The Dissolved Mineral Composition of the Water flowing into and out of the Hartbeespoort Dam

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Abstract

A two year analytical survey was conducted of the waters flowing into and out of the Hartbeespoort Dam. The Crocodile River was the main source of water and chemical input to the dam, contributing from 88 to 99 per cent of the dissolved mineral input. The concentrations of dissolved minerals in the inflowing waters were highest during the winter dry weather flow and lowest during the summer rainfall period. The mineral content of waters from the outflow of the dam was not subject to the same variation. Considerable quantities of dissolves nitrogenous and phosphate compounds disappear from the water in the dam either through biological or chemical conversions.

Introduction

The Hartbeespoort Dam has been subjected to heavy loads of industrial and treated sewage effluents (Allanson and Gieskes, 1961). As a result of this, radical changes in both the chemical and biological characteristics of the impoundment have been experienced and the waters have changed from an original condition of oligotrophy to one of extreme eutrophy (Hutchinson, Pickford and Schuurman, 1932; Allanson and Gieskes, 1961: Botha, 1968) At present, the impoundment serves as an irrigation and potable water supply and is one of the major recreational centres in the Transvaal. The eutrophied condition of the waters has caused concern in recent years because of problems caused by excessive growths of the toxic alga *Microcystis aeruginosa* Komarek and the water hyacinth *Eichhornia crassipes* (Solms) Mart. (Adler, 1974). Furthermore, the concentrations of specific mineral constituents in the water may reach levels which are detrimental to the irrigation schemes situated below the impoundment (Fuls, 1975). Wittman and Förstner (1975) have also shown that there is considerable heavy metal enrichment of the sediments in this impoundment.

Since trends in water quality have implications for the management of impoundments, a two year survey of the chemical quality of the inflowing and outflowing waters of the Hartbeespoort Dam was undertaken between 1973 and 1974 and compared with earlier results.

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Methods and Materials

Locality and sampling procedures

The Hartbeespoort Dam is situated approximately 40 km west of Pretoria in the Brits magisterial district (25° 34' S; 27° 51' E). The dam is fed by two river systems, the Magalies-Skeerpoort system which drains a predominantly agricultural basin to the west and the Jukskei-Crocodile-Hennops system which drains urban and industrial areas of Johannesburg to the south of the dam. The Leeuspruit, a small stream also to the south of the dam drains a small agricultural area and water flow is small by comparison with that of the other two systems.

The sampling locations are schematically presented in Figure 1. Samples of the inflowing waters were obtained from accessible points on the Magalies River, the Leeuspruit and the Crocodile River whilst the outflow from the dam was sampled at the irrigation canal directly below the dam wall. Samples were taken at 14-day intervals during the period February 1973 to January 1974 whilst the following year (until January 1975) samples were taken at monthly intervals. Water samples were transported in polyethylene bottles to the laboratory where they were stored at 2°C overnight.

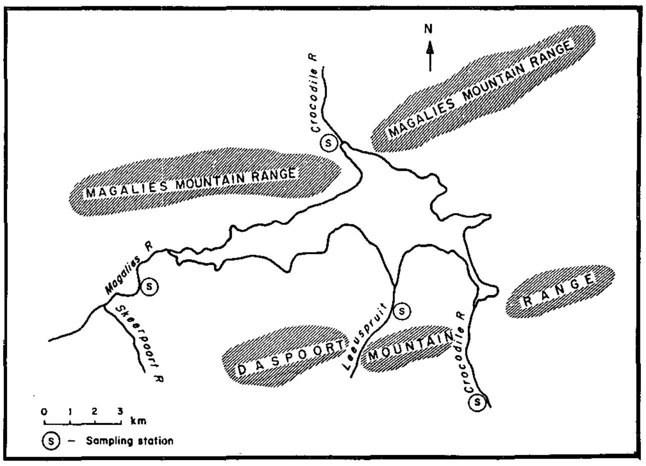

Figure 1
Hartbeespoort Dam showing sampling stations

Chemical analysis

Samples were filtered (Sartorius glass fibre filter) and analysed for sodium, potassium, calcium, magnesium, sulphate, chloride, ammonia, nitrite, nitrate, Kjeldahl nitrogen, orthophosphate, total dissolved phosphate, chemical oxygen demand (COD), dissolved silicon (as Si), alkalinity (as $CaCO_3$) and conductivity. All analyses were conducted by the Division of Water Quality of the National Institute for Water Research, mostly using automated techniques (National Institute for Water Research, 1974).

Dissolved mineral loading

The dissolved mineral loads were calculated by the following method:

$$L_{Cn} = \frac{F_1C_{n1} + F_2C_{n2} + \ldots F_rC_{nr}}{1 \times 10^9}$$

L_{Cn} = load in t a^{-1} of chemical n

F = total flow in ℓ since previous sampling period

C_n = concentration of chemical n in mg/ℓ

1, 2, ... r = number of sampling period in year

The loads were calculated for the Crocodile and Magalies Rivers and for the outflow from the dam. The contribution of the Leeuspruit was ignored since this stream contributed little to the total inflow and also because its flow was not measured.

Results

The results obtained for the different determinations conducted over the study period are presented in Figs. 2 to 16. With the exception of alkalinity, magnesium and dissolved silica (Fig. 3, 7 and 10), values for parameters in the waters of the Crocodile River were usually higher than those of the waters of the Magalies Rivier and the Leeuspruit. The waters of the Crocodile River therefore contained larger quantities of dissolved minerals. The outflow waters of the dam displayed characteristics which were intermediate between those of the Crocodile River on the one hand and the Leeuspruit and the Magalies River on the other. In this regard, the Leeuspruit and the Magalies River displayed similar characteristics, indicating that both these systems drained catchments of a rather similar nature.

Conductivity values of waters from the Crocodile River varied between 39 and 98 mS m^{-1} and showed considerable fluctuation (Fig. 2). The waters appeared to contain higher concentrations of dissolved minerals during periods of low water flow by comparison with periods of high water flow (Fig. 17). The Magalies River and the Leeuspruit also showed similar seasonal trends, however conductivity values were lower (16 to 58 mS m^{-1}). By comparison, the outflowing waters of the dam were not subject to the same variation and the conductivity ranged between 40 and 66 mS m^{-1}.

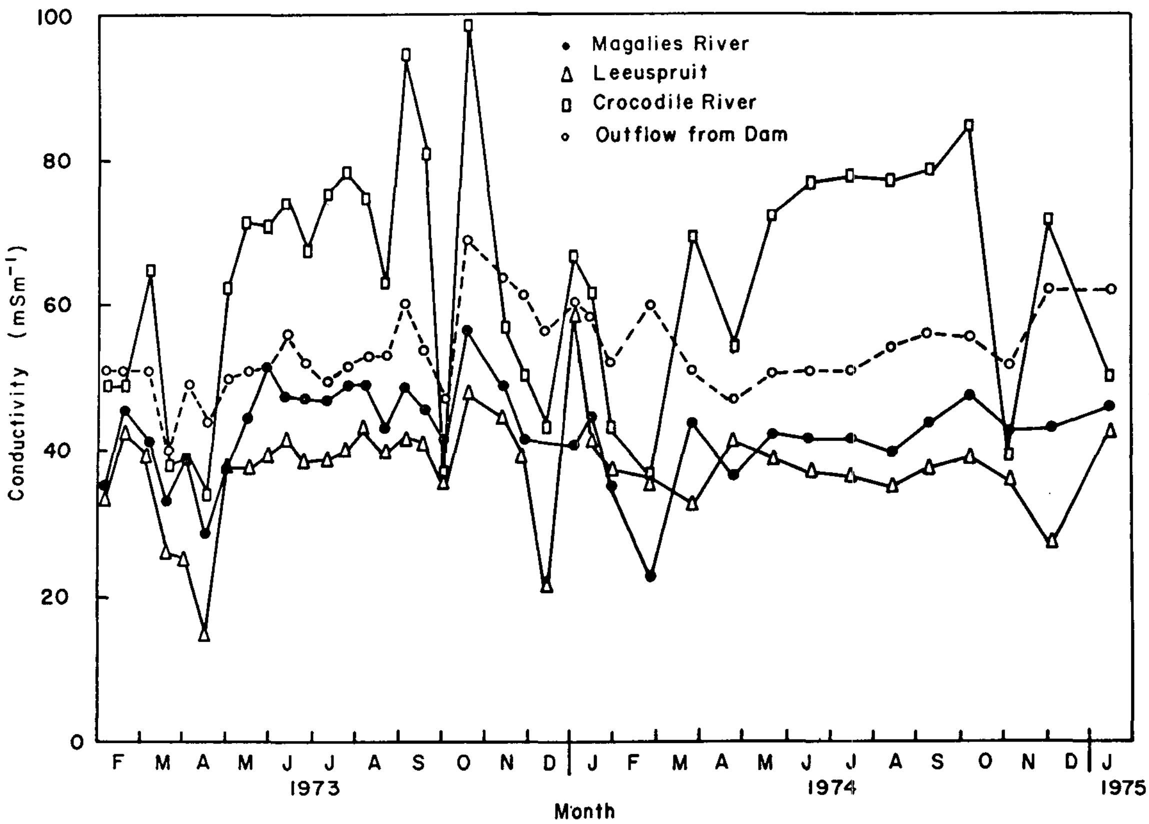

Figure 2
A comparison of the conductivity values of the inflows and the outflow of Hartbeespoort Dam.

