includes the three main components described in Table 8.1.

Table 8.1: Pollution Charge Components

CHARGE COMPONENT	Type of charge	Applicable to	Determining the charge
ADMINISTRATION CHARGE (AC)	Fixed charge in R/a	All actual and potential polluters, regardless of whether they discharge any effluent.	Charge based on recovering the full cost of administering the system, including monitoring.
WASTE LOAD CHARGE (WLC)	Fixed rate in R/t/month	All effluents when the concentration at a control point exceeds the impact level.	Charge per ton of pollutant load discharged - intended to create an effective deterrent to pollution.
NON COMPLIANCE CHARGE (NCC)	Variable rate in R/t/month, rising arithmetically or exponentially with increasing concentration	All effluents, when the effluent concentration or the concentration at a control point exceeds the Water Quality Management Objective (Co).	Penalty charge per ton of pollutant load, depending on the level of exceedance of Co and the toxicity of the discharge.

The following sections provide an explanation of the different charge components.

8.2.2 Administration Charges (AC)

8.2.2.1 Catchment Administration Charges (AC)

Any system of pollution monitoring, identifying polluters, determining impact costs and collecting discharge information, sending out accounts, receiving payments, and recording data and transactions incurs significant costs. These costs are referred to as administration costs and will be incurred by the institution administering the pollution charge system. According to the National Water Act, Act 36 of 1998 such a charge "may be made by and are payable to the relevant water management institution" (section 57.2). In the interests of consistency and as a result of the policy directions of the DWAF, we will refer to the administering institution as the catchment management authority (CMA).

Administration costs are incurred as a direct result of industry wanting to use surface water systems as a means of disposing of waste, and society requiring that such actions be monitored and controlled. As it is industry, which benefits from this privilege, it is unfair to burden society as a whole with these costs. Such costs must be paid for in full by the polluters in that area and the charge system must relate to the specific characteristics of the relevant catchment. In order to implement a system of pollution charges there must be the equipment, staff and financial capacity to:

- collect sufficient data to monitor levels of pollution from point and/non-point sources;
- purchase, operate and maintain the necessary equipment to carry out these tasks; and
- calculate and administer the collection of charges.

The first two items determine the needs of a water quality monitoring system required to estimate pollution charges. Such monitoring system has four key objectives:

- to monitor whether the charge system is having any impact on water quality;
- to establish whether the pollution loads disclosed on a voluntary basis by the polluters balance with independently monitored data by carrying out spot checks on individual polluters;
- to monitor streams at control points, and
- to monitor the background contribution and loads transferred from other catchments.

The costs associated with meeting these objectives are significant part of the administration costs.

It is generally problematic to develop an administrative charge based entirely on the costs associated with administering a waste load charge system as the same administrative structure is used for general water quality management. In addition, if a number of pollutants are included in the charge system, the calculation of their charges will require use of the same administrative structure, control and compliance monitoring points and information support etc. The estimation of the AC later in this Chapter is an indication of the likely costs and can be used to compare the relative significance of the AC with the WLC and the NCC. In reality, the AC might form part of the charge for the water resource management levy, as defined in section 56.2(a) of the National Water Act, Act No.36 of 1998. In this case it would be estimated according to the National Water Pricing Strategy as a part of the CMA's Water Management Plan.

It is important that the CMA be transparent in the determination of the administrative charge. It would be unfair and unacceptable to burden polluters with the cost of maintaining an inefficient or bloated bureaucracy, or indeed an over diligent pollution monitoring system. The CMA should publish annual accounts showing a breakdown of its running costs and giving a projection of the expected running costs for the next year. Polluters, and the general public, should be afforded the opportunity to challenge such accounts and should be able to refer unresolved objections to an arbitrator or Ombudsperson.

8.2.2.2 Administration Charge (AC) for an individual source

The procedure for calculating the AC for an individual polluter needs to be considered at length. It would be unfair to divide it amongst individual polluters according to their pollution load. This is because the total administrative cost is not proportional to the pollution load and therefore the individual AC should not be proportional to the discharge. The simplest approach is to divide the catchment AC equally between all pollution sources in the catchment. To make it fairer, diffuse sources should pay more, because they generally have more compliance points and more auditing has to be done by the CMA. Another approach is to divide the polluters into certain categories, e.g. small, medium and large and to make the individual AC higher for larger sources. Sources could also be categorised to prioritise basic human needs and to redress the results of past discrimination. In this case sewage works treating effluents for a previously disadvantaged community would pay only a nominal AC.

In a case where a Water Management Plan for a catchment is available and the catchment is divided into Management Units (MU), then it is practicable to split the AC between MUs. The total projected annual running costs for the CMA to administer the charge system (excluding the cost of auditing compliance points) could be estimated for each MU and the cost per MU allocated to polluters upstream of each control point. Individual polluters should also pay an additional fee, which is proportional to the number of their compliance monitoring points that the CMA is required to audit. This way a polluter with several waste discharge points, which has to have a number of compliance monitoring points, would pay a higher AC than a polluter with just one discharge monitoring point.

The list of options is long and international experience indicates that an AC can be either very simple or extremely complex, depending on circumstances and needs. In South Africa the AC will be determined in accordance with the National Water Pricing Strategy, which is in the process of being prepared.

8.2.3 Waste Load Charge (WLC)

8.2.3.1 Introduction

A Waste Load Charge is paid by every polluter located upstream of a control point during the months when the concentrations measured at this control point exceed the impact level (i.e. when pollution reaches the level that causes measurable damage to the water users in this catchment). The charge for an individual polluter is equal to Waste Load Charge Unit (R/ton) multiplied by the load contributed by this individual polluter. The WLC Unit is equal to the total direct impact cost to the users of the catchment divided by the total load contributed by polluters in the catchment. This applies in a simple case when the loads contributed by each polluter are known. The options for calculating WLC in more realistic situations are presented below.

The function of the WLC is two-fold: firstly to recover a portion of the costs associated with the discharge of a pollutant-containing waste; and secondly, to deter polluters from excessive pollution. It is proposed that the maximum revenue obtained from all WLC payments in a catchment should not exceed the direct impact costs (C_{De}) of that pollution on downstream water users. An incentive mechanism should also be built into the charge to encourage polluters to convert as much of their effluent as possible from diffuse source to point source.

8.2.3.2 Connection between effluent concentration and WLC

The water quality point where the WLC becomes payable is debatable, and several options exist.

- One option is to **charge the polluter for the total pollutant load discharged regardless of the effluent concentration**, even if the concentration of that pollutant is so low that it actually improves the quality of the receiving water. The logic behind this approach is that the charge is being levied on the quantity of pollutant discharged in load form, irrespective of whether it is associated with a large quantity of water or a small quantity of water. This option also discourages polluters from attempting to store fresh water on-site for later use in diluting waste to below a specified WLC starting concentration. In terms of the PPP this option enjoys limited support in that the discharge of an effluent which improves the quality of the receiving water is unlikely to exert a cost impact on downstream water users.
- Another option would be **start the WLC at the receiving water's background or pristine concentration of the pollutant**. In this way the WLC would be levied only on waste discharges, which cause a deterioration in the quality of the receiving water. This approach would certainly enjoy the full support of the PPP. However, the practical determination of the background level could pose a problem, and again polluters may adjust the concentration of their waste using fresh water in order to avoid payment.
- A third option would be to **apply the WLC at a point of impact concentration,** (concentration that causes a negative impact on downstream users). The simplifying assumption can be made that the charge would only be payable on effluents of a concentration which exceed the maximum no-impact levels of downstream water users. Again determining what the maximum no-impact level for a pollutant could be problematic and contentious. This approach does not cater for the changing nature of a waste stream over time in large catchments, whereupon evaporation and water quality deterioration/dilution may occur.

In summary, while the PPP theoretically supports the starting of the WLC at either the background concentration or the point of impact, the practical application of the PPP in a user charge system would probably require that the WLC is applicable to all wastes regardless of effluent concentration. This approach is also the only one, which can be implemented for non-measured diffuse sources.

8.2.3.3 Use of Diffuse source differential (Dsd)

A differential in the charge between point and non-point source is suggested as a means for creating an incentive for the more effective control of diffuse sources. This coefficient should be high enough to make it worthwhile for industry to minimise diffuse pollution. The "Diffuse source differential" (Dsd) could be determined from monitoring costs. If diffuse source pollution were measured with acceptable accuracy, by adequate monitoring upstream and downstream of the source, then this source would pay the same charge as an equivalent point source polluter (the Dsd coefficient is equal to 1.0). This measure not only reduces the charge for the polluter, but also helps to separate its contribution from the other diffuse load contributors and to avoid paying for other polluters.

The ultimate purpose of the differential charge is to provide the polluter with an incentive to physically convert the diffuse source into a point source. This could be done by building cut-off trenches around the source and draining them all through one (or a few) measured outlets. A range of technical options exist for controlling non-point source pollution. The advantage of the suggested charge system is that it gives industry an incentive to control their pollution without any limitation on how to achieve this control. It allows them to find the most economic solution, suitable for their specific conditions and circumstances.

8.2.3.4 Use of revenues

Use of the revenue generated by the WLC to directly compensate other water users for the adverse affects of pollution must be minimised. Direct compensation could result in endless litigation over what individual water users might be entitled to. Rather it should be spent indirectly in the catchment for water quality improvement measures such as building new water treatment works or upgrading existing ones, improving sanitation, and tackling those pollution problems where the offending party cannot be located (e.g. abandoned mines). A portion of the WLC revenue may also go towards offsetting the costs of higher level authorities involved in water quality management. This could *be* justified by the fact that the cost impacts of pollution go far beyond the boundary of the catchment in which they first occur. Expenditure on aspects such as water quality policy development, water quality research, and national data storage would all be acceptable in terms of the PPP.

8.2.4 Non Compliance Charge (NCC)

The NCC is a penalty charge that is levied on waste discharges when the concentration at control point exceeds the Water Quality Objective (Co) for the particular pollutant. There are two instances, in which it can be introduced. Either during the later phase of the implementation of a charge system, if the introduction of full WLCs still does not improve water quality to the desired level (phased approach), or if the pollution is already unacceptable and the NCC might replace lengthy prosecution processes (prescriptive approach).

The NCC could be levied on a monthly basis and is justified by the PPP in two ways. Firstly, it can assist in recovering indirect costs, which the WLC can not do. Secondly, discharges that cause pollution in excess of the Co for a catchment or area are assumed to exert a significant and unwanted cost impact on other water users. Thus the purpose of an NCC is both to recover some of the significant indirect costs of pollution and to deter polluters from imposing impacts from their activities on other water users and penalise those that do so.

For these reasons it is proposed that a catchment-specific NCC be levied at variable rates based on the degree to which concentration at control point exceeds the Co, as determined by the CMA or a higher authority. The CMA may decide to make the variable aspect of the rate arithmetic, i.e. the rate increases in equal proportions as the pollutant concentration rises. In situations where the pollutant is highly problematic, an exponential rate increase may be employed.

A decision should be made regarding which sources are levied with the NCC and which are exempt. It would be fair that this charge is only applied to those sources that discharge effluent with a concentration above the target concentration for that area. However, as the effluent concentration is unknown for unmeasured diffuse sources, it is suggested that it be assumed that all these sources discharge at concentrations higher than the target value. This is not ideal since the concentration for some of them might be below Co, but it will provide another incentive to polluters to quantify their contribution.

So, the NCC could be paid by the individual polluters that discharge effluent at concentrations higher than the Co for this area or that do not measure their discharge.

The NCC would only be levied during months when the concentrations at the control point exceed Co. The NCC unit charge (R/ton) is higher than the WLC unit by a factor decided upon by the CMA and may change annually according to circumstances. This factor should be proportional to the level of exceedance at the control point.

Another approach might be to introduce a surcharge on monthly discharge returns that reflect a particularly high pollutant concentration. This would be tantamount to a sliding scale - "the more you pollute the more you pay". The concept has merit for those pollutants, which impose a disproportionately high impact at higher concentrations, i.e. toxic pollutants, and in this context it is often employed in other countries. However, it is unnecessary to apply it to the concentration of less toxic pollutants. For pollutants such as sulphate, it would be better to adopt a sliding scale based on load, or load per unit area of mining operation. In this way those mines which make no attempt to curb pollution would be penalised by a higher than normal tariff. It would also avoid the situation whereby a mine discharges a very small amount of highly concentrated waste water which has very little impact on catchment water quality but incurs a high pollution charge due to a concentration based surcharge.

Revenues from the NCC are difficult to determine because of their variable nature. Furthermore, it is not possible to set the NCC to be equivalent to or less than specific costs impacts, because the NCC might have to be quite high to be an effective deterrent. For this reason, it is proposed that the NCC be a revenue neutral charge, which is placed in a separate fund. This fund could be utilised to provide partial subsidies for selected polluters to help and encourage them to improve the quality and sophistication of their waste treatment systems. The extent of the subsidy award would of course be determined by the availability of funds in the NCC account, which would in turn be determined by the frequency and extent of discharges in excess of the Co. If a CMA were found to be frequently levying NCCs, it would be an indication that there are relatively severe pollution problems in the catchment. Revenues from the charge could therefore provide the financial resources to tackle those problems.

8.3 Calculation of pollution charges for the Witbank Dam catchment

8.3.1 Methodology

A model has been developed to demonstrate how a pollution charge system might function in the Witbank Dam catchment. It is both simple and flexible. It has the potential to become more site specific and thus more complex. However, such a move would depend upon the availability of information and the cost-effectiveness of collecting and using that information. To some extent this is an issue that can only be resolved through application and feedback.

A spreadsheet model was developed to determine the WLC and the NCC charges for the Witbank Dam catchment (see Appendix D). The features of the model are as follows:

1. The model caters for the individual sources that are known to pollute the Witbank Dam catchment and takes into account their pollution loads and ambient concentrations.
2. It caters for both point and non-point source pollution. A facility exists for setting different charges for point source and non-point source pollution.
3. It provides an algorithm for allocating the total diffuse load estimated from monitoring at the control point to known sources. This algorithm is the most

complex part of the model. A few variations for distributing total diffuse load amongst individual mines are suggested and demonstrated in section 8.5.1.

4. It provides an algorithm for calculation of the Dsd.
5. It allows determination of an introductory level of the WLC for the 1st phase of the implementation.

The calculations in the proposed model are based on the concentrations measured at a control point. The relationship between these concentrations and the charge components is presented graphically in Figure 8.1.

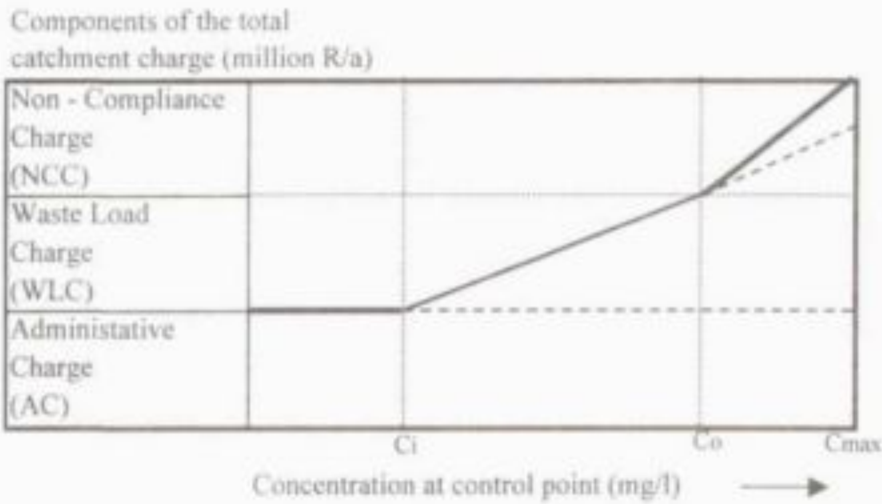

Figure 8.1: Pollution concentrations and charges tested in the Witbank Dam catchment

The vertical axis represents the components of total catchment charge in million R per year. Every pollution source (excluding those that are too small or insignificant to be registered) has to pay the administration charge (AC). This charge should be constant for any pollution condition in the catchment and is therefore depicted as a horizontal line.

The horizontal axis depicts the pollutant concentration at the control point. The three levels (Ci, Co and Cmax) define the boundaries for application of different components of the charge. Ci is the concentration at which pollution starts to affect water users (according to the SA Water Quality Guidelines (DWAF, 1996) this is the upper value of the "No effect range" or "Target range"), Co is the Water Quality Objective for the catchment and Cmax is the maximum allowable concentration. These concentrations are usually determined as a part of the Water Management Plan and based on the user water quality requirements in the catchment. If the catchment is polluted to the degree that the pollutant concentration at the control point exceeds Ci, then in addition to the AC the WLC has to be paid. When the measured concentration is higher than Co then in addition to the AC and WLC the NCC is justified. The charges are only sufficient while concentrations remain below Cmax. Thereafter, the CAC approach should be utilised to halt unacceptable pollution.

Calculation of the AC is the same for both wet and dry hydrological years and is unrelated to pollution loads. Therefore it was not calculated in the model spreadsheet.

The model calculates the different types of pollutant loading from each individual source and the charges payable. The waste load charges are determined on a monthly basis, although some of the factors are calculated on an annual basis only. In the demonstration model the NCC is calculated on an annual basis, although in practice it should be based on the monthly flow-weighted concentrations at a control point and would be payable on a monthly basis.

8.3.2 Calculating an administrative charge

8.3.2.1 Human resource requirements

It is estimated that a relatively small staff contingent will be required to carry out the necessary tasks. It is envisaged that staff members with only part-time obligations to the pollution charges system in the Witbank Dam catchment will be in the full-time employ of the responsible authority. They will spend the remainder of their time on other water quality monitoring or permitting tasks.

There may also be periodic requirements for more staff when the programme is first being set up or if difficulties are encountered. The number of staff should grow or shrink according to the number of polluters and pollutants. There will also be some need for back up services in dealing with legal issues, should they arise and possibly when responding to polluter queries. The minimum human resources requirements envisaged for the study area are presented in Table 8.2. The estimated annual cost of this staff component is R183 000. The calculations for this estimated cost are recorded in Appendix C.

Table 8.2: Minimum staff requirements for monitoring in the Witbank Dam catchment.

Position	Basis	Task	Person days/annum
Water Pollution Control Officer	Full-time	Taking of samples and recording data	260
Principal Water Pollution Control Officer	2 person day per week	Data processing and analysis and liaison with authorities and pollutants	104
Administrator	1.5 person day per week	Data processing and general administration	78

8.3.2.2 Equipment and facilities required

Equipment and facilities will be required to undertake the following tasks:

- Monitoring water quality in Witbank Dam, at the downstream boundary of each Management Unit (MU) and at background stations. This should capture the overall level of pollutant entering and leaving each MU. It is suggested that the monitoring includes measuring continuous flow and EC and regular water quality sampling analysis (twice weekly in winter and once a week in summer).
- Spot checks. The administering authority will undertake random spot checks of polluters in the catchment. This will involve regular sample collection at every compliance point. The data gathered by the authority will be cross-checked with polluter reports and followed up if there are discrepancies.

- Monitoring the levels of pollution being discharged by specific polluters. While each polluter will ideally have its own set of equipment for monitoring its discharge, temporary monitoring points will also be set up by the authority. This will involve the use of a mobile auto sampler, which will monitor the discharges of one polluter at a time. The levels of pollution, which the polluters in that area report to the administering authority, will be cross checked with the data gathered in the same area by the authorities. This equipment will be installed in points where spot checks can identify discrepancies between the levels reported by polluters and those measured by authorities.

