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THE INCIDENCE AND VARIATION OF
BACTERIA IN A STOCK DAM

A thesis presented in partial fulfilment
of the requirements for the degree
of Master of Agricultural
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at Massey University

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ABSTRACT

The effects of agricultural activities, including grazing and fertilizer application, and environmental factors, on the incidence and variation of bacteria in a stock dam were investigated. A survey of water quality at sites around the edge of a dam was carried out over a period of 15 months. Samples were analysed for water temperature, pH, turbidity, dissolved oxygen, 5-day biochemical oxygen demand (BOD_5), total and soluble phosphorus, total nitrogen, ammonia, nitrite, nitrate, total plate count (TPC), total coliform (TC), faecal coliform (FC) and faecal streptococcal (FS) counts.

The bacterial content of faecal samples from animals around the dam and of littoral sediments were determined. Experiments with incubation of fresh and sterilized pond water samples were carried out to examine the effects of trophic status and nitrate and phosphate addition on bacterial growth and survival.

The presence of grazing animals and wildlife around the dam resulted in significant increases in BOD_5 , turbidity, FS and FC counts. Turbidity, ammonia, nitrate, $\log_{10} TPC$, $\log_{10} TC$ and $\log_{10} FC$ were positively correlated with the amount of rainfall in the 5 days prior to sampling. While dissolved oxygen saturation was positively correlated with water temperature, ammonia, nitrate, $\log_{10} TPC$ and $\log_{10} TC$ exhibited a negative correlation. Ammonia, nitrate and $\log_{10} TPC$ were correlated with turbidity, and $\log_{10} TPC$ was correlated positively with ammonia and nitrate concentrations. Fertilizer application resulted in slightly increased phosphate concentrations.

The bacterial content of cattle and goose faeces was similar to those reported in the literature, with FC/FS ratios less than 0.01.

FC and FS bacteria were observed to grow in sterilized pondwater samples in pure cultures and in a community of indigenous bacteria harvested from the water. Addition of phosphate and nitrate, and increasing trophic status caused growth stimulation in both pure culture and in the mixed community. In fresh samples, while indigenous bacterial populations increased, indicator bacteria survived longer in less eutrophic water.

It was concluded that BOD_5 , turbidity, FC and FS counts were good indicators of animal pollution in this situation. Land drainage and mixing of dam sediments resulted in increased indigenous bacterial counts and chemical enrichment. While the physico-chemical nature and trophic status

of the water may have influenced bacterial growth and survival, direct pollution, land drainage and mixing of sediments were overriding factors. The concentrations of faecal indicator bacteria encountered suggested that pathogenic organisms such as Salmonella could be present in littoral water and bottom sediments.

THE INCIDENCE AND VARIATION OF BACTERIA IN A STOCK DAMPREFACE

On farms, providing water supplies for livestock is a necessity. This creates a special problem for the extensive farming situations in New Zealand since the land is often hilly with few permanent streams. The advent of aerial topdressing in the nineteen fifties stimulated the development of large areas of such country.

This rapid development led to the increased use of stock watering dams which were built in gullies, hollows, or on slopes. In most cases stock was allowed to drink around the edge of the dam, fouling the water and breaking down the banks. On some farms the water was reticulated to troughs.

By the late 1960's it was possible to see many dams which had filled with mud to become swamps and dried up. This was due to several processes including soil erosion in runoff, increased fertility of drainage water due to topdressing, and animal contamination increasing the fertility of the dam water and mud. These resulted in luxuriant weed growth and development of a thick rich bottom mud. Where dams were shallow, particularly those excavated on slopes, the filling process was very rapid.

Along with this accelerated eutrophication process, the water which is necessary to increase the carrying capacity of the land and improve the well-being of the stock has become a source of disease for the stock. The growth of blue-green algae which produce compounds toxic to stock has become a problem. Flint (1970) included reservoirs and farm ponds in a list of eutrophic waters which would be expected to contain blue-green algae. Faecal contamination of the water has also led to potential disease transfer. Josland (1953) suggested that on farms where Salmonellosis outbreaks occur polluted water supplies were the cause.

The present study is directed at the problem of faecal contamination of the water at sites around a dam where stock drink. The thesis is that inorganic and organic pollution of stock dams by adjacent farming activities could change the nature of the water so as to encourage the survival or stimulate growth of pollution indicator organisms and/or pathogens. The incidence and variation of faecal indicator organisms was investigated over a period of 15 months, along with changes in the chemical nature of the water. Laboratory experiments were used to determine how the faecal indicator organisms reacted in waters of different trophic status.

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CHAPTER ONE

INTRODUCTION

1. Water Pollution from Agricultural Activities:

Water pollution arising directly or indirectly from agricultural activities, both from farms or product processing plants, is either organic or inorganic. Animal wastes are basically organic in nature, containing also dissolved salts and ions (Appendix 1.1). Micro-organisms which proliferate in the alimentary and urinogenital tracts abound in the wastes. Some of these microorganisms may be pathogenic to man or animals.

Agricultural activities thus affect water quality in several ways:

- (i) Addition of organic waste to waterways from sheds, yards, pasture, and places where stock has access to waterways. These wastes exert an oxygen demand in the water and the products of mineralization encourage the growth of water plants and algae.
- (ii) Fertilizer applications find their way into waterways directly or in runoff and subsurface drainage. Intensive farming activities increase soil fertility causing higher nutrient levels in drainage.
- (iii) Agricultural practices often increase the rate of soil erosion which adds suspended material, organic matter and inorganic compounds to the drainage waters.
- (iv) The numbers of microorganisms in the water are generally increased, particularly faecal organisms and possibly pathogenic organisms.

1.1 Eutrophication:

There are many interrelated processes affecting the trophic status of inland basins (Greenson, 1969), some of the more important being:

- (a) the morphometry of the basin (its size, shape and volume) in relation to the size and shape of the catchment;
- (b) rainfall and evapotranspiration rates in the vicinity;
- (c) other climatic factors including temperature, day length and light intensity;
- (d) the catchment topography and the stability and fertility of the soils;
- (e) the flora and fauna present in the basin and their state of growth.

If a lake or pond was completely isolated, receiving no runoff, its nutrient status would depend upon the parent rock on which it was formed and the fertility of the rainfall. Where runoff flows into a lake or pond the trophic status will be affected by the fertility of the catchment. The agricultural use of the catchment is extremely important since richly fertilized and heavily stocked areas provide abundant supplies of soluble and organic nutrients. Erosive activity may lead to accelerated eutrophication, which is aided by evaporation. The ultimate result of this is accelerated succession or senescence of the dam which proceeds to the development of a swamp and finally a terrestrial ecosystem.

At present it is thought that only two nutrient elements need be examined with regard to eutrophication, namely phosphorus and nitrogen (Metson, 1971). Agricultural land use in New Zealand increases the concentrations of these nutrients in our waterways. (O'Connor, 1968.)

The Water and Soil Division, Ministry of Works, Nelson, (unpublished data) carried out a study on drainage from various types of catchments entering Tasman Bay during the low flow period in 1971 (Appendix 1.2). Farmed catchments yielded more nitrate, phosphorus and potassium than forested catchments. Mixed farming appeared to result in higher nitrate concentrations in runoff, while 'farming' had lower, and extensive grazing catchments still lower concentrations. The data for the Wangapeka and Collins Rivers where there were low levels of nitrate, total phosphorus and potassium, are indicative of the nutrient levels in catchments having a minimum of agricultural activity.

The chemical nature of natural waters has been extensively discussed by Hutchinson (1957) and Ruttner (1953).

1.2 Organic Pollution:

The prime sources of organic pollution on farms are the areas where stock are concentrated for prolonged periods of time or for short regular periods. On dairy farms, the main sites of stock concentration are the milking shed and wintering pads. On sheep farms, shearing sheds, yarding areas and sheep dips are the main areas. Piggeries and poultry units are also important. However, on most sheep and cattle farms, stock are concentrated in paddocks, particularly where there is water, to facilitate farming activities such as cultivation, weaning, shearing, and wintering. Rotational grazing results in temporary high stocking intensities as opposed to set-stocking.

While it is impossible to measure the exact amount of organic pollution from livestock in New Zealand or to estimate the capability of the land and water to break down the waste, it is possible to estimate the

amount of waste produced and its polluting capacity. Estimates of either waste production per capita per unit time, or of comparative Biochemical Oxygen Demand (BOD) loading per capita per unit time have been made (Appendix 1.3). Population Equivalents on the basis of BOD production per human of 0.2 lb/day and by liveweight comparisons are similar in the case of poultry, pigs and cattle, but not sheep. Table I shows the total population equivalent for N.Z., in terms of its human and animal population's BOD production, using 1970-71 population estimates. The total estimate of an animal population twenty times the size of the human population in terms of BOD production may be too high, although Brown (1969) estimated a population increase of 13.9 times the human population in terms of weight of excrement.

Whatever the population equivalent is, the estimate indicates that as the areas of farmland and intensive stocking systems increase, the demand on our soils and water as waste treatment systems will be as important as the demand by urban and industrial waste treatment. At present, the most important sites of livestock concentration in terms of pollution are piggeries and poultry houses (Appendix 1.4). However, point sources of pollution such as these are easier to control and treat than non-point sources such as farm drainage.

1.3 Bacterial Contamination and Indicator Organisms:

The wide variety of heterotrophic organisms normally found in large numbers in water are extensively described elsewhere (e.g., Salle, 1967; Frobisher, 1963; Pelczar & Reid, 1965). Bacteria which are pathogenic for man and animals are normally found in small numbers, and their survival in water is limited.

The main human diseases transmitted via water are typhoid, dysentery and cholera. Diseases that could be transmitted through water containing animal wastes are salmonellosis, staphylococcal and streptococcal infections, tetanus, tuberculosis, brucellosis, and fungal and viral diseases (Decker & Steele, 1966). Leptospirosis enters water from animal secretions, especially from rats, this being a common means of transmission. Poultry manure is well-known to be a rich source of Salmonella organisms. It is also likely that pathogenic members of the Escherichia and Proteus genera may be transmitted through water.

Since most pathogenic organisms are usually present in relatively small numbers in water and are difficult to culture, organisms which are characteristic of faecal material and which can normally survive for longer periods in water are relied on as indicators of potential contamination of the water with pathogenic organisms. The most common of these

are coliform organisms, which were thought to be characteristic of human faeces as early as 1880. The discovery of similar organisms in soils lead to uncertainty as to which were indicative of faecal contamination. Biochemical tests were then developed which could separate the coliform group organisms into strains from faecal and non-faecal sources. Later, other groups of organisms such as the faecal streptococci and some clostridia were also found to be characteristic inhabitants of the gut of warm-blooded animals. (Geldreich, 1966, Ch.1.)

TABLE I: Equivalent Population of New Zealand in Terms of BOD Production

	Population Size ^a millions	Population Equivalent per capita	Equivalent Population millions
Human	2.8	1.0	2.8
Dairy Cattle -			
Cows	2.4)	7.7 ^b	18.5)
Others	1.4) 3.8	4.0 ^b	5.6) 24.1
Beef Cattle -			
Cows	1.5)	6.0 ^b	9.0)
Others	3.5) 5.0	3.5 ^b	12.3) 21.2
Pigs	0.5	1.7	0.9
Sheep	59.9	0.1	6.0
Poultry -			
Layers	5.0	0.08	0.4
Broilers	10.0	0.05	0.5
		Total Equivalent Population	= 56.0
		<u>Total Equivalent Population</u> Population Humans	= 20-fold increase

^a1970-71 population estimates.

^bFrom Witzel et al, 1966, Table 5.

To determine the effect of farming activities on bacterial water quality, Thomas et al (1949) tested untreated farm water supplies in the U.K. Samples from shallow wells and springs and from river and canal water had the highest counts of total bacteria, coliforms and faecal coliforms. While upland surface water had relatively satisfactory coliform counts in winter when few sheep and cattle were grazing, after rain in late spring and summer, high presumptive and faecal coliform counts were observed.

Weidner et al (1969) found that faecal coliform and streptococcal

counts in farm runoff were lower under cropping than meadow (pasture) systems. Improved meadow systems, with increased lime and fertilizer applications, contour tillage, and improved pasture species, resulted in higher bacterial runoff than the prevailing system. Stocking rates were not reported.

The M.O.W. Tasman Bay stream data (Appendix 1.2) shows that higher coliform counts can be expected in runoff from agricultural land than from forest catchments.