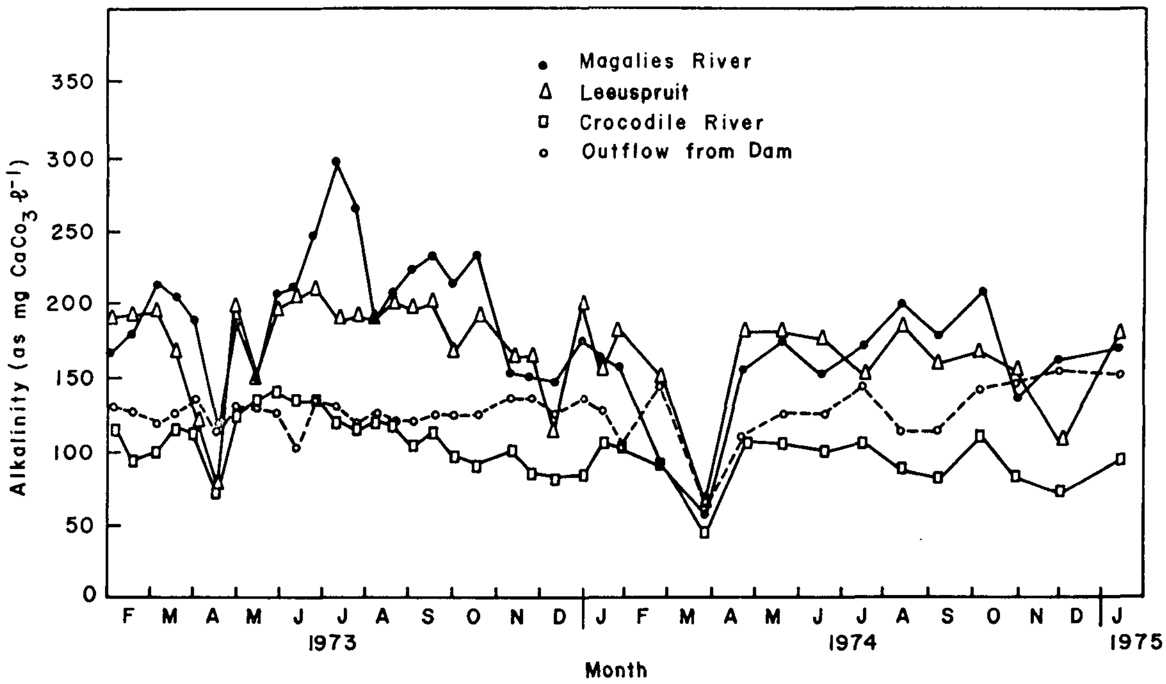

Figure 3
A comparison of the alkalinity of the inflows and outflow of Hartbeespoort Dam

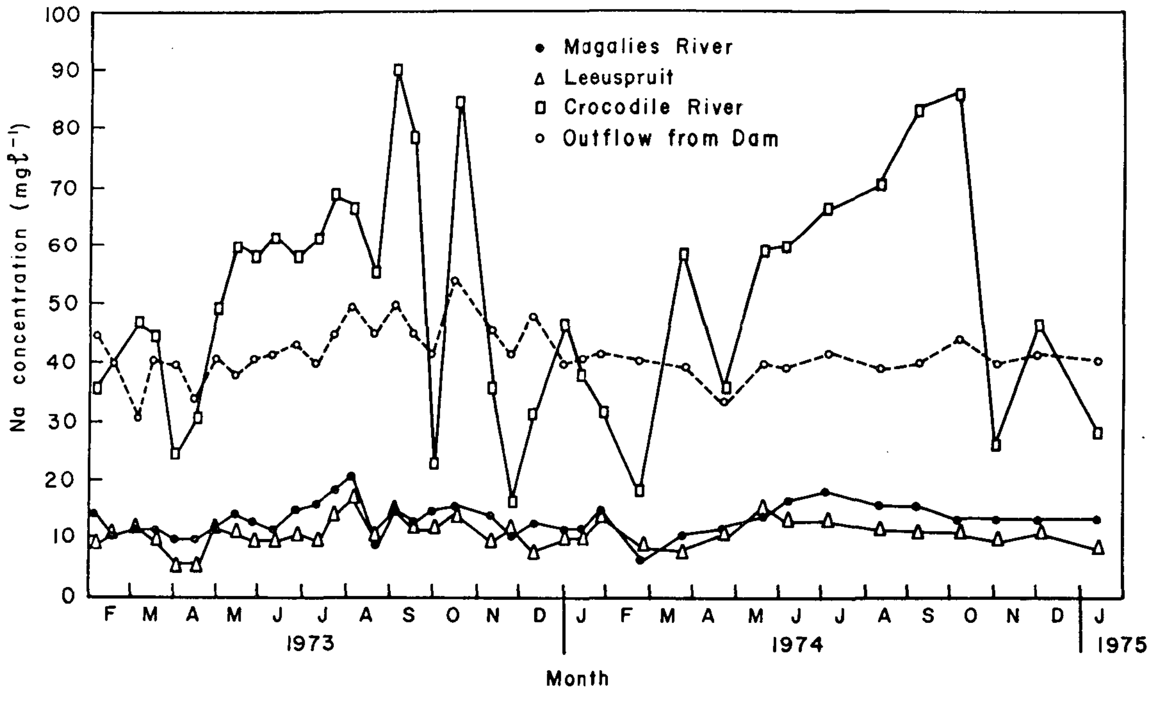

Figure 4
A comparison of the sodium concentrations of the inflows and outflow of Hartbeespoort Dam

The alkalinity of the waters from the Magalies River and the Leeuspruit was consistently higher than that of the Crocodile River and the outflow from the dam (Fig. 3). When the values for the cations (Na, K, Ca and Mg) are compared (Fig. 4, 5, 6 and 7 respectively) it is evident that the concentrations of magnesium in the waters from the Magalies River and the Leeuspruit (9 to 35 mg ℓ^{-1}) were consistently higher than in the Crocodile River (10,5 to 32 mg ℓ^{-1}). These higher magnesium concentrations were probably the reason for the higher alkalinity values of the Magalies River and the Leeuspruit. On the basis of the cationic content, all the waters flowing into the Hartbeespoort Dam may be classified as hard because of the relatively high concentrations of the alkaline earth metals calcium and magnesium.

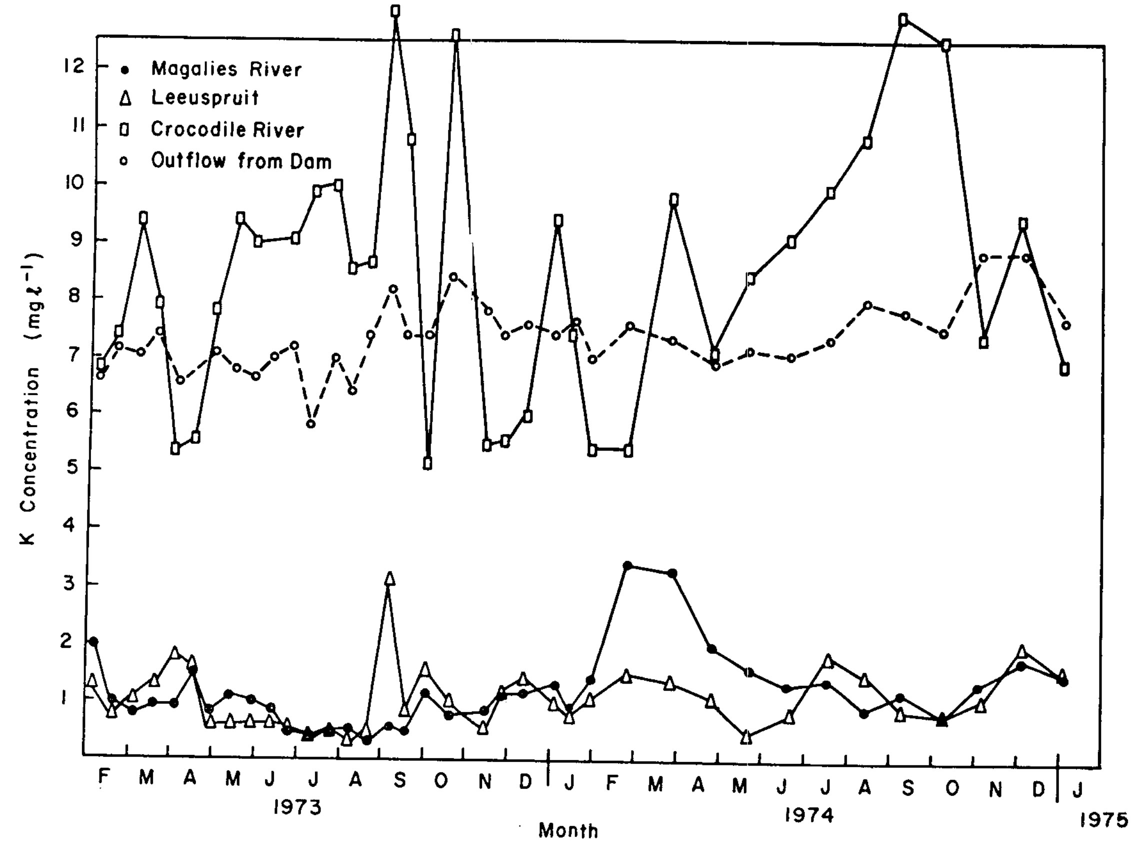

Figure 5
A comparison of the potassium concentrations of the inflows and outflow of Hartbeespoort Dam