In order to carry out these tasks three key pieces of equipment will be required. The equipment is fairly basic and will measure continuously flow, conductivity/salinity and levels of pH. In terms of the information it gathers, it will also be useful in future pollution charge systems concerned with other pollutants.

The existing monitoring system is inadequate for the implementation of a charge system (see details in section 6.3). WMB (1993a) provided the requirements for a legal compliance system, which differs in emphasis to a polluter pays system. For a charge system, which is intended to place the burden of monitoring on the polluter, the proposed legal compliance monitoring system is excessive. However, it is used in part here to demonstrate the cost of monitoring.

As a minimum requirement it is recommended that three weirs be added at MU4 (Bosmanskrans), MU5 (Saaiwater) and MU8 (Upper Olifants) in order for proper flow measurements to be taken. For water quality monitoring the continuous samplers at all 8 control points are sufficient (one for each MU except MU9, which is controlled by Witbank Dam, where weekly samples are taken at the outflow). Two background stations are suggested.

It is expected that due to wear and tear on equipment and the development of more sophisticated systems, instrumentation will have to be replaced periodically. A typical replacement period of around ten years is generally accepted for weirs. It is proposed that this period be reduced to five years for monitoring instruments, because of the general incidence of damage to and loss of this kind of equipment.

Travelling will also be required in order to collect samples and check equipment. An average distance of 50km per site has been estimated. The cost of checking and collecting instruments to be calibrated has been factored into the cost of a service contract for the equipment.

Other equipment such as computers, office furniture and office space is required for the administration of the system. Two personal computers with appropriate software is more than enough for the tasks to be completed, along with a printer and sufficient office space for three staff members. Taking into account the rapid development of computer industry a replacement period of five years is assumed, for converting capital costs into annual capital recovery cost.

8.3.2.3 Total system costs

The main expenses associated with the implementation and operation of a polluter pays system include:

- capital expenditure on monitoring stations;
- capital expenditure on instrumentation;

- operational expenses for data collection and analysis; manpower and associated expenses;
- auditing of information provided by the polluter;
- management, administrative and support expenses associated with the above; and
- office equipment and office space.

Tables 8.3 and 8.4 provide an overview of these expenses estimated at 1997 prices and based on the following assumptions:

- The original 1994 prices utilised in the WMB, 1993a report have been brought up to 1997 using an average inflation rate of 9% per annum.
- Existing infrastructure will be utilised as far as possible.

Some of the capital investments and operational expenses may coincide with expenses that are already incurred or will be incurred for permitting and controlling water quality according to existing regulations and the new National Water Act, Act No. 36 of 1998. It is however not possible to determine to what extent these expenses will coincide at this stage. A conservative view has therefore been taken and all expenses associated with compliance monitoring have been included in this analysis.

Table 8.3: Estimated capital costs of charge system.

Capital costs (R)			
Control points and background stations			
Number of weirs	Cost per weir	Total costs for weirs	
3	R 228 000	R 684 000	
Number of instruments	Cost per instrument	Total costs for instrumentation	
10	R 25 000	R 250 000	
Total costs of control points			**R934 000**
Auto samplers			
Number of auto samplers	Cost per instrument	Total cost for instrumentation	
3	R15 000	R45 000	
Total costs of auto samplers			**R45 000**
Computers & auxiliaries			
Number of computers	Cost per computer	Total costs for computers	
3	R15 000	R45 000	
Total costs of computers & auxiliaries			**R45 000**
Total capital costs			**R1 024 000**

Table 8.4: Estimated operating costs of charge system.

Annual operating costs				
Item	**Units**	**Quantity/annum**	**Rate per unit (R)**	**Total per annum**
Sample analysis	samples	1 528	310	473 680
Travelling	km	78 400	0,51	39 980
Independent annual audit	person hours	100	500	50 000
Calibration of instruments	person days	5	1 940	9 700
Maintenance costs	person days	2	1 940	3 880
Office space	square m	13.2	360	4 750
Total annual operating expenses				**582 000**

8.3.2.4 Catchment administrative charge (AC)

The total annual AC for the catchment is assumed to be equal to the total annual cost of administering the charge system. It is calculated by converting capital costs into an annual capital recovery cost assuming 10% interest and replacement periods as stated above. Then it is added to the cost of staff and operational costs. This calculation results in a value of about R 966 000 for the Witbank Dam catchment.

Table 8.5: Estimated catchment Administrative Charge.

Capital recovery cost	Cost of staff	Operational costs	AC
R201 000	R183 000	R582 000	R966 000

The estimated catchment AC can be translated into a unit charge by dividing by the total load. For 1990/91 the resulting unit charge is R40.0 per ton of sulphate and for 1995/96 it is R11.8 per ton of sulphate. These are relatively low charges even for dry years. These values are used for determining an introductory value for the WLC in section 8.3.3.3.

Calculation of administrative charge for an individual source could not be performed as the methodology for this calculation still has to be negotiated during preparation of the Pricing Strategy.

8.3.3 Calculating a waste load charge (WLC)

8.3.3.1 Introduction

The main assumption of the model was that the total catchment WLC should be equal to the direct impact cost to water users. The methodology for determination of this cost is described in section 7.2.

For the purpose of the WLC calculation a diffuse source is defined as a source with a non-measurable amount of pollution. So, for the WLC account, the sources should be separated into measured and unmeasured sources. The first category includes point sources and the diffuse sources that have comprehensive monitoring system sufficient for accurate estimation of their contribution.

It must be stressed that the concentrations in the discharge do not determine the WLC directly. The combination of discharge characteristics and the hydrology in the catchment determine the concentration at the control point. In the case of the Witbank Dam catchment, the WLC is implemented only when this concentration exceeds that level at which water use is affected and the damage cost to water users can be determined. Hence, the controlled releases scheme (similar to that executed during the wet 1996/97 hydrological year) can still be implemented provided the damage costs are met. If the cost to the users resulting from these releases is zero then the polluters would not pay an additional Waste Load Charge.

8.3.3.2 Allocation of diffuse load to individual sources

The following approach was used for calculating the diffuse (non-measured sources) of pollution for the Witbank Dam catchment:

1. The total catchment sulphate load was calculated from the sulphate concentration and flow measurements at the control point;

2. Point sources and releases for the Management Unit (MU) upstream of the control point were estimated from monitoring data;

3. The contribution of background loads (and water transfer, if necessary) was estimated by using monitoring data at background stations;

4. Total diffuse load for each MU was calculated by subtracting both (3) and (4) from the total load.

The total diffuse load estimated in Chapter 6 was used as input into the model. This calculated Total Diffuse Load (see **TDL** in Appendix D.1) was allocated to known diffuse sources. An algorithm was developed to do this allocation based on the method accepted by polluters and regulatory authorities for sharing the available assimilative capacity during the Controlled Releases Scheme in 1996/97. This method has already been described in section 6.6.3 and the Potential Pollution Mobilisation Rates (see **PPMR** in Appendix D.1) for each type of mine (j) were provided in Table 6.10. Areas of mining operation at each mine (i) of specific type (j) were provided by the DWAF (personal communication, 1997).

The Total Potential Mobilisable Pollution for the whole catchment was calculated from this input data (see **TPMP** in Appendix D.1). The diffuse load from each mine was then calculated by multiplying the potential load by a correction coefficient equal to the ratio between TDL to TPMP as follows:

$$Ld_i = PPMR_j \times A_i \times \frac{TDL}{TPMP}$$

This correction ratio for the Witbank Dam catchment was equal to 2.3, which means that the corrected load was higher by 230% than the diffuse load estimated from PPMR. The reason for this large overestimation is that 1995/96 was an extremely wet year, while the PPMR factors are based on average hydrological conditions. It could also mean that other sources, which were not accounted for in the list of known diffuse sources, may be significant contributors to the total load. If the latter is true it indicates that a more comprehensive register of diffuse sources should be compiled.

Additional methods of allocating the total diffuse load to known non-point sources are discussed in section 8.5.1.

8.3.3.3 Introductory level of WLC

Firstly, the unit WLC (WLC_i, expressed in R per ton of sulphate load discharged by polluters) was calculated as follows:

$$WLC_i = \frac{Total\ catchment\ WLC}{\sum point\ \ source\ \ loads + Dsd \bullet \sum diffuse\ \ loads}$$

Where Dsd is the Diffuse source differential (see explanations in section 8.2.3.3).

The first objective of the charge system was to create a financial incentive to minimise diffuse source pollution through comprehensive compliance monitoring for all diffuse polluters. To achieve this, the total catchment differential in the diffuse pollution charge (WLC_i)· (Dsd-1) · ∑diffuse load) should be equal to or bigger than the cost of such a monitoring system. Many simplifying assumptions regarding monitoring costs had to be made to calculate Dsd (see Appendix D.2). Therefore its calculation is still a rough estimation and has to be improved when more data on monitoring costs becomes available. It was found that in order to create a financial incentive to monitor diffuse pollution Dsd should be equal to at least 2.4 for 1990/91 (which means that non-measured sources would pay almost double compared to point sources) and 1.5 for 1995/96 (see calculations in the Appendix D.2). To simplify the model, the same Dsd value was applied for both years. It was decided that it would be sufficient to use a lower Dsd of 1.5 for the first phase. The reason is that most of the polluters might be motivated to monitor in order to separate their own contribution from the catchment diffuse load to ensure that they do not pay for contributions from other unregistered sources. The determination of the optimal Dsd should be investigated further when more data is collected. The value of Dsd could also be adjusted periodically in the light of the actions taken by polluters to measure diffuse sources.

The waste load unit charge (WLC_i) was calculated from the equation above using the initial Dsd value. For 1990/91 the resulting WLC_i was R268 per ton of sulphate, while for 1995/96 it was R136 per ton of sulphate. This difference is explained by the variation in the hydrology of the two years.

In addition to Dsd, the optimisation coefficient (Oc) for a phased implementation was introduced. The Oc used in the WLC calculation is simply a cost multiplier to reduce charges to optimal values in a particular implementation phase. This coefficient determines the percent recovery of the estimated impact cost through the WLC. The intention is to increase Oc at regular intervals until it reaches a value of 1.0, whereupon the full value of the WLC is applied and full recovery of the direct financial impact cost is achieved .

For the first implementation phase two criteria were used to determine the WLC. The first criterion is that a unit cost of at least R60 per t of sulphate pollution from mine is accepted as a minimum charge (see section 3.3.4). This criterion was chosen to ensure that the objective of economic viability is adhered to. A minimum charge of 60 R/t is based on coal mining in Poland where the economy is also in transition and competition on the global market is more important than national environmental priorities. If this charge is considered too low to be efficient in Poland (REC, 1995) it is probably suitable for determining the lower range of charges in South Africa. However, this conclusion should be reassessed if the mining industry provides sufficient proof that the proposed minimum charge is too high for the local situation.

The second criterion deals with the effectiveness of the system. According to Katko (1992) the fixed part of the charges should cover not more than 20-40% of total, while in order to be effective the rest should be a volume based charge. In the proposed charge system the AC is the fixed part and ranges between 40 R/t for 1990/91 to 12 R/t for 1995/96 with an average of about 26 R/t (see section 8.3.2.4). Then WLC, was calculated assuming that the WLC component must be 60-80% of the total. This results in a range of WLC, between 39 R/t and 104 R/t with an average of R72/t.

The closer to the minimum the WLC is set, the less effective the system will be. Therefore, an average cost of 72 R/t based on the second criterion was chosen as the initial estimate of the unit WLC.

The resulting optimisation coefficients (Oc), which produce initial unit charge are 0.27 for 1990/91 and 0.53 for 1995/96 (see Appendix D.3). This means that if the first year of implementation is dry, the proposed recovery of the impact cost might be only 27%, and if the year is wet, it might be as high as 53%.

Although in our basic demonstration model (see Appendix D) most of the calculations were done on an annual basis, in a real situation the charges should be calculated and levied on a monthly basis. Flows and loads have to be calculated each month from monitoring data. If for smaller point sources only annual data is available, the annual data can be divided into equal monthly amounts.

8.3.4 Calculating a non-compliance charge (NCC)

In most countries the non-compliance charge is based on the concentration or load of a point source discharge, when that discharge is above the allowed level. However, this approach is inappropriate for the Witbank Dam catchment because a significant portion of the pollution is contributed by diffuse sources. Thus a catchment specific NCC has been calculated, which in practice would be set by the CMA. For the purposes of this demonstration model, the NCC was applied when the annual flow-weighted concentration at a control point exceeded an agreed management objective.

Ideally, the catchment NCC should be equal to the full cost of pollution minus the direct cost to users in the catchment, which is already taken care of by the WLC. As was discussed before this ideal is never achieved because it is impossible to determine the full cost of pollution. Therefore a proxy of abatement or treatment costs was chosen instead as the upper limit for the sum of the NCC and WLC charges. The determination of this proxy is based on many assumptions and at this stage is only used for demonstration purposes. The setting of the NCC will in practice be based on a trial and error process. However a starting point is required. This starting point should be low enough to be accepted and high enough to be a deterrent. As the NCC unit charge should be higher than the WLC unit charge (see Figure 8.1) it could be very high. Therefore, negotiation with I&APs, economic and political judgement are essential before its implementation.

As the main objective for implementation of the NCC is penalising polluters for exceeding a given limit, the NCC should be related to the degree of exceedance. The proposed exceedance factor for a particular control point *j* is expressed as follows:

$$Fex_j = 1 + \frac{C_j - Ct_j}{Ct_j}$$

Where:

- Fex_j is factor of exceedance;
- C_j is the measured flow-weighted sulphate concentration in control point j; and
- Ct_j is accepted water quality objective for sulphate concentration at control point j.

It is suggested that the non-compliance unit charge is calculated by multiplying WLC_i (in R/t) by Fex_j. If, for a given management unit, there is no exceedance of the management water quality objective, no sources in that MU should pay any NCC for that month.

To demonstrate the calculation of the NCC only two MUs were considered – MU1 upstream of B1H021 and the MU2 for the rest of the catchment (to B1R001). The resulting calculations appear in the Appendix D.4.

It was verified (see Appendix D.5) that for the case study the sum of the NCC_i and the WLC_i is lower than the minimum treatment cost (used as a proxy of full cost, which was calculated for non-point sources in section 7.3.3 and is equal to R3585/t). This confirms that the charge system is more favourable for polluters than CAC regulation, which demands treatment of all pollution above the management objective. However, this verification is based on very limited data and the NCC should be debated before being introduced.

8.3.5 Discussion of the results

In this section the results of applying the model for the case study are discussed. These results have limited value as absolute figures and should be considered only for demonstrating the model capability and for comparing different hydrological conditions. They should not be used to compare the costs and charges for individual mines, as there are many inaccuracies regarding data for specific sources. For example, there was no data at all for Kleinkopje mine for 1990/91, which had the largest release for 1995/96. This omission could distort the calculation of charges for other mines. The charges as calculated by the model are summarised in Table 8.6.

Table 8.6: Catchment charges calculated by model

Charge components (million R/a)	1990/91	1995/96
ACC	0.97	0.97
WLC	7.72	15.44
WLC(phase 1)	2.08	8.18
NCC	7.02	18.53
Total charge	**15.71**	**34.94**
Total charge(phase1)	**3.05**	**9.15**

The limitations of the data used are noted and further studies are listed in Chapters 10 and 12. The timing for additional studies is specified, with a clear distinction between those that should be completed before the charge system can be implemented, and others that can be carried out as part of the implementation phases.

8.3.5.1 Estimated AC

The calculation of the capital costs for the upgrading of the monitoring system is based on what the study team extracted from the available reports. The price of weirs should be estimated taking into account site specific conditions. Also the price of equipment may change. More comprehensive planning of the monitoring network is required before finalising the AC calculation. As most of the compliance monitoring in a pollution charge system is carried out by polluters, the final decision on the choice of stations should be made after consultation with polluters.

The options for dividing the total catchment AC between individual polluters should be discussed and the most acceptable option should be agreed upon by the CMA and the polluters.

8.3.5.2 Estimated WLC

As was established in Chapter 6 much of sulphate pollution is contributed by diffuse sources. However, the calculation of total diffuse load was inaccurate because of limitations in the monitoring data. Continuous data is the best for the accurate estimation of loads. The use of weekly grab samples in river stations, compared to daily sampling can overestimate loads by up to 85% (see section 6.3). Unfortunately, no daily or continuous data was available for control points for the case study.

As the establishment of an adequate monitoring system can take about a year, it is suggested that a simplified approach is used for the 1 phase of implementation. It is believed that total catchment diffuse load can be calculated with sufficient accuracy from the reservoir balance for Witbank Dam. This is a large reservoir and therefore weekly grab samples at the B1R001 station are representative of the variation in water quality. The main shortcoming of this approach is that it makes allocation of total load to individual sources less accurate, as it lumps the whole catchment together. When continuous monitoring is established at each control point the contribution of individual diffuse sources can be calculated from the load estimated for each MU.

Even for regular point sources, the available data was insufficient. In this project the calculations were based on rough estimates for 1995/96 (see section 6.6.1), which is probably unacceptable for a charge system. Agreement needs to be reached between the CMA and the polluters on whether the sulphate discharges from point sources have to be measured more accurately before the charge system can be implemented. It is presumably in the interests of polluters to do this themselves to avoid excessive charges and penalties.

The WLC is assumed to approximate the direct cost of pollution to water users, which was estimated in Chapter 7. The cost of pollution to coal mines and to Eskom has to be re-assessed before system implementation. It was stressed in section 6.5.2 that the data on water use by mines looks questionable and better data has to be collected. All of the costs should be discussed with I&APs and modified if necessary.

8.3.5.3 Estimated NCC

The NCC calculated by the model is quite high and should not be introduced in the first phase of implementation. Before introducing the NCC it should be checked that the total charge (i.e. AC+WLC+NCC) does not exceed the direct costs associated with the optimal level of pollution. The optimal point is the point at which the marginal costs of pollution equals the marginal benefits. The direct economic benefits of pollution might be the profits, wages and taxes associated with each of the polluters. The indirect benefits include the multiplier effects of coal mining in the area. As neither direct nor indirect benefits are calculable without the close co-operation of the mines, the marginal benefit cannot be determined. Ensuring that the total charge does not exceed the total cost requires this cost to be less than the total benefits of coal mining in the area. Verification of this is important because if the total costs were to exceed the total benefits then the mining economy of the area would eventually decline. This potential conflict between development and environmental needs is unlikely to happen. As charges increase and start to erode the benefits (i.e. profits) of mining, the mining companies will take corrective measures to restore margins. These measures will probably include pollution reduction actions. It must be noted that the overriding purpose of the charge is to control pollution, not mining or any other industrial activity.

In an attempt to overcome the problem between developmental and environmental needs, Germany (OECD, 1989) introduced a hardship clause. This provided the possibility of exemption if considerable adverse economic effects are expected and helps to lessen industries resistance to the charge system. However, this approach should not be adopted as it flies in the face of the PPP by destroying the economic linkage between commodity benefits and pollution costs. In essence it undermines the free market principle and opens the way to corrupt practices.

