WATER RESEARCH COMMISSION

FINAL REPORT

ON

The Economic Effects Of The Mineral Content Present In The Vaal River Barrage On The Community Of The PWVS-Complex

(A Desk Study)

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by

J.J.C. HEYNIKE

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WATER RESEARCH COMMISSION

P.O. BOX 824, PRETORIA. 0001

JUNE 1981

C O N T E N T S

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SUMMARY REPORT

ECONOMIC EFFECTS OF THE MINERAL CONTENT PRESENT IN THE VAAL RIVER BARRAGE WATER ON THE COMMUNITY OF THE PWVS-COMPLEX

INTRODUCTION

In 1974 the present project was embarked upon to investigate the mineral pollution of the Vaal River with the main emphasis focused on the stretch of river between the Vaal Dam and the Barrage which serves the Pretoria, Witwatersrand, Vereeniging, Sasolburg Complex. Once the pattern of pollution had been established, the question arose : What is the pollution costing the community now and what will it be in the future? In order to ascertain these costs a desk study was undertaken, the results of which are set out in this report.

This desk study covers the future cost effects that could result for all users of water in the PWVS-Complex should the mineral content of the water in the Vaal Barrage basin continue to rise as experienced over the past thirty year or so.

The necessity to determine the factors responsible for this situation, the sources of such mineral loads and possible solutions for this problem has been keenly felt by many for many years. In 1974 the Water Research Commission (WRC), realizing the seriousness of this situation and the effects on the most important industrial region in the Republic of South Africa, organized and financed an investigation into the sources and extent of mineral pollution. In November 1976 the Commission appointed Messrs. Stewart, Sviridov and Oliver (Consulting Engineers) as Project Managers. The Hydrological Research Unit of the University of the Witwatersrand by developing a series of mathematical models has made a most important contribution to the project. For the purpose of this investigation it has been assumed that the mineral content (total dissolved solids - TDS) of the present water supply is 300 mg/l and that, if unrestrained it will rise to an average value of 800 mg/l towards the end of this century.

If remedial measures are applied timeously however, the rise might be contained and therefore costs have also been determined for an average value of 500 mg/l TDS.

In carrying out this desk study the most important fields of water use were firstly ascertained and thereafter examined viz:

(a) the effects on private households and flats in White and Non-white living areas;
(b) effects on the Rand Water Board's operations and equipment;
(c) effects on water storage, supply and distribution systems of local authorities;
(d) effects on industrial undertakings including electric power stations;
(e) overall effects on factors (a) to (d).

A. EFFECTS ON PRIVATE DWELLINGS AND FLATS

An inventory of the plumbing and associated equipment and the value in an average European home was determined with its life expectancy and associated maintenance/operational costs when using water of 500 and 800 mg/l TDS.

This covered the following aspects in a house:

(i) the plumbing equipment and fittings;
(ii) washing machines, geysers etc;
(iii) washable clothing and fabrics;
(iv) soap and detergent requirements.

Although at first it appeared difficult to establish such costs for a Non-white household, additional information was acquired to determine such costs on a similar basis as that for Euorpean housing. The following table illustrates the various additional costs for all races:

Per Household	Whites R/a/household		Non-whites R/a//household	
Water Quality TDS	800	500	800	500
Plumbing and washing equipment	24,59	10,02	1,44	0,86
Washable fabrics and clothing	14,13	5,40	3,87	1,55
Soap and deter= gents	40,00	24,00	23,91	14,32
Total	78,72	39,97	29,22	16,73
No. of houses	500 000		775 000	
Total cost/a for the complex $R \times 10^6$	39,36	20,00	22,65	12,97

Total additional costs for all races with water of 800 and 500 mg/l TDS are R62 x 10^6 and R33 x 10^6/a respectively.

The investigation shows that the costs for soap and detergents to be the greater contribution towards the overall costs for both population sectors. With regard to the plumbing and washing equipment, the contribution by the European sector is much greater than that for the the Non-European sector. The latter situation is now rapidly improving and already the cost contribution of cleaning materials i.e. soap and detergents for the Non-white sectors is almost similar to that of the white section of some R20 x 10^6a each.

The study indicates that the additional cost effects when operating with water of 800 mg/l TDS could raise the water tariff in the European sector by some 20c/kl and by 10c/kl for water of 500 mg/l TDS. Due to unreliable data for water consumption the effects on the water tariff in the Non-white sector could not be determined.

B. EFFECTS ON RAND WATER BOARD'S OPERATIONS

Although increased mineral salts assist flocculation in the Vaal Barrage (mainly below Zuikerbosch Water Works) and so reduce the chemical requirements somewhat, additional costs for chlorination to combat increased algal growths cancel this cost advantage. The softening of the water supply is also not regarded by the Board as a solution or advantage in spite of low costs, as the TDS does not decrease and the consequent high sodium content of water is a disadvantage. There is also insufficient sodium chloride in the country to run a suitable ion exchange softening plant of this magnitude, and the disposal of brine regenerant poses a serious problem. With increased TDS (500 and 800 mg/l) it is still possible to chemically/physically balance the water to prevent corrosion and/or post precipitation in service supply lines and reservoirs. Overall it would appear that Rand Water Board's costs will not be appreciably affected. However, RWB will have to extend its water works plant to cater for appreciable additional industrial water when the TDS increases. Such costs are mainly for industry's account and estimated at some 10c/kl additional, equivalent to R5,4 x 10^6 and R15 x 10^6 for water of 500 and 800 mg/l TDS respec= tively.

C. EFFECTS ON WATER SUPPLY AND DISTRIBUTION SYSTEMS IN LOCAL AUTHORITIES

Corrosion in steel water mains has been experienced and with increasing TDS this could intensify. Corrosion is most pronounced in water mains up to 300 mm diameter. A suitable formula is applied to indicate the tendency of different waters towards corrosion. In the complex some 60 - 70 percent of steel mains have already been replaced. Water meters are also affected mainly by lime deposits in the mechanisms resulting in under-registering and often in stoppages. The additional costs to maintain the distribution mains and meters are, however, comparatively small.

Local authorities supplying industry with water containing higher TDS will have to increase their storage capacity to maintain a 36h retention period as industries will not be able to recycle the water to the same extent as at present. Such costs are shown under Section E.

D. EFFECTS ON INDUSTRIAL UNDERTAKINGS

Industries will suffer rather extensively, especially those requiring high quality water for cooling and steam raising. It appears that some 35 percent of all the water used in the complex is for industrial purposes. Several industries along the Vaal abstract large quantities directly from the Vaal Barrage equivalent to some 15 percent of the total estimated abstraction of 874 x $10^6 m^3/a$.

The additional costs for industry are for additional water, chemicals and plant installations to treat larger amounts of water for generating steam. Of the total additional costs that could be expected for the complex in future, that for industry is the greatest followed by that for private households. Industrial water could cost the industry some 10c/kl extra. (See Section E for additional costs for industry).

E. OVERALL RESULSTS

The total estimated additional costs/annum for water qualities of 800 and 500 mg/l TDS are R139 x $10^6/a$ and R77,5 x $10^6/a$ respectively, details of which are shown below:

Water Quality TDS (mg/l)	800		500	
Total additional costs for	R x $10^6/a$		R x $10^6/a$	
(i) Private households		%		%
(a) White households	39,4	28	20,0	20
(b) Non-white households	22,7	16	13,0	17
(ii) Rand Water Board : Additional Water	15,2	11	5,4	7
(iii) Corrosion in pipe networks and additional reservoirs	4,6	3	1,6	2
(iv) Industry and power stations	57,4	41	37,5	48
TOTAL	139,3		77,5	

Based on an estimated water consumption of 874 000 Ml/a by 1980 for the PWVS-Complex and assuming the water to contain 800 and 500 mg/l TDS, the additional costs could increase by 16c and 9c/kl respectively.

F. ECONOMIC EFFECTS OF THE ORGANIC MATERIAL CONTENT IN THE VAAL RIVER BARRAGE WATER

The presence of organic material in the Vaal Barrage water has been established and is expected to grow should such material not be con= trolled. Trihalomethanes (THM) are produced upon chlorination and levels at times exceed the standard of 100 ug/l as proposed by the United States Environmental Protection Agency (US EPA). These values do not exceed the Canadian standard of 350 ug/l, but the German standard of 25 ug/l.

The quality of Barrage water is much poorer than Vaal Dam water with respect to organic material and will require most advanced treatment. Laboratory tests conducted gave some indication what additional processes and plant may be required in future to reduce the organic matter from water taken from the Barrage.

The Board estimates an additional annual cost to the consumer of approximately R10 x 10^6/a and based on a production of 2100 Ml/d of water of which 1100 Ml/d receives this additional treatment, the water tariff will rise between 1,3 to 2,6c/kl dependent on the degree of GAC (granular activated carbon) treatment.

The capital involved is R45 x 10^6 for a GAC plant providing 12 minutes contact time.

These costs are not incorporated in that shown under section E of the summary.

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9 JUNE 1981

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ECONOMIC EFFECTS OF THE MINERAL CONTENT PRESENT IN THE VAAL RIVER BARRAGE WATER ON THE COMMUNITY OF THE PWVS-COMPLEX

This report forms a sub-division of the Report on the PWVS Research Project on Water Pollution and Effluent Reclamation In the Pretoria-Witwatersrand-Vereeniging-Sasolburg Complex.

OBJECTIVE

To indicate by means of a 'desk study' the additional costs that could accrue for all users of Vaal Barrage Water in the Complex should the quality of this supply continue to deteriorate. The following category of users are reviewed:-

A. EFFECTS ON PRIVATE HOUSEHOLDS

1. INTRODUCTION

1.1 Present conditions

The area covered in this report is the Pretoria, Witwatersrand Vereeniging, Sasolburg region, referred to as the PWVS-Complex of the Southern Transvaal. The water in question is that supplied by the Rand Water Board, (RWB) from water at its Zuikerbosch station - derived from the Vaal Dam and the Barrage, and from its two Vereeniging stations No.1 and No.2 out of the Vaal Barrage source. The water qualities supplied from these three stations differ greatly at times, but the Board mixes them in order to supply a fairly even quality to all its consumers.

There are large quality variations, especially at the Vereeniging stations as is shown in the Board's Annual Reports. Approxi= mately 70 percent of the supply is derived from the Zuikerbosch station and 30 percent from its Vereeniging stations. Of the total water supplied by the Board approximately 60 percent is Barrage water and 40 percent Vaal Dam water.

The total dissolved solids (TDS) vary widely from 120 mg/l to as high as 910 mg/l as indicated in Tables 15 and 16 of the RWB's 1978 and 1979 reports. There is abundant evidence that the water in the Vaal Barrage is deteriorating from year to year and this is mainly as a result of mineral pollution. This mineral load originates largely from the leaching of mineral salts which are present in slimes dams, rock and sand dumps; in the irregular discharges of large volumes of penstock waters and the discharge of underground pumping operations. In addition there are irrigation return flows, purified sewage effluents from several municipal sewage works, industrial effluents (including some apparently illegal discharges) and urban washoff making a significant contri= bution.

These effluents together with natural surface waters enter the Vaal Barrage through several streams and their tributary system viz the Klip River, Suikerbosrand River and Rietspruit on the Transvaal side, and the Taaibosch River from the Free State side.

The total dissolved solids load entering the Vaal Barrage has been determined by the Hydrological Research Unit (HRU) of the University of the Witwatersrand headed by Professor Midgley and appears in Table 1*. Although it covers only a period of some 5 months it shows that 56 percent of the total mineral load is contributed by the Klip River, 28 percent by the Suikerbosrand River and 15 percent by the Riet- and Taaibosch Spruits. It is also significant to see that 57 percent of the mineral load is diffused load and only 43 percent point-load. The total tonnage of dissolved salts entering the Barrage over the 153 days, excluding Vaal Dam loads amounted to some 234 000 tons equivalent to 1530 t/d.

At a later stage the HRU prepared a salt mass balance for the Barrage[1] for the period September 1977 to August 1978. Table 2* reflects the conditions which includes the contribution of Vaal Dam water. It is alarming to note the heavy load from nonpoint sources amounting to 38 percent of the total load.

* Confidential report to the Water Research Commission

TABLE 1

DISSOLVED SOLIDS ENTERING THE VAAL BARRAGE

Period September 1977 - January 1978 (153 days)

River	Diffuse load (tons)	Diffuse load % total*	Point Load (tons)	Point Load % total*	Total catch= ment load (tons)	Total catch= ment load % total*
Klip	57056	24	74925	32	131990	56
Suikerbos	46937	20	18189	8	65126	28
Rietspruit	5530	2	6689	3	12219	5
Taaibos= spruit	24544	10	0	0	24544	10
Total into Barrage	134076	57	99803	43	233879	100

Note : * % Total implies percentage of total tributary load reaching the Barrage (viz. 233879)t) not counting load brought in with Vaal Dam release.

TABLE 2

SALT MASS BALANCE FOR THE BARRAGE : SEPTEMBER 1977 - AUGUST 1978

Barrage inputs and ouputs	Load totals (t)*				
	From point sources	From nonpoint sources	From Vaal Dam	Total	Percent of Total
Vaal Dam	-	-	270 000[1]	270 000[1]	30
Suikerbosrand River	31 000[1]	73 000[2]	-	104 000[2]	12
Klip River	235 000[1]	115 000[2]	-	350 000[2]	39
Ungauged subcatchment[4] and the upper Taaibosspruit	4 000[1]	121 000[2]	-	125 000[2]	14
Groot Rietspruit	14 000[1]	30 000[2]	-	44 000[2] +893 000	5
All abstractions from the Barrage	-84 000[3]	-38 000[3]	-38 000[3]	-160 000[1]	-893 000
Barrage outflow	-200 000[3]	-301 000[3]	-232 000[3]	-733 000[1]	

* Note that point source loads (from recorded data) and nonpoint loads are adjusted downwards where necessary to account for stream bed losses and for irrigation abstractions. Consequently, point source load totals shown here are, in general, slightly smaller than the summed point discharges into the relevant tributaries.

(1) Calculated from recorded data (See also footnote *above)
(2) Obtained in model calibration runs
(3) Estimated quantities
(4) For location see Figure 2 of the Green Report, SS & O Vol. 1 April, 1979 - not yet released

1.2 Future tendency of the PWVS-Complex

The flow of the streams referred to into the Vaal Barrage, and the abstraction of water as a potable supply by the RWB, results in continuous recirculation/reuse of the water. Returned effluents constitute more than 30 percent of the RWB supply at present which consists of large quantities of purified sewage, mining and other industrial effluents. This situation is largely responsible for the continual rise in TDS experienced from year to year. This practice no doubt conserves fresh water in the Vaal Dam but constitutes a burden to industries and other consumers.

The present population of the Complex is of the order of 4,75 million persons and during 1977/78 some 1740 Ml/d of water was supplied by the RWB from the Vaal Dam and the Barrage. The abstraction rate is expected to increase to some 4000 Ml/d by the year 2000 AD when the expected population will escalate to an estimated 8 million persons. In step with these changes the mineral load can be expected to increase accordingly.

During a trial run with the mathematical model developed by the HRU+, the model indicated that by the time the water demands of the Rand Water Board (RWB) have doubled (say by the year 1990-1995) and assuming all pumping from underground mine workings have ceased, the peak TDS concentration in the Barrage for a similar sequence of river flows to those which occurred during September to December 1977, could increase from 800 mg/l to about 1100 mg/l.

With the present high gold price and the increasing demand for gold, it would appear that underground mine pumping will continue and could even increase during this period resulting in even higher concentrations than the 1100 mg/l now forecast. In a study by the Hydrological Reseach Unit on behalf of the Project Mananagers, it was shown over the period September 1977 - August 1978 that the contribution of salt load by mine pumpage is some 25 percent by mass but only 5 percent by volume of the total discharge to the Vaal Barrage.

\+ Confidential Report to the Water Research Commission by the Project Managers (Stewart, Sviridov and Oliver) : Report on the PWVS Research Project and the pollution problems in the Vaal Barrage, November 1978, page 5 item ii.

1.3 Future conditions and assumptions

In order to indicate to what effect increasing TDS will have on all users of such water in the Complex, it is necessary to assume a realistic TDS concentration that could occur in the water supply in future. For this purpose it was decided to assume an average TDS value of 800 mg/l. As an average value this could be somewhat high but it must be borne in mind that water abstracted directly by Sasol and Iscor (1979) from the lower portion of the Barrage had an average TDS of 550 mg/l with long periods of 600 - 700 mg/l and peaks of 1000 mg/l.

In the first instance the study is based on a TDS of 800 mg/l. Later in this report a TDS of 500 mg/l is also considered. The costs so determined are compared with present day costs (1979) based on a TDS concentration of 300 mg/l and the results ex= pressed as additional costs. With such data available it is possible to give a graphic presentation of costs versus TDS concentrations (See Table 26 on page 117 and graph No. 3).

1.4 Expected potable water composition

Assuming that the TDS concentration will increase as predicted, the question arises how the water composition will change. From the RWB's reports on composition, it can be seen that the hard= ness increases directly with increasing dissolved solids. In Table 16 of the 1978 RWB report, the following ratios of total hardness : dissolves solids are found:-

TH : TDS

Average Conditions		Highest Conditions	
$\frac{98}{170} = 0,58$	(Z)	$\frac{160}{310} = 0,52$	(Z)
$\frac{94}{142} = 0,59$	(Z)	$\frac{106}{192} = 0,55$	(Z)
$\frac{140}{259} = 0,54$	(V)	$\frac{370}{650} = 0,57$	(V)
$\frac{252}{482} = 0,52$	(V)	$\frac{520}{910} = 0,57$	(V)

(Z = Zuikerbosch, V = Vereeniging)

In the case of the Zuikerbosch Station where water of a better quality is found, the ratio of hardness : TDS drops slightly as the TDS increases, whilst at the Vereeniging stations where the water is more mineralized, the ratio increases slightly with increasing TDS. One could then assume that with a TDS of 800 and 1000 mg/l, the hardness will be approxi= mately 0,55 x TDS = 440 and 550 mg/l as $CaCO_3$ respectively.

The hardness and dissolved solids are mainly responsible for problems in steam boilers and cooling plant, where chlorides could cause some corrosion in pipes and metal structures. Also, the hardness could cause lime deposition, especially in hot water installations and service pipelines.

The following figures indicate the changes in chlorides when the TDS increases : (Ratio of chlorides : TDS).

Cl : TDS

Average Conditions		Highest Conditions	
$\frac{16}{170} = 0{,}094$	(Z)	$\frac{29}{310} = 0{,}094$	(Z)
$\frac{9}{142} = 0{,}063$	(Z)	$\frac{11}{192} = 0{,}057$	(Z)
$\frac{23}{259} = 0{,}089$	(V)	$\frac{38}{650} = 0{,}058$	(V)
$\frac{47}{482} = 0{,}098$	(V)	$\frac{83}{910} = 0{,}091$	(V)

(Z = Zuikerbosch Station V = Vereeniging Stations)

From the above figures it appears that the chloride ratio increases slightly with increase in TDS.

Concerning sulphates the following figures are indicated:
(Ratio of sulphates : TDS)

SO_4 : TDS

Average Conditions		Highest Conditions	
$\frac{36}{170} = 0,21$	(Z)	$\frac{95}{310} = 0,31$	(Z)
$\frac{14}{142} = 0,10$	(Z)	$\frac{28}{192} = 0,15$	(Z)
$\frac{66}{259} = 0,25$	(V)	$\frac{125}{650} = 0,19$	(V)
$\frac{162}{482} = 0,34$	(V)	$\frac{395}{910} = 0,43$	(V)

Here the indications are that with increasing TDS, the sulphate ratio rises rapidly.

Comparing the ratios of alkalinity and bicarbonates to TDS, there is a tendency for them to drop as the TDS increases which indicates that the hardness changes from temporary hardness to permanent hardness. This is probably due to increasing permanent hardness entering the Barrage from mining and industrial operations.

1.5 Assumptions and Conclusions

From the foregoing, it is clear that if no further pollution control is applied, the following could be expected in the PWVS Complex:

(a) The degree of pollution will increase in proportion to increasing population and industrial growth. (See population growth item 1.1 Section B of this report).

(b) The average hardness and TDS of the water supply will increase in future : cost studies for water of 500 and 800 mg/l TDS to be indicated.

(c) The increased mineralization will cause undue hardships and additional costs to industry and private water consumers. Pipelines, especially hot water installations will be affected by corrosion and/or encrustration with reduced life, carrying capacity and additional costs for pumping and replacement of pipes.

(d) Plumbing equipment and soap consumption in households and institutions will be affected.

(e) Industry will have to spend more on demineralisation plants and chemicals to improve water for special application such as boiler feed, food preparation and cooling.

2. ECONOMIC EFFECTS UPON PRIVATE WATER CONSUMERS (Cost figures given are those related to the period 1979/80)

2.1 Introduction

This part of the report refers mainly to additional costs incurred by the private and flat residential consumers from the expected highly mineralized water from the Rand Water Board supply. Reference will also be made to commercial and institutional premises.

Costs incurred on consumer premises would result from the effects of mineralized water upon the plumbing systems including hot water heaters, washing machines, clothing, household fabrics and soap. Such costs will result from reduced service life and increased operational and maintenance costs. The assumption is that the present dissolved solids concentration of 300 mg/l will rise to an average of 800 mg/l with peak concentrations of 1100 mg/l causing hardness to increase from the present average of approximately 130 mg/l ($CaCO_3$) to some 440 mg/l with peaks of 600 mg/l. Later in this report cost effects when employing water of 500 mg/l TDS are also considered.

2.2 General cost considerations

Black and Veatch[2], in a study during the 1960's found that a highly mineralized water of 1750 mg/l dissolved salts decidedly added to the costs of a householder compared to where water of 250 mg/l was used. They found that the costs to the private consumers was ten times higher than that which the Water Utility Organization will incur operating with same water qualities. Experience similar to this is described by Ryder[3] in the Seattle Water Department.

In order to arrive at some specific cost estimates, it is necessary to know:

(a) the initial investment capital of water facilities in an average residential house including flat dwellings;

(b) the service life of the facilities (equipment);

(c) the time value of the invested capital;

(d) operational and maintenance costs.

The objective is to find the differential costs incurred for the householder between the so-called good and bad water.

2.3 <u>Capital Investment</u>

The capital investment covers all the plumbing requirements - from the water meter to the sewer connection within the consumer's boundary. It can be sub-divided as follows:

. water supply piping (hot and cold)
. wastewater piping
. hot water geyser(s)
. water taps (faucets)
. toilet flushing mechanisms
. washing machines (dish washers included)
. cooking utensils including electric kettles and steam irons
. washable fabrics and clothing
. additional soap and detergent consumption

2.4 <u>General plumbing installation</u>

In order to arrive at the capital invested by an average householder cost figures for all the above items, excluding washing equipment, i.e. washing machines, cooking utensils and washable fabrics, were obtained from a leading plumbing supplier in Pretoria. The cost items were that for an accepted tender (1979) for several hundred average houses for a large elctricity undertaking in the Transvaal Highveld. Such an average modern house will have two bathrooms, one shower, one electric hot water geyser of 150 litre and two toilets. For the servants quarters, a toilet, a shower and a wash basin with hot and cold water supply. The bulk of the water and wastewater piping is of galvanized iron; the taps in brass and chromium plating; lead traps for wash troughs, kitchen sink, baths and wash basins, with copper connectors on taps.

Cast iron is used to connect toilet and bath outlets with the ventilating pipes. Earthenware drains, pipes, bends and junctions are employed. Gutters and downpipes are not included in this study. All details with costs are set out in Table 3.

The total capital invested amounts to R1408 and does not include for the installation thereof which could amount to a similar figure.

At this stage it could be said that many existing households have only one bathroom and toilet and no hot water facilities for servants quarters. In this investigation the deteriora= tion costs for the bath, hand- and toilet basins are not taken into consideration as these items are hardly, if at all affected by harder water. It is only the additional water piping involved here that should be taken into account. However, this is a minor cost item.

<u>NB.</u>
Modern houses tend to have more than one bathroom, toilet and geyser so that it might be realistic to assume a factor of between 1,2 and 1,5 times the total number of houses. Interested parties wishing to be more specific in this respect could make their own deductions accordingly.

2.5 <u>Washing machines</u>

It is assumed most houses will have some type of washing machine whilst only a few will have a dish washing machine - details later.

2.6 <u>Cooking utensils</u>

Although each household has a sizeable investment of such utensils it is believed that the poorer quality water will hardly affect the life of such and is therefore not taken into consideration here.

TABLE 3

SUMMARY OF CAPITAL INVESTMENT FOR AN AVERAGE MODERN HOUSEHOLD+

ITEM NO		NO. OF ITEMS	VALUE (R)	
1.	Water piping:			
	(a) cold	1	110	
	(b) hot	1	88	
	(c) copper	1	22	
2.	Wastewater piping and drains		450	
3.	Water geyser:			
	(a) vessel only	1	160	
	(b) electric element	1	10	
4.	Water taps and shut-off valves	20	84	
5.	Toilet flushing mechanisms	3	80	
6.	Washing machine	1	350	
7.	Electric Kettle		24	
8.	Steam Iron		30	1408
9.	Washable fabrics and clothing		2 622	
	TOTAL		4 030	

+ Items like baths, basins, gutters and down pipes etc are not included here as these will not be affected.

3. ANNUAL CAPITAL COST ASSESSMENT PER HOUSEHOLD

Each household has to set aside an annual amount to cover the replacement of items employed depending on their service lives when employing the two types of waters indicated. The following cost assessments for each item are described and are represented by the equal annual payments required by amortizing the investment over the estimated life of the equipment at a 10 percent/a interest rate:

3.1 Water piping (cold)

It can be assumed that the water supplied by the RWB will be balanced with a slight positive Langelier Index. At distant delivery ends the Index could become zero or negative and pipes here could show slight signs of corrosion. Black and Veatch[2] investigated conditions and experiences on service lives of facilities and related matters concerning water utilities and use of water in private houses in 38 communities in the Midwest of the U.S.A. From such data only broad conclusions were drawn and the lives of facilities were graphically illustrated. Thus for galvanized iron piping the lifespan for a water of 250 mg/l TDS was approximately 33 years and for 1 000 mg/l some 18 years.

There appears only scant evidence on problems in the PWVS area arising from cold water distributed in galvanized piping in private homes. Discussions with pipe galvanizers, plumbing suppliers and experienced plumbers did not reveal any alarming situation with this type of installation. It would appear that such piping conveying cold water of the present quality could have an average lifespan of 35 years.

With an expected TDS of 800-1100 mg/l and hardness of 400-600 mg/l $CaCO_3$, chloride and sulphates will increase accordingly and it is probably correct to infer that this additional hard= ness could provide even better protection than at present. On the other hand, the character of the hardness in the Vaal Barrage water tends, with the increasing pollution, to change from temporary to permanent hardness, the effects of which are not readily known. It appears likely under such con= ditions with the presence of sulphate, chlorides and bicarbo= nates that both scaling and corrosion could occur resulting in a reduced lifespan of 25 years.