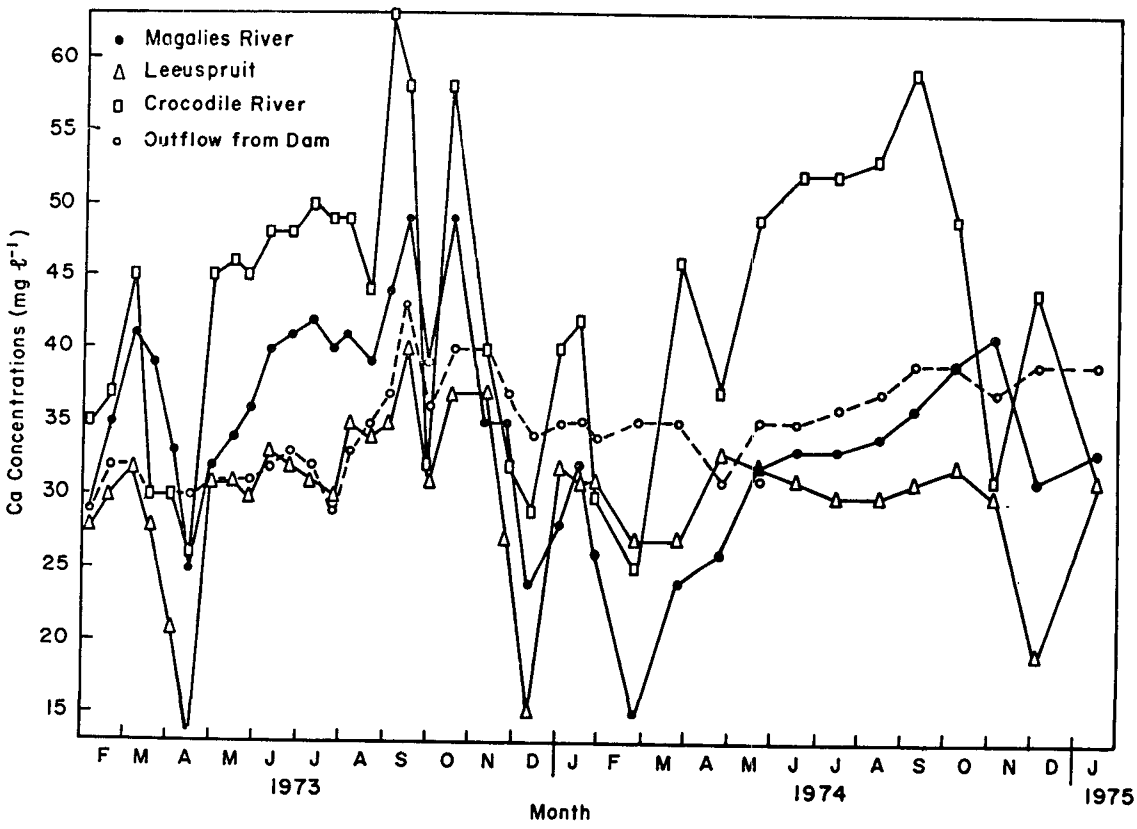

Figure 6
A comparison of the calcium concentrations of the inflows and outflow of Hartbeespoort Dam

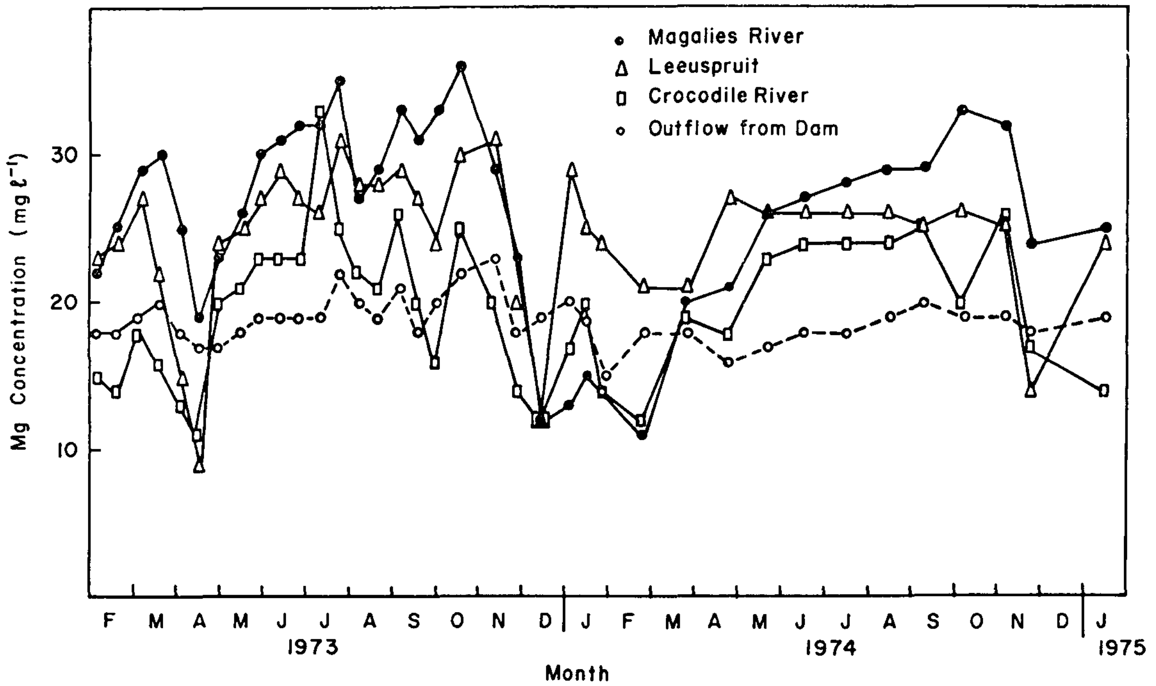

Figure 7
A comparison of the magnesium concentrations of the inflows and outflow of Hartbeespoort Dam

The chloride concentrations of the Crocodile River (20 to 110 mg ℓ^{-1}) and the outflow from the dam (32 to 60 mg ℓ^{-1}) were extremely high by comparison with those of the Magalies River (<16 mg ℓ^{-1}) and the Leeuspruit (<10 mg ℓ^{-1}) (Fig. 8). The same situation prevailed for sulphate (Fig. 9) where concentrations in the Crocodile River (30 to 110 mg ℓ^{-1}) and the outflow (45 to 78 mg ℓ^{-1}) were also higher than those of the Magalies River (4 to 36 mg ℓ^{-1}) and the Leeuspruit (2 to 12 mg ℓ^{-1}). Conversely dissolved silica concentrations of the Magalies River (6,5 to 17 mg ℓ^{-1}) and the Leeuspruit (7,5 to 18 mg ℓ^{-1}) were always higher than those of the Crocodile River (4 to 10 mg ℓ^{-1}) and the outflow (1,0 to 7,0 mg ℓ^{-1}; Fig. 10). The concentrations of dissolved silica in the outflow waters were usually lower than those of the inflowing waters and this may be attributed to either uptake by diatom growth in the impoundment or chemical precipitation of silica.

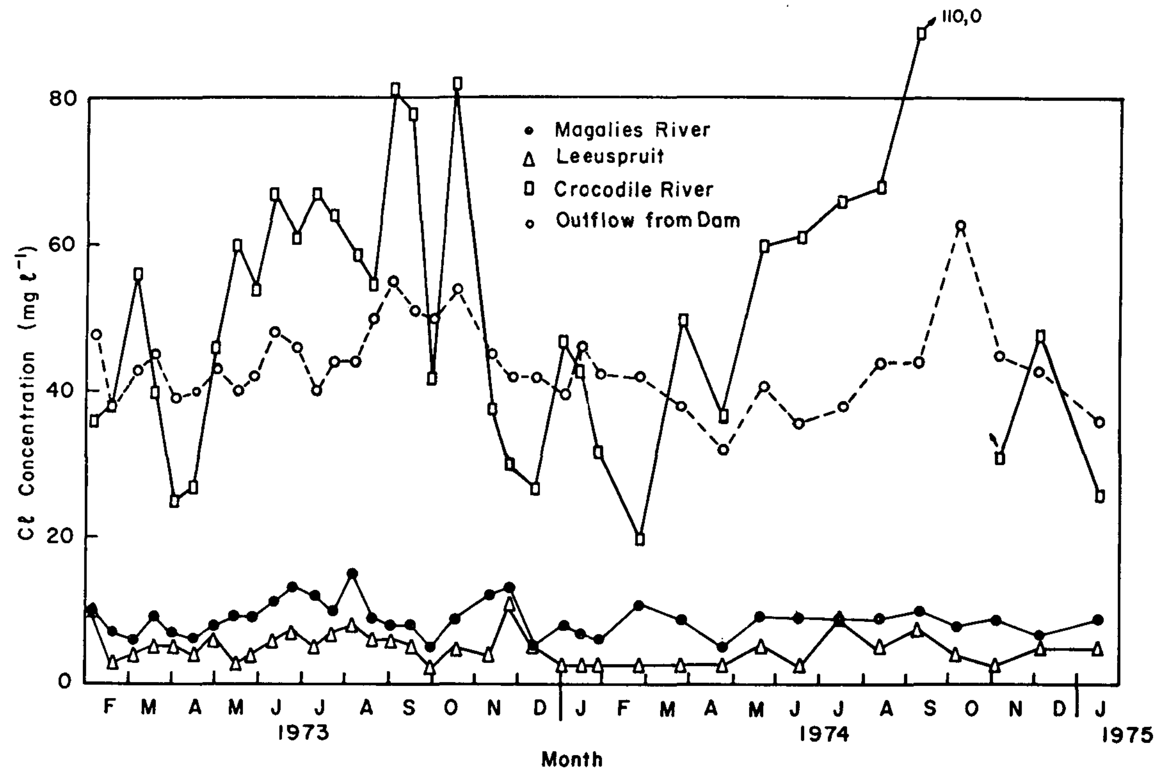

Figure 8
A comparison of the chloride concentrations of the inflows and outflow of Hartbeespoort Dam