8.4 Limitations of the proposed charge system

1. Several requirements for the implementation of the above system could be seen as limitations. These include:
   - A significant quantity of data is required including: background pollution, the point at which the impact of pollution is noticeable, the point at which management objectives are met and the maximum acceptable level of pollution. Collecting this information requires the completion of a catchment study with a resulting water quality management plan. This is however true of almost every system of pollution control.
   - The compliance monitoring by polluters must be set up as a part of the catchment management plan. The results of compliance monitoring are absolutely essential for the functioning of the charge system. Although compliance monitoring has not yet been executed extensively under the existing CAC system, its results will be of assistance for water control, environmental and other organisations.
   - Information on the costs of impacts is specific to the application of pollution charges. A few comprehensive projects aimed at estimating the costs of salinisation were utilised in this study. However, this information has not yet been obtained for other pollutants.
   - An iterative trial and error process is required over time to find the correct level of charges. Although this means that the optimal solution will be not be reached immediately, the advantage of this approach is that it may prevent costly mistakes and make the introduction of a new system more politically acceptable and democratic. To a significant extent, this process also mitigates the impact of the first two limitations in the long term.

On the whole, the establishment of a pollution charges system does require extensive ground work, however what is required is not necessarily much greater than that required for other systems.

2. The proposed generic approach to pollution charges tested in the Witbank Dam catchment, does not address the conversion of pollution from one media into another and deals with surface water only. In order to make this system more holistic and to cover both air and soil it should cover another two processes:

    - Modification of atmospheric deposition through air pollution, such as acid rain. This impact is similar to that of diffuse source pollution and could be significant for sulphate pollution (see the preliminary estimation in section 6.7.2).
    - Aquifer recharge using waste or water containing waste. This process was not considered as no information on intentional aquifer recharge was available to the study team.

    The above two processes have already been declared to be "Controlled activities" by the National Water Act, No. 36 of 1998 (see section 37.1) and will require additional regulations. When these regulations are introduced they should be dovetailed with the charge system.

    In the Witbank Dam catchment case study, the potential contribution of air pollution is included as a part of the background load. Further research is required to account for this contribution. The potential pollution of ground water as a result of mining activities also has to be considered. This should also include the possible impact on surface water from the decanting of polluted water.

3. There is no control over the revenue collected through application of the WLC and NCC. These charges are functions of not only the amount of pollution discharged (which is a characteristic of the pollution sources and controlled by the polluters), but also of the hydrological conditions (that can not be predicted). Therefore, the planning of revenue disbursement should be flexible enough to accommodate this limitation. Hydrological and water quality modelling will become an important tool in financial planning.

8.5 Other possible approaches to calculating the charges for the study area

8.5.1 Other options for determining non-point source pollution charges

8.5.1.1 Coal production levy on coal mines

This involves a charge being levied on each ton of coal produced from a coal mine. It is assumed that non-point source pollution is proportional to coal production and that mining methods and the pollution content of the coal is constant for each mine. While this method is far from accurate, it is easy to levy and as such is widely used overseas.

8.5.1.2 Mine production ratio estimates

The above method was slightly improved upon in the allocation of diffuse loads for the Water Management Plan developed for the Lower Vet River (see DWAF, 1997, vol.6, p.11-12). The revised method allocates the total diffuse load to individual sources according to the sum of the two following ratios:

- the ratio of current production by a mine to the current production of all mines in the catchment; and

- the ratio of a mine's total production over the whole life of the mine to the total production of all mines in the catchment.

This methodology, particularly the second ratio is especially useful for calculations involving gold mines with seepage from large surface dumps.

8.5.1.3 Improving calculations based on potential pollutant mobilisation rates

One option is to use the potential pollutant mobilisation rates for distributing diffuse loads among the polluters in an area. Two variations can be considered in making potential mobilisation rates either site specific or operation specific. These are considered in the context of open-cast coal mines.

An unambiguous method of deriving a more accurate potential mobilisation rate for individual mines is to use the sulphate concentration of the coal that is mined. Each mine is usually contractually required to determine the sulphate concentration for each shipment of coal, generally done by an independent laboratory at the expense of the mine. If we assume that the sulphate concentration of the coal is roughly proportional to the potential sulphate pollution from the mine then the mine could be required to furnish the charge system managers with regular production weighted potential sulphate mobilisation rates. Thus, those mines extracting sulphate rich coal will incur a greater non-point source pollution charge per unit of area. This approach can also be used as an incentive not to mine high sulphate content coal. It is generally considered to be the preferred option for the levying of non-point source pollution charges overseas.

Unfortunately, no information on coal sulphate concentrations for the mines in the study area could be obtained, so this method could not be tested.

Another way of making the PPMR more site specific is to take into account rainfall variation. The higher the rainfall the higher the mobilisation rate. As average mobilisation rates represent average climatic conditions, these are proportional to the Mean Annual Precipitation (MAP) in the area. An attempt was made to recalculate diffuse loads for each mine using site specific rainfall during the study period by using

$$Ld(cor)_i = Ld_i \times \frac{R_i}{MAP}$$

the following formula:

Where: *$Ld(cor)_i$ is the corrected diffuse load for mine i*

Ld_i is the diffuse load for mine i estimated using the average mobilisation rate

Ri is the rainfall measured in the vicinity of mine i

MAP is the Mean Annual Precipitation in the study area

The corrected loads varied from +4.3% to -16.6% (see Appendix D.6). The problem with this algorithm is that during dry months the calculated loads are equal to zero, while in reality the diffuse source contribution is greater than zero, even in winter.

To make PPMR a more site specific it could be adjusted according to other mine characteristics, such as a presence of a washing plant that might increase diffuse pollution as a result of the increased polluted storm-water.

8.5.1.4 Use of monthly mining areas

Another parameter, which is extremely important in charge calculations, is the mined area. Mines are dynamic operations, which change in size and type on a continuous basis. As the model uses the area of specific operations as a basis for calculating the charge it would be in the mine's interests to ensure that any changes in the extent of operations are reflected in the model. It is therefore possible for the model to be modified to include monthly areas of each mining operation at each mine. When a mined area is fully rehabilitated and no longer contributes any more to the diffuse load, it should be excluded from the charge calculations. This could provide a useful incentive for a mine to properly rehabilitate mined areas as soon as possible so that they no longer constitute a pollution threat.

8.5.2 Incorporation of sulphate concentration into the pollution charge system

During the course of this study it was suggested that sulphate concentration be incorporated into the pollution charge system. This is an understandable comment for several reasons. Firstly, it is pollutant concentration and not load, which imposes damage costs on other water users. Secondly, the prevailing water quality management plan for the Upper Olifants catchment uses a predetermined sulphate concentration for Witbank Dam as its objective and on this basis has permitted scheduled discharges of sulphate rich mine effluent at times when the dilution potential of the catchment has been high. Thirdly, it can be argued that if a mine has invested in sound water quality management and has subsequently accumulated a volume of reasonable quality waste water capable of being discharged without being adversely affecting downstream consumers, then why should that mine be further penalised by having to pay a pollution charge on the discharge of such water? In the event of a mine imposing a benefit and not a cost on society shouldn't the charge system reward or credit such behaviour?

The simple response to these arguments is that yes, concentration can be incorporated into the charge system. However, the practical aspects of such a move and the associated costs and benefits should first be determined. It is also the type of modification that could be considered once a pollution system is installed and under evaluation. At the policy investigation stage it is sufficient to note the consequences and problems associated with the incorporation of pollutant concentration into a load-based pollution charge system. These are described below.

Pollution charge systems in place around the world are predominantly load based. This is the simplest and least controversial type of pollution charge. The charge is levied on the dry weight of the pollutant being discharged into rivers and streams. The presence of water is incidental and has absolutely nothing to do with the charge other than in the calculation of the pollutant load. The purpose of the charge is to compensate society for the impact of the pollution and to deter the contribution of the pollutant to the surface drainage system - regardless of how much, or how little, water is associated with the pollutant. There are two further points to note in this argument. Firstly, the water associated with a particular load of pollution is non-conservative, i.e. it is prone to evaporation and to extractive use and subsequent discharge of a lesser volume. Secondly, the fate of any particular load of pollution is not discrete, rather it contributes to the larger pool of pollution and must assume proportional responsibility for any damage costs associated with that pollution. Hence each unit of pollution shares proportionally in the economic costs associated with the pollution regardless of how much water was associated with the pollutant discharge. The polluter discharging a low concentration has no control over the fate of his pollution load nor can he make any guarantees regarding the permanence of the water associated with it. Consequently, in any pollution charge system, which is based exclusively on load, it is important to completely divorce the pollutant from the water, which transports it.

A simple analogy is traffic accidents caused by bad driving. The pollutant in this case is the bad driver, the damage cost is the traffic accident caused by the bad driving, and the water is the car the bad driver is driving. By introducing concentration into the charge system we are essentially diluting the blame that should be placed solely on the driver by sharing the blame with the vehicle. The faster the vehicle (i.e. the greater its capacity) the more blame it assumes for the traffic accident caused by the bad driving. Such a move would be good for bad drivers (i.e. polluters) but ultimately bad for society.

Despite this argument it has to be acknowledged that the discharge of water containing only a small concentration of pollutant, i.e. dilution water, can have a beneficial impact on the pollution status, and hence the pollution impact status, of a water regime. In keeping with the Polluter Pays Principles it would be incumbent upon the pollution charge system managers not to charge for the discharge of water which had a dilution effect. In anticipation of such a situation arising, it is useful to examine how the managers might respond.

Firstly, it is important to note that the proposed pollution charge system is a monthly one and that any discrete discharge of dilution water would have to be integrated into the total monthly discharge of waste water from a mine. However, let us assume that a mine's total monthly discharge of waste water has a beneficial dilution effect on a river system. The easiest form of incorporation would be to calculate the pollutant load needed to bring the waste water to a concentration where its dilution potential is zero. This 'negative' load could then be subtracted from the polluters discharge returns in subsequent months in much the same way as a tax rebate works. One of the loopholes of such a system is the purchase of dilution water from a non-polluter by the mine or the abstraction and discharge of fresh groundwater for the purpose of dilution. Neither action could be permitted to occur in a water scarce country ,such as South Africa, and mechanisms would have to be developed to prevent polluters from taking such steps. As indicated previously, all actions aimed at monitoring polluters has a cost associated with it and this cost would have to be compared with the potential benefits of introducing a load rebate system.

Another approach might be to start levying pollution charges at a predetermined concentration only. Apart from the impact this would have on essential revenues required to manage the pollution charge system, it would tend to encourage extensive 'boundary manipulation' by polluters; i.e. the manipulation of the timing and concentration of waste water discharges and associated monitoring records so as to minimise charge payments. The costs to the system managers of trying to check on the correctness and acceptability of such manipulation could be considerable. Consequently, this approach should be avoided at all cost.

9. FATE OF REVENUES

9.1 Overview

Fiscal instruments used for environmental management have considerable potential for generating revenue by charging for activities that are harmful to society and the environment and for the injudicious use of natural assets. In addition, the process of levying charges often stimulates a positive change in the behaviour of manufacturers and consumers regarding environmentally unsound practices and purchases. In order to redress economic distortions arising from polluting activities, it is essential that the revenues derived from charges be properly employed.

A well designed system of charges and dispersals can also help to reduce the inefficiencies arising from other forms of taxation. It is generally accepted by economists, that taxes result in distortions and inefficiencies in resource allocations because they impose the priorities of government on the system rather than the priorities of the market. However, it is accepted that to meet certain collective and individual social needs, taxes are important. A pollution charge, however is not the same as a tax. This is because the charge system forces companies to internalise costs, which they are imposing on society. The system does not impose a cost on one party resulting from the activity of another, which is what taxes generally do. Pollution charges can, in fact, help to reduce the reliance on distorting taxes, if introduced on a large enough scale.

There are some general criteria that should be utilised when deciding how revenues should be used. While ideally these criteria should be adhered to as closely as possible, it is still likely that day-to-day decisions will be somewhat subjective, and will probably be based upon whichever need or interest group is perceived as being most important at the time. This is in essence an institutional issue, as the outcome depends heavily on who has the final authority to decide on the fate of revenues. Institutional issues are examined in more detail in Chapter 10.

9.2 General criteria

The general criteria for disbursing revenues from pollution charges, should be adhered to the PPP. The philosophy behind this principle is that polluters should pay for the true cost of their production processes. Shortfalls in this payment are made up in the form of charges. In accordance with the PPP, the spending of any revenue arising from the collection of charges should be linked to reducing either the costs or impacts of pollution. In fact it is critical to the success of the incentive mechanisms in a charge system that this link is visibly maintained. Other criteria include the following:

- Charge revenues should be used to cover the administrative costs of establishing and operating the pollution charges system.
- Where a direct and unambiguous causal link can be established between pollution and a negative impact on individuals, priority should go to that individual's compensation. However this is very unusual and unlikely to happen. More often the impacts of pollution are more indirect and it is more appropriate to compensate the economy which has been negatively affected by bringing about a proportional improvement in the quality of the national resource base (i.e. water quality).
- Whatever fate is decided upon for revenues, their use should result in a positive environmental and social impact. It would be counter-productive for charges to be

levied as an incentive to reduce pollution only to be spent on activities that somehow encouraged environmental degradation, or the poor management of natural resources. An example of such a situation may be the installation of waterborne toilets in an area where there are scarce water resources, or even the installation of pit latrine systems, where the geohydrology of the area is unsuitable and as a result ground water is contaminated.

- Revenues should be disposed of in such a way that the maximum benefit is derived. Double or treble dividends are an attractive result of certain uses of revenues. An example of a where a treble benefit is derived is when revenues are spent on water quality enhancing measures, which also have a welfare benefit (e.g. sanitation). In this case there is the benefit of a cleaner water source for users, better sanitation for nearby communities and a reduction of demand on the fiscus to provide such services.
- If revenues are to be partially spent on subsidies, they must be well designed so as to reach the intended target group and to avoid causing further market distortions or inefficiencies. A good subsidy is well targeted and always applied to capital costs, never operational costs. In accordance with this principle, it makes sense that revenues from water pollution charges are spent on activities with a positive water quality impact, within the same river system in which the revenue was raised.

In some countries, a portion of revenues is also invested in relevant national and regional research and the development of water quality management technologies, strategies and policies. The split of revenues between national and local uses can be flexible and changed according to needs. In order to avoid haphazard decisions, long term planning based on national strategic priorities is required in the water sector. Pollution charges could conceivably be used for this and still comply with the PPP.

9.3 Options

9.3.1 Overview

There is a range of ways that revenue from pollution charges can be spent. One of the first priorities is the implementation of the system for pollution monitoring and control, and the administration of the charge system. This practice is widely accepted in pollution charge systems in other countries. After paying for the establishment and operation of the system, revenues could be spent to mitigate against negative environmental impacts, to implement measures to improve water quality management or to fund research and development and national water quality policy development. Excess revenue could be spent on subsidies to a number of groups, from companies needing to invest in new pollution control technologies to under-serviced communities to provide for environmentally sound sanitation. The clean up of past pollution can also be subsidised from this revenue.

9.3.2 Returning revenues to the general fiscus

Revenues from pollution charges can be treated like revenues from other taxes and returned to the general fiscus. However, doing so means it is highly unlikely that the revenues will be used in relation to polluting activities anywhere, let alone in the area where the impacts of the pollution are felt. This is in direct contravention of one of the key premises of the Polluter Pays Principle, which requires that there be a link between the spending and levying of charges. The PPP states that firms must know that they are paying for the costs of their actions, and their actions only. If they are paying for the actions of others in the economy, then they are likely to treat charges like other taxes and optimise investment, expenditure and output accordingly. This option also decreases the likelihood of victim of pollution impacts receiving indirect benefits from the charge system.

If a pollution charge were to be administered in the same way as a tax, it would also be problematic since in practice, taxes are difficult to increase. There are generally long processes of negotiation involved in making changes to the levels and structures of taxes, referred to as fiscal drag. To be effective, pollution charges need to keep pace with inflation and with the amount of pollution. This will be near impossible if changes to the system are slow and if they are costly. Such rigidity is also incompatible with an implementation process which supports gradual increases in charges. This phased process of implementation is followed in many other countries and is proposed for implementation in the Witbank Dam catchment. Such a process would be seriously hampered if pollution charges were treated in the same manner as normal taxes.

The fact that the administration of this option is problematic and that it contravenes the transparency requirement of the PPP, have meant that this option has been unpopular in other countries, and has thus been rejected by the working group preparing the new South African water laws.

9.3.3 *Funding the water management control and monitoring system*

The establishment of a system to manage the control, monitoring and treatment of pollution is an important use of charge revenues. There is a need for an institution to administer a charge system and to ensure that levels of pollution are monitored and charged for accordingly. It makes sense for the costs of this administration to be funded out of the charge revenues. If polluting firms know that the charges they pay fund this administration, they are likely to ensure that it is as transparent and accountable as possible. It must always be very clear that the reduction of pollution and mitigation of impacts, rather than the institution itself, is the reason for the charges. A number of features may encourage this:

- The revenue used for system administration should not be a set portion of the total charges collected. It should rather be a fixed amount, to limit the temptation of increasing charges in order to expand administrative capacity unnecessarily.
- The idea that the charge administering institution exists to ensure pollution reduction must permeate its culture and decision making, so as to avoid empire building and the institution existing for its own sake. Regular audits of pollution control improvements, with public scrutiny of the results, would go a long way towards engendering such a culture. The use of revenues must be transparent and should be open for examination by any interested or affected party.

Secure funding provides the opportunity for institutions to resource themselves adequately for the tasks of measurement, monitoring and charging. This is particularly important in South Africa, where many existing local structures are weak and there is a deficit of skills in the public sector.

9.3.4 *Financial compensation for negative impacts of pollution*

In some countries, revenues from pollution charges have been used to compensate the individual victims of pollution. This is the case in Japan (Tietenberg, 1990), where a national compensation program has been established to provide reparation to sufferers of ill health, as a result of air pollution. However such systems require an extremely well-resourced administrative structure to deal with individual applications and disbursements. South Africa does not presently have substantial resources available for such a system.

In order for compensation to be rightfully given, causality between the impact on the affected population and a source, or a number of sources, of pollution must be established. The beneficiaries from charge revenues will not always be in close proximity to the pollution source and the negative impacts from pollution are often difficult to link to a local area alone. Acid rain, for example, does not necessarily fall locally and may be difficult to trace and measure if it falls across large areas. It is possible that emissions from power stations in Mpumalanga might affect the water quality in Lesotho. In such instances, it is not easy to argue that revenues should be used to compensate specific individuals locally. The nature of most pollution is such that its economic impacts are rarely confined by political or hydrological boundaries. This is particularly true in South Africa, where an extensive network of inter-basin transfer schemes transports water across catchment boundaries and major rivers flow across national boundaries.

In addition, instituting a system of direct compensation would, in all likelihood, halt the disbursement of pollution charge revenues, whilst endless and expensive litigation on the correct amounts of compensation is undertaken. It is conceivable that under a system of direct compensation the pollution charge revenue coffers could experience liquidity problems in a similar way to that of SA's third party road fund.

A further consideration is that rewarding victims of pollution for reduced productivity via direct compensation mechanisms, is an incentive for them make inefficient use of resources and to entrench low productivity systems. Whereas by receiving compensation via indirect systems, they will be encouraged to adapt to poorer water quality. By encouraging the victims of pollution to implement adaptation measures, their resilience to changes in water quality will be increased and their overall use of water may even be reduced.