1.4 Conclusions:

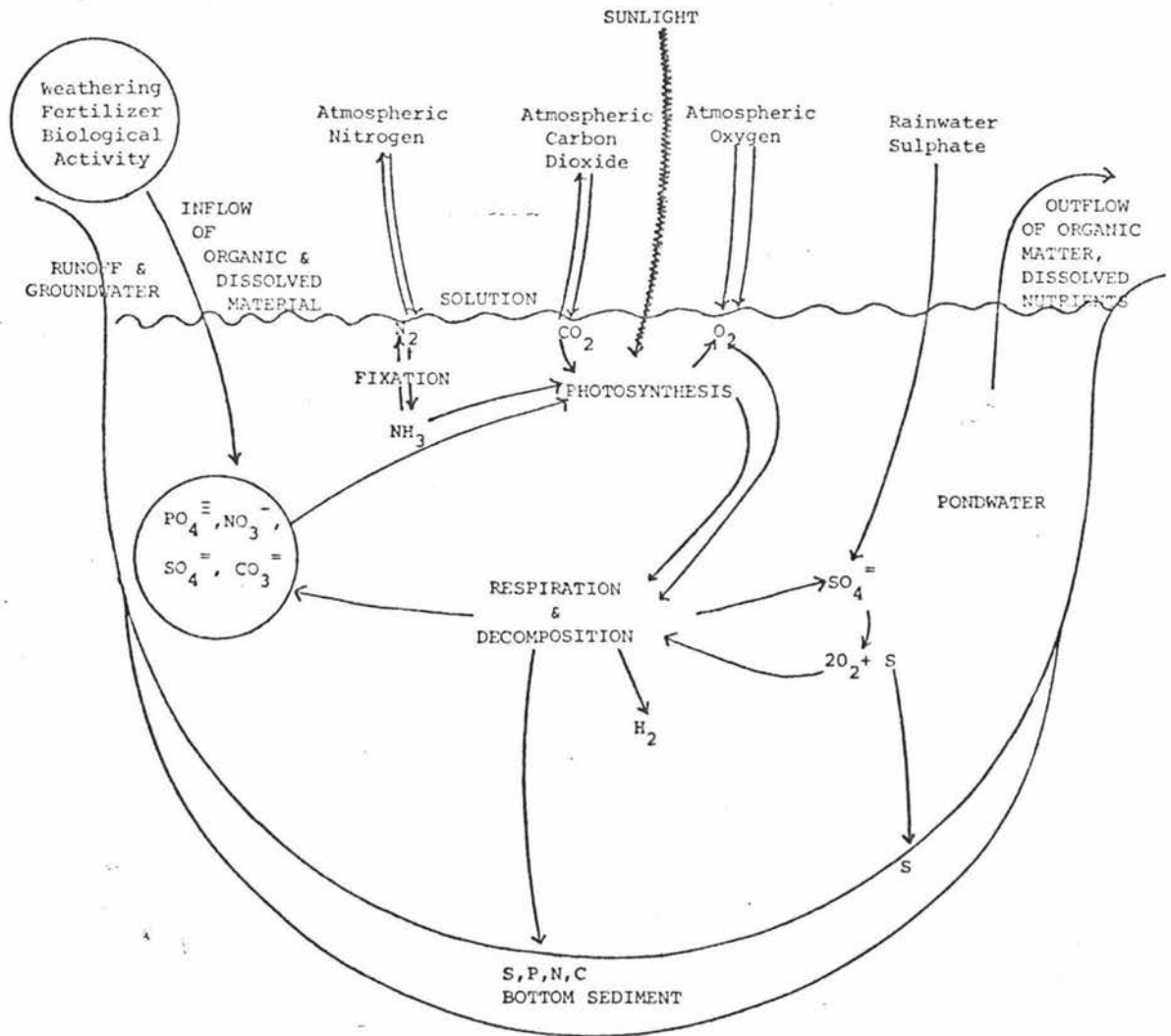
The above data shows that as surface waters proceed from the upland catchments to the sea they are progressively polluted with inorganic and organic material. Progressive bacterial contamination also occurs. The sources of such pollution and contamination are agricultural, urban and industrial, although in N.Z. the effects of agricultural activities may continue to increase while urban and industrial sources are being controlled.

2. The Stock Dam:

A stock dam is a small expanse of water at least partially isolated from other bodies of water. In the extreme case, water enters the pond as rainfall and is lost by evaporation and seepage. In most cases, however, runoff is received from the surrounding land and during periods of prolonged runoff, water may be lost by overflow. Dams may also be situated on streams where they are continuously supplied with fresh water. The habitat is essentially one of still water (lentic), and differs from a lake mainly in that wave action is not sufficient to prevent growth of vegetation immediately at the water's edge.

The relationships between the various groups of organisms likely to be present in such a habitat were described by Lindeman (1942). The system incorporates flow of energy from primary producers through herbivores and carnivores to top carnivores, and from all these levels to decomposers, and cycling of nutrient material in a similar manner, except that decomposers return nutrients to the system for re-use. A stylized biogeochemical cycle in a pond is shown in Fig. 1.1. As well as classification by trophic levels (producers, consumers and decomposers), the organisms in fresh water ecosystems can be described by their life-form or habit and by their spatial zonation in the pond. Extensive discussion of ecological considerations can be found elsewhere (e.g., Odum, 1959; Kormondy, 1969; Brock, 1966).

FIGURE 1.1: The Biogeochemical Cycle in a Pond.
(Adapted from Redfield, 1958)



CHAPTER TWO

LITERATURE REVIEW

1. Bacterial Flora of Animal Faeces and Farm Wastes:

Most bacteria found in fresh animal faeces are acid producers, the lactose fermenters dominating in the low faecal pH (Witzel et al, 1966). The faecal bacterial flora of humans has different proportions of bacteria from that of animals (Table II). Overall, the bacterial content of faeces incorporates about 10^7 total organisms, 10^5 to 10^8 faecal coliforms and 10^3 to 10^8 faecal streptococci.

The strain distribution of faecal coliforms (Table III) and the species distribution of faecal streptococci (Table IV) also differ. Citrate positive strains seldom make up more than 10% of the coliform strains present in animal faeces (Holden, 1970). Witzel et al (1966) reported that from some dairy cows and bulls, 98% of the cocci observed were S. bovis and S. faecium.

Medrek and Barnes (1962) obtained mean streptococcal counts of 8×10^4 /gram in cattle and 2×10^6 /gram in sheep faeces. S. bovis was found in every sample and was the predominant species in 15 cattle and 6 sheep. S. faecalis, S. faecium and S. durans were rare in cattle, but formed a significant part of the population in sheep. The conclusion of Cooper and Ramadan (1955) that S. faecalis was typical of animal faeces while S. bovis (starch +ve) was typical of farm animal faeces is supported by the above data.

In feedlot waste there were about 500 million enterobacteria per gram dryweight (Hrubant et al, 1972). More than 90% of these were E. coli, none of which were enteropathogenic, while Citrobacter and Enterobacter cloacae were present in moderate numbers. Enrichment resulted in isolation of the four Proteus spp., both Providencia spp., Klebsiella, Enterobacter aerogenes, Arizona, and a single isolate of Salmonella, but no Shigella. There were fewer bacteria in the runoff and drainage ditch, and these had the same predominant bacteria, but neither Salmonella nor Arizona was isolated there. In a 2-monthly quantitative determination of the microflora of beef cattle feedlot waste and runoff, the viable counts per gram dryweight of raw waste were 10^{10} total organisms, 10^9 anaerobes, 10^8 gram-negative bacteria, 10^7 coliforms, 10^6 spore formers, and 10^5 yeasts, fungi and streptomycetes (Rhodes and Hrubant, 1972). Little microbial growth was observed in the waste. The runoff contained the same population pattern but varied more

TABLE II: Bacterial Content of Human and Animal Faeces (Counts per gram).

Species	Total Plate Count	Faecal Coliform	Faecal Streptococci	FC/FS
Human ^a	-	1.3×10^7	3.0×10^6	4.4
Human ^b	-	7.0×10^7 ($5.0 \times 10^5 - 7.9 \times 10^8$)	2.0×10^4 ($2.5 \times 10^3 - 2.5 \times 10^8$)	5.0
Cattle ^a	-	2.3×10^5	1.3×10^6	0.2
Cattle ^b	-	1.6×10^4 ($50 - 6.3 \times 10^5$)	3.2×10^5 ($2.0 \times 10^4 - 2.5 \times 10^6$)	0.05
Cattle ^c	$2.2 \times 10^7 - 4.3 \times 10^7$	$3.4 \times 10^5 - 5.6 \times 10^5$	$3.5 \times 10^6 - 1.7 \times 10^7$	-
Sheep ^a	-	1.6×10^7	3.8×10^7	0.4
Sheep ^b	-	2.0×10^6 ($1.6 \times 10^5 - 1.0 \times 10^8$)	1.6×10^6 ($1.0 \times 10^5 - 3.2 \times 10^7$)	1.3
Pig ^d	-	3.3×10^6	8.4×10^7	0.4
Pig ^b	-	5.0×10^6 ($1.6 \times 10^5 - 4.0 \times 10^7$)	3.2×10^6 ($5.0 \times 10^5 - 1.6 \times 10^8$)	1.6
Duck ^a	-	3.3×10^7	5.4×10^7	0.6
Chicken ^a	-	1.3×10^6	3.4×10^6	0.4
Turkey ^d	-	2.9×10^5	2.8×10^6	0.1

Sources: a - Geldreich & Kenner, 1969.

b - Williams-Smith, 1961. Values converted from \log_{10} to normal.

c - Witzel *et al*, 1966. Coliform counts on EMB agar; 95% typical *E. coli*.

d - Geldreich, 1966; Chapter VII.

TABLE III: Coliform Types in Faecal Samples (per cent occurrence).

Coliform Type	Human	Livestock	Poultry	Summary
<u>++--</u>	<u>87.2</u>	<u>95.6</u>	<u>97.9</u>	91.8
--++	<u>5.4</u>	a	<u>0.1</u>	2.8
+++--	<u>2.4</u>	<u>2.5</u>	a	1.9
-+--	<u>2.2</u>	<u>0.6</u>	<u>1.1</u>	1.5
-+-+	<u>1.1</u>	a	<u>0.3</u>	0.6
+-+-	<u>0.8</u>	<u>1.2</u>	<u>0.6</u>	0.8
-+++	<u>0.5</u>	a	a	0.2
++++	<u>0.1</u>	a	a	0.1
+---	<u>0.3</u>	a	a	0.2
----	a	a	a	0.1
---+	a	a	a	a
-+-+	a	a	a	a
Dominant types (underlined)	99.1	99.2	97.9	

a - Insufficient number of cultures examined.

Source: Geldreich, 1966: Chapter III.

TABLE IV: Species and Strain Distribution of Faecal Streptococci.

Faecal Source	Enterococci*	<u>Strep.</u> <u>faecalis</u> var. <u>liqu.</u>	<u>Strep.</u> <u>saliv.</u>	<u>Strep.</u> <u>bovis.</u>	<u>Strep.</u> <u>equinus.</u>	Enterococcus biotype
Human ^a	76.3	-	16.3	0	0.6	6.8
Human ^b	73.8	26.2	-	0	0	0
Cow ^a	12.3	-	0	61.2	14.1	12.4
Cow ^b	29.7	4.1	-	-----66.2-----		0
Sheep ^a	24.8	-	0	40.0	6.4	28.8
Sheep ^b	38.9	19.0	-	-----42.1-----		0
Pig ^a	10.0	-	0	32.0	24.0	34.0
Pig ^b	78.7	2.4	-	-----18.9-----		0
Fowl ^a	61.8	-	0	0.4	0	37.8
Duck ^b	51.2	0	-	-----48.8-----		0
Chicken ^b	77.1	21.8	-	-----1.1-----		0
Turkey	76.7	21.8	-	-----1.8-----		0

Sources: a - Kenner et al, 1960.

b - Geldreich & Kenner, 1969.

due to the volume of liquid. Large ditches which received runoff and subsurface water from fields where waste was stockpiled had a population similar to the runoff but with fewer coliforms.

2. Bacterial Flora of Soils, Vegetation and Insects:

Of the coliforms, the citrate positive members inhabit soil and decaying vegetation. They do not necessarily indicate faecal pollution. Some can multiply in water, particularly in association with decaying vegetation such as dead algae, water plants, grass, and organically rich bottom muds. They are frequently present in surface waters especially during floods (Holden, 1970).

Coliform counts from various soils showed that faecal coliform bacteria were usually absent in undisturbed soils, or present in small numbers; in polluted soils the numbers increased markedly (Geldreich, et al, 1962a).

The - - + + and - + - + coliform strains predominate in soil (Geldreich et al, 1968). Intermediate types were found to make up 76% of the strains isolated from undisturbed soils; but only 17% from polluted soils (Geldreich et al, 1962). The - + - + 45^o lactose negative type was thought to be characteristic of unpolluted soils.

The numbers of coliforms, faecal coliforms and faecal streptococci

on plants are very low (Geldreich et al, 1964). On fresh grass the - - + + type was predominant and the - + - + type was present while there were few E. coli (Holden, 1970). Of the streptococci isolated from vegetation, 34% were typical enterococci, 18% atypical S. faecalis, 12% S. faecalis var. liquefaciens, and 11% intermediate starch and litmus milk positive. (Geldreich et al, 1964.)

With various insect groups, completed coliform counts at the 75 percentile level ranged from 9.4 million to 4,900 million per gram, while faecal coliforms ranged from less than 20 to 79,000 per gram and faecal streptococci from 0.24 million to 4,900 million per gram (Geldreich et al, 1964). The - + - +, + + - -, and + + - + and - - + + strains made up 87.7% of the coliforms isolated, and of the streptococci, 45% were S. faecalis var. liquefaciens and 39% were typical enterococci.

3. Faecal Indicator Organisms in Rural Surface Waters:

Thomas et al (1959) investigated the distribution of coliform organisms isolated at 37°C from unpolluted and polluted farm waters. In unpolluted waters, with no 44°C E. coli I/100 cm³, Citrobacter and Klebsiella species predominated; in polluted waters, with more than 250 44°C E. coli I/100 cm³, E. coli I was the predominant species, making up 76% of the coliform population.