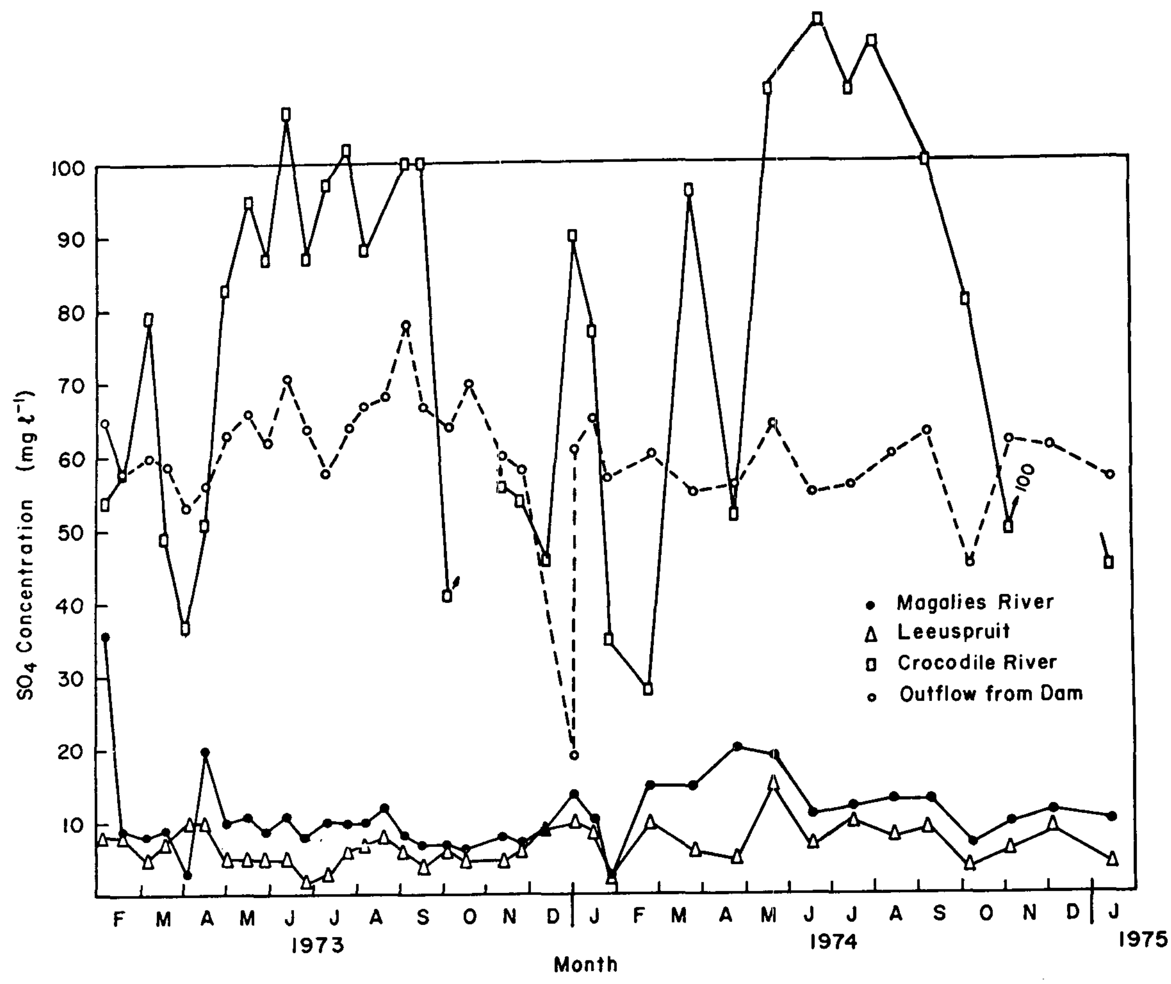

Figure 9
A comparison of the sulphate concentrations of the inflows and outflow of Hartbeespoort Dam

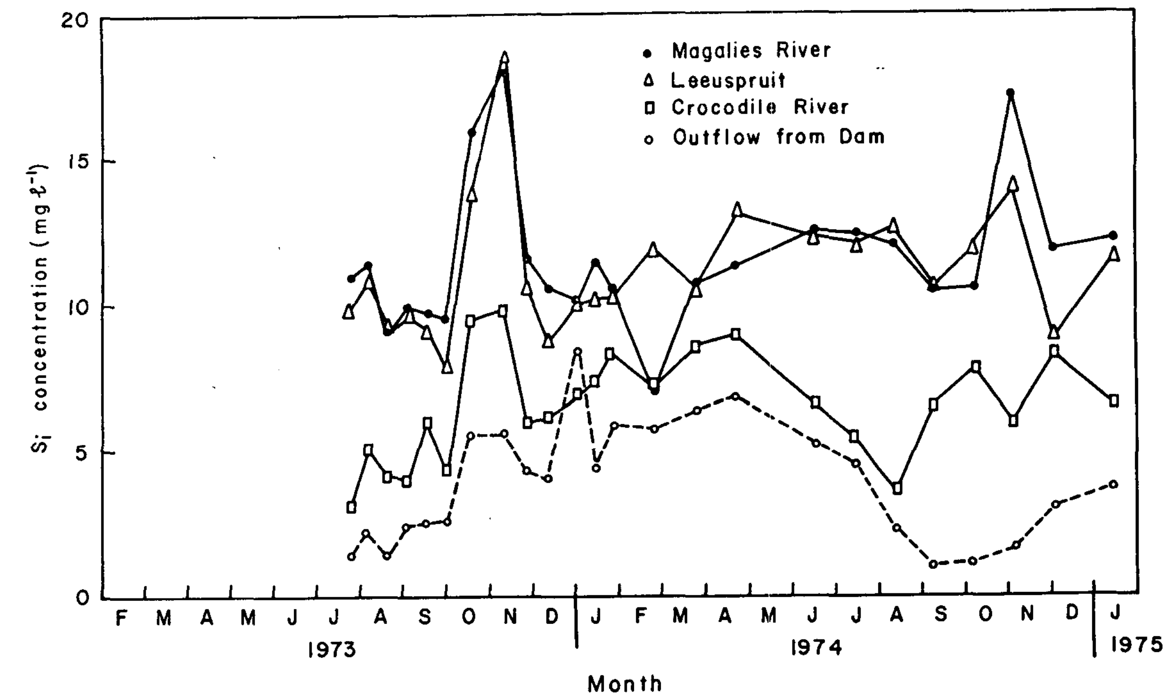

Figure 10
A comparison of the silica concentrations of the inflows and outflow of Hartbeespoort Dam