For these two qualities of water, taking the capital amount of R110 and amortizing such over the respective lifespan of 35 and 25 years at 10%/a, the annual costs are R11,41 and R12,12 with a differential cost of R0,71/a.

NB : The effects of corrosion on the outside of piping due to poor soil conditions are not considered here. Such corrosion is often found but it is not the result of the quality of the water flowing inside the piping but often as a result of humic acids and bacterial activity in the soil.

3.2 Water piping (hot)

There has been frequent evidence over the past two decades of failures in hot water systems - not only in South Africa but also in the Northern hemisphere. The corrosion is mainly found in highrise building complexes, like hospitals and large office and apartment buildings. Already in 1973, the problem had reached serious proportions in Durban as well as in Cape Town, Port Elizabeth and East London, so much so that the Council for Scientific and Industrial Research (CSIR) was called in to investigate the problem. During this time, according to the CSIR[4] five hospitals, several multi-storey flats and a university have suffered severely. This problem is not restricted to coastal areas where rather soft and slightly buffered water is used, but also occurs in the PWVS area with its much harder water.

According to Dr. Bird[5], the corrosion products found in the coastal towns contained no lime. For the PWVS area one would expect high quantities of lime in the corrosion products but the report indicates that this is not the case. The author's own observations and tests corroborate this phenomena.

The contributing factors responsible for this phenomena appear to be temperature, hydrostatic pressure, water velocity and even the protective scale formation. The presence of oxygen is also a major factor. Bird also states that the general design of the hot water circulation system could be respon= sible for such deterioration. Oxygen, no doubt plays a role and under conditions of oxygen depletion, cathodic evolution of hydrogen causes excessive corrosion.

Since this study deals with effects on the ordinary household equipment, it is necessary to guage the life of the hot water system as experienced presently and in the future.

At present the hot water appears to cause slight scaling in hot water pipes whilst corrosion appears to be minimal. With increased dissolved solids and hardness, no doubt much more scaling will result. The additional chlorides and other non-scaling salts could cause some corrosion. An estimated lifespan of 30 years with the present water is reasonable, whilst for the poor water quality, only 20 years is assumed, during which period the piping could require descaling after each 10 years.

The replacement costs involved here appear to be R9,34 and R10,34/a respectively for the two waters with a differerential of R1,00/a. Charges for cleaning of pipes will be dealt with later on under maintenance and are not included here.

This study does not cover conditions in large high-rise public buildings where even more problems are encountered in the hot water galvanized piping in closed circulation. For this condition, consult Dr. Bird of the CSIR, Pretoria. His main recommendation for high-rise buildings is to switch over to copper or stainless steel piping.

3.3 Wastewater piping and drains

The materials used here are mainly cast iron, chromium plated steel and lead which take the wastewaters to the outside earthen=ware drains, and hence to the municipal sewer system. These materials handle high pH soapy and fatty effluent, as well as sewage. The materials employed stand up well to corrosion and their lives are rather extensive and could be on average 50 years. With the higher mineral salts expected the life will still be extensive at an estimated 45 years. The capital involved here is R450. Replacement costs for the two qualities of water are R45,39 and R45,63/a with a differential cost of R0,24/a.

3.4 Hot water geyser

From discussions with the large electric hot water geyser manufacturers, it is reasonable to allow an average lifespan of 25 years for the geyser.

With the expected highly mineralized water the inside of the geyser will receive scale deposits with little or no corrosive effects on the enamel linings used in the bulk of geysers now marketed. Also in the case of copper geysers, no corrosion is expected.

With the much harder water the geyser - depending on its temperature setting, will scale-up within 15 years after which it will require replacement.

The costs involved for the geyser with these service lives will be R17,63 and R21,04/a respectively, with a differential cost of R3,41/a. The effects of the water quality on the element is considered to be a maintenance item and is therefore dealt with under item 4.4 Operation and Maintenance.

3.5 Water taps (faucets)

Deliberations with water tap manufacturers and the Bureau of Standards indicate that the modern tap available today, especially those carrying the SABS mark conveying Rand Water Board water has a long life of at least 30 years. Gland packing has been improved and replaced with an '0' ring and the SABS mechanical specifications allows for $0{,}25 \times 10^6$ open and close cycles again a 3 Nm torque force.

The general opinion of the life of such taps handling the expected mineralized water would be almost the same as for the present water. A life period of 25 years is reasonable i.e. a 15 percent deterioration. Costs involved are R8,91/a for the present water and R9,25 for the bad water, giving a dif= ferential of R0,34/a.

3.6 Toilet flushing mechanisms

With todays sophisticated materials available, corrosion of flushing mechanisms as well as for the toilet cisterns, is almost totally under control. The only item that is subjected to corrosion by water is the cast iron high level cistern sometimes used in outbuildings. This item made of cast iron is normally well protected by paint and corrosion is so minimal that it is left out of this study as a contributing and maintenance factor. In many cases plastic low level cisterns are now employed. These could crack by physical means but the impact of water appears to be negligible.

3.7 Washing machines

Figures obtained from Market Research Africa, Johannesburg[6], indicate that of the 500 000 European households in the PWVS area, (1978/79) 83 percent have washing machines i.e. 415 000 machines. One-third are automatic machines = 137 000 and two thirds semi-automatic machines = 278 000.

The average cost of a washing machine is approximately R350. Investigations with washing machine manufacturers and a large maintenance organization indicate the average lives for automatic and semi-automatic machines are 8 and 11 years respectively. During this period at least one major overhaul is required plus some minor replacements every three or four years. There are still many automatic machines with galvanized drums which are prone to corrosion caused by poor galvanizing and partly due to high pH of ± 10 in wash water from the detergents and soaps used. With the much higher mineralized water, additional detergent powders will be employed i.e. higher concentrations of detergent and mineral dissolved solids and probably a higher pH of approximately 11. It is quite possible that additional rinsing might be required to rid the washable materials from such solids and precipitates. It is possible that additional softening and sequestering agents will be in= corporated in the washing powders*. All of these factors will very likely lessen the life of such machines. The lifespan could be reduced by some 10 percent at least i.e. reduced to 7 and 10 years respectively for automatic and sem-automatic machines. There are indications that the automatic machine is replacing the twin tub semi-automatic machine.

Costs involved for replacement are as follows:

Automatic machines : R71,89 and R65,60/a with a differential cost of R6,29/a.

Semi-automatic machines : R53,89 and R56,96 with a differential cost of R3,07/a.

These are equivalent to R6,29x0,83x0,33 = R1,72/a and 3,07x0,83x0,67 = R1,71 /a respectively per household for the entire region based on the number of machines in use.

* From discussions with soap/detergent manufacturers

3.8 Dishwashers

According to Market Research Africa[6], there are 46 000 such machines in the PWVS complex. This equals approximately 10 percent of the PWVS European households.

The average cost for a machine is approximately R450 and its useful service life some 10 years. It appears that all dishwashers have stainless steel linings whilst some have built-in tanks in which softening chemicals are charged to deal with hard waters. Information from servicing organiza= tions indicates one major overhaul per 10 years with costs of approximately R60. There may be frequent minor repairs to the water hoses and electric control equipment. It is doubtful whether the expected harder water will influence its life much. A 10 percent reduction is reasonable giving it a life of 9 years with the harder water. The costs in= volved for replacement are : for present water R73,24/a and for future bad water R78,14/a giving a differential of R4,90/a which is equivalent to 0,1xR4.90 = R0,49c per household/a for the entire region.

3.9 Cooking utensils

Although each household has a sizeable investment in these utensils, it is believed that the poorer quality water that may be expected will have little or no influence on the life of these and is therefore not taken into consideration here.

3.10 Electric Kettles and Steam Irons

It would appear that each house has an electric kettle or a similar heater whilst only some have steam irons. The quality of the water will have an influence upon their livespan too. Electric kettles undergo deposition of hardness salts on the inside and upon the element. The following information was accepted after discussing the effects and costs with an electric appliance supplier and maintenance organization:

Kettle life: 15 years with present water quality;
: 12 years with 800 mg/l water quality;

Value of kettle R24 and the differential replacement lost per household is R0,36/a.

3.11 Electric Steam Irons

It would appear that steam outlets become blocked with salt deposition upon evaporation and that the steam valve becomes inoperative. Upon discussing this with a supplier and maintenance organization the following conditions were accepted:

Number of steam irons in PWVS complex : one-sixth of houses/ flats $= \frac{500\ 000}{6} = 83\ 330$

Cost of steam iron = R30
Life of iron with present water, 6 years.
Life of iron with bad water, 4 years.
The differential cost/house = R0,43/a.

3.12 Washable fabrics

The average capital investment for an ordinary family of four people is surprisingly high. The head of the Home Economics Section of the Department of National Education has kindly set out the amount of value of washable household items and clothing used in an average home of two adults, a boy and a girl. A detailed list of such items with its capital re= quirements amounting to R2 622 at present day prices (1979), is set out in Table 7. The Home Economic Section is rather reluctant to indicate the lifespan of such fabrics with present water quality, but thought the average life to be higher than the 4,6 and 4,4 years (4,2% difference) for the two classes of water examined by Black and Veatch[2]. A realistic figure under our present conditions of a good water could be 6 years. With poorer water the detergent and soap consumption will increase with some additional rinsing, which will affect the life of washable materials. The life under these conditions is therefore taken as 5,85 years which is a reduction of 2,5 percent. The differential cost is therefore R616,17 and R602,04 = R14,13/ annum/household. Table 4 below summarizes the capital and lifespan involved for the various items des= cribed.

TABLE 4

ESTIMATED CAPITAL AND LIFESPAN OF HOUSEHOLD EQUIPMENT

NO	ITEM	CAPITAL (R)	ESTIMATED LIFESPAN	(YEARS)
			300 mg/l TDS	800 mg/l TDS
1.	Water piping			
	(a) Cold water	110	35	25
	(b) Hot water	88	30	20
2.	Wastewater piping and drains	450	50	45
3.	Water heaters			
	(a) Geyser vessel	160	25	15
	(b) Geyser heating element	10	7	3
4.	Water taps	84	30	25
5.	Washing machines			
	(a) Automatic	350	10	8
	(b) Twin tub-semi= automatic	450	12	10
	(c) Dishwasher	450	10	9
	(d) Kettle electric	24	15	12
	(e) Steam iron	30	6	4
6.	Washable fabrics	2 622	6	5,85

4. ANNUAL OPERATIONAL AND MAINTENANCE COSTS

The mineral content in water not only affects the life of household plumbing and other equipment but also the operation and maintenance thereof. With excessive mineral content the quantity of soap and detergents and rinsing waters will increase accordingly. General in= formation used in this study is from background information, experience of investigators and literature. The maintenance costs of facilities and equipment quoted here are due only to the expected deterioration of water supplied from the Vaal Barrage through the Rand Water Board+.

As the precise time of carrying out the maintenance is not known the philosophy adopted below is simply to spread the assumed cost of the maintenance over the full lifespan of the item.

4.1 Cold water piping

Operation and maintenance costs could be due to leaks, breaks, corrosion and scale. In some cases a plumber could be called out whilst in other cases the owner will be able to undertake the repairs himself. In determining an allowance for operation and maintenance costs, it appears reasonable to assume one repair to cold water piping during the lifespan of 35 years. At an average cost of R50 per repair the cost for present water quality is R1,43/a.

With the expected hard water one repair also appears to be adequate over the lifespan of 25 years. At a similar cost of R50 the cost/a is R2,00 giving a differential cost of R0,57/a.

4.2 Hot water piping

Piping handling hot water will be subjected to both cold and hot conditions causing additional strain on joints and beds. With the present water quality minor scaling will occur but no replace=ment will be required over its service life of 30 years. However, here also one service for possible repairs is allowed for at R50. The costs involved for these two qualities of water are:

Present water R1,67/a, future water R2,50 giving a differential cost of R0,83/a.

With harder water severe scaling is expected requiring cleaning (acid every 10 years at say R50 per cleaning), which would not be required with present water. Therefore differential is R5,00/a. (If this method is unseccessful, piping will have to be chopped away and replaced at even higher costs). Total differential cost therefore amounts to R4,17/a.

+ Major replacements are not considered here as they are capital expenditure which are covered under section 3 of this report.

4.3 Wastewater piping and drains

Expenditure on maintenance of this type of equipment will be minimal. Blockages of pipes and drains are not taken into consideration here as these are not attributable to the water itself. Even with the harder water no maintenance is foreseen.

4.4 Electric hot water geyser

The geyser itself will become coated in time especially with the harder water, but this will not cause damage to the body through its life time. Information from geyser manufacturers allows a life of 25 years under present water conditions and 15 years with the harder water when it becomes heavily blocked with lime deposits and needs replacement. No maintenance or operational costs are involved. Installation costs amount to R90 giving an annual differential cost of R6,00 and R3,60 = R2.40/a.

The electric element is valued at R10 and is usually not reparable and is replaced when spent. The cost of an element is R10 and installation a further R15. The lifespan with present water is taken at 7 years and with 800 mg/l water at 3 years. The annual maintenance costs for the two qualities of water are therefore R8,33 and R3.57 respectively. Differential is R4,76/a.

4.5 Water taps (faucets)

As stated before the quality of taps with the SABS mark is excellent. No maintenance is expected with the present water available. With the harder water lime deposits will call for one cleaning operation during its life time of 25 years. At a cost of R40 the annual costs amounts to R1,60/a.

4.6 Toilet flushing mechanisms

The life of these mechanisms are unaffected by the water qualities in question and no cost is involved for maintenance.

4.7 Washing machines

4.7.1 Automatic machines

With the hard water and additional soap/detergent requirements its life will be reduced from 8 to 7 years with one major overhaul during its life at R100. The costs involved for the owner will be R12.50/a with the present water and for the harder water R14,29/a, giving a differential cost of R1,79/a.

4.7.2 Semi-automatic machines

With these machines the life will be reduced from 11 to 10 years for the two types of water respectively. One major overhaul will be require during its life time at R60.

The following costs are involved : For the present water R5,45/a, and for the hard water R6,00/a, giving a diffe= rential cost of R0,55/a.

4.7.3 Overall differential costs

Overall differential costs for washing machines based on the Market Research figure given under item 2,5 will be as follows:

Automatic machine	0,83x0,33xR1,79	=	R0,49
Semi-automatic machine	0,83x0,66xR0,55	=	R0,30
	TOTAL		R0,79/a

4.7.4 Dishwashers

The service lives of a dishwasher with the two types of water is 10 and 9 years respectively. One major overhaul is required during its lifetime at R70. This gives costs of R7,00 and R7,78/a for the two waters respectively and a differential of 78c/a.

Since only 10 percent households have dishwashers, the differential is 8c/a.

4.8 Kettle element

Lifespan of element with present water is 10 years and with 800 mg/l water, 7 years. Replacement cost is R10 per element giving annual costs of R1,00 and R1,43 respectively. Differential is thus R0,43/a.

4.9 Steam Iron

Repairs to steam valve will cost R6.00. This will be necessary every 4 years with present water and every 2 years with the harder water. Costs are therefore R1,50 and R3,00 respectively with a differential of R1,50/a equivalent to R0,25 per household per annum, since only 1/6th of the households have a steam iron.

4.10 Washable fabrics

There are no maintenance costs attached to this item.

4.11 Soap and detergent consumption

A short survey amongst European households covering soap and deter= gent requirements per average household of five people gave the following amounts required per month (Servant included).

MONTHY REQUIREMENTS (EUROPEAN)

Detergent Powder (Washing Machines)	Liquid Detergent (Kitchen)	Toilet Soap Bath and Personal	Laundry Soap Bars	Total
2,29 kg R2,86	1071 ml R1,07	578 grams R1,16	286 grams 26c	R5,35

Cost of soaps :			
	Detergent	R1,25 kg	for 1979
	Liquid detergents	75c/750 ml	
	Toilet soap	30c/150 g	
	Bar soap	45c/500 g	

Soap and Detergent consumption for the RSA according to the Department of Statistics in 1977+ is as follows:

Soap in bar from	13 435 tons
Toilet soap	30 062 tons
Soap/detergent powder	102 817 tons
Liquid soap	29 767 kl

Gauging the soap/detergent consumption against the 1978 population[7] figures for the country, excluding the Transkei and Bophuthatswana, of 23 894 000 (whites 4 408 000) the following figures are indicated:

\+ See Manufacturing Statistics, Products Manufactured, Department of Statistics, Pretoria, November 1978 Table 12.3

	Non-white	All Races	European
Soap in bar form	486g	560g/c/y	(686)g/c/y
Toilet soap	1185g	1260g/c/y	(1387)g/c/y
Detergent powder	3,60 kg	4,30 kg/ ~~c/y~~	(5,50) kg/c/y
Liquid soap	0,47 l	1,25 litre/ c/y	(2,57) litre/ c/y

(g/c/y = gram/capita/year)
(Figures in brackets are author's own limited survey for the European households in the PWVS complex in mid 1979. Figures for Non-whites are calculated figures).

As could be expected, these figures differ markedly with European requirements, especially with regard to toilet and liquid detergent soap.

4.12 Future soap and detergent consumption : European

In order to estimate the future soap and detergent requirements, soap consumption tests on three samples of water taken from the Vaal Barrage Basin were undertaken by the S.A. Bureau of Standards with the following results:

	Sample No.		
	1	2	3
TDS at 105 C mg/l	210	620	980
Total hardness as Ca CO_3 mg/l	115	336	515
Soap requirements g/l (Sofnol)	1,5	4,3	6,3
Ratio of TH:TDS	0,55	0,54	0,53
Ratio of soap required : hardness	0,013	0,013	0,012

From the above ratio's it is clear that the hardness and soap requirements are directly proportional with the TDS.

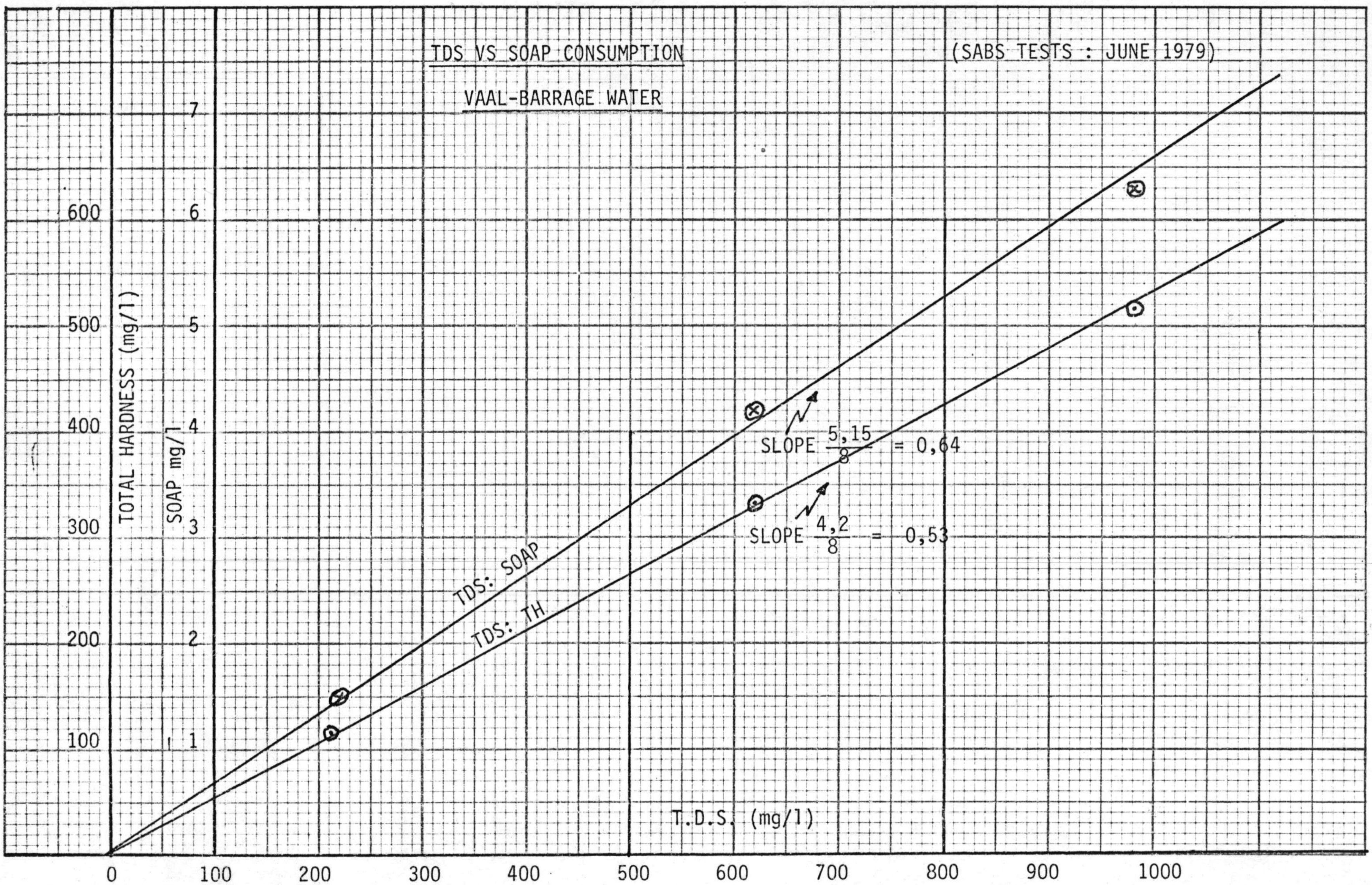
Taking sample 1 as a basis of the present soap requirements then,

sample 2 requires $\frac{336}{115} \times 1,5 = 4,38$ g/l of soap

and sample 3 requires $\frac{515}{115} \times 1,5 = 6,73$ g/l of soap

The present water has a TDS of 280-300 mg/l and a hardness of 0,54xTDS = 152 to 162 mg/l $CaCO_3$, whilst water of 800 mg/l TDS will have a hardness of 432 mg/l $CaCO_3$.

GRAPH NO 1


TDS VS SOAP CONSUMPTION
VAAL-BARRAGE WATER
(SABS TESTS : JUNE 1979)
TOTAL HARDNESS (mg/l)
SOAP mg/l
TDS: SOAP
TDS: TH
SLOPE $\frac{5,15}{8}$ = 0,64
SLOPE $\frac{4,2}{8}$ = 0,53
T.D.S. (mg/l)
0
100
200
300
400
500
600
700
800
900
1000
1
2
3
4
5
6
7

As the amount of soap and its cost is proportional to the hardness, costs will increase by the following factor for the two classes of water: $\frac{432}{152} = 2,8$

Graph No. 1 indicates the TDS/Soap and TDS/Total Hardness Relation= ship for various qualities of water.

From item 4.11, the monthly soap consumption (1979) per average household (European) is approximately 578 gram toilet soap and 286 gram household soap. Accordingly, the costs will increase from R1,16 to R3.25 for toilet soap and from 26c to 73c per month for household bar soap or together approximately R3,98 per month. Concerning future detergent usage, tests by the S.A. Bureau of Standards indicated that a water of 200 mg/l hardness with a standard detergent test gave a 63,5% cleaning efficiency. Work done in this field by Lever Bros, on additional detergent require= ments for Vaal Barrage water of 800 mg/l TDS compared to the require= ments of the present RWB water, indicated a 20 percent increase. This is more or less in agreement with tests by the Bureau.

The future costs for detergents will therefore increase by 20 percent from R2,86 to R3.43 per month per household (See 4.11). Similarly, a leading soap manufacturer indicated that liquid soap requirements for water of 800 mg/l will also increase by approx= imately 20 percent, from R1,07 to R1,28 per month (See 4.11).

<u>Summing up</u> : Cost/household/month with TDS of 800 mg/l

Future soap costs (toilet and household)	R3,98
Future detergent costs	3.43
Future liquid soap	1,28
Total future costs	8.69
Present total cost per month	5.35
<u>Additional</u> future cost per month	R3.34

or R40/a per household or R40x500 000 households = R20x10^6/annum.

4.13 <u>Summary of Total Costs for European Households (Water 800 mg/l TDS)</u>

Table 5 gives details of the various additional costs that could arise should the water attain a TDS value of 800 mg/l.

TABLE 5

SUMMARY OF ANNUAL TOTAL ADDITIONAL COST EFFECTS FOR AN AVERAGE EUROPEAN RESIDENTIAL WATER USER (WATER QUALITY TDS 800 mg/l)

Line No.	Item	Estimated Annual Cost Differential		
		Capital	Operational and Maintenance Cost	Total
	Facility	(R)	(R)	(R)
1	Water piping			
	(a) Cold Water	0,71	0,57	1,28
	(b) Hot Water	1,00	4,17	5,17
2	Wastewater piping and drains	0,24	nil	0,24
3	Electric geyser	3,41	7,16	10,57
4	Water Taps	0,34	1,60	1,94
5	Toilet flushing mechanism	nil	nil	nil
6	Washing Machines etc			
	(a) Automatic	1,72	0,49	2,21
	(b) Semi-automatic	0,84	0,30	1,14
	(c) Dishwasher	0,49	0,08	0,57
	(d) Electric Kettles	0,36	0,43	0,79
	(e) Steam Irons	0,43	0,25	0,68
7	Washable fabrics and clothing (see item 6)	14,13	nil	14,13
8	Soap/detergents	nil	40,00	40,00
	TOTAL	R22,97	R55,05	R78,72

For the 500 000 households in the PWVS-Complex the additional costs to the European population appears to be 39,4 x 10^6/a. Should the effect of washable fabrics and clothing be omitted the diffe= rential cost will be R32,3 x 10^6/a which is a reduction of 17 percent.

Assuming an average water consumption of 250l/capita/day and 4,5 persons per household, the additional cost, should the water attain a TDS of 800 mg/l, could be $\frac{78,72 \times 100}{0,250 \times 4,5 \times 365}$ =19c/kl of water (approximately).

Table 6 gives details of the investment of washable fabrics and clothing in an average European household of four people whereas Table 7 gives details of the annual additional costs for an average European household when using water with 500 mg/l TDS.

In Tables 5 and 7 the effects of the additional cost on the water range are given viz 19c/kl and 9,7c/kl for the two classes of water.

