The Economic Cost Effects of Salinity

SERVICES SECTOR

VOLUME VI

Urban - Econ

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Water Research Commission

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VOLUME VI

The Economic Cost Effects of Salinity

SERVICES SECTOR

by the

Urban-Econ

Report to the Water Research Commission and the Department of Water Affairs and Forestry on the project

Determining the impact of the salinisation of South Africa's water resources with respect to economic effects

Project Leader: Urban-Econ

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EXECUTIVE SUMMARY

1 PURPOSE OF THE STUDY

The Water Research Commission and the Department of Water Affairs and Forestry commissioned an investigation into the economic, social and behavioural impacts that would result due to changes in the salinity of South Africa's water resources.

The aim of the study was, primarily, to develop a generalised methodology model to determine the generic impact of changes in the total salt concentration found in South African rivers and to interpret these impacts in financial, economic and social terms. The resultant model was required to be:

i. comprehensive with respect to addressing the salinity problems
ii. applicable to any salinity situation in any water sector in South Africa.

An important role of the study was to verify the generalised model. This was achieved by applying it to a specific geographic area, namely the Middle Vaal River area. In order to achieve this, actual data gathering exercises were conducted and applied in the conceptual model. Based on this, a process of verification and model adjustments was undertaken, to incorporate the distinctive circumstances pertaining specifically to the Middle Vaal River area.

A generic model, making provision for all possible conceptual elements applicable to salinisation, has thus resulted. The model comprises separate equations representing the different sectors of the economy as well as the natural environment and water feeder systems. An outstanding feature of the model is that it is a generalised model and as such is applicable to any salinisation situation in South Africa.

The value of the study lies in applying the findings of the study in a policy environment. This means that the study results can provide motivation to formulate new policy directives for utilising water resources in a given area.

2 BACKGROUND TO STUDY

There has been a steady increase in the salt content of the Vaal River since 1935. This increase has accelerated markedly since 1965 with a further pronounced effect caused by the droughts prior to 1996. This increase in the salt content affects all water use components exposed to such water.

A major salinity problem exists in the Middle Vaal River area, between the Barrage and Bloemhof Dam. Various options for solving the problem have already been identified. All the options are, however, costly and it is important to quantify the benefits of a reduction in salt concentration in order to justify expenditure on measures to reduce the salinity.

3 OBJECTIVES

Prior to deciding how salinity in the water supply could be managed, it is necessary to determine the total cost of salinity to the economy, namely its direct, indirect and induced cost effects. Costs borne by the various sectors in the economy have to be determined, including the identification of behavioural impacts. The study addresses the impacts of increased level of salinity throughout the economy.

In order to address the uncertainties with respect to the economic implications of salinity, the Water Research Commission identified the need to develop a methodology that can be utilised in difficult salinity situations.

The project was divided into two phases:

- The development of a generalised methodology for the determination of the generic impact of salt concentration of South African rivers and the interpretation of these impacts.

- The application of the methodology to an investigation of the impact of increased salt concentration in the Middle Vaal River.

4 FORMAT OF RESULTS

The research conducted to determine the economic effects of salinity is based on a sectoral approach. The economy had been classified into different sectors and research was conducted separately for each sector. These results were integrated to determine the total economic effects on the economy. On account of the volume of research results, the sectoral research is presented in separate volumes to support the integrated results contained in the main report (Volume I).

Each of the sectoral reports, combining its initial inputs for the generalised model with its findings in the case study, has been separately bound. These are individually available as:

Volume II	:	Household Sector
Volume III	:	Agriculture Sector
Volume IV	:	Mining Sector
Volume V	:	Industrial Sector
Volume VI	:	Services Sector
Volume VII	:	Water Quality Analysis, Feeder Systems, Natural Environment.

As the main report is an integration and interpretation of the background research, variations may occur. The background research should be interpreted as the development of a reference framework by the different specialists and during the course of the study, research findings were continually refined.

5 STUDY APPROACH

The approach followed with the study is based on economic theory by conceptualising sectoral behaviour within the economy. In quantifying these conceptual formulae, surveys were undertaken in the Middle Vaal River study area to obtain the direct costs related to salinity. These direct costs represent only a partial estimate of the total costs of salinity. In order to determine the indirect costs and other spin-off effects, an integrated costing framework had to be set up. This was done by utilising the input-output (IO) technique and a combination of IO applications.

Despite the inherent limitations of the IO technique, it is a very versatile and flexible model to simulate real-world situations. Furthermore, its ability to determine the indirect and induced cost effects, renders the approach as well as the results unique and comprehensive.

The sectors analysed are households, agriculture, mining, industry, services and feeder systems, as well as the natural environment. Conceptual cost formulae were formulated to determine the direct costs and behavioural impacts on costs for different levels of salinity. Based on this background research to set develop these formulae, the research results indicated that both the feeder systems and the natural environment would not incur significant (incremental) costs within the specified salinity range of

200 mg/ℓ to 1200 mg/ℓ Total Dissolved Solids (TDS). These two sectors were therefore not incorporated into the integrated model.

Upon conducting surveys in the study area to determine the direct sectoral costs, a variety of problems was encountered. The most important of these is the fact that many respondents (i.e. sectoral water users) are not aware of the costs of salinity and therefore assigning costs to behaviour becomes rather presumptuous. Behaviour does, however, play an important role in the household and agricultural sectors. With the other sectors, behaviour is driven by technology and production factors.

The survey results obtained in the Middle Vaal River study area were analysed and transformed where necessary, to be integrated into the IO modelling framework. The following approaches were followed:

- Conducting a multiplier analysis that provides a first approximation of the additional costs of salinity due to a change in the TDS and using this to rank sectoral sensitivities with respect to the impact of salinity.
- Setting up a pricing model that simulated the cost increases of different levels of salinity in terms of price changes being passed on as price increases. These price changes are passed on as price increases to all sectors of the economy and can be interpreted as proxies for changes in the Consumer Price Index (CPI) and Producer Price Index (PPI).
- Running an augmented IO model to estimate total additional resource usage as salinity rises. To cost this, a new industry was postulated to enter the economy to combat salinity. A new row and column representative of this industry was inserted into the IO table.

Each of these approaches focused on a different aspect in determining the total cost effects of different levels of salinity.

6 INTERPRETATION OF RESULTS

The results obtained with the IO analyses indicated that the total costs of salinity are significant in the Middle Vaal River study area.

6.1 Direct Cost Effects

The direct costs of salinity to the entire economy of the case study area are established from the mathematical combination of the survey data collected within each individual sector. There are constraints with much of the data, since most interviewees were unable to supply data for any conditions other than those currently being experienced and were generally rather uninformed about salinity and its potential effects.

Despite the drawbacks, the data provided some indication of the direct economic effects of increased salinity. The collected data was centred around 500 mg/ℓ which is the average salinity level presently experienced in the study area. Data for salinity levels below 500 mg/ℓ implies a corresponding saving at these lower salinity levels. A 100 mg/ℓ increase in the TDS to 600 mg/ℓ is expected to effect a R26 million increase in annual direct costs in the study area (refer to Table 1). Increasing the TDS to the highest limit (1200 mg/ℓ) is expected to result in a direct cost of R183 million/a to the region. Conversely, a saving of R80 million/a is anticipated should the salinity drop from current levels to 200 mg/ℓ.

Table 1. Direct Costs of Salinity, (1995 Values in Millions of SA rands)

SALINITY / SECTOR	mg/ℓ TDS						% Contribution at 600 mg/ℓ
	200	400	600	800ℓ	1000	1200	
Mining	(7.309)	(2.212)	0.844	4.863	10.209	17.816	3.17
Business and Services	(1.843)	0.487	1.211	1.707	2.209	2.697	4.55
Manufacturing 1	(0.145)	0.028	0.086	0.123	0.160	0.198	0.32
Manufacturing 2	(2.825)	0.294	1.351	1.993	2.635	3.278	5.07
Agriculture	0.000	0.000	0.439	0.439	0.427	0.503	1.65
Households (suburban)	(35.121)	(11.707)	11.707	35.121	58.535	81.949	43.94
Households (township)	(27.927)	(9.309)	9.309	27.927	46.544	65.162	34.94
Households (informal)	(5.081)	(1.694)	1.694	5.081	8.469	11.855	6.36
TOTALS	(80.251)	(24.113)	26.640	77.253	129.225	183.457	100.00

In considering these direct cost changes the effects can be equated to changes in prices in the economy. The percentage direct impact of salinity abatement on CPI and PPI at a salinity level of 600 mg/ℓ TDS, amounts to 0.0013% and 0.0016% respectively. In effect this implies a relatively small change in these indices which can be equated to changes in inflation.

The greatest direct cost implications occur to the household sector. The direct costs to the households comprise approximately 85% of the total direct costs within the economy under investigation. This is not unexpected, since the household sector comprises the largest group of treated water users in the economy even though the per capita cost increases are not the highest. Conversely, the sectors that use very little water and those using predominantly untreated water are expected to have lower direct cost effects.

Manufacturing 1, where water requires no treatment, has a relatively low water consumption and experiences less than 0.5% of the direct cost of salinity increases at 600 mg/ℓ. By way of contrast, business and services, a relatively large sector within the economy, can be attributed with 4.5% of the total direct costs, while Manufacturing 2 (which treats its water) will face cost increases owing to the costs of treatment. Thus, unsurprisingly, this latter sector experiences 5% of the direct costs to the economy.

Although the mining sector uses large volumes of water in terms of production, much of the water employed is used in re-circulating circuits. Further, this water does not, in general, require a high degree of purification and thus the costs are lower than might otherwise be expected (3%).

