EXECUTIVE SUMMARY

This report is an account of the major physical, chemical and biological changes which have taken place in Hartbeespoort Dam over the period 1980 to 1990. From a management point of view, two of these changes are of interest. The first is the impact of the 1 $mg\ell^{-1}$ special orthophosphate standard for effluents on the load of phosphorus on the dam. The second is the disappearance of *Microcystis* in the summers of 1988/89 and 1989/90. Arising out of this, the cause of the disappearance and future replication of the cause in order to manage *Microcystis* are of management importance.

After a general description of Hartbeespoort Dam, its catchment and the sampling points used in the study, the methods used are described. The reported analytical values for Kjeldahl nitrogen, orthophosphate and total phosphorus depended on the laboratory analysing the water samples. This resulted from the fact that the analysis of all chemical samples was transferred from the Division of Water Technology, CSIR, to the Hydrological Research Institute of the Department of Water Affairs & Forestry. The origins of the differences and the manner in which the problem was overcome are described in the methods section of the report.

The period of the study included the drought phase of the long-term hydrological cycle. Hartbeespoort Dam was full when the study commenced. Its mean volume was between 35 and 42 percent of full supply volume from 1982/83 to 1985/86. During this time its minimum volume was between 20 and 30 percent of full supply volume. Thereafter the dam filled rapidly and spilled in 1987/88 and in the years thereafter. Inflow volumes were low during the drought. The hydrological mass balance for the reservoir is good, except during the periods when the volume of water stored in the dam changed rapidly. At these times, inaccuracies in the measured components of the balance resulted in volumes of stored water estimated from the previous year's stored volume plus inputs less outputs differing from the measured year end stored volumes by up to 28 percent. These inaccuracies were taken into account in the estimation of nutrient mass balances for the dam.

The temperature and stability of the water column are presented in the form of temperature isotherms and the frequency of occurrence of diurnal mixed layers at the water surface. An analysis of the temperature and stability conditions in 1988/89 and 1989/90 showed that conditions in these years were not outside the range of conditions found in previous years.

Records of the chemical data from 1984 to the present show that since the dam filled after the

drought, the annual mean concentration of the major ions in the inflowing water, the dam and its outflow have declined. Silica concentrations have been particularly low.

In the Crocodile River the flow-weighted annual mean total phosphorus concentration peaked at nearly 3 $mg\ell^{-1}$ in 1983/84 and has since declined to between 1.4 and 1.1 $mg\ell^{-1}$ from 1985/86 to 1988/89. Simultaneously the annual mean flow-weighted total nitrogen concentration has varied between 8 and nearly 12 $mg\ell^{-1}$. In the surface waters of the dam the mean annual total phosphorus concentration peaked at about 0.7 $mg\ell^{-1}$ in 1983 and 1984, whereafter it hardly changed until 1988 when it dropped to 0.2 $mg\ell^{-1}$ in 1988 and to 0.14 $mg\ell^{-1}$ in 1989 and 1990. The total nitrogen concentration in the surface waters of the dam built up to a peak of over 5 $mg\ell^{-1}$ in 1986, but has subsequently declined to about half this concentration. The ratio between total nitrogen and total phosphorus in the surface waters has risen from below 5 from 1980 to 1985, to about 10 between 1986 and 1988, to 17 in 1989 and to 21 in 1990.

The phytoplankton species composition during the summer months was dominated between 1982 and 1988 by *Microcystis*, which virtually disappeared thereafter. It was largely replaced by Chlorophytes (green algae) and Cryptophytes (flagellated, motile unicellular algae) in the summers of 1988/89 and 1989/90 until the beginning of February. At this time there was a two month bloom of a very small celled blue-green alga, *Aphanothece*, which had previously been a rarity in the dam. This blue-green alga has never been recorded in the literature as a nuisance.

The abundance of the phytoplankton, measured as chlorophyll *a*, has shown only minor changes over the study period, given that on occasion during the times of *Microcystis* dominance scum concentrations of chlorophyll were measured. Over the past two years winter chlorophyll values have been lower and peak monthly concentrations have tended to be slightly lower.

There have been several long term trends in the abundance of the zooplankton species relative to one another. Over the study period the relative abundance of the Cyclopoid Copepoda has increased and the *Daphnia* and *Ceriodaphnia* have declined in abundance. Numbers of the other major species have fluctuated and no systematic long term trends were evident.

The only possibly meaningful change seen in the zooplankton biomass over the study period occurred during the last two months of the study, April and May 1990. In these months the highest ever biomass for this time of the year occurred.

Possible causes of the disappearance of *Microcystis* were then considered. There was no evidence that a change in the water temperature or in the stability of the water column brought about the disappearance of the species.

The disappearance was associated with the greatly altered total nitrogen to total phosphorus ratio which has occurred in the last two years. This is consistent with observations on the occurrence of *Microcystis* and total nitrogen to total phosphorus ratios made in the northern hemisphere. The lack of a decline in the chlorophyll *a* concentrations with the decline in the total phosphate concentration is also consistent with overseas work. This showed that the chlorophyll *a* yield per unit total phosphorus increases as the ratio rises.

Factors contributing to the sharp decline in the mean total phosphorus in the surface waters of Hartbeespoort Dam in 1989 and 1990 were considered from an analysis of the mass balance of total phosphorus in the dam. The major cause of the low phosphorus concentration was that the dam filled up. This resulted in a very much larger percentage of the incoming phosphorus load being sedimented, despite the fact that the actual sedimentation rate per unit area was lower. The lower flow-weighted mean annual phosphorus concentrations in the inflowing Crocodile River in recent years further contributed to the decline. Comparing the phosphorus sedimentation rate with the mean total phosphorus concentration in the dam revealed a close association between the concentration and the rate. This confirmed the conclusion reached in earlier laboratory studies that the adsorption rate of phosphorus by the sediments is governed by the ambient dissolved phosphorus concentration.

There was no evidence that changes in the zooplankton population composition or size was responsible for the change in the phytoplankton species composition.

It is recommended from the results of this study that the phytoplankton of Hartbeespoort Dam should be managed by maintaining the total nitrogen to total phosphorus ratio at least at its present levels. It is pointed out that there is an uncertainty about the validity of this recommendation, should conditions of high total phosphorus concentration arise. This is because the impact of the absolute total phosphorus concentration on the critical level of the total nitrogen to total phosphorus ratio is unknown. Should the total phosphorus concentration tend to rise relative to the total nitrogen concentration, more nitrogen could be made available by relaxing the nitrogen standards for effluents or by destratifying the dam. A previous study had shown that large amounts of nitrogen are lost from the dam by denitrification under anoxic conditions. Destratification could prevent the loss of most

of this nitrogen.

The application of the special effluent phosphate standard should not be relaxed in the Hartbeespoort Dam catchment, since a further drop in the phosphorus load on the dam would only improve its algological quality.

It is recommended that the nutrients and phytoplankton in Hartbeespoort Dam should continue to be monitored, but that the frequency of monitoring might be lowered in the future.