Considering the problematic nature of direct compensation in the South African context, the pollution charge system should not make provision for the direct compensation of victims of pollution. The only compensation that should occur should be of an indirect nature to the water quality economy to mitigate against negative environmental impacts.

The indirect compensation can be in the form of subsidies for new water treatment plants, better drainage on irrigated lands, sanitation, improved water quality research and water user education etc. For example, water treatment from the polluted Witbank Dam could be subsidised to reduce the impact of mine pollution on the water users. Some of the above-mentioned options have been further examined in the following sections.

9.3.5 Financing research and policy development

Ongoing research and subsequent policy development is a cornerstone of any new policy initiative. If the goals of equity, efficiency and maximising benefit are to be achieved in a pollution charge system then research and review procedures will have to be instituted.

It is therefore legitimate, appropriate and in keeping with the polluter pays principles for this activity to be financed from charge revenues. Such tasks are best outsourced to avoid stimulating unnecessary public sector growth. Outsourcing will also enable a flexible approach to funding, which will be necessary as the quantity and nature of research needed is expected to change over time and from place to place.

Only a small part of the revenues should be diverted to national use. The local research needed for a phased implementation of the system has first priority. Then the revenues could be used for research of the technical options for mitigation of the environmental impacts. It is possible to use the financing of research as an indirect subsidy, by funding the research conducted by the polluting firm. However, this should only be done on condition that the results of the research will help to reduce pollution not only from this specific firm, but for the whole industry sector. This approach was successfully applied in Malaysia (see section 3.2.8).

9.3.6 Financing environmentally benign projects

9.3.6.1 Overview

It is possible for a fiscal instrument to at least double its environmental benefit and at the same time to relieve the government of some of the financial burden of welfare projects. This is the so-called 'double dividend' feature of fiscal instruments used for environmental management and it may be achieved by spending revenues on projects with clear social and /or environmental benefits.

It is important that the return from such projects is maximised and that any negative impacts are environmentally benign. With this type of option, the issue of beneficiary boundaries is also very important. With other options, the beneficiaries are more easily defined, i.e. for technology subsidies it is the companies or consumers using the polluting technology and for compensation it is the victims of pollution impacts. With this system the beneficiaries are likely to vary according to who makes the decision and to whom the decision-maker is accountable.

9.3.6.2 The case for financing basic services

Water services which, include both water supply and sanitation facilities, are critical to improving health and contributing to the alleviation of poverty. Adequate water supply is necessary for human survival and a combination of good water supply and sanitation is a key to reducing the incidence of water-borne diseases and other health risks. The health, productivity, employment and capacity of a society can be greatly improved by effective investment in water supply and sanitation because the costs of poor health are high. Ill health robs people of the ability to generate a livelihood for themselves and their families. It costs society both now and in the future because it affects the productivity of the workforce and the learning capacity of the young. It also costs the State, in that it increases the demand on community health care and social welfare services.

Effective sanitation systems can be installed at a relatively low cost, particularly if communities contribute their labour free of charge. A well installed, Ventilated Improved Pit Latrine is the official choice of the DWAF, for appropriate geohydrological conditions. A current sanitation subsidy of R600 per household is available, which is intended to be a contribution to a system, not to cover the full costs (DWAF, 1996d). Even with the subsidy and community contributed labour there will still be areas where systems are unaffordable to communities.

A sanitation subsidy from pollution charges revenue is an option for reducing overall pollution trends in a catchment affected by industrial pollution sources. It could help to improve the quality of water sources and be targeted towards disadvantaged communities. It would have a treble dividend in that it would encourage a reduction in industrial pollution, reduce the polluting impact of community effluent and decrease the service provision burden on government. Such a subsidy is in keeping with the Government's equity objectives in that the more wealthy firms, some of whom have prospered under the Apartheid system, will be contributing to upgrade the community.

9.3.6.3 Deciding who will benefit from subsidised basic services

If it is decided that basic sanitation services are to be financed from pollution charge revenues, consideration needs to be given to establishing priorities and criteria for where the revenue is to be spent. Both the criteria and priorities should be developed with the involvement of local stakeholders, prior to the implementation of the system.

Efforts should be made to ensure that the priorities and criteria are consistent with the development priorities of the area. This will involve consultation with local government structures. Where they exist, Land Development Objectives (LDOs), developed in accordance with the requirements of the Development Facilitation Act, should act as a guide.

The localities and boundaries for beneficiaries also need to be discussed and decided on as part of this process. There may be cases where the communities in the catchment where charges are collected, are well-served and have their needs met in terms of the stated priorities. In this instance, it may be appropriate for projects to be funded which benefit communities in another catchment, with unmet needs. The possibility of such scenarios would need to be clearly communicated to all interested parties. This should avoid possible concerns that anyone was misled about who the beneficiaries of revenues were to be.

9.3.7 Subsidising the use of pollution control or reduced emissions technology

Subsidies are a useful mechanism for softening the impact of the 'moving the goal posts' syndrome. 'Moving of the goal posts' occurs when policy changes are introduced, which have a significant effect on companies that are only part-way through the life of a major investment. The introduction of environmental charges or regulations is a classic example of this. In such situations, companies may have set up their operations in complete accordance with the regulations, at the time. Then years later, when new pollution standards are introduced, they are forced to substantially change their operations with unplanned upgrades. Partial subsidies for the capital equipment required to meet new regulations can be an effective way to reduce the impact of these types of policy changes on existing companies. At the same time, such subsidies should not unduly discriminate against new companies entering the area, which may have to pay higher set up costs for low pollution technology than the existing subsidized companies.

There are several examples from other countries where revenues have been used to subsidize pollution control technology. In France, revenues from charges were used as an inducement for the early adoption of pollution control technology, and the purchase of the necessary equipment. In this case, it could be argued that victims affected by pollution should have had priority over the firms that pollute. However, it is likely to depend on whether compensation for victims or the rapid uptake of technology is the more immediate priority. Both needs can be met by such a system if the early uptake of technology is subsidized for a set period of time and after that revenues are used for either compensation or some other use.

An important lesson about subsidies comes from Sweden, where revenues from charges were used to subsidize the use of low pollution technology by consumers (Titenberg, 1990). In this instance, consumers purchasing cars with catalytic converters benefited from a tax break. Cars without catalytic converters were taxed, while new cars with them were not. In this case, the incentive to buy cars with catalytic converters proved to be so strong, that the demand for subsidies overtook the revenue generated from the charges. As a result, the government had to step in to finance the difference between the subsidy and the revenue. All subsidies distort markets, which is why they must be handled with care. The case of Sweden shows the damage, that can result from poorly designed subsidies.

Had this occurred in South Africa, it would have been highly problematic, given the already stretched national budget and a macro-economic policy of restrained government expenditure. Bearing in mind the experiences of other countries, subsidies in South Africa should have a limited use of charge revenues and should be designed according to conservative estimations of demand.

9.3.8 Revenues from NCC

The revenues acquired by levying a non-compliance charge (NCC) should be dealt with separately. Since the NCC is planned as a penalty to deter exceedance of water quality objectives, it cannot be planned for. Revenues from the NCC are also difficult to determine because of their variable nature and the fact that the NCC might have to be quite high to be an effective deterrent. Thus it is not possible to set the total revenues from NCCs equivalent to or less than specific cost impacts. For this reason it is proposed that the NCC be a revenue neutral charge which is placed in a separate fund from which partial subsidies are given to worthy polluters to help and encourage them to improve the quality and sophistication of their waste treatment systems. The extent of the subsidy award would of course be determined by the availability of funds in the NCC account. Thus a catchment where NCCs are frequently levied presumably has some pollution problems that need to be addressed. Revenues from this charge can provide some of the financial resources needed to tackle these problems.

9.4 Conclusion

It appears that a combination of uses is the most appropriate way to spend charge revenue and is likely to yield the highest overall dividends. Table 9.1 provides a summary in order of various options aimed at upholding the polluter pays principle and the pre-conditions under which they are most effective.

An investigation of the use of revenues for funding the treatment of past pollution was outside of the original scope of this study. However, it was found to be an important need, particularly in the study area. Further investigation of the matter is recommended.

Table 9.1: Overview of options for spending revenues from pollution charges.

Options for spending revenues	Suitability	Necessary pre-conditions
1. Water management control and monitoring	• It is essential that part of the revenues is used to operate and maintain water management control and monitoring capacity. • This use upholds the PPP because of the direct link between pollution and the funds required to run the system.	• Close monitoring and accountability should be made possible with regular audits open to public scrutiny. • Responsible institution should receive a set amount from the revenue collected to avoid empire building.
2. Indirect compensation to victims	• This is a good means for compensating affected parties. It is also in keeping with RDP initiatives.	• Expenditure should be within the catchment in which revenues are raised and should benefit parties affected by pollution sources.
3. Research and policy development	• It is essential for adequate water management control and is therefore an appropriate use.	• Only a small part of the revenues should be diverted to national use. The local research needed for a phased implementation of the system has first priority. Then the revenues could be used for research of the technical options for mitigation of the environmental impacts.
4. Environmentally benign projects	• Can produce a treble dividend in terms of returns to beneficiaries and government. •	• The link between charges and revenue spent is maintained. • The users who incurred the costs used to calculate the pollution charges should ideally see a benefit from it.
5. Subsidise environmentally benign technology	• Subsidies can assist by making charges more revenue neutral.	• Unless well designed subsidies can cause undesirable distortions.
6. Direct compensation to individual victims	• This is not a recommended option in the South African context.	• There must be sufficient resources for individual disbursements. compensation. • Causality between victim's suffering and activities of specific polluter/s must be proven.

10. IMPLEMENTATION OF A POLLUTION CHARGES SYSTEM

10.1 Potential impact on investment and other economic policies

10.1.1 General

Among the most important considerations facing the use of economic measures to manage environmental costs, are possible negative economic repercussions that they may have. Of immediate concern in most instances is the potential impact on investment, and in the longer term, the impact on other economic policies. There are two aspects of these concerns that warrant examination.

- Whether the economic measures dovetail with other elements of economic policy; and
- The possible impact on the attractiveness of the area to current and potential investors.

10.1.2 Consistency with other elements of economic policy

10.1.2.1 South African macro-economic goals

Current macro-economic policy in South Africa, as outlined in the Growth, Employment and Redistribution (GEAR) strategy has a number of key goals. The main focus is the creation of 400 000 jobs per annum, the containment of inflation, and the reduction of the national deficit to 4% of GDP. To reach this deficit target requires a target level of GDP, which has been set at the relatively high level of 6% per annum. Meanwhile, the government is taking a tight fiscal stance, trying to improve South African competitiveness and achieve an improvement in income distribution. There are numerous strategies being employed to meet these goals including departmental drives and a monetary policy programme. It is important that the economic measures being proposed for pollution charges have a level of consistency with the national macro-economic goals and programmes.

10.1.2.2 Job creation

Current policy proposals maintain that industries that pollute will have to pay pollution charges. It is possible that these charges may reach a level where, in order to remain profitable, firms need to reduce their labour force. The loss of jobs is obviously contrary to the national goal of creating 400 000 jobs annually. As such, where possible economic measures for environmental control should try to discourage firms from taking this option.

One way of achieving this is by building incentives into the charge systems, which encourage firms to find other ways of reducing their costs, such as investing in more efficient technology or adjusting their production processes to reduce their emissions. Gains may then reduce operating costs, and reductions in emissions will reduce pollution charges. It can generally be assumed that industry will find the best way to cut their costs. However, the cost of unemployment to society makes it important to also encourage firms to find cost saving mechanisms, which do not require staff reductions.

Where pollution charges are introduced and job losses are unavoidable, it is likely that there are general inefficiencies in the firm. High levels of pollution and a workforce, of which a large proportion can be retrenched, are usually signs that a factory is relatively inefficient. Large-scale retrenchments are usually indicative that the work force was under–productive and too large for the level of production. As such, pollution charges may act as a trigger for retrenchments and changes in the factory, but they are rarely the true reason for the changes. The polluter pays system can highlight firms that are fundamentally uncompetitive. Firms that can only absorb the costs of their pollution by retrenching people, will continue to act as a net drain on the economy.

The introduction of pollution charges may stimulate the creation of new jobs for controlling pollution. Some jobs will be created within the polluting companies to better monitor and manage emissions. Specialist external services will also be required to design, build and support pollution monitoring and pollution prevention systems and auxiliary services. These jobs will require relatively high skill levels.

In addition to their incentive effect, which is the main concern in environmental management, pollution charges can be structured to yield revenue. Before this type of charge is implemented, it must be determined if the revenue it will raise is consistent with overall targets for the size of the revenue base of the country.

A variety of revenue options exist, including:

- making the charges revenue neutral by offsetting them with subsidies within the water management structure or with reductions in other forms of general taxation; and
- using them as a temporary (and substantially self-liquidating) feature of the revenue base.

The current trend in terms of tax revenue in South Africa is a move away from broad based taxation towards a greater number of targeted taxes to meet specific objectives. In the next year the government plans to introduce sixteen such taxes in a variety of sectors. While pollution charges are not taxes they are consistent with the direction of the national taxation framework.

10.1.2.3 International competitiveness

An important goal of the GEAR strategy, is an increase in South Africa's international competitiveness. Compliance with high standards of environmental regulation is likely to increase the production costs of South African goods initially. However, over the longer term it will increasingly serve as a competitive advantage for South African firms. International pressure for countries to reduce the environmental impact of their domestic industries is already high, as evidenced by the number of countries involved in the Kyoto Treaty on emissions reductions. In all likelihood, the pressure to reduce environmental degradation will continue to increase. This will take the form of both international treaties and agreements, and the requirements of individual countries.

Many of South Africa's trading partners are extremely environmentally conscious, if they perceive that South Africa is paying insufficient attention to effective environmental management it could jeopardise export drives. Fruit exports from South Africa have already experienced the protectionist consequences of very high production standards imposed by importing countries. The South African coal with its high sulphur content has also been penalised on certain markets because of environmental standards.

In a climate where importing countries require higher standards of environmental responsibility in production, international pressure to reduce environmental impacts is increasing, South Africa's competitiveness will be enhanced by having domestic industries which conform to high standards of environmental management.

In addition, now is the best time for South African exporters to absorb higher production costs, as the weak Rand makes South Africa's exports attractively priced to importing countries. These higher standards of production will pay-off in the long term.

It is worthwhile noting that economic analysis done in the US (Cropper and Oates, 1992) has shown that the introduction of even the most strict pollution control, add only 1 - 2.5% of the total cost in most pollution intensive industries. The exception to this was electrical utilities which could expect a 5.4% increase. This relatively high increase can be attributed to SO_2 regulations, which do not exist in South Africa and are not likely to be introduced in the near future. Unfortunately, information about the impact of charges on industrial costs is not publicly available for South Africa at present.

10.1.2.4 Inflationary and GDP growth effects

Any economic measures implemented for environmental management will need to have a minimal, if not zero, detrimental impact on inflation and economic growth. A pollution charge, which represents an additional burden on firms, may have inflationary effects. If, however, the introduction of a charge is accompanied by greater efficiency, then the inflationary effect will be largely absent. Inflationary effects flow from the Producer Price Index (PPI) to the Consumer Price Index (CPI). Upward pressures can be the result of numerous factors from increases in the prices of inputs to new regulations, increases in wages, skills shortages, a weak domestic currency, monopolies and weak competition. Downward pressure is usually caused by efficiency gains, increases in mechanisation, a strong domestic currency, competition and low inflation in exporting countries.

The implementation of a pollution charge system is likely to exert both upward and downward pressure on the PPI; upward pressure as charges increase the costs to producers and downward pressure as they act as an incentive to make production more efficient.

10.1.2.5 Redistribution in favour of the poor

One of the goals of the macro-economic strategy is a redistribution of income and opportunities in favour of the poor. This is going to be very difficult if economic measures are introduced that lower the purchasing power of the poor. Industry will incur an increase in costs under a polluter pays system. Over time, as the charges increase, some of these costs may be passed on to consumers. Consumers will either pay directly if they purchase the good, or indirectly, through an increase in the price of products. What is important in terms of opportunities and income for the poor, in particular, is the price of essential items like foodstuffs and energy.

There are a number of factors, which may limit the effect of price rises on basic goods. The first is competition. Where a market is competitive, the firms able to internalise the costs of pollution charges and hold down their prices will have a competitive advantage. These firms are also likely to be more efficient. In the case where competition is either weak or non-existent because of a monopoly, government intervention will be required. Electricity is one example in South Africa, where government intervention may be required, particularly in the case of Witbank, because coal is the major input to electricity generation in South Africa. The government will need to regulate price rises attributed to pollution charges in monopolistic sectors.

The pollution charges proposed for the Witbank pilot study would initially be relatively low. As such, it is unlikely at first that the cost of the charges will be passed on to consumers. If they are, consumers are unlikely to feel them because of their small size. However, over time the charges will increase on an incremental basis. If charges reach the level where costs are going to be passed along to consumers, the transfer will have to be managed very carefully, with possible government intervention, where there is insufficient competition in the market.

Additionally, it is possible to set charges differently for pollution sources which create pollution in a profit making process, e.g. manufacturing and between non-profit organisations, which provide a service to community, e.g. municipal sewage works. If a poor community can not afford the charges, a preferential rate could be used on a temporary base. This rate should be reconsidered regularly.

10.1.3 Risk of investment migration

10.1.3.1 Overview

From an intuitive point of view it would seem reasonable to suspect that the introduction of economic instruments, such as pollution charges, may result in industries and investment migrating to other regions, provinces or even countries. Logically, there are two conditions, in the context of the current discussion, which could raise this possibility.

- The first condition is that a significant differential exists in environmental regulation, between South Africa and neighboring states or even between neighbouring regions.
- The second is that environmental legislation imposes additional costs of sufficient magnitude on an industry to give industrialists or investors the incentive to absorb relocation costs or extra set-up costs in less regulated regions. A "threshold" environmental cost could be envisaged, which could provide sufficient incentive to trigger relocation or migration.

While these conditions may seem likely to influence the investment location decisions of firms, international experience demonstrates otherwise. Research to date has shown that other factors are usually more important to firms when they are deciding on where to invest.

The spatial pattern of economic activity is a function of a number of factors. Firms must generally consider: the location of necessary natural resources - at least water in most instances; the cost and availability of qualified labour; access to markets; levels of infrastructure and general security and stability in the area. Most firms also consider the stringency of environmental regulations although, international research indicates it is generally not a significant factor in investment decisions. According to Jaffe, Peterson and Portney (1995) there are two sources of evidence, which can be used to demonstrate the possible implications of environmental regulations on the investment decisions of firms: changes in direct foreign investment and the siting decisions for domestic plants.

10.1.3.2 Direct foreign investment

According to a study by Wheeler and Mody in 1992, corporate tax rates appear to have little impact on the investment decisions of multinational firms. Factors such as access to markets and a developed industrial base carry more weight in a firm's decision making than the tax regime of a country. In so far as environmental regulations can be considered in the same light as taxation, it can be inferred that they too will have little impact on the investment decisions of multinational firms (Wheeler & Mody, 1992).

Various international studies have been conducted to examine the relationship between environmental regulation and investment. The studies investigated investment flows between countries in a number of industries and tried to establish whether there were preferences for investing in countries with less stringent environmental regulations. To date, these studies have not uncovered evidence to suggest that firms prefer countries on the basis of the stringency of environmental regulations. Factors such as labour costs and skills, general security and stability in an area, local by-laws, incentive packages and those mentioned previously; access to markets and a developed industrial base, all have a far greater influence on investment location decisions. As such, investment flight from countries with high environmental standards to countries with low environmental standards seems unlikely.