TABLE 6

INVESTMENT IN WASHABLE FABRICS AND CLOTHING IN AN AVERAGE HOUSEHOLD OF FOUR PEOPLE

Domestic Articles

Item	Quantity	Price (R)	Cost (R)
Sheets (6 single beds) - fitting	11	11,49	126,39
- top sheet	11	7,49	83,39
Pillowslips (2 pillows per bed)	18	2,39	43,02
Mattress covers	6	5,59	35,94
Bedspreads	6	14,99	89,94
Towels (bath)	10	6,39	63,90
Towels (face)	10	3,10	31,90
Face cloths	10	0,69	6,90
Bath mats	4	1,99	7,96
Table cloths	4	9,99	39,96
Table napkins	16	0,99	15,84
Place mats	12	0,69	8,28
Tea towels	8	0,89	7,12
Dish cloths	6	0,69	4,14
Tea cloths	3	8,99	26,97
Tray cloths	6	2,45	14,70
Table runners	4	3,49	13,96
Antimacassars	12	4,49	53,88
Lace curtains	20	R3/m 197m	591,00
Guest towels	4	1,49	5,96
Ironing board covers	2	1,12	2,24
			1192,39

	Quantity	Price	Cost
		(R)	(R)
Husband's clothing			
Shirts (office and best)	10	8,49	84,90
Shirts (home)	6	10,97	65,82
Safari suits	3	24,95	74,85
Sports shorts	2	6,99	13,98
Tennis shorts	2	6,99	13,98
Tennis shirts	2	3,99	7,98
Briefs	6	1,65	9,90
Vests	4	2,05	8,20
Handkerchiefs	12	2,34/3	9,36
Socks	10 pr	1,64	16,40
Light-weight jersey	1	9,99	9,99
Winter jersey	1	17,99	17,99
Dressing gown (summer)	1	15,49	15,49
Dressing gown (winter)	1	19,99	19,99
Pyjamas (shorties)	2	6,99	13,98
Pyjamas (winter)	2	9,49	18,98

Wife's clothing			
Dresses (home)	4	11.99	47,96
Dresses (better)	2	21,49	42,98
Blouses	8	9,49	75,92
Skirts (summer)	2	10,99	21,98
Skirts (winter)	2	24,99	49,98
Slacks	2	8,99	17,98
Lingerie : Brassieres	3	2,99	6,87
: vests	3	1.99	5,97
: panties	6	0,99	5,94
: petticoats	3	6,99	20,97
Pyjamas (summer)	2	7.50	15,00
Pyjamas (winter)	2	9,99	19,98
Stockings	6	0,98/pr	5,34
Dressing gown (summer)	1	12,99	12,99
Dressing gown (winter)	1	13,99	13,99
Jerseys (short sleeved)	2	6,99	13,98
Jerseys (winter)	1	17,99	17,99
Pinafores	3	2,85	8,55
Scarves	4	3,99	15,96
Tennis dresses	2	17,49	34,98
Tennis socks	2	0,84	1.68
			456,99

	Quantity	Price (R)	Cost (R)
Boy (13 years) : clothing			
Shorts (school)	4	5,59	22,36
Shorts (house)	4	4.49	17,96
Trousers (school)	2	9,99	19,98
Trousers (home)	2	12,99	25,98
Shirts (school)	6	3.74	22,44
Shirts (home)	4	3,09	12,36
Jerseys	2	8.99	17,98
Jerseys (school)	1	6,74	6,74
Jerseys (winter)	1	13,50	13,50
Dressing gown (summer)	1	14,99	14,99
Dressing gown (winter)	1	10,59	10,59
Handkerchiefs	12	2,34/3	9,36
Briefs	6	1.99	11.94
Vests	4	1.19	4.76
Hose (school)	6 pr	1.39	8,34
Tennis shorts	2	4,49	8,93
Tennis shirts	2	5,15	10,30
Tennis socks	2 pr	1.95	3,90
			250,43
Girl (8 years) : clothing			
Dresses (school)	2	8,39	16.78
Dresses (home)	4	3,99	15,96
Dresses (best)	2	9,99	19,98
Skirts	2	10,99	21,98
Slacks	2	4,99	9,98
Shorts	4	3,95	15,80
Blouses	4	7,50	30,00
Bodyshirts	4	5,99	23,96
Jerseys	2	7,95	15,90
Jerseys (school)	1	6.99	6,99
Dressing gown (summer)	1	6.50	6.50
Dressing gown (winter)	1	8.50	8.50
Pyjamas (summer)	2	4,95	9,90
Pyjamas (winter)	2	5,50	11,00
Vests	6	1,79	10,74
Panties (home)	8	0,89	7,12
Panties (school)	4	1,29	5,16
Socks (home)	6	0,89	5,34
Socks (school)	4	0,89	3,56
			246,93
		TOTAL	2621,54

4.14 SUMMARY OF COST TO A HOUSEHOLD (TDS 500 mg/l)

A study of the costs for a household employing water of 500 mg/l TDS was also undertaken on the same basis as described. Table 7 gives details of such costs:

TABLE 7

SUMMARY OF ANNUAL TOTAL COST EFFECTS FOR AN AVERAGE EUROPEAN HOUSEHOLD USING WATER OF 500 mg/l TDS

	Facility	Estimated Annual Cost Differential		
		Capital Cost (R)	Operational and Maintenance Cost (R)	Total Cost (R)
1.	Water piping			
	(a) Cold Water	0,26	0,24	0,50
	(b) Hot Water	0,36	2,50	2,86
2.	Wastewater piping and drains	0,10	nil	0,10
3.	Electric geyser	1,16	0,69	1,16
	Element	nil	1,43	1,43
4.	Water taps	0,18	nil	0,18
5.	Toitlet flushing mechanism	nil	nil	nil
6.	Washing machines etc			
	(a) Automatic	0,73	0,23	0,96
	(b) Semi-automatic	0,70	0,15	0,83
	(c) Dishwasher	0,12	0,04	0,16
	(d) Electric kettle	0,10	0,18	0,28
	(e) Steam iron	0,17	0,08	0,25
7.	Washable fabrics etc	4,95	nil	4,95
8.	Soap and detergents	nil	25,00	25,00
	TOTAL	8,83	31,14	39,97

Total cost for 500 000 households = R20 x 10^6/a

Based on a daily average water use of 250 l/capita/d and 4,5 persons per household, the additional costs when the water contains 500 mg/l TDS is:

$$\frac{39,97 \times 100}{0,250 \times 4,5 \times 365} = 9,7 \text{ c/m}^3$$ water (10,4c/kl for a household of 4,2 persons).

There appears to be three factors responsible for the deteriora= tion of clothing etc. when subjected to washing, ironing and wear and tear. It is believed that the last two factors, whether one washes with a low or highly mineralized water have little influence on the life of the clothing, but that when washing with a highly mineralized water, the quality and life suffer. This is due to the fact that more soap and longer wash time is required.

Investigations revealed that no precedent for the determination of the reduced lifespan of fabrics exists and nor could con= sensus of opinion on this matter be obtained.

Black and Veatch[2], in their investigation assumed a lifespan reduction from 4,6 to 4,4 years, equivalent to 4,34% for water of 250 and 1 700 mg/l TDS respectively. In our case, a reduc= tion of 2,5% in the lifespan is allowed assuming the fabric life to reduce from 6 years to 5,85 years. On a capital investment of R2 622 per household in washable fabrics and clothing, a differential cost of R14,13/a was found. This is a substantial figure amounting to R7,07 x 10^6/a for the 500 000 households in the complex or 17 percent of the total costs.

Persons interested in this field of additional household costs which appear to arise when washing with mineralized water, are at liberty to draw their own conclusions .

The additional costs when operating with water of 500 mg/l TDS have been determined on a similar basis as that for water of 800 mg/l, and this is reflected in Table 7. The additional costs for the 500 000 households is approximately R20 x 10^6/annum which is a reduction of 50 percent compared to that of water of 800 mg/l TDS.

5. FUTURE SOAP AND DETERGENT CONSUMPTION FOR THE TOTAL POPULATION IN THE COMPLEX

It is believed that the soap and detergent consumption by the non-white sector is also substantial. By employing the con= sumption figures supplied by the Department of Statistics and the author's own limited survey, it is possible to determine the consumption by the non-white section for the PWVS-complex. The calculations are based on the 1980 population figures as given by Browett and Hart[8.] in Section B1.1.

By employing the cost figures for all various types of soaps/ detergents as shown under section 4.11 it was possible to calculate the present consumption and costs for all soap/detergent users and is shown below in Tables 8(a) and 8(b).

TABLE 8(a)

PRESENT SOAP/DETERGENT USE BY ALL RACES IN THE PWVS-COMPLEX (TDS 300 mg/l)

(g/capita/annum)

	Whites	Non-whites	All races
Soap in bar form	686	486	560
Toilet soap	1387	1185	1260
Detergent powder	5500	3600	4300
Liquid Soap (litre)	2,57	0,47	1,25
Population 1980 in 1000's	1808	3065	4873

TABLE 8(b)

VALUE OF SOAP/DETERGENTS USED BY ALL RACES IN THE PWVS-COMPLEX (1980) in R1000 (TDS 300 mg/l)

Product	Bar Soap	Toilet Soap	Detergent Powder	Liquid Soap	Total Cost
Value/a R x 1000	R1000	R1000	R1000	R1000	R1000
Whites	1116	5016	12430	4646	23208
Non-whites	1340	7264	13792	1445	23841
All races	2456	12280	26192	6091	47019

Assuming as before under section 4.12 that the hardness will increase by a factor of 2,8 and that the detergent powder and liquid consumption will increase by 20 percent, then the following costs will arise: (See Table 8(b)).

For soaps (bar + toilet) : $R(1,340 + 7,264) \times 10^6 \times 2,8$
$= R24,09 \times 10^6/a$

and detergents and liquids : $R(13,792 + 1,445) \times 10^6 \times 1,20$
$= R18,28 \times 10^6/a$

∴ Total costs $= R42,37 \times 10^6/a$

∴ Additional cost for the complex by the Non-white community
$= (R42,37 - R23,84)10^6 = R18,53 \times 10^6/a$ for a TDS of 800 mg/l.

For water of 500 mg/l TDS, the estimated cost for the Non-white community is also taken as approximately 60 percent that for water of 800 mg/l TDS (see Tables 5 and 7 for soap/detergent requirements viz R40 and R25/household/annum respectively).

Therefore costs contributed by Non-whites is taken as $0,60 \times R18,53 \times 10^6$
$= R11,1 \times 10^6$/annum for water of 500 mg/l TDS.

5.1 Additional cost effects of clothing and washable fabrics for the Non-white community

Data available for cost effects for the Non-white community is sparse whilst vast strides are made in modernising its housing standards. Nevertheless, an attempt is made to calculate these additional costs as follows:

TABLE 8(c)

Housing Units in the PWVS-complex 1980ˣ		Population		Persons/houseˣ estimate
		1980 census	Browett and Hart	
Whites	500 000	1 874 300	1 807 600	4,2
Coloureds	28 000	177 485	182 570	6
Asians	17 000	96 770	86 660	5
Blacks	730 000	3 010 000	2 796 000	8
Total	1 275 000	5 158 555	4 872 830	-

x Figures from Market Research Africa, Johannesburg[6].

The following are the assumptions taken for the value of washable clothing and fabrics found in an average Coloured, Asian and Black house:

Coloured	:	R1500
Asian	:	R2622 - similar to an European house
Black	:	R500

Assuming as before that the life of these materials deteriorate during washing at the same rate as taken for the European viz 6 years with present water of 300 mg/l TDS and 5,85 years with water of 800 mg/l TDS, then the following additional costs will arise:

Costs : Washable Clothing and Fabrics : Non-whites

Coloureds : Amortized differential costs on R1500 over 6 and 5,85 years at 10% interest/a = R7/a/house
= 28 000 x R7 = R196 000/a

Asians : As above on R2622 the rate is R14,13/a/house
= 17 000 x R14,13 = R240 000/annum

Blacks : As above on R500 the rate is R3,50/a/house
= 730 000 x R3,50 = R2 555 000/annum

Total Costs : R2,991 x 10^6/a - assume R3 x 10^6/a.

The cost effects of soap, detergent and washable clothing are summarized in Table 8(d). (All races).

TABLE 8(d)

Population	Soap and Detergents Rx10^6/annum	Washable Clothing/fabrics Rx10^6/annum	Total Rx10^6/a
Coloureds } Asians } Blacks }	18,53	0,196 } 0,240 } 2,91 2,555 }	21,52
Whites	20	6,715	26,72
TOTAL	38,53	9,71	48,24

See Tables 5 and 8(b).

Lack of information prevents one to calculate the additional costs for the other faclities in houses of Non-whites as shown in Table 5 i.e. facilities 1 to 6.

For water of 500 mg/l TDS, the soap/detergent cost is taken as 60 percent of the cost for water of 800 mg/l TDS (See item 4.13 and tables 5 and 7).

For washable clothing etc. a 40 percent of the cost for water of 800 mg/l is taken.

On this basis the following additional costs are indicated for water of 500 mg/l TDS:

TABLE 8(e)

(Water of 500 mg/l TDS)

Population	Soap/detergent $Rx10^6/a$	Clothing and Fabrics $Rx10^6/a$	Total $Rx10^6/a$
Non-whites	11,1	1,2	12,3
Whites	12,0	2,7	14,7
TOTAL	23,1	3,9	27,0

5.2 Additional Costs for Plumbing in Non-white Housing

Table 8(c) gives the number of households in the non-white community of the PWVS-complex, viz 775 000 at present.

The following assumptions are used to calculate the rise in plumbing costs for the different non-white communities:

5.2.1 Asians : 17 000 households which plumbing etc. is comparable to that of the European houses and therefore the additional costs could be : 17 000 x R24,59 = R418 000/a.

5.2.2 Coloureds : 28 000 households : The assumption is that 75 percent of these houses have equivalent plumbing equipment to that of European housing. The additional costs are therefore 0,75 x 28 000 x R24,59 = R516 000/a.

5.2.3 Non-whites : 730 000 households : The assumption is that one percent of these are comparable to that of an average European house and the additional costs could be 7300 x R24,59 = R180 000/a.

Summing up, the total additional plumbing costs are R1 114 000/a or R1,44/a/household. For water of 500 mg/l TDS this cost will be reduced to 60% of R1,44 = R0,86/a/household.

5.3 Non-white Household Costs

5.3.1 Soap and Detergent Costs

Table 8(b) indicates that the soap and detergent costs for both whites and non-whites at present are very similar viz R23 x 10^6/a (1980 figures). These costs are based on data taken from the Manufacturing Statistics (1978) issued by the Department of Statistics. However, the additional costs for non-whites with water of 800 mg/l TDS is R18,53 x 10^6/a. For the whites the additional costs are R20 x 10^6/a based on a limited survey of soap and detergent consumption. (See Table 5).

5.3.2 Washable Fabric and Clothing Costs

According to Table 8(d) these additional costs for the non-whites appear to be approximately R3 x 10^6/a compared to R7 x 10^6/a for whites. (See Table 5).

5.3.3 Plumbing and Associated Equipment Costs

Under section 5.2 the plumbing costs for Non-whites are R1,114 x 10^6/a

Following from the above the total additional costs for the non-white community appear to be as follows:

	Cost/a
Soap and detergents	R18,53 x 10^6
Washable fabrics and clothing	R 3,0 x 10^6
Plumbing and associated equipment	R1,114 x 10^6
TOTAL	R22,644 x 10^6

6.

The final costs for all races when water of 800 mg/l TDS is used is reflected in Table 9 below.

TABLE 9

FINAL ADDITIONAL COSTS PER HOUSEHOLD PER ANNUM FOR ALL RACES FOR WATER OF 800 mg/l TDS

Per Household	Whites R/a/household	Non-whites R/a/household
Plumbing and accessories	24,59	1,44
Washable fabrics and clothing	14,13	3,87
Soap and detergents	40,00	23,91
TOTAL	78,72	29,22
Number of housing units	500 000	775 000
Total costs for whole complex/annum	R39,36 x 10^6	R22,65 x 10^6

Total additional costs/a for all races: R62 x 10^6

If the above cost figures are accepted as reasonable the following deductions ensue:

(a) The total soap and detergent consumption of the Whites is about the same as that consumed by the Non-whites. However, the whites' consumption per capita is almost double that of the Non-whites.

(b) The plumbing costs for non-whites are very low compared to that of the Whites, but this will increase rapidly with rising standards among Non-whites and Coloureds.

(c) At present the total additional costs for the Whites are almost double that for the Non-whites. This pattern is now changing.

7.

The final costs for all races when the water reaches 500 mg/l TDS are as shown in Table 10.

TABLE 10

FINAL ADDITIONAL COSTS PER HOUSEHOLD PER ANNUM FOR ALL RACES FOR WATER OF 500 mg/l TDS

Per Household	Whites R/a/household	Non-whites R/a/household
Plumbing and accessories	10,02	0,86
Washable fabrics and clothing	5,40	1,55
Soap and detergents	24,00	14,32
TOTAL	39,97	16,73
Number of houses	500 000	775 000
Total cost for whole complex/ annum	R20 x 10^6	R12,97 x 10^6

Total additional costs/s R32,97 x 10^6 = R33 x 10^6

At this stage it is impossible to indicate to what degree these costs will affect the water costs (c/kl additional) since the water consumption of the Non-whites is not known.

B. THE ECONOMIC EFFECTS OF THE ENHANCED CONTENT OF THE VAAL RIVER BARRAGE WATER ON THE RAND WATER BOARD'S OPERATIONS

1. INTRODUCTION

It is indeed fortunate that the supply of water to the PWVS-Complex is almost exclusively controlled by one central authority viz the Rand Water Board. This utility company or Board as it is known generally, was established in 1903 with limits of supply covering an area of over 17 000 km^2. Some 50 percent of the Republic's manufacturing production takes place in this area where almost 5 000 000 people are resident. This is about 1/5th the Republic's population. The PWVS-Complex covers an area of some 13 000 km^2.

The bulk of the water supplied by the Board, 98,6 percent, is abstracted from the Vaal Dam and the Vaal Barrage basin, whilst 1,4 percent is from the Zuurbekom boreholes. Of the 98,6 percent water, approximately 59 percent is Vaal Barrage water and 39,6 percent Vaal Dam water via the Vaal Dam Zuikerbosch pipeline. For the year 1978-1979 some 1898 Ml/d was supplied to its area of jurisdiction by the Board. Fig. 1 indicates the Board's past and future water supply and the estimated growth whilst Fig . 2 gives the average and maximum Total Dissolved Solids in the Barrage from 1960 to 1979.

In a recent forecast by Hall[9] for the end-of-the century water demand he determined the breakdown of water supplied to the PWVS-Complex during 1978/79 as follows:

	$10^6 m^3/a$	Percent
RWB from Vaal Dam and Barrage	683	84
RWB from Zuurbekom wells	10	1,2
Taken directly from the Barrage by Iscor, Sasol and Escom	84	10,3
Ergo from underground	14	1,7
Pretoria City own sources	22	2,7
TOTAL	813	100

A breakdown of the approximately 1898 Ml/d supplied by the Board during 1978-1979 appears to be as follows:

	Ml/d	Percent
Foundation Local Authorities	1 112	58,6
Gold and other mines	217	11,5
Preferent Consumers	497	26,2
S.A. Railways	20	1,0
Others	52	2,7
	1 898	100
or	693×10^6 kl/a	

1.1 Future Conditions in the PWVS-Complex

Projections of urban population in the Complex for the years 1980, 1990 and 2000 were carried out by Browett and Hart[8] of the University of the Witwatersrand for the Water Research Commission. The following population figures are mentioned in their report :

	Whites	Coloureds	Asians	Africans	Total
1970	1 429 764	128 570	68 172	2 124 488	3 750 994
1980	1 807 600	182 750	86 660	2 796 160	4 872 990
1990	2 194 860	254 290	109 420	3 685 190	6 243 760
2000	2 679 670	344 130	135 925	4 855 380	8 015 105

The overall percentage increase between 1970 and 2000 = 114%, and between 1980 and 2000 = 64%. It is reasonable to expect the industrial and manufacturing activities to increase in accordance with the population figures indicated above. Simi= larly, the water demand could increase in a likewise manner and perhaps faster as the living standards of all, particularly the non-white population will rise.

As indicated before, the expected activities in this Complex could result in a TDS concentration of 500 to 800 mg/l on average with peaks of 1100 mg/l With these assumptions it becomes necessary to examine these effects upon the Rand Water Board's operations.

1.2 Future Effects on the Rand Water Board's Operations

The Rand Water Board is well known and respected for its clear headed and discreet approach to water management, purification and quality control matters. It is indeed unfortunate that the return flow of large quantities of used water (effluent) including mining effluents enter the Vaal Barrage through the Klip and Zuikerbosch Rivers, which cause the quality of water supplied to fluctuate almost daily. These fluctuations are of minor consuequence to household users but to the industrialist who is subjected to these frequent quality fluctuations, especially those encountered in the lower reaches of the Vaal Barrage, it is a costly burden. Furthermore, the conditioning of cooling and boiler feed waters results in large increases in chemical consump= tion (mineral salts) which enter the Vaal Barrage basin aggravating the mineral content. Some of these are contained in the water supply to the PWVS-Complex which eventually are returned to the Vaal River and so generate a spiralling build-up of mineral salts.

The influence of these parameters upon the Board's future operations were discussed and examined after which the following views were submitted:

1.2.1 With the peaks in total dissolved solids already experienced, preciptation of suspended matter occurs in the Barrage basin with a marked degree of clarification leading to increased light penetration. The result is an increase in photosynthesis and subsequent algal growth requiring chemical chlorination for control. Such costs could be of the order of 0,16 c/m^3 and on a continuous basis could amount to some R2,7x10^6/a for chlorine only. See Table 11 and Figs 3 and 4 for prevailing conditions.

1.2.2 The reduction in suspended matter referred to in 1.2.1 above will result in a decrease in chemical consumption needed for coagulation. Table 12 shows the average chemical dosages and costs for Barrage water with increasing TDS concentrations from 200 to 1000 mg/l. The savings in the two cases of 306 and 906 mg/l TDS as shown in Table 12, amount to some R600 000/year for a water supply of 1750 Ml/d.

1.2.3 Since the suspended matter and chemical requirements appear to be lower with the high TDS waters, a decrease in sludge production with reduced sludge disposal costs could occur. The Board indicates that no records to quantify this cost reduction are available.

1.2.4 The water treatment costs for the Board's steam raising plant will increase should water of 800 mg/l dissolved solids be used. The additional cost over and above that when using Zuikerbosch water of 200 mg/l will amount to R60 000/a. This cost is regarded as negligible.

1.3 The Board's views were probed as to the effects which such high TDS and hardwater could have upon its pumping equipment, rising mains and reservoirs. The following views were expressed:

1.3.1 As the TDS rises the hardness will increase, whilst the character will change from temporary to permanent hardness. The latter is due to increasing amounts of chlorides and sulphates and less bicarbonates of calcium and magnesium. This tendency could lead towards corrosion and probably to less scaling in pipe=lines. Although the rising mains are lined with cement mortar or bitumen and the reservoirs constructed with concrete, damage could result but it will probably be at a very low rate. Costs of this is not known or easily quantifiable.

1.3.2 The Board is not at all enthusiastic about the idea of having to supply high TDS water to its customers. The many disadvantages to the private householder, industry and from a human health point of view are disturbing. From the latter point of view it prefers to adhere to the World Health Organization's standard of 500 mg/l total disoolved solids. The Board is of the opinion that the problem of escalating TDS should be tackled at source.

1.3.3 The possibility of softening the water by ion exchange will have some advantages for household and industrial users but such water after softening still contains about the same concentration of dissolved solids prior to softening. The high hardness salts of calcium and magnesium will be replaced by sodium. It is very likely that the sodium sulphate and bi= carbonate content could cause a poor taste in the water (unpalatable) and be corrosive, requiring additional treatment. In addition the high sodium content will have deleterious effects on soil and plants.

1.3.4 The following are details of the costs for softening Rand Water Board water :
The possibility of softening the water was examined with a well-known company supplying softening plant. It was assumed that should the hardness in future reach 400 mg/l as $CaCO_3$ - presently approximately 150 mg/l. and 50 percent of the present daily supply of say 2000 Ml/d is softened to zero and is mixed with the other 50 percent hard water, the following conditions will result :

(a) Cost of complete plant : R20 x 10^6
(b) 3700 kl resin at R1,2 x10^6 per 1000 kl resin equals R4,5 x 10^6
(c) Salt consumption 800 t/d at R40/t equals R11,7 x 10^6/a.

1.4 Summing up : Water Softening Costs

	$R \times 10^6$/annum
Capital repayment over 25y at 10%/a. interest (f = 0,11017)	2,2
Annual salt consumption	11,7
Annual resin ($\frac{1}{4}$ of R4,5 x 10^6)	1,1
Operation and maintenance (4% of capital)	0,08
Salaries and wages	0,20
TOTAL	15,28
Allow extras ± 10%	1,52
TOTAL	16,80

Additional cost/kl mixed water = $\frac{16,80 \times 10^6 \times 100}{2000 \times 1000 \times 365}$ = 2,3/kl

There are, however, a few snags attached to this process, viz:

(i) there might not be sufficient salt available in the country,

(ii) the disposal of large volumes of excess salt (brine) rinsed from the ion exchange columns - approximately 800 t/d which contains much sodium and which could reach the Vaal River again and increase mineralization.

(iii) it is well-known that base exchange softened water is corrosive and in need of stabilisation.

1.5 Harmful Trace Organics in Rand Water Board Water

The Rand Water Board, as the only supplier of potable water to the PWVS-Complex, has over the past decade been well aware of the presence of trace organics in the Vaal Barrage Water. It has also lately commenced with the testing and identification of the well-known organic compounds which could be harmful to man. Preliminary tests have shown the presence of six of the so-called trihalomethanes (THM) and there is reason to believe that other dangerous carcinogenic compounds might be present. It is well-known that upon chlorination trihalomethanes are formed which appear to increase with time after chlorination. This phenomena has been established by the Board.

There appears to be no standards laid down for these compounds in terms of COD and TOC. The Environmental Protection Agency of America has put forward some standards which, for some com= pounds appear to be unnessarily stringent - 100 ug/l for THM.[x]

The source of these organic compounds originates mainly from municipal and industrial discharges, run-off from residential and agricultural areas which enter the Vaal Barrage through its tributaries. Such organics are also present in natural waters and observed in the Vaal Dam. Although the natural purifying capacity of the Vaal Barrage imparts a degree of natural purification, it is believed that this has now been fully exploited and that positive controls at source and at the water works should be provided. To this effect the Rand Water Board has now commenced with an intensive study to establish the degree of organic pollution and to study the various methods of removing such harmful compounds. The study will probably take several years and it is impossible at present to gauge the exact costs and effects of such a system. There is no doubt that as the PWVS-Complex expands the costs to control these organics will increase. The Board has in the interim prepared an interim statement on this issue of organic pollution present in the Vaal Barrage and the probable cost of treatment. See RWB's statement at conclusion of this report - Section 'G'. It appears that treatment cost could increase by as much as 20 percent and could add R10 x 10^6/annum to Rand Water Board's bill, and increase the price to a consu= mer by 2,6c/kl.

x Amended National Interim Primary Drinking Water Regulations, 29 November 1979.

2. CONCLUSIONS

2.1 No changes in the present method of water purification are foreseen should the TDS increase up to 500 or 800 mg/l and the additional costs to the Board will probably be minimal, if any.

2.2 In the light of paragraph 1.3.1 the Board anticipates the water to have a slight tendency towards corrosion whilst no tendency towards scaling is expected. This is as a result of an increase in chlorides and sulphates whilst the bicarbonates will decrease.

2.3 Pumping plant, rising mains and reservoirs could suffer but it will most likely be slight especially with water of 500 mg/l TDS. This tendency could very likely be controlled by conditioning the water during its purification.

2.4 The Board is not in favour of softening the water supply as a solution and would strongly support the idea of finding alternative means of preventing the increasing mineralization build-up.

