INSTITUTE OF APPLIED SCIENCES

THE UNIVERSITY OF THE SOUTH PACIFIC

WATER QUALITY IN THE MONASAVU RESERVOIR AND WAILOA RIVER IN 1996

IAS TECHNICAL REPORT NO. 97/01

by

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EXECUTIVE SUMMARY

The monitoring of Monasavu dam, the Wailoa river and the five dams has been carried out by the Institute of Applied Sciences since the filing of the reservoir. The principal aim of the study has been threefold; to study the water chemistry of the reservoir; to monitor the Wailoa river below the power station and the outfall and to monitor the public health status of the reservoir (Lloyd *et al.*, 1993). The following summarises the water quality monitoring for 1996.

- Water quality in the Monasavu reservoir and the Wailoa river has not changed significantly from previous years. Most of the parameters measured were within the range of that observed in previous years.
- Water level in the dam and the weirs was characteristically low in winter. Low water levels in the dam would result in high total suspended solid levels in the weirs high chlorophyll a levels in the water column. This may increase abrasion in the generating equipment.
- High ammonia levels and low dissolved oxygen concentration recorded in the dam is attributed to dead trees and vegetation in the dam. Decomposition of such organic matter results in oxygen depletion.
- Manganese and iron levels are low and there is so far little risk of metal deposition on machinery in the power station.
- Relatively high levels of phosphate in the weirs can not sufficiently explain the presence of the water weed, *lumi*. Other factors such as nitrates, clarity and chlorophyll *a* should be considered.

WATER QUALITY IN THE MONASAVU RESERVOIR

THE FIVE WEIR SITES AND THE WAILOA RIVER

1. INTRODUCTION

The monitoring of the Monasavu dam, the five weir sites and the Wailoa river is funded by the Fiji Electricity Authority (FEA). The Institute of Applied Sciences, University of the South Pacific (USP), has been monitoring the water quality in the Monasavu dam and the Wailoa river since 1985. In 1990, the five weir sites at Wainisavulevu (North and South), Wainabua, Wainikasou and Nabilabila were also monitored. Monitoring is carried out twice yearly during the summer and winter months which in previous years has been usually December and July respectively. This year however, the winter visit was later than usual in September. Biological survey of the dam and algae survey at the five weir sites have also been carried out annually by the School of Pure and Applied Sciences (SPAS), USP. This year no biological survey was carried out due the unavailability of staff.

A weed survey carried out by the Koronivia research station in August 1996 found 3 weirs to be infested with an aquatic weed identified as *Chara* sp. belonging to the family *Choraceaea*, commonly known as *lumi*. The three weirs were Wainisavulevu, Wainikasou North and Wainikasou South. The other weirs were found to be free of the *lumi*. This finding prompted the IAS to test for the nutrient phosphate in the weirs, a parameter never analysed for in the weirs. Phosphate is a nutrient taken up by algae and other aquatic plants. Excess of this nutrient results in excess growth of the plants.

This report represents the results of the water quality monitoring in 1996.

1.1 BACKGROUND

Previous monitoring show water quality in the dam, the five weir sites and the Wailoa river to be generally good. Temperature distribution in lakes is mainly by turbulence or mixing. Generally, summer temperatures indicate apparent stratification due to thermal resistance to mixing. This is a result of warm surface waters overlying dense cooler waters. In winter, however, this stratification is destroyed as surface waters get cooler density approaches that of underlying waters. This results in circulation of the water as there is little thermal resistance to mixing. The distribution of dissolved oxygen over the years has also been dictated by the extent of mixing in the water column. The low oxygen levels at greater depth has been attributed to oxygen uptake during bacterial respiration and decomposition of organic matter. Anaerobic conditions at these depths is further aggravated during summer months as a result of unreplenished waters resulting from overlying thermocline barriers.

With high levels of manganese and iron, there is a risk of metal deposition on the machinery in the Wailoa power station. So far there has been no cause for concern with regards to the status of iron and manganese in the river and the weirs as in most years levels have been below the detection limit.

2. THE MONITORING PROGRAMME

2.1 Organisation

The winter monitoring of the Monasavu reservoir, weirs and Wailoa river was carried out in early September 1996. The summer monitoring was carried out in early January 1997. The water quality indicators measured at the various sites are shown in Table 1. An additional parameter, phosphate, was analysed for in the weirs to ascertain whether this had been, in any way, responsible for the growth of the water weed, *lumi*, in three of the weirs. Due to unavailability of the biologist-in-charge, no biological survey was conducted.

The winter visit showed the level of water in the dam to be significantly lower than the past three years. This is especially notable in stations 1 and 2.

2.2 Location of Sampling Sites

The sampling sites remain the same as in previous years. These are shown in Figures 1, 2, and 3.

Details of the entire monitoring programme are summarised in Table 1 below .

Table 1 : Summary of 1996 Water Quality Monitoring Programme

Location	No. of Sites Monitored	Monitoring Sequence	Parameters Measured
Reservoir	3 stations each at three depths	Sept. 10 & 11 Jan. 14 & 15	pH, clarity, temperaure/dissolved oxygen (DO) profiles, alkalinity, nutrients, chlorophyll a, iron (Fe) and manganese (Mn)
Wailoa River	3 stations	As above	As above except for depth profiles
Weirs	5 stations	As above	Temp., pH, DO, total and dissolved Fe and Mn, total dissolved solids (TDS), total suspended solids (TSS)