10.1.3.3 Domestic plant location

Analyses of plant location decisions in the United States indicates that new environmental regulations will not cause firms to relocate existing plants or be the major factor in their decision on where to site a new plant. A number of studies from the late eighties to the mid-90s examined the sensitivity of firms' plant location decisions to environmental regulation. While these studies discovered that the stringency of environmental regulations did have an effect on investment decisions, this effect was not found to be statistically significant.

10.1.3.4 The case of the Witbank Dam catchment

For the purposes of this polluter pays case study, it is critical that the potential for investment migration is clearly understood. Witbank is an interesting case because it originally attracted investment as a result of its rich coal deposits. For the coal industry, its investment decisions in the past were essentially made for them by the location of coal resources. This is likely to continue to be the case, although the mining of coal must remain profitable and very high pollution charges could still affect that profitability. It may dissuade firms from investing further in the area or force them either to scale down production or only mine the best grades of coal. Therefore, while coal mining may be less sensitive to pollution charges than other industries, which can be established or relocated to anywhere there may still be impacts on their planning decisions in the future.

A further factor, which must be considered, is local attitudes towards 'dirty' industries, such as coal mining and coal generated electricity. Most of the population of Witbank is either directly employed by a 'dirty' industry or a firm somehow connected to these industries. In choosing to live in Witbank and be employed in such firms, many of the people of Witbank have essentially internalised the cost to them of the pollution. People have accepted the pollution as a trade-off for their jobs. This does not, by any means, make the level of pollution acceptable. Neither is it a justification for firms to carry on polluting at the same levels. However, it is likely to be currently serving as an incentive for 'dirty' industries to locate themselves in Witbank. The fact that polluting firms are unlikely to encounter local resistance to their activities, is an added attraction to investing in the area.

10.1.4 Conclusion

In terms of the consistency of pollution charges with South Africa's economic strategies there is a relatively high degree of congruence, particularly as pollution charges should result in more internationally competitive firms - a key goal of current macro-economic strategy. In addition, the weak Rand makes this an appropriate time for exporting firms to come to terms with and internalise costs, such as pollution charges. In terms of employment, pollution charges may be the trigger for some firms to retrench, but it is very unlikely that they will be the cause of such retrenchments. Only firms that are inherently inefficient will have to rely on retrenchments to be able to absorb pollution charges. However retrenchments are not an inevitable consequence, as the charges will be implemented slowly, giving firms time to increase their efficiency and offset the impact of the charges on their margins.

International experience shows that firms are not particularly sensitive to environmental regulations in their investment location decisions, which indicates that in all likelihood, Witbank area is not at risk of investment migration. In the case of the Witbank area there are other drawcards which, can both attract new investment and ensure that current levels of investment are maintained. These drawcards include coal deposits, water resources, the investment that will accompany the Maputo Corridor development, and the general community acceptance of 'dirty' industries.

In conclusion, the introduction of pollution charges in the Witbank Dam catchment, are not likely to have a significant negative economic effect. In fact in the long term there should be positive spin-offs.

10.2 Institutional aspects

10.2.1 Overview

The institution responsible for the implementation and operation of a polluter pays system must be financially viable, it must have sufficient capacity in terms of human resources to undertake the task and it must have the trust of the stakeholders in terms of its independence and impartiality. The National Water Act, Act no.36 of 1998, puts this responsibility on to Catchment Management Authorities (CMAs). It is expected that eventually they will be the bodies that run pollution charge systems in every catchment in the country. Although the Act has just passed (August 1998), it will take some time for CMAs to be fully operational and to be able to run pollution charge systems. As such, the DWAF is going to have to play a role in running pollution charge systems in the interim while CMAs are being established. This section describes the current policy framework that the DWAF is operating within, the role that it is likely to play in pollution charge systems and the role that some other institutions may also be able to play.

10.2.2 Department of Water Affairs and Forestry

10.2.2.1 Policy overview

The previous structures, which governed the management of water allocations and water quality were influenced by the priorities of the apartheid system and as such served to benefit only a narrow slice of the population. Sectors such as commercial agriculture, mining and other industries benefited from generous water allocations for many years, often to the detriment of the domestic needs of the rural, non-white population. The system of management of water resources was run by a centralised bureaucracy with little local input. With the change in government, the shift in priorities and a move to more co-operative governance, previous structures have had to undergo significant transformations. The Department of Water Affairs and Forestry is undergoing a major internal transformation in order to be able to respond to the pressing water needs of South Africa as far as water supply, water resource management and water quality are concerned. As part of this reorientation the Department is increasingly adopting more of a regulatory and co-ordinating role on water resource and water services matters.

The key policy paper released by DWAF pertaining to water resource management in South Africa, is the *White Paper on National Water Policy for South Africa*. Released in April 1997, this paper is concerned with the management of water resources at a national level. It places water resource management and water conservation firmly on the government's agenda. The paper proposes that certain concepts be formalised, namely that water is an indivisible national asset and that it be held in Trust by the national government as custodian. The role of the Department as custodian is envisaged as being a designer and enforcer of regulatory requirements pertaining to water resource, water quality and water services.

10.2.2.2 The National Water Law Review

A reformed legislative framework will be a key pillar to the successful implementation of the policies and strategies outlined in the White Paper on National Water Policy. Current legislation does not reflect the rights entrenched in the new constitution and is inconsistent with the reconstruction and development (RDP) goals of the country. As such a process of Water Law Reform was set under way in 1994. The new laws will be based on a set of principles that were developed in a consultative, national process. These 28 principles are the backbone of the future management of water related issues. Some of these principles refer to institutional arrangements, which are relevant to the implementation of pollution charges.

For example, Principle 23 of the Water Law Principles states that the management of water resource should occur at a catchment or regional level, where possible and appropriate, in order for interested parties to be able to participate. In accordance with this principle functions associated with pollution charges systems should be delegated to a more local or regional level.

Two Acts, which have relevance for pollution charge systems have come out of the Water Law Review process; the National Water Act and the National Water Services Bill. The National Water Act outlines the role of Catchment Management Agencies (CMA), addresses national water conservation and water management concerns and the management of water allocations. For pollution charges systems, the role it defines for CMAs is particularly important.

The Water Services Act is primarily concerned with water services, defined as water supply services (including basic water supply) and sanitation services (including basic sanitation). It addresses the functions, powers and interactions of Water Service Providers, Water Service intermediaries, Water Service Authorities and Water Boards. The Act provides significant leeway for Water Service Authorities[1] to engage other

[1] Ideally water service authorities are local government but where their capacity is weak DWAF takes over the role

bodies as Water Service Providers on a contractual basis to provide certain water supply services including water quality management. The sections pertaining to Water Boards, the scope of their operations and their interaction with other institutions are important for pollution charges systems. The Act essentially allows Water Boards to participate in activities outside water services (as defined above), as long as their capacity to undertake their primary function is not threatened and it is responsibly planned and managed. The activities that Water Boards are allowed to undertake include providing catchment management services to or on behalf of the responsible authorities. Participating in the operation of a pollution charge system could be allowed under this provision.

10.2.2.3 The role of the DWAF in pollution charge systems

The role of the DWAF in terms of pollution charges systems should be consistent with the general policy direction of the delegation of functions and the adoption of the regulatory and co-ordinating roles. Water management at a regional level is currently carried out by regional DWAF offices. In accordance with its changing role, the DWAF will begin to delegate the functions of these offices to local, catchment based and/or regional institutions. DWAF will still retain prime responsibility for these functions, with other institutions acting as agents on behalf of the DWAF. The White Paper on National Water Policy clearly states that "Whatever arrangement is introduced (for water management), it must be clear that it will remain subject to national authority" (DWAF, 1997i). As such the institutions delegated with the relevant functions will effectively be agents of the DWAF. It is recognised that an important element of delegating functions is building the capacity of the institutions to take over such functions.

10.2.3 Water Boards

Water Boards are agents of the DWAF. By the nature of their activities, several boards are already involved in water quality management. Those that provide purification services have significant water quality testing resources. These resources, along with their experience with water quality management, could potentially be utilised to operate pollution charge systems in some parts of the country, on a temporary, agency basis for DWAF. It is suggested that the use of Water Boards as agents to manage pollution charge systems only be an interim measure, until CMAs are established. The reason being that there is a possible conflict of interest in boards playing an enforcement role with regard to pollution because they are also polluters.

10.2.4 Catchment Management Agencies (CMAs)

Alongside the other institutional changes that the national Department has identified is the 'possible development of other bodies at national and regional level to carry out specific water management functions.'

Catchment Management Agencies are structures, designed generally to bring together water users in a catchment to negotiate around issues of conflict. The types of issues they are intended to deal with include the allowable amounts of pollution discharge, where there are significant polluters in the catchment and water allocations. They serve as a form of self-regulation for catchments.

It is envisaged that the functions carried out by CMAs will be in line with national policies and standards. While the CMAs will have to be financially self-sufficient, they will still be answerable to national government. In accordance with the Water Services Act, national government will also have a role in the design of CMAs and the appointment of their management. The National Policy makes it very clear that in terms of governance there will be a careful balance between the interests of stakeholders in the catchment and the effective management of the catchment.

The financial viability of the CMAs will rely on the implementation of new national water pricing proposals. Where CMAs are responsible for pollution charge systems, revenues may also form part of their financial base.

The National Water Act, No 36 of 1998 clearly states that national government shall support the establishment and promote the functioning of Catchment Management Authorities (CMAs) as and where conditions permit. While Chapter 7, which deals with CMAs does not specifically make provision for CMAs to implement pollution charges, the Director-General may delegate this function to a CMA under section 73.

10.2.5 Local authorities

The direct responsibilities of local authorities, in terms of water, are limited to water supply. In accordance with the competencies outlined in the Constitution, local government is responsible for the provision of sufficient, safe water supply to its constituents. In as far as this responsibility is concerned, local government does not have a major role in water resource development. However, local government is more broadly responsible for local development.

Being responsible for local development means that local government must give due consideration to a number of issues including local economic development, local environmental issues and service provision. As such, local government needs to participate in decisions, which may affect local development. The implementation of a pollution charge system may have implications for local development and for the environment and as such requires the participation of local government at least in the developmental stages. In 1997 the WRC funded a project, the "Review of industrial effluent tariff structures in South Africa and guidelines on the formulation of an equitable effluent tariff structure" (Kardachi, 1997b). The effluent charges for discharge into sewers must be dovetailed with the pollution charges for discharge into streams.

Local government may not need to implement the overall catchment PPP system but should be kept updated on a regular basis. It is essential that local government takes account of PPP charges in setting their own charges to contributers to each water treatment works. While participation in early design stages and information updates are important, it is critical that local government remain autonomous from the system. Local government needs to ensure its independence from the pollution charges authority as it is also likely to be a polluter in the catchment.

10.3 Implementation issues

10.3.1 Penalties

Penalties are an essential component of a polluter pays system. However, unlike compliance oriented systems, they are not intended to be the primary incentive driving polluter behaviour. The threat of penalties should not be the driving force behind pollution reduction. Rather penalties in a pollution charges system should be a back up measure to ensure that all of the polluters play by the rules. They should ensure that no one polluter is gaining an unfair advantage because of inaccurate measurement or monitoring of pollution. They are applied in the following situations:

- failure to monitor point source discharges adequately and accurately;

- late return of pollution discharge data;
- late payments;
- falsification of data; and
- failure to inform of changes in any parameter used in charge calculations (e.g. area of mine).

Penalties need to provide a significant enough incentive for polluters not to try to cheat the system and to pay on time. It is suggested to use the example of the system in China, which has a time component built in. For each day that the pollution charge payment is late the charge increases by 1%.

If a firm was found to be reporting inaccurate information it would be important to discern whether the inaccuracy was a result of accident or intent. The previous record of the firm should also be taken into consideration.

In terms of the size of the penalties, they need to be a strong deterrent to ensure that firms will not be tempted to try to cheat the system and provide sufficient incentive for firms to ensure that their monitoring systems are accurate. If the firm is a repeat offender, the penalty should be 100% to 200% of what they owe on top of their charge. A minimum recommended penalty is 20% to 30% of the charge.

A mistake in monitoring results should be penalised, because even if it is unintentional, it points to inadequate care and maintenance. The penalty needs to be high enough to encourage a very high standard of monitoring on behalf of the polluter.

10.3.2 Additional implementation issues

10.3.2.1 Adjusting for inflation

It was learnt from overseas experience that the charge system should have an automatic inflation adjustment mechanism (see section 3.4.3). This is quite common for financial tools and does not require any special measures in order to be applied.

10.3.2.2 Recourse to appeal against charges

Charges could either be too low and insufficient to compensate, or too high and as a result curtail economic development. In both cases the affected parties should have an opportunity to appeal. At the moment there is no special body that could deal with such appeals. The National Water Bill, 1997 suggested the establishment of a Water Appeal Board which would be an independent body for dispute resolution. Although there is no provision in the National Water Bill, 1997 on how to deal with questionable charges, it seems that the Water Appeal Board could be ideal for this purpose.

10.3.2.3 Issues to be addressed prior to implementation of the system

1. Institutional arrangements must be finalised and working relationships with the polluters should be formed – see discussion on Phase 1 below.
2. The method, which was utilised for allocating total diffuse load to known non-point sources has many limitations. Some suggestions for its possible improvement have been proposed in Chapter 8. It is suggested that the matter be discussed with I&APs. Only then should the most acceptable option be chosen.

3. If a decision is taken that additional monitoring is required, then the new monitoring system should be optimised and its cost determined.

10.3.2.4 Issues to be addressed during phase 1

The following issues will need to be addressed at an early stage of the study, but need not delay implementation of the PPP.

A decision on the need for more than one control point and the associate monitoring requirements should be taken. More comprehensive data should be collected for water use by mines in the study area (see section 8.7.3.2) and the loads discharged by point sources (section 8.7.3.1).

10.4 Phasing in of pollution charges

10.4.1 Introduction

It is important to note that a system of charges which is based on information or assumptions that are open to dispute in any way is unlikely to yield any revenue whatsoever. Moreover, it would most likely burden society with additional costs such as those incurred through the appointment of specialists and lawyers. Therefore the acceptability of all information and assumptions used for charge calculations by all affected parties is of paramount importance.

In order to achieve such acceptance the following four processes should be completed:

- *effective participation by the main role players*: effective participation occurs where a participant is placed in a position to be heard, to be understood and to receive feedback on their contribution;
- *effective decision making*: effective decision making is possible with a clear framework where the role and responsibility of participants is clearly defined and where those responsible for decisions are identified;
- *sufficient time to facilitate effective participation and decision making*: consultation and participation is time consuming, if participants are cornered or forced into premature decisions due to time constraints, the system may not be accepted at the end of the project; and
- *adequate technical analysis*: participation should not become the end in itself – the plan, which is eventually adopted, must be technically sound, affordable and able to be practically implemented.

The project described in this report is a research investigation, which focused on principles and methodology. It provided adequate technical analysis, but did very little concerning the first three processes. Therefore, it is necessary to complete all of the above processes before implementing the charge system.

It is proposed that the charge system be implemented in four phases described in section below.

10.4.2 Phase 1

This phase involves establishment of the charge system and the full recovery of administrative costs and partial recovery of Waste Load Charges.

The suggestion of including at least partial recovery of the WLC is based on the consensus reached by the parties consulted during the project execution. Since the primary objective of the charge system is to change the behaviour of polluters a link between pollution charge and pollution level is necessary.

If no dedicated institution is established for administering the charge system, the regional office of DWAF may run the system initially in co-operation with a catchment forum. This way, a significant portion of the revenue collected initially could be used to establish an administrative institution, such as a Catchment Management Authority. It must be stressed that the administering of a charge system will be only one of the functions of a CMA, therefore the revenue collected from pollution charges would be only part of the funding used for establishing and operating the CMA.

In the catchments where Water Boards exist they may undertake the administration of the charges, on a temporary basis until CMAs are established. They have an advantage in being able to borrow the capital for the first phase from private sources and repay it from the next phase.

The algorithm for calculating the costs incurred by Eskom as the result of low water quality at Witbank Dam should be developed. This algorithm, together with methodologies used for calculation of other costs, should be negotiated with I&APs and accepted by polluters and regulators. It should be attempted to complete this algorithm development by the end of the first phase.

10.4.3 Phase 2

By the conclusion of this phase full implementation of the WLC will have been achieved. Initially the optimization co-efficient is recommended to be at least 0.5, increasing up to about 0.75, probably within a year followed by another increment up to 1.0. These increments should ideally be introduced and monitored for one year each to determine the effect on pollution levels. A full year is necessary because of seasonal climatic variations.

10.4.4 Phase 3

The degree of pollution reduction must be determined and compared with the desired water quality objectives. Once this is achieved Phase 4 can be implemented. If it still falls short of the objectives then the investigations regarding the introduction of the NCC must be planned and carried out. The NCC should be introduced in annual increments similar to that for WLC. It should be monitored and increases stopped when water quality objectives are achieved. Once again the monitoring and review period needs to be one year.

10.4.5 Phase 4

This is the status quo phase in which the charges are set at a level that achieves the required water quality objectives. However, monitoring must remain diligent and on going as mines open and close on a regular basis. At some point it may become necessary to re-evaluate the water quality objectives. If this occurs the need may arise to repeat part of Phases 2 and 3.

10.4.6 Concluding remark

With the above phased approach, a system of pollution charges could be gradually introduced thus, permitting polluters adequate time to get used to the charges and to plan and introduce any pollution control system involving capital expenditure.

11. CONCLUSIONS

11.1 Philosophy of the PPP

Extensive research into the philosophy and practical application of the polluter pays principle revealed that the concept is being widely used to design pollution charges and has proven to be successful in many cases.

The six philosophical pillars upon which a polluter pays system stands are;

- The **ethics** of the 'polluter pays principle' derives from the universal moral principle that, all other things being equal, we ought not to cause harm to others.
- **Sustainable economic development,** which involves an "inter-generational social contract", which requires this generation to act as the steward of environmental resources, so that the interests and needs of future generations are met.
- Everybody has an **equal right** to use environmental resources. Pollution charges systems protect this right.
- Current generations need to optimise **economic efficiency** for future generations. PPP systems provide an opportunity to optimise the choice between emission treatment and treatments at point of use technologies.
- Introducing a PPP system requires an extensive **consultation** process and the participation of regulators, polluters and parties affected by pollution.
- PPP implementation encourages polluters to stay below prescribed standards, resulting in a maximisation of environmental benefits or **environmental efficiency**.

11.2 Overseas experience

There is a general trend to combine CAC based systems with systems which utilise fiscal instruments such as PPP based pollution charge systems. An extensive examination of the overseas experience is described in section 3.3 and the key lessons are summarised below:

- If polluters in developing countries do not pay for their pollution, the impact of the pollution is felt most by those who are dependent on environmental resources for their livelihoods such as in the rural poor communities.
- Less developed countries which undergo structural transformation have an advantage when implementing PPP based systems because the resistance to new systems is less extreme than in more developed countries where current systems are highly entrenched.
- The implementation of a PPP system can be politically problematic if public sector enterprises have significant interests in polluting industries and are thus both referee and player.
- Experience from other developing countries indicates that the most common problem in implementing pollution charge systems is the shortage of skilled personnel. However, this problem is even more pronounced for CAC systems.
- Pollution charge systems must automatically be adjusted for inflation.