Similarly, most of the water employed in the agricultural sector is drawn directly from the river itself. The water costs to agriculture are low, and agriculture is a small sector, occupying a fairly narrow band along the Vaal River. Thus, agriculture occupies a small niche in the economy and its contribution of 1.5% of the total direct costs of the study region, is not unexpected.

6.2 Indirect and Induced Effects

The models employed for the case study calculated the direct, indirect and induced costs to the economy. Since the IO table was closed with respect to households, an allowance was made for the *reciprocal relationships between income and consumption, as well as the impact on the economy,* resulting from the interdependence of industries in their production process and the behaviour of households. The closing of the IO table effectively added another industry to the economy. Households have a large impact on the economic processes in the region of study and wider, resulting in the expectation of larger impacts than would have been anticipated if the table had been in its open format, considering direct and indirect effects alone.

Ratios of the direct, indirect and induced costs to the direct costs (Direct Cost Multipliers, DCM) determined by means of the multiplier analysis, range from 1 to about 3.3. This implies that the spin-off effects of increased salinity are significant and the direct costs alone are a poor reflection of the cost impacts of salinity.

The ranking of the sectors researched, based on the salinity multipliers, indicates that at relatively low levels of salinity it is the community and other service sectors which will be most adversely affected. At high levels of salinity the gold mining sector will have to incur the highest cost to combat salinity.

The results of the pricing model are expressed in terms of percentage changes in the consumer and producer price indices and essentially represent forward linkages. The impacts have been determined in terms of regional and national impacts. Considering only the impact on the productive sectors, results of the same order as the multipliers provided are found, but with less spread. The direct and indirect DCMs for PPI and CPI are found to lie between 1.36 and 1.84, whilst the direct, indirect and induced DCMs are found to lie between 1.96 and 3.5. It should be noted that the pricing model results indicate variables for a base year expressed in percentages. This implies annual changes in costs or prices.

The percentage total increases in CPI and PPI for salinity levels increases from 600 mg/ℓ to 1200 mg/ℓ can be summarised as indicates in Table 2:

Table 2: Percentage increase in price indices

Salinity abatement by :	CPI: % change	PPI: % change
Productive sectors	-0.008 to 0.01	-0.01 to 0.015
Productive sectors & households	-0.1. to 0.22	-0.11 to 0.26

These changes seem to be small but are significant when related to Rand values in regional and national context. This had been done and the regional and national annual impacts are summarised as indicated in Table 3:

Table 3: Impacts on price indices

IMPACTS	CPI	PPI
National increase		
600 mg/ℓ	R101.5m	R402.6m
1200 mg/ℓ	R647.5m	R2623.4m
Regional increase		
600 mg/ℓ	R7.4m	R18.0m
1200 mg/ℓ	R47.1m	R117.3m

The augmented model was executed using both regional and national IO tables to determine the total cost effects of salinity abatement. Multipliers were calculated for comparison with the other model applications.

The chief outcome was that the DCM was 3.0 for the national case, and 2.6 for the regional case. These figures did not change significantly over the salinity range of 600 mg/ℓ to 1200 mg/ℓ TDS. The difference in the national and regional DCM is due to the differences in structure between the national and the regional economies. Since the IO analysis is based upon coefficients, the actual size of the economies has no influence on the DCMs. Only changes in the size of the input (or technical) coefficients (which in turn reflects a change in the structure of the tables) would influence the outcome.

6.3 Behavioral Effects

The decisions regarding salinity changes made in the mining, business and services and the manufacturing sectors tend to be driven by technology and production regimes. These sectors are likely to make changes to combat the effects of salinity, based purely on the financial implications to the concern. As a result, there are few, if any, unexpected responses to salinity effects and the calculated costs can be accepted as reliable.

During the data collection in the agricultural sector, the cost effects of two possible scenarios, based on management decisions or behaviour, were established. These included a "best case" scenario, where the farmer would 'maintain the current levels of production, regardless of cost, and a second scenario, where the farmer would choose to allow the crop yields to be reduced. This was only done for the hybrid model and the overall costs to the economy were found to be hardly affected by the two alternatives. At the 600 mg/ℓ level, the total costs decrease by less than R0.3 million. The variations are found to be between 0.1% and 0.3% of the overall costs, which are less significant than the probable errors in the data. Thus, the different behavioural responses available in the agricultural sector are unlikely to impact on the total costs to the economy.

The most significant behavioural effects are, however, from the household sector. The responses to increased salinity, while to some extent determined by the need to adapt to the changes, are largely driven by the availability of finances to maintain the *status quo* and overcome the problems arising from increased salinity. These behavioural responses are more likely to appear in those sectors of lower earning potential, and the informal household sector is far less likely to effect changes arising from increased salinity than suburban households. This is borne out by the variance in the data collected.

7 CONCLUSIONS

Based on the output from the model established for the Middle Vaal River region, the economic costs attributable to changing salinity, have been determined.

There exists an effective limit to the cost of salinisation. This is determined by the cost of desalinating the bulk water supply which would represent the most costly option of water treatment. Care must be taken not to allow the costs of salinisation to reach high levels. The viability of desalinating may be increased if selective desalination is applied to the consumer sectors incurring the highest relative costs, although other options should be explored first.

This is obviously a simplistic first-line approach, but it highlights the need to consider bulk or partial treatment of the water supply in the Middle Vaal area as the *status quo* is already 500 mg/ℓ. Behavioural response is particularly important as the quality of the water in the area is already perceived to be problematic.

The results of the study identified the total economic effects of increased salinity levels for the Middle Vaal River area. Based on these findings and the knowledge gained with respect to behaviour, the following observations are made:

- The application of the generic model in the Middle Vaal River area was accompanied by some limitations mainly on account of the undiversified economic structure. Undiversified, in this regard, refers to the strong reliance of the economy on the mining and services sectors. Despite this, very significant information could be obtained on the relative importance of cost effects between the various sectors. To validate these, the model should be applied in a diversified economy such as that of the Gauteng area. More insight concerning relative costs could be obtained on, for instance, the manufacturing sector.

- Differential desalination may be considered. The reason for this is that the household sector has been found to bear relatively high costs in terms of combating salinity, followed by the industrial and services sectors. It may be of value to motivate differential desalination of waters on a purely experimental basis, that is, to study the social and socio-economic benefits to be gained by households if the costs of salinity are decreased. This also implies that sectors that experience relatively low salinity costs may have to continue bearing these.

- It may benefit water users if a salinity awareness campaign were introduced. If end users were made aware of the cost effects, they might choose to behave differently and take informed decisions which may lessen the costs of salinity.

- A specialised database has been established. As part of an awareness campaign, users can contribute towards the refinement and extension of a more comprehensive database that can be utilised when the model is applied elsewhere. Since the availability of the data determines to a large extent the robustness of the model, such a database can contribute significantly to the ease of applying the model.

The interpretation of the findings of this study does not take into account alternative options with respect to water provision. This implies that the costs of salinity have not been related or compared to the situation of utilising transfer water and other allocation options. Furthermore, the results of the study are expressed in direct and spin-off effects and thus any further interpretation or comparison of these results with specific options, should be done in the same manner, namely to refer to total costs.

8 FURTHER RESEARCH

The value of the study lies in the fact that a first approximation of the spin-off effects of salinity on the economy had been determined. Furthermore, an indication of the behavioural costs for specific sectors has been obtained. On account of the specific study area chosen and the difficulties encountered in applying an integrated economic cost model to its specific considerations/circumstances, the following shortcomings may be addressed with further research:

- Application of the model in a relatively diversified economy such as that of Gauteng. In doing this, a more disaggregated model can be executed. Cost effects for more subsectors may then be identified, such as for the leather industry. Based on expectations the total costs of salinity may be higher.

- In applying the model to a chosen study area more significant costs may be identified if the study population is made aware of the problem in advance. The benefits arising from this approach, namely more accurate cost estimates and possibly more correct reporting of behaviour, could outweigh potentially over-reporting, due to increased awareness of the problem.

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The Steering Committee responsible for this project, consisted of the following persons

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1. INTRODUCTION

1.1. PURPOSE

The purpose of this report is to develop a generalised methodology for the determination of the generic cost impact of salinity and applying this in a case study in the Middle Vaal River Area for the services sector. This report (Volume VI) and analysis form part of a larger study to determine the total cost impact of salinity on the Middle Vaal River Area. The main findings of the study are presented in an integrated report (Volume I).

This report (Volume VI) contains the detail information related to the integrated model and study approach for the services sector in developing conceptual formulae to determine the economic costs of salinity.

The study consists of two distinct phases, although the results have been integrated into a single report. The first component refers to the conceptualisation of the costs and behaviour with respect to salinity, whereas the second component tests the formulae in the Middle Vaal River Area.

1.2. SERVICES SECTOR IN PERSPECTIVE

The services sector consists of commercial and recreational activities including retail and business concerns, government services and offices. Recreational concerns such as hotels, resorts and other profit motivated concerns are included under the commercial category. Non-economic recreational activities such as swimming, angling, etc are included under recreation.

The services sector is not a very intensive water user, except with specific applications such as a car valet service concern. What is important, however, is that it is a relatively large sector representing a substantial component of the economy.