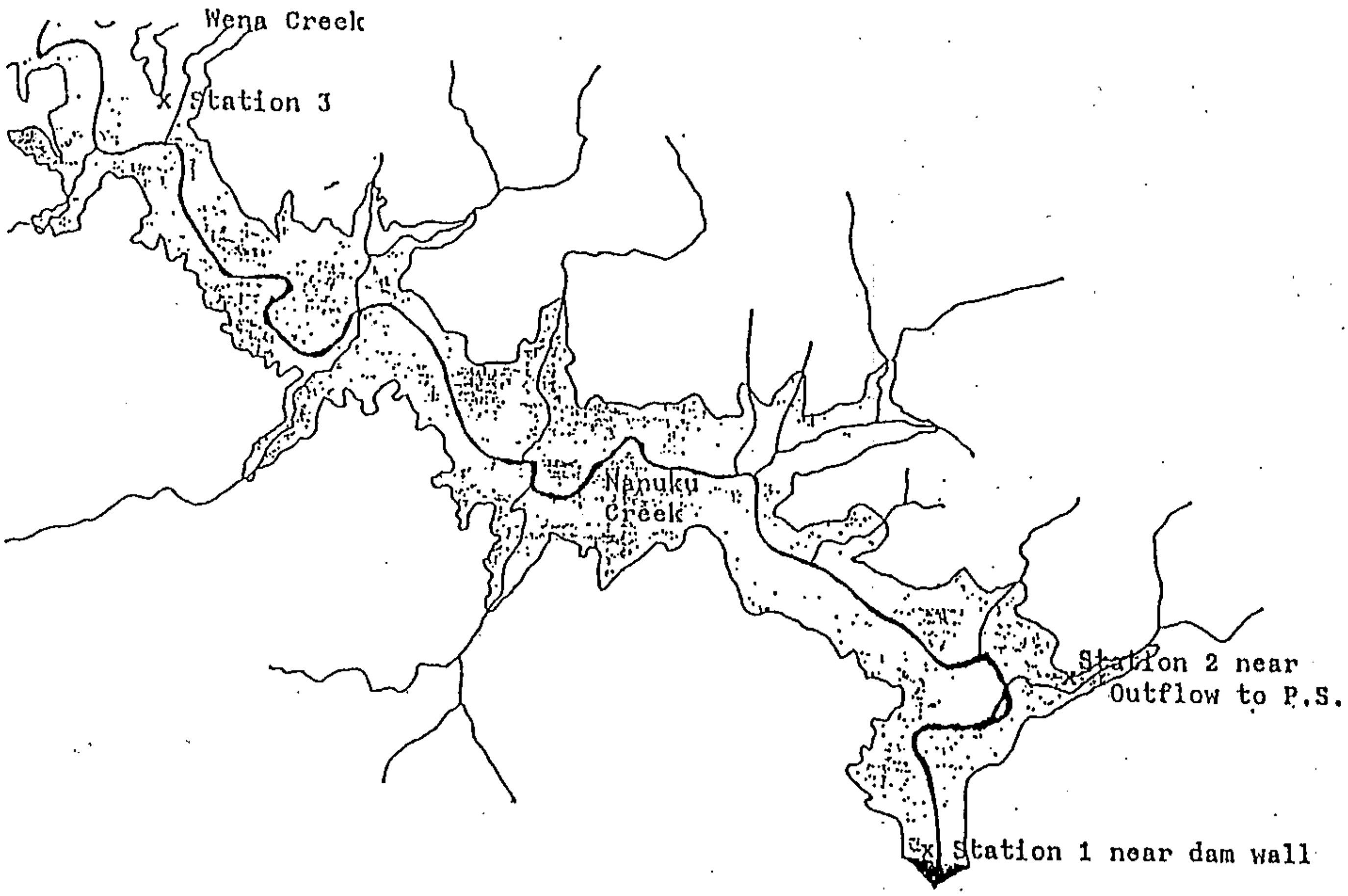


FIGURE 1 : Location of the sampling stations in the Monasavu Reservoir

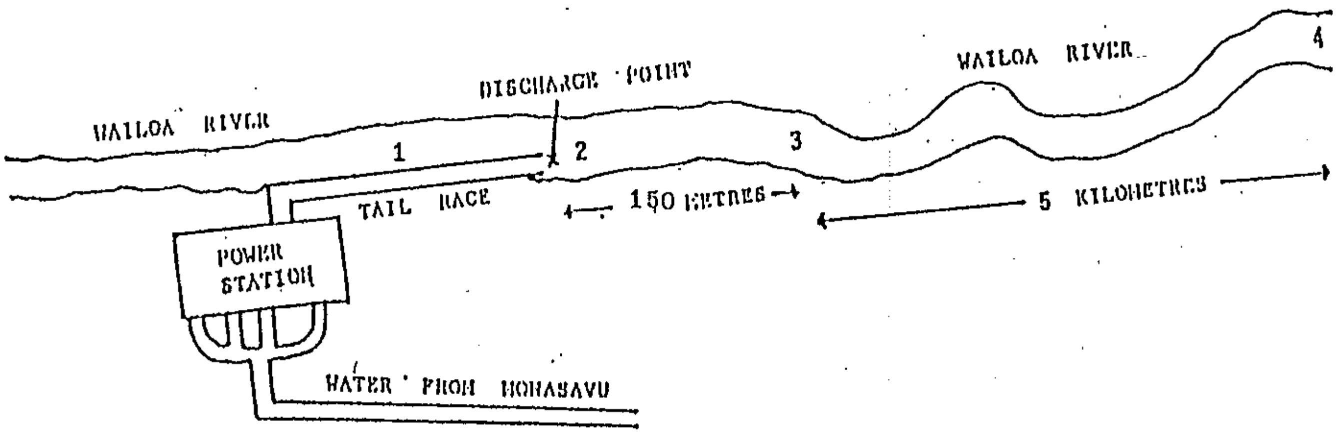


FIGURE 2 : Sampling sites along the Wailoa River

Site : 1 100 m above P.S. discharge
2 Tailrace
3 150 m below P.S. discharge
4 Wailoa at Laselevu