They found a much higher proportion of E. coli I strains during "summer" (May/October) than "winter" (November/April) associated with higher E. coli I counts in summer. During mid-summer (June/August), 47% of samples had E. coli (37°C) counts of more than 50/100 ml, while in mid-winter (December/February) there were only 31%. Also in mid-summer 60% had more than 10 44°C E. coli per 100 ml compared to 41% in winter. They suggested that the seasonal factors operating in summer could be the higher temperature of the soil and ground water, the heavy August (autumn) rainfall, and the grazing of cattle in those months.

In the United States, Geldreich et al (1968) observed a seasonal variation of indicator organisms in rural runoff (Table V). They attributed summer and winter peaks to the increased lateral drainage in summer and the ground freezing in winter. Spring and autumn cultivation would increase infiltration.

TABLE V : Seasonal Variations (median values) for Bacterial Discharges in Agricultural Land Drainage, Coshcocton, Ohio. (From Geldreich et al, 1968.)

Season	Total Coliform ^a	Faecal Coliform ^a	Faecal Streptococcus ^a	Ratio ^b FC/FS	Per cent faecal coliform
Spring	4,400	55	3,600	0.02	1.3
Summer	29,000	2,700	58,000	0.05	9.3
Autumn	18,000	210	2,100	0.10	1.2
Winter	58,000	9,000	790,000	0.01	15.5

^aCounts per 100 ml.

^bFC/FS ratio = Faecal Coliform to Faecal Streptococcal Ratio.

4. Survival of Enteric Bacteria in Surface Waters:

Geldreich et al (1968) inoculated test cultures of faecal bacteria into filter-sterilized stormwater. Stormwater samples collected in spring, summer and autumn were incubated at 20° C. Streptococcus faecalis survived much longer than Aerobacter aerogenes, a faecal coliform, or Salmonella typhimurium. In winter samples incubated at 10° C, survival of all the organisms increased, but Strep. faecalis still survived longer. The faecal coliform and Salmonella typhimurium had similar die-off characteristics. Geldreich and Kenner (1969) concluded that while faecal streptococci may persist for long periods in water, they generally do not multiply in polluted water. Strep. bovis and Strep. equinus, the live-stock types, are the most sensitive indicator faecal streptococci because of rapid die-off outside the alimentary tract. Compared to the 50% survival of Strep. faecalis and Strep. faecalis var. liquefaciens after 14 days in stormwater stored at 10° C, Strep. bovis had died off to 0.1% in 24 hours. On the other hand, at 20° C, while die-off of Strep. faecalis and Strep. faecalis var. liquefaciens was more rapid and fell to less than 20% after 14 days, the Strep. bovis declined at a slower rate than at 10° C, to reach 0.1% after 8½ days. They reported that Strep. equinus has even lower survival rates than Strep. bovis and is difficult to maintain in laboratory culture.

Klock (1971) examined the survival of coliform bacteria in wastewater treatment lagoons. He attributed die-away to low temperature, limited reduced organic nutrients, and possibly an inadequate soluble nutrient recovery mechanism. This would result in reversion to endogenous metabolism and hence exhaustion. Factors affecting survival were said to be ingested materials (nutrients, growth factors, toxicants), and

surrounding water (temperature, quality). Nutrients and growth factors would not be important since die-off was associated with endogenous metabolism, and toxicants would not be expected to exist in sewage. Coliform survival rates of 0.4-0.15 per day in polluted rivers and 0.3-0.1 per day in clean rivers are quoted.

Miura (1971) found that in fresh water over periods of three days, test bacterial populations changed as shown in Table VI. He suggested that E. coli should be used as an indicator in winter and S. faecalis in summer. Adding glucose did not alleviate the decrease, but increased the magnitude of the reduction. There appeared to be no limiting nutrients or physical factors, such as temperature, pH or oxygen. Bacteriophage, antibiotics, predation and competition had no effect on population decrease.

TABLE VI : Population changes of test bacteria in fresh water in summer, winter, and after addition of 0.1% glucose (final concentration), over periods of 3 days. (Miura, 1971)

Species	Summer		Winter		+ Glucose	
	Start	Finish	Start	Finish	Start	Finish
<u>E. coli</u>	10^7	10^4	No decrease		10^6	10
<u>Ps. aeruginosa</u>	10^5	10^4	"	"	10^6	10
<u>Ser. marcescens</u>	10^6	10^5	"	"	10^7	10
<u>Strep. faecalis</u>	No sig. decrease		"	"	10^6	3
Natural flora	10^4	10^6	"	"	-	-

In the U.K., Gameson and Saxon (1967) carried out field studies on the effect of daylight on mortality of coliform bacteria. The results were expressed at the time required for 90% die-off of the organisms (T_{90}). Die-off of coliform bacteria in the dark was approximately exponential with time. The values of T_{90} were variable, but they increased from April to October (spring/autumn), the increase being unrelated to storage temperature. The die-off rate appeared to be unrelated to the initial coliform concentration except when there was more than 90% sewage, in which case the die-off rate was slower. In undiluted sewage there was initial growth of coliform bacteria, followed after about 2 days by an exponential die-off at about half the rate found for samples diluted with sea water. In daylight, the rate of die-off at any time of the year was approximately proportional to the intensity of short-wave radiation received by the sample, and the lethal effect of sunlight decreased from April to September. The lethal effect of sunlight could not be attributed to algal toxins released during the time of exposure in bottles. The

predicted reduction in coliform counts in the sea associated with increases of radiation were much larger than those observed.

In a study of factors affecting the survival of E. coli in sea water Carlucci and Pramer (1960 a, b, c, d) and Carlucci et al (1961) found that high pH, high salinity, low inorganic nutrients, and low organic matter levels were the main factors limiting survival. Survival was better in autoclaved sea water but the reason was not elucidated.

When selected enteric bacteria (E. coli, Aerobacter aerogenes, Proteus rettgeri, Paracolobacterium arizonae, Salmonella seftenberg, Shigella flexneri) were grown in environments approximating those in a cold mountain stream, measurable multiplication and protein synthesis rates were observed (Henricks and Morrison, 1967). An extract of river bottom sediments provided a better nutrient source than did river water from sites above and below a sewage plant or two low nutrient control media. Field studies in the river, using dialysis sac-culture, also resulted in periods of bacterial multiplication. The clear mountain stream could thus not only maintain enteric bacteria, but could supply nutrients to initiate multiplication and de novo protein synthesis. River purification mechanisms must thus be important in the normal reduction in numbers of enteric organisms when they are discharged into rivers.

Hendricks (1972) grew enteric bacteria, including pathogenic species and organisms naturally present in the stream, in a chemostat with autoclaved river water taken 750 m below a sewage outfall. Maximal specific growth rates occurred at 30° C, with culture generation times ranging from 33.3 to 116 hr. Of the laboratory strains, E. coli and Ent. aerogenes grew at generation times of 34.5 and 33.3 hr respectively, while the Proteus, Arizona, Salmonella and Shigella spp. grew at a rate two to three times slower than the coliforms. At temperatures of 20° C and 5° C, little or no growth occurred, and Salmonella seftenberg died at 20° and 5° C, and E. aerogenes and Proteus rettgeri died at 5° C. Coliform bacteria naturally present in the river grew at a generation time of 116 hr, while faecal coliforms failed to grow. Growth of the river bacteria had a periodicity of 100 hr, which suggested that much of their growth may have been on glass surfaces in the chemostat. However, the stocked enteric species did not exhibit this phenomenon. None of the bacteria studied was able to grow in autoclaved river water taken above the sewage outfall.

Garvie (1955) exposed a strain of E. coli to sodium hypochlorite, after which it was able to grow in a solution of a metabolite in

phosphate buffer. A strain of Pseudomonas fluorescens was able to grow when inoculated directly into buffer, and a strain of E. coli I grew in phosphate buffer to which a source of carbon had been added. The organisms grew to a maximum of one to ten million per ml only under aerobic conditions. Since growth took place even when very pure ingredients were used, it appeared probable that the food was not transferred with the bacterial suspension nor obtained from dead cells. Traces of impurities in the chemicals, water, or on glassware were thought to have supplied the necessary energy.

5. The Significance of Indicator Organisms in Water:

Geldreich & Kenner (1969) pointed out that in the faeces of man, faecal coliform bacteria are more numerous than faecal streptococci, with a faecal coliform to faecal streptococcal ratio always greater than 4.0. In the faeces of farm animals, cats, dogs and rodents, the ratio is less than 0.7 (see 1. above). These characteristic ratios also appear in fresh sewage and farm drainage. It is thus possible to determine whether pollution originated from human or animal sources if the ratio is determined. However, care must be taken when applying these ratios to water or wastewater. Water temperature, available organic nutrients, toxicants, unfavourable water pH and other ecological factors affect different strains in different ways, so that the ratios change. It is thus important to sample close to the point of pollution both spatially and temporally. (Geldreich, 1972.)

While it is useful to know whether the pollution was from human or animal sources, it is more important to know if the presence of the indicator bacteria bears any relationship to the presence of pathogenic organisms. Smith and Twedt (1971) investigated the natural relationships of indicator and pathogenic bacteria in stream waters. In samples from the Saline River, counts of coliforms, faecal coliforms (FC) and faecal streptococci (FS) were 920 organisms per ml or greater at all sites, the faecal coliforms comprising less than 16% of the coliforms. An average faecal coliform to faecal streptococcal (FC/FS) ratio of 0.4 at 5 of the 10 sites suggested that the main source of pollution was animal waste; at the other 5 sites, FC/FS ratios of about 1.0 indicated mixed pollution from human and animal sources. Salmonellae were isolated 6 times from 4 sites, 3 of which had average FC/FS ratios of 1.0. No salmonellae were isolated when the FC count was less than 100 per 100 ml. In Upper Huron River samples, the bacterial counts fluctuated along the river, with coliform counts ranging from 950 to 14,000 per 100 ml, FC

counts from 46 to 500 per 100 ml, and FS from 29 to 1,000 per 100 ml. In the 11 samples from the Upper Huron, the FC comprised less than 10% of the TC. Seven of the sites had FC/FS ratios of less than 0.7, the other 4 exceeding 1.0. In Lower Huron River samples, average coliform and FC levels ranged from 5,200 to 12,000 organisms per 100 ml and from 86 to 820 organisms per 100 ml respectively. The FC comprised from 1 to 7.5% of the TC. The FS concentrations ranged from 10 to 1,500 per 100 ml. Five sites had average FC/FS ratios of greater than 1.0. No salmonellae were isolated from samples containing less than 200 FC per 100 ml.

The data of Smith and Twedt support the conclusions of Geldreich (1970) and Van Donsel & Geldreich (1970) that the level of 200 FC/100 ml may be a significant limiting relationship between indicator and pathogen. However, the work of Gallagher and Spino (1968) did not support this. They compared coliform densities with salmonellae isolation and found that low FC densities did not preclude the isolation of salmonellae. They advocated routine examination for salmonellae. This recommendation was based partly on the evidence that Sal.typhimurium was found to be more persistent than faecal coliforms at low temperatures.

Dutka and Bell (1973) also isolated salmonellae from moderately polluted waters. Salmonellae were isolated from 27 out of 46 stations, and the frequency of salmonella isolation increased with increasing coliform, FC, FS and standard plate count density. But they managed to isolate salmonellae from about 25% of samples containing less than 9/100 ml FC and FS, and less than 99 per 100 ml 35°C standard plate count.

Dunlop et al (1952) developed a quantitative method for isolating salmonella in sewage-contaminated irrigation water. Eight out of 11 samples were positive for salmonellae, while the median value for all 11 samples was 0.9 salmonellae per 100 ml.

Spino (1966) used an elevated temperature technique for isolation of salmonella from streams. Salmonellae were recovered from stream sites having low coliform densities of 2,200 per 100 ml and FC densities of 220 per 100 ml.

Several authorities quoted above reported the numbers of indicator bacteria related to the isolation of salmonellae (Table VII). While the means and ranges vary from place to place, it appears that counts in the order of 10^4 - 10^5 coliforms, 10^2 - 10^5 FC, and 10^2 - 10^4 FS could result in salmonella isolation from waters polluted with sewage.

TABLE VII: Numbers of faecal indicator bacteria associated with the isolation of one Salmonella.

Authority	Source of Sample	Coliforms	Faecal Coliforms	Faecal Streptococci
Smith & Twedt, 1971	Saline R.	32,960	2,737	8,702
Smith & Twedt,	Upper Huron R.	11,580	300	191
Dunlop <u>et al</u> , 1952	Sewage- contaminated Irrigation Water	255,000	-	4,800
Chang <u>et al</u> , 1971	St. Mili Creek	-	540-190,000	-
Chang <u>et al</u> ,	Yahara R.	-	460-9,700	-

Screening enrichments of surface water specimens by means of a polyvalent fluorescent antibody reagent for salmonellae yielded about 60% more positive specimens than did cultural procedures (Cherry et al, 1972). In moderately polluted water, 65% of all specimens were positive; in minimally polluted water 38% were positive; and in unpolluted streams, 44% were positive. They suggested the possibility that salmonellae and arizonae may be free-living organisms, but nonetheless potential animal pathogens.