1.3. CONTENTS OF REPORT

Apart from this introductory section the rest of the report consists of the following sections :

2 : Conceptual Framework
3 : Case Study
4 : Data Analysis
5 : Input Data for Modelling
6 : Conclusion

2. CONCEPTUAL FRAMEWORK

2.1. ORIENTATION

The purpose of this section is to formulate a conceptual framework which can be used to model the cost implications of increased levels of salinity in water. In doing so, it is necessary to review existing literature as well as to apply and utilise specialised expertise in conceptualising the services sector's behaviour due to increased salinity.

This approach suggests that cost formulae are constructed which take cognisance of all quantifiable items as well as behavioural aspects related to salinity. As with any other modelling process, assumptions underline the approach and specific conditions influence the results.

2.2. IMPACT OF WATER QUALITY CONSTITUENTS

This section aims at providing an overview of the potential impact of salinity and specific water constituents related to salinity, on the services sector.

An account of the diversity of the services, ie, referring to both economic and non-economic activities, the water quality constituents impacting on the services sector can be distinguished into two groups. This implies that water quality constituents impacting on service and business activities will be discussed as well as water quality constituents impacting on water used for recreation.

2.2.1. Constituents Impacting on Commercial Activities

i. Electrical Conductivity

The Total Dissolved Solids (TDS) concentration is an important water quality constituent for services. It gives an indication of the concentration levels of a number of important constituents and properties. These are intimately involved with water quality related problems such as scaling, corrosion and sedimentation. Since electrical conductivity measures the concentration of the TDS of a water, albeit imprecisely, it is a rapid and convenient method to monitor TDS levels in the water supply. Such monitoring allows services to control their water conditioning processes in order to keep scale and corrosion problems to a minimum more efficiently. TDS is also a key factor in steam purity generated in high pressure boilers. Increasing TDS makes it more difficult to treat the water supply to meet the requirements for boiler-feed water.

As a general rule for most South African fresh waters, the approximate TDS can be calculated from electrical conductivity according to the following formula:-

TDS (mg/ℓ) = electrical conductivity (mS/m) x 6.5

To remove excessive salt content, and thus reduce the electrical conductivity of a water source, several treatment options are available. These depend on what salts must be removed and the degree of purity required. Some of the more common methods of demineralising or desalinating water are distillation, ion exchange, electrodialysis and reverse osmosis.

ii. pH

Although pH is one of the most frequently measured water quality properties, pH on its own is seldom a problem. However, pH is involved in nearly every phase of water supply and waste water treatment, and is often a vital factor in various processes.

pH gives an indication of the acidic (pH < 7) or basic (pH > 7) nature of the water.

The pH of the incoming water is normally adjusted to the required pH by dosing the process water with acid or alkali, whichever is appropriate.

iii. Suspended Solids

Suspended solids (or total suspended matter) are a measure of the organic and inorganic particulate matter in water. It contributes to the formation of sediment deposits commonly found in boilers, heat exchange systems and in pipelines.

Removal of suspended solids from water is conventionally achieved through coagulation and flocculation with mixing, followed by sedimentation and filtration. Various designs of mixing basins, sedimentation tanks and filter beds are available to clarify the water supply.

iv. Total Hardness

Wherever water is heated either for heating purposes, steam production or in the cooling process, scaling is one of the major problems. The main source of scaling in heat exchange equipment is hardness. Scaling is, however, not the only problem associated with hardness.

A certain degree of calcium hardness may inhibit corrosion by forming a thin protective layer on the metal surface, and water with a hardness concentration greater than 50 mg/ℓ prevents concrete dissolution.

Calcium and magnesium are regarded as the principal components of hardness. Other metals making a minor contribution to hardness include iron, strontium and manganese. Scale forming from temporary hard waters, when the alkalinity is greater than or equal to the concentration of calcium and magnesium, is primarily calcium carbonate and magnesium hydroxide, while scale forming from permanently hard water low in alkalinity is primarily sulphates and chlorides.

Two modern techniques are applied to hard waters in order to soften them. In the lime-soda process, both lime and soda are added to the water to remove the calcium and magnesium salts. The second technique uses ion exchange principles to soften the water. Calcium and magnesium ions are exchanged for sodium in cation exchange columns. Boiling can soften temporary hardness, while both temporary and permanently hard water can be softened by the addition of sodium carbonate.

v. Alkalinity

Alkalinity is an important consideration as it has a number of undesirable consequences such as increasing the scaling tendency of water. The severity of scaling depends on the bicarbonate alkalinity and the calcium hardness of the water, while the rate of scaling is dependant on the temperature and pH of the water.

On the other hand, a certain degree of alkalinity is desirable in waters since, under the right conditions, calcium carbonate acts as a corrosion protector by forming a thin layer which shields metal surfaces.

The alkalinity of a water supply is corrected by chemical dosage, either by adding lime or sodium carbonate to raise the alkalinity, or by bubbling carbon dioxide into the water to reduce the alkalinity.

vi. Summary

The various water quality constituents mentioned here are considered to be the most significant with respect to the modelling of costs of salinity (or total dissolved solids). Other water quality constituents such as organic matter and bacteria may have more profound cost implications in terms of treatment but the focus of this study is on total dissolved solids (TDS), ie salinity.

2.2.2. Constituents Impacting on Recreation

Water needs to be fit for recreational use, based on specific norms and values. These norms and values may differ substantially depending on the actual extent of contact, if any, with water. Furthermore, it can also be influenced by cultural and social factors. A body of water may be considered fit for recreational use if it is aesthetically pleasant, does not give rise to adverse health effects and does not pose a safety hazard to recreational water users. This implicity includes the requirement of healthy aquatic ecosystems, which is an important aspect in terms of the growing economic importance of eco-tourism in South Africa. Water quality guidelines for recreation have been obtained from the South African Water Quality Guideline (1993) and used as a basis. The aim is to describe the effects of water quality on recreational water users. This requires the identification of norms in terms of which effects on users may be characterised and water fitness for use may be evaluated. Norms were identified on the basis of problems experienced by recreational water users as a result of water quality.

* ***Effect on human health and safety***

Health and safety effects comprise the primary norm by which fitness of water for contact recreational use is measured. This applies to substances or organisms that are known or suspected to have adverse health effects. Several types of health effects may occur. Microbial contaminants can cause infectious diseases and surface infections (e.g. skin and ear infections). Chemical contaminants are associated with skin irritations and acute and chronic toxic effects. Acute effects are those which occur immediately after exposure and response is associated with chronic effects. Chronic effects may include carcinogenicity and require prolonged exposure. These effects are also the most difficult to estimate and control. Human health also includes the aspect of safety. Swimmers and other recreational water users should not be in danger of physical harm such as entanglement or injury as a consequence of their activities. A level of zero health effects is difficult both to achieve and to measure or control. However, it is essential that recreational water quality is managed to minimise all known and anticipated health risks.

* ***Effects on aesthetic appreciation of water bodies.***

A number of factors may affect the aesthetic acceptability of recreational waters, including odour, refuse, oil films and nuisance plants. This becomes the primary consideration in determining the fitness of water for recreational use if little or no contact recreational use is foreseen. Aesthetic considerations are also of importance in maintaining the economic value of waterfront properties.

Factors affecting the natural environment, e.g. specific requirements of fish species, are important to recreational water use insofar as they determine whether the environment is pleasant and healthy. These factors are not dealt with here.

What needs to be clarified at this point is that this study focuses on the salinity content of the water and therefore many of the constituents can only an indirect effect of the specific TDS levels and not considered for inclusion of the model.

Water quality constituents relevant to recreation have been obtained from the South African Water Quality Guidelines (1993) and are discussed.

Recreation is not considered to be an economic sector, although some indirect cost may be experienced by economic sectors as a result of increased levels of salinity.

i. Clarity

Clarity refers to the depth to which light can penetrate in the water body. Lack of clarity is frequently associated with turbidity. Turbidity is a measure of suspended material, such as clay, sand, silt, finely divided organic and inorganic matter, plankton and other micro-organisms. Clarity and turbidity together pose a danger for swimming since potentially hazardous objects and shallow bottoms may be obscured. Swimmers should be able to see when swimming under water.

Ideally, recreational water should have a low turbidity and colour. The lower the turbidity the higher the clarity of recreational water, the more desirable it becomes for swimming and other water contact sports. Studies on user perceptions of recreational water have shown that clarity and turbidity play a significant role in judgement of the safety or suitability of water for swimming. Clear water is generally aesthetically more pleasing than water that is not clear. There is also possible health risks from micro-organisms which may be associated with suspended particular matter.

ii. Colour

Colour in water is an important constituent in terms of aesthetic considerations. The acceptability of colour in recreational water is extremely subjective. However, it is of aesthetic importance and intense colour is likely to be aesthetically objectionable. This is particularly true if the colour is "non-natural", e.g. if a dye or coloured effluent is discharged by textile or chemical industries. To be aesthetically attractive, water should be virtually free from substances which produce objectionable colour. Objectionable colour is defined to be colour which is of significantly greater intensity than natural background levels. This is especially important to those who gain pleasure by viewing water in its natural state. The aesthetic attributes of water depend on appreciation of the water setting.

iii. Floating matter / refuse

The presence of floating and shoreline litter and other floating matter of human and natural origin detracts from aesthetic enjoyment of water bodies. Submerged refuse also represents a danger to recreational water users.

iv. Odour

Odours associated with recreational water detract from aesthetic appreciation of water bodies and are perceived to indicate the presence of pollutants. Complaints concerning odour of water are often a useful guide to the suitability of waters for recreational use.

v. Chemical irritants

The presence of chemicals in recreational water, at concentrations which can cause irritant effects in humans or which are toxic if ingested in small amounts, interferes with all forms of recreational water use which entails water contact. Absorption of potentially toxic chemicals through the skin is another possible effect associated with chemical irritants in recreational water (NAS/NAE, 1973, Australian Guidelines, 1990; Hart *et al*, 1992 as quoted in the South African Water Quality Guidelines, 1993).