2.5 Pollution caused by organic material is slowly increasing and is now receiving serious attention by the Board. The costs to control and remove such is now being determined and could increase the annual overal treatment costs by 20 percent i.e. by R10 $\times 10^6$/a, or even more depending on the contact time required with granular activated carbon (GAC). The unit cost of water could thus rise by 1,3 to 2,6c/kl. See section G for details.

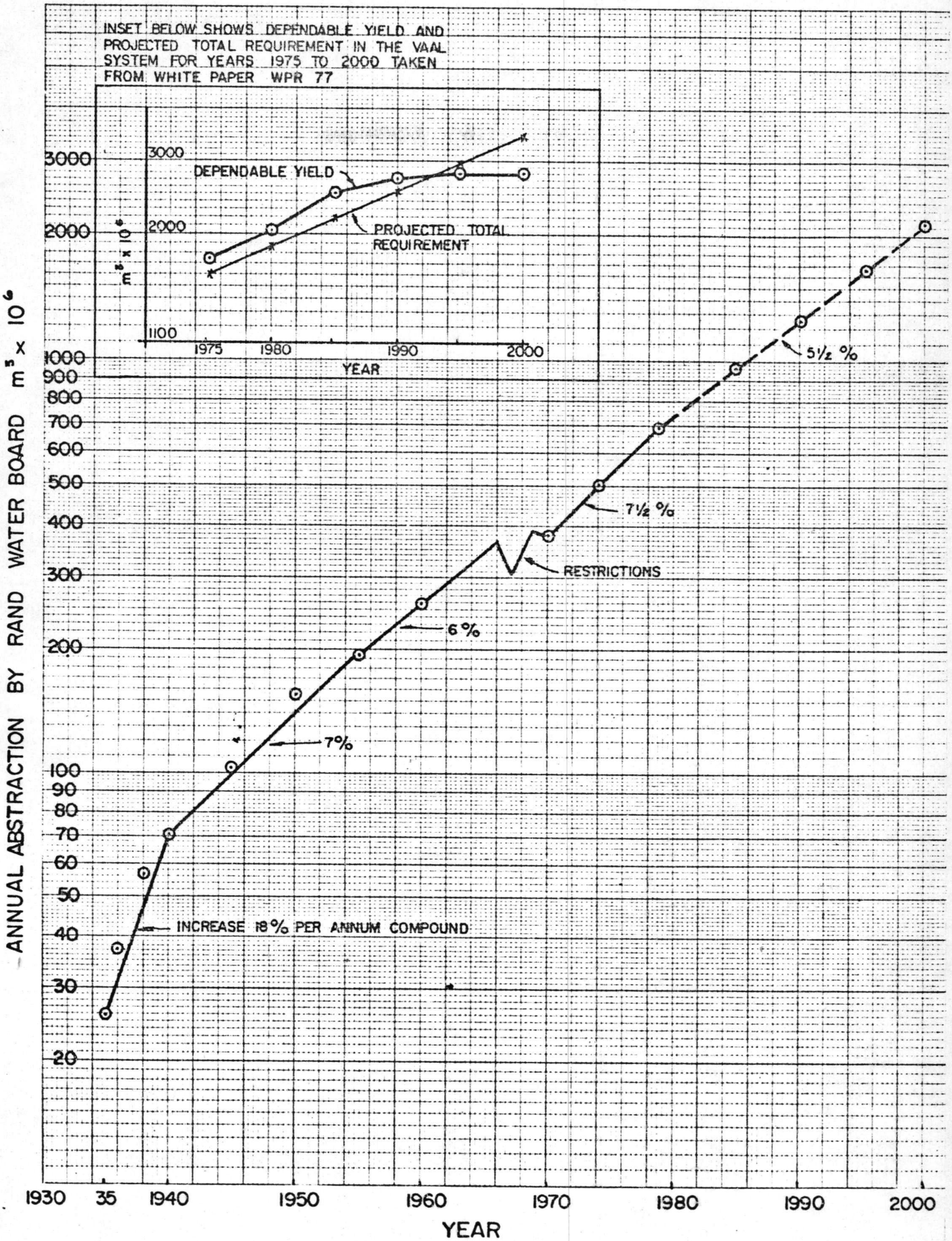
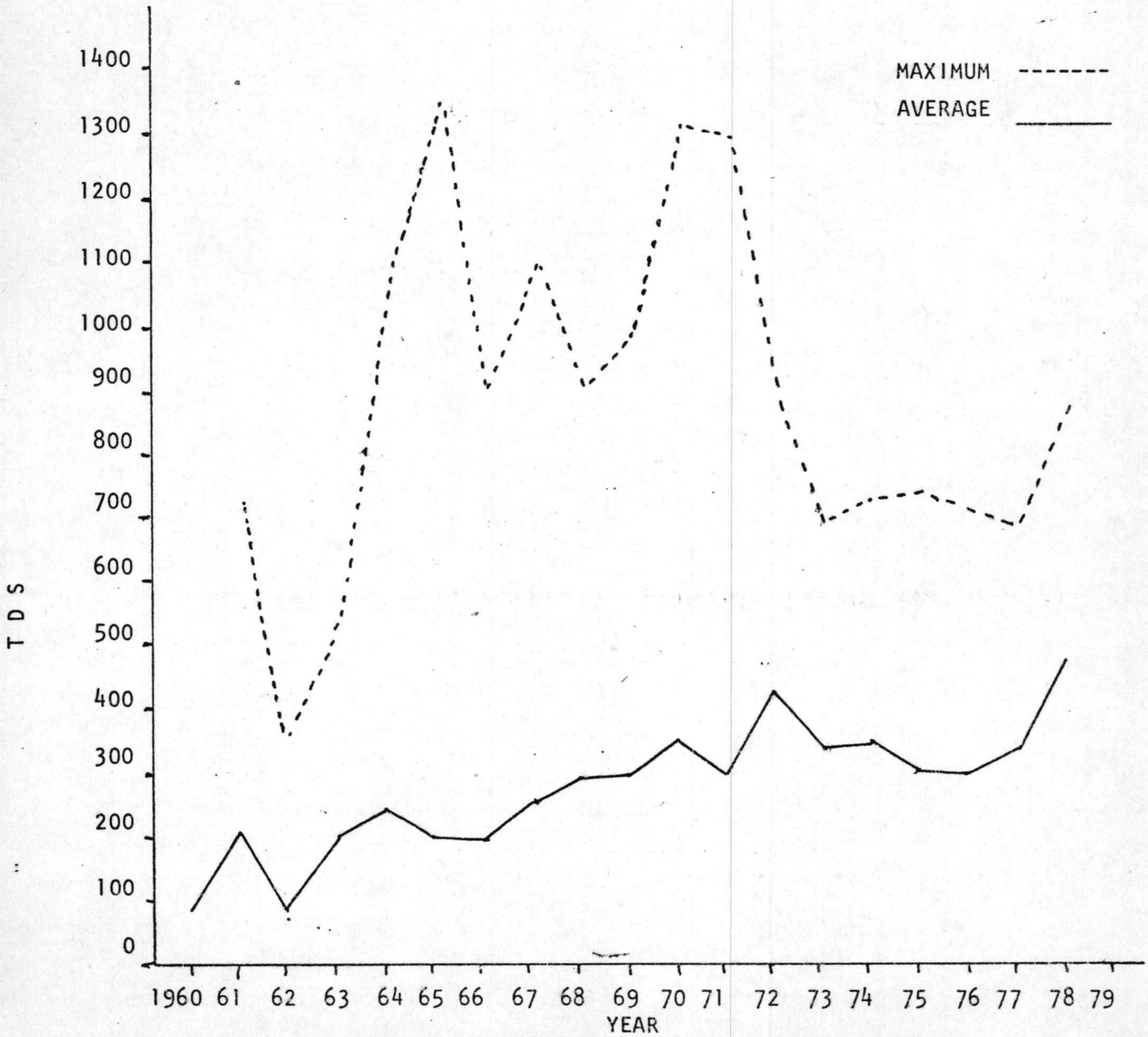


FIGURE 1 : ANNUAL RAND WATER BOARD ABSTRACTION FROM VAAL SYSTEM 1935 TO 1979 AND PROJECTED ABSTRACTION 1980 TO 2000.

FIG. 2

TOTAL DISSOLVED SOLIDS IN THE BARRAGE AT VEREENIGING



(ACCORDING TO BOARD'S FINANCIAL YEAR - EG 1979 = MARCH 78 - APRIL 79)

TABLE 11

NUMBER OF DAYS DURING THE BOARD'S FINANCIAL YEAR TO MARCH, 1979, THAT PRECHLORINATION WAS NECESSARY AT NO. 1 and 2 RIVER INTAKES (VEREENIGING)

TDS	NO. 1 INTAKE	NO. 2 INTAKE
100	0	0
100-200	0	0
200-300	0	0
300-400	0	0
400-500	0	0
500-600	9	24
600-700	18	34
700-800	11	13
800-900	19	21
900-1000	10	10

TABLE 12

AVERAGE WATER PURIFICATION CHEMICAL DOSAGE AND COSTS OF BARRAGE WATER WITH TDS VALUES VARYING FROM 200 TO 1000 mg/dm^3

DATE	TDS mg/dm^3	SS mg/dm^3	LIME mg/dm^3	COST+ c/kl	SiO_2 mg/dm^3	COST+ c/kl	FERROUS SULPHATE mg/dm^3	COST+ c/kl	CHLORINE mg/dm^3	COST+ c/kl	TOTAL COST+ c/kl
7/3/78	202	127	64	0,2957	1,7	0,0479	3,5	0,0088	2,32	0,1128	0,4652
25/4/78	306	72	62	0,2865	1,4	0,0394	5,0	0,0126	1,95	0,0948	0,4333
11/4/78	400	61	58	0,2680	1,0	0,0282	3,4	0,0085	2,19	0,1064	0,4111
21/179	508	20	50	0,2311	-		4,5	0,0113	2,13	0,1035	0,3459
7/6/79	599	15	55	0,2542	0,50	0,0141	3,8	0,0095	1,87	0,0909	0,3687
10/12/78	705	28	56	0,0588	-		3,1	0,0078	2,27	0,1103	0,3769
9/10/78	810	19	59	0,2726	-		3,9	0,0098	2,58	0,1254	0,4078
4/9/78	906	8	52	0,2403	-		3,6	0,0090	2,22	0,1079	0,3572
4/10/78	1001	16	57	0,2634	-		3,7	0,0093	2,59	0,1259	0,3986

+ The above figures are based on the cost of chemicals as at February 1979 (Prechlorination costs excluded)

FIG. 3

A COMPARISON OF CONDUCTIVITY, TURBIDITY AND CHLOROPHYL AT THE BOARD'S NO 2 INTAKE (VEREENIGING) FOR THE MONTH OF MARCH 1978

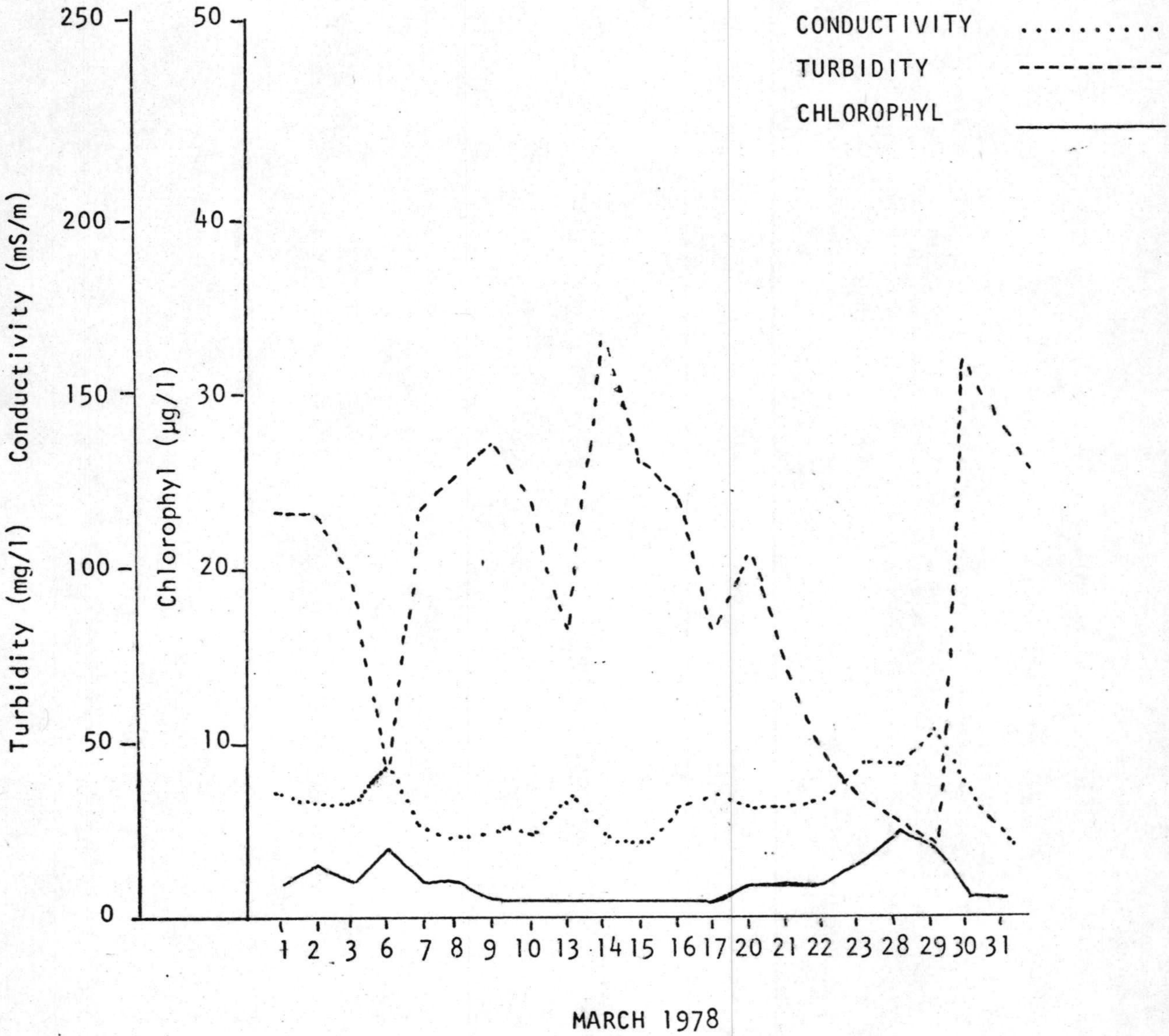
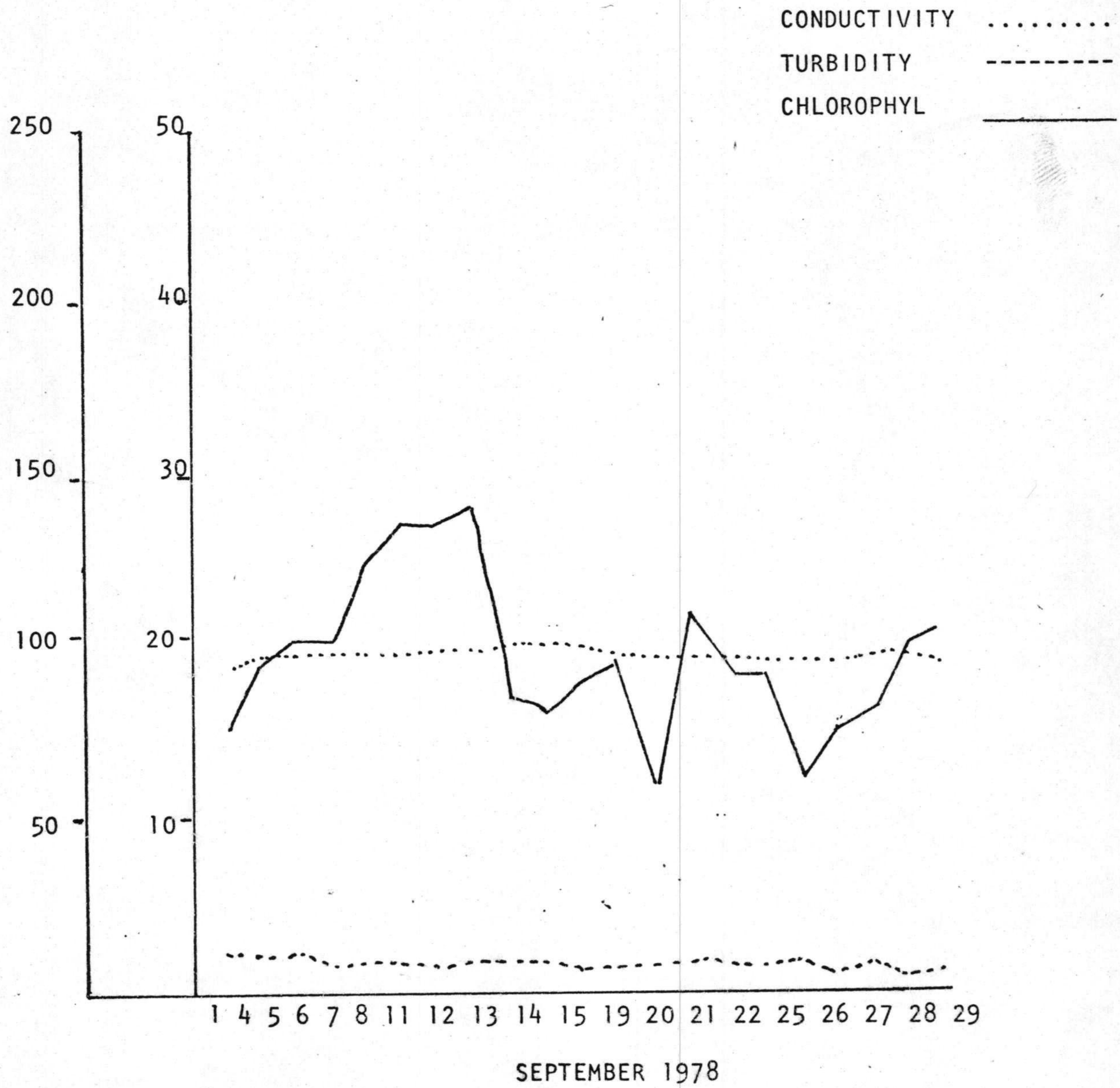


FIG. 4

A COMPARISON OF CONDUCTIVITY, TURBIDITY AND CHLOROPHYL AT THE BOARD'S NO 2 INTAKE (VER=EENIGING) FOR THE MONTH OF SEPTEMBER 1978



C WATER SUPPLY AND DISTRIBUTION IN THE JOHANNESBURG AND PRETORIA MUNICIPAL AREAS : EFFECTS OF HIGHLY MINERALIZED (TDS) WATER ON THE DISTRIBUTION NETWORKS

1. JOHANNESBURG

The Johannesburg Municipality consumes an average of 552 Ml/day or 180 091 Ml/a of water (1978/79), equivalent to an average daily water consumption of 383 litre per capita. Its reservoir capacity amounts to 719 Ml providing a retention of 1,30 days on average and one day at peak periods.

1.2 Effects on Distribution Lines

During discussions with officials of the Johannesburg City Engineers Department, it became clear that the department was concerned about the quality of the water it received. During the past year (1978/79) there were many complaints of 'dirty' water which upon investigation was found to be due to encrustations being dislodged on the inside of steel pipes. The supplier of the water i.e. the Rand Water Board rectified this condition resulting in great improvement.

It would appear that in the pipe network which is practically 99 percent in steel, there is a slow build-up of encrustatious material which appears to be the products of corrosion, mainly from the steel piping itself.

It is probably correct to infer that a small portion of the encrustation is the result of post precipitation of the water supplied, but that the bulk is the result of corrosion ac= tivity. Analyses of such material by the S.A. Bureau of Standards indicated that it consists of almost 100 percent of oxides of iron. The question arises whether the highly mineralized water which could be expected in future could cause increased corrosion. As pointed out before, the chlorides and sulphates are expected to increase and therefore corrosion could also increase likewise.

Based on work done in many parts of the world, it is probably correct to state that the cause of such deposits found in steel pipes is not so much as a result of poor water prepa= ration or oversaturation, but due to corrosion factors.

This phenomena is found in practically all distribution systems in England and Europe. Ainsworth[10] et al of the Water Research Centre in England, upon examination of corrosion products and deposits in iron mains state : "Calcium carbonate deposition seldom occurs in U.K. mains and it was found to be a minor component of corrosion products. This fact, in conjunction with the observation that hard waters with negative Langelier Indices are frequently non-corrosive, whereas soft waters with positive Indices are corrosive, indicates that the magnitudes of the hardness and or alkalinity are more important factors than the Index. Our observations agree with the view expressed by others that for soft waters at least, the main=tenance of a positive Langelier Index does not necessarily reduce the corrosivity of a water towards iron pipes".

In their studies, Ainsworth et all also find the presence of sulphur, probably as sulphide inside the tubercles indicating sulphate reducing bacteria. Bird[5], in his study on "The Corrosion Behaviour of Black Iron and Galvanized Iron Pipes in Hot Water Systems", refers to the presence of sulphur reducing bacteria being the cause of high corrosion rates. He states inter alia : "Corrosion by micro-biological action is almost certain to occur in hot water systems once circu=lating water becomes sufficiently depleted in its dissolved oxygen concentration and where chlorination is ineffective". Although this study does not concern the effects of hot water on piping in high rise buildings, the findings of Dr. Bird[5] are, nevertheless, important. The effect of the accumulation of corrosion products in distribution lines causes :

(a) reduced life of service pipelines
(b) head losses due to friction
(c) reduction in water supply

It is generally accepted that constituents like oxygen, carbon dioxide, chlorides and sulphates are responsible for the corrosive tendencies of water. When examining the composition of Rand Water Board water (Annual Report 1978, Table 16) one notices that as the quality deteriorates the temporary hardness decreases whilst the permanent hardness increases. In other words, there is an increase in chlorides and sulphates at the expense of bicarbonates. It is therefore surmised that should the TDS rise from 300 to say 800 mg/l, corrosion problems will tend to increase.

To forecast the degree of deterioration is well nigh impossible, but using the formula prescribed by the "Standard Methods for Examination of Water and Wastewater" in its 13th Edition 1971, page 46, one might get an idea of the corrosive tendency in future. The proposed forumula to gauge this tendency is given by:

$$\text{ratio} \ \frac{\text{me per litre of } (Cl^- + SO_4^{=})}{\text{me per litre alkalinity as } CaCO_3}$$

(me = milli equivalents)

Quoting from "Standard Methods for the Examination of Water and Wastewater" it says on page 46 :

"In the pH range of 7 to 8 and in the presence of dissolved oxygen, ratios equal or below 0,1 indicate freedom from corrosion, whereas increasingly higher ratios are generally indicative of more aggressive water".

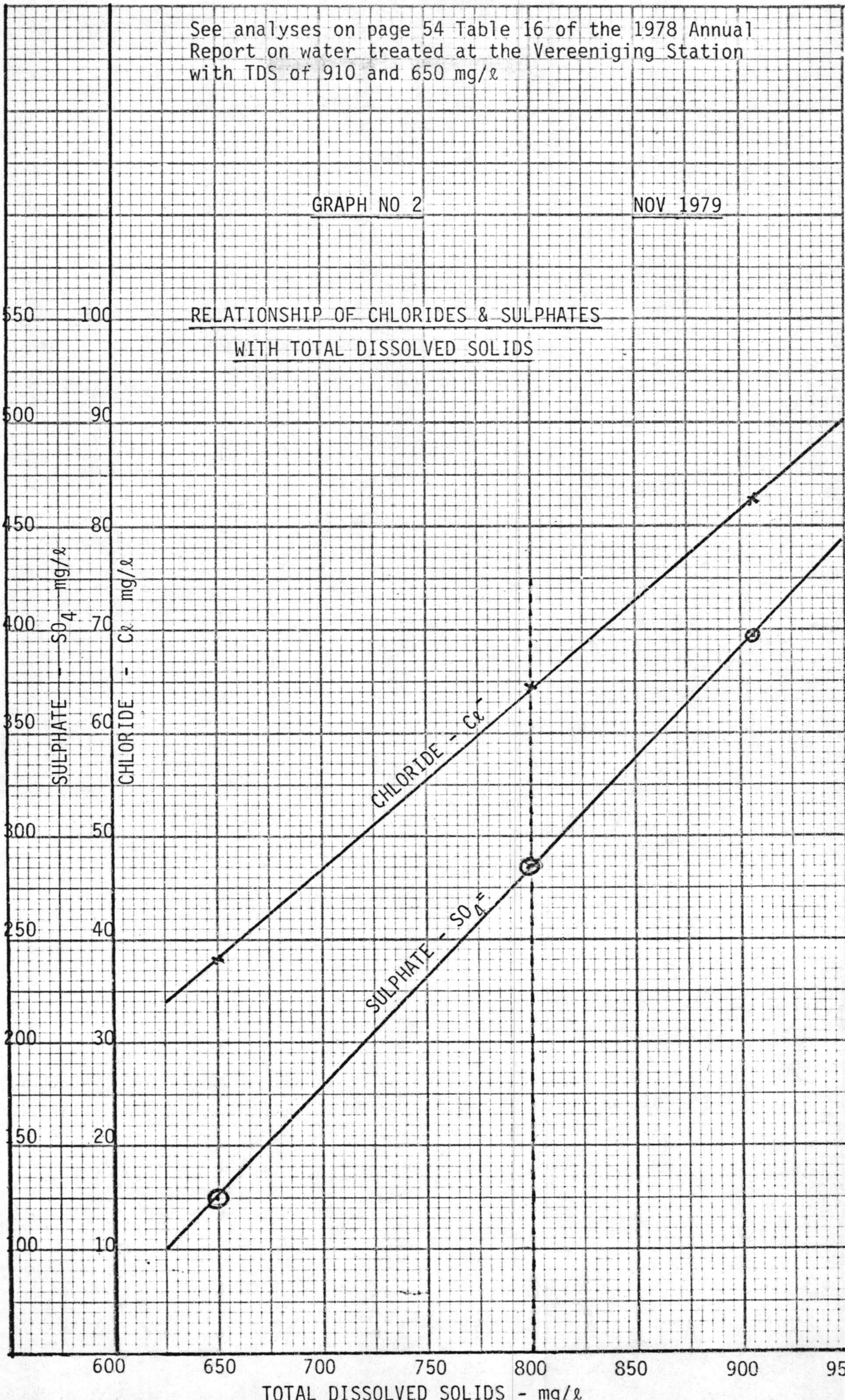
Graph No. 2 shows how the chloride and sulphate concentrations were deducted from two water analyses shown in Table 16 of the Rand Water Board's 1978 Report - TDS 310 and 910 mg/l resulting in the following ratios:

	TDS 310 mg/l Present water quality	TDS 800 mg/l Future water quality
Alkalinity	= 90 mg/l $CaCO_3$	150 mg/l $CaCO_3$
Chlorides	= 29 mg/l as Cl^-	74 mg/l Cl^-
Sulphates	= 95 mg/l as $SO_4^{=}$	285 mg/l $SO_4^{=}$

$$\frac{\text{me/litre of } (Cl^- + SO_4^{=})}{\text{me/litre alkalinity as } CaCO_3} = \frac{2,80}{1,8} = 1,56 \qquad \frac{9,06}{3,00} = 3,02$$

(Water of 500 mg/l TDS has a ratio of 2)

RAND WATER BOARD WATER



1.3 Indicated Life and Costs of Pipe Network

Of the service pipelines larger than 75 mm dia in steel there are approximately 2000 km in length in the Johannes= burg Municipal area. (See City Engineer's Annual Report for 1978/79). Sections of the smaller sizes examined contained heavy corrosion deposits of iron oxide in the form of tubercles. These decrease the capacity of such pipelines so that replacement or cleaning and relining becomes necessary. From observations and discussions, the average life due to internal conditions appears to be some 55 years. In discussing the corrosive tendency of the present water with the water engineers of thirteen municipalities in the PWVS-complex, it appears that they all experience similar problems in steel pipelines and that these require replacement after 50 to 60 years of operation. Applying the value of the ratios calculated by the formula as shown under item 1.2, the corrosive tendencies of the two waters referred to are indicated. Accordingly, the pipe life is halved, i.e. from 55 years to 28 years for water of 800 mg/l TDS, whilst for water of 500 mg/l TDS the life is calculated to be 42 years. Often steel lines are replaced due to external corrosion before internal corrosion sets in. For this reason many local authorities have and are replacing such with asbestos cement piping with good effect.