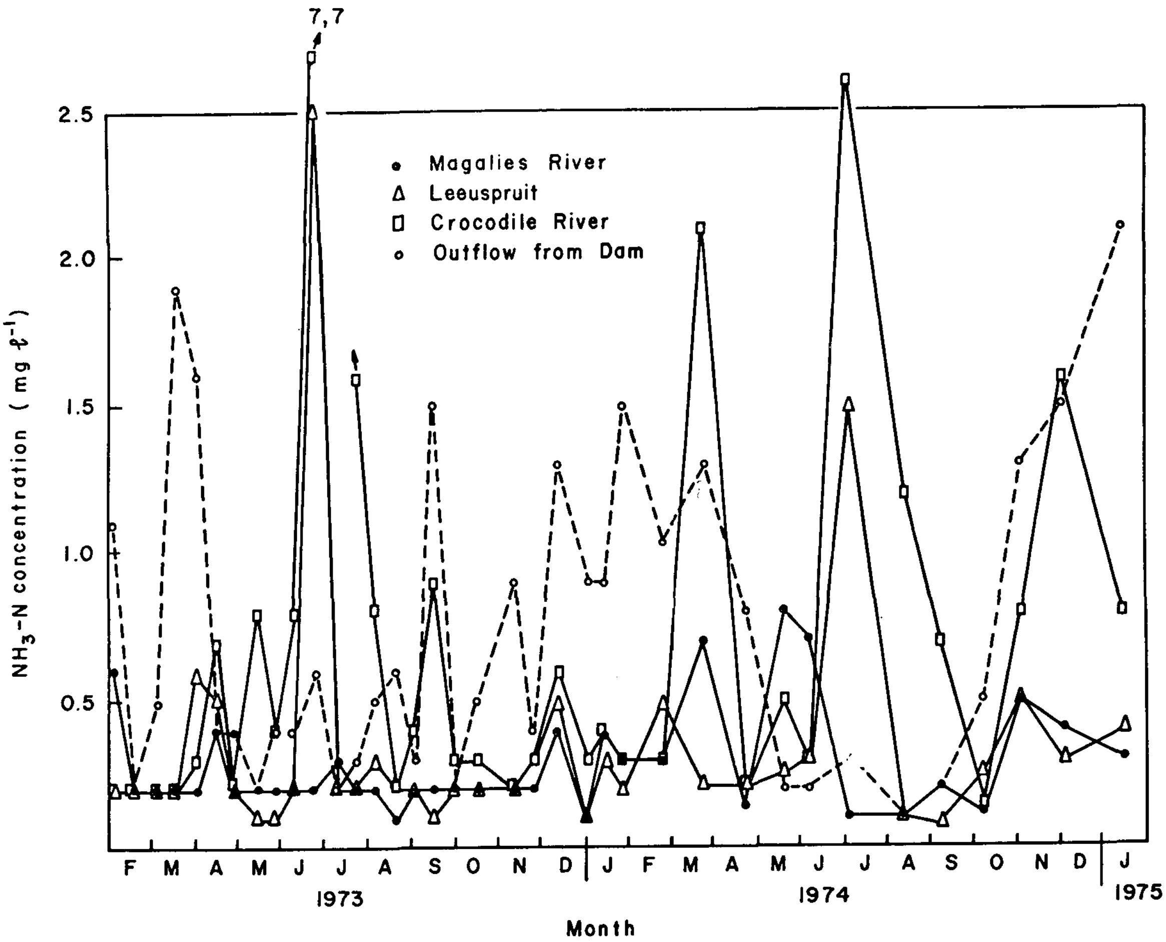

Figure 11
A comparison of the ammonia nitrogen concentrations of the inflows and outflow of Hartbeespoort Dam

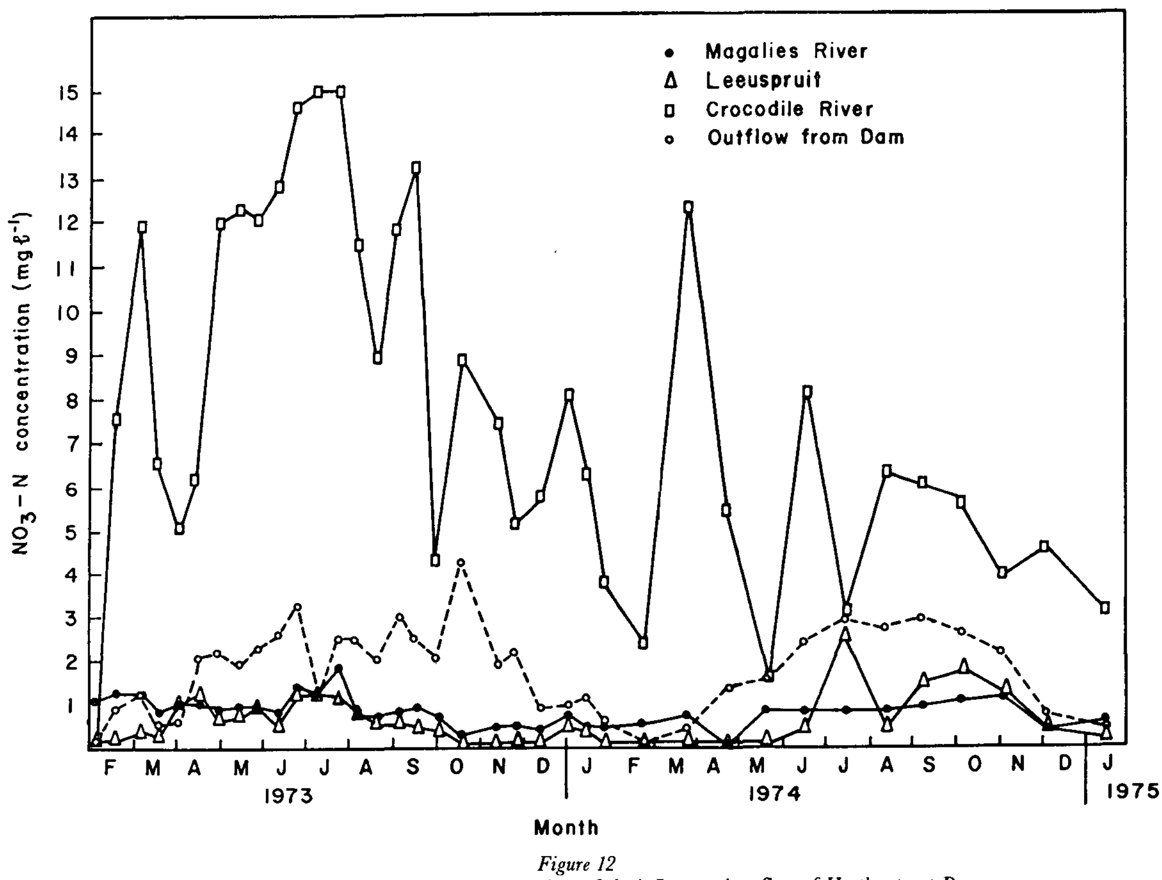

Figure 12
A comparison of the nitrate nitrogen concentrations of the inflows and outflow of Hartbeespoort Dam

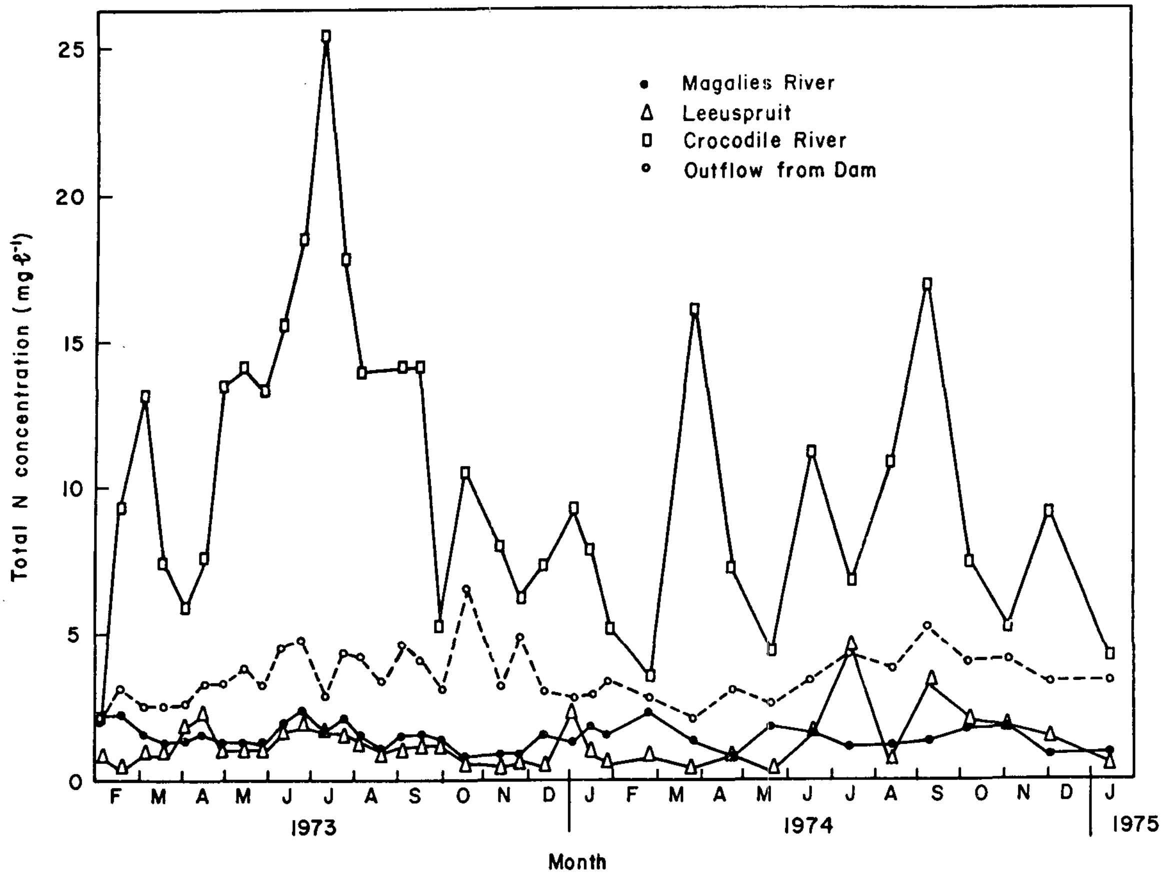

Figure 13
A comparison of the total dissolved nitrogen concentrations of the inflows and outflow of Hartbeespoort Dam