Contact recreation is characterised by bodily immersion or submersion where there is a direct contact with the water and includes activities such as swimming, diving, water skiing and surfing. People engaged in contact recreation may swallow quantities of water and absorb toxic chemicals through the skin. The amount of water accidentally swallowed may vary considerably but probably does not exceed 100 $m\ell$ for any individual per recreational event. The human body is capable of tolerating greater concentrations of most chemicals upon occasional content with, small quantities of water than are most forms of aquatic life. High concentrations of chemicals may cause skin or mucous membrane irritation.

vi. pH

The pH of a solution is the negative logarithm of the hydrogen ion concentration, according to the expression :

$$pH = -\log_{10}[H^+]$$

where H^+ is the hydrogen ion concentration.

At pH < 7 water is acidic, while pH > 7, water is alkaline. The pH of most natural waters lies within the range 6.5-8.5.

The pH of a water does not indicate ability to neutralise additions of acids or bases without appreciable change. This characteristic, termed buffering capacity, is controlled by the amounts of acidity and alkalinity already present.

Extreme deviations in pH from the target guidelines range cause irritation of eyes of swimmers and other contact recreational water users. The lachrymal fluid (tears) of the eye has a normal pH of approximately 7.4, which is maintained within a narrow range by complex organic buffering agents. When the buffering capacity of these agents is exhausted, the lachrymal fluid becomes unable to adjust the immediate contact layer of another liquid and eye irritation results. A pH change of as little as 0.1 in the lachrymal fluid can cause irritation, and greater change can cause severe discomfort and pain. Ideally, water used for contact recreation should be as close to pH 7.4 as possible. However, a wider range can be tolerated due to the action of the lachrymal fluid buffering agents. Extreme pH can also cause discomfort and irritation of the ears, skin and mucous membranes.

The pH of recreational water has no direct aesthetic effect, but may cause an indirect effect, e.g. by triggering changes in the colour or odour of chemical which may be present in the water.

vii. Summary

The discussion of the water constituents points to the fact that salinity per se is not as important as other aspects in causing negative effects on the recreation sector.

2.3. COMPILATION OF FORMULAE

The purpose of this section is to compile cost formulae for the services sector. Each sector will be discussed separately in terms of assumptions and cost formulae.

The services sector includes recreational and commercial activities. Although these activities are grouped into one category they are diverse with respect to water use.

Recreational concerns such as hotels, resorts and other profit motivated concerns are included under the commercial category, namely business and offices. All other non-economic activities, namely swimming, etc. are included under recreation.

2.3.1. Commercial Formula

The commercial sector is a relatively large sector in terms of the number of concerns. On account of this the amount of water used is quite extensive although only a limited number of concerns are actually intensive water users.

Water is mainly used for non-production purposes, ie. washing, cleaning and human consumption.

2.3.1.1. <u>Definition and conditions</u>

* Commercial sector is driven by profit motivation and includes offices, retail and business concerns
* Water usage is relatively similar to households
* Water supply needs to be potable as minimum standard
* Water is utilised for drinking, washing and specific retail applications
* Water systems may be subject to a relatively higher degree of corrosion and scaling due to periodic non-utilisation of water (week-ends)
* Electrical conductivity - indication of dissolved salts, ie TDS content.
  - low concentrations - nutritional value
  - high concentrations - undesirable aesthetic or economic treatment effects
  - 0-450 mg/ℓ TDS - no health, aesthetic or economic treatment effects (>300 mg/ℓ- tastes salty)
  - 450-1000 mg/ℓ TDS - tastes salty but is tolerated
  - 1000-2000 mg/ℓ TDS - marked salty taste and will not be used on aesthetic grounds if alternatives are available. No short term adverse health effects; effects on economics of treatment and distribution
* Odour - potable water should have no odour
  - may originate from stagnant water conditions in low-flow sections of distribution systems
* pH - range between 6.0 - 9.0 -no significant effects on health or aesthetics

* Total hardness - cause problems with respect to the lathering capabilities of soap and scale on heat exchange surfaces.
  - implication on health - aesthetic
  - should be limited to 100 mg/ℓ $CaCO_3$

2.3.1.2. Assumptions

* Potable water supply from municipalities

2.3.1.3. Formulae

S	=	(I; B)
I	=	f(W)
W	=	f(U; C)
U	=	f(H; Q)
C	=	f(H; Q)
(H; Q)	=	f(water use, treatment, capital equipment, maintenance)
B	=	f(T; M)

Where

S	=	services - commercial
I	=	inputs
B	=	behaviour
W	=	water use
U	=	utility
C	=	consumption
H	=	amount of water
Q	=	quality of water - potable
M	=	management

2.3.1.4. Application

Utilisation of water requires a specific water quality which implies a specific cost. In most cases potable water is supplied and adequate to be used by commerce. A change in quality may lead to unacceptance which will again have cost implications in terms of treatment or alternatives.

2.3.1.5. Specification

The functional relationship of the commercial sector is based on water quality requirements of the purpose for which water is used. Based on the nature of this sector, water quality requirements relate to that of potable water, which coincides with that of the domestic sector.

Users may experience a range of impacts as a result of changes in water quality. These may be categorised as follows :

- health impacts (short term and long term)
- aesthetic impacts, which may include
  - changes in water taste, odour and colour
  - staining of laundry or household fittings and fixtures
- economic impacts, which may include
  - increased cost of treatment
  - increased cost of distribution due to scaling, corrosion, and deposition of sediments in the distributing system
  - scaling or corrosion of household pipes, fittings and appliances.

The casualty of the functional relationship leads from sublements to the cost of water expressed in Rands. The sublements to be quantified are the following :

•	H	=	amount of water used : m^3 water
		=	cost of water in Rands
•	Q	=	quality of water
		=	mg/ℓ TDS
		=	minimum quality requirements for potable water
		=	cost of treatment / alternatives
		=	Rand
•	M	=	management decisions
•		=	capital return rate of management
		=	bench-mark where treatment or alternatives are introduced
		=	probabilistic interval

The cost of increased salinity for the utility water is as follows :

$$\textbf{Cost} = \left| TDS_{thres} - TDS \right| (TDS/TDS_{curr} \times V) + \left| TDS_{thres} - TDS \right| (TDS/TDS_{curr} \times M) + (TDS/TDS_{curr} \times C) + \left| TDS - TDS_{thres} \right| P$$

where : TDS_{thres} = threshold where capital expenditure would be required for larger or altered plant

TDS = new /anticipated TDS conditions

TDScurr = currently acceptable TDS conditions

V = volume of water currently used

C = cost of treatment chemicals currently incurred

M = current costs of maintenance and replacement

P = capital cost for plant, dependent on size, site etc.

Note : Δ | TDS | = modular function = 0 if <0 and 1 if 0

The water quality requirements are the following :

Electrical conductivity range mS/m (mg/ℓ TDS)	Effects
Target guideline range 0 - 70 (0 - 450)	No health, aesthetic or treatment effects associated with the electrical conductivity of water are expected below 45 mS/m (300 mg/l TDS). the taste threshold for dissolved salts in water is in the regions of 45 mS/m (300 mg/l TDS), hence a slight salty taste may be detected above this concentration. The upper limit of this range takes into account the higher water consumption which may be expected in hot climates (Kempster and Smith, 1985; Aucamp and Vivier, 1990; Kempster and van Vliet, 1991).
70 - 150 (450 - 1 000)	Water has a noticeable salty taste, but is well tolerated in terms of health, aesthetic and treatment factors (Kempster and van Vliet, 1991).
150 - 300 (1 000 - 2 000)	Water has a marked salty taste and would probably not be used on aesthetic grounds if alternative supplies are available. Consumption of water does not appear to produce adverse health effects in the short-term (Kempster and van Vliet, 1991). Some effect on economics of treatment and distribution, such as increased corrosion and scaling, may be expected.
300 -450 (2 000 - 3 000)	Water tastes extremely salty. Short-term consumption may be tolerated, but with probable disturbance of the salt balance (Kempster and van Vliet, 1991). Corrosion or scaling of pipes and equipment will increase.
>450 (>3 000)	Water tastes extremely salty and unpleasant. Short-term consumption leads to disturbance of the salt balance (Kempster and van Vliet, 1991). At high concentrations, noticeable short-term health effects may be expected. Economic effects such as corrosion or scaling increases.

Source : SAWQG, 1993

2.3.2. Recreation Formulae

2.3.2.1. Definition and conditions

* Change in water quality lead to problems with regard to :
  - health and safety of water users in contact with water
  - aesthetic appreciation of water
* Constituents of relevance are
  : aesthetic - colour, floating, odour, clarity
  : physio-chemical - chemical irritants, pH
* Body of water is fit for use if - aesthetically pleasant
  - not adverse effects on health
  - not pose safety hazard

* Aesthetic appreciation (little or no contact)
  - influenced by odour, refuse, oil films, nuisance plants
  - maintenance of economic value of waterfront properties
  - factors affecting natural environment determine environment being pleasant and healthy
* Human health and safety (contact)
  - chemical contaminants - skin irritants and acute, toxic effects
  - safety - physical harm
* Types of reaction
  - Full contact
  - Intermediate contact
  - Non-contact
* Clarity and turbidity - suspended material - danger for swimming
* Colour : acceptability is subjective : colour not objectionable
* Floating mater - distracts from aesthetic enjoyment
* Odour : detracts from aesthetic appreciation
* Chemical irritants : irritant effects or toxic
* pH - irritation if extreme variations - indirect aesthetic effect.