While the data shown above suggests that even in unpolluted environments it is possible to isolate enteric pathogens, Claudon et al (1971) found that agricultural and urban runoff were much safer than sewage in terms of pathogen contamination.

CHAPTER THREE

THE SITE, MATERIALS AND METHODS

1. Site Description:

In July, 1971, several farms in the Bunnythorpe area were visited and stock water dams were inspected. Most of the dams were fairly small and shallow, and the farmers said that many would dry up over the summer. One large dam on the property of Mr. L. Morris, Dixon's line, was said to be fed by springs and was not thought to be likely to dry up completely in the summer. It was said to have a population of carp, and provided habitats for pukeko, wild ducks, and free-ranging geese, as well as providing drinking water for sheep and cattle. The ephemeral stream which feeds the dam flows mainly in the winter and spring, running about 1.75 km from the top of the catchment through sheep/beef farms and finally through a smaller shallower dam on Mr. Morris's property before entering the larger lower dam. (Figures 3.1, 3.2.)

The larger lower dam was selected for study because it was on a mixed sheep/beef farm, the stock had direct access to the water, the water supply was normally present the whole year round, and there were few other animal species present.

1.1 Soils:

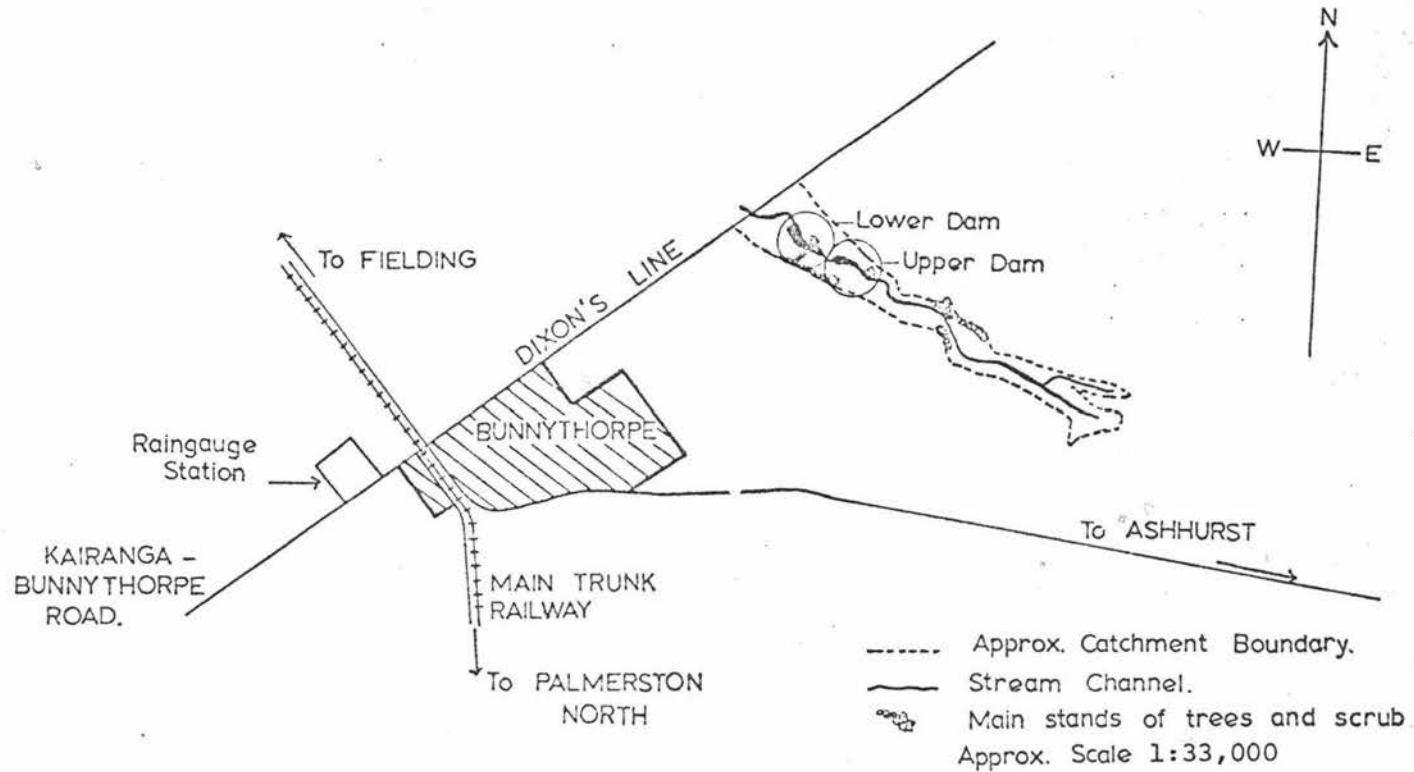
The soils of the catchment are located in a Marton silt loam - Halcombe silt loam complex (Gibbs, 1956). These soils are weakly leached, strongly gleyed yellow/grey earths. The Marton silt loam is found on undulating high terraces, being formed from thin deposits of loess under low to moderate rainfall with a dry summer season. The soils are poorly drained with a compact fragipan at about 76 cm (30"). Internal drainage is very slow. The natural nutrient status is moderate, with low phosphate (1-2 mg % Truog P.) and medium potassium (0.5-0.8 m.e. % exchangeable K) and calcium (5-10 m.e. % exchangeable Ca). Under pasture the soil responds to topdressing with phosphate, lime and potash, and soil erosion is negligible. When the rolling land is cultivated, slight sheet erosion may occur (Cowie, 1972). In the upper layers under rough pasture, the soil pH is around 6, these layers containing 3-5% carbon, and 0.2-0.4% nitrogen, with a C/N ratio of about 12 (N.Z. Soil Bureau, 1968).

1.2 Farming Activities:

From 1971 to June, 1972, Mr. Morris ran sheep and beef cattle at the rates of 2.6 sheep/ha and 0.01 steers/ha. Grazing was largely by set stocking with periods when the paddocks were spelled. No fertilizer was

LOCATION MAP OF AREA AND CATCHMENT

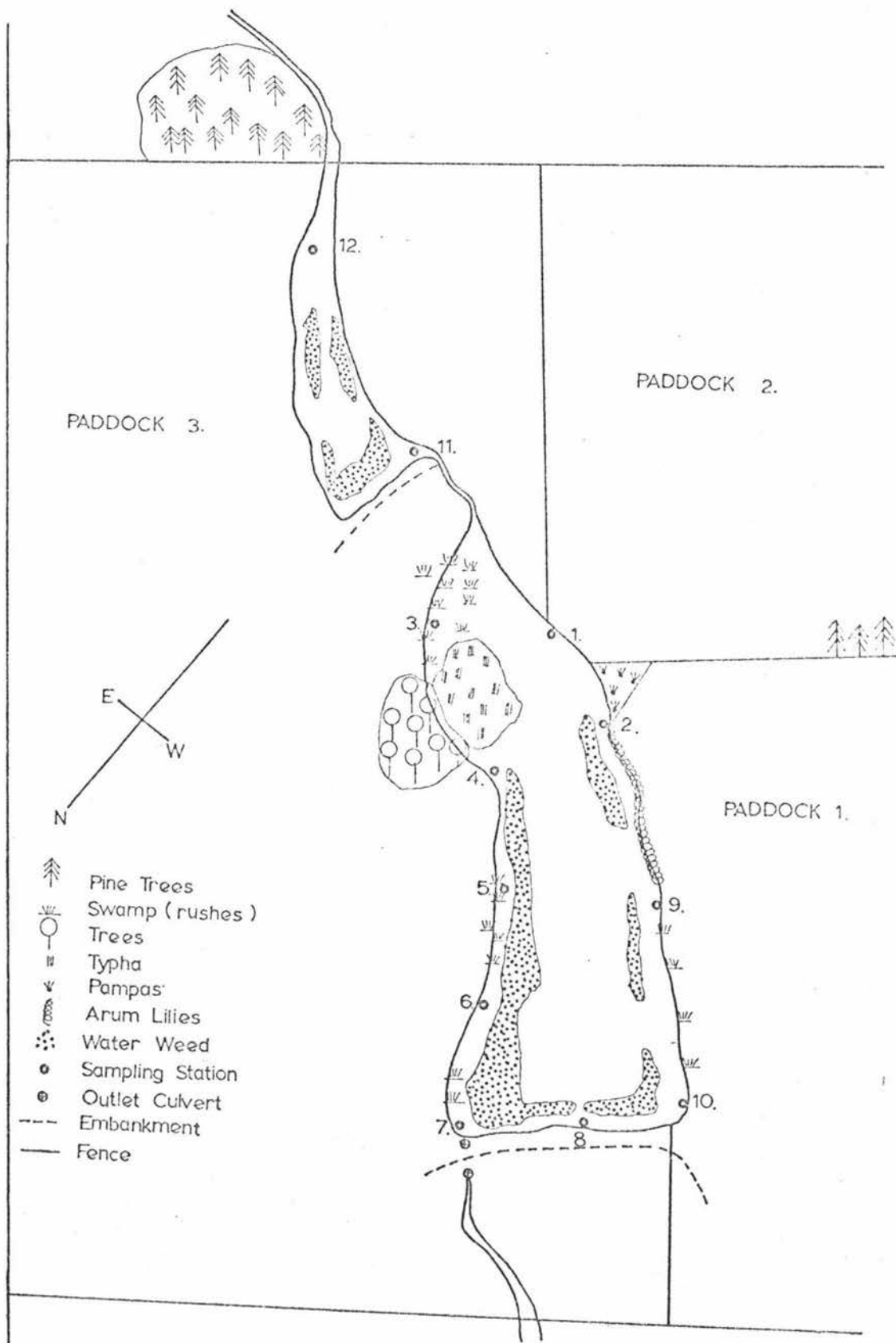
Fig. 3-1



Sketched from Lands and Survey Aerial Photographs 4147/23, 4147/24 - 21-3-68.
 Map Reference : N149:143457 and Approx. Elevation : 75 m.a.s.l. (Lands and Survey - NZMS.1.)

SKETCH MAP OF UPPER AND LOWER DAMS.

Fig. 32



applied and no land was taken out of pasture for cropping purposes during that period. Fertilizer had previously been applied at the rate of 486 kg/ha of superphosphate in the spring of 1971 - about October. The paddocks around the dams were most frequently grazed by sheep.

In June, 1972 the property on which the dams were situated was purchased by Dr. Griffith, who owned the dairy farm on the other side of the road. His sharemilker^x then began to farm the property, running dairy cows and replacement stock. He rotated the cattle around the paddocks, using an electric fence to break-feed in the spring. In October, 1972 365 kg/ha of superphosphate was applied to the paddocks around the dams. That spring the paddock on the eastern side of the dams was ploughed out of pasture and a crop of turnips sown. Owing to the drought, the crop was not good and the area was re-sown in choumoellier. However, over the summer, the area remained largely bare ground. Stock continued to graze the paddocks west of the dam, although there was little grass growth, so that grazing was very spasmodic.

2. Sampling:

2.1 Sites:

Initially, ten sites around the edge of the lower dam were selected for sampling stations (Figure 3.2). Stations 1, 3, 4, 5, 6, 7, and 10 appeared to be stock drinking sites, while stations 2, 8, and 9 appeared to be inaccessible. However, over the dry summer, stock was observed to drink at most sampling stations from time to time.

In October, 1972 two sampling stations (11 and 12) on the upper dam were selected, and the sample collection at stations 5 and 8 on the lower dam was discontinued.

2.2 Frequency:

From one to four samples were collected each month from November, 1971 to January, 1973, except June, 1972. In November and December, 1971 the tests were being familiarised and not all were completed on each run. Regular results were collected from January, 1972.

2.3 Collection and Storage:

All samples were collected from surface waters at the edge of the dam. Samples for bacterial counts were collected in dry, sterile 270 ml glass bottles with aluminium caps and rubber seals, taking appropriate care to avoid contamination. Dissolved oxygen and BOD₅ samples were collected in 300 ml bottles with ground glass stoppers. Care was taken to avoid aeration during sample collection. Samples for chemical analysis were collected in clean, dry 270 ml bottles with aluminium caps and rubber seals. All chemical and bacteriological bottles were labelled

^x Mr R.G. Clapperton

permanently and used each time to collect a sample from the same station. They were not cleaned with chemicals or detergents but were rinsed with cold then hot water and brushed, and finally rinsed well with distilled water and dried.

Dissolved oxygen was fixed within 30 minutes of sample collection and BOD₅ samples were transported to the laboratory and immediately placed in the covered water bath at 20°C. Bacteriological and chemical samples were transported to the laboratory at air temperature and arrived within 1½ hours of collection. They were immediately placed in the refrigerator at 4°C, and analyses carried out within 6-8 hours of collection. On return of chemical samples to the laboratory, pH was measured immediately and the samples were then stored at 4°C and analysed within 6-48 hours of collection. Samples for the analysis of NH₃, NO₃, NO₂ and ortho-phosphate were centrifuged at 9,000 r/m (5,000G) for 10 minutes. All absorbance readings were made on a Beckman DB180 spectrophotometer.

At the time of sample collection, the air and water temperatures were recorded, and the climatic conditions of wind direction and strength, cloud cover, sunlight and the presence or absence of rainfall were observed. Any signs of recent animal activity at the water's edge or in the water at sampling stations were observed and recorded, as was the presence of animals in the surrounding paddocks.