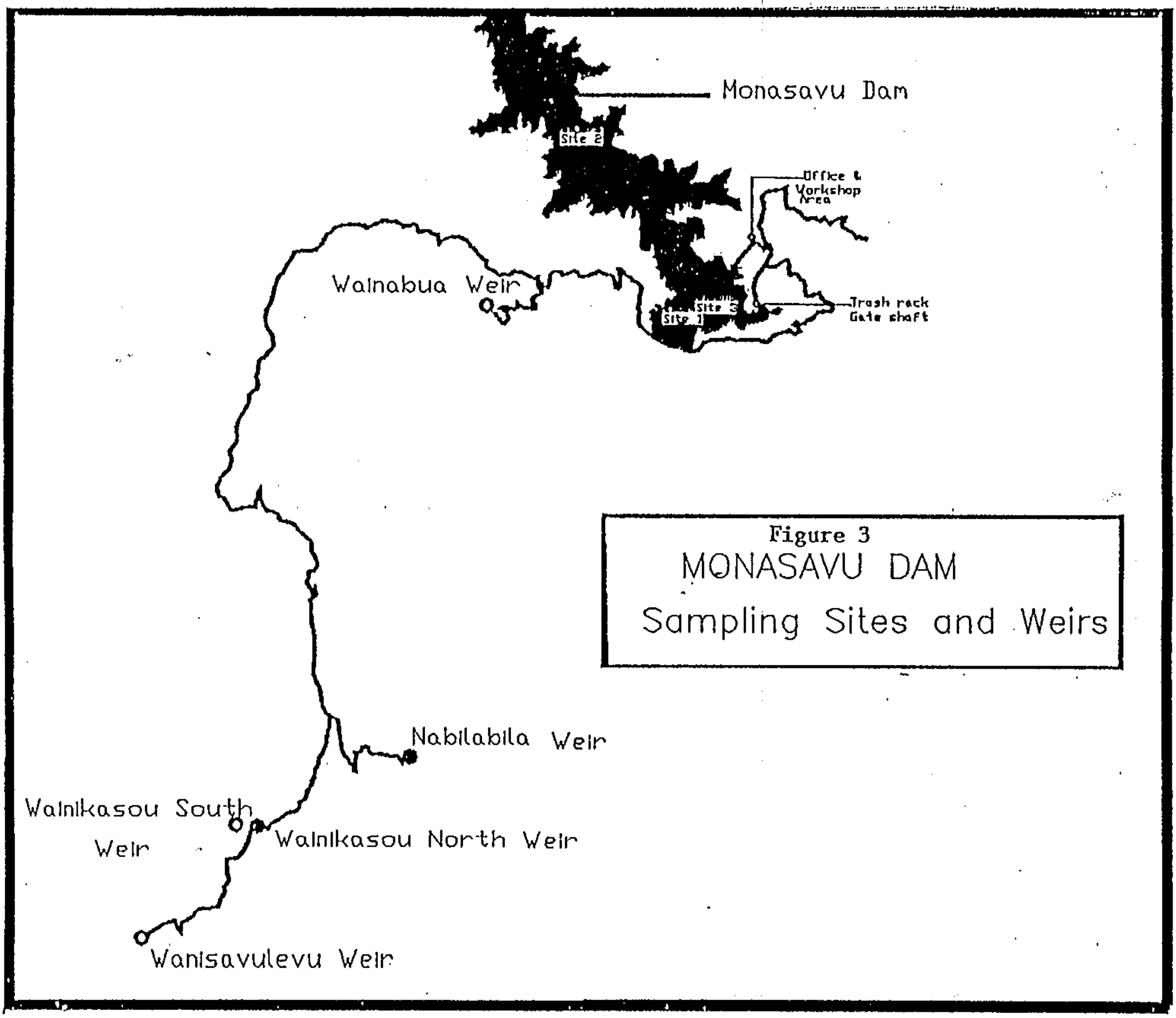


Figure 3
MONASAVU DAM
Sampling Sites and Weirs

3. METHODOLOGY

On-site measurements

At the weir sites and Wailoa river, temperature and dissolved oxygen were measured just below surface waters. At the dam stations these two parameters were measured at 1 meter intervals to the bottom. The pH at all sites were taken just below surface waters.

At each site water temperature and dissolved oxygen (DO) concentration were measured using a YSI Model 51B dissolved oxygen meter. The meter was calibrated on site for altitude set at 2 500 feet.

The pH was measured using an Orion model 250A pH meter.

Clarity was determined only in the dam and this was using a white secchi disk which was lowered into the water until it just disappears from sight.

Laboratory analyses

Water samples were collected in clean acid-washed (10% HCl) plastic bottles and stored in ice. At the dam water samples were collected from three depths: near the surface, mid depth and the bottom waters. At the weir sites and Wailoa river water samples were collected from just below surface waters.

Alkalinity was measured by titration with standard 0.01 HCl to the phenolphthalein end point for carbonate alkalinity and to the bromocresol green/methyl red end point for bicarbonate alkalinity (APHA, 1992).

Nitrate concentration was measured using the Cadmium Reduction/Colorimetric method and measurement of absorbance on the UV Spectrophotometer at 543nm (IAS methods of Analysis of Water, May 1992).

Dissolved phosphate was determined using the Molybdenum blue-Colorimetric Method and measurement of Absorbance on the UV Spectrophotometer (IAS methods, 1992).

Analysis of ammonia was by the phenate method. Absorbance was measured on the spectrophotometer at a wavelength 660nm (APHA 1992).

Total suspended and dissolved solids was measured using the Filtration/Gravimetric method (APHA, 1981).

The metals were analysed by direct Atomic Absorption/Emission Spectrometry (APHA 1992).

The concentration of chlorophyll was determined by Spectrophotometry (APHA 1989) 10200H, 10-31).

4. WATER CHEMISTRY AT MONASAVU

4.1 Results

The dissolved oxygen and temperature profiles for each of the three stations in the reservoir are shown in figures 4 - 6 with the data given in Appendix A. The data on water chemistry for the reservoir, weirs and Wailoa river for the winter and summer monitoring are given in Tables 2 - 5.

At the weirs the presence of *lumi* was especially significant in Wainisavulevu, the largest weir, and Wainikasou North. This *lumi* was predominant in the weir entrance. At Wainikasou South the bottom of the creek towards the weir entrance was clearly visible and this was covered in most areas by an algal mat. Though the bottom of the creek at Nabilabila was visible, the water column was opaque green, suggesting a high presence of phytoplankton.

4.2 Interpretation of Results

(a) Temperature and dissolved oxygen profiles

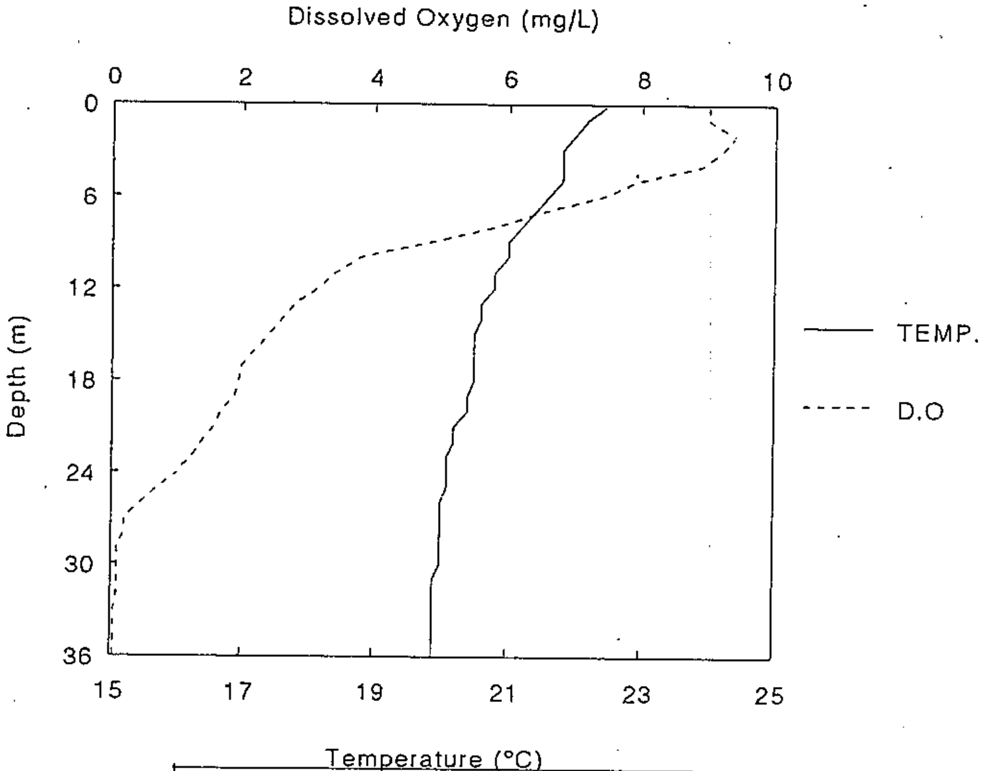
The profiles for the three stations during winter and summer are shown in figures 4 - 6.