1.3.1 Repayment

In discussing this problem with Johannesburg and Germiston engineers it was said that steel mains larger than 300 mm dia show much lesser signs of encrustation build-up. It is said that most of these have a resistant lining built in.

The theory/explanation involved here is :

(a) that the smaller mains which are more predominant in the residential areas, are often subjected to stagnant or low flows - especially in winter, whilst the larger mains suffer much less in this respect and

(b) from a hydraulic point of view the volume/surface area ratios for large pipes are many times higher than that for smaller pipes. One local authority states that during springtime when residential users draw water extensively many complaints of muddy and 'red' water and blocked meters are received. In the colder climates of Europe and the U.S.A., this is a well established phenomena.

In Johannesburg as an example , there is some 2000 km of steel mains ranging from 75 to 300 mm dia. The cost for replacement amounts to some R60 x 10^6 or R30/m for the approximate 2000 km steel piping. (Cost figures by the Chief Water Engineer, Johannesburg).

N.B. Johannesburg is adopting the policy of rather relining old pipelines at a lower cost than replacing such with steel at approximately R30/m. The annual assumed cost to Johannesburg for replacement under the present conditions based on a 10 percent/a interest over 55 and 28 years for the two classes of water, amounts to R6,447 x 10^6/a and R6,032 x 10^6/a respectively, with a differential annual cost of R415 000. For water of 500 mg/l TDS and a 42 year life expentancy the differential annual cost is R83 000/a.

1.3.2 Maintenance (Distribution lines and meters)

For maintenance of water mains Johannesburg spent R1 322 000 during 1978/79. This amount covers a large number of items to keep the water services intact and it is virtually impossible to isolate the costs attributable to internal corrosion maintenance. This situation was also found with other municipalities visited. After deliberation it was felt reasonable that 10 percent of this expenditure could be allowed for maintenance caused by internal corrosion i.e. R132 000/a and half this amount when handling water of 500 mg/l TDS.

Sufficient evidence was found that at times the corrosive products i.e. incrustateious material, are dislodged blocking meter screens as well as the mechanisms. Johannesburg spent R533 000 for meter repairs during the 1978/79 financial years. Here it was also felt that 10 percent of this amount was for meter repairs due to water quality effects. For water of 500 mg/l TDS costs for meter repairs were taken at 5 percent of R533 000/a.

The total additional costs for Johannesburg due to corrosion effects are :

Water quality TDS (mg/l)	800	500
Main replacement	R415 000	83 000
Maintenance of steel water mains	132 000	66 000
Meter repairs	53 000	26 000
Total additional costs/a	R600 000	175 000

The total additional costs for Johannesburg is R600 000/a and at the present rate of water sold in Johannesburg of 171 245 Ml/a (1977/78) will increase the cost by

$$\frac{600\ 000 \times 10^2}{171\ 245 \times 10^3} = 0{,}35 \text{ c/kl},$$

which is an increase of $\frac{67}{18{,}41}$ = 1,9% on the water tariff of 18,41 c/kl (1978).

The question arises why the Rand Water Board experiences little or no corrosion in pipelines. This could be ascribed to the fact that the Rand Water Board employs mainly concrete and bitumen lined pipes with continuous high water velocities. The greater proportion of the Johannesburg and Pretoria Municipal pipe network is of steel and often velocities are low and stagnant at times.

A further cost factor which is difficult to establish is the additional costs involved to make up the loss of head experienced due to increase in friction in the pipelines.

Concerning metering, there appears to be evidence that meters tend to run slower and eventuallly stop resulting in loss of revenue. The latter is usually taken care of by raising the water tariff slightly. The causes appear to be liming of the meter mechanism and occasionally by algae growing in 'wet' meters when light is present. The loss in revenue and cost of maintenance were discussed with the Johannesburg Water Engineers and agreed that it was very difficult to ascertain the costs of this particular cause of meter stoppages or even the number of meters suffering from this cause. The same situation was found upon dis= cussions with the Pretoria Municipal water branch. It is believed that only a small percentage of meters suffer from the causes mentioned and no such costs have been allowed for in this report.

As stated, Johannesburg is now adopting a system of relining corroded steel lines with either a cement mortar lining or with an epoxy resin which could hopefully reduce the costs of new pipes by as much as 50 percent. If such is the case the capital costs of replacing such is of the order of R15/m, equivalent to R30 x 10^6 for the 2000 km of piping to be replaced. It is said that under these conditions the pipe life could be longer than that for ordinary steel. No life expentancy could, however, be given presently. An attempt at present to indicate the maintenance costs of such relined pipes and subsequent costs for meter maintenance is futile.

1.4 Industrial Water and Reservoir Extentions

As stated before the average retention period of water in reservoirs in Johannesburg is 1,30 days (31,2h) and 24h at peak periods. Presently, additional reservoirs are being constructed.

The industrial water requirements are not known and to extract this data would require a great deal of time and additional work according to the City Treasurer. However, Gebhardt[11] of the City Engineer's Department estimated that during 1964/65 the industries consumed 39 Ml/d i.e. 14 percent of the total water of 281 Ml/d delivered then to Johannesburg. He also indicates that the larger water consuming industries during 1964/65 consumed 20 Ml/d water which represents 6,9 percent of the total water used in Johannesburg.

Projecting a 14 percent industrial requirement to the total 1978/79 water requirement of 552 Ml/d, the present industrial use is approximately 77,3 Ml/d. Assuming that the industries will use 25 percent additional water due to the poorer quality expected in future, then an additional quantity of 20 Ml/d will be required based on today's figures. Under such conditions the industrial water use increases to 17 percent of the total use $\left(\frac{77,3 + 20}{552 + 20} \times 100\right)$ (ave. industrial for the complex is 35% of the total use).

Additional reservoir capacity is therefore required and based on a 36 h retention period, a reservoir of 30 Ml will be required at an approximate costof R2,0 $\times 10^6$. The additional cost to industry based on repayment over 25 years at 10%/a interest amounts to R220 034/a. This is equal to 0,11 cents/kl water which is almost negligible. Should the industries have to carry this cost it appears to be

$$\frac{220\ 034 \times 10^2}{20\ 000 \times 365} = 3\text{c/kl additional}$$

1.5 Summing up - Johannesburg

In accepting the above reasoning of what could take place in future when the water becomes increasingly mineralized, the following additional costs could occur :^{x}

	R/a
To replace pipe network after 28 years instead of 55 years including maintenance	600 000
Additional cost to industry for reservoirs	220 000
Total additional costs	820 000

x Not relining but replacement of steel piping

Cost increase on total water sold is 0,45c/kl or $\frac{45}{18,41} = 2,4\%$

$$\left(\frac{820\ 000 \times 10^2}{180\ 091 \times 10^3} = 0,45\right)$$

The City Council as a Foundation Member or Consumer buys its water from the Rand Water Board at 9,02c/kl. (See p 21 of the Board's 1978 report). Sales revenue derived from selling water at 18,41 c/kl realized some R33,154 x 10^6. The additional costs to maintain its pipe network and to cater for additional reservoir capacity for the additional industrial water, appears to be R820 000/a. This represents an increase in costs for Johannesburg City Council of some

$$\frac{0,820 \times 10^6}{33,154 \times 10^6} \times 100 = 2,5\%$$

(Water sold 1978/79 = 180 091 Ml at 18,47c/kl = R33 154 753)

2. PRETORIA

The possible future effects of high TDS water (800 mg/l) on the Pretoria Municipal supply network was discussed on several occasions with officials of the water and sewage branch. Areas which could be affected are :

(a) water supply network (distribution)
(b) the supply reservoirs
(c) industries

2.1 Water Supply Network

The officials responsible for water supply and distribution do not appear much concerned with the effects on pipelines should the TDS increase from the present 300 mg/l to 800 mg/l, mainly because problems are infrequent. At present there is some accumulation of deposits in the older supply lines which, according to their opinion, is not serious after 30-35 years of service. These deposits appear to be less than that found by the Johannesburg officials in their distribution systems.

The question arises, where do these deposits originate from. On closer examination the metal surfaces below these deposits appear to be rather unaffected, but analyses of such deposits indicate large amounts of iron in different forms - probably 95 percent of the deposit is iron oxide with small amounts of calcium, manganese, aluminium and silica. There are usually trace amounts of other metals like zinc, cadmium, nickel, chromium, lead etc. The appearance of these deposits is brownish with a black under layer when disturbed, with wavelike tubercles and of a spongy nature. It is wellknown that these deposits form all kinds of metal and non-metal complexes with large volumetric content. Severe roughness is associated with it and high friction losses result causing high head losses - a factor of great concern to the Johannesburg officials. It is assumed that the tendency towards corrosion for the same water whether at Johannesburg or Pretoria, is very similar. The formula used in the Johannesburg report is also applicable here viz:

	TDS 310 mg/l Present RWB water quality	TDS 800 mg/l Future RWB water quality
Alkalinity	= 90 mg/l as Ca CO_3	150 mg/l as $CaCO_3$
Chlorides	= 29 mg/l as Cl^-	74 mg/l as Cl^-
Sulphates	= 95 mg/l as $SO_4^=$	335 mg/l as $SO_4^=$

$$\frac{\text{m e of } (Cl^- + SO_4^=)}{\text{m e of alkalinity as } CaCO_3} = \frac{2,80}{1,8} = 1,56 \qquad \frac{9,06}{3,00} = 3,02$$

(Water with a TDS of 500 mg/l has a ratio of 2,0).

Assuming the average life of the pipe network to be 55 years as in the case of Johannesburg, the future mineralized water could reduce the life to $55 \times \frac{1,56}{3,02} = 28$ years.

The length of existing steel piping of 80 mm to 300 mm diameter in the Pretoria municiapl area is approximately 735 km. Assuming the replacement costs also to be R30/meter as for Johannesburg, the total replacement costs will be R22 x 10^6.

Reasoning on a similar basis as that for Johannesburg, the differential replacement costs over 55 and 28 years will be R1,612 x 10^6 and R1,508 x 10^6 respectively, equivalent to differential cost of R152 000/a (10%/a interest).

For maintenance the Pretoria municipality allocates some R700 000/a for the water network. Allowing also 10 percent of this for maintaining water pipes damaged by internal corrosion by water, an amount of R70 000/a is allowed. For meter repairs an amount of R570 000 is set aside of which 5 percent is allowed for meter repairs caused by corrosion products blocking meters i.e. R29 000/a say R30 000/a. The total additional costs for Pretoria due to corrosion effects on steel mains are as follows:

	R/a additional
Mains replacement	152 000
Maintenance of steel mains	70 000
Maintenance of meters	30 000
Total additional costs	252 000

This annual cost will raise the water tariff - 95 664 Ml water distributed in Pretoria (1978/79), by

$$\frac{252\ 000 \times 10^2}{95\ 664 \times 10^3} = 0,26\text{c/kl or by } \frac{26}{18,37} = 1,4\%\ \text{(water tariff 18,37c/kl)}$$

2.2 Additional Cost Due to Friction Losses

There is no doubt that the accumulation of corrosion products in pipelines will reduce the supply capapcity/head which can only be restored by spending additional energy in the form of boosting. To quantify this cost appears to be difficult and is not included in this study or in that for Johannesburg. The cost effects on the blockage of the smaller diameter pipes consisting of a mixuture of asbestos cement, steel and bitumen lined piping are not included. It is assumed that asbestos cement and bitumen piping will show little or no sign of corrosion.

2.4 Reservoir Capacity - Industrial Water Supply

In the early days of water supplied to Pretoria, it appeared to be undersaturated with respect to its stability resulting in 'red-water' complaints. The Municipality added lime to its reservoirs which improved conditions but caused additional labour problems in cleaning reservoirs etc. Since then for many years, the Rand Water Board adjusts the stability of water supplied to Pretoria with good effect.

Concerning water requirements for industrial purposes, the Pretoria officials state that approximately 17 percent additional water would be required by industry should the TDS increase to 800 mg/l. In order to maintain a 36 h retention period in the supply reservoirs like that assumed for Johannesburg, additional capacity is required.

Average total water consumption	=	263 Ml/d
Present industrial use excluding Iscor	=	25 Ml/d
Present industrial use including Iscor	=	46 Ml/d

Assume that with poorer water in future that the industries use 25% more water (excluding Iscor)	=	6,25 Ml/d
Iscor future additional use as given by Iscor	=	9 Ml/d
∴ Total additional industrial water	=	15,25 Ml/d

For a reservoir retention period of 36 h, the reservoir capacity is 22,87 Ml say 23 Ml.

Approximate capital cost for a 23 Ml reservoir is R1,50 x 10^6 and the capital redemption over 25 years at 10%/a interest = R165 000/a or 7,5 c/kl additional for industrial water. The cost will probably be recoverable from industry.

2.5 Conclusion - Pretoria

The factors and costs responsible for additional costs in future are :

	R/a
Pipeline replacement	152 000
Maintenance on network and meters	100 000
Reservoir extensions	165 000
Total	417 000
Allow	420 000

The cost increase for this additional cost for the 95 664 000 kl sold during 1978-79 is 0,44 c/kl or $\frac{44}{18,37} = 2,4\%$.

3. ADDITIONAL CORROSION COSTS IN THE PWVS REGIONAL DISTRIBUTION NETWORKS

Although the Johannesburg municipal water networks is comprised of almost 100 percent steel mains viz 99 percent, a survey of the larger municipalities has shown that there is a tendency to replace their steel water mains with asbestos cement pipes and to a lesser extent with PVC plastic pipes. In most areas the larger water mains accommodating high pressure are of steel. The main causes for this change has been stated before. The survey conducted covering 13 municipalities in the complex revealed that some 67 percent of the water mains still comprises steel. The following data based on Johannesburg's findings is used to arrive at the approximate additional costs for the complex caused by internal corrosion action :

	R/a
Cost to Johannesburg networks (replacement and maintenance)	600 000
Johannesburg's population (1980 estimate by Browett and Hart[8])	$1{,}781 \times 10^6$
PWVS-complex population (1980 est.)	$4{,}8 \times 10^6$

Additional corrosion costs for the PWVS-complex for water

of $0{,}67 \times \dfrac{4{,}8}{1{,}781} \times R600\ 000 = R1{,}083\ 000/a$

Say $= R1{,}1 \times 10^6/a$

For water of 500 mg/l TDS : Additional costs will be

$0{,}67 \times \dfrac{4{,}8}{1{,}781} \times R175\ 000 = R316\ 000/a$ (Johannesburg figures used as basis)

The costs indicated here viz $R1{,}1 \times 10^6/a$ is the additional cost that the complex will have to spend per annum to replace and maintain the existing steel mains in use now which also includes maintenance of water meters caused by corrosion products blocking meters. Kindly note, the $4{,}8 \times 10^6$ population figure excludes the towns of Brits, Bronkhorstspruit, Cullinan, Delmas and Balfour.

At this stage it must be reported that Johannesburg, from an economical point of view is relining[+] many of its smaller affected steel mains with an epoxy resin or a cement/sand mortar. It is said that such lining can extend the pipe life extensively but time will indicate the value of this.

\+ These costs not yet available

D. ECONOMIC EFFECTS OF THE MINERAL CONTENT OF THE VAAL RIVER BARRAGE WATER ON INDUSTRY

1. INTRODUCTION

Approximately 50 percent of the manufacturing activities in the Republic of South Africa is concentrated in the PWVS-complex. The 7 000 (approx) such establishments are responsible for 50 percent of the Republic's gross output equivalent to more than R10 000 x 10^6/a (1976 figure).

In the PWVS-complex a large number of industries are dependent upon water supplied by the Rand Water Board. The proportion of water supplied by the Board for industrial and domestic purposes respectively is:

For the year 1978	Percentage of total water supplied %	Quantity for 1978 Ml/d
Industrial purposes+	31	534
Domestic purposes	69	1210
Total	100	1753

Approx. 52 600 Ml/moth

Apart from the above quantitative requirements there are several large industries in the Vaal-Barrage area which abstract large volumes of raw water under permit conditions. directly from the Barrage. Such industries are Iscor, Sasol, AECI and ESCOM and a few smaller ones. The following figures indicate the approximate annual volumes so abstracted for industrial purposes:

1978-79	Ml/d
Iscor, Vanderbijlpark	59
Sasol 1 including boiler water upstream	97
AECI (Midlands)	9
Escom (4 Stations) : Highveld, Klip, Taaibos and Vaal	98
	263

\+ Private communication from Rand Water Board

The bulk of the water so used is for cooling purposes, washing, and steam production.

2. COST EFFECTS FOR THE LARGER INDUSTRIES OPERATING WITH HIGHLY MINERALIZED RAW VAAL RIVER WATER

Several industries are discussed in this section of the report. In all cases information was solicited from them with the supposition that in future the Vaal River water available will deteriorate from the present average Total Dissolved Solids of 300 mg/l to approx= imately 800 mg/l on average. The companies were requested to submit their views supported with technical information, the extent to which their operations would be effected and the economic effects thereof.

3. ISCOR WORKS - VANDERBIJLPARK

This works abstracts most of its water directly from the Vaal Barrage and uses such after clarification for production purposes. The water required for steam raising and for human consumption is RWB water and is purchased from the Vanderbijlpark Town Council. Water is reused intensively and the bulk of the effluent is treated before discharge into the Rietspruit which enters the Loch Vaal basin upstream of the Vaal Barrage. The effluent is subjected to a permit from the Department of Water Affairs allowing a TDS of 1 200 mg/l to be discharged into Rietspruit.

Apart from the works effluent discharging into Rietspruit, highly mineralized regeneration effluents emanating from softening and demineralization plants preparing water for steam boiler operations, are collected in a large evaporation dam. There is no visible discharge from here. Effluents from coke oven and by-products operations not used for coke quenching are also collected in an evaporation dam portions of which are used for spray irrigation of animal feed crops.

In the case of Iscor and other industries reviewed in Section D of this report where effluent is discharged directly into a water course under governmental permit, the concentration allowed for total dissolved solids (TDS) is 1 200 mg/l. Many of the calculations are based upon this assumption.

Table 13 gives operational details of the Iscor Works, Vanderbijlpark, whilst items 3.1 and 3.2 give details of cost involved should water of 800 mg/l be used in future.

3.1 Additional Capital Requirements

In order to cope with the higher mineralized water additional capital is needed as follows:

		$R \times 10^6$
(a)	Increased river water pumping transpor= tation equipment, clarification and distribution facilities	5,0
(b)	Additional softening and demineralization plant and associated equipment	3,8
(c)	Larger clarification plant for handling additional final effluents	2,9
(d)	New evaporation dams for mineralized effluent	1,5
(e)	Increased land for evaporation dams	1,0
	Total additional capital	14,2

TABLE 13

WATER AND EFFLUENT DATA - MONTHLY FIGURES

	Present			Future			
Raw River Water TDS mg/l Ingot Steel Production t/month	480 310 000			800 310 000			
	kl/t	Ml/month	%	kl/t	Ml/month	%	Percent Increase
Vaal River raw water intake	5,40	1674	100	10,40	3222	100	93
Effluent discharge to Vaal Barrage	2,52	781,2	47	7,34	2274	71	191
Effluent to evaporation dams	0,12	37,2	2	0,30	93	3	150
Effluent to irrigation	0,22	68,2	4	0,22	68,2	2	nil
Water evaporated in process	2,54	787,4	47	2,54	786,8	24	nil
TOTAL	5.40	1674	100	10,40	3222	100	

Salt Loads

	Ml/month	Quality mg/l	Salt load t/month	Ml/month	Quality mg/l	Salt load t/month
Vaal River water intake	1674	480	804	3222	800	2578
Effluent return to Vaal River	781,2	1200	937	2274	1200	2729
Mineralized effluent to evaporation dams	37,3	4000	149	93	4000	372
Effluent to irrigation	68,2	3900	266	68,2	3900	266

Additional Salt load to Vaal River :	937 - 804 = 133 t/m	2729 - 2578 = 151 t/m + 14%
Salt load retained on works :	149 + 266 = 415 t/m	372 + 266 = 638 t/m + 54%
Total salt load generated :	= 548 t/m	= 789 t/m + 44%
Percentage increase in salts generated		= 44% increase
Increased water from Vaal River		3222 - 1674 = 1548 Ml/m = + 92%
Increase effluent to Vaal River		2274 - 781 = 1493 Ml/m = + 191%

Additional salt load to Vaal Barrage = 2729 - 937 = 1792 t/m = 21 504 t/a
Additional salt load retained on works = 638 - 415 = 223 t/m = 2676 t/a

3.2 Operating Costs in Cents Per Ton Ingot Steel Produced

Period	1978/79		1978/79	
Water quality mg/l TDS	480		800	
Costs	c/t	R/month	c/t	R/month
(a) Administrative costs	36,73	113 863	40,00	124 000
(b) Electricity for river water pumping, ind. water distribution and effluent clarification	47,40	146 940	51,13	158 503
(c) Chemicals for river water clarification	0,65	2 015	1,64	5 084
(d) Regenerants for ion-exchange columns	4,78	14 818	21,22	65 782
(e) Cooling tower treatment chemicals	2,84	8 804	5,47	16 957
(f) Industrial water purchased	4,98	15 438	15,47	47 957
Total	97,38	301 878	134,93	418 283
Increase %			38,6	

3.3 Summary of Additional Costs Involved

Monthly ingot steel (t) 310 000

Additional capital required $R14,2 \times 10^6$

Additional Costs	R/month	R/annum
Redemption + interest at 12%/a over 25y on capital	150 878	1 810 536
Operatint costs	116 405	1 396 860
Maintenance at 3%/a on capital	35 500	426 000
Total	302 783	3 633 396
Add 10% extras	333 000	4 000 000

Additional cost per ingot ton steel = R1,07

$310\ 000 \times 12 \times R1,07 = R4 \times 10^6/a$

3.4 Conclusions

3.4.1 In order to produce the same quantity of steel/a with highly mineralized water a substantial additional amount of capital will be required viz R14 x 10^6. Although the total added cost to produce a ton of steel increases by approximately R1/ton may appear to be small, the total annual additional cost amounts to some R4 x 10^6/a.

3.4.2 Alarmingly, also are the additional salts entering the Vaal River viz 151t/month and the additional large quantity of salts retained on the works, viz. 223t/month. Some of this is retained in evaporation dams and some sprayed on land. It is not impossible that portions of such salts could enter the Vaal River - by surface and underground movement. The total additional salts to be disposed of is thus 24 180t/a, which includes 2676t/a held in dams.

3.4.3 To be noted, is the large increase in water required when producing steel with the higher TDS water as well as the additional effluent discharged into Loch Vaal. The additional water is 1 548 Ml/month or 18,576 x $10^6 m^3$/a, equivalent to an increase of 92 percent.

The extra cost alone for industrial water purchases will amount to R32 580 per month or R1,91 x10^6/a, which is an increase of 211 percent.

3.4.4 Apart from additional internal operating problems that could arise, there could be problems and costs with corrosion and scaling which are difficult to assess.

3.4.5 The Corporation, in presenting its report stated that with the poorer water conditions it becomes necessary to investigate alternative desalination processes, like reverse osmosis for boiler feed and production water, a process which appears to be cheaper and with less disposal problems. As an example it stated that the capital costs for a demineralization (ion exchange) plant capable of desalting a portion of the present effluent viz 175 000 kl/month with 1 200 mg/l TDS, will be R10 x 10^6, with a total operating cost of approximately 70c/kl. With such a plant in operation, an inland lake is required to store the highly mineralized regeneration effluents, receiving each month some 945 tons of salt equivalent to 8 800t/a.

Here it must once again be pointed out that demineralization with the ion exchange process, for each ton of mineral salt removed, approximately two to two and a half additional tons of chemicals are generated which are to be disposed of. It is a fact that whenever desalination or softening is practised in this manner, exhorbitantly high loads of mineral salts result which in most cases revert back to the Vaal Barrage water basin causing further deteriora= tion. Most industries having to deal with such expected water are seriously considering the reverse osmosis process instead of the ion exchange process.

3.4.6 The present cost for water and effluent services is approximately R3,10/ton steel. The additional cost is R1/t steel produced equivalent to an increase of 32% or R4 x 10^6 per annum, which appears to be substantial. Compared to the overall production cost per ingot ton of steel it is small - of the order of 0,84 percent, excluding the costs of raw materials and its transport costs.

4. ISCOR WORKS - PRETORIA

This works receives its total water supply from the Pretoria Municipality of which 90 percent is Rand Water Board water and 10 percent local water. With a TDS of 800 mg/l as compared with the present intake water of 348 mg/l TDS, 45 percent more water will be required mainly for its cooling and boiler water requirements.

4.1 Present situation

	Vol Ml/month	Quality mg/l TDS	Salt Load t/month
Intake Water	597,5	348	208
Effluent Discharged	96,0	1600	154

Present salt load discharge : 154t/month

4.2 Situation with 800 mg/l intake water

Intake Water	861	800	689
Effluent Discharged	360	1600	576

Salt load discharge : 576t/month

Increase in water requirements is 264 000m^3/month equivalent to 45% and a cost increase of R593 000/a.

Increase in salt load discharged, 422t/month equivalent to an increase of 274 percent.

In order to cope with 800 mg/l of water, Iscor states that it will have to prepare larger quantities of softened water for cooling purposes and steam requirements.