Assumptions

* Extensive and extended contact with water are made.
* pH ranges between 6.0 and 8.5.
* Water is relatively acceptable with respect to clarity, colour, floating material, odour and organic components.

Formula - Reaction

S - f (B)
B - f(F; I; N)

Where :

S	=	Services
B	=	Behaviour
F	=	Full-contact recreation
I	=	Intermediate contact recreation
N	=	Non-contact recreation

Application

The extent of contact with water in terms of duration and occurrence determines the acceptability of water quality of recreational water bodies. Direct costs relate to authorities treating water to attain a specific water quality, whereas most of the costs will be of an indirect nature.

2.3.2.2. Full-contact recreation (swimming)

Definition and conditions

* Full body water contact, including swimming and diving
* Immersion and probable ingestion of water
* Age group - children susceptible to a number of health effects (infectious diseases)
* Health status
* Clarity <1m Secchi disk depth - unsuitable for swimming - impairment of aesthetic enjoyment.
* Colour - free of objectionable substances
* Floating : free from matter, waste water and discharges
* Odour : free of substances causing objectionable odour; indicative of pollution
* Chemical irritants - no concentrations that may be toxic, free of chemicals causing irritation to skin, eyes or mucous membrane
* pH : >6.5 - 8.5< : irritations and no direct aesthetic effects

Formula : Full contact reaction

$$F = f(H;A)$$
$$H = f(C;Q)$$
$$A = f(C;Q)$$

Where

F	-	full contact recreation
H	-	health
A	-	aesthetic
C	-	extent of contact with water
Q	-	water quality, ie TDS, pH, etc

Application

The extent of contact with water in terms of duration and occurrence determines the acceptability of water quality of recreational water bodies. Direct costs relate to authorities treating water to attain a specific water quality, where most of the costs will be of an indirect nature.

Specification

The functional relationship of this sector is based on the health and aesthetic effects of water during contact.

The causality of the functional relationship leads from subelements to the cost of water expressed in Rands. The subelements are the following:

- C = extent of contact with water
  = proxy is the cost of alternative recreation
- Q = water quality
  = mg/ℓ TDS
  = proxy is the cost of medical treatment due to adverse health effects
  = Rand

The water requirements for full-contact recreation are discussed.

* Clarity

Clarity range (Secchi disk depth m)	Effects
Target guideline range 0 - 2.75	In studies of user perceptions of water clarity, a Secchi disk depth of 2.75m was required by 90% of people to perceive water as suitable for swimming. This allows to judge and to see possible hazards. Turbidity in this range is extremely low, hence chances of disease transmission by organisms associated with particulate matter are minimal. However, this possibility cannot be excluded on the basis of clarity or turbidity measures alone. No adverse effects on aesthetic enjoyment are expected.

Source : SAWQG, 1993

* Odour

Recreational waters should be free of any substances which cause noticeably unpleasant or objectionable odours. Odours detract from aesthetic enjoyment of water and are considered by water users as indicative of water pollution.

* Chemical irritants

Recreational waters should not contain chemicals in such concentrations as to be toxic to man if small quantities are ingested or absorbed through the skin. Furthermore, water should be free of chemicals which are irritating to the skin, eyes, ears or mucous membranes.

* pH

pH range (pH units)	Effects
0 - 5.0	Skin, ear and mucous membrane irritations likely. No direct aesthetic effects are expected. Severe eye irritation occurs.
5.0 - 6.5	Swimming in water of this pH is generally acceptable, provided buffering capacity is low at the lower limit of this range. Some guidelines specify pH 6 as

	the lower limit. Eye irritation is minimised. Studies using human volunteers showed no deleterious effects to external ocular tissue when eyes were exposed to lake water having a pH as low as 4.5; Canadian Guidelines, 1992; Hart *et al*, 1992). Skin, ear and mucous membrane irritation may occur. No direct aesthetic effects are expected.
Target guideline range 6.5 - 8.5	Minimal eye irritation occurs in this range. The pH of water is well within the buffering capacity of the lachrymal fluid of the human eye; No direct aesthetic effects are expected
8.5 - 9.0	It is generally considered acceptable to swim in water in this pH range, provided that buffering capacity of water is very low at the upper limit of this range. Eye irritation is minimised inside this range. Skin, ear and mucous membrane irritation may occur. No aesthetic effects are expected
>9.0	Eye irritation becomes increasingly severe as pH values become more extreme. Skin, ear and mucous membrane irritation are likely to occur. No direct aesthetic effects are expected

Source : SAWQG, 1993

2.3.2.3. <u>Intermediate contact recreation</u>

Definition and conditions

* Include activities which involve a high degree of water contact (waterski, canoeing) and those which involve relatively little water contact (paddling, wading).
* More stringent with higher degree of contact.
* Number of contact incidence as well as duration.
* Degree of water contact distinguishes from full-contact recreation.
* Adults mainly practice intermediate contact.
* Users in good state of health.
* Variety : activities require visibility although extent of water contact is important.
* Colour : affects aesthetics
* Floating : affects aesthetics
* Odour : affects aesthetics
* Chemical irritants : extent of water contact
* pH : extent of water contact.

Formula : Intermediate contact recreation

I = f(h; A)
H = f(C; Q
A = f(C; Q)

Where

I	=	intermediate contact recreation
H	=	health
A	=	aesthetic
C	=	extent of contact with water
Q	=	water quality; ie TDS, pH etc.

Application

The extent of contact with water in terms of duration and occurrence determines the acceptability of water quality of recreational water bodies. Direct costs relate to authorities treating water to attain a specific water quality, whereas most of the costs will be of an indirect nature.

Specification

The functional relationship of this sector is based on the health and aesthetic effects of water during contact.

The causality of the functional relationship leads from sublements to the cost of water expressed in Rands. The sublements are the following :

• C	=	extent of contact with water
	=	proxy is the cost of alternative recreation
• Q	=	water quality
	=	mg/ℓ TDS
	=	proxy is cost of medical treatment due to adverse health effects
	=	Rands

Water quality requirements are discussed (SAWQG,1993).

* **Clarity**

Since this class includes activities which require reasonable to good visibility in water and may on occasion include full-body immersion, the same guideline as full contact reaction (swimming) is suggested. However, this should be applied with discretion and cognisance should be taken of the extent of water contact. Where water contact is slight or infrequent, the less stringent ranges may be used.

It is recognised that recreational waters in some regions of South Africa (e.g. most of the Orange Free State) have very low clarity (high turbidity) for most of the year. Mostly there are no alternative water bodies available for recreational use. In practice, most recreational resorts have some form of control over boat clubs and skiing, and are usually familiar with the dam basin. This will further protect water users.

* **Colour**

Colour affects the aesthetic aspect of all forms of recreational water use hence the guideline for full-contact recreation applies.

* **Floating matter / refuse**

The presence of floating matter and refuse affects the aesthetic appeal of all forms of recreational water use, hence the guideline for full-contact recreation (swimming) applies.

* **Odour**

Odour effects the aesthetic aspect of all forms of recreational water use, hence the guideline for full-contact recreation (swimming) applies. There should be no adverse impact on aquatic life.

* **Chemical irritants**

Since activities in this class may include occasional full-body immersion, the same guideline as presented above is suggested. However, cognisance should be taken of the extent of water contact. Where water contact is slight or infrequent, the guideline may be less stringently applies.

* **pH**

Since activities in this class involve some degree off the direct contact with water, including occasional possible full-body immersion, the same guidelines as above is suggested. However, cognisance should be taken of the extent of water contact. Where water contact is slight or infrequent, the guideline may be less stringently applied.

2.3.2.4. Non-contact recreation

Definition and conditions

* All forms of recreation with no direct contact.
* Picnicking, hiking, scenic appreciation.
* Scenic and aesthetic appeal and appreciation.
* Economic value of water bodies relates to scenic appreciation.
* Clarity
  - no harmful effects
  - minimal adverse impacts on aesthetic appreciation
  - health and safety not relevant
  - water quality such that occasional accidental contact will pose no risk.
* Colour : effects, aesthetic, should not be adverse impacts on aquatic life.
* Floating : effects, aesthetic, should not be adverse impacts on aquatic life.
* Odour : effects, aesthetic, should not be adverse impacts on aquatic life.
* Chemical irritants : not relevant if no contact

- extent of water contact when it happens
- exceptions - volatile toxicant
- not levels that will cause irritation if rare accidental contact occur.

* pH : non-contact levels are relevant.

Formulae - Non-contact recreation

N	=	f(H; A)
H	=	f(C; Q)
A	=	f(C;Q)

Where

N	=	non-contact recreation
H	=	health
A	=	aesthetic
C	=	extent of contact with water
Q	=	water quality, ie TDS, pH etc.

Application

The extent of contact with water in terms of duration and occurrence determines the acceptability of water quality of recreational water bodies. Direct costs relate to authorities treating water to attain a specific quality, whereas most of the costs will be of an indirect nature.

Specification

The functional relationship of this sector is based on the health and aesthetic effects of water during contact.

The causality of the functional relationship leads from two sublements to the cost of water expressed in Rands. The two sublements that need to be quantified are the following :

• C	=	extent of contact with water
	=	proxy is cost of alternative recreation
• Q	=	water quality
	=	$^{mg}/_{\ell}$ TDS
	=	proxy is cost of medical treatment due to adverse health effects
	=	Rands

The water quality requirements are discussed.