Major oxygen sources are:

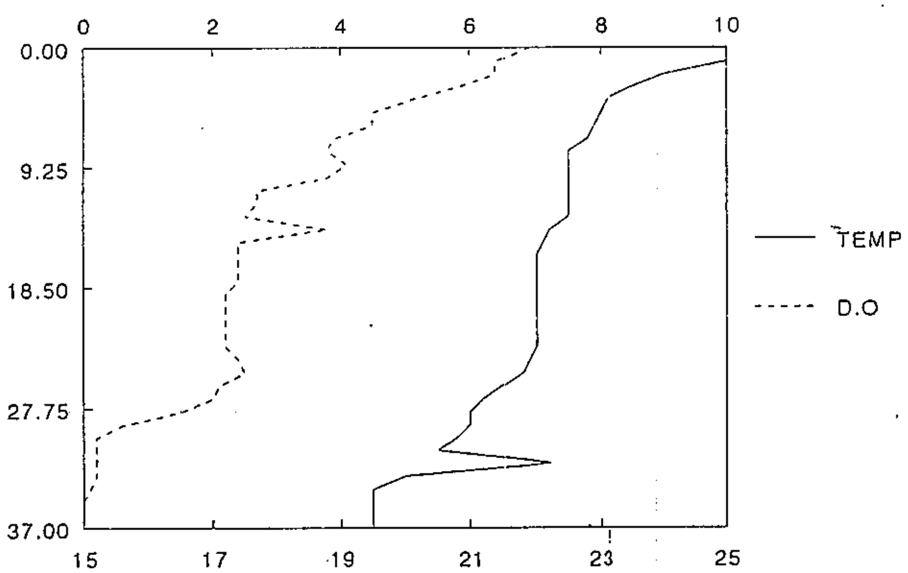
1. Atmospheric reareation, where oxygen is transported from the air into the water during turbulence at the air water interface.
2. Photosynthesis, where chlorophyll-containing organisms (producers such as algae and aquatic plants) convert CO_2 (or alkalinity of water) to organic matter with a consequent production of oxygen.

The levels of fish tolerance to low DO stresses vary. Cold water fish and biota require higher DO concentration than warm water fish and biota. The warm water biota DO standard is set at 3mg/L (Novotny and Olem, 1994). In reservoirs and lakes the autochthonous productivity (such as photosynthetic action by algae) may increase the DO balance therein and overwhelm the effect of allochthonous inputs of oxygen demanding wastes (such as organic bottom deposits). This, however, is dictated by stratification of the water column.