4.3 Capital Requirements (Additional)

	Rand
Water Softening Plant	215 000
Effluent Treatment Plant	190 000
Additional piping etc.	505 000
	910 000

4.4 Additional Costs

	R/a
Capital redemption + interest of 12%/a over 25 years on R910 000	116 025
Extra water	592 800
Softening plant operating costs	39 600
Maintenance on additional equipment at 3%/a on R910 000	27 000
Total/a	775 425
Add 10% extras	77 543
Total cost/a (approx)	854 000
Steel production per month (ingot tons)	112 600 ton
Additional cost per ingot ton steel	R 0,63

The present approximate cost for all water and effluent services is R2,60/ton ingot steel. The above costs of R0,63/ton represents an added cost of 24% for the services mentioned, but on the total production costs of steel, excluding raw materials and its transport costs, it is only 0,44%, which is negligible. However, on an annual basis it amounts to R854 000/a, which is close on R1 x 10^6/a.

4.5 Salt Generation

The Corporation's approach to the problem should it have to operate with the much higher mineralized water as stated before, is to prepare larger volumes of soft water partly demineralized, which are to be bled into the main cooling systems where most of the water on a steel works is required. The softening process unfortunately, generates much additional salts to be disposed of and which eventually finds its way into the nearest catchment area - in this case the Bon Accord Dam. It is believed this dam might in future supply much needed water to a large concentration of Black people of Bophuthatswana, north of Pretoria.

The following figures are submitted by the Iscor Works, Pretoria, indicating the increase in salts for soft water prepartion:

Soft Water Preparation Requirements

Per Month	Present	Future	% Increase
Water for softening m^3	188 500	372 500	98
Water for regeneration m^3	7 625	33 600	340
H_2SO_4 acid required-ton	20	84,5	323
Sod. chloride required-ton	25	81	224
Phosphate required-ton	0,6	1,2	110
Caustic soda required-ton	1,2	1,9	58
Total salts excluding intake water - tons	46,8	168,8	160

The figures indicate an increase of 1464t/a of salts, only from water softening operations and a total additional load of 422/tmonth, (see item 4,2) or some 5064 tons of salt per year. (The 1464t/a are included in the 5064t/a).

At the present moment there are negotiations between Iscor and the Pretoria City Council whereby Iscor will purchase large volumes of purified sewage from the Council. This undertaking is of value to both parties and could save substantial volumes of water from the Vaal River. However, this whole undertaking will come to naught should future Vaal River water deteriorate as indicated when Iscor will not be keen to purchase purified sewage effluent containing some 1000 - 1100 mg/l TDS in future.

4.6 Conclusions

4.6.1 The cost effects on steel production when operating with highly mineralized water are not so serious in so far as additional capital and cost per ton steel are concerned, but will no doubt have serious effects on the Bon Accord Dam which will have to cope with an additional salt load exceeding 5000t/a. The additional costs in terms of total works operating costs is approximately 0,5% excluding costs of raw materials and their transportation costs.

4.6.2 Additional water costs will be high at approximately R600 000/a i.e. 3163 Ml/a extra.

4.6.3 Should the water quality deteriorate, the advantages of using purified sewage effluent on the steel works could fall away and additional water must be supplied by the Rand Water Board - a loss to all concerned.

5. AECI LIMITED

5.1 INTRODUCTION

This chemical manufacturing company known as AECI Limited operates two large chemical factories in the PWVS-complex viz:

5.1. The Midland factory situated on the south bank of the Vaal Barrage close to the Sasol Works. It produces polyolefenes using ethylene produced by Sasol. A major extension to produce PVC, caustic soda and chlorine using anthracite coal, lime and salt as raw materials came on line in 1978. In addition to the plastics so manufactured, many other products such as peroxide solvents, fluorocarbon refrigerants and propellants, cyanide and vinyl sheet are also manufactured on site.

5.1.2 The Modderfontein factory situated north east of Johannesburg is the largest manufacturer of commercial explosives. In addition to explosives and associated accessories it also produces industrial chemicals such as ammonia, urea, nitric acid, ammonium nitrate, methanol and urea formaldehyde resins.

5.1.3 With respect to this study which concerns the effects of deteriorating water quality on the factory operations, the greatest cost impact is that of water for cooling, processing and steam raising. The report deals thus mainly with this cost aspect and does not go into detail on the lesser aspects of deteriorating quality on the processes, amenities and services usage at these factories.

5.2 The Midland Factory

This factory is supplied with Vaal River water ex Vereeniging via Sasolburg Municipality and used for process and cooling. Steam required is supplied by pipeline from the Sasol factory at a cost.

Water circulating in open cooling systems approximates 16 000 m^3/h.

N.B. When hot water from various process exchangers flows across a cooling tower it is cooled by evaporation when pure water is lost to atmosphere as vapour. This results in an increase in the total dissolved solids (TDS) of the re=maining circulating water. By comparing the TDS of the circulating water with that of the make-up water it is possible to tell how much the circulating water is concentrated. The number of times the water so concentrates is referred to as the "cycles of concentration" or the "concentration factor".

The total make-up rate and blowdown rate for different concentration factors can be determined by using the well-known equations given as follows:

$$B = M - E$$

$$B = \frac{E}{(C-1)}$$

$$M = E + \frac{E}{(C-1)}$$

$$C = \frac{\%E + \%B}{\%B}$$

Where B = Blowdown

E = Evaporation

M = Make-up

C = Cycles of concentration

On the basis that the blowdown from cooling towers should comply with effluent from the gazetted standards in terms of the Water Act No. 54 of 1956 i.e. 500 mg/l TDS above that of the intake water supply, the following table shows the effect of cooling in towers when the present incoming and future incoming RWB waters have concentrations of 340 and 800 mg/l TDS respectively:

Incoming water TDS mg/l	Effluent Discharge Limit TDS mg/l	Cycles of concentration
340	840	2,5
800	1300	1,6

By means of the equations referred to it is possible to determine make-up and blowdown rates for different cycles of concentration. Therefore it can be seen from these equations that the higher the concentration factor the lower the blowdown and make-up rates are and the lower the costs for make-up and associated treatment chemicals.

For water of 340 and 800 mg/l TDS the comparative make-up and blowdown would be as follows:

	Present	Future
Circulating rate kl/h	16 000	16 000
Make-up water TDS (mg/l)	340	800
Blowdown water TDS (mg/l)	800	1 300
Evaporation kl/h	200	200
Blowdown kl/h	133	333
Make-up kl/h	333	533
Incoming salt load t/d	2,7	10,2
Salt load discharged t/d	2,7	10,7

It can be seen from the above that the blowdown to ensure compliance with the gazetted standards, will increase from 133 to 333 kl/h and the make-up water will increase from 333 to 533 kl/h and that the additional cost for water per annum at 18,5 c/kl will be R296 000.

It should be noted that the salt load in the incoming make-up water is ultimately discharged in the blowdown except for a small percentage loss as windage. Where additional blowdown is required, however, there is a greater loss of treatment chemicals. The expected additional cost will be of the order of R350 000/a. Although the amount of chemicals used is small it will give rise to an additional effluent load increase to stream.

5.2.3 Additional Costs

Deteriorating quality in water means increased usage and discharges. Ultimately there will be a need to replace the capacity being utilized in the supply lines. There could also be a need to provide additional effluent holding capacity for the increased volumes expected. The total additional capital required to accommodate for these changes is of the order of R750 000 with an annual payback of R95 600 calculated at 12%/a interest rate over 25 years.

Furthermore, there are additional costs for extra water, (already referred to) conditioning chemicals and steam. Presently 636 000 tons/annum of steam is purchased from the Sasol factory at R3,86/t. The future cost of steam, according to Sasol, which is to be prepared from poorer quality water will cost some R4,25/t, giving rise to an additional cost of R0,39 x 626 000 = R248 000/annum.

5.2.4 Total Additional Costs

The following then appears to be the additional annual costs for this factory should the water deteriorate from 340 mg/l to 800 mg/l TDS.

	Rand/annum
Make-up water	296 000
Cooling water treatment chemicals	350 000
Steam	248 000
Capital repayment on R750 000 for additional facilities	96 000
TOTAL	990 000
Assume	1 000 000

The effect of this R1 x 10^6/a additional cost on the total factory operating cost excluding the purchase of raw materials and its transport, factory overheads but including power, water and services costs, is approximately two(2) percent.

5.3 Modderfontein Factory

5.3.1 Present Conditions

Presently the intake of fresh Rand Water Board water into this factory is 14 000 Ml/a, equivalent to 38,4 Ml/d at an average concentration of 340 mg/l TDS. The annual cost for water

(1978) at 16,5c/kl amounts to R2,3 x 10^7/a. Second grade water present locally on the premises, is also utilized in the factory. An approximate breakdown of RWB water usage (1978 figures) is as follows:

	Ml/a	Ml/d	Present
Cooling water make-up	7 350	20,14	53
Water for steam raising	3 650	10,00	26
Process, services and amenities	3 000	8,22	21
TOTAL	14 000	38,4	100

At present water circulating in open cooling systems is of the order of 43 000 kl/h. For RWB water of 340 mg/l TDS at present and 800 mg/l in future, the comparable make-up water and blowdown rates to comply with the Government effluent standards+ appear to be as follows:

	Presently			Future		
	mg/l TDS	kl/h	t/d TDS	mg/l TDS	kl/h	t/d TDS
Cooling water make-up	340	1000	8,2	800	1600	30,7
Blowdown	840	400	8,1	1300	1000	31,2
Evaporation	-	600	nil	-	600	nil

\+ It is based on the assumption that the TDS concentration when operating with water of 800 mg/l TDS will be allowed to attain 800 + 500 = 1300mg/l.

5.3.2 Future Conditions and Costs

When operating with water of 800 mg/l TDS significant additional costs would be incurred of which the following appear to be important:

(i) The necessity for extending the demineralization capacity for maintaining the steam requirements : the additional capital could be R2 x 10^6.

(ii) Chemical costs for boiler and demineralization operations R2 x 10^6/a.

(iii) Additional make-up water costs : R1,3 x 10^6/a

(iv) Additional cost for water treatment : R1,2 x 10^6/a.

5.3.3 Final Additional Costs

Taking into consideration the cost shown under 5.3.2, the final additional cost for the factory could well be as follows:

	R x 10^6/a
Capital redemption and interest on R2 x 10^6 at 12%/a over 20 years	0,235
Additional water	1,3
Additional chemicals for boiler and cooling water treatment	3,2
Total additional costs/a	4,735

In terms of the factory's operating costs excluding raw materials water, power, factory overheads and headquarter costs, the impact of the additional costs appears to be approximately 5 percent.

6. NATIONAL CHEMICAL PRODUCTS (PTY) LIMITED : GERMISTON

6.1 INTRODUCTION

This is an important chemical manufacturer producing a large range of different chemical products viz :

(a) Butyl alcohols and acetone from fermentation of molasses.

(b) A range of organic solvents and chemicals from the products produced under (a) above.

(c) Phthalic anhydride and phthalate plasticisers.

(d) Polystyrene

(e) The well known "Rumevite" cattle feed system produced from the fermentation residues.

The NCP factory, situated in Germiston requires large quantities of water and steam for its many manufacturing processes (heating, distillation etc.), and demineralizes large volumes of Rand Water Board water. With the possible deterioration of feed water quality from the present TDS of 300 mg/l to 800 mg/l in future, the company will have to invest money for an additional demineral=

ization plant with additional chemicals for its operation. Also, with respect to cooling water requirements, larger quantities of water will be required as the present four cycles of concentration will be reduced to only two cycles.

As a result of all these changes there will be a general increase in salt load discharged to the municipal sewers which eventually reaches the Vaal River. Should this eventuate, the Company is of the opinion that the concentration will still be below the acceptable 2000 mg/l TDS limit involving no additional cost for its discharge to the municipal sewage works. The company also foresees that operating with the higher TDS cooling and circulating waters, there could be increased costs for maintaining acceptable conditions in circulating cooling systems and plant, but it is unable to quantify the costs thereof. An allowance for this is, however, made.

6.2 Additional Costs

6.2.1 Demineralization Plant

Monthly chemical costs during 1979 for operating its demineralization plant:

Sulphuric acid	R1 460	
Caustic soda	2 500	
Rinse and regeneration water	1 190	(7000 kl at R0,17/kl)
	5 150	
Yearly costs	62 000	

When operating with water of 800 mg/l the annual costs will approximate :

$\frac{8}{3}$ X R62 000 = R165 300

$\therefore$ Additional costs = R103 300/a

Added to this cost is that of a larger demineralization plant as the number of regenerations per day becomes impractical with the present plant. Additional costs amount to R50 000/a (Capital cost of plant is R350 000 for one Ml/d of demineralized water).

The water requirements and TDS loads discharged from demineralization plant operation are as follows:

Presently : Plant output 27 500 kl month. Regeneration and backwash rinse effluent is 7 000 kl/m. This effluent at 2 750 mg/l generates 19,25 t/m salt.

Future : Regeneration and backwash water will be $\frac{8}{3} \times 7\ 000 = 18\ 700$ kl/m with a concentration of 2750 mg/l containing a salt load of 51 t/m. The cost of the water so required at 17c/kl = 18 700 x 0,17 = R38 150/a.

6.2.2 Additional Cooling Water

With the poorer quality water for cooling purposes the present 4 cycles will be reduced to 2 cycles i.e. the blow-down will increase from 5000 to 15 000 kl/moth which is an additional cost of R1 700/month. Chemical conditioning cost is R1 300/moth, so that the total additional cost for cooling water amounts to R(1300 + 1700) = R36 000/a.

6.3 Final Effluent Discharge

The present monthly effluent volume discharging including demineralization plant effluent and cooling tower blow-down is 40 000 kl, with a TDS concentration of 2000 mg/l. This is equivalent to a salt load of 81,25 t/month. In future, anticipated effluent will increase to 62 000 kl/month without any significant change in TDS concentration giving a salt load of some 125 t/month. The additional increase expected should be 22 000 kl and 44 tons salt per month.

6.4 Additional Costs

In summing up, the additional costs appear to be as follows:

	Add. Cost/a
Chemicals for demineralization plant	R103 000
Demineralization plant redemption and interest	51 400
For cooling plant water and chemicals	36 000
For cleaning equipment extensions	20 000
Additional water - R2 000/month	24 000
	R233 000
Miscellaneous expenses ± 10%	23 000
Total	R256 000

6.5 Summing Up (Summary)

6.5.1 Table 14 sums up the changes that could result should the water quality change from a TDS concentration of 300 mg/l to 800 mg/l. There will be a nett increase in salt load eventually reaching the Vaal River of 44 tons per month or 528t/a.

6.5.2 Cost-wise, the company has to spend an additional amount of R256 000/a. Due to the nature and diversity of products manufactured it is difficult to express these costs in terms of Rand/ton of product. However, based on the factory's annual operational cost, this additional cost of R256 000/a amounts to less than one percent - actually 0,85 percent, which appears to be of minor importance.

6.5.3 The total additional water required appears to be 22 000 kl/m or 264 000 kl/a which is an increase of 20% over the present intake of 110 000 kl/month or $1,32 \times 10^6$ kl/a.

TABLE 14

NATIONAL CHEMICAL PRODUCTS

SUMMARY : VOLUMES, CONCENTRATION AND LOADS DISCHARGED (MONTHLY)

	Present			Future			Increase		
	Effluent kl/m	Concentr mg/l	Load kg/m	Effluent kl/m	Concentr mg/l	Load kl/m	Effluent kl/m	Concentr mg/m	Load kg/m
Demineraliza=tion Plant	7 000	2 750	19 250	18 667	2 750	51 333	11 667	2 750	32 083 385t/a
	Blow-down kl/m	Concentr	Load	Blow-down kl/m	Concentr	Load	Blow-down kl/m	Concentr	Load kg/m
Cooling Water Plant	5 000	1 200	6 000	15 000	1 600	24 000	10 000	1 800	18 000 216t/a
	Discharge	Concentr	Load	Discharge	Concentr	Load	Discharge	Concentr	Load
Final Effluent	40 000	2 000	81 250	62 000	2 016	125 000	22 000	2 000	43 750

7. LEVER BROS (PTY.) LTD BOKSBURG

7.1 Introduction

This Company operates in the Boksburg Municipal area manufacturing three basic commodities viz:

(a) liquid and powder detergents

(b) margarine

(c) icecreams

Water conservation and effluent control measures are practised. The water required for operations in supplied by the Rand Water Board through the local municipality, whilst the factory effluent is treated in the municipal sewage purification works. The present cost for this latter service is R49 000/a for 165Ml/a of effluent (R2,97/Ml).

7.2 Technical Details

The present water contains on an average 300 mg/l TDS and in this study it presumes that in future a TDS of 800 mg/l will be realized. Concerning water requirements, such are required for steam raising, cooling operations, washing and sterilizing.

Water is prepared firstly by de-alkalization (partly demineralization), followed by softening in a base ion exchange plant. The bulk of this product is mainly used in boilers for steam generation (low pressure) and the rest for processing products like liquid detergents, edible oils etc. Large quantities of water are used in eleven cooling towers where blow-down is practised to control scaling and corrosion.

7.3 Operating Conditions

The following data is submitted by the Company and used to determine the effects should the water deteriorate to a TDS concentration of 800 mg/l.

7.3.1 Boiler Water Preparation : Water is softened in two stages in series. Firstly, in a de-alkalization unit followed by a base ion exchange unit utilizing sulphuric acid and sodium chloride respectively. The amount of steam produced is 13 000 t/month.

7.3.2 <u>Back wash and rinse water</u> : The present volume of water for backwash and rinsing in the softening units is 150 kl/d. This will increase to 150 x 8/3 = 400 kl/d. This additional amount of 250 kl/d amounts to 75 000 kl/a and at a cost of 15,5c/kl is R11 625/a (6 day week and 50 week/year).

7.3.3 <u>Boiler Blow-down</u> : The present blow-down is 8,5 percent and will increase to 25 percent of the 13 000 t/month steam produced. Therefore the additional water required to cope with additional blow-down is 0,165 x 13 000 x 12 = 25 740 kl/a at an annual additional cost of R4 000.

7.3.4 <u>Additional Softening Plant</u> : Since the present softening unit will be unable to supply boiler feed water fast enough, additional plant is required estimated to cost R100 000. The annual payback over 15 years at 12% p/a interest amounts to R14 700/a.

7.3.5 <u>Cooling Water</u> : The present blow-down from eleven towers is 8t/h or 57 600t/a. In future this could reach 8 x 8/3 = 21,3t/h and the additional water so required is then 13,3 x 24 x 6 x 50 = 95 800 t/a at a cost of R14 850/a.

7.3.6 <u>Additional Chemical Requirements</u>

7.3.6.1 <u>For Softening Plant</u> : Presently 175 kg/d of H_2SO_4 (98%) is required which will increase to 175 x 8/3 = 467 kg/d in future. The additional mass required amounts to 87,6 t/a at R80/t. This will cost an additional R7 000/a.

Presently, 240 kg/d NaCl is required whilst for future conditions 240 x 8/3 = 640 kg/d will be required. The additional requirement amounts to $\frac{400 \times 6 \times 50}{130} = 120$ t/a at R50/t equivalent to R6 000/a.

7.3.6.2 <u>Cooling Tower Chemicals</u> : Presently 80 kg/month of chemicals is required which will increase to 145 kg/m in future. The additional mass appears to be $\frac{65 \times 12}{1000}$ = 0,78t/a the cost to be negligible.

7.4 Summary of Additional Costs

7.4.1 Capital Required:

For additional softening plant	R100 000

7.4.2 Operating Costs

		R/a
7.4.2.1	**Softening plant**	
	Chemicals for softening	13 000
	Backwash/rinse water (75 000 kl)	11 625
	Water for additional boiler blow-down (25 750 kl)	4 000
7.4.2.2	**Cooling system**	Rand
	Additional make-up water (95 700 kl)	14 900
	Additional chemicals for cooling systems	2 900
	Additional operational and main= tenance costs (softening and boilers etc)	27 600
	Interest and redemption on R100 000 capital (15 years and 12%/a interest)	14 700
	Total	88 725
	Allow 10% extra	8 870
	TOTAL	97 595
	Allow	100 000

Based on the Company's annual operating costs exluding purchase costs of all raw materials, the additional costs should the water deteriorate to 800 mg/l TDS is of the order of 1(one) percent.

7.5 Effluent Discharged and Treatment Loss

The following figures indicate the present and future conditions of effluents on a monthly basis :

	Present	Future
Total factory water intake (kl)	51 000	67 400
Mean total effluent discharged (kl)	13 720	30 000
Total cost (R/month)	4 094	8 952
Total dissolved solids (mg/l)	2 280	2 040
Salts discharged per month (t)	31,3	61,2
Effluent as percent of intake (%)	27	34

From the calculations it appears that in future a further 196 800 kl/a of water will be required as make-up to cooling systems, as backwash water in the softening plant and as boiler blow-down.

The additional salts discharged as regeneration chemicals are 208 t/a or 17,3 t/m. Added to this are the salts in the 196 800 kl/a (or 16 400 kl/m) extra water at 800 g/kl equivalent to 13t/month. The total additional salts to the sewer is 30t/m or 360 t/a.

8. SASOL I - SASOLBURG

8.1 Present Conditions

This factory is situated on the south side of the Vaal River opposite Vanderbijlpark. It produces oils, gas and petro-chemical products by processing low grade coal. It abstracts its water requirements from two intakes along the Vaal Barrage viz:

(a) a good quality water for boiler and other purposes at a point between the Rand Water Board's Zuikerbosch Station intake and the Vaal Dam. Water of 100 - 120 mg/l TDS and higher at times, is abstracted here by Escom for its three power stations, from which Sasol receives a portion for its boilers. etc.

(b) from the lower reaches of the Barrage for cooling purposes and industrial use - TDS concentration + 500 mg/l reaching peakes of 800 - 1000 mg/l on occasions.

The data as shown in Table 15 presents the present situation with respect to water requirements and effluent discharged (1979/80).

TABLE 15

PRESENT WATER REQUIREMENTS AND EFFLUENT DISCHARGE

	Ml/d	Quality mg/l TDS	TDS t/d	TDS t/a
Zuikerbosch intake water	55,3	100	5,53	3018
Vaal Barrage intake water	42,0	550	23,10	8432
Total intake	87,3	294	28,63	10450
Final Effluent Discharged (Below Barrage)	59,0	950	56,05	20458
Nett increase to Vaal River				10008

8.2 Future Water Quality

For the purpose of this study the following water qualities could be expected in 10 - 15 years from now, provided no attempts are made to improve the quality or reduce expected pollution and assuming the population to continue to grow as predicted by Browett and Hart[8] :

For boiler purposes abstracted above the Zuikerbosch station:

500 mg/l TDS for 6 months of the year and 120 mg/l TDS for the remaining 6 months of the year.

For general use in the factory:
800 mg/l TDS for cooling and industrial water abstracted from the lower part of the Barrage.

It must be noted that presently the water quality taken from the Barrage area for cooling has an average TDS concentration of 550 mg/l with peaks of 1000 mg/l.

8.3 Costs Involved with Poorer Water Quality

8.3.1 Water for Boiler Purposes

Sasol states that should the water in the upper reaches of the Vaal Barrage continue to deteriorate as shown under section D9.2 of this report, it prefers to either abstract water directly out of the Vaal Dam or from the Rand Water Board's proposed Vaal Dam-Zuikerbosch canal now being constructed.

Since this study assumes that boilerfeed water in future will still be taken at a point in the river above Zuikerbosch station as shown under section D9.2, a capital investment for a demineralization plant with associated evaporative effluent plant handling the regenerants, of R20,5 x 10^6 is required. Based on costs submitted by Sasol the following expenditure can be expected:

Boiler Water Demineralization and Effluent Plant

Capital required	R20,5 x 10^6
	R/annum
Interest and redemption over 25 years at 12% interest/a	2 614 000
Chemical Costs : 500 mg/l TDS for 180 days/a	484 000
120 mg/l TDS for 180 days/a	116 000
Resin replacement	210 000
+Operating and Maintenance	-
Total Cost	3 424 000
Allow 10% additional	342 400
Say	3 800 000

\+ It is assumed that Sasol's current hot lime/base exchange softening plant for preparing boiler feed water will fall away and that its operating and maintenance costs will be similar for the new demineralization plant. The costs given above are additional costs and for this reason no operating and maintenance costs are shown.

8.3.2 Cooling and Industrial Water

From studies carried out by Sasol the water presently available from the Barrage has a TDS concentration of some 550 mg/l - at times it is higher. With water of 800 mg/l, Sasol states that such water will be used with only 1½ to 2 concentrations and when its present Barrage pipeline and pumping station is fully utilized it prefers to augment its supply by employing purified town sewage effluent for cooling etc. the latter to be demineralized by ion exchange.

The following additional costs will be involved to desalinate 4,7 Ml/d of purified sewage (TDS 800 mg/l) and to evaporate the resultant regenerant effluent in a solar evaporation installation:

Capital for demineralization plant	R 2 000 000
Capital for a solar evaporation plant	R 350 000
Total capital	R 2 350 000

	R/a
Interest and redemption over 25 years at 12%/a on R2,0 x 10^6	255 000
Interest and redemption over 25 years at 12%/a on R350 000	44 625
Chemicals : acid	56 550
: alkali	186 560
Resin replacement	30 000
Operating and maintenance at 2,5%/a on capital involved	46 250
Total	618 985
Allow 10% additional	62 000
TOTAL	681 000

8.4 Total Additional Costs

The total costs appear to be as follows:	R/a
For boiler purposes	3 800 000
For cooling purposes	681 000
Total	4 481 000

	R/a
Added to this is additional river water for cooling purposes of 13 Ml/d at R24/Ml	114 000
Total	4 595 000

8.5 Disposal of Salts

8.5.1 From Boiler Water Treatment

With the demineralization of water for boiler and cooling requirements, e.g. excessive amounts of chemicals are required for regeneration viz. sulphuric acid and caustic soda as follows:

For boiler water from the upper reaches of the Vaal Barrage Basin:

For half year : 7 200 Ml at 500 mg/l TDS :

Chemicals + salts in water (Chemical mass = twice salt mass in water)	10 800 tons

For half year : 7 200 Ml at 120 mg/l TDS :

Chemicals + salt mass in water (Chemical mass = 1½ salt mass in water)	2 160 tons
Total salts to evaporation	12 960 t/a
Say	13 000 t/a

8.5.2 From Cooling Water

4,7 Ml/d sewage effluent at say 800 mg/l TDS is to be demineralized. Assume that for each ton salt removed 2½ tons of chemicals are required.

$$\therefore \text{Total salts removed} = \frac{3{,}5 \times 4{,}7 \times 800 \times 1000 \times 365}{10^6}$$

$$= 6000 \text{ t/a which will be stored}$$

in solar evaporation ponds:

From boiler water treatment	13 000 t/a
From cooling water treatment	6 000 t/a
Total to storage	19 000 t/a

Although these salts are impounded in ponds which could be covered with soil if so required, it is, nevertheless, a potential source of salts which upon leaching could reach the Vaal Barrage waters.

According to details given in Table 16 below, Sasol's present nett discharge of salts into the Vaal River below the Barrage is 27,4 t/d or 10 000 t/a.