Monthly rainfall records from the Bunnythorpe Station E05261 were supplied by the N.Z. Meteorological Service. This station is situated about 2.3 km west of the site.

3. Physical Tests:

3.1 Temperature:

Water temperature was measured with a mercury thermometer, 0 to 50°C in 0.1°C divisions, or -5 to 100°C in 0.5°C divisions.

3.2 Turbidity:

Water turbidity was measured as light absorbance in a 1 cm cell at 420 nm against a distilled water blank. The water sample was shaken immediately before "turbidity" was measured. Although this was not a nephelometric measure of turbidity, it was measured over the duration of the survey for comparative purposes.

4. Bacterial Counts:

4.1 Total Plate Count:

Appropriate dilutions of the samples were prepared in 9 cm³ sterile 25% Ringer's solution (Oxoid Tablets) and pour-plated in duplicate 1.0 cm³ amounts with BBL Standard Methods Agar (Tryptone Glucose Yeast Extract Agar). The plates were inverted and incubated at 37°C for 24 hours before counting. An American Optics Quebec Colony Counter with Wolfheugel

rulings and 1.5x magnification was used for counting with the aid of a hand tally counter. Plates containing 30-300 colonies were counted (Standard Methods*).

4.2 The Multiple Tube Dilution (MTD) Coliform Method:

Presumptive coliform counts were made using MacConkey Broth (Report No.71⁺), inoculating 5 replicate tubes of 3 decimal dilutions. Positive tubes were sub-inoculated into further MacConkey Broth tubes for the 44.0°C Eijkman test. The tables in Standard Methods (1971) were used to determine the Most Probable Numbers (MPN).

4.3 Membrane Filter Method:

Appropriate volumes or dilutions of sample were filtered through Gallenkemp type FD 300 Filter Units with sintered glass supports, silicone O-rings, and 100 ml capacity funnels. Ten of these filters were used so that one could be used for the samples from each individual station. The smallest volume (highest dilution) was filtered first, proceeding to the larger volumes so that with adequate rinsing, sterilisation between filtrations was not necessary. All filtrations were made in duplicate.

For volumes less than 5 ml, 5 ml of sterile 25% Ringer's solution was poured into the funnel just before the sample was added and mixed by gentle swirling. The samples were vacuum filtered using an Edwards High Vacuum pump, type RB4. The sample was rinsed through twice with sterile 25% Ringer's solution, then the filters were transferred aseptically to the broth-saturated pads in petri dishes.

Oxoid cellulose acetate discs of mean pore size 0.45 µm and 47 or 55 mm diameter were used. They were autoclaved as directed. Fifty mm absorbant pads or 55 mm Whatman No.1 filter papers (3 for each pad) were sterilized at 121°C for 15 minutes in glass petri dishes wrapped in Kraft paper.

Batches of four pads were placed in sterile large pyrex petri dishes and 1.8-2.2 cm³ of media pipetted onto each pad, any excess media being removed from the dishes.

4.4 Membrane Filter (MF) Coliform Method:

Membranes were transferred to pads saturated with 0.4% Teepol Broth (Taylor and Burman, 1964). The broth was prepared as described, but the phenol red was added as 0.05 g soluble powder, the dry ingredients then

*Standard Methods refers to "Standard methods of the examination of water and wastewater", 13th ed., APHA & AWWA, 1970.

⁺Report No.71 refers to "The bacteriological examination of water supplies", Report on Public Health and Medical Subjects, No.71. Ministry of Housing and Local Government. HMSO, London, 1973.

being dissolved in 262.5 cm³ of distilled water.

Total coliform membranes were incubated for 4 hours at 30°C, then for 14 hours at 37°C, while faecal coliform membranes were incubated at 37°C for 2 hours then at 44°C for 16 hours. Bright yellow colonies were counted on plates with 20 to 80 coliform colonies.

The MF method was tested against the MTD method as recommended by Geldreich ^{et al} (1967) except that only the presumptive MTD coliform and elevated temperature faecal coliform tests were used. Both MF coliform counts fell within the MPN ranges in most cases, but in some cases were higher. On average, total coliform MF counts were 2.1 times the MPN mean counts, and faecal coliform MF counts were 1.4 times the MPN mean counts. This was considered to be a reasonable difference and the MF method was adopted, although both coliform counts were thought to be over-estimating the number present.

4.5 Confirmatory Tests for Coliforms:

From time to time, colonies were selected from faecal coliform membranes and subjected to confirmatory tests (Standard Methods, 1971). Over 90% were found to be IMViC + + - - Gram negative rods which fermented lactose. Thus the MF faecal coliforms were considered to be mainly Gram negative rods, capable of growth at 44°C on 0.4% Teepol Broth which produced acid from lactose within 18 hours. They were not necessarily E. coli type I but were mainly of the IMViC + + - - strain.

4.6 The Faecal Streptococcal Test:

The MF method was used according to the BBL Manual, using BBL KF Streptococcal Broth, prepared as specified (BBL, 1968). The filters were incubated for 24 hours at 37°C, and all pink or red colonies were counted.

4.7 Confirmation of Faecal Streptococci:

From time to time, colonies were selected from faecal streptococcal plates and streaked onto Barnes Thallous Acetate Agar (BBL, 1968) or Mead's Tyrosine Sorbitol Agar (Burman et al, 1969). Most cultures grew to produce colonies typical of S. faecalis, S. faecium, S. durans and S. bovis. It was concluded that the MF test was selective for members of the Lancefield Group D. Streptococci.

5. Chemical Tests:

5.1 Dissolved Oxygen:

The Alsterberg Azide modification of the Winkler test was used, as described in Standard Methods, 1971. The azide removes interference by nitrite. Saturation values were obtained from Golterman (1970).

5.2 Biochemical Oxygen Demand:

A duplicate 300 ml sample in a bottle with a ground glass stopper was placed in the water bath with lid for 5 days at 20°C. On some occasions it was necessary to dilute the samples at ratios of 1:2, 1:3 or 1:4. Aerated distilled water was used for this, not buffered dilution water as recommended in Standard Methods. After the 5 days incubation, the final dissolved oxygen was measured by the Winkler test as in 4.1.

5.3 Ammonia:

The method of Harwood and Kuhn (1970) was used. A sample containing ammonia was treated with phenol (phenate) and hypochlorite. In the presence of sodium nitroprusside as catalyst, a blue colour develops rapidly at room temperature, the intensity being proportional to the ammonia content of the sample. The optical density was read at 630 nm against an ammonia-free blank. A standard curve was prepared for solutions containing 0.1-20 ug $\text{NH}_4\text{-N}$. When excessive colour or turbidity in the centrifuged sample was thought to interfere with the test, the light absorbance of the sample at 630 nm was read and a sample blank correction made. The minimum detectable level was 5 ug $\text{NH}_4\text{-N/l}$.

5.4 Nitrite:

The sulphanilamide-ethylene diamine method was adapted from the methods in the IBP Handbook No.8 (Golterman, 1970) and Strickland & Parsons (1968). One cm^3 of a 1% acid solution of sulphanilamide was added to 50 ml of sample which was mixed and allowed to react for 7-8 minutes. One ml of 0.1% ethylene diamine solution was then added, mixed, and allowed to react for 10 minutes to 2 hours before measuring the extinction against a distilled water blank at 543 nm. A calibration curve was prepared in the range 1-30 ug of nitrite-N using diluted KNO_2 standard solution. In this range the curve is linear. A sample blank read at 543 nm was used if necessary. The minimum detectable level was 5 ug $\text{NO}_2\text{-N/l}$.

5.5 Nitrate:

Nitrate was determined by an adaptation of the methods of Strickland and Parsons (1968) and Standard Methods (13th edition, 1971). A 300 mm glass column with a 100 ml thistle funnel was prepared as described in Standard Methods. Cadmium filings were prepared from a cadmium ball and the column was packed according to Strickland and Parsons. After packing, the column was rinsed with dilute ammonium chloride solution and when the column was not in use this solution was allowed to cover completely the cadmium filings.

Each day the column was used, blank and standard solutions were

passed through it before passing the samples through.

Two ml of conc. NH_4Cl solution was added to 80-90 ml of sample and mixed well. About 5 ml was poured into the column and allowed to pass, discarding the eluate. The remainder of sample was then added and the first 40 ml collected in the collection vessel which was then rinsed and used to collect the remainder. Fifty ml of this final eluate was rapidly emptied into a flask and treated as for nitrite (5.4). A sample blank read at 543 nm after the sample had been passed through the column was used if necessary.

When all samples had been passed through the column, it was rinsed with dilute NH_4Cl and blanks and standards again passed through and tested for nitrite, finally rinsing the column with dilute NH_4Cl . With the standard solution, 50 ml was used for initial flushing.

Each day, three standards in the range 0.01-0.5 $\mu\text{g NO}_3\text{-N/cm}^3$ were checked in duplicate. When the resulting capacity fell markedly and the standard curve lost linearity, the column was re-made.

If necessary, samples were diluted with nitrate-free water to contain less than 0.5 $\mu\text{g/cm}^3$ of nitrate-N. The minimum detectable level was 5 $\mu\text{g NO}_3\text{-N/l}$.

5.6 Soluble Phosphate:

The Molybdate-ascorbic acid method of Golterman (IBP Handbook No.8, 1970) was used. In strongly acid solutions, orthophosphate ($\text{PO}_4^{\equiv -\text{P}}$) forms a yellow complex with molybdate ions which can then be reduced to a highly-coloured blue complex. If ascorbic acid is used as the reducing agent, the formation of the blue colour is stimulated by antimony. After 10 minutes the absorbance can be read at 735 nm. A sample blank read at 735 nm was used if necessary.

Standard curves were prepared in the ranges 5-40 $\mu\text{g PO}_4^{\equiv -\text{P}}$ and 0.5-5 $\mu\text{g PO}_4^{\equiv -\text{P}}$. The minimum detectable level was 10 $\mu\text{g PO}_4^{\equiv -\text{P/l}}$.

5.7 Digestion for Organic Nitrogen and Total Phosphate:

The IBP method was used. Fifty ml of sample was digested in a long-necked Kjeldahl flask with 4 ml c. H_2SO_4 and 10 drops (0.5 ml) 10% CuSO_4 solution. Sixty ml flasks were used, so 25 ml of water sample was initially evaporated down by gentle boiling with the acid and CuSO_4 . After cooling, a further 25 ml of sample was added, evaporated down and finally digested until fuming ceased and the solution cleared. If necessary, H_2O_2 was added after digestion as directed.

The digest was nearly neutralised with 10N NaOH and then washed carefully into a Volumetric flask and diluted to 100 ml after cooling. Up to 40 ml was used for the phosphate determination (5.6). A small

aliquot was used for ammonia determination by the phenol-nitroprusside test (5.3). Because the ammonia test was not operating satisfactorily until Run 17, total nitrogen results (organic + ammonia nitrogen) were recorded throughout and organic nitrogen concentrations as well were calculated from Run 17 onwards.

6. Bacterial Growth Experiments:

Several types of experiment were undertaken to investigate the growth response of heterotrophic bacteria, coliform bacteria, and faecal streptococci in the waters being studied. The first of these was concerned with the response of bacteria in the fresh and sterilized water to nitrate and phosphate additions. Others investigated the growth and survival of the bacteria in sterilized and fresh samples of "high fertility" and "low fertility" waters. All experiments were carried out at $26.0 \pm 1.0^{\circ}\text{C}$ unless otherwise stated.

6.1 Materials:

6.1.1 Glassware:

All flasks and other glassware used for these experiments were acid-washed, rinsed well with distilled water and dried before samples were added. Where necessary, flasks were sterilized by autoclaving and dried overnight at 60°C with cotton wool plugs intact before samples were added.

6.1.2 Water Samples:

Water for sterilization was collected in 2 l flasks or 1 l pyrex bottles. The samples were pre-heated in the steamer and then autoclaved at 121°C for 10 minutes. Before use for any experiments, sterility was checked by plating five 1.0 ml aliquots in Standard Methods Agar and incubating for 24 hours at 37°C .

6.1.3 Innocula:

Pure cultures of bacteria were prepared from colonies picked from faecal coliform test or faecal streptococcal test membrane filters. Faecal coliform colonies were subject to confirmation of lactose fermentation on EMB agar. Single colonies were re-streaked on MacConkey agar the next day and lactose⁺ isolates were subject to the Eijkman, IMViC and Triple-Sugar-Iron tests. A nutrient agar slant was prepared from Gram strain preparation and as a stock culture. Faecal streptococci were confirmed by streaking onto Thallous Acetate Agar (BBL, 1965) with incubation at 44°C for 24-48 hours. In some cases, Meads Tyrosine Sorbitol Agar (Burman et al,¹⁹⁶⁹ was also used. Nutrient agar slants were inoculated from stock cultures.