FIGURE 4.   TEMPERATURE/DO PROFILE FOR STATION 1

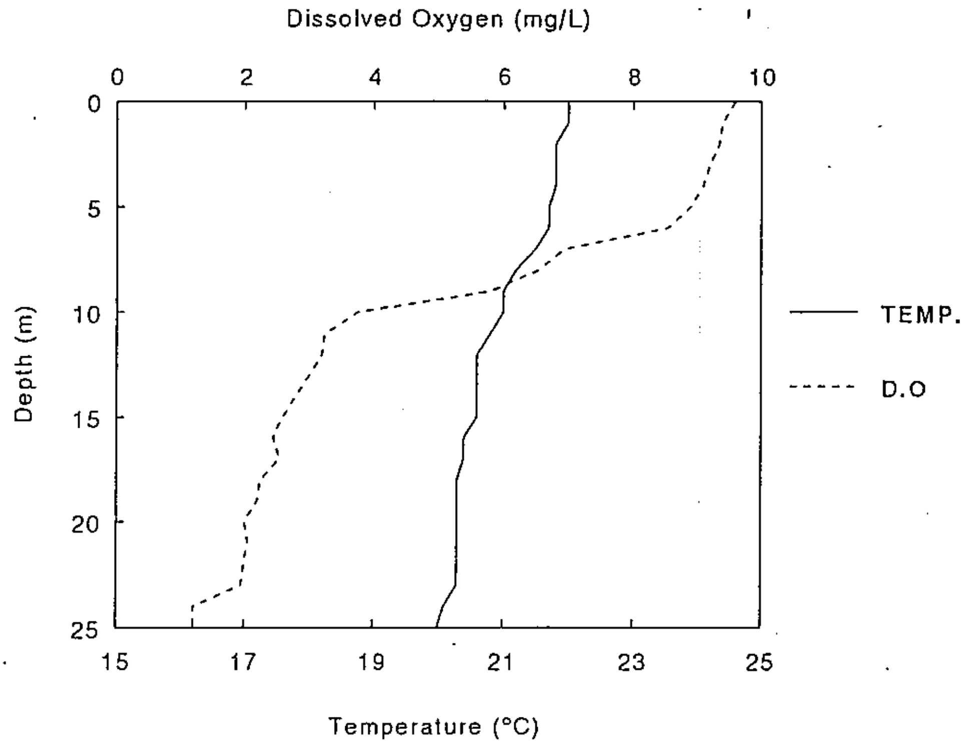


STATION 1 - SEPTEMBER 1996

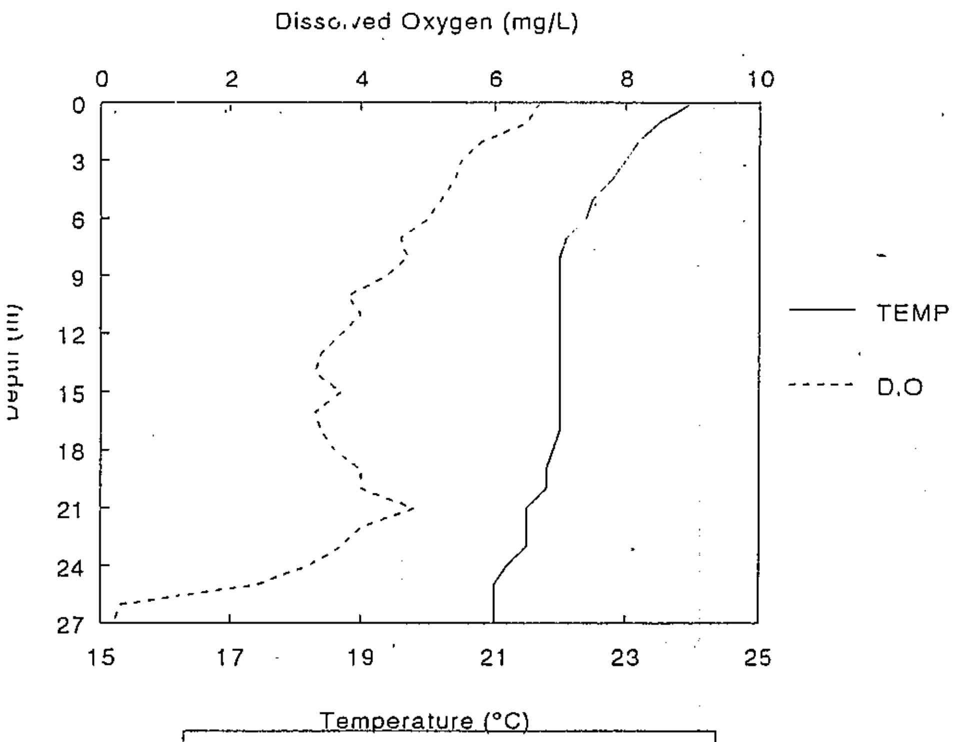


STATION 1 - JANUARY 1997

FIGURE 5. TEMPERATURE/DO PROFILE FOR STATION 2

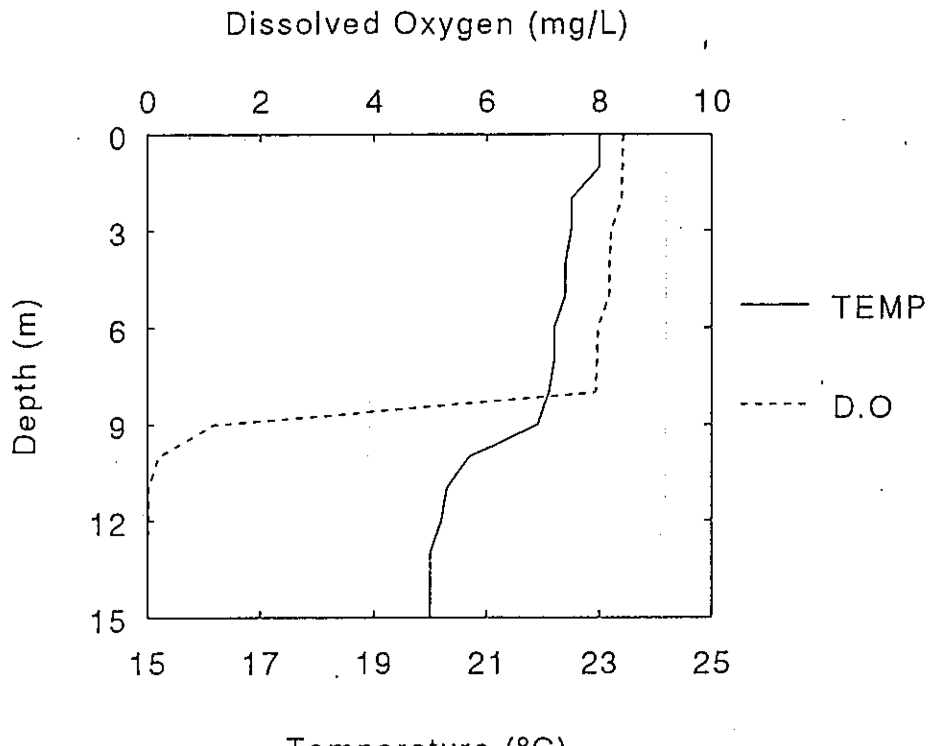


STATION 2 - SEPTEMBER 1996

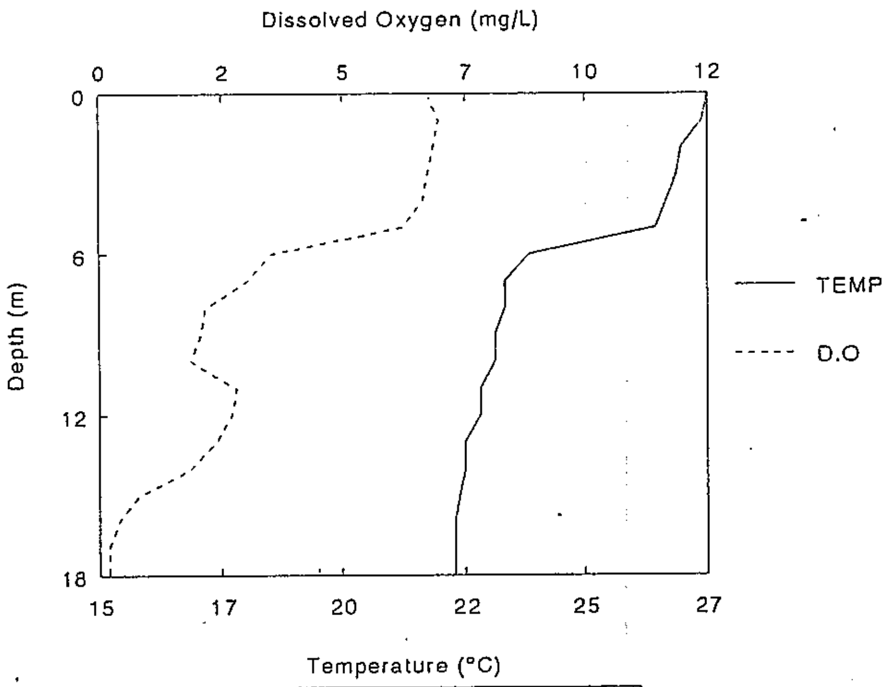


STATION 2 - JANUARY 1997

FIGURE 6. TEMPERATURE/DO PROFILE FOR STATION 3



STATION 3 - SEPTEMBER 1996



STATION 3 - JANUARY 1997

TABLE 2. WATER QUALITY RESULTS FOR MONASAVU DAM AND WAILOA RIVER - SEPTEMBER 1996

	Station 1 Surface	Station 1 Middle	Station 1 Bottom	Station 2 Surface	Station 2 Middle	Station 2 Bottom	Station 3 Surface	Station 3 Middle	Station 3 Bottom	Wailoa Above PS	Wailoa at Tailrace	Wailoa at Laselevu
Lab No.	96/1164	96/1165	96/1166	96/1167	96/1168	96/1169	96/1170	96/1171	96/1172	96/1173	96/1180	96/1174
Total alkalinity (mg/L CaCO3)	18	18	30	19	18	18	20	20	25	45	16	35
Clarity (m)	1.9			1.8			1.5					
pH	8.16	6.70	6.70	8.09	7.02	6.85	7.50	7.38	7.40	7.88	7.00	7.68
Total N (mg/L)	0.91	1.03	1.60	0.68	1.16	2.84	1.33	<0.1	1.37	1.49	0.42	2.49
NO3 (µg/L)	<34	324.3	124.2	<34	<34	<34	<34	<34	362.1	228.0	<34	166.2
NH3 (µg/L)	<12.2	23.0	271.0	<12.2	29.3	41.3	<12.2	<12.2	21.2	<12.2	<12.2	13.3
Chlorophyll a (µg/L)	13.70	1.87	1.48	13.60	7.71	3.74	11.20	10.80	9.50	1.79	2.26	2.65
Dissolved Mn (mg/L)	<0.2	<0.2	0.9	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Total Mn (mg/L)	<0.2	<0.2	1.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dissolved Fe (mg/L)	<0.3	<0.3	0.4	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Total Fe (mg/L)	<0.3	<0.3	4.2	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Temperature (°C)	22.5	20.5	19.9	22.0	20.6	20.1	23.0	22.2	20.0	22.8	21.0	22.0
Dissolved O2 (Mg/L)	9.0	2.0	0.1	9.6	3.0	1.2	8.4	8.0	0.0	8.0	7.8	8.1
Depth (m)	0	18	36	0	13	25	0	7	14	0	0	0
Dissolved PO4 (µg/L)	25	<20	50	40	<20	<20	<20	<20	134	<20	<20	108