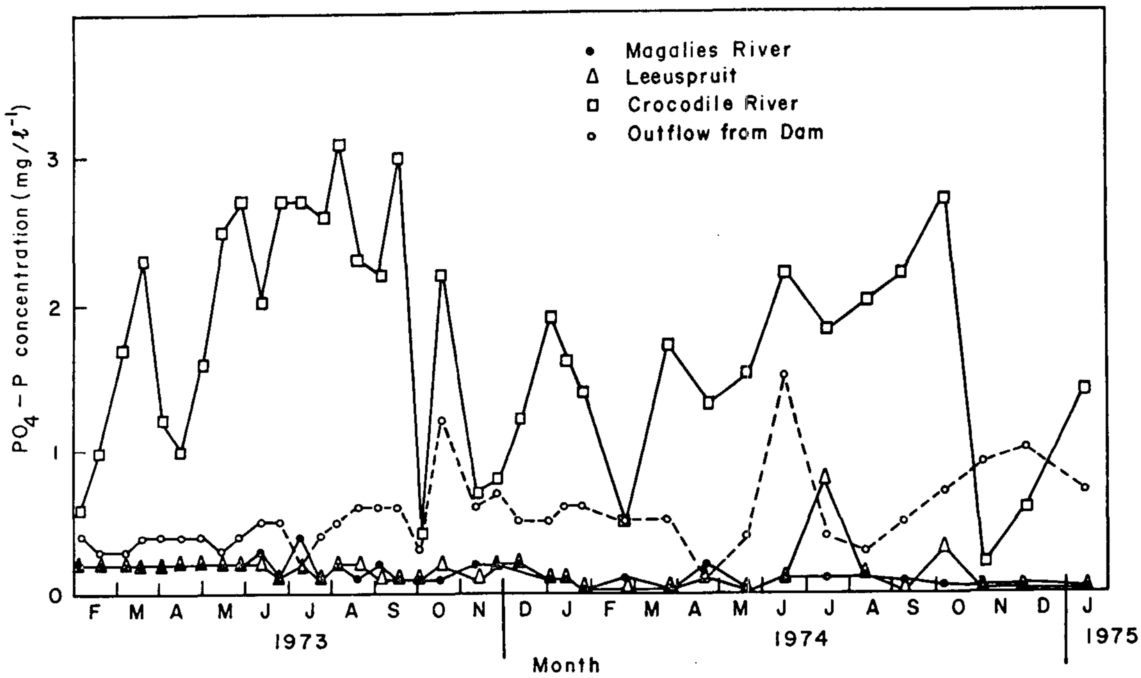

Figure 14
A comparison of the orthophosphate phosphorus concentrations of the inflows and outflow of Hartbeespoort Dam

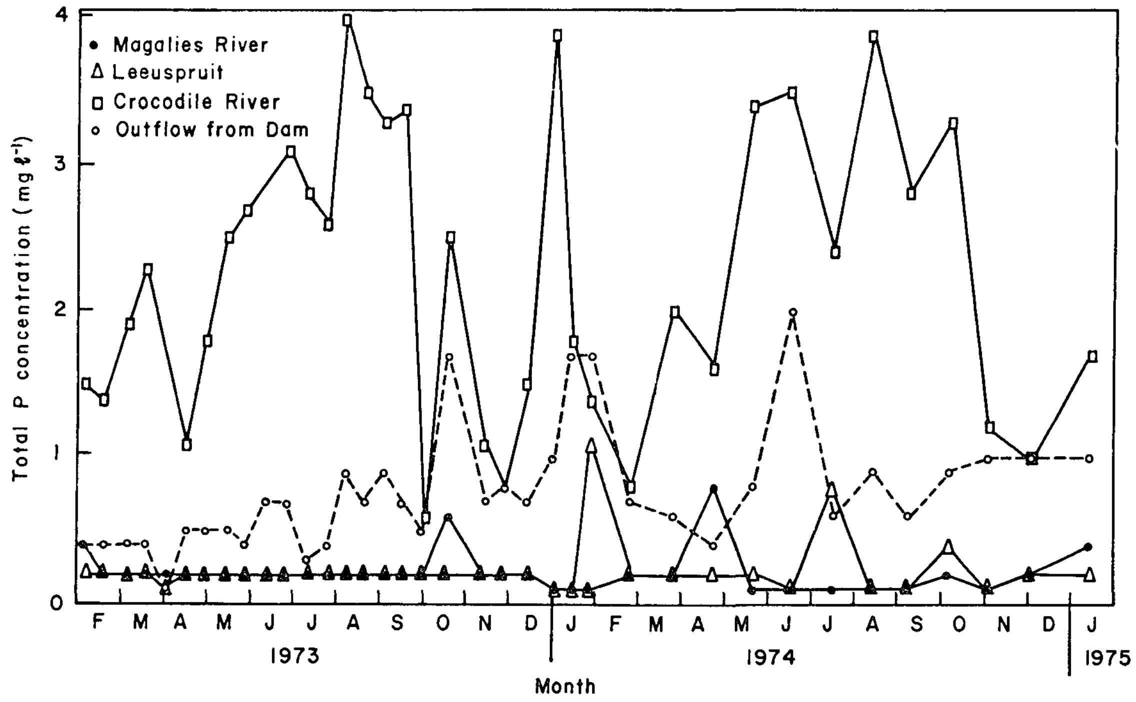

Figure 15
A comparison of the total dissolved phosphorus concentrations of the inflow and outflow of Hartbeespoort Dam

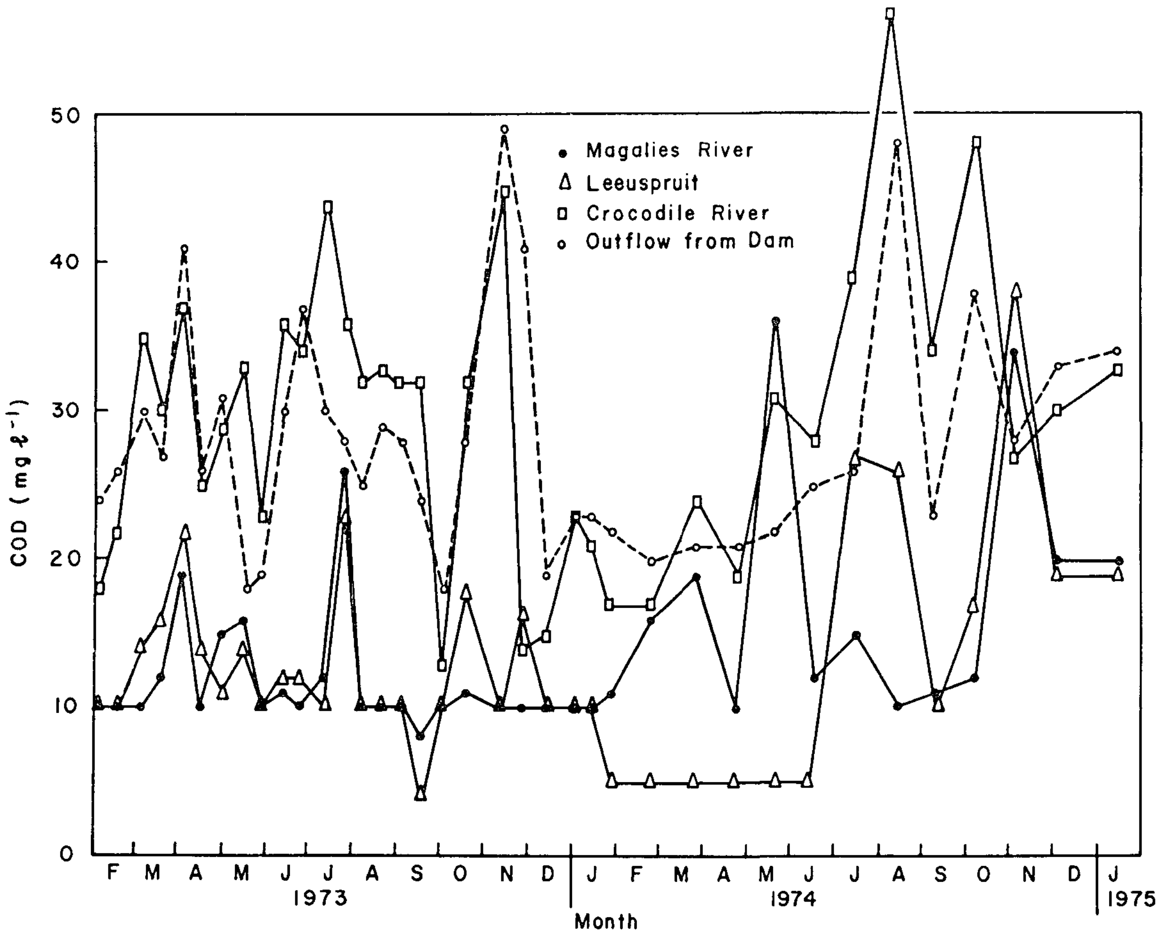

Figure 16
A comparison of the chemical oxygen demand (COD) values of the inflows and outflow of Hartbeespoort Dam