* **Clarity**

If a water body is used only for non-contact recreation, then water clarity and turbidity should be such that there are no harmful effects on aquatic organisms and minimal adverse impacts on aesthetic appreciation. Clear water fosters aesthetic enjoyment of water, hence the clearer the water, the more pleasure will be derived from non-contact recreation.

Since no contact with water occurs, health and safety considerations are not relevant. However, water quality should be such as to pose minimal risk to non-contact recreational water users as a result of occasional contact.

* **Colour**

Colour affects the aesthetic aspect from all forms of recreational water use, hence the guideline for full-contact recreation applies. Comments pertaining to contact water use are not relevant to non-contact recreation. There should be no adverse impacts on aquatic life.

* **Floating matter / refuse**

The presence of floating matter and refuse affects the aesthetic appeal of all forms of recreational water use, hence the guideline for full-contact recreation applies. Comments pertaining to contact water use are not relevant to non-contact recreation. There should be no adverse impacts on aquatic life.

* **Odour**

Odour affects the aesthetic aspect of all forms of recreational water use, hence the guideline for full-contact recreation (swimming) applies.

* **Chemical irritants**

If the water body is used exclusively for non-contact recreation, irritant or toxic effects to humans are not relevant. Possible exceptions are volatile toxicants, such as hydrogen sulphide, or volatile organics, which may be toxic by inhalation after volatilisation or evaporation from the water surface. Chemical irritants should not be presented at levels which will have adverse impacts on aquatic organisms or which will cause irritant effects to humans in instances of rare accidental contact.

* **pH**

If the water body is used exclusively for non-contact recreation, the effect of pH on humans are not relevant. However, pH should not adversely affect aquatic organism or cause irritant effects to humans in the case of rare accidental contact.

2.4. CONCLUSION

The services sector includes a wide variety of activities which have relatively similar water patterns. Recreation concerns are included under the commercial sector, since the driving force is the profit function. The actual recreation activities such as swimming, etc. are included in the recreation model. The recreation model has various similarities to the household sector in terms of behavioural aspects.

The discussion in this section indicates that the recreational sector cannot be treated in the same manner as the commercial component since the cost effects of salinity will only become relevant at TDS levels beyond those specified for this study. The recreational sector is therefore not included in the integrated model since it is not an economic sector with cost implications.

The next section is used to test the validity of the conceptual framework by conducting a case study in the Middle Vaal River Area.

3. CASE STUDY

3.1. INTRODUCTION

The purpose of this section is to discuss the methodology followed with surveying the services sector in the Middle Vaal River Area. The reason for conducting surveys is to obtain information on the effect of salinity on services. This information has been analysed and transformed to be inputted to an integrated model to determine the total costs of combating salinity and relate the findings to the conceptualisation of costs.

The results of the surveys are discussed to identify the important cost factors of concerns using saline water in their operations.

3.2. STUDY AREA

The study area identified for the case study refers to the Middle Vaal River Area which stretches from the Barrage to the Bloemhof dam. The following magisterial districts are included :

* Klerksdorp (Orkney, Stilfontein)
* Odendaalrus (Allanridge)
* Virginia
* Welkom
* Bothaville
* Hennanman
* Ventersburg
* Parys
* Viljoenskroon
* Wesselbron
* Theunessen

A sample of services concerns in the study area were included in the survey.

3.3. SURVEY METHODOLOGY

The services surveys were conducted in Klerksdorp and Welkom. A questionnaire has been compiled which was used to obtain the relevant information from the services sector. The process that was followed in undertaking the surveys is discussed.

3.3.1. Pilot Survey

The questionnaire was piloted to test the suitability of the questionnaire and whether businesses can actually provide the information. The results of the pilot survey indicated that not all the businesses are adequately informed about or aware of the technical aspects relating to the costs of salinity. It was, however, established that the questionnaire is suitable.

3.3.2. Sample

Due to the specific nature of the data required as well as the conditions prevailing in the study area, it was decided that a limited sample of service concerns will generate adequate data to meet the requirements of the model. The focus is therefore not on the representativeness of the sample, but rather on the quality of the information to identify general trends.

The sampling was strongly influenced by the local conditions of the study area. This means that the services profile of each town in the study area was evaluated in terms of the diversity and number of concerns. Based on this, it was determined that a total of about 55 interviews were to be held in Klerksdorp and Welkom.

Table 3.1 contains the total number of services concerns in the Middle Vaal River Area.

TABLE 3.1: TOTAL NUMBER OF CONCERNS IN MIDDLE VAAL RIVER AREA.

MAGISTERIAL	PERCENTAGE DISTRIBUTION	
DISTRICT	TRADE	PUBLIC
Klerksdorp	29,6	29,7
Odendaalrus	12,5	10,8
Welkom	22,8	13,5
Virginia	6,1	5,4
Ventersburg	1,6	5,4
Hennenman	4,7	5,4
Parys	5,2	8,1
Viljoenskroon	5,3	5,4
Bothaville	5,7	5,4
Wesselsbron	3,4	5,4
Theunissen	3.2	5,4
TOTAL	**1204**	**37**

Source: BMR, 1993

Based on the table, it is evident that Klerksdorp and Welkom are the two major towns in the study area in terms of concentration of economic activities. Despite this, the economic structures of these areas are rather undiversified, focusing on supporting the mining and agricultural activities of the region.

3.3.3. Field Report

The purpose of this section is to provide feedback on the main findings observed during the survey. These observations provide valuable insight to the results of the surveys.

i. ***Klerksdorp***

The business surveys in Klerksdorp were undertaken during October 1995. A total of 30 interviews were held in Klerksdorp. In most cases the interview was conducted with the business manager or other relevant authority within each business.

The main findings of the Klerksdorp survey are as follows :

- Very few companies ever test the quality of their water intake and only a small number of people understand or have any knowledge of what TDS - levels are.
- The overwhelming majority of respondents complained that their drinking water often has a bad smell and bad taste. Many also complained of water being milky and having a chlorine taste.
- Many respondents complained that their geysers, kettles and urns do not last very long due to corrosion and scaling.
- A few respondents complained about the high costs of replacing blocked water pipes.
- A few of the smaller businesses have specific complaints of how the water quality affects their businesses. Some examples include a car valet service that has high maintenance costs on its machinery and a pet shop that loses many fish due to the poor water quality.

ii. ***Welkom***

The Welkom business surveys were undertaken during October and November 1995. A total of 25 business interviews were held. A diverse sample of businesses was interviewed and where possible, concerns were sought out that are water-intensive users. The businesses interviewed are all situated within Welkom's central business district.

The main findings of the survey are as follows:

- Very few businesses were found which regularly test the TDS levels of their water intake.
- As in the case of Klerksdorp, the water tests in Welkom are undertaken by private companies and the businesses themselves are relatively ignorant about the technical details of the water quality.

- Very few companies, are concerned about testing their water and few people understand or have any knowledge of what TDS levels in their water are.
- Relatively fewer people complained about bad tasting or smelling water as was the case in Klerksdorp.
- Many respondents complained of the high costs of replacing water pipes that often corrode or scale to the point that they are no longer serviceable.
- The most prominent problems related to TDS levels in water appears to be high maintenance and service costs followed by cost of replacing water pipes.
- Very few specific complaints with respect to the costs of salinity were received from the respondents. However, one problem in Welkom which was also prevalent in Klerksdorp is valet services which have problems with clogged nozzles on their cleaning machines due to scaling.
- A general perception exists that the water in Welkom is of a low quality since it is transported from the Vaal River to Welkom over a distance of more than 100km.

3.3.4. Summary

The methodology used in the survey ensured that the best possible information was obtained from the sample of services in the study area. Upon completing the surveys, the results were computerised and analysed to extract data to be related to the conceptual cost framework.

Before providing the results, it is, however, necessary to discuss the assumptions of the study as well as conditions impacting on the results of the surveys.

3.4. ASSUMPTIONS AND CONDITIONS

Since the purpose of the study is to verify and test a conceptual model, it is imperative to discuss how the assumptions of the model impact on the fieldwork. Furthermore, the specific conditions relating to the survey and analysis of results must also be discussed.

3.4.1. General Conditions

The following general conditions apply :

- The average TDS for the study area varies between 300 mg/ℓ and 600 mg/ℓ The average TDS has been accepted as ranging between 470 mg/ℓ and 500 mg/ℓ.
- The 1995/6 rain season has had limited impact on the reporting, since it can be considered as a deviation from the norm and does not influence average trends.

- The behavioural aspects obtained from the survey are mainly technology-driven where water is used for processing and as input to the end product.
- Compensatory behaviour or related changes in water use, treatment, etc. only becomes relevant at TDS ranges with potential negative health effects, e.g. TDS of 1100 mg/ℓ and more.
- Scaling of heating surfaces is one of the main problems experienced in the study area due to relatively high levels of TDS.
- Obtaining information on the cost of salinity is greatly influenced by the general lack of knowledge on the issue.
- The responsibility of supplying water with an acceptable level of TDS is considered to be that of the water supply authorities, e.g. the municipalities and water boards.
- Concerns in high salinity areas incur additional costs above the base line production costs due to salinity.

3.4.2. Services Sector

The issues relating to the services sector include the following:

- Subsectors included under the services sector are trade, offices, government services, recreation services, storage, financial and personal services.
- The activities classified as services have been aggregated into a single sector since the water usage patterns and behavioural aspects are relatively similar.
- Water is mainly used for human consumption and related aspects, such as washing and cleaning.
- Behavioural aspects come into play mainly when water reaches levels of TDS which may have negative effects on health. These levels mainly fall outside the 200 mg/ℓ-1200 mg/ℓ range.