TABLE 3. WATER QUALITY RESULTS FOR MONASAVU WEIRS - SEPTEMBER 1996

	Wainabua	Nabilabila	Wainakasou North	Wainakasou South	Wainisavulevu
Lab No.	96/1175	96/1176	96/1177	96/1178	96/1179
pH	7.46	7.39	7.08	7.07	6.83
Dissolved Mn (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2
Total Mn (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2
Dissolved Fe (mg/L)	<0.3	<0.3	<0.3	<0.3	<0.3
Total Fe (mg/L)	<0.3	<0.3	<0.3	0.4	0.4
Temperature (°C)	20	19	19	20	21
Dissolved O2 (mg/L)	8.6	8.4	8.6	8.4	9
Total dissolv. solids (mg/L)	2	7	5	4	6
Total susp. solids (mg/L)	42	27	43	23	27
PO4 (µg/L)	170	134	93	22	<20

TABLE 4. WATER QUALITY RESULTS FOR MONASAVU DAM AND WAILOA RIVER - JANUARY 1997

Description	Station 1 Surface	Station 1 Middle	Station 1 Bottom	Station 2 Surface	Station 2 Middle	Station 2 Bottom	Station 3 Surface	Station 3 Middle	Station 3 Bottom	Wailoa Above PS	Wailoa Tailrace	Wailoa at Laselevu
Lab. No.	97/30	97/31	97/32	97/33	97/34	97/35	97/36	97/37	97/38	97/39	97/40	97/41
Total Alkalinity [mg/L $CaCO_3$]	<20	<20	<20	<20	<20	<20	<20	<20	<20	28	<20	22
Clarity [m]	1.5			1.3			1.5					
pH on site	8.21	5.85	5.85	8.53	5.95	5.78	8.26	6.14	5.69	7.19	5.89	7.75
Total N [mg/L]	<0.1	<0.1	0.12	<0.1	4.58	<0.1	<0.1	0.12	<0.1	1.21	0.1	0.95
Total P [µg/L]	24.5	<20	160	29.1	<20	52.6	32.9	<20	33.5	49.6	<20	34.9
NO_3^- [µg/L]	<34	<34	125	<34	98.4	267	35.4	36.4	39.4	128	124	110
NH_3 [µg/L]	<12.2	<12.2	1746.2	<12.2	<12.2	113.4	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2
Chlorophyll a [µg/L]	11.0	1.40	<1	10.6	2.64	<1	14.9	2.23	1.90	<1	1.65	1.07
Dissolved Mn [mg/L]	<0.2	<0.2	1.23	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Total Mn [mg/L]	<0.2	<0.2	1.31	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dissolved Fe [mg/L]	<0.3	<0.3	3.95	<0.3	<0.3	0.87	<0.3	<0.3	0.33	<0.3	<0.3	<0.3
Total Fe [mg/L]	<0.3	<0.3	4.37	<0.3	<0.3	2.82	<0.3	0.50	0.54	<0.3	<0.3	<0.3
Temperature [°C]										23.5	22.0	24
Dissolved O_2 [mg/L]	6.9			6.7			6.5			6.40	6.8	6.05
Depth [m]	50			26			18					
Dissolved PO_4 [µg/L]	<20	<20	376	<20	<20	<20	<20	<20	<20	78.9	58.0	36.1

TABLE 5. WATER QUALITY RESULTS FOR MONASAVU WEIRS - JANUARY 1997

Description	Wainabua	Nabilabila	Wainakasou South	Wainakasou North	Wainisavulevu
Lab No.	97/43	97/42	97/44	97/45	97/46
pH on site	6.90	7.79	7.02	7.10	5.57
Dissolved Mn [mg/L]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Total Mn [mg/L]	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Dissolved Fe [mg/L]	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Total Fe [mg/L]	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Temperature [°C]	21.9	21.1	21.5	21	22.9
Dissolved O_2 [mg/L]	6.3	6.3	6.8	6.2	6.5
Total Dissolved Solids [mg/L]	59	65	45	44	24
Total Suspended Solids [mg/L]	6	4	2	6	11
Dissolved PO_4 (µg/L)	167.6	163.5	19.7	53.8	56.6

The winter profile shows high surface temperatures as compared to previous visits. The normally homothermal profile observed during the winter monitoring over the years was not apparent this year. This could be due to the monitoring being later in the year, when the weather was taking a warmer turn. The surface water temperature was around 22.5°C decreasing to 20°C to the bottom. Some stratification is indicated from the profiles during winter. This results in a difference in DO levels between the surface and underlying waters. Though the surface waters are oxygen enriched it sharply declines below nine meters. This may be due to an existing thermocline layer which prevents mixing between the warm surface waters and the cooler dense underlying waters. Since diffusion of oxygen in water is a very slow process, oxygen accumulates at the surface. Bottom waters are depleted.

During summer, surface temperature was higher and DO levels were lower relative to those of winter. Temperature and DO was seen to decrease with depth. Surface temperature was as high as 27°C (station 3) and decreased to temperatures as low as 19.5°C to the bottom (station 1). Stations 1 and 2 did not exhibit any apparent stratification unlike station 3. At station 3 both temperature and DO were lower at depths of about 6 meters. A thermocline layer exists at depths of about 6 to 8 meters. The existing thermocline acts as a barrier and diffusion of oxygen into underlying waters is impeded. Below these depths temperature and DO were at anoxic levels of 0.2 mg/L. At these depths oxygen is taken in decomposing organic matter. This trend is consistent with previous years where stratification is present in the summer visit.

(b) pH

The pH at all sites during September ranged from 6.70 to 8.16. This is within the accepted range for recreational waters in Fiji which is 5.0 - 9.0 (NEMP 6, 1992). Over the years the pH range for the Monasavu dam has been from 6 to 9. This is typical of a bicarbonate-type lake. At all stations in the dam pH was greatest at the surface.

The pH during the summer visit ranged from 5.69 to 8.85. As to be expected, the highest pH was at the surface waters.

The pH depends primarily on the dissociation of carbonic acid and the hydrolysis of bicarbonate ions to H^+ and OH^- respectively. Thus the pH of fresh water systems is closely related to the carbonate/bicarbonate balance. The higher surface temperatures results in greater abstraction of carbon dioxide from surface waters during photosynthesis. The lower the CO_2 concentration the lower the concentration of H^+ ions and the higher the pH. This explains the higher pH levels in surface waters.