- No charge system for diffuse pollution was found. However, the theoretical discussions found in the literature recommend encouraging polluters to convert their pollution discharge from non-point source to measurable point source. Higher charges for non-point than for point source discharges provide an incentive for such an action.

- Only one waste water charge system dealing with sulphate pollution was found. This is the system utilised in Poland, where the waste water charge on saline mine effluent is the largest contributor to total revenue collected in water management. The charge has been in effect since 1970 and has been increased a few times since then. The latest charge published is 24.3 ECU/t of sulphate for 1993, which is about 60 R/t inflated to 1997 prices.

11.3 Pollution control in South Africa

South Africa has previously relied on a number of systems based on the CAC approach. While this has been effective in certain instances, there is a need for a system which relies on economic incentives rather than regulatory supervision and which is self-funding. Since 1994 South Africa's legal and policy framework has evolved such that it is now suitable for the introduction of PPP based systems.

11.4 Witank Dam catchment - the case study area

The Witbank Dam catchment and the pollutant sulphate were selected for a case study of pollution charges as they were in accordance with the objectives of the study.

As much information as possible was collected about the catchment. Some attempts were made to improve the quality of the data, however to bring all the data up to the necessary quality was far beyond the scope of this study. The monitoring and data collection systems will have to be modified at some stage to support a charge system in this catchment.

Once the information had been collected and analysed it was processed to provide the following input into the pollution charge model:

- the assessment of the monitoring data was used to determine the monitoring costs that form a part of the Administrative Charge (AC);

- the water quality status was used as an input to calculate the exceedance of the Co that determines the Non-Compliance Charge (NCC);

- the water use data was utilised to estimate the impact cost that determines the catchment Waste Load Charge (WLC); and

- the pollution sources were characterised to calculate the WLC for individual polluters.

The AC, WLC and NCC are the main components of the charge system that described in Chapter 8.

The limitations of the pollution loads data are discussed in detail in section 8.5. In particular, the estimation of pollution loads from diffuse sources is quite complicated. In this area it was found to be especially difficult, because some mines are located so close to each other that it is possible that seepage from one mine can go through the area of the other mine before reaching the stream. In addition, some of the mines discharge to several streams, which are located in more than one MU, which makes estimation of pollution loads even more complicated.

11.5 Impact and abatement costs

The costs in this study have been calculated for two water quality regimes in the Witbank Dam catchment: the 1990/91 and the 1995/96 hydrological year. These two years represented different hydrological conditions - one of the driest and one of the wettest years in the last decade. The impact cost considered was only the direct financial cost and not the full cost to society of the impact of pollution. Another limitation is that only water users within the study area were considered. It was found that the impact costs vary widely between wet and dry years.

The abatement costs were estimated from the costs ranging from treatment at the source to the point of use, as a proxy.

It was concluded that the direct impact cost is small when compared to abatement costs.

11.6 Charge system model

From an examination of international experience and the case study at Witbank it is concluded that pollution charges are a viable water quality management tool for South Africa to implement.

The model that has been developed for implementing pollution charges in the Witbank Dam catchment is essentially a framework model intended to demonstrate the practical application of the system. No model is perfect, although models such as this are intended to eventually achieve a degree of 'perfection' which is acceptable to both polluter and society as they are implemented and modified with experience.

The model takes into account relevant lessons learnt from an extensive literature survey and also proposes new solutions to local problems, which are not as yet addressed elsewhere.

It is successful in satisfying all the following design objectives (see section 8.1):

- Net revenue must be equal to or exceed local direct impact costs of pollution.
- Minimised implementation costs.
- A deterrent to polluters from excessive and harmful pollution.
- A deterrent to non-point source pollution.
- Charges must be reasonable, justifiable and must not promote economic decline.
- The model must be simple and flexible.

The proposed system arrived at during the course of the research is a combination of cost covering charges and an incentive system and includes the three main components:

Administration Charges (AC) - Administration costs are incurred because polluters want to use surface water systems to dispose of waste and society wants such actions to be monitored, controlled and paid for. These costs must be specific to the pollution characteristics of the administered area and paid in full by polluters in that area.

Waste Load Charge (WLC) - This applies to all effluents when the concentration at the control point exceeds the impact level. The WLC is charged per ton of pollutant load discharged, based on the impact cost.

Non Compliance Charge (NCC) – the NCC is a penalty charge, which is levied on waste discharges when the concentration at the control point exceeds the Co for a particular pollutant.

The model calculates the different types of pollutant loading from each individual source and the charges payable. The calculations made in the spreadsheet model (see Appendix D) are only a demonstration of the model capabilities. The limitations of these calculations are discussed in detail in section 8.5.

This model was developed assuming that its implementation will be undertaken in phases. It provides input for the first phase and each succeeding phase should include further model development based on feedback from the previous phase.

11.7 Likely income from charge system

The proposed system is expected to generate a revenue of R3.05 million/a to R9.15 million/a for the first year of implementation. Although this revenue is less than the estimated cost of pollution for the first few phases of implementation, according to the schedule this objective could be achieved within four years. The suggested phased approach for system implementation is described in section 10.4.

11.8 Comparison with CAC system

The implementation of the charges system to complement the old CAC approach should reduce state expenditure on water quality management because of the following:

- It might be possible for the DWAF to use some monitoring equipment installed for the charge system.
- The system should minimise monitoring costs to the regulating authority, because polluters will have strong incentive to carry out comprehensive monitoring themselves. In particular there should be no need for compliance monitoring with only spot checks at compliance points being required.
- Use of NCC and penalties will simplify control systems and minimize enforcement costs (e.g. the cost for legislative procedures).

The charge system will definitely provide polluters with an incentive to reduce their pollution without limiting their choice of an optimum economic solution. Pollution prevention by utilising better water management practices will become a first option for the minimisation of the WLC paid by polluters. This option is the most effective and economically viable first step for improving overall water quality in the catchment. The use of a Diffuse Source Differential is an incentive that eventually will minimise non-point source contributions.

11.9 Choice of model algorithms

Extreme care was taken in developing algorithms for the charge calculations and implementation procedures to ensure that charges are reasonable and justifiable. A need to prevent charges from promoting economic decline was stressed (see section 8.3.5.3).

Finally, the simplicity of the model was paramount. Section 8.4.1 discusses numerous possibilities for improving the model, although some will make the model more complex and therefore should only be introduced at a later stage if it becomes certain that the increased complexity is justifiable and necessary.

11.10 Fate of revenues

The spending of any revenue arising from the collection of charges should be linked to reducing the impact costs of pollution and should aim for maximum impact. Where possible double or even triple dividends should be achieved.

Treating revenue from pollution charges like other taxes and returning it to the general fiscus is problematic and contravenes the transparency requirement of the PPP. It has been rejected as an option in the review of South African water laws.

One of the first priorities is the implementation of the system for pollution monitoring and control, and the administration of the charge system. Following this, revenues should be used to mitigate against negative environmental impacts, to implement measures to improve water quality management or to fund research and development and national water quality, policy initiatives.

Excess revenue should be spent on subsidies to a number of groups, from companies needing to invest in new pollution control technologies to under-serviced communities to provide for environmentally sound sanitation. The clean up of past pollution can also be subsidised from this revenue.

A combination of uses for charge revenue is the most appropriate and is likely to yield the highest overall dividends.

11.11 Need for consultation

The success of a charge system depends on the presence of two features: an effective incentive to reduce, manage and monitor pollution by the polluter, and acceptance by the polluter of the pollution charge system, inclusive of its design and methodology. Whilst this particular model achieves the objectives of model design as described earlier, its success will also depend on consultation and understanding between the system managers and the polluters. This aspect is outside of the scope of this project, but appropriate recommendations are provided in sections 10.4 and in the next chapter.

12. RECOMMENDATIONS

12.1 Implementation of a charge system for the Witbank Dam catchment

It is recommended that serious consideration be given to the implementation of a sulphate pollution charge system in the Witbank Dam catchment. The model proposed under this project is simple to apply and effective in achieving the design objectives. Its implementation should bring a twofold benefit of improved environmental control with reduction of implementation costs to government and society. With time it may have a further benefit, when revenues from the charge system are spent on water quality enhancing measures, which also have a welfare benefit (e.g. sanitation).

From overseas experience it was found that in introducing such a system it is better to test it in one area in order to evaluate public reaction and determinate its effectiveness. The Witbank Dam catchment seems to be a good choice for an introductory implementation.

12.2 Acceptance of a charge system for the Witbank Dam catchment

It is important that the design of a waste water charge system, the information used as an input and the underlying assumptions are accepted by all affected parties. A charge system which is open to dispute in any way is unlikely to yield any revenue whatsoever. Moreover, it would most likely burden society with additional costs such as those incurred through the appointment of specialists and lawyers.

The specific issues, which have to be considered and accepted by I&APs are discussed in section 10.3.2.3 and 10.4. They include, but are not restricted to the following points:

- Institutional arrangements for the effective administration of waste water charge systems must be finalised by government. It is recommended that such systems be initiated by the DWAF and that a catchment forum be used for negotiation among stakeholders. Ultimately, a catchment management authority should administer the system.
- The best method for allocating total diffuse load to known non-point sources has to be selected in consultation with the I&APs.
- The appropriate level of monitoring must be determined. The monitoring and auditing of polluters are components of the administrative cost of the waste water charge system. Hence, a decision regarding the design of control and compliance monitoring systems should be taken.
- All algorithms and all input data used in the proposed model must be discussed with I&AP's and accepted, including procedures for determining the direct financial cost of pollution.
- The more in-depth investigation of possible negative socio-economic effects of the charges on industry was suggested by the Chamber of Mines (see section 5.4).
- This study has paid insufficient attention to the disbursement of the revenues generated by the waste water charge system. This needs to be investigated further, agreed upon by all parties, and guidelines drawn-up prior to introduction of a charge system generating a significant revenue surplus.

12.3 Monitoring of economic effects

It is essential to the successful running of the system that the economic effects and environmental effectiveness of the charges system are closely monitored during each stage. The CMA should respond quickly enough to such indicators to ensure that appropriate charge levels are maintained.

Should it be decided that a pilot waste water charge system be introduced in the Witbank Dam catchment, it is important that its introduction is gradual and closely monitored as the threshold charge (i.e. the charge at which polluters start to reduce discharges due to the cost involved) remains unknown.

12.4 Extension to other pollutants and catchments

As this study focussed on only a one single catchment and only one water quality parameter, it is imperative that further studies be conducted to extend the charge system to include other pollutants. Priorities should be set for this extension, based on the results of the classification of the water resources. The priorities for implementing the charge system for other river catchments will be an outcome from the same process.

The procedure for determining the direct financial cost of current pollution on downstream water users is still lengthy and imprecise. Clear guidelines need to be developed to streamline this procedure before the charge system is applied in other catchments.

Pollutants that have a clear economic impact, such as salinity or salinity related parameters could be the first priority for the charge system implementation. In cases when no clear economic impact cost can be determined a combination of AC and NCC charges might be utilised.

12.5 Method of dealing with old pollution sources

The control of backlog pollution was beyond the scope of this project, but it is recommended that the cost of water pollution control measures from abandoned mines be included as one of the revenue uses. This activity will relieve the government of the financial burden caused by past polluters, improve water quality for water users and provide present polluters with an additional assimilative capacity.

12.6 Pollution charges as part of the water management

Any charge system that is introduced should form part of a Water Management Plan (WMP) for the catchment. Both the charge system and the WMP should arise from the establishment of an appropriate CMA. The CMA will be responsible for determining the water quality objectives, water allocation for the catchment and other components of the WMP that are also needed for design of the charge system. The WMP must be developed in close co-operation with all I&APs.

The current project provides a basis for further development of water related legislation. The implementation of the new national water pricing proposals must be dovetailed with waster water and environmental charges so as not to undermine incentives or distort prices. It is strongly recommended that the findings of this project be used for dealing with issues such as pollution prevention and financial provisions for CMAs.

APPENDIX A

MAPS

A1 – Base Map of the Witbank Dam Catchment
A2 – Water quality monitoring points
A3 – Irrigated areas
A4 – Pollution sources