For the early growth experiments, pure cultures were inoculated into brain heart infusion broth (500 cm^3) and incubated on the shaker at 37°C for 12 hours. The culture was then transferred to sterile centrifuge bottles and centrifuged at 5,000 G for 10 minutes and re-suspended in minimal medium. After re-incubation on the shaker at 37°C for 4 hours, the culture was re-centrifuged at 5,000 G. The broth was then transferred to sterile centrifuge bottles and centrifuged at 5,000 G for 10 minutes. The supernatant fluid was discarded and the cells re-suspended in sterile 25% Ringer's solution, re-centrifuged, and finally re-suspended in sterile 25% Ringer's solution and standardised to an Optical Density of 300 Klett Units (1/10 dilution = 30 K.U.). A 10^{-4} dilution of this stock culture was prepared and 1.0 cm^3 inoculated into the 50 cm^3 sample to bring the initial cell concentration to about 10^3 per cm^3 . Since this procedure was tedious and prone to contamination, subsequently only 10 cm^3 of BHI broth in sterile centrifuge tubes was inoculated, incubated, centrifuged and re-suspended, etc. The procedure was still too long, so the cultures were finally grown in peptone water for 18-24 hours and the resultant suspension used as inoculum, either by the loopful or by pipette, depending on the water sample volume.

For the mixed population experiment in sterilized waters, a fresh water sample ($1,000 \text{ cm}^3$) was dispensed into sterile centrifuge bottles and centrifuged at 2,000 G for 20 minutes to remove larger particulate material, including most algae and protozoa. The supernatant liquid was transferred to fresh sterile centrifuge bottles and re-centrifuged at 5,000 G for 10 minutes to collect the bacteria. The pellet was then re-suspended in sterile distilled water and re-centrifuged at 5,000 G for 10 minutes and finally re-suspended in sterile distilled water (Hendricks, 1972). Initially total plate counts were made on samples treated in this way to determine the amount of inoculum required per 500 cm^3 water sample. The resultant suspension was referred to as the "Harvested Inoculum". One ml of harvested inoculum was used to inoculate 500 cm^3 water sample.

6.2 Enrichment Experiments:

A large fresh sample of water was collected and carefully dispensed into clean sterile 2 l flasks. Of ten 500 cm^3 aliquots, 5 were passed through a sintered glass filter of No.3 porosity to remove protozoa and algae. One unfiltered and 1 filtered sample were used as controls, while 2 of each were enriched with 2 levels of nitrate and 2 levels of phosphate. Sub-samples were removed for estimations of bacterial populations and nutrient concentrations. The flasks were then incubated

on a gyratory shaker and sub-samples at intervals of 3 to 10 hours for bacterial population estimates. Changes in optical density were also recorded.

Enrichment of 50 cm³ aliquots of sterilized pond water was also carried out. Pure cultures of bacteria isolated from the water (see 6.5.2) were used as inocula, their growth being followed by means of total plate counts.

6.3 Pure Cultures in Sterilized Water:

Samples of water from both dams were collected and sterilized. Similar samples were subject to bacterial and chemical analysis. The waters from the lower dam were designated "low fertility" as compared to the "high fertility" waters of the upper dam (see 6.5.2). Fifty cm³ aliquots were transferred aseptically to 150 ml flasks. Fifty cm³ aliquots of sterile 25% Ringer's solution were used as controls. Controls and sample flasks were inoculated with pure cultures of faecal coliform and faecal streptococci bacteria. The growth of bacteria was followed by total plate counts made at intervals from 3 to 12 hours with estimations using membrane filtration counts at longer intervals to check for contamination.

6.4 Mixed Cultures in Sterilized Water:

Fifty cm³ aliquots of sterilized water and Ringer's solution controls were inoculated with "harvested inoculum" and faecal coliform and streptococcal cultures. The growth of bacteria was then followed at 6 to 12 hour intervals by means of total plate counts and specific tests for coliforms and faecal streptococci.

6.5 Bacterial Survival:

When fresh samples of water were collected for the growth experiments described in 6.1 and 6.2, several samples of about 250 cm³ were collected in sterile 270 cm³ bottles. After the initial estimations of bacteria and chemicals, unopened bottles were shaken, the lids loosened, then the bottles left on the windowsill. These samples were shaken each day, and estimations of bacterial population made at 3 to 4 day intervals for 25 days.

7. Examination of Faeces and Pond Sediments:

Samples of dam sediments, and faeces from cattle, sheep and geese were collected from the vicinity of the dams. The samples were transferred with clean spoons to clean plastic bags which were closed with rubber bands and transported to the laboratory (at air temperature) within 1 hour of collection. The samples were then mixed well either within the bags or in a Waring Blender and mixed samples transferred to sterile petri dishes. Where necessary, sterile distilled water was added to aid mixing

in the blender. 10.0 g amounts were weighed into dry glass petri dishes and placed in the oven at 105°C for drying overnight to obtain an estimate of dry matter content.

For bacterial determination, 1.0 g of each sample was weighed out onto sterile Kraft paper and transferred to a 120 cm³ bottle containing 99 cm³ of sterile 25% Ringer's solution. Five glass beads in the bottle facilitated mixing. As a trial, 0.1 cm³ of Tween 80 solution was added to help remove bacteria from particulate matter. Subsequently, the Tween 80 was not added as it impaired bacterial growth. The bottles were all shaken well for some time and allowed to settle before proceeding to prepare further dilutions. The initial dilution of 1.0 g in 99 cm³ of water was regarded as a 1/100 dilution. Appropriate dilutions were prepared for each sample, and three duplicate dilutions used for tests to estimate the number of total heterotrophic bacteria (TPC), total and faecal coliforms and faecal streptococci.

8. Statistical Analysis of Data:

A Burroughs B6700 machine at the University of Auckland Computer Centre was used, with programmes written in FORTRAN (with Burroughs modifications) by Mr. J.C. Rutherford.

8.1 Testing the Differences Between Animal-Polluted and Un-Polluted Samples:

The Mean and Sum of Squares of each parameter for Animal-Polluted Samples (APS) and Un-Polluted Samples (UPS) for each run were calculated using the standard formulae (Kreyszig, 1970), i.e.,

APS = samples taken where signs of the presence of livestock or wildlife had been recorded, and those where stock in the adjacent paddock had access to the sampling station;

UPS = samples taken where no animal signs or presence were recorded.

$$\text{Mean} = \bar{X} = \frac{1}{n} \sum_{j=1}^n X_j.$$

$$\text{Sum of Squares} = SS = \sum_{j=1}^n (X_j)^2 - n(\bar{X})^2.$$

The difference between the two means so obtained was compared by determining the statistical t value, i.e.,

$$t \text{ value} = t_o = \sqrt{\frac{n_1 n_2 (n_1 + n_2 - 2)}{(n_1 + n_2)}} \cdot \frac{(\bar{X}_1 - \bar{X}_2)}{\sqrt{(SS_1 + SS_2)}}$$

where subscript 1 refers to UPS and subscript 2 to APS. The significance of t_o was tested against the 70% confidence interval value of the t-statistic with $n_1 + n_2 - 1$ degrees of freedom.

8.2 Covariance Analysis:

The covariance between pairs of parameters was determined for APS and UPS and the coefficients of the linear regression line obtained using the standard statistical formulae, i.e.,

$$S_X = \sqrt{\frac{\sum (X^2) - n (\bar{X})^2}{n - 1}}$$

$$S_Y = \sqrt{\frac{\sum (Y^2) - n (\bar{Y})^2}{n - 1}}$$

$$S_{XY} = \sqrt{\frac{\sum (XY) - n\bar{X}\bar{Y}}{n - 1}}$$

$$\text{Covariance} = \frac{S_{XY}}{S_X S_Y}$$

$$A = \frac{[\sum Y \sum (X)^2 - \sum X \sum XY]}{n \sum (X)^2 - (\sum X)^2}$$

$$B = \frac{n \sum XY - \sum X \sum Y}{n \sum (X)^2 - (\sum X)^2}$$

where A and B apply to the formula $Y = A + BX$, and CVR is the covariance between the two parameters, i.e., the regression coefficient. Correlation coefficients of 0.65 or more were considered to indicate a significant correlation, those of 0.05 or more being reported for comparative purposes. Where there was a correlation of more than 0.50 in either APS or UPS, the corresponding correlation was reported.

8.3 Bacterial Parameters:

Bacterial results were converted to natural logarithms (\log_e) for the statistical analysis, thus obtaining geometric mean values. The linear regression results were converted to common logarithms (\log_{10}).

CHAPTER FOUR

RESULTS

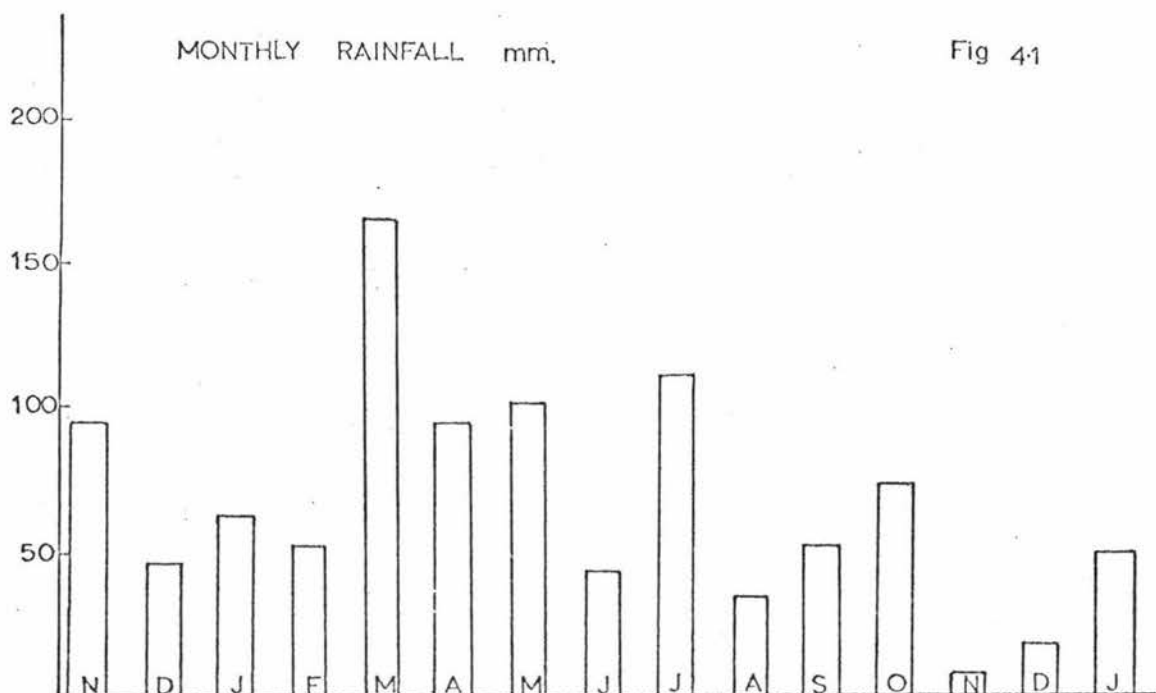
1. The Survey:

1.1. Environmental Factors:

Environmental factors affecting the catchment were recorded. These included weather conditions, stock activities around the dams, rainfall, dam inflow and outflow, and general observations made when sampling (Appendices 2.1, 2.2 and 2.3).

Various classes of sheep (ewes, hoggets, lambs) and a few steers were grazed around the dams from December, 1971 to July, 1972. Dairy stock were grazed spasmodically from then onward. Domestic geese, pukeko and wild ducks also frequented the dams.

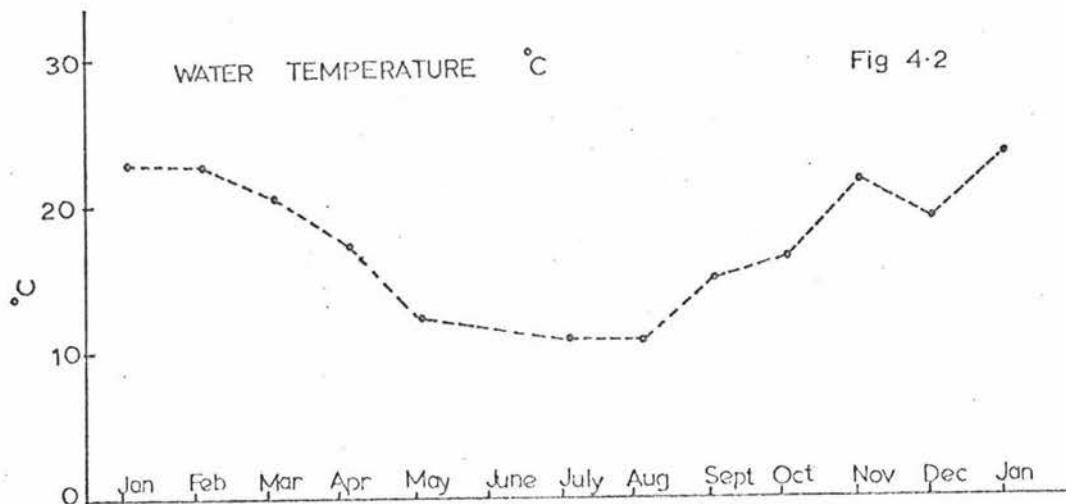
The monthly rainfall and weather conditions measured at the Bunnythorpe Meteorological Station (Appendix 2.3) were supplied by the N.Z. Meteorological Service. The wettest months were March and July, 1972 (Fig. 4.1), and the 5-day period before the July sampling received the



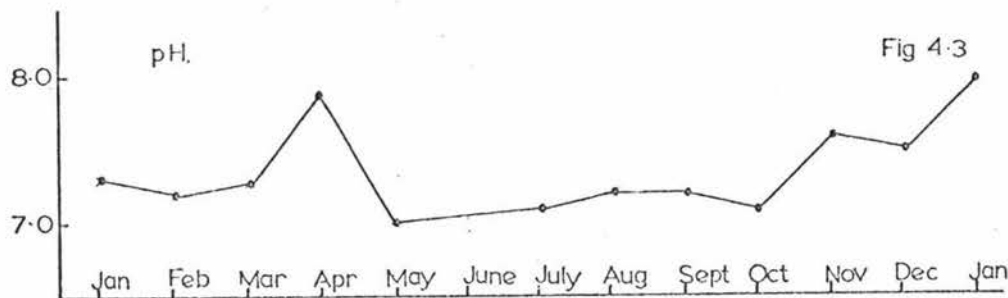
most rainfall. Runoff was recorded from April to mid-October, and the tile drains operated from mid-May to mid-October. The maximum flow through the dams was observed in July. November, 1972 was extremely hot and dry, and although there was some rain in December, 1972 and January, 1973, both months were extremely hot and no flow through the dams was recorded.