(c) Total Alkalinity

Total alkalinity in the dam and Wailoa river during the winter ranged from 16 to 35 mg/L $CaCO_3$. These values are low compared to past observation but very similar to the values obtained during summer in past years. This is attributed to the warmer weather as the winter monitoring was later in the year than usual.

In January the total alkalinity was less than 20 mg/L$CaCO_3$ at all stations in the dam while along the river total alkalinity ranged from 22 (at Laselevu) to 28 (above the power station) mg/L$CaCO_3$. These values were consistent with values obtained in previous years.

(d) Nutrients

Total Nitrogen, Nitrates and Ammonia

The September monitoring showed total nitrogen ranging from < 0.1 to 2.84 mg/L. Nitrate (NO_3) concentration ranged from < 34 to 362.1 μg/L. The surface waters low in both nitrate (< 34 μg/L) and ammonia (< 12.2 μg/L). Ammonia (NH_3) concentration during winter ranged from < 12.2 to 271.0 μg/L.

In January total nitrogen ranged from < 0.1 to 4.58 (station 2 at mid depth) mg/L. Nitrates ranged from < 34 to 267 (station 2 at bottom depth) μg/L. As in the September visit surface waters were again low in nitrate. Except for station 3, nitrate was relatively high in the deeper waters. These nitrate values however are lower than ammonia levels. Ammonia levels ranged from < 12.2 (surface) to 1746.2 (station 1 at the bottom) μg/L.

These very high levels of ammonia at the bottom of station 1 has been the trend for the past several years. Station 1 is the deepest station in the dam and therefore would have a thicker layer of deoxygenated water on the bed.

The reservoir receives a major portion, if not all of its nutrients from internal sources. Nitrate and ammonia is released as a byproduct in the decomposition of organic matter. Organic matter in the water column originates from cellular tissues of all organisms and from excreta and organic byproducts of living processes (Novotny and Olem, 1994). In the water column, often up to mid-depth, decomposition is usually aerobic. The aerobic decomposition of this organic matter releases nitrates, phosphates and carbon dioxide into the water. As ammonia and nitrate are nutrients to photosynthetic organisms surface waters are usually depleted of these nutrients. In addition, at the surface well oxygenated waters prevent the formation of ammonia as a decomposition product. With increasing depth these organisms decrease and nutrients (nitrate and ammonia) tend to accumulate. Up to mid-depth nitrate levels are higher than ammonia as decomposition of organic matter is largely aerobic. The higher nitrate values at mid-depth relative to ammonia concentrations may also be due to nitrification. The unoxidised organic ammoniacal nitrogen present in the water column deplete the dissolved oxygen demand by nitrification (Novotny and Olem, 1994). Nitrification is a two-stage process where ammonium ion is first converted to nitrite and nitrite is later converted to nitrate. Ammonium ion may originate from the underlying waters where reactions are mostly anaerobic. The nitrification reaction is strictly aerobic. If the oxygen concentration is depleted to below 2 mg/L, the reaction decreases rapidly (Novotny and Olem, 1994). Under anoxic conditions nitrate may be taken up in the oxidation of organic matter resulting in the release of carbon dioxide into the water and loss of nitrogen gas to the atmosphere. The high nitrate values at depth indicates the continuing release of nitrates from decomposition of organic matter or the accumulation of the nutrient from overlying aerobic waters.

At the bottom depths, conditions are normally anaerobic. Under these conditions (anaerobic) organic matter is broken down by bacteria into methane, carbon dioxide and ammonia. This explains the high ammonia concentration at the bottom levels of each station. Furthermore, ammonia ions have an affinity for adsorption on soil particles (primarily clay and organic fractions) and by the same mechanism on sediments (Novotny and Olem, 1994). The higher ammonia levels during the January visit is likely to be from higher organic matter in the bottom waters and sediments.

Phosphates

In the dam, dissolved phosphates (PO_4) ranged from < 20 to 134 (station 3, bottom) μg/L in September. In January dissolved phosphate ranged from < 20 to 376 (station 1, bottom) μg/L. The higher phosphate values during the summer monitoring is consistent with previous years monitoring. Sources of phosphate in the reservoir would originate mainly from the decomposition of organic matter. Generally phosphate levels is higher as depth increases. This may be due to nutrient uptake by photosynthesising organisms in the water surface.

In the Wailoa river phosphate levels were found to range from < 20 to 108 (Laselevu) μg/L during winter and 36.1 (Laselevu) to 78.9 (above power station) μg/L during summer. These values are within the range of that obtained in previous years.

A significant feature was the high phosphate levels in the Wainabua and Nabilabila weirs. This ranged from < 22 (Wainisavulevu) to 170 (Wainabua) μg/L during winter and 19.7 (Wainakasou South) to 167.6 (Wainabua) μg/L. However, since no previous analysis of this parameter has been carried out in the weirs, no comparison can be made. A possible source of phosphate would be from soils carrying phosphorus washing into creeks.

(e) *Chlorophyll a*

Winter values ranged from 1.48 to 13.70 μg/L and summer values ranged from < 1 to 14.9 μg/L. As to be expected chlorophyll *a* levels are highest at the surface waters and decreases with depth. These levels are within the range of that from previous years.

The chlorophyll levels reflects the algal biomass in the water. As these are photosynthesising organisms they would be largely expected to be in the surface waters where light is abundant. The chlorophyll levels indicate that the euphotic zone in station 3 exceeds mid-depth during summer. The euphotic zone represents the depth of effective light penetration for photosynthesis.

(f) *Total and Dissolved Manganese and Iron*

In the dam and the river total mangansese during summer was below the detection limit of 0.2 mg/L at all stations except for the bottom at station 1 where it was 1.5 mg/L. Dissolved manganese during the same monitoring was also < 0.2 mg/L at all sites except for the bottom of station 1 where it was 0.9 mg/L. In the weirs during the summer monitoring both total manganese and dissolved manganese were below the detection limit of 0.2 mg/L.

For the winter monitoring total mangansese levels were below the detection limit of 0.2 mg/L at all stations except station 1. At the bottom of station 1 total manganese was 1.32 mg/L. Dissolved manganese levels were also below the detection limit at all stations except for the bottom of station 1 which was 1.23 mg/L.

Total iron in all sites and stations in September was below the detection limit of 0.3 mg/L at all stations but for the bottom of station 1. At the bottom of station 1 total iron was 4.2 mg/L. Dissolved iron was below < 0.3 mg/L at all stations in the dam and the river except for the bottom of station 1. Three out of five of the weirs had levels below 0.3 mg/L. Wainakasou South and Wainisavulevu both had levels of 0.4 mg/L.

In January the dam had total iron ranging from < 0.3 to 4.37 mg/L. The bottom waters at all stations were above 0.3 mg/L. The river and the weirs had levels < 0.3 mg/L. Dissolved iron was also below the detection limit 0.3 mg/L at all sites except for the bottom waters of the three stations in the dam.