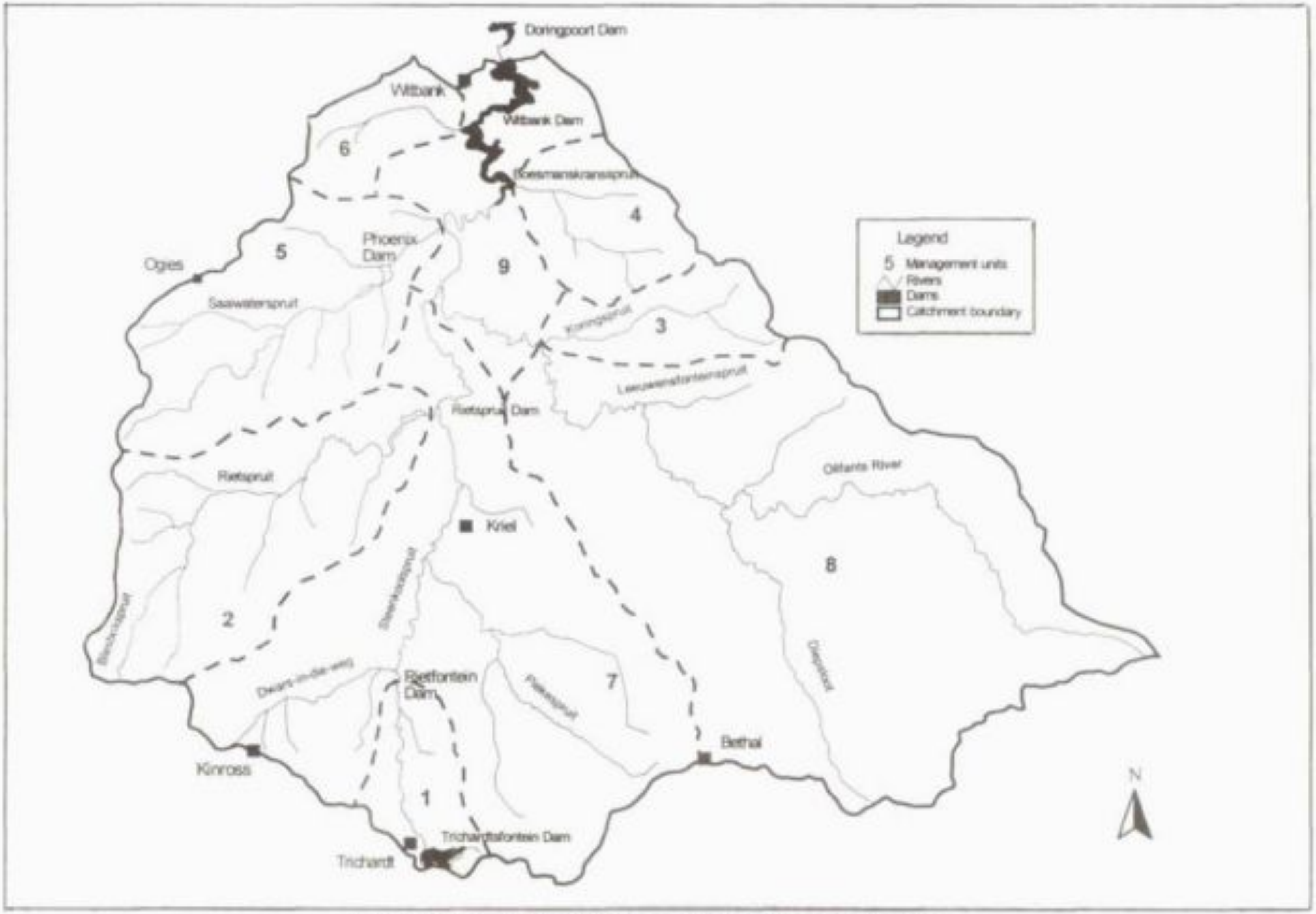

Figure A.1. : Witbank Dam Catchment Base Map

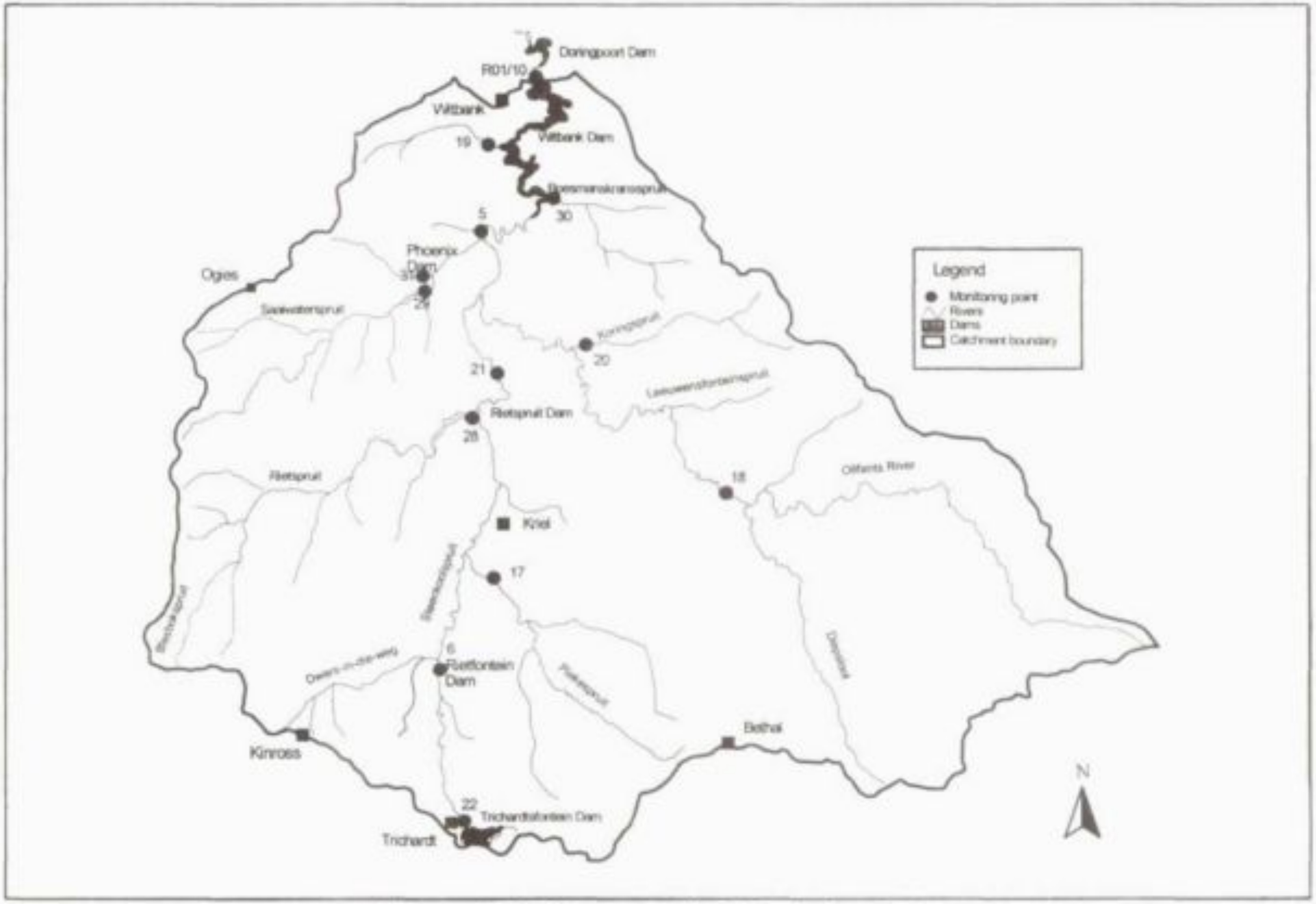

Figure A.2. : Water Quality Monitoring Points

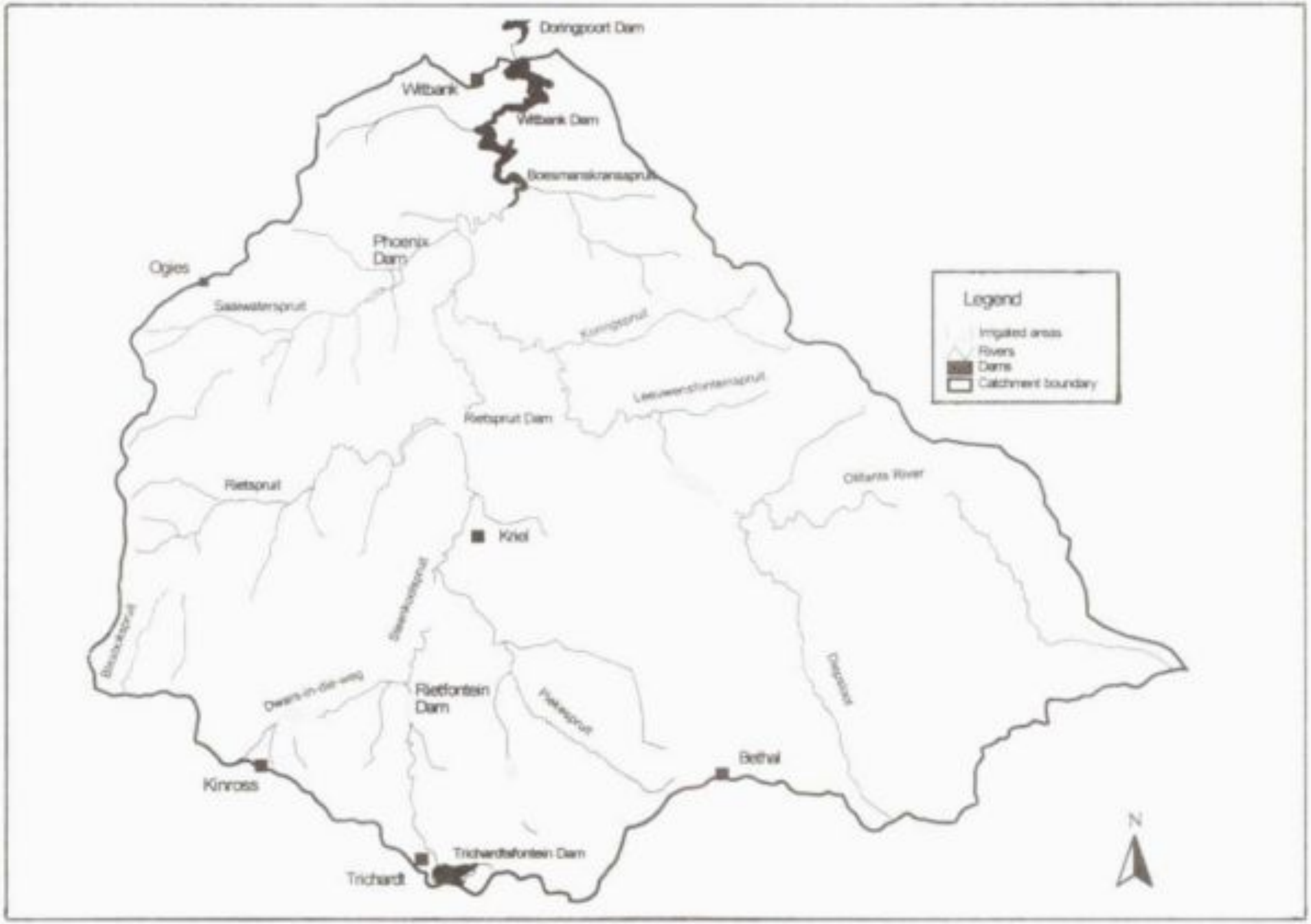

Figure A.3. : Irrigated areas

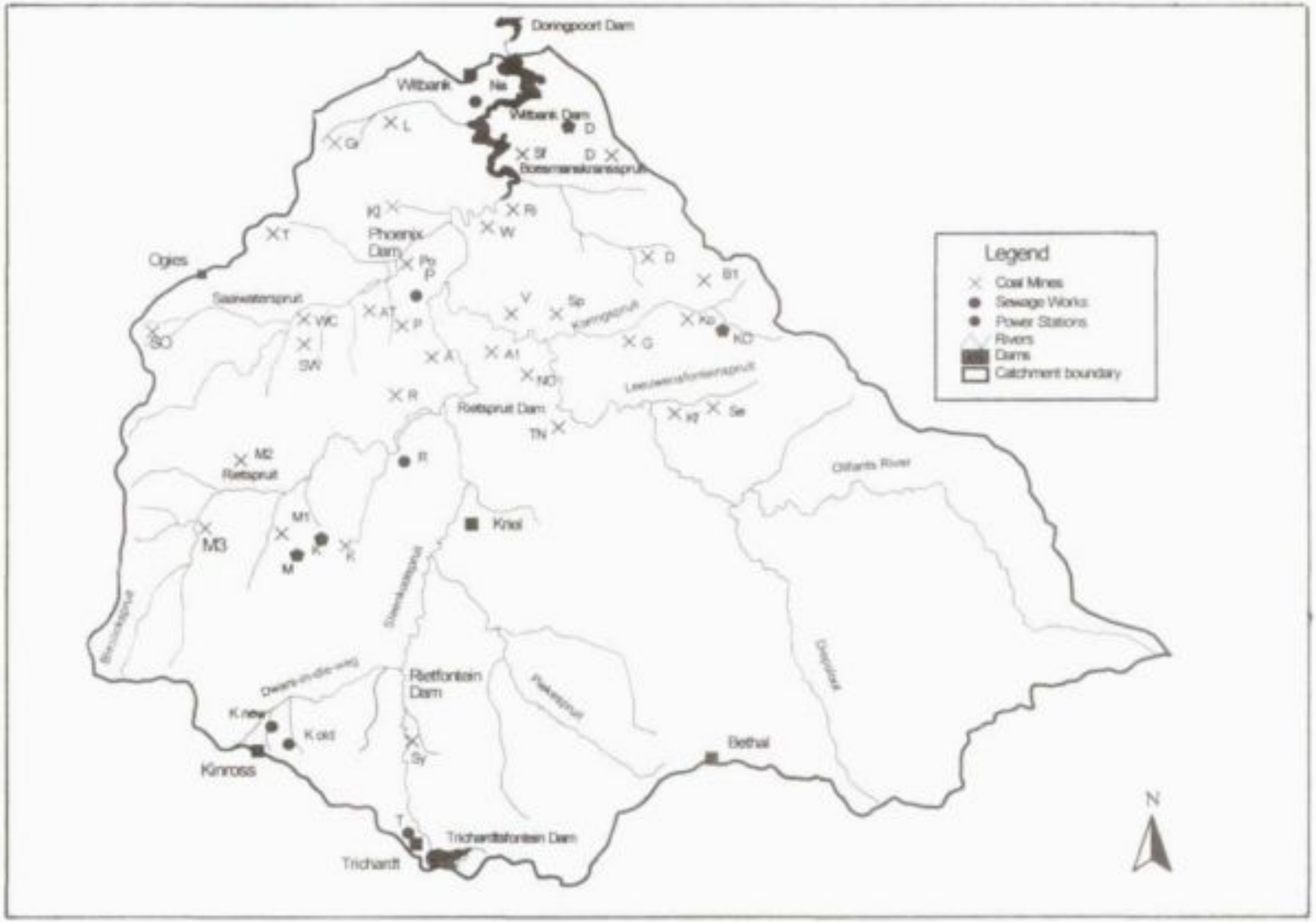

Figure A.4. : Pollution sources

APPENDIX B

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APPENDIX C

NOTES ON THE CALCULATION OF ADMINISTRATION COSTS

1. Equipment and facilities (weirs)

According to figures from the DWAF, the cost of a weir is R10 360 per running metre. The weirs are estimated to be an average length of around 22m.

Thus the total cost of a weir is estimated to be 22 x R10 360 = R228 000.

2. Manpower costs

The assumption is made that rates will be the same as for similar positions in the DWAF. These rates include 13th cheque and fringe benefits.

DWAF positions	Daily rate
Assistant Water Pollution Control Officer	R380
Principal Water Pollution Control Officer	R680
Administrative assistant	R180

3. OPERATIONAL COST

3.1 Sampling

Assume weekly samples for all 13 instruments and weekly sampling at Witbank Dam - 14*52 weeks is 728 samples. Additionally the spot checks at compliance points can be assumed on a monthly base. According to the WMB report (WMB, 1993a), 30 compliance points are required. This is probably an underestimation, as for a few mines that were examined up to 5 compliance points could be required. Another 30 compliance points for point sources and releases were therefore added. Releases are monitored only during wet periods, so the number of monthly samples can be reduced to 20. Assuming 70 compliance points means that 70*12 months = 840 additional samples will need to be collected for spot checks. The total number of samples comes to 1568.

Cost for sample analysis was assumed to be R 310.

3.2 Travelling expenses

Taking of 1568 samples @ 50 km per sample = 78 400 km

AA rate per kilometre (2 litre vehicle) = R 0,51 for fuel and maintenance; capital expenditure is included in staff fringe benefits (see section 2).

3.3 Calibration of instruments

13 instruments calibrated once every six months = 26 calibrations per annum

26 calibrations @ 5 calibrations per day = 5 man days (to nearest day)

Calibration contract, including instruments, travelling and manpower: R1 940 per day

Total annual cost of calibration 5 x R1 940 = R9 700.

3.4 Maintenance of instruments

13 Instruments serviced once per annum

13 services @ 10 services per day = 2 man days (to nearest day)

Service contract, including equipment, spares and travelling: R 1 940 per day

Total annual cost of services 2 x R1 940 = R3 880.

3.5 Office space

1 Office for full time Assistant Water Pollution Control Officer: 9m^2

1 Office part time (20%) for Principal Water Pollution Control Officer: 2,4m^2

1 Office part time (20%) for admin support: 1,8m^2

Cost of office space @ R 30/m^2 per month = R 360/m^2 per annum

Total annual cost of office space 13.2 x R360 = R4 752.

3.6 Independent audits

An annual water quality data audit will require 100 days at R500/day equalling R50 000.

APPENDIX D

PRINTOUT OF THE MODEL

LIST OF TABLES IN APPENDIX D

Appendix D.1: Calcualtion of diffuse loads from mines for 1995/96

Input parameters

TDL: Total diffuse load calculated from monitoring data (t)
PPMR: Potential Pollution Mobilisation Rate for mine I of a specific type j (t/ha/a)
Area: Area of mining operation at mine I of specific type j (ha)

Calculated parameters

PMP: Potential Mobilisable Pollution = PPMRij*Areaij (t/a)
TPMP: Total PMP for the mine I = sum(PMPi); (t/a)
APPMR: average PMP for mine I = TPMP/sum(Areai)) (t/ha/a)
PPMRC: Corrected APPMR = APPMR * ratio of TDL to sum of TPMPs for all mines - MU4&MU6*

* Assumption: TDL is at B1H005, which excludes MU4&MU6 - Douglas, Middelburg & Greenside mines

Final result

PMPC: Diffuse load contributed by mine I =PPMRC* total area of the mine I (t/a)

Total diffuse load (TDL) in t/a = 32339

MINE	Method	PPMR	Area	PMP	TPMP	APPMR	PPMRC	PMPC
Kleinkopje	Opencast	1.5	1637	2456				
	Board&Pillar	0.15	3413	512				
	High Extract.	0.7	0	0				
mine total					2967	0.59	1.36	6884
Matla	Opencast	1.5	0	0				
	Board&Pillar	0.15	4044	607				
	High Extract.	0.7	484	339				
mine total					945	0.21	0.48	2193
Kriel	Opencast	1.5	1283	1925				
	Board&Pillar	0.15	2000	300				
	High Extract.	0.7	0	0				
mine total					2225	0.68	1.57	5160
Rietspruit	Opencast	1.5	1800	2700				
	Board&Pillar	0.15	153	23				
	High Extract.	0.7	0	0				
mine total					2723	1.39	3.23	6317
Douglas	Opencast	1.5	1221	1832				
	Board&Pillar	0.15	7663	1149				
	High Extract.	0.7	8	6				
mine total					2987	0.34	0.78	6928
Koornfontein	Opencast	1.5	78	117				
	Board&Pillar	0.15	3874	581				
	High Extract.	0.7	0	0				
mine total					698	0.18	0.41	1619
TNC	Opencast	1.5	243	365				
	Board&Pillar	0.15	1880	282				
	High Extract.	0.7	173	121				
mine total					768	0.33	0.78	1781
Syferfontein	Opencast	1.5	450	675				
	Bord&Pillar	0.15	53	8				
	High Extract.	0.7	0	0				
mine total					683	1.36	3.15	1584
Goedehoop	Opencast	1.5	11	17				
	Board&Pillar	0.15	3811	572				
	High Extract.	0.7	0	0				
mine total					588	0.15	0.36	1364
Tweefontein	Opencast	1.5	80	120				
	Board&Pillar	0.15	3807	571				
	High Extract.	0.7	0	0				
mine total					691	0.18	0.41	1603

Tavistock	Opencast	1.5	226	339				
	Board&Pillar	0.15	8755	1313				
	High Extract.	0.7	0	0				
mine total					1652	0.18	0.43	3833
Greenside and NCC	Opencast	1.5	181	272				
	Board&Pillar	0.15	3866	580				
	High Extract.	0.7	867	607				
mine total					1458	0.30	0.69	3383
Middleburg	Opencast	1.5	4580	6870				
	Board&Pillar	0.15	0	0				
	High Extract.	0.7	0	0				
mine total					6870	1.50	3.48	15937
Total			56641	25255	25255			58587

Appendix D.2: Calculation of Dsd

		1990/1	1995/6
Input data		1990/1	1995/6
WLC:	Price for water users =WLC (rmillion/a)	7.72	15.44
Nd:	Number of diffuse sources	9	15
Mc(1):	Cost for one monitoring station (R/mon)	8000	8000
Lp:	Load from point sources (incl releases) (t/a)	15597.0	23228.6
Ld:	Load from diffuse sources (t/a)	8595.6	58587.2
Calculated			
Mc:	Monitoring cost=Mc(1)*12*Nd*Ns/10^6 (R*10^6)	2.59	4.32
Final value			
Dsd:	(Mc*Lp+WLC*Ld)/(Ld*(WLC-Mc))	2.42	1.54
Assumptions:			
Ns:	Average of 3 stations required for each diffuse source.		3

Appendix D.3: Calculation of waste load charges.

D.3.1: Calculation of WLC for 1990/91

Input data

WLC:	Price for water users(R million/a)	7.72
Load(p):	point source load (t/a)	
Load(r):	release load (t/a)	
Load(d):	diffuse source load (t/a)	
Dsd:	Diffuse sources differential	1.54
O(Uwlc):	Initial Unit charge	72

Optimisation parameter

Oc:	Optimisation coefficient	0.269

Calculated parameters

Uwlc:	Unit cost =WLC/(Sum[(load(p)+load(r)]+Sum[load(d)*Dsd)]} (R/t)	267.54
WLC(m):	Charge for measured sources =Uwlc*[Load(p)+Load(r)]*Oc/12 (R/mon)	
WLC(d):	Charge for diffuse sources = Uwlc*L (d)*Oc*Dd/12 (R/mon)	

Final value

WLC:	initial monthly total WLC = Sum[WLC(m)+WLC(d)] (R/mon)	173135
Load:	Total Load = Load(p)+Load(r)+Load(d) (t)	24193

Assumption:

Load(m): Load from measured sources = Load(p) + Load(r)

Table 1: Output from WLC charges spreadsheet (1990/91).

MU	Source	Load(p)	Load(r)	Load(d)	WLC in R/month		
					WLC(m)	WLC(d)	WLC(t)
1	Trichard sw	47.3			284	0	284
	Syferfontein				0	0	0
2	Matla	5.8	134		839	0	839
	Rietspruit	18.1	549		3403	0	3403
	Kriel		102		612	0	612
	Matla ps				0	0	0
	Kriel ps		265.2		1591	0	1591
7	Kinross sw	72.2	0		433	0	433
	Kriel sw	48.2	0		289	0	289
	Krielt sw				0	0	0
	Albion				0	0	0
	Phoenix				0	0	0
	ATCOM				0	0	0
8	Transvaal Navigation	38.4		1750	230	16196	16427
	New Clydesdale				0	0	0
	Kleinfontein				0	0	0
	Sealby				0	0	0
3	Komati	21.2	448.9		2821	0	2821
	Douglas	32.8		167.3	197	1548	1745
	Koornfontein	0	0	0	0	0	0
	Goedehoop			790	0	7312	7312
	Blinkpan	14.9	41.2		337	0	337
4	Douglas			167.3	0	1548	1548
	Middelburg			0	0	0	0
	Duvha ps		60.5		363	0	363
	Duvha			1208	0	11180	11180
	Speekfontein				0	0	0
5	South Witbank				0	0	0
	Arthur Taylor				0	0	0
	Phoenix and sw	34.6	1468	2379	9016	22018	31033
	Tweefontein		96.7		592	0	592
	Kleinkopje				0	0	0
	Sondagsvlei				0	0	0
	Witbank Cons.				0	0	0
6	Witbank	218.9			1313	0	1313
	Greenside			682	0	6312	6312
	Landau		11842	829	71052	7672	78724
9	Vandyksdrift				0	0	0
	Wolwekrans				0	0	0
	Riverside				0	0	0
	Springbok and sw	35.1		623	211	5766	5977
	Total(excl Landau)	552.4	3167.5	7766.6	22530	71881	94411
	Total	587.5	15010	8595.6	93582	79553	173135

D.3.2: Calculation of WLC for 1995/96

Input data

WLC:	Price for water users (R million/a)	15.44
Load(p):	point source load (t/a)	
Load(r):	release load (t/a)	
Load(d):	diffuse source load (t/a)	
Total releases, excl Kl (t/a)		15604
O(Uwlc):	Initial Unit charge	72.0
Load (r), Kl:	Release from Kleinkopje (t/a)	6922

Optimisation parameters

Oc:	Optimisation coefficient	0.53
Dsd:	Diffuse sources differential	1.54

Calculated parameters

Uwlc:	Unit cost =WLC/{Sum[Load(p+r)]+Sum[Load(d)*Dsd)]} (R/t)	135.92
WLC(m):	Charge for measured sources =Uwlc*[Load(p)+Load(r)]*Oc/12 (R/mon)	
WLC(d):	Charge for diffuse sources = Uwlc*Load(d)*Oc*Dd/12 (R/mon)	
Load(r):	Release from each mine *i* (excl Kl) = Rload*Load(d)/[Sum[Load(d)]-Load(d) for Kl)	

Final value

WLC:	initial monthly total WLC = Sum[WLC(m)+WLC(d)] (R/mon)	681602
Load:	Total Load = L(p)+L(r)+L(d) (t)	81815.8

Assumptions:

1. Distribution of diffuse loads from DIFLOAD sheet:
   Douglas mined area split 50/50 between MU3 & MU4
   Tavistock group consists of Arthur Tylor & South Witbank mines, assume 50/50 split
2. For releases other than Kleinkopje mine assume distribution in releases in proportion to Load(d)
   Load(m): Load from measured sources = Load(p) + Load(r)

Table 2: Output from WLC charges spreadsheet (1995/96).