1.2 The Lower Dam:

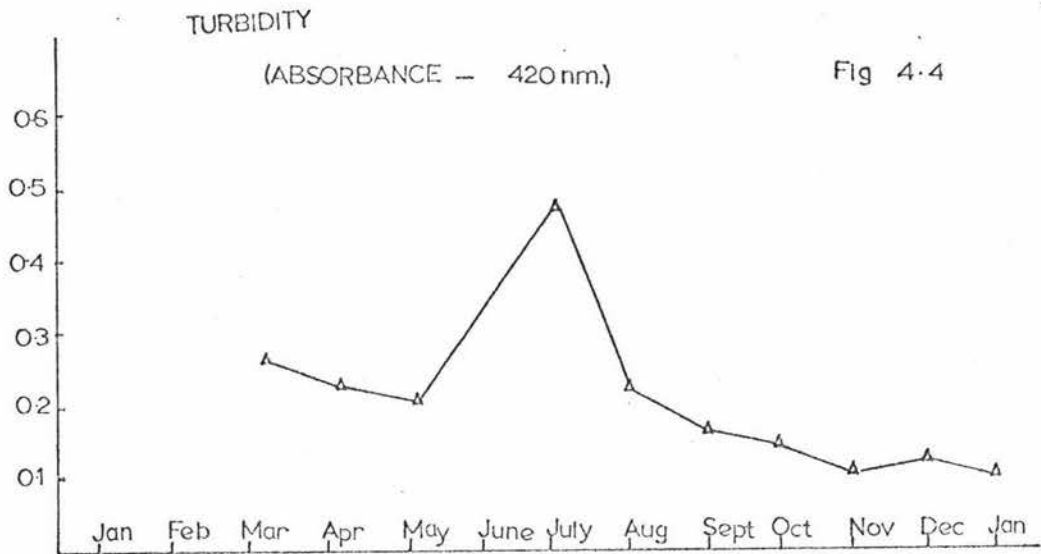
Overall mean monthly results appear in Figures 4.2 to 4.10 and the tabulated data for these appears in Appendix 4. Detailed records for each station are listed in Appendix 3.



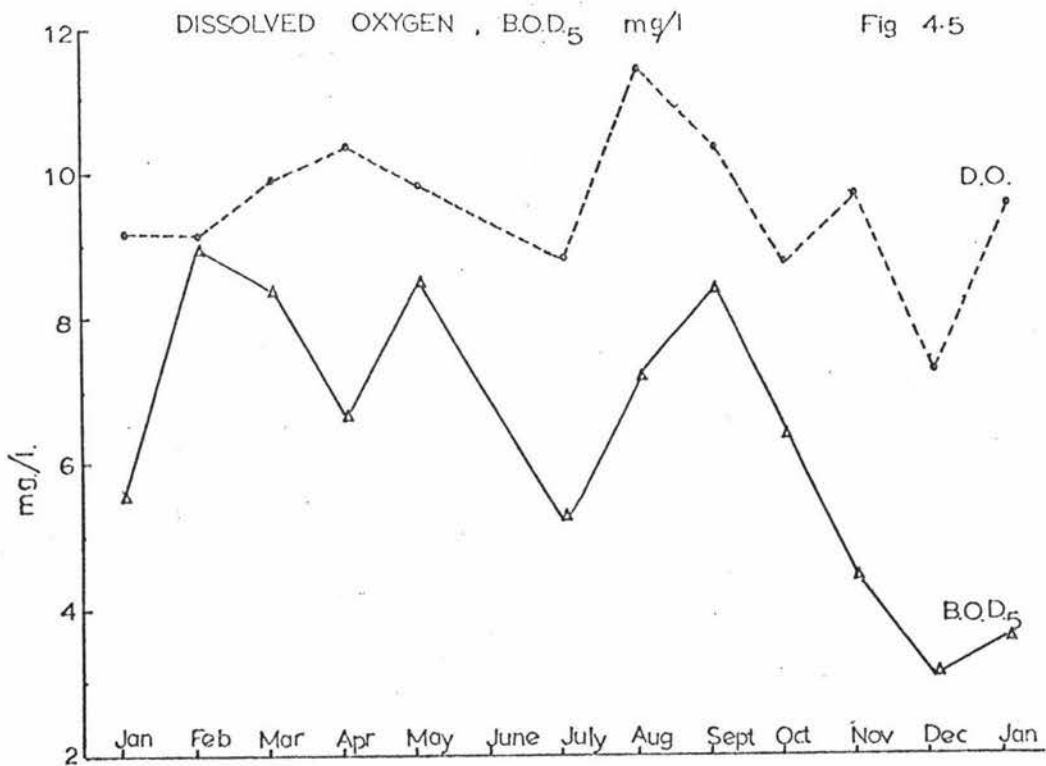
The normal seasonal temperature variation was observed (Fig. 4.2), a minimum of 9.0°C being recorded at several stations on Run 19 (26/5/72), and a maximum of 30.5°C on Run 3 (16/12/71). The 1972/3 summer maximum recorded was 26.0°C at Station 3 on Run 31 (5/1/73).

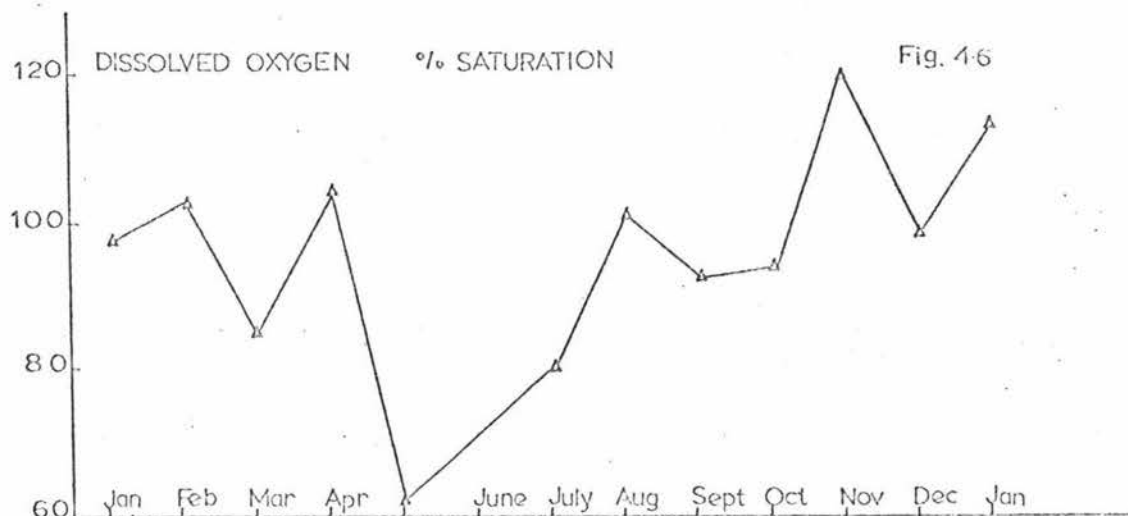


Water pH showed small variations (Fig. 4.3), the lowest values being recorded during the winter. Values from pH 6.4 to 6.9 on Run 18 (16/5/72), from 7.5 to 8.6 on Run 14 (11/4/72) and from 7.2 to 8.6 on Run 32 (15/1/73) were recorded.

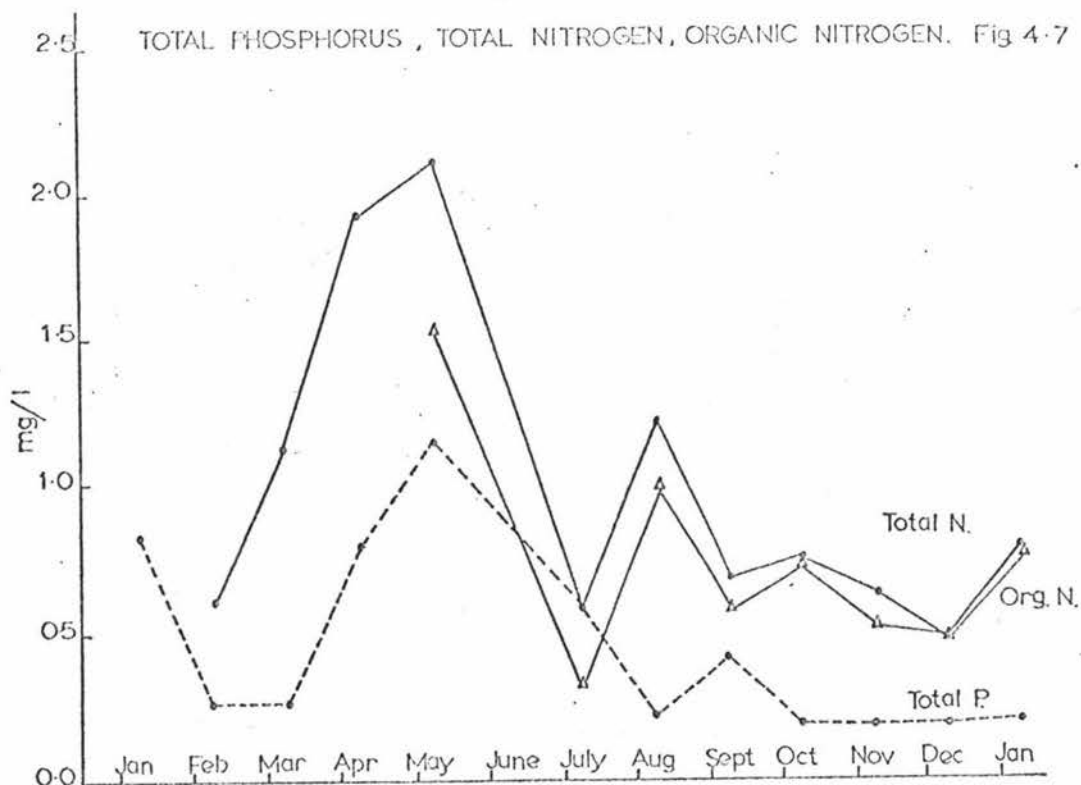


Peak absorbances of from 0.39 to 0.56 occurred in July (Fig. 4.4) as a result of the large amounts of suspended material in the drainage water following rainfall. Minimum values were recorded on 12/12/72, ranging from 0.08 to 0.12, except for Station 9 where recent cattle activity had resulted in mud being stirred up, giving an absorbance of 0.93.