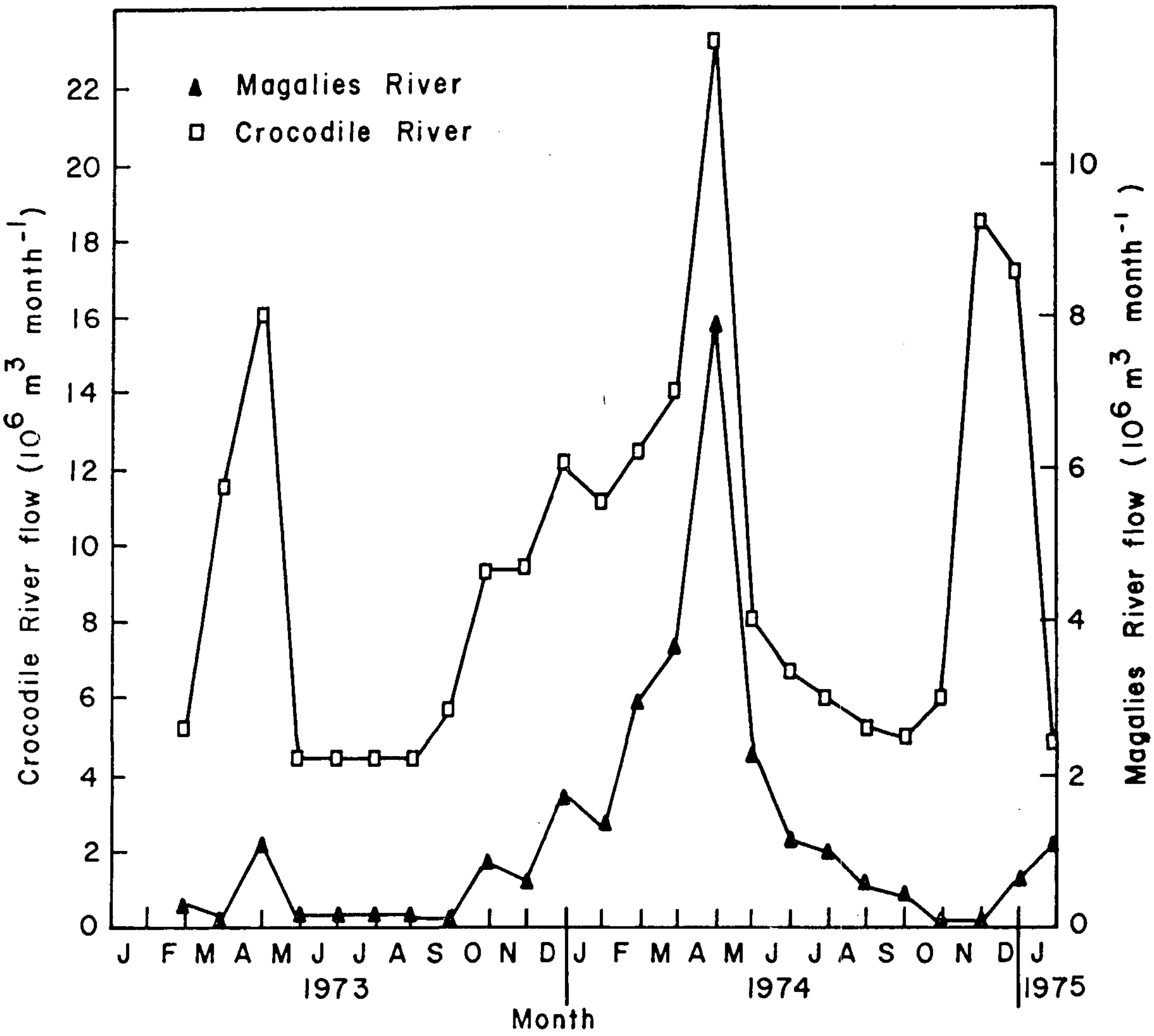

Figure 17
The total monthly flows of the Magalies and Crocodile Rivers during the study period.

The concentrations of ammonia, nitrate and total dissolved nitrogen (NO_2-N + NO_3-N + Kj-N) in the Crocodile River were usually higher than those in the dam outflow, the Magalies River and the Leeuspruit (Fig. 11, 12 and 13). The large variation which was encountered may be attributed to the seasonal nature of the water flow, since higher concentrations were recorded during the dry months when water flow was low (Fig. 17). In the Crocodile River, the highest concentration values of these nitrogen forms were 7,7 mg ℓ^{-1} for NH_3-N, 15,0 mg ℓ^{-1} for NO_3-N and 25,2 mg ℓ^{-1} for total dissolved nitrogen. These concentrations in the outflow of the dam showed a distinct seasonal trend related to the stratification pattern of the reservoir. During summer stratification, ammonia concentrations were much higher than in winter because of the fact that during summer these waters were discharged from the anaerobic zone of the reservoir (as deduced from the stratification patterns for the dam given by Scott, Seaman, Connell, Kohlmeyer and Toerien (1977)). Ammonia concentrations exceeding 1,5 mg ℓ^{-1} were recorded in these waters. On the other hand, nitrate concentrations of the outflow followed a different trend with higher concentrations being recorded in the winter months when there was little stratification in the reservoir (Scott *et al.*, 1977).

Orthophosphate and total dissolved phosphate also followed a distinct pattern with the highest concentrations being found in the Crocodile River during the months of low river flow (Fig. 14 and 15). The mean ortho-phosphate phosphorus and total dissolved phosphate phosphorus concentrations determined in the Crocodile River were 1,7 mg ℓ^{-1} and 2,3 mg ℓ^{-1} respectively. By comparison, concentrations of total dissolved phosphate phosphorus in the Magalies River and the Leeuspruit rarely exceeded 0,2 mg ℓ^{-1}.

COD values of the Crocodile River (mean concentration 29 mg ℓ^{-1}) and the outflow (mean concentration 28 mg ℓ^{-1}) of the dam were higher than those of the Magalies River (mean concentration 13 mg ℓ^{-1}) and the Leeuspruit (mean concentration 13 mg ℓ^{-1}, Fig. 16). These higher COD values are probably a reflection of the effects of sewage effluents which are discharged into the Crocodile River and the high productivity within the impoundment.

Mineral loads

The annual loads of dissolved minerals which entered and left the impoundment along with the annual water inflow/outflow are summarised in Table 1. The dam received a higher water input in the second year of the study (approximately 2,5 times greater than the first year). Variations in the water input and output and the volume of water in the impoundment make it difficult to assess whether a specific chemical was removed from the soluble state in the impoundment (either through biological activity or chemical precipitation). Therefore, in terms of input the normalized change [(total input – total output)/total input] of the different chemical parameters was compared with that of the water input (Table 1). If the normalized per cent change [(total input-total output)/(total input) × 100] of a mineral greatly exceeded that of the water input then that mineral was probably removed from the soluble state by biological or chemical means (allowing for negligible evaporation).

For the two years of the study, only nitrogen (65,1% and 58,3%) and phosphorus (58,8% and 61,3%) were removed from the soluble state. Since dissolved silica analyses were only started in July 1973, this element was not included in these calculations. Analyses, however, suggest that the concentration of this constituent was affected considerably in the impoundment, either through diatom activity or chemical precipitation (Fig. 10).

TABLE 1

DISSOLVED MINERAL LOADS WHICH ENTERED AND LEFT THE HARTBEESPOORT DAM DURING THE STUDY PERIOD

	February 1973 – January 1974					February 1974 – January 1975				
Parameter	Crocodile River $t\,a^{-1}$	Magalies River $t\,a^{-1}$	Total input $t\,a^{-1}$	Total output $t\,a^{-1}$	*% annual change	Crocodile River $t\,a^{-1}$	Magalies River $t\,a^{-1}$	Total input $t\,a^{-1}$	Total output $t\,a^{-1}$	*% annual change
Na	3 987	75	4 062	4 625	−13,9	8 342	362	8 704	6 729	+22,77
K	702	7	709	758	−6,9	1 687	59	1 746	1 271	+27,2
Ca	3 553	180	3 733	3 624	+2,9	7 978	835	8 813	6 232	+29,3
Mg	1 615	138	1 753	2 049	−16,9	3 501	664	4 165	3 090	+25,8
SO_4	6 367	70	6 437	6 759	−5,0	14 382	435	14 817	9 499	+35,9
Cl	4 058	47	4 105	4 797	−16,9	8 361	230	8 591	6 756	+21,3
Total P	176	1	177	73	+58,8	391	10	401	155	+61,3
Total N	893	9	902	396	+56,1	1 416	36	1 452	606	+58,3
Water input ($10^6\,m^3$)	93,36	5,98	99,34	105,75	−6,5	219,655	29,186	248,84	165,469	+33,5

Water in dam beginning February 1973, 115 829 × $10^6\,m^3$
Water in dam beginning February 1973, 109 389 × $10^6\,m^3$
Water in dam beginning February 1975, 192 770 × $10^6\,m^3$

$$*\frac{\text{Total input} - \text{Total output}}{\text{total input}} \times 100$$

The contributions of the Crocodile and the Magalies Rivers to the dissolved mineral loading are summarized in Table 2. In the first year of study, the Crocodile River contributed over 92 per cent of the inputs of individual ions, and notably more than 99 per cent of the total dissolved combined nitrogen and total dissolved phosphate. In the second year of study, the Crocodile River contributed over 84 per cent of the dissolved mineral input and more than 97 per cent of the total dissolved combined nitrogen and total dissolved phosphate. The Magalies River appeared to be important only in the second year of study, when the magnesium input to the total was 15,9 per cent. Otherwise, this system played a minor role in the nutrient and mineral loading of the Hartbeespoort Dam.

TABLE 2

CONTRIBUTIONS (PERCENTAGE) OF THE CROCODILE AND MAGALIES RIVERS TO THE TOTAL LOADS ENTERING HARTBEESPOORT DAM

Parameter	February 1973 – January 1974		February 1974 – January 1975	
	Crocodile River	Magalies River	Crocodile River	Magalies River
Na	98,2	1,8	95,8	4,2
K	99,0	1,0	96,6	3,4
Ca	95,2	4,8	91,5	9,5
Mg	92,1	7,9	84,1	15,9
SO_4	98,9	1,1	97,1	2,9
Cl	98,9	1,1	97,3	2,7
Total P	99,4	0,6	97,5	2,5
Total N	99,0	1,0	97,5	2,5
Water flow	94,0	6,0	88,3	11,7

Discussion

Water quality

A comparison of the water quality trends of the Crocodile River above Hartbeespoort Dam is difficult because of the extreme variation in the annual run-off of the river. For example the average annual flow of the river at the Department of Water Affairs measuring weir A2M12 for the period 1922 to 1960 (Department of Water Affairs, 1964) was $84,3 \times 10^6$ m^3 with a coefficient of variation of 61 per cent. Therefore a straight comparison of the chemical concentrations encountered during different study periods could be extremely misleading. To overcome this problem we approximated the chemical loads of each study period using the product of the mean chemical concentration and the annual run off figure. A comparison of these mean chemical concentrations and approximate loads for different studies are presented in Table 3.