It is evident from the preceding discussion that determining the cost of salinity to the various sectors is not a simplistic matter due to the various factors influencing production, water usage and management decisions relating to combating salinity.

4. DATA ANALYSIS

The purpose of this section is to discuss the results of the services surveys. Some general information is provided which is useful for classification of activities after which specific data on water usage and costs of salinity are discussed.

4.1. INTRODUCTION

The services sector in the study area consists of approximately 1241 concerns and a total sample of 81 concerns have been surveyed, representing a sample of 6,5%.

4.1.1. General Information

Most of the concerns included in the survey were retail, wholesale, offices, or business services. The average employment of the concerns amounted to 15 workers. This suggests that if employment is taken as a norm for determining size, the services concerns in the study area can be classified as relatively small concerns.

Another parameter that can be used to evaluate the size of concerns is annual turnover. The average annual turnover in the study area amounted to approximately R11,35 million. This figure is only indicative and the turnover distribution provided in Table 4.1 actually provides a more realistic picture of the turnover profile.

TABLE 4.1 : AVERAGE ANNUAL TURNOVER

CATEGORY (R'000)	PERCENTAGE
0 - 50	0
50 - 100	0
100 - 500	12,5
500 - 1000	16,1
1000 - 5000	41,0
5000 - 10000	12,5
10000 - 50000	10,7
50000 - 100000	5,4
100000 +	1,8
TOTAL	**100,0**

It is evident that most of the services concerns have an annual turnover falling in the one to five million Rand category. This means that the concerns surveyed are relatively small in terms of turnover.

4.1.2. Water Usage

The services sector is a relatively large water user due to the size of the sector. The average water usage per concern, however, indicates that the individual concerns are relatively less intensive water users, namely 1023,23 kilolitres per annum, costing about R12 420 per annum. The processes for which water is used, are indicated in Table 4.2.

TABLE 4.2: WATER USAGE

PURPOSE	PERCENTAGE
Human Consumption	59,0
Washing (cleaning , buildings, products, parts, vehicles)	25,0
Cooling	3,0
End product	4,6
Gardening	3,8
Boiler	0,8
Test product	0,8
Cooking	1,5
Other	1,5
TOTAL	**100,0**

Based on the information contained in the table it is evident that water is mainly used for human consumption and washing purposes.

The respondents were asked to indicate what their perceptions of the water quality is (refer to Table 4.3).

TABLE 4.3: QUALITY OF WATER

QUALITY OF WATER	PERCENTAGE
Lime	27,5
Bad taste/smell	23,2
Milky	26,1
Hard	2,9
Chlorine/chemicals	13,0
Colour	1,5
Other	5,8
TOTAL	**100,0**

Generally speaking the respondents feel that the quality of water in the study area is relatively low in terms of the lime content, being milky or smelling and tasting bad.

4.1.3. Purification

Since the services sector uses water mainly for human consumption and washing purposes, it was necessary to determine the possibility of taking any measures to purify or treat water for these purposes. The respondents were asked if the concern provides any form of drinking water purification and the majority (about 93%) indicated that they do not. The concerns that responded positively indicated that the quality of the water was bad and therefore they preferred to purify the water.

The services sector was also asked to indicate whether they would ever consider using a purification system. The responses were as follows:

- will consider - 11,3%
- will not consider - 88,7%

The first category of respondents motivated that they will consider taking measures if the quality of the water becomes unpalatable necessitating action in this regard. There has been a definite positive response towards considering alternatives to water if the water becomes unpalatable or undrinkable. More than 97% of the respondents will consider alternatives. In many cases the responsibility for the quality of the water is considered to be that of the authority providing water, namely the municipality.

Alternatives considered include boiling of water, the use of filtering/purification systems or obtaining water from other sources. The implication of this is that costs will be incurred when the quality of the water deteriorates considerably. In all probability these measures will only come into action with TDS levels nearing 1200 mg/ℓ and having possible adverse effects on health.

4.1.4. Maintenance and Replacement

The most important cost factor for the services sector in terms of combating the effects of salinity relates to maintenance and replacement of equipment. These refer mainly to appliances used for heating water for human consumption and washing purposes.

The average annual maintenance and replacement costs for the services sector are indicated in Table 4.4.

TABLE 4.4: MAINTENANCE AND REPLACEMENT COSTS

COST ITEM	OCCURRENCE PER YEAR	AVERAGE ANNUAL COSTS (R)
REPLACEMENT		**393,29**
• Kettles	0,54	95,70
• Urns	0,16	19,73
• Geysers	0,18	224,40
• Piping	0,04	53,46
MAINTENANCE		**341,93**
• Pumps	0,13	26,63
• Filters	0,05	15,30
• Equipment	0,03	300,00
TOTAL		**735,22**

The information in the table indicates that the total average annual cost per concern to combat salinisation amounts to R735,22. It is, however, important to see this in context, since the total cost comprises both replacement and maintenance costs. The replacement costs amount to about R393,29 per annum whereas the maintenance costs amount to R341,93. The information contained in the table should be seen in perspective to fully understand the implications. As an example the replacement of kettles every second year amounts to an average annual cost of R95,70 per annum. The information has also been verified where relevant with the results obtained with the household survey. On average geysers are replaced once every six to ten years. The information in the table shows that geysers are replaced nearly twice (1,8 times) of a period over ten years. The total water costs are also important since at a TDS level of 500 mg/ℓ the water usage has already increased from the base line usage to compensate for increased salinity levels. A portion of the total water costs can therefore be assigned to salinity. When it is considered that the total number of concerns in the services sector amounts to about 1241, the costs for the sector are as follows :

- Water costs R15 415 702 p.a.
- Replacement R 488 073 p.a.
- Maintenance R 424 835 p.a.
- Total R 912 408 p.a.

4.1.5. Conclusion

The services sector is relatively diverse but in terms of water usage relatively homogenous. Water is mainly used for human consumption and washing purposes. As a result, the cost of salinity is mainly incurred in replacing household-type of appliances such as kettles and geysers more often than in low salinity areas.

The behavioural component cannot be costed in the current TDS range since the general perception is that mitigation actions will only be taken when the TDS levels are health threatening (i.e. > 1200 mg/ℓ TDS).

5. INPUT DATA FOR MODELLING

The purpose of this section is to interpret the data obtained through the surveys in a format to be inputted to the interactive model.

5.1. INCREMENTAL COST CHANGES

The changes in cost related to increased salinity levels of water may be in terms of the overall cost of water, the complexity and level of water treatment technology, the level and intensity of supervision as well as the complexity of water handling. The effect of any of these will be in terms of increased costs as a result of any of the following :

- paying more for in-house treatment of the water to attain the required standard
- change the level or complexity of technology used in water treatment
- increase the level or intensity of supervision of water treatment facilities
- handle additional wastes resulting from the water treatment process.

Changes in salinity do not imply that all the above will be done, but mean that costs will increase. The specific actions taken and resultant cost increases will be influenced by the severity of the salinity changes. Actions in any or all of the mentioned aspects would lead to additional costs and the sum of these will give rise to increased water treatment costs.

Any water using concern (business services) has a "baseline" cost for its water usage. This refers to the basic cost of water purchased, capital costs for equipment and facilities, costs for chemicals for treatment and costs for handling wastes. Changes in salinity will be reflected in the increases above this cost.

The costs recorded during the surveys indicate the total current costs related to treatment, which means that the costs represent "baseline" cost plus incremental costs due to a salinity level of 500 mg/ℓ.

Total water costs have been obtained, which represent typical water usage as part of the production process as well as additional water usage to compensate for higher levels of salinity.

5.2. SERVICES SECTOR COSTS

The services sector consists of the recreational and business subsectors. The formula for the recreation sector states that contact with water will determine the cost of high levels of salinity to the sector. Since the given range (200 mg/ℓ - 1200 mg/ℓ) does not imply any adverse health effects due to contact, no costs will be inputted to the model. The costs that will be inputted to the model refer to recreational business concerns such as hotels, resorts, etc. which are operated on the same business principles to that of the rest of the services sector. As a result, the costs will be recorded as part of the services sector.

The costs of the services sector to be inputted to the model are presented in Table 5.1.

TABLE 5.1: COSTS OF SALINITY OF SERVICES SECTOR (RANDS PER YEAR)

BUSINESSES AND SERVICES				
COST ITEM	**INPUT SECTOR**	**AVERAGE COST PER BUSINESS**	**TOTAL COST AT**	
			500 mg/ℓ	**1200 mg/ℓ**
REPLACEMENT				
Kettle	Trade	95,70	118764	178146
Urn	Trade	19,73	24485	28106
Geyser	Trade	224,40	278480	417721
Pipes	Light industry	53,46	66344	82930
SUBTOTAL		**393,29**	**488073**	**706902**
MAINTENANCE				
Pumps	Trade	26,63	33048	41310
Filters	Light industry	15,30	18987	23734
Equipment	Light industry	300,00	372300	465375
SUBTOTAL		**341,93**	**424335**	**530419**
TOTAL		**735,22**	**912408**	**1237321**
Water costs	services	12420	15415702	17728057

The information provided in the table indicates that the current costs related to salinity amount to approximately R912 400 p.a. and will increase by approximately 36% at a TDS of 1200 mg/ℓ amounting to R1 237 321. The incremental costs due to higher salinity levels of water (changing from 500 mg/ℓ to 1200 mg/ℓ) will thus amount to about R324 913. This incremental cost will be due to more frequent replacements of appliances and equipment as well as increased maintenance, leading to higher operational costs. Inherent in these incremental costs will be, among others, increased use of water, which will increase by about 15%. This amounts to an incremental cost increase of R2 312 355 p.a.