MU	Source	Load(p)	Load(r)	Load(d)	WLC(m)	WLC(d)	WLC(t)
1	Trichard sw	47.3			284	0	284
	Syferfontein	0	478.1	1584.3	2869	14663	17532
2	Matla	0.0	661.9	2193.1	3971	20298	24269
	Rietspruit	25.0	1906.4	6316.7	11588	58462	70050
	Kriel	0.0	1557.4	5160.4	9344	47760	57104
	Matla ps	0.0	0.0		0	0	0
	Kriel ps	0.0	0.0		0	0	0
7	Kinross sw	72.8	0.0		437	0	437
	Kriel sw	48.2	0.0		289	0	289
	Krielt sw	32.9	0.0		197	0	197
	Albion	0.0	0.0		0	0	0
	Phoenix	0.0	0.0		0	0	0
	ATCOM	0.0	0.0		0	0	0
8	Transvaal Navigatio	38.4	537.4	1780.7	3455	16480	19935
	New Clydesdale	0.0	0.0	0.0	0	0	0
	Kleinfontein	0.0	0.0	0.0	0	0	0
	Sealby	0.0	0.0	0.0	0	0	0
3	Komati	21.2	0.0	0.0	127	0	127
	Douglas	32.8	1045.5	3464.1	6470	32061	38530
	Koornfontein	0.0	488.7	1619.5	2932	14988	17921
	Goedehoop	0.0	411.8	1364.4	2471	12628	15098
	Blinkpan	0.0	0.0	0.0	0	0	0
4	Douglas	0.0	1045.5	3464.1	6273	32061	38333
	Middelburg	0.0	4809.8	15937.1	28859	147499	176358
	Duvha ps	0.0	0.0	0.0	0	0	0
	Duvha	0.0	0.0	0.0	0	0	0
	Speekfontein	0.0	0.0	0.0	0	0	0
5	South Witbank	0.0	578.4	1916.4	3470	17737	21207
	Arthur Taylor	0.0	578.4	1916.4	3470	17737	21207
	Phoenix and sw	34.6	0.0	0.0	208	0	208
	Tweefontein	0.0	483.8	1603.1	2903	14837	17740
	Kleinkopje	0.0	6922.0	6883.9	41532	63711	105243
	Sondagsvlei	0.0	0.0	0.0	0	0	0
	Witbank Cons.	0.0	0.0	0.0	0	0	0
6	Witbank	349.4	0.0	0.0	2097	0	2097
	Greenside	0.0	1021.0	3383.0	6126	31310	37436
	Landau	0.0	0.0	0.0	0	0	0
9	Vandyksdrift	0.0	0.0	0.0	0	0	0
	Wolwekrans	0.0	0.0	0.0	0	0	0
	Riverside	0.0	0.0	0.0	0	0	0
	Springbok and sw	0.0	0.0	0.0	0	0	0
	Total	702.6	22526.0	58587.2	139372	542231	681602

Appendix D.4: Calculation of Non-Compliance charges

Appendix D.4.1: Calculation of NCC for 1990/91

Input data

Load(p): point source load (t/a)
Load(r): release load (t/a)
Load(d): diffuse source load (t/a)
Ct: target SO_4 concentration (mg/l) - 50 & 95 pecentiles (mg/l)
C: measured SO_4 concentration (mg/l)- 50 & 95 pecentiles (mg/l)

Calculated parameters

Fex: exceedance factors for 50& 95 percentiles = 1+(C-Ct)/Ct and their average
NC load: Load of all releases and diffuse sources (t/a)
Uwlc: WLC unit cost for 1990 (R/t/a) 267.54

Final value

NCC: Charge for a source upstream of control point **i** (R/a)=Fex**i** *Unit cost*Ncload

Calculation for 1st control point (B1H021), MU7

Calculation of exceedance factor (Fex)

C(50%)	Ct(50%)	Fex(50%)	**Fex**
89	100	1.000	1.861
C(95)%	Ct(95%)	Fex(95%)	
381	140	2.721	

Table 3: Output from NCC spreadsheet for 1st control point(1990/91)

MU	Source	Load(p)	Load(r)	Load(d)	NC load	NCC(R/a)
1	Trichard sw	47.3			0.0	0
	Syferfontein				0.0	0
2	Matla	5.8	134.0		134.0	66706
	Rietspruit	18.1	549.0		549.0	273297
	Kriel		102.0		102.0	50777
	Matla ps				0.0	0
	Kriel ps		265.2		265.2	132019
7	Kinross sw	72.2			0.0	0
	Kriel sw	48.2			0.0	0
	Krielt sw				0.0	0
	Albion				0.0	0
	Phoenix				0.0	0
	ATCOM				0.0	0
	Total	191.6	1050.2	0.0	1050.2	522799

Assumptions:
If C<Ct then Fex =0

Calculation for 2nd control point (B1R001), MU9

Calculation of exceedance factor (Fex)

C(50%)	Ct(50%)	Fex(50%)	Fex
97	84	1.155	1.077
C(95)%	Ct(95%)	Fex(95%)	
116	155	1.000	

Table 4: Output from NCC spreadsheet for 2nd control point(1990/91)

MU	Source	Load(p)	Load(r)	Load(d)	NC load	NCC(R/a)
8	Transvaal Navigati	38.4		1750.0	1750.0	504418
	Kleinfontein				0.0	0
	Sealby				0.0	0
3	Komati	21.2	448.9		448.9	129390
	Douglas	32.8		167.3	167.3	48222
	Koornfontein				0.0	0
	Goedehoop			790.0	790.0	227709
	Blinkpan	14.9	41.2		41.2	11875
4	Douglas			167.3	167.3	48222
	Middelburg				0.0	0
	Duvha ps		60.5		60.5	17438
	Duvha			1208.0	1208.0	348193
	Speekfontein				0.0	0
5	South Witbank				0.0	0
	Arthur Taylor				0.0	0
	Phoenix and sw	34.6	1468.0	2379.0	3847.0	1108855
	Tweefontein		98.7		98.7	28449
	Kleinkopje				0.0	0
	Sondagsvlei				0.0	0
	Witbank Cons				0.0	0
6	Witbank	218.9			0.0	0
	Greenside			682.0	682.0	196579
	Landau		11842.0	829.0	12671.0	3652275
9	Vandyksdrift				0.0	0
	Wolwekrans				0.0	0
	Riverside				0.0	0
	Springbok and sw	35.1		623.0	623.0	179573
	Total	395.9	13959.3	8595.6	22554.9	6501200

Appendix D.4.2: Calculation of NCC for 1995/96

Input data

Load(p): point source load (t/a)
Load(r): release load (t/a)
Load(d): diffuse source load (t/a)
Ct: target SO_4 concentration (mg/l) - 50 & 95 pecentiles (mg/l)
C: measured SO_4 concentration (mg/l)- 50 & 95 pecentiles (mg/l)
Load(r): copied from Appendix D.3.2

Calculated parameters

Fex: exceedance factors for 50& 95 percentiles = 1+(C-Ct)/Ct and their average

NC load: Load of all releases and diffuse sources (t/a)
Uwlc: WLC unit cost for 1995 (R/t/a) 135.92

Final value

NCC: Charge for a source upstream of control point **i** (R/a)=Fex**i** *Unit cost*Ncload

Calcualtion for 1st control point (B1H021), MU7
Calculation of exceedance factor (Fex1)

C(50%)	Ct(50%)	Fex(50%)	**Fex1**
87	100	1	1.332
C(95)%	Ct(95%)	Fex(95%)	
233	140	1.664	

Table 5: Output from NCC spreadsheet for 1st control point(1995/96)

MU	Source	Load(r)	Load(d)	NCload	NCC
1	Trichard sw	0.0		0.0	0
	Syferfontein	478.1	1584.3	2062.5	373424
2	Matla	661.9	2193.1	2855.0	516927
	Rietspruit	1906.4	6316.7	8223.1	1488857
	Kriel	1557.4	5160.4	6717.8	1216314
	Matla ps	0.0		0.0	0
	Kriel ps	0.0		0.0	0
7	Kinross sw	0.0		0.0	0
	Kriel sw	0.0		0.0	0
	Krielt sw	0.0		0.0	0
	Albion	0.0		0.0	0
	Phoenix	0.0		0.0	0
	ATCOM	0.0		0.0	0
	Total	4603.8	15254.6	19858.4	3595523

Assumptions:
Douglas mined area split 50/50 between MU3 & MU4
Tavistock group consists of Arthur Tylor & South Witbank mines, assume 50/50 split
For releases other than Kl assume distribution in proportion to Load(d)

Calcualtion for 2nd control point (B1R001), MU9

Calculation of exceedance factor (Fex2)

C(50%	Ct(50%)	ex(50%	**Fex2**
154	84	1.833	1.794
C(95)	Ct(95%)	ex(95%)	
272	155	1.755	

Table 6: Output from NCC spreadsheet for 2nd control point(1995/96)

MU	Source	Load(r)	Load(d)	NCload	NCC(2)
8	Transvaal Navigati	537.4	1780.7	2318.1	565250
	New Clydesdale	0.0		0.0	0
	Kleinfontein	0.0		0.0	0
	Sealby	0.0		0.0	0
3	Komati	0.0		0.0	0
	Douglas	1045.5	3464.1	4509.6	1099628
	Koornfontein	488.7	1619.5	2108.2	514072
	Goedehoop	411.8	1364.4	1776.2	433106
	Blinkpan	0.0		0.0	0
4	Douglas	1045.5	3464.1	4509.6	1099628
	Middelburg	4809.8	15937.1	20746.8	5058976
	Duvha ps	0.0		0.0	0
	Duvha	0.0		0.0	0
	Speekfontein	0.0		0.0	0
5	South Witbank	578.4	1916.4	2494.8	608347
	Arthur Taylor	578.4	1916.4	2494.8	608347
	Phoenix and sw	0.0		0.0	0
	Tweefontein	483.8	1603.1	2086.9	508880
	Kleinkopje	6922.0	6883.9	13805.9	3366476
	Sondagsvlei	0.0		0.0	0
	Witbank Cons.	0.0		0.0	0
6	Witbank	0.0		0.0	0
	Greenside	1021.0	3383.0	4403.9	1073873
	Landau	0.0		0.0	0
9	Vandyksdrift	0.0		0.0	0
	Wolwekrans	0.0		0.0	0
	Riverside	0.0		0.0	0
	Springbok and sw	0.0		0.0	0
	Total	17922.2	43332.7	61254.9	14936583

Appendix D.5 Summary of charges

Table 7: Total catchment charges

Charge components (R	1990/91	1995/96
ACC	0.97	0.97
WLC	7.72	15.44
WLC(phase 1)	2.08	8.18
NCC	7.02	18.53
Total charge	**15.71**	**34.94**
Total charge(phase1)	**3.05**	**9.15**

Unit costs

ACC	39.9	11.8
WLC	267.5	135.9
NCC	297.6	228.5
Total	605.0	376.2

Appendix D.6:Calculation of monthly diffuse loads from mines for 1995/96 using rainfall data

Input parameters

TDL: Total diffuse load calculated from monitoring data

TPMP: Copied from Appendix D.1

MAP: Mean Annual rainfall for the area

Mrain: Monthly rainfall measured at the rainfall station nearest to mine

Calculated parameters

Load(adj): Monthly load = TPMP*Mrain/MAP

Load(cor): Monthly load corrected by measured value = LOAD(adj)*TDL/sum Load(adj)

Comparison with PMPC, annual loads from Appendix D.1

dif: difference as result of using rainfall data = (PMPC-sum[Load(cor)])/PMPC

TDL= 32319 (calculated from monitoring data)

MAP= 692

Table 8: Comparison of montly diffuse loads calculated with and without rainfall correction

MINE	Data	Oct	Nov	Dec	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Total	TPMP (t/SO4/a)	Load(adj)	Load(cor)	PMPC (t/SO4/a)	%dif
Kleinkopje	Mrain	63.9	193.5	258.0	117.5	241.8	118.8	57.4	0.0	0.0	14.5	7.1	0.0	1072.5	2967.5	4599.1	3633.0	3797.4	4.33
	Load(adj)	274.0	829.8	1106.4	503.9	1036.9	509.4	246.1	0.0	0.0	62.2	30.4	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	216.5	655.5	874.0	398.0	819.1	402.4	194.4	0.0	0.0	49.1	24.1	0.0	0.0	0.0	0.0	0	0.0	
Matla	Mrain	149.0	212.0	298.0	102.5	314.5	107.5	110.5	0.0	0.0	0.0	13.5	0.0	1307.5	945.4	1786.3	1411.1	1209.8	-16.63
	Load(adj)	203.6	289.6	407.1	140.0	429.7	146.9	151.0	0.0	0.0	0.0	18.4	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	160.8	228.8	321.6	110.6	339.4	116.0	119.3	0.0	0.0	0.0	14.6	0.0	0.0	0.0	0.0	0	0.0	
Kriel	Mrain	149.0	212.0	298.0	102.5	314.5	107.5	110.5	0.0	0.0	0.0	13.5	0.0	1307.5	2224.5	4203.1	3320.2	2846.7	-16.63
	Load(adj)	479.0	681.5	957.9	329.5	1011.0	345.6	355.2	0.0	0.0	0.0	43.4	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	378.4	538.3	756.7	260.3	798.6	273.0	280.6	0.0	0.0	0.0	34.3	0.0	0.0	0.0	0.0	0	0.0	
Rietspruit	Mrain	63.9	193.5	258.0	117.5	241.8	118.8	57.4	0.0	0.0	14.5	7.1	0.0	1072.5	2723.0	4220.2	3333.7	3484.5	4.33
	Load(adj)	251.4	761.4	1015.2	462.4	951.5	467.5	225.9	0.0	0.0	57.1	27.9	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	198.6	601.5	801.9	365.2	751.6	369.3	178.4	0.0	0.0	45.1	22.1	0.0	0.0	0.0	0.0	0	0.0	
Douglas	Mrain	63.9	193.5	258.0	117.5	241.8	118.8	57.4	0.0	0.0	14.5	7.1	0.0	1072.5	2986.6	4628.7	3656.4	3821.9	4.33
	Load(adj)	275.8	835.1	1113.5	507.1	1043.6	512.7	247.7	0.0	0.0	62.6	30.6	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	217.8	659.7	879.6	400.6	824.3	405.0	195.7	0.0	0.0	49.4	24.2	0.0	0.0	0.0	0.0	0	0.0	
Koornfontein	Mrain	63.9	193.5	258.0	117.5	241.8	118.8	57.4	0.0	0.0	14.5	7.1	0.0	1072.5	698.1	1082.0	854.7	893.4	4.33
	Load(adj)	64.5	195.2	260.3	118.5	243.9	119.8	57.9	0.0	0.0	14.6	7.2	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	50.9	154.2	205.6	93.6	192.7	94.7	45.7	0.0	0.0	11.6	5.7	0.0	0.0	0.0	0.0	0	0.0	
TNC	Mrain	63.9	193.5	258.0	117.5	241.8	118.8	57.4	0.0	0.0	14.5	7.1	0.0	1072.5	767.6	1189.7	939.8	982.3	4.33
	Load(adj)	70.9	214.6	286.2	130.3	268.2	131.8	63.7	0.0	0.0	16.1	7.9	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	56.0	169.6	226.1	103.0	211.9	104.1	50.3	0.0	0.0	12.7	6.2	0.0	0.0	0.0	0.0	0	0.0	

MINE	Data	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*April*	*May*	*June*	*July*	*Aug*	*Sep*	*Total*	*TPMP* (t/SO4/a)	*Load(adj)*	*Load(cor)*	*PMPC* (t/SO4/a)	*%dif*
Syferfontein	Mrain	149.0	212.0	298.0	102.5	314.5	107.5	110.5	0.0	0.0	0.0	13.5	0.0	1307.5	683.0	1290.4	1019.3	874.0	-16.63
	Load(adj)	147.1	209.2	294.1	101.2	310.4	106.1	109.1	0.0	0.0	0.0	13.3	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	116.2	165.3	232.3	79.9	245.2	83.8	86.1	0.0	0.0	0.0	10.5	0.0	0.0	0.0	0.0	0	0.0	
Goedehoop	Mrain	63.9	193.5	258.0	117.5	241.8	118.8	57.4	0.0	0.0	14.5	7.1	0.0	1072.5	588.2	911.5	720.1	752.7	4.33
	Load(adj)	54.3	164.5	219.3	99.9	205.5	101.0	48.8	0.0	0.0	12.3	6.0	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	42.9	129.9	173.2	78.9	162.3	79.8	38.5	0.0	0.0	9.7	4.8	0.0	0.0	0.0	0.0	0	0.0	
Tweefontein	Mrain	138.0	223.1	267.7	119.5	241.8	107.0	110.5	0.0	4.0	0.0	10.0	0.0	1221.6	691.1	1219.9	963.7	884.3	-8.97
	Load(adj)	137.8	222.8	267.3	119.3	241.5	106.9	110.3	0.0	4.0	0.0	10.0	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	108.9	176.0	211.2	94.3	190.7	84.4	87.2	0.0	3.2	0.0	7.9	0.0	0.0	0.0	0.0	0	0.0	
Tavistock	Mrain	63.9	193.5	258.0	117.5	241.8	118.8	57.4	0.0	0.0	14.5	7.1	0.0	1072.5	1652.3	2560.7	2022.8	2114.4	4.33
	Load(adj)	152.6	462.0	616.0	280.5	577.3	283.7	137.1	0.0	0.0	34.6	17.0	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	120.5	365.0	486.6	221.6	456.1	224.1	108.3	0.0	0.0	27.3	13.4	0.0	0.0	0.0	0.0	0	0.0	
Greenside and	Mrain	138.0	223.1	267.7	119.5	241.8	107.0	110.5	0.0	4.0	0.0	10.0	0.0	1221.6	1458.3	2574.4	2033.6	1866.2	-8.97
	Load(adj)	290.8	470.2	564.1	251.8	509.6	225.5	232.9	0.0	8.4	0.0	21.1	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	229.7	371.4	445.6	198.9	402.5	178.1	183.9	0.0	6.7	0.0	16.6	0.0	0.0	0.0	0.0	0	0.0	
Middleburg	Mrain	63.9	193.5	258.0	117.5	241.8	118.8	57.4	0.0	0.0	14.5	7.1	0.0	1072.5	6870.0	10647.5	8410.8	8791.5	4.33
	Load(adj)	634.4	1921.0	2561.4	1166.5	2400.5	1179.4	569.9	0.0	0.0	144.0	70.5	0.0	0.0	0.0	0.0	0	0.0	
	Load(cor)	501.1	1517.5	2023.3	921.5	1896.3	931.7	450.1	0.0	0.0	113.7	55.7	0.0	0.0	0.0	0.0	0	0.0	
Total															25255.3	40913.5	32319.0	32319.0	-2.55