TABLE 16

PRESENT WATER REQUIREMENTS AND EFFLUENT DISCHARGE

	Vol/day Ml/d	Quality mg/l	TDS t/d	TDS t/a
Zuikerbosch water intake	55,3	100	5,53	2018
Vaal Barrage water intake	42,0	550	23,10	8432
Total intake	97,3	294	28,63	10 450
Final effluent discharge	59,0	950	56,05	20 458
Nett increase to Vaal River				10 008

In future with the poorer quality water expected, the salt load from the works could be at least 10 008-2 018 + 19 000 = 26 990 t/a of which the greater portion viz. 19 000 t/a will be stored in evaporation dams. Therefore, the additional salt load will be 26 990 - 10 008 = 16 981 t/a.

It was hoped to express the additional cost of approx= imately R5 x 10^6/annum as a percentage of Sasol's operating costs, but the company was not prepared to disclose such costs.

E. POWER STATIONS : ECONOMIC EFFECTS OF MINERALIZED WATER UPON THE PRETORIA MUNICIPAL POWER STATIONS

In the Pretoria Municipal area are two steam power stations generating electric power for Municipal use, viz:

(a) The Rooiwal Power Station of 300 MW capacity, situated some 15 km north of Pretoria, and
(b) The Pretoria West Power Station situated in Pretoria West of 180 MW capacity.

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1. ROOIWAL POWER STATION : 300 MW CAPACITY

This station prepares its own boiler feed water by demineralizing Rand Water Board water of approximately 300 mg/l total dissolved solids through cation and strong base anion exchange units with degasification between the two stages. Approximately 2% of the total boiler requirements is freshly demineralized water, the bulk being condensed steam and reused.

Exhaust low pressure steam from the steam turbines is condensed by cooling in condensers utilizing purified sewage effluent containing 600 mg/l TDS, supplied by the adjacent Rooiwal sewage purification works where raw sewage is treated in biological filters and matura= tion ponds. The effluent absorbing heat in cooling the low pressure exhaust steam from the turbines, is cooled in several hyperbolic cooling towers, from where blowdown and fresh make-up of purified sewage takes place.

For this study it is assumed that the future Rand Water Board water will attain a TDS concentration of 800mg/l. Under such conditions the resultant sewage effluent will also deteriorate to reach a TDS content of 1100 mg/l.

Table 17 illustrates the conditions which prevail presently at Rooiwal (1979/80) as well as the conditions should the Rand Water Board water supply deteriorate as indicated above. The conditions shown are approximate, based on data given.

Table 18 illustrates the calculated salt loads discharging from the power station into the Apies River as well as the additional costs involved. There appears to be sufficient sewage effluent available for future requirements by gravity feed (Figures must be regarded as approximate).

Conclusions

(i) The salt load discharged from the power station will quadruple from approximately 5 000 tons to 22 000 tons/a whilst the volumetric load will increase 4 times - from 4×10^6 to $16 \times 10^6 m^3/a$. These conditions represent a salt concentration increase from approximately 1 200 to 1 440 mg/l in the station effluent discharge.

(ii) The increase in volume and salt load to discharge, is mainly as a result of the doubling-up of sewage effluent required and its rising salt content.

(iii) The additional cost to the Municipality is relatively small, viz R170 000/a equivalent to a negligible rise of approximately 0,012c/kWh or 1,5% in total cost per unit of electricity generated. (N.B. the charge for sewage effluent remains unchanged and negligible).

2. PRETORIA WEST MUNICIPAL POWER STATION : 180 MW CAPACITY

This is an old steam station consiting of 10 boilers of medium pressure operating at irregular rates to take care of peak demands, especially during the cold winter months. The power supplied during the last year (1978/79) was of the order of 375×10^6 kWh (± 30% station capacity). The data received is incomplete but an attempt is, nevertheless, made to determine the present and future conditions.

2.1 Boiler Water Preparation

This is based on a split stream process employing a hydrogen ion (starvation) column and a sodium zeolite column in parallel, producing a total flow of $138\ 000 m^3/a$. This process reduces the mineral content of the Rand Water Board feed water from 300 mg/l to 220 mg/l and the total hardness from 150 to zero. This combined flow is demineralized in steam evaporators with a blow-down to waste. For operating the softening and evaporator units, a flow of water equiva=

TABLE 17

ROOIWAL POWER STATION PRETORIA

	Present conditions (1979/80)	Future conditions
Demineralization Section		
Station capacity	300 MW	300 MW
Feed water (RWB) mg/l	300	800
Purified sewage effluent mg/l TDS	600	1100
Feed water to demineralization plant m^3/a	53150	64420
Feed water to boilers m^3/a	46420	46420
Effluent to waste m^3/a	6730	18000
H_2SO_4 consumption kg/a (98%)	15200	40540
NaOH consumption kg/a (99%)	24415	65110
Total chemicals from demineralization plant (t/a)	40	106
Cooling Section (Sewage effluent)		
Cooling water circulating rate m^3/d	916 000	916 000
Daily make-up m^3/d	28 000	60 000
Cycles of concentration	2	1,3
Temperature drop across towers	8^0C	8^0C
Evaporation rate m^3/d	13 740(1,5%)	13 740(1,5%)
+Blow down m^3/d	13,740(1,5%)	48 800(5%)
Windage m^3/d	2 750(0,3%)	2 750(0,3%)
∴ Total losses m^3/d	27 480	59 540
+ Net blow down = (B/d - Windage) m^3/d	11 000	43 000

Blow down includes windage loss

TABLE 18

ROOIWAL POWER STATION PRETORIA

Effluents Discharged	Present Conditions		Future Conditions	
	t/a	Vol Ml/a	t/a	Vol Ml/a
Demineralization plant	40	6,73	106	18,00
Blow down from cooling towers	4818	4015	22 444	15 700
Raw feed water to demineralization plant	16	nil	52	nil
Total	4874	4022	22 602	15 718

Effluent concentration to Apies River 1212 mg/l 1438 mg/l

Additional Costs	Running R/a	Capital Rand
Demineralization plant extensions	-	100 000
Chemicals-regenerants	17 000	-
Additional cooling water at 1,3c/m^3 : 25 000 m^3/d	120 000	-
Additional pumps and piping	-	20 000
Additional tanks	-	20 000

N.B. : Cost figures are based on that provided by the Muncipality

<u>TABLE 18</u> (Cont)

Additional Costs (Con)	Running R/a	Capital Rand
Descaling of condensers	5 000	-
Labour : one operator	10 000	-
Total	152 000	140 000
Capital repayment : 12%/a over 25 years	18 000	
Total additional costs	170 000	

Annual power generated kWh $\quad 1480 \times 10^6$

Additional costs $\quad = 0{,}0120$ c/kWh

This represents approximately 1,5 percent of total costs lent to 15% of the product is required and discharged to waste i.e. 15% of 138 000 = 20 700 m^3/a.

2.2 Cooling Water

Purified sewage from the Pretoria Daspoort Works with an average total dissolved solids content of 500 mg/l is employed for cooling. A portion of the blow-down from the cooling system is used for hydraulic ash handling. The average daily volume used at present for cooling is of the order of 24 000m^3/d.

Data in Tables 19 and 20 indicate the prevailing conditions as well as those should the Rand Water Board water in future increase in TDS from 300 mg/l to 800 mg/l. Additional TDS pick-up of 200 mg/l through the domestic cycle will result in a sewage effluent TDS of 1000 mg/l in future.

2.3 Conclusions

(i) Due to the expected increase in TDS of both the RWB water and sewage effluent with the attendant larger quantities required in future as well as additional chemicals for softening, large additional effluent discharges with higher salt loads can be expected. As a result of this the effluent discharge will increase from 5 900 to 8 400 Ml/a and the tonnage of salt associated therewith will increase from about 4 000 to 11 000 t/a - an increase of some 175%. This is mainly due to the increase in sewage effluent volume required at almost double its original concentration, plus additional chemicals for softening etc.

(ii) The total cost increase to cope with the poorer water in future is small at R84 000/a, representing a cost increase of 0,022c/kWh, which approximates about a 2,6% rise on the total present cost per unit of electricity.

(iii) The corrosion/encrustation effects of the higher TDS cooling water is difficult to assess. Although

TABLE 19

PRETORIA WEST POWER STATION

	Present Conditions 1979	Future Conditions
Station Capacity (at full capacity)	180 MW	180 MW
Boiler Water Prepartion		
Feed water (RWB) mg/l TDS	300	800
Purified sewage effluent mg/l TDS	500	1 000
Feed water to boilers m^3/a	138 000	138 000
H_2SO_4 (98%) t/a	30,7	82
NaCl t/a	18,4	104
Total salts for softening t/a	9,1	186
Rinse and back-wash water m^3/a	20 700	55 000
Total raw water for softening m^3/a	158 700	193 000
Cooling Water System (Sewage effluent)		
Cooling water in circulation m^3/d	600 000	600 000
Daily make-up m^3/d	25 000	31 000
Cycles of concentration	1,4	1,3
Temperature drop across towers ^oC	6,6	6,6
Evaporation m^3/d	7 200(1,2%)	7 200(1,2%)
Blow-down m^3/d	8 000(3%)	24 000(4%)
Windage loss m^3/d	1 800(0,3%)	1 800(0,3%)
Total make-up m^3/d	25 000	31 200
Nett blow-down (18 000 - 1 800) m^3/d	16 200	22 200

TABLE 20

PRETORIA WEST POWER STATION

Effluents discharged	Present Conditions		Future Conditions	
	ton/a	Vol Ml/a	ton/a	Ml/a
Softening and evaporation chemicals	49	21	186	55
RWB intake to boilers	41	nil	110	nil
Blow-down from cooling towers	4139	5913	11056	8395
Total	4229	5934	11352	8450

Concentration of effluent 713 mg/l 1345 mg/l

Additional Costs	Operational	Capital
	R/a	R
New demineralization plant	-	100 000
Chemical for regeneration	12 000	-
Additional cooling water : 7 000 m^3/d at 2c/m^3	51 000	20 000
Additional pumps	-	20 000
Descaling of condenser tubes	3 000	-
Total	66 000	140 000
Capital redemption at 12%/a, 25 years	18 000	
Total cost/a	84 000	

TABLE 20 (Con)

Additional Costs (con)	Operational	Capital
	R/a	R
Total additional cost	84 000	-

Annual kWh generated 375×10^6

$\therefore$ Additional cost c/kWh $\dfrac{84\ 000 \times 10^2}{375 \times 10^6} = 0{,}0224$ cent

Based on the total operating costs this represents an increase of 2,6 percent.

some costs for additional cleaning of condenser tubes are allowed for in this study, there could probably be additional smaller costs for more pumps and pipes in the cooling system etc.

(iv) One alarming aspect of having to utilize poorer quality water in future is the tremendous additional effluent and salt loads discharged. Table 21 shows the present and future conditions for both power stations.

TABLE 21

PRESENT AND FUTURE CONDITIONS+

	ROOIWAL POWER STATION		PRETORIA WEST POWER ST	
	Present	Future	Present	Future
Effluent discharge Ml/a	4022	15718	5934	8450
Salt load discharge t/a	4874	22602	4230	11350
Concentration of effluent mg/l	1212	1438	713	1345
Increase in volume Ml/a	11696 = 291%		2516 = 42%	
Increase in salt load t/a	17728 = 364%		5300 = 168%	

+ Please note these figures are calculated figures and are approximate. This also applies to Kelvin and Orlando power stations

3. ECONOMIC EFFECTS ON ELECTRIC POWER GENERATION UTILIZING HIGHLY MINERALIZED WATER IN THE KELVIN AND ORLANDO POWER STATIONS OF THE JOHANNESBURG CITY COUNCIL

INTRODUCTION

The Johannesburg City Council operates two coal fired power stations to supplement its power requirements, viz:

(a) The Kelvin 'A' and 'B" stations of 600 MW capacity.

(b) The Orlando Station of 300 MW capacity.

Both stations employ Rand Water Board water for steam raising after demineralizing such by means of ion exchange plant.

For cooling water, purified sewage effluent is used - in the case of Kelvin from the Johannesburg Northern sewage works and in the case of Oralando, from the Klipspruit sewage works.

3.1 KELVIN POWER STATION

3.1.1 Boiler Water Treatment

The present Rand Water Board water available has a TDS of 300 - 350 mg/l. In future it is assumed that this water will deteriorate to an average TDS content of 800 mg/l under which conditions additional demineralization plant capacity would be required to furnish the required boiler feed water. Attended with this is a substantial increase in regenerant chemicals leading to increased amount of effluent and salt loads.

3.1.2 Cooling System

For cooling purposes, sewage effluent is used and such will also deteriorate in future. Presently, the pick-up of mineral salts in sewage is high and from information submitted by the City Council the following concentrations of salts will be present:

	Presently	Future
Northern Works effluent mg/l TDS	405	905
Klipspruit effluent mg/l TDS	485	985

At the present time waste sulphuric acid regenerant from the demineralization plant plus additional acid (286 t/a) is introduced in the cooling water system at a cost of R20 000/a. In future with water of higher TDS an additional R20 000 will be used for controlling excess alkalinity.

In addition to the above, approximately R20 000 is spent annually in descaling heat exchanger tubes with hydrochloric acid. In future this cost can be expected to escalate and a further R20 000/a would be involved.

The effect of scaling in heat exchangers in reducing heat transfer results in an increased coal consumption amounting presently to some R300 000/a. With the poorer cooling water in view this figure could escalate to R500 000/a.

When the purified sewage reaches a concentration of 905 mg/l TDS, the required volume will increase from 40 Ml/d to 57 Ml/d. The existing pipeline and pumping plant is capable of delivering only 45 Ml/d and to install another pipeline, will according to the opinion of the Engineers Department of the Johannesburg City Council, be very costly and difficult to lay. To obtain permission to lay the pipeline in provincial road reserves and or obtain servitudes over numerous private properties will be a costly and time consuming undertaking. The alternative is to purchase the additional water required for cooling from the Rand Water Board.

The following additional costs could arise:

5 Ml/d purified sewage at R36.20 Ml = R66 065/a
12 Ml/d RWB water at R103,70/Ml (1979 tariff for Johannesburg as a foundation consumer) = R454 206/a.
$\therefore$ Total additional cost = R520 271/a

3.2 ORLANDO POWER STATION

At this station additional demineralization capacity will be required with additional chemicals for regeneration which will increase the mineralized effluent load to waste.

On the cooling plant no acid is used presently for alkalinity control but in future such will be required at an estimated cost of R10 000/a. An allowance for descaling heat exchanger tubes of R10 000/a is made and R100 000 for additional coal.

Additional cooling water of 19 Ml/d is required at a cost of R1,60/Ml of purified sewage from Klipspruit sewage works, delivered by an existing gravity feed line. This will cost R11 100/a.

3.2.1 Technical Details

Details of operating conditions with respect to the demineralization and cooling sections for the two stations are shown in the attached Tables 22 and 23. (The calculated figures are approximate).

3.2.2 Effluent to Waste

Except for a small quantity of effluent used for ash handling, all cooling water and boiler blow-down with demineralization plant effluent, discharges to stream en route to the Vaal River. (This applies at Orlando Station only, whilst at Kelvin the effluent runs to the Jukskei River).

The following details are given with respect to additional volumes and mineral loads so discharged as a result of having to operate with the higher TDS water:

Station	Kelvin		Orlando	
	Present	Future	Present	Future
Effluent discharged Ml/d	11,4	30,6	12,6	31,3
Salt load in discharge t/d	10,6	42,8	8,3	39,0
Concentration of effluent mg/l	925	1400	740	1246
Increase in volume Ml/d	19,2 = 168%		18,7 = 148%	
Increase in salt load t/d	32,2 = 304%		29,7 = 319%	

TABLE 22

KELVIN POWER STATION

Demineralization Section	Present Conditions (1979)	Future Conditions	Increase
Station capacity	600 MW	600 MW	
Feed water (RWB) mg/l	300-350	800	
Feed water to demin. plant m^3/d	1020	1240	
Feed water boilers m^3/d	890	890	
H_2SO_4 (98%) consumption kg/d	371	990	
NaOH (100%) consumption kg/d	186	500	
Vol. of effluent (12,5%) m^3/d	130	350	
Cooling Section			
Ml/d (purified sewage) circul. rate	1510	1510	
TDS of sewage mg/l	405	905	
Daily make up Ml/d	40	57+	
Cycles of concentration	2	1,5	
Temp. drop across cooling towers °C	7	7	
Evaporation rate Ml/d (1,25%)	19,0	19,0	
Nett blow-down Ml/d (0,75%)	11,3	30,2	
Windage loss (0,5%) Ml/d	7,6	7,6	
Total losses Ml/d	38,9	56,8	
Effluents Discharged			
TDS of cooling blow-down mg/l	810	1360	
Vol. of blow-down including demineralization effluent Ml/d	11,4	30,6	19,2
Salt load discharge including demineralization effluent t/d	10,6	42,8	32,2
Concentration of final effluent mg/l	925	1400	

\+ N.B. When using 65 Ml/d of sewage instead of 57 Ml/d, the final effluent contains 1310 mg/l compared to 1400 mg/l

TABLE 23

ORLANDO POWER STATION

Demineralization Section	Present Conditions (1979)	Future Conditions	Increase
Station capacity	300 MW	300 MW	
Feed water conc. (RWB) mg/l	300-350	800	
Feed water to demineralization plant m^3/d	393	478	
Feed water to boilers m^3/d	343	343	
H_2SO_4 (98%) consumption kg/d	470	1253	
NaOH (100%) consumption kg/d	490	1307	
Vol. of effluent (12,5%) m^3/d	40	107	
Cooling Section			
Cooling water circ. rate Ml/d	504	504	
(Purifed sewage - Klipspruit)			
TDS of sewage effluent mg/l	485	985	
Daily make-up of sewage Ml/d	21	40	
Cycles of concentration	1,5	1,2	
Temperature drop across cooling towers °C	7	7	
Evaporation (1,25%) Ml/d	6,3	6,3	
Windage loss (0,5%) Ml/d	2,5	2,5	
Nett blow-down (0,75%) Ml/d	12,6	31,2	
Total	21,4	40,0	
Effluents Discharged			**Increase**
TDS of blow-down from cooling towers mg/l	730	1230	
Volume of blow-down Ml/d	12,6	31,3	18,7
Total salt load discharged t/d	8,33	39,0	29,7
TDS of blow-down + demineralized effluent mg/l	740	1246	-

The salt load increase stems from the large amount of chemicals required for regeneration of ion exchange plant and from larger volumes and more concentrated purified sewage effluent.

3.2.3 Additional Costs

The following additional costs appear to be involved based on data supplied by the power stations Chief Chemist. See Table 24.

TABLE 24

ADDITIONAL COSTS

STATION	KELVIN	ORLANDO
Capital for demineralization plant	R350 000	R165 000
Operating costs	R/a	R/a
Chemicals for deminralization	285 000	165 000
Acid for cooling water	20 000	10 000
Acid for descaling of tubes +	20 000	10 000
Extra coal	230 000	100 000
Extra water for cooling	520 000	11 100
Total	1075 000	396 100
Capital redemption and interest (10% p/a over 25 years) on capital employed	38 600	16 500
Final additional cost/a	1113 600	312 600
Total kWh generated x 10^6 for 1977/78	2635	910
Additional cost c/kWh	0,0423	0,0344
Present generating cost c/kWh	1,3567	1,4684
Percentage increase	3,12%	2,34%

\+ Residual regenerating acid used in cooling water system

3.3 Conclusions

Table 21 indicates the additional capital required for the two stations viz. R350 000 for Kelvin and R165 000 for Orlando. The total additional costs - mainly running costs, amount to R1,114 x 10^6 and R313 000/a respectively for the two stations, raising the cost per kWh by 0,042c and 0,034c This amounts to 3,12% in the case of Kelvin and 2,34% in the case of Orlando stations.

4. THE ESCOM POWER STATIONS IN THE PWVS AREA INCLUDING THE VIERFONTEIN STATION AT ORKNEY

The four power stations dependant on Vaal River water abstracted from the Vaal Barrage basin are:

Vaal, Highveld and Taaibos situated on the Free State side and Klip on the Transvaal side of the Vaal River.

Included in this study is the Vierfontein power station in the Free State near Orkney, operating on water passing through the Vaal Barrage.

4.1 Assumptions for Vaal, Highveld and Taaibos Stations

The assumption in this study is that the water quality in the Vaal River at the point of abstraction below the Vaal Dam wall to be 500 mg/l TDS for 6 months of the year and normal for the other 6 months ($\pm$ 120-150 mg/l TDS). This is similar to the conditions for Sasol as explained under item D9.2.

4.1.1 Demineralized water : Additional Costs
(Cost figures supplied by Escom)

The following appear to be the additional cost per annum for producing demineralized water for the boilers:

Vaal	R62 000 per annum
Highveld	R194 000 per annum
Taaibos	R122 000 per annum

The capital redemption and interest on the R1 500 000 required for a demineralization plant and equipment over

15 years is R220 000/a.

4.1.2 Additional Costs for Cooling Water

Additional costs for cooling water make-up for these three stations operating at their different load factors are:

Vaal	R37 000/annum	(81% l.f.)
Highveld	R45 000/annum	(72% l.f.)
Taaibos	R45 000/annum	(68% l.f.)

The existing pumping capacities are sufficient to provide the required make-up water.

4.2 Assumptions for the Klip and Vierfontein Stations

4.2.1 Demineralized Water

The Klip station demineralization plant capacity has now been extended by a further unit received from the ex-Congella station (Durban) so that no additional capital cost is required here. For Vierfontein station the water of 800 mg/l TDS will be demineralized in a Reverse Osmosis unit at an annual cost of R220 000/a. (Capital cost estimate R1 500 000).

4.2.2 Cooling Water

The present cooling water supplied to the Klip station is close on 800 mg/l TDS and the pumping capacity still adequate and no further capital expenditure is required here.

For Vierfontein station the cooling water at 800 mg/l TDS presents problems in so far that the station with its present pumping and other facilities will only be able to produce a portion of its power requirements. It appears cheaper to look for the short-fall in power elsewhere than to equip the station with additional pumping and other equipment. The incremental replacement cost at today's prices would be R1 230/GWh and for the shortfall of 24,7 GWh per year would cost R30 380 per year extra.

The present make-up of cooling water at Vierfontein is 6 liters/unit sent out, but with water of 800 mg/l TDS this will increase to 9,3 l/uso, at an annual additional cost of R87 000/a.

4.3 Summary of Costs

4.3.1 For Demineralized Water Production Costs

Vaal	R62 000/a	
Highveld	R194 000/a	
Taaibos	R122 000/a	R378 000

4.3.2 Demineralization Plant : Capital and Interest Costs

Vaal, Highveld and Taaibos	R220 000/annum	
Vierfontein	R220 000/annum	R440 000

4.3.3 Cooling Water Make-up Costs

Vaal	R37 000/a	
Highveld	R45 000/a	
Taaibos	R45 000/a	
Vierfontein	R87 000/a	R214 000

4.3.4 Incremental Load Replacement Costs

Vierfontein	R30 380/a	R30 380
Total cost		R1 062 380

Escom's total operating cost was R548 x 10^6 for 1978 (Annual Report) Percentage cost of total operating costs : 0,194%/a. $\left(\frac{1,0624}{548} \times 100 \right)$

From Escom's 1978 Annual Report, the five stations under study sent out 8707 x 10^6 kWh and at R1 062 380 additional cost, this is equivalent to 0,0122c/kWh additional.

Escom's total cost per unit sent out is 1,696c.

Assuming this also to be the average cost per unit sent out for the five stations received, the additional cost is equivalent to:

$$\frac{0,0122 \times 100}{1,696} = 0,72\% \text{ increase}$$

4.4 Side Effects (Notes by Escom)

There appears to be several side effects on the use of Vaal River water due to increasing pollution as a result of water evaporation in cooling towers and demineraliza= tion for boiler use. The following must be taken cognisance of:

4.4.1 The zero discharge of effluent cannot be maintained

4.4.2 The increased amount of blow-down with additional chemicals added renders the water of less value to users down-stream.

4.4.3 Any future power plants or industries employing water for cooling will have to resort to dry cooling and reverse osmosis for desalination.

F WATER REQUIREMENTS AND OVERALL ADDITIONAL COSTS TO INDUSTRY+ WHEN OPERATING WITH MINERALIZED WATER OF 800 AND 500 mg/l TDS

1. Summary of Additional Costs with Water of 800 mg/l TDS

Table 25 is a summary of additional water required, effluent and salt loads generated should the industries and the power stations examined operate with water of 800 mg/l TDS. The data supplied must be regarded as approximate but it gives a reasonable picture of what could occur. Also given are the approximate additional operating costs for the organizations studied. It will be seen that these additional operating costs vary from 0,65 to about 5 percent. Costs for Sasol are not available but it could be of the order of a few percent additional.

Table 26 gives more details of costs including additional capital required should the two classes of water viz. 800 and 500 mg/l TDS be used. The overall factory costs exclude costs of raw materials and transportation costs.

2. Summary of Additional Costs with Water of 800 and 500-600 mg/l TDS

Calculations were also done to determine the additional costs should water of 5-600 mg/l TDS be used. Table 27 gives details of present water requirements for the various organizations examined and the additional costs when operating with water of 800 and 500-600 mg/l TDS. The additional water required when operating with 800 mg/l instead of 300 mg/l TDS is also shown.

3. Projected Water Demands for the PWVS-Complex

The projected water demands by 1980 for the PWVS-Complex according to estimates given by the Department of Water Affairs in its White Paper WPR-77, is 874 000 Ml. (Table 2 page 3).

The Rand Water Board estimates that 30 percent of all water supplied by it is used for industrial purposes i.e. 30 percent of approximately 700 000 Ml/a for 1978/79 viz. 210 000 Ml/a. There are several large industries in the PWVS-Complex abstracting water directly out of the lower reaches of the Vaal Barrage e.g. Sasol, Iscor, Escom, etc., which quantities are not included in the

\+ Industry includes the power stations examined.

TABLE 25

ADDITIONAL COSTS FOR VARIOUS ORGANIZATIONS USING MINERALIZED VAAL BARRAGE WATER

(800 mg/l TDS)

ORGANIZATION	ADDITIONAL				ADDITIONAL		ANNUAL ADD. OPERATING COSTS (R)	ADDITIONAL COST AS PERCENT OF OPERATING COSTS	
	Water Ml/a	%	Effluent Ml/a	%	Salts t/a	Generated %			
Iscor-Vanderbijlpark	18576	92	17916	191	21504(1)	191	4×10^6	0,85	
Iscor-Pretoria	3162	44	3168	275	5064	274	$0,85 \times 10^6$	0,45	
Sasol	35515	-	-	-	17000	170	$4,6 \times 10^6$	-	
AECI : Midlands)	2136	73	2136	200	2933	325	$1,00 \times 10^6$	2,0	
: Modderfontein)[4)]	7666	60	6333	112	12000	150	$4,74 \times 10^6$	5,0	
NCP-Germiston	264	20	264	55	528	54	260000	0,85	
Lever Bros-Boksburg	200	32	195	123	411	127	100000	1,0	Add : c/kWh
Rooiwal Power Station	11,3	21	11700	291	17728	364	170000	1,0	0,0115
Pretoria West P.S.[(2)]	34,3	22	2516	42	7123	168	84000	3,0	0,0224
Kelvin Power Station	80,3	22	7010	168	11753	304	1140000	3,12	0,0423
Orlando Power Station	31,0	22	6825	148	10840	319	313000	2,34	0,0344
Escom Power Stations[(3)] along the Vaal River	15000	26	-	-	-	-	$1,062 \times 10^6$	0,72	0,0122

Municipalities:

Pipe network replacement) (Total Complex) $4,56 \times 10^6$ (See pages 63 and 121)
Reservoir additions)

(1) Apart from the 21504t/a discharged, a further 2676t/a remain on the property i.e. 11% of the total
(2) This station operates very irregular to meet peak demands i.e. at 30% of its annual capacity (1979)
(3) Details of additional water, effluent and salts not available.
(4) These figures were calculated from rather meagre information and are not necessarily the conditions ruling at the two factories. The data must be regarded as indicative only.