6. CONCLUSION

The results of the case study analysis indicate that the services sector do not incur substantial costs to combat salinity at the current level of 500 mg/ℓ The increase in costs to a TDS level of 1200 mg/ℓ is also not significant, implying that the impact of salinity is relatively low. These findings are in line with the assumptions and relationships specified in the conceptual framework.

The conceptual formulae rely on complete and high quality information which is relatively difficult to obtain on account of the general ignorance with respect to the technical and cost impacts of salinity on the part of business concerns. Furthermore, the behavioural aspects are not easily quantifiable, since decisions are generally based on technical specifications. To some degree it may be inferred that the costs could be overstated, since costs are attributed to be caused by salinity when in fact it could be due to other factors, such as replacement of piping and kettles, as a result of malfunctioning or old age.

In conclusion it can be said that the study has produced valuable insight in the cost impacts of salinity in the services sector.

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INDUSTRIAL AND BUSINESS QUESTIONNAIRE

A. BACKGROUND INFORMATION

1. Name of concern: ____________________

2. Town/Address: ____________________

3. Contact person ____________________

4. Telephone no: ____________________

5. Give a short but complete description of what the company manufactures and the main activities the company is involved in.

	SIC

6. Give a detailed list of the products and/or services that the company manufactures sellls or provides and what percentage each represents of total production or turnover

Product/Service	Percentage of total
TOTAL	100

7. Please state the nature of ownership of firm

8. Does the firm own the premises it is occupying?

9. What is the size of the premises ?

10. What is the average number of employees for the last financial year ?

11. What is the firm's average annual turnover ?

TURNOVER CATEGORY	"√"
R0 - R50 000	
R50 000 - R100 000	
R100 000 - R500 000	
R5 00 000 - R1 000 000	
R1 000 000 - R5 000 000	
R5 000 000 - R10 000 000	
R10 000 000 - R50 000 000	
R50 000 000 - R100 000 000	
R100 000 000 + MORE	

B. WATER RELATED INFORMATION

12. Please provide a breakdown of the company's cost structure according to the following elements:

Cost element	%
Water	
Water treatment	
Material	
Stock	
Labour	
Energy	
Admin	
Maintenance	
Plant	
Transport	
Machinery	
Other	
Total	100%
	R

13. For what purposes is water used, i.e. human consumption, cooling, etc.

14. What is the average water intake per month per source and the average cost thereof.

No.	Source description	Volume m^3	Cost

15. What is the quality of water intake (TDS), what quality is required and what is the cost of treatment to obtain the correct TDS levels:

No:	Source description	Quality at intake TDS (mg/l)	Quality required TDS (mg/l)	Cost/m^3

16. Please classify the water using production processes according to the following and allocate as a percentage of the total production.

1. Process water: Water is used as transport medium. The composition of the water is not critical, as process conditions are prevalent.

2. Water for end product: Composition is critical as it affects the process and quality of the end product.

3. Utility water: Generally used for cooling processes. Corrosivity and scaling properties are important particularly with high concentration ratios in recirculating systems.

4. Potable water. Water used for human consumption.

Process	Classify				Water intake TDS (mg/l)	Water use		Treatment costs
	1	2	3	4		m^3	TDS(mg/l)	R/m^3

17. If the quality of intake water changes to the levels given, what are the reaction of management to attain desired levels for each process.

TDS mg/l		Process 1	decision	Cost
increase	desired level			
200				
400				
600				
800				
1000				
1200				

TDS mg/l		Process 2	decision	Cost
increase	desired level			
200				
400				
600				
800				
1000				
1200				

TDS mg/l		Process 3	decision	Cost
increase	desired level			
200				
400				
600				
800				
1000				
1200				

TDS mg/l		Process 4	decision	Cost
increase	desired level			
200				
400				
600				
800				
1000				
1200				

18. At what stage per process, due to increased salinity, will management opt for: (a) introducing new capital, (b) technology, (c) replacing plant, (d) cease production or, (e) produce products of a lower quality, (f) increased maintenance (g) increased water use.

Process	Stage or level of TDS mg/l	Choice							Reason
		A	B	C	D	E	F	G	

C. WATER TREATMENT

19. What is the cost of maintenance of plant and capital equipment in terms of scaling and corrosion ?

Process	Cost (R)

20. What type of water treatment and cost thereof are applied per process.

Process	Treatment	Cost/m^3

21. What inputs are required to treat water per process (e.g. chemicals, labour etc.)

Process	Water treatment inputs

22. What is the cost involved in treating discharge water to ensure effluent is in accordance with prescribed water quality levels.

Discharge m^3	Cost/m^3

23. How does water with increased TDS levels impact on effluent treatment and what are the costs related to that

TDS	EFFECT	COST R/m^3
200		
400		
600		
800		
1000		
1200		

24. How will increased levels of salinity influence the cost structure and ultimately profit of the company ?

____

____

____

D. POTABLE WATER

25. Does the firm provide any form of drinking water purification such as the aqua filter system ?

Yes	motivate: ____________________
No	____________________

26. Will the company ever consider using a water purification system ?

Yes	motivate: ____________________
No	____________________

27. If the water is considered to be undrinkable or unpalatable, will the ompany consider to provide the staff with alternatives ?

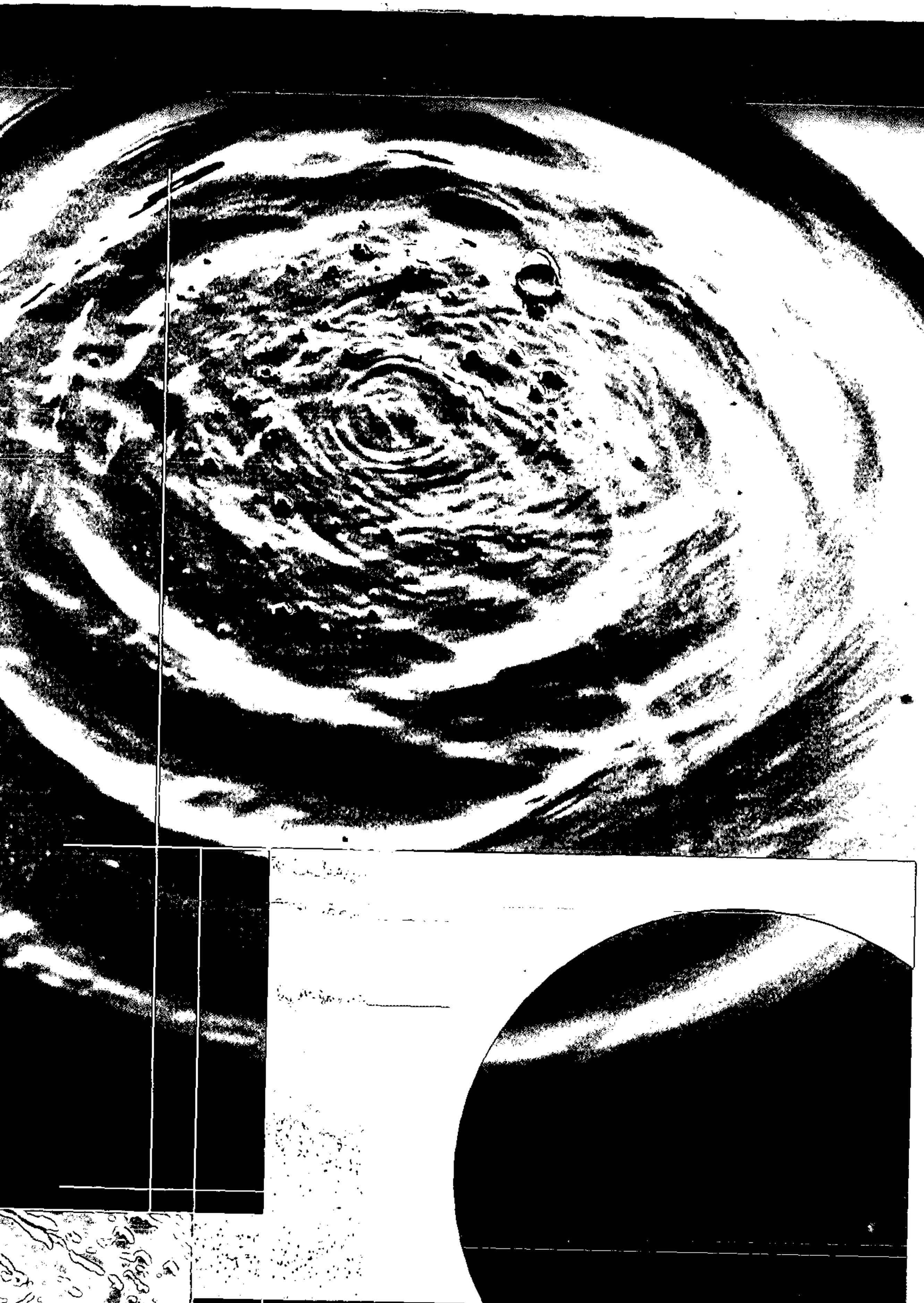
____

____

____

28. Does the firm have to replace the following items and what is the estimated cost thereof.

Item	Replacement/Year	Cost/Year
Kettles		
Urns		
Geysers		
Other		



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