The higher levels of iron and manganese in the bottom waters results from the the oxidation of the metals in the surface. This results in the precipitation of the metals which then sink to the bottom. At the bottom , anoxic conditions brings about the dissolution of iron and manganese. Therefore the insoluble iron and manganese is returned to the bottom waters in the form of iron (II) and manganese (II) ions.

These levels are typical of observations from previous years. Total manganese and iron levels in the Wailoa river is below the detection limit. Metal deposition on the machinery at Wailoa power station is not therefore an immediate threat.

(g) Total Dissolved and Total Suspended Solids

Total dissolved solids (TDS) in the weirs in September ranged from 2 to 7 mg/L and total suspended solids (TSS) ranged from 23 to 42 mg/L. In January levels were reversed with TDS levels (24 - 65 mg/L) being higher than TSS levels (2 - 11 mg/L). The higher TDS levels in September is due to low water levels in the dam which results in a higher sediment concentration. These levels are similar to that of previous years and as expected for fresh water.

5. CONCLUSION

- A notable observation is the lower water levels in the dam. This was evident from the exposed dead vegetation which was once below water surface level. Low water levels in the dam would result in higher TSS levels, higher chlorophyll a levels (due to increased light penetration through the water column) and a less stratified water column.

- Water quality in the Monasavu reservoir and the Wailoa river has not changed significantly from previous years. Most of the parameters measured were within the range of that observed in previous years.

- The low DO levels and relatively high ammonia levels at depth in the dam is most likely to be from the decomposition of organic matter in the water column. Dead trees and vegetation are a common sight in the dam and this results in oxygen depletion as it gradually decomposes.

- Manganese and iron levels are low and there is so far no risk of metal deposition on machinery in the power station.

- The high levels of phosphates alone would not explain the presence of *lumi* as other factors such as nitrates, secchi disc depth (clarity) and chlorophyll *a* should be considered.

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APPENDIX

DATA FOR MONASAVU DAM

MONASAVU DAM - STATION 1, SEPTEMBER 1996

DEPTH (m)	TEMP. (°C)	D.O (mg/L)	DEPTH (m)	TEMP. (°C)	D.O (mg/L)
0	22.5	9.00	19	20.4	1.90
1	22.2	9.00	20	20.4	1.70
2	22.0	9.40	21	20.2	1.60
3	21.8	9.20	22	20.2	1.40
4	21.8	8.90	23	20.1	1.25
5	21.8	7.90	24	20.1	1.00
6	21.6	7.40	25	20.1	0.70
7	21.4	6.50	26	20.0	0.45
8	21.2	5.80	27	20.0	0.20
9	21.0	4.85	28	20.0	0.20
10	21.0	3.80	29	20.0	0.10
11	20.8	3.40	30	20.0	0.10
12	20.8	3.15	31	19.9	0.10
13	20.6	2.80	32	19.9	0.10
14	20.6	2.60	33	19.9	0.05
15	20.5	2.40	34	19.9	0.05
16	20.5	2.20	35	19.9	0.05
17	20.5	2.00	36	19.9	0.05
18	20.5	1.95			

MONASAVU DAM - STATION 2, SEPTEMBER 1996

DEPTH (m)	TEMP. (°C)	D.O (mg/L)	DEPTH (m)	TEMP. (°C)	D.O (mg/L)
0	22.0	9.60	13	20.6	3.00
1	22.0	9.40	14	20.6	2.80
2	21.8	9.35	15	20.6	2.60
3	21.8	9.20	16	20.5	2.45
4	21.8	9.10	17	20.4	2.55
5	21.7	8.90	18	20.4	2.25
6	21.7	8.55	19	20.3	2.20
7	21.5	6.95	20	20.3	2.00
8	21.2	6.55	21	20.3	2.05
9	21.0	5.80	22	20.3	2.00
10	21.0	3.75	23	20.3	1.95
11	20.8	3.25	24	20.1	1.20
12	20.6	3.20	25	20.0	1.20

MONASAVU DAM - STATION 3, SEPTEMBER 1996

DEPTH, (m)	TEMPERATURE, (°C)	DISSOLVED OXYGEN, (mg/L)
0	23.0	8.44
1	23.0	8.42
2	22.5	8.40
3	22.5	8.22
4	22.4	8.18
5	22.4	8.18
6	22.2	7.98
7	22.2	7.96
8	22.1	7.94
9	21.9	1.80
10	20.7	0.20
11	20.3	0.05
12	20.2	0.02
13	20.0	0.00
14	20.0	0.00
15	20.0	0.00

DATA FOR MONASAVU DAM - STATION 1 JANUARY 1997

DEPTH (m)	TEMP. (°C)	D.O (mg/L)	DEPTH (m)	TEMP. (°C)	D.O (mg/L)
0	25	6.9	19	22	2.2
1	25	6.4	20	22	2.2
2	24	6.4	21	22	2.2
3	23.5	5.8	22	22	2.2
4	23.1	5.1	23	22	2.2
5	23	4.5	24	21.9	2.4
6	22.9	4.5	25	21.8	2.5
7	22.8	3.9	26	21.5	2.1
8	22.5	3.8	27	21.2	2.0
9	22.5	4.1	28	21	1.5
10	22.5	3.8	29	21	0.6
11	22.5	2.7	30	20.8	0.2
12	22.5	2.7	31	20.5	0.2
13	22.5	2.5	32	22.2	0.2
14	22.2	3.8	33	20	0.2
15	22.1	2.4	34	19.5	0.1
16	22	2.4	35	19.5	0
17	22	2.4	36	19.5	0
18	22	2.4	37	19.5	0

DATA FOR MONASAVU DAM - STATION 2 JANUARY 1997

DEPTH (m)	TEMP. (°C)	D.O (mg/L)	DEPTH (C)	TEMP. (°C)	D.O (mg/L)
0	24	6.7	14	22	3.3
1	23.5	6.5	15	22	3.7
2	23.2	5.8	16	22	3.3
3	23	5.5	17	22	3.4
4	22.8	5.4	18	21.9	3.6
5	22.5	5.2	19	21.8	4.0
6	22.4	5.0	20	21.8	4.0
7	22.1	4.6	21	21.5	4.8
8	22	4.7	22	21.5	4.0
9	22	4.4	23	21.5	3.7
10	22	3.8	24	21.2	3.2
11	22	4.0	25	21	2.4
12	22	3.7	26	21	0.3
13	22	3.4	27	21	0.2

DATA FOR MONASAVU DAM - STATION 3 JANUARY 1997

DEPTH (m)	TEMP. (°C)	D.O (mg/L)
0	27	6.5
1	26.9	6.7
2	26.5	6.6
3	26.4	6.5
4	26.2	6.4
5	26	6.0
6	23.5	3.4
7	23	2.9
8	23	2.1
9	22.8	2.0
10	22.8	1.8
11	22.5	2.7
12	22.5	2.6
13	22.2	2.3
14	22.2	1.8
15	22.1	0.8
16	22	0.4
17	22	0.2
18	22	0.2