TABLE 26

SUMMARY OF ADDITIONAL COSTS FOR DIFFERENT TDS VALUES

Organization	Additional Capital Requirements		Additional Costs/a Capital Repayment & Operational Costs		% Difference in Cost from	% Increase of Overall Working Production Costs[5] Percent(%)	
TDS Content	5-600 mg/l (Rx10⁶)	800 mg/l (Rx10⁶)	5-600 mg/l (Rx10⁶)	800 mg/l (Rx10⁶)	800 to 5-600 mg/l %	5-600 mg/l %	800 mg/l %
Iscor-Vanderbijlpark	7,15	14,2	1,86	4,0	53,5	0,39	0,85
Iscor - Pretoria	0,60	0,91	0,63	0,85	26	0,32	0,45
AECI - Midlands	0,50	1,00	0,74	1,00	26	1,4	2,00
AECI - Modderfontein	0,75	4,74	3,47	4,74	27	3,15	5,0
Sasol[1]	20,5	22,85	3,30	4,60	28	-	-
NCP - Germiston	0,28	0,35	0,184	0,260	29	0,61	0,85
Lever Bros. - Boksburg	0,060	0,10	0,050	0,100	50	0,50	1,00
Power Stations							
Rooiwal - Pretoria	0,105	0,140	0,134	0,170	21	0,40	1,0
Pta. West - Pretoria	0,090	0,140	0,052	0,084	38	-	3,0
Kelvin - Johannesburg	0,200	0,350	0,474	1,004	57	1,3	3,6
Orlando - Johannesburg	0,110	0,165	0,201	0,313	36	0,90	2,45
ESCOM : Vaal[2]) Highveld) Taaibos)	1,5	NA	0,725	NA	-	0,13	-
Klip	Nil	Nil	Nil	Nil	-	-	-
Vierfontein[3]	Nil	1,50	NA	0,337	-	-	-
Household consumers	-	-	20,0	39,4	49	-	-

1. River water for cooling at Barrage according to Sasol already 550 mg/l TDS
2. Water abstracted just below Vaal Dam wall at concentrations of 120-500 mg/l TDS
3. Vaal River at Orkney often 800 mg/l TDS
4. Klip Station demineralizes own borehole water. Vaal River water for cooling often + 600 mg/l TDS
5. These costs exclude raw materials, railage and transport

TABLE 27

WATER REQUIREMENTS AND ADDITIONAL COSTS WHEN OPERATING WITH WATER OF 800 AND 500-600 mg/l TDS

Industry including Power Stations	Present Ind. Water Usage Ml/a (300 TDS)	Additional Water Usage Ml/a (800 TDS)	Additional Costs Per Annum R x 10^6	
			800 mg/l TDS	500-600 mg/l TDS
Iscor - Vanderbijlpark	20 088	18 576	4,0	1,860
Iscor - Pretoria	7 170	3 162	0,85	0,630
Sasol	35 515	3 806	4,60	3,300
AECI - Midlands	3 224	2 136	1,00	0,472
AECI - Modderfontein	14 000	8 000	4,74	3,470
NCP - Germiston	1 320	264	0,260	0,184
Lever Bros. - Boksburg	612	200	0,100	0,050
Rooiwal P.S. - Pretoria	53	11	0,170	0,134
Pretoria West P.S.	138	34	0,084	0,052
Kelvin P.S. - Johannes=burg	372	80	1,114	0,474
Orlando P.S. - Johannes=burg	143	31	0,313	0,201
Escom-Vaal River	15 000	15 000	1,062	0,725
TOTAL	97 635	51 300	18,29	11,552
Assume	98 000	51 000	18,43	11,6

approximate 700 000 Ml/a supplied by the RWB.

Table 28 shows the water consumption figures for 1978/79 for the major cities and towns in the complex. From this data it appears that the industrial consumption is approximately 36 percent of the total water supplied (Figs. in Ml/a).

4. Total Projected Additional Cost to Industry

Assuming that the additional cost to industry for the whole complex is based on that established as reflected in Table 27, and assuming that industry uses 35 percent of the total water supply to the complex, then it appears reasonable that the total additional cost to industry could be as shown below for the two qualities of water referred to:

Water Quality TDS	Annual Add. Cost
800 mg/l	$R18,3 \times 10^6 \times \frac{874}{98} \times 0,35 = R57,1 \times 10^6$
500-600 mg/l	$R11,6 \times 10^6 \times \frac{874}{98} \times 0,35 = 36,3 \times 10^6$

There is a decrease of 36 percent when operating with the better quality water of 5-600 mg/l TDS.

5. Additional costs for Supplying, Pumping and Storing Additional Industrial Water for the PWVS-Complex

5.1 Additional Industrial Water and its Costs

Under section F4 it was shown that the projected additional cost to industry when operating with the two classes of water viz. 800 and 500 mg/l TDS could be $R57,1 \times 10^6$ and $R36,3 \times 10^6$/a respectively.

With the expected deterioration of water quality in future - if no attempt is made to stop this tendency, industry will no doubt have to use more water to safeguard its equipment from scaling, corrosion and to comply with TDS limits as prescribed under the Water Act. Less cycles of concentration will have to be practised and blow-down volumes will increase. It has already been shown that by 1979/80 industry will require 35 percent of the total water required in the complex i.e. 35% of 874 000 Ml/a = 306 000 Ml/a. The following basis is

TABLE 28

WATER CONSUMPTION OF THE MAJOR CITIES AND TOWNS IN THE PWVS-COMPLEX IN Ml/a FOR 1978/79

Town	Domestic	Industrial	Total	% Industrial
Springs	10 669	12 692 1)	23 361	54
Brakpan	5 146	6 040 2)	11 186	54
Benoni	9 939	4 854	14 793	33
Boksburg	8 323	3 352	11 675	29
Germiston	14 089	6 419	20 508	31
Alberton	4 722	4 730	9 452	50
Kempton Park	1 108	4 123	5 231	27
Krugersdorp	-	-	-	30
Roodepoort	10 201	1 139	11 340	10
Pretoria	79 575	16 425	96 000	17
Johannesburg	147 271	23 974	171 245	14
Vanderbijlpark	7 059	23 207 3)	30 266	77
Sasolburg	4 212	66 856 3)	71 068	94
Vereeniging	9 141	2 741	11 882	23
TOTAL	311 455	176 552	488 007	36,2

1. Includes RWB water for SAPPI (6 324 Ml/a)
2. Includes RWB water for ERGO (5 760 Ml/a)
3. Includes Vaal Barrage Water taken directly out of Barrage by Iscor and Sasol

used for calculating the additional water required assuming the effluent water for discharge upon evaporative cooling must not exceed 1200 mg/l TDS as is generally prescribed for the larger industries by the Department of Water Affairs.

Make-up (Mu) = Evaporation (E) + Blow down (B)

$$Mu = E+B$$

$$Mu = \text{cycles of concentration } (C) \times B$$

$$Mu = C \times B \text{ or } C = \frac{Mu}{B}$$

$$\therefore C = \frac{E + B}{B}$$

$$\text{or } \%B = \frac{\%E}{(C-1)} \quad \text{or } \%E = \%B(C-1)$$

From the above data and reasoning it is possible to determine the amount of water required for cooling for different make-up concentrations:

Make-up Water TDS mg/l	Evaporation Vols. E	Cycles of Concent. C	TDS mg/l in B/down	Make-up Vols E + B = Mu
300	1	4	1200	1 (Assume)
400	1	3	1200	1 + 0,5 = 1.5
500	1	2,4	1200	1 + 0,71 = 1.71
600	1	2	1200	1 + 1 + 2
800	1	1,5	1200	1 + 2 = 3

Thus with water of 500 mg/l TDS the additional industrial water required will be 0,71 x 306 000 = 217 000 Ml/a. Similarly, for water of 800 mg/l TDS the additional water required will be 2 x 306 000 = 612 000 Ml/a.

Since only some industries concentrate their water to the full extent of 1200 mg/l TDS, it appears reasonable to assume that only 25 percent of such water will be so concentrated. The additional water required will then be reduced to the following quantities:

For intake water of 500 mg/l TDS : 54 250 Ml/a

For intake water of 800 mg/l TDS : 153 000 Ml/a.

It must be pointed out that although additional water is required for industrial purposes when the water deteriorates, its costs at the present TDS of 300 mg/l has already been taken into account in the investigations of the several industries and power stations under Section D. Item F5.2 shows the additional costs for additional reservoir capacity to cope with additional industrial water. It is foreseen that there will be no or very little additional water required for domestic use should the water deteriorate. However, the water utility undertaking that supplies water will have to provide the extra plant and pumping capacity for the additional industrial water. This cost has now been determined by the Rand Water Board and appears to be as follows:

For water treatment	3,85 c/kl
Capital redemption and interest for additional plant to prepare, deliver and store water	13,75c/kl
Miscellaneous costs	0,65c/kl
Total costs	18,25c/kl
Present cost for water supply by RWB (See RWB 1979 Annual Report)	8,35c/kl

Therefore, additional cost is 18,25 - 8,35 = 9.90c/kl

Based on the additional industrial water required, the additional costs appear to be as follows:

Water of 500 mg/l TDS = 54250 Ml/a x 9,90c/kl = R5.37 x 10^6/a

Water of 800 mg/l TDS = 153 000 Ml/a x 9,90c/kl = R15,15 x 10^6/a

5.2 Additional Reservoir Capacity and Costs for Industrial Water

In order to comply with a 36h average retention period, the following additional reservoir capacity will have to be supplied for industrial water supply:

For 54250 Ml/a : $\frac{54250 \times 1,5}{365}$ = 223 Ml (TDS 500 mg/l)

For 153 000 Ml/a : $\frac{153\ 000 \times 1,5}{365}$ = 629 Ml (TDS 800 mg/l)

Several small reservoirs will have to be constructed and as= suming reservoirs of 50 Ml capacity each can be erected for R2,5 x 10^6 each, then the costs could be as follows for the two water qualities:
(Capital recovery at 10%/a interest over 25 years)

TDS mg/l	Reservoir Vol Ml	Capital cost of Reserv. (R)	Annual Repay= ment (R)
500	223	11,15	1,24 x 10^6
800	629	31,46 x 10^6	3,46 x 10^6

5.3 Additional Corrosion Costs

The additional corrosion in steel mains which could result in the PWVS-Complex has been dealt with under Section B item 3 of this report and appears to be as follows:

For water of 500 mg/l TDS R0,316 x 10^6/a
For water of 800 mg/l TDS R1,1 x 10^6/a

6. Summary of Total Additional Costs to the PWVS-Complex when Water Quality Deteriorates to 500 and 800 mg/l TDS

The areas investigated where increasingly mineralized water could result in increased costs are summarized as follows:

6.1 Private residential and flat owners - Europeans
6.2 Non-white housing - Asians, Coloureds and Blacks
6.3 Water supply authorities - Rand Water Board
6.4 Local authorities - Municipal water networks
6.5 Industry and Power Stations:
(a) Additional water, pumping plant, water treatment and effluent plant costs.
(b) Additional reservoir capacity.

Table 29 is the final summary of the additional costs involved in the main fields of use for the PWVS community for the two qualities of water examined.

Assuming the additional cost when using the present water supply to the Complex of 300 mg/l TDS to be zero and the additional cost for water of 500 and 800 mg/l TDS to be that determined viz. R77 x 10^6 and R138 x 10^6 respectively, a graph can be drawn to illustrate the probable costs for water of higher TDS. N.B. To illustrate this graphically with only three points could be somewhat misleading. However, Graph No 3 indicates that the rate of cost-rise decreases with the rise in TDS. This is possible, particularly within industry where for instance the doubling of the TDS does not necessarily call for twice the capital cost, nor double the operating cost for plant required. Similarly, with regards to detergent use and washable clothing, a doubling up of TDS does not mean doubling the costs. It is, therefore, possible to use the graph to indicate the tendency of rise in cost should the water deteriorate above 800 mg/l TDS.

7. Conclusions

The following conclusions appear to arise from this study :

7.1 This cost study with the findings of the overall investigation on "The Mineral Pollution in the Vaal Barrage and its Tributaries", indicates the seriousness of the present situation which will become even more acute the longer remedial action is delayed.

7.2 The cost study also indicates that private householders and industrialists will be the main sufferers having to bear over 80 percent of the additional costs should no relief be forth= coming. By improving the water quality, all consumers using water related equipment will benefit through a reduction of costs. Such benefits are equivalent to 16c/kl water used by all in the complex whilst for an European household the benefit will be 19c/kl for water of 800 mg/l TDS.

7.3 Dilution as a solution to the problem can only be considered as a short term aid, and should not be relied upon.

7.4 Although it is clear that a total solution to the overall problem cannot be realized in the immediate future, some action should be considered as soon as possible. The most likely relief appears to be the isolation of underground mining effluents and its further treatment - probably in evaporation dams or by means of desalination. Such a step will relieve the Barrage by 25 percent of the mineral solids inflow.

7.5 In view of the high costs initiated in the study and conse=

quent savings which would be realized if a better quality were made available, it appears that costly drastic action implemented will still prove to be an economically viable undertaking.

7.6 In recognition of the extreme concern expressed by water users, particularly the "wet industries", it appears appro= priate to issue a situation statement aimed at setting their minds at ease, indicating the magnitude and complexity of the problem and also what action is being contemplated to alleviate the problem in the short and long term.

7.7 Should no action be taken the mineral quality of the water will continue to deteriorate and industry and local authorities will be obliged to condition their water supplies by intro= ducing additional chemicals for softening and/or demineraliza= tion processes, resulting in an escalation of the tempo of mineral build-up.

This study indicates the additional costs that could result under the present situation concerning population, industrial and mining activities with water of 500 and 800 mg/l. However, by the end of the century when the mineral content of the water could be 800 mg/l TDS, the population and industrial activity would also increase markedly resulting in much larger additional costs than that given in this study.

In this cost study the cost effects of the following items are excluded which no doubt will increase the total costs further:

(a) high-rise buildings - office and institutions hot water systems;
(b) steel pipes smaller than 75mm and larger than 300mm diamter;
(c) corrosion in steel pipes conveying cooling and other classes of water in industry;
(d) effects of mineralized water on agriculture where such is used for irrigation;
(e) additional sewers to convey increased volumes of industrial effluent;
(f) additional water distribution networks to convey additional industrial water;

(g) increased mineralization passing downstream of the Barrage generating costs to private, industrial and agricultural users of such waters;

(h) removal of organics from Rand Water Board water. This cost is given under Section G, but not included in costs given in Table 29.

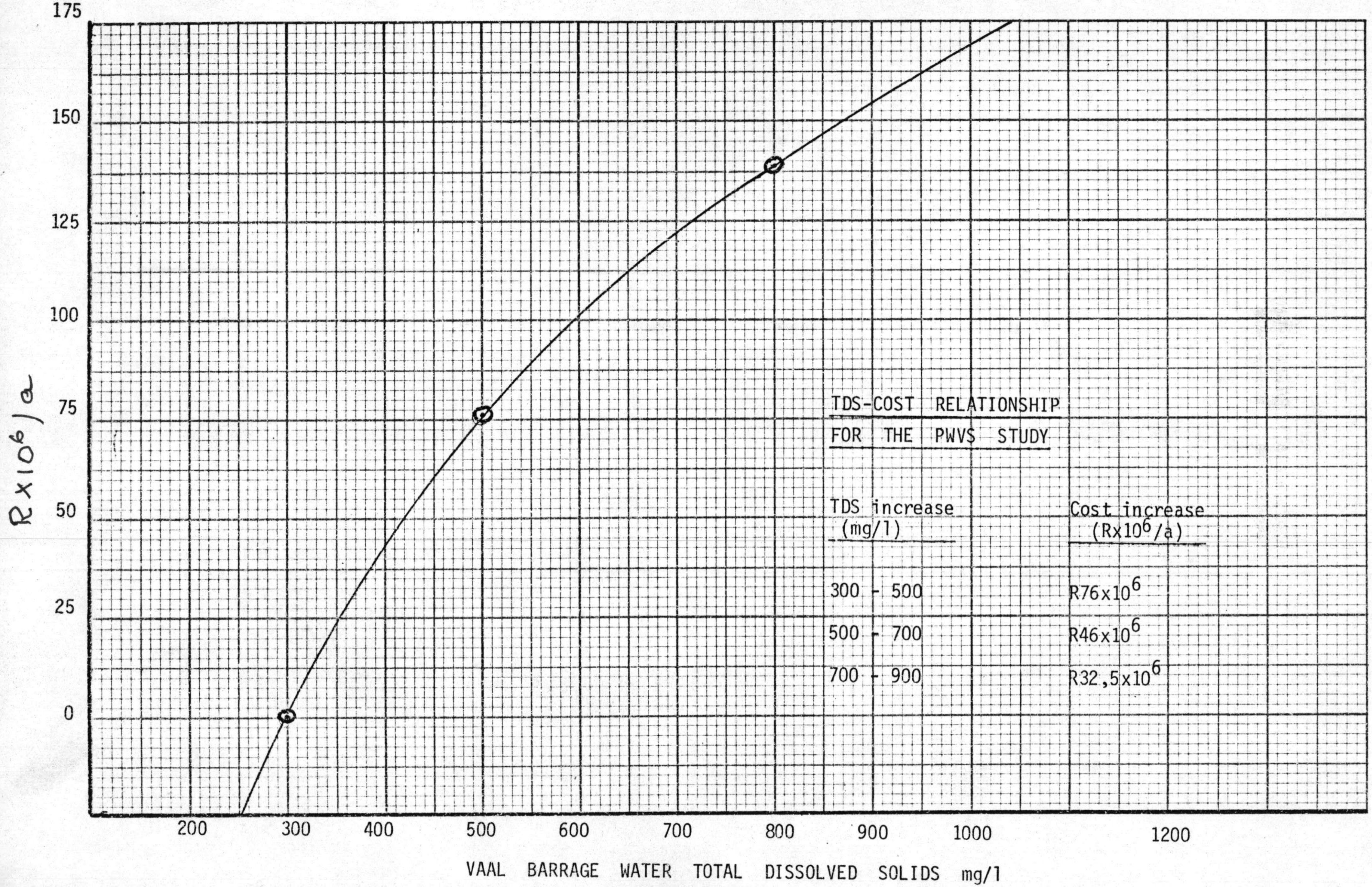
In conclusion I wish to express my thanks to Mr. H.C. Chapman of the Water Research Commission for valuable guidance given from time to time.

TABLE 29

SUMMARY OF ANNUAL ADDITIONAL COSTS FOR THE PWVS-COMPLEX UTILIZING WATER OF 800 AND 5-600 mg/l TDS

COST PER ANNUM Rx 10^6

Water Quality mg/l TDS	800	% of Total Cost	500	% of Total Cost
Field of Water Use :				
Private Households (Whites) Table 9	39,4	28,4	20,0	26
Private Non-white Households - Table 10	22,65	16,0	13,0	17
Water Supply Authority - Rand Water Board :				
Additional industrial water : F2.1	15,15	11,5	5,37	7
Local Authorities : Municipalities :				
Corrosion in water networks and additional reservoirs (F2.1)	4,56	3	1,56	2
Industry including Power Stations :				
Additions, operation/maintenance E1.3, 1.4	57,10	41	36,3	48
TOTAL	138,86	100	76,23	100


175
150
125
100
75
50
25
0
R x 10⁶ / a
200
300
400
500
600
700
800
900
1000
1200
TDS-COST RELATIONSHIP
FOR THE PWVS STUDY
TDS increase (mg/l)
Cost increase ($R\times10^6$/a)
300 - 500
$R76\times10^6$
500 - 700
$R46\times10^6$
700 - 900
$R32,5\times10^6$
VAAL BARRAGE WATER TOTAL DISSOLVED SOLIDS mg/l

GRAPH NO 3

G. THE ECONOMIC EFFECTS OF THE ORGANIC CONTENT OF THE VAAL RIVER BARRAGE WATER ON THE COMMUNITY OF THE PWVS-COMPLEX

Prepared by the Rand Water Board.

An addendum to the Water Research Commission's Report : THE ECONOMIC EFFECTS OF THE MINERAL CONTENT PRESENT IN THE VAAL RIVER BARRAGE WATER ON THE COMMUNITY OF THE PWVS-COMPLEX.

The Rand Water Board's records regarding organic compounds in the water of interest to the PWVS consumers are not as comprehensive as those for inorganic constituents. The available information is limited but it is sufficiently comprehensive to meet the needs of this preliminary report.

There is no doubt that the quality of the Board's raw water sources, and consequently the quality of water produced, has materially deterio= rated in respect of organic content during recent years.

At present the dissolved chemical oxygen demand (COD) and dissolved organic carbon (DOC) values in the major Vaal Barrage Tributaries at times exceed concentrations of 100 and 15 mg/l respectively. Removal efficiencies affected by conventional water purification methods such as those used by the Rand Water Board vary depending on the coagulant used and the source of the raw water used.

For the period February to October, 1980 removal efficiencies of compounds producing dissolved COD varied from 6 to 15%. The lowest efficiency was encountered on the systems treated with polyelectrolyte. DOC removal was most marked on the lime/silica treatment systems treating Vaal Dam water. It appears that DOC's are more readily removed from Vaal Dam water than the more polluted Vaal River Barrage water.

The effect of high levels of DOC on chlorine demand to disinfect the potable water supplied by the Board has been a matter of concern for a long time. To maintain satisfactory bacteriological counts at terminal distribution points, requires high residual chlorine levels in the water leaving the purification works. A reduction of DOC will lead to a decrease in chlorine demand and will greatly improve the effectiveness of disinfection and reduce the level of Trihalomethanes (THM's) in the water Much concern has been expressed internationally regarding the presence of THM's in potable water supplies and these aspects may eventually force the Board to install the necessary processes to reduce DOC.

The maximum contaminant level for total Trihalomethanes (TTHM) proposed by the United States Environmental Protection Agency (USEPA) is 100 µg/l (Pakcham 1979). In Canada a limit of 350 µg/l has been set while a standard of 25 µg/l is set by the German authorities.

Trihalomethane analysis are done on a weekly basis at selected terminal points in the Board's distribution system. Values in excess of 200 µg/l have occurred in the Board's distribution system. Although these values exceed the German and USEPA recommended standards no TTHM values have been found to exceed the Canadian recommendations. No clear picture regarding the degree of TTHM removal through a conventional water treat= ment system has as yet been established from preliminary studies done by the Board.

Work on the feasibility of using a granular activated carbon (GAC) in the Rand Water Board treatment process is presently being investigated. Preliminary laboratory scale work indicates that Trihalomethane formation potential (THM-FP) removal efficiencies varying from 40% to 80% could be achieved. Trihalomethane formation potentials were determined after a four hour contact time and a 3mg/l initial chlorine dosage. Determi= nations were done after 5, 10, 15 and 20 minutes contat times based on empty volume. The research into GAC treatment done so far points to a GAC contact time of 10 minutes being sufficient to obtain the 100 µg/l TTHM standard recommended by the USEPA. Research in Holland however has indicated an optimum retention time of 30 minutes for the most economic filter run, in view of the high cost of the GAC material.

The Additional (1980) Water Supply Scheme being implemented by the Rand Water Board will increase the total quantity of water treated by the Board to approximately 3 500 Ml/day of which the Board will abstract 1 100 Ml/day from the Barrage. The quality of the Barrage water is much poorer from the point of view of organic constituents than that of the Vaal Dam and it is this water in particular that would need more advanced treatment such as GAC if the set standards THM's as indicated by the USEPA are to be maintained.

Based on a 1 100 Ml/day plant with GAC contact time of 12 minutes, using the construction design criteria of the 50 Ml/day GAC plant at Secunda (which is similar to the plant at Dusseldörf, Germany) the following costs are calculated:

1. Capital Cost

Cost of a GAC treatment plant capable of treating 1 100 Ml/day (12 minutes contact time)	R45 000 000

2. Running costs per annum

2.1	GAC losses due to regeneration	R 2 042 000
2.2	Pumping costs - passage through filters	R 500 000
2.3	Energy costs - regeneration	R 750 000
		R 3 292 000

The above excluded manpower additional to that required to operate conventional plant

3. Estimated annual costs to the consumer

3.1	Running costs	R 3 292 000
3.2	Interest calculated at 12,65%	R 5 693 000
3.3	Capital redemption calculated at 9,25% on the invested capital	R 855 000
		R 9 840 000

4. Increase in price of water to the consumer

4.1	Based on production of 2 100 Ml/day of which 1 100 Ml/day is treated by GAC at 12 minutes contact time	1,284c/kl
4.2	As above but 30 minutes contact time	2,571c/kl

Not included in the above costs are the following important aspects which need consideration.

1. According to preliminary work done by the Board's laboratory, the chlorine additional required after GAC treatment may be considerably less than the present requirement. Based on a saving of lmg/l for 1 100 Ml/day a total saving of R237 000 per annum may be realised

2. Pre-oxidation which is practised almost without exception by other water treatment authorities using GAC has not been considered in the above estimate. Pre-oxidation, apart from other quality improvements it may produce in the final water, will increase the GAC life between regnerations thus reducing the running costs of the GAC plant. The capital outlay and the running costs of the pre-oxidation plant for 1 100 Ml/day may be high as 0,3c/kl if spread over a total production of 2 100 Ml/day.

The possible effect of lime incrustation on the GAC, which may require costly process variations, is a very important aspect which may be a prime factor in deciding on the feasibility of GAC treatment. No cost estimates can be coupled to this possibility at this stage.

CONCLUSIONS AND RECOMMENDATIONS

1. In view of the above, it is recognised that additional treatment beyond the conventional methods will have to be applied.
2. Activated carbon with all its advantages and disadvantages has been extensively studied by various organizations throughout the world. Unfortunately there seems to be no clear-cut demonstration as to what can be achieved, how to apply GAC in the most efficient manner, quality to be used, regeneration cycles etc. These factors depend largely on the particular water to be treated.
3. In view of the high costs involved, any water authority will be unwise to move into the field of activated carbon treatment before thoroughly investigating all possible solutions.
4. In view of all these factors the Board will continue to investigate additional purification processes and GAC and powder activated carbon will be considered as possible solutions to be investigated.

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