TABLE 3

A COMPARISON OF THE CHEMICAL COMPOSITION AND APPROXIMATE LOADS (IN PARENTHESES) OF THE CROCODILE RIVER ABOVE HARTBEESPOORT DAM FOR THE PERIOD 1955 TO 1975

Parameter	mg ℓ^{-1} and (t a^{-1})			
	1955-57[a]	1964-65[b]	1965-66[c]	1973-75[d]
NH_3-N	3,9	1,1	N.D.	1,0
	(470)	(50)	N.D.	(180)
NO_3-N	10,9	9,5	N.D.	7,5
	(1300)	(450)	N.D.	(1050)
Total	15,0	10,5	15,5	11,0
dissolved N	(1790)	(500)	(460)	(1650)
PO_4-P	N.D.	1,5	1,7	1,7
	N.D.	(70)	(50)	(240)
Conductivity				
(mS m^{-1})	46,8	N.D.	N.D.	64,3
Na	N.D.	47	55	52
	N.D.	(2230)	(1620)	(8090)
Cl	39	39	N.D.	53
	(4660)	(1850)	N.D.	(8310)
SO_4	76	N.D.	N.D.	85
	(9080)	N.D.	N.D.	(13700)

a = Allanson (1961)
b = NIWR study
c = Botha (1968)
d = The present study
ND = not determined

Since 1955 the mineral compositon of the Crocodile River has changed as reflected by an increase in conductivity and the annual loadings of sodium, chloride and sulphate. There appeared to be a decrease in the chloride load between 1957 and 1964, but thereafter it increased again. The loads of total dissolved combined nitrogen were similar between 1955 and 1957 and between 1973 and 1975, but were appreciably less between 1964 and 1966. The ortho-phosphate phosphorus load increased from between 50 to 70 tons during 1964 to 1966 to about 240 tons in 1973 to 1975. In general it appears that the chemical quality of the Crocodile River improved during the period 1957 to1964 but since then it has gradually deteriorated.

The improvement in the chemical compositon during the period 1957 to 1964 was probably due to the adoption of a new wastewater disposal system at the Modderfontein AE&CI factory (e.g. Lever, 1966; Lever, Alexander, Buttery, Moffat and Henzen, 1970) whereby a strong effluent rich in ammonia and nitrate was used for the irrigation of grassland instead of being discharged into the Crocodile River system. The change in the chemical composition after 1964 is probably due to the commissioning and expansion of the large Northern sewage works of the Municipality of Johannesburg which discharges directly to the Jukskei River, a main tributary of the Crocodile River.

The general water quality of the Crocodile River just above the Hartbeespoort Dam is still relatively good by comparison with the limits recommended by the South African Bureau of Standards (1971) for potable waters. The recommended limits for most inorganic constituents were rarely exceeded during the study period and the only parameter which exceeded these limits regularly appeared to be nitrate (Fig. 12). COD values represented analyses conducted on filtered samples so that it is not possible to compare these COD values with the limit laid down for effluents in terms of the Water Act of 1956 (75 mg ℓ^{-1}) which applies only for total COD. It is possible that on occasions total COD values of the Crocodile River water and the outflow of the dam might have exceeded this limit, particularly when the COD values of these filtered samples exceeded 40 mg ℓ^{-1} (Fig. 16).

Chemical loads at present

This present study has shown the relative importance of the Crocodile and Magalies Rivers as sources of dissolved minerals to the Hartbeespoort Dam (Table 2). The contribution from the Leeuspruit could not be evaluated because of the absence of flow data, however it appeared to be negligible. A question which may be considered however, is whether the load calculations may be erroneous because of the nature of sampling and the irregular occurrence of summer flood peaks. A comparison of the recorded concentrations of different chemicals in Hartbeespoort Dam with the expected values derived from the total chemical inputs divided by the total water inputs would in a system with a reasonably short water residence time (about one year or less) such as Hartbeespoort Dam, serve as a rough check on the validity of the load figures. Fair agreement was obtained between the calculated concentration values and those recorded for the same period by Seaman (1977) except for total dissolved nitrogenous compounds and total dissolved phosphate (Table 4). This is not surprising because of the non-conservative nature of these two constituents. It therefore appears that the calculated loads of minerals which entered the dam during this study were a fair reflection of the actual loads.

Man-made influences

The large differences in chemical quality between the waters of the Magalies and Crocodile Rivers are obviously a result of man-made influences in the catchment of the Crocodile River since the geology of the drainage basins of these two rivers is

TABLE 4

A COMPARISON OF THE POSSIBLE, MEASURED AND PROBABLE NATURAL CHEMICAL COMPOSITIONS OF HARTBEESPOORT DAM WATER

Parameter	CHEMICAL COMPOSITION (mg ℓ^{-1})					
	Possible[a]			Probable natural[c]		Man-made
	1st year	2nd year	Measured[b]	1st year	2nd year	difference[d]
Na	40,9	35,0	41,9	12,5	12,4	22 to 29
K	7,1	7,0	7,4	1,2	2,0	5 to 6
Ca	37,5	35,4	35,6	30,1	28,6	5 to 9
Mg	17,6	16,7	19,1	23,1	22,8	–5 to –6,5
SO_4	64,8	59,5	63,8	11,7	14,9	45 to 53
Cl	41,3	34,5	42,3	7,9	7,9	27 to 34
Total dissolved P	1,78	1,61	0,63	0,18	0,34	1,3 to 1,6
Total dissolved N	9,1	5,8	3,6	1,5	1,2	4 to 8

a Based on the total dissolved load/flow for the 1st and 2nd years of this study
b After Seaman (1977) for the period October 1972 to March 1975
c Based on the load/flow for the 1st and 2nd year results on Magalies River
d Difference between probable natural composition and measured values

very similar (except that Archean granites occur in the catchment of the Crocodile River). Thus without the influence of man, one could argue that the natural chemical composition of these two rivers should be fairly similar. If this argument is acceptable, then a comparison of the chemical composition of Hartbeespoort Dam water arising from the loading from natural waters (Magalies River) with that caused by the present loading (i.e. Crocodile River plus Magalies River) should provide some indication of the order of magnitude of these man-made influences. The estimates of the possible (Crocodile plus Magalies River annual loading/water flow) and probable natural (Magalies River annual loading/water flow) chemical compositions of Hartbeespooort Dam water during the two study years are presented in Table 4. These suggest that man-made influences have resulted in large increases in sulphate, chloride, and sodium, and moderate increases in potassium and calcium. The phosphate and nitrogen status of the waters has also been significantly increased.

The mineral content of Hartbeespoort Dam water is not yet at the level where normal use of this water would be impaired, but chloride has reached levels which might be detrimental to tobacco farming (Fuls, 1975). The man-made increase in chloride concentration (27 to 34 mg ℓ^{-1}) is almost certainly caused by the discharge of industrial and sewage effluents.

Future water quality trends

The development of the Crocodile River catchment for urban and industrial purposes is still continuing. For instance, a new sewage treatment plant was recently commissioned at Verwoerdburg (discharging to the Hennops River system) and one is planned in the vicinity of Roodepoort in the upper Crocodile River area. Further mineralization and eutrophication of the Crocodile River can therefore be expected unless new techniques for effluent handling are employed.

Since a major portion (more than 95 per cent) of the nitrogen and phosphate loads into the Hartbeespoort Dam is derived from a small portion (about 30 per cent) of the total inflow, i.e. the volume of effluents discharged in the catchment (Toerien and Walmsley, 1976; Osborn and Halliday, 1976), the question arises as to whether these effluents should be discharged into the dam at all. The present and future amounts and the quality of the effluents discharged in the catchment may cause a further deterioration of water in the dam. Since the water is earmarked mostly for irrigation purposes (Keyser, 1976), care must be taken that the quality of the discharged effluent is compatible with the needs for irrigation farming (Fuls, 1975). Consideration should also be given to other possible uses of these effluents. Were effluents not discharged into the tributaries of the dam, the chemical quality of the dam would certainly show an improvement.

Conclusion and Recommendations

1. The Crocodile River was the main source of flow and chemical input to the Hartbeespoort Dam, contributing from 88 to 99 per cent of the dissolved mineral inputs. The Magalies River was a significant source of magnesium only.
2. The concentrations of dissolved minerals in the rivers, but particularly the Crocodile River, were highest during the dry winter and spring months and lowest during the wet summer and autumn months. The outflow from the dam was not subject to the same variation in mineral concentrations.

3. None of the investigated elements, except nitrogen and phosphorus, appeared to be retained in the dam to any large degree. Considerable portions of the nitrogen and phosphorus loads may be retained in the impoundment or leave the impoundment in the particulate form.

4. The chemical quality of the Crocodile River can be expected to deteriorate further with increased development of the catchment, especially through increased discharges of treated sewage effluents.

5. The chemical quality of water leaving the impoundment is suitable for most purposes, but elevated chloride levels may be detrimental for tobacco farming.

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