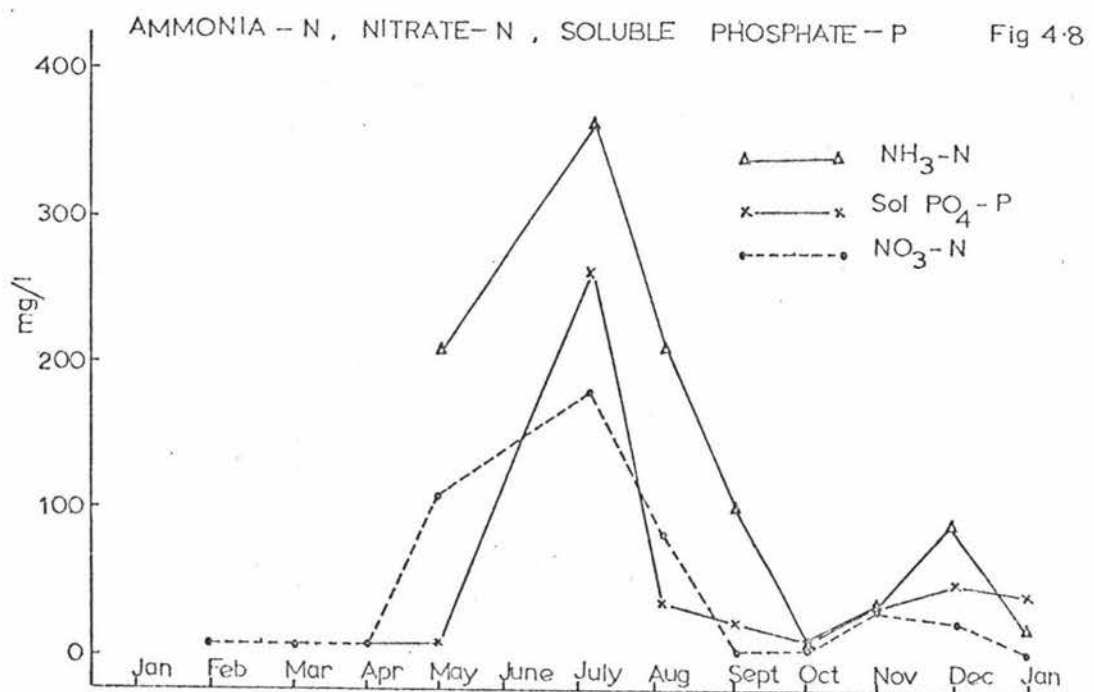




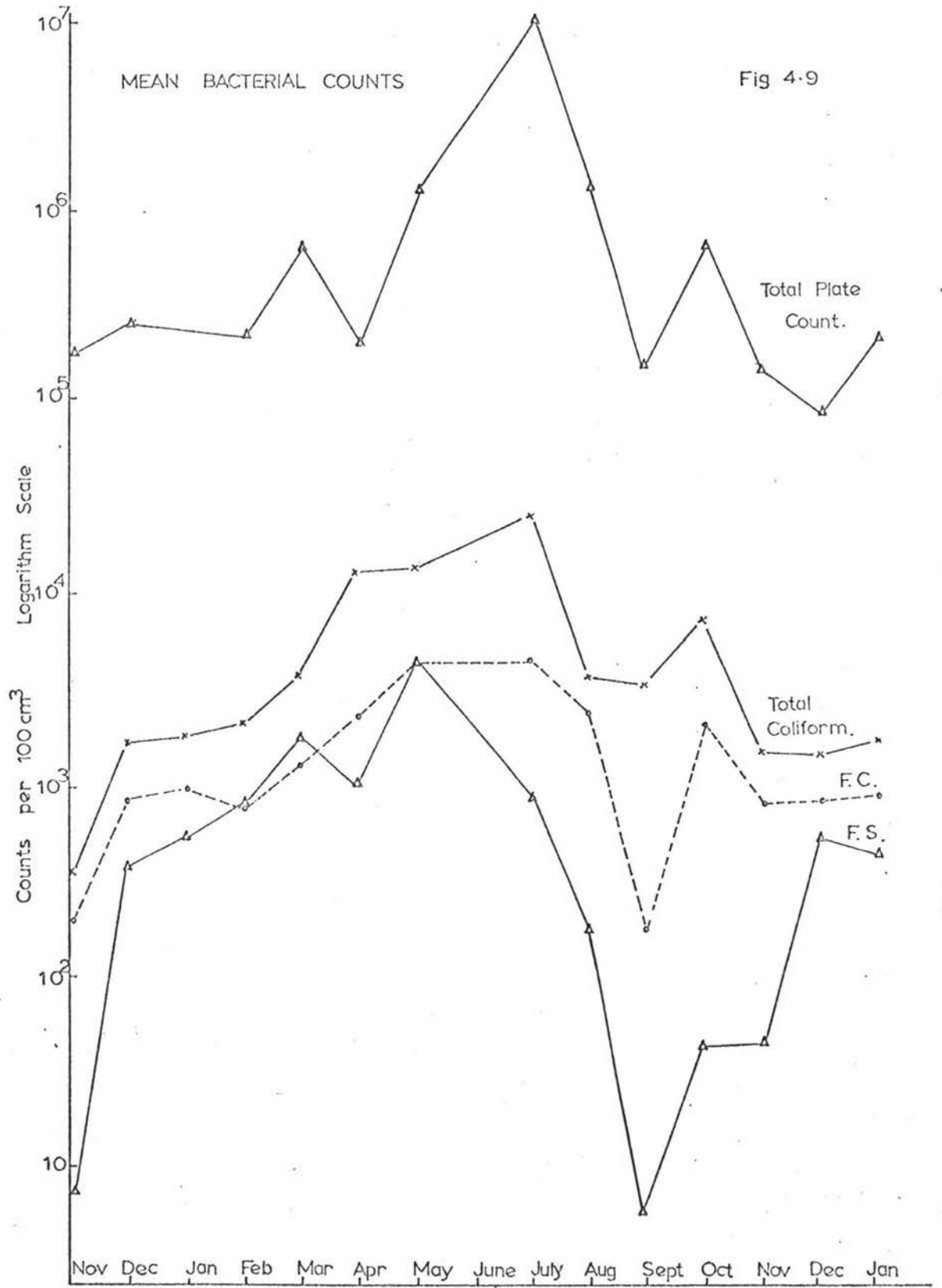
Normal seasonal trends for dissolved oxygen (Fig.4.5) were not observed, at least partly because the samples were not collected at the same time of the day on all occasions (see Appendix 2.1). There were large variations between stations; Station 3 often had much lower levels of dissolved oxygen than other stations because the water there was shallow and the mud putrid. High D.O. concentrations were often observed in the summer at stations with dense weed growth, the highest value of 14.4 mg/l being recorded at Station 4 on 16/12/71. Dissolved oxygen per cent saturation values were lowest during the autumn/winter period (Fig. 4.6). BOD₅ concentrations (Fig. 4.5) were generally indicative of moderately polluted water. High values in the summer/autumn period could have been due to oxidisable products of plant and algal photosynthesis or the presence of algal cells in the samples.



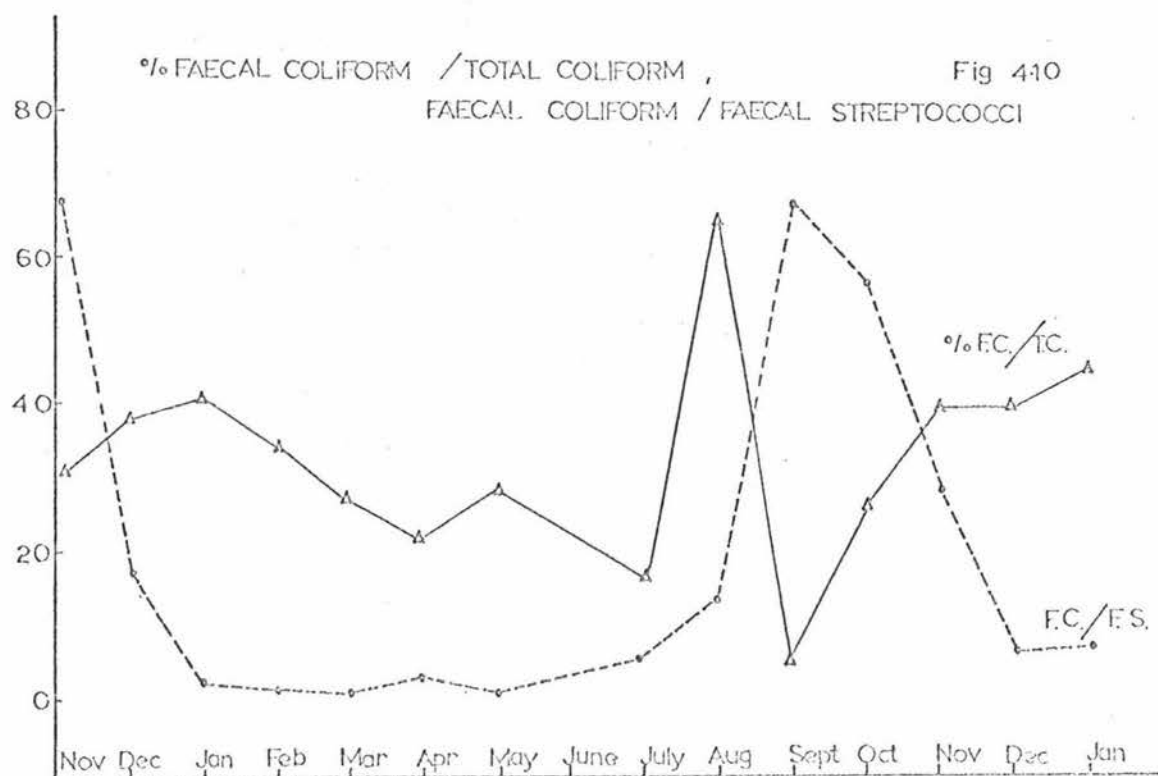
The monthly mean concentrations of total phosphorus, total nitrogen, and organic nitrogen reached a maximum in the May samples (Fig. 4.7). Maximum total N concentrations at most stations occurred on Run 14 (11/4/72), ranging from 2.0 to 3.65 mg/l. On Run 17 (9/5/72) high concentrations at Stations 2 and 3 associated with high BOD_5 and total P concentrations, and the presence of animals and weed, were recorded. Total phosphorus concentrations were also at their maximum in the April/May samples.



Soluble phosphate, ammonia and nitrate reached their peak concentrations in July, when land drainage both as runoff and from the subsurface mole/tile system were at their maximum (Fig. 4.8). Fertilizer applied in October appeared to boost the concentration of soluble phosphate from trace levels although there was a concurrent increase in ammonia and nitrate concentrations. Nitrite appeared spasmodically at detectable concentrations, mainly in the winter. Nitrate concentrations began to increase in April from undetectable levels in March.



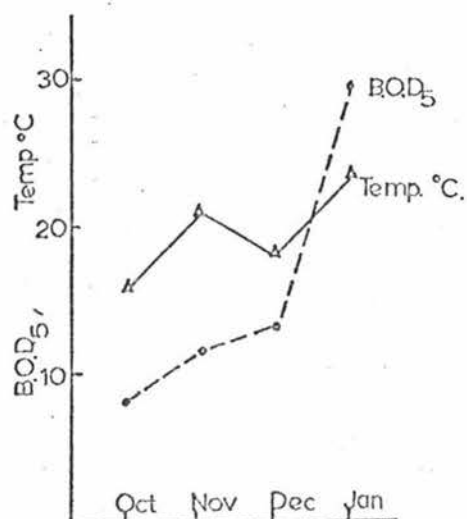
Total plate and coliform counts reached their peak in July (Fig. 4.9). Faecal coliform (FC) bacteria increased in numbers during the grazing periods, and faecal streptococcal (FS) counts showed more sensitive fluctuations due to grazing. This was reflected in the percentage of FC/TC and FC/FS ratio (Fig. 4.10).



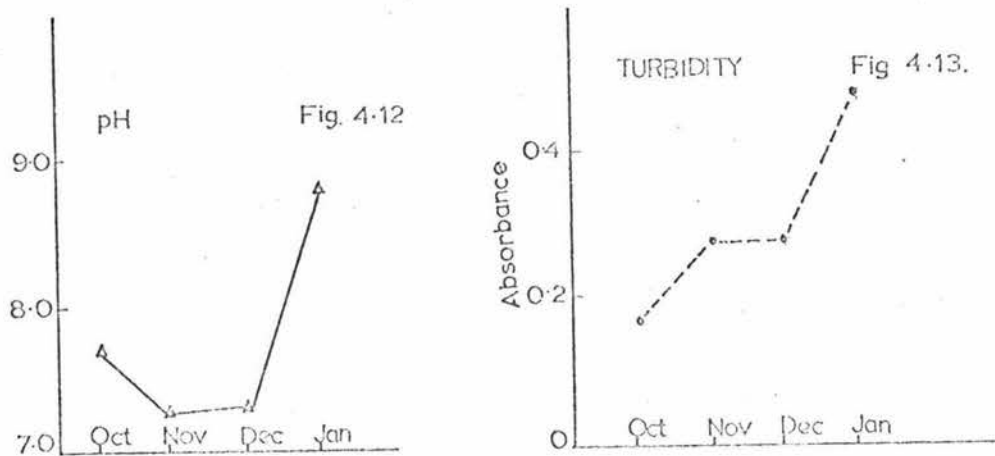
1.3 The Upper Dam:

The mean monthly results appear in Figs. 4.11 to 4.18, the tabulated data for these being listed in Appendix 4. Detailed results can be found in Appendix 3.

TEMPERATURE °C, BOD₅ mg/l. Fig. 4.11

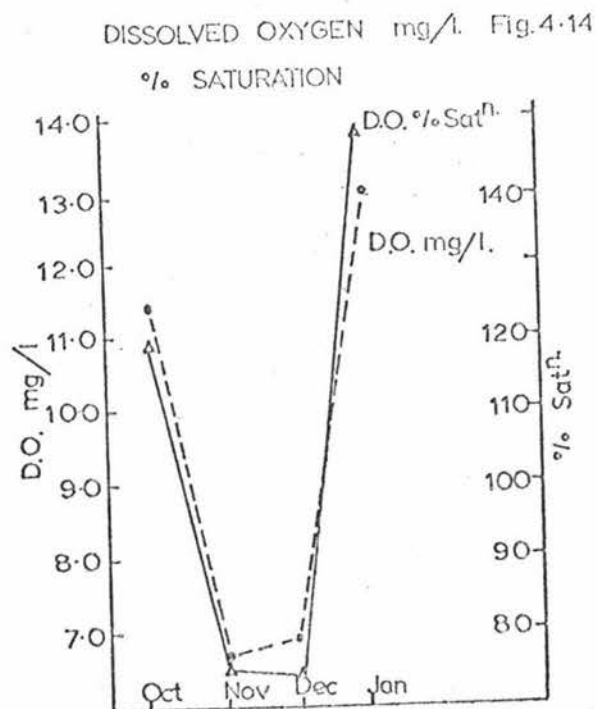


Water temperatures (Fig. 4.11) were similar to those of the Lower Dam, generally increasing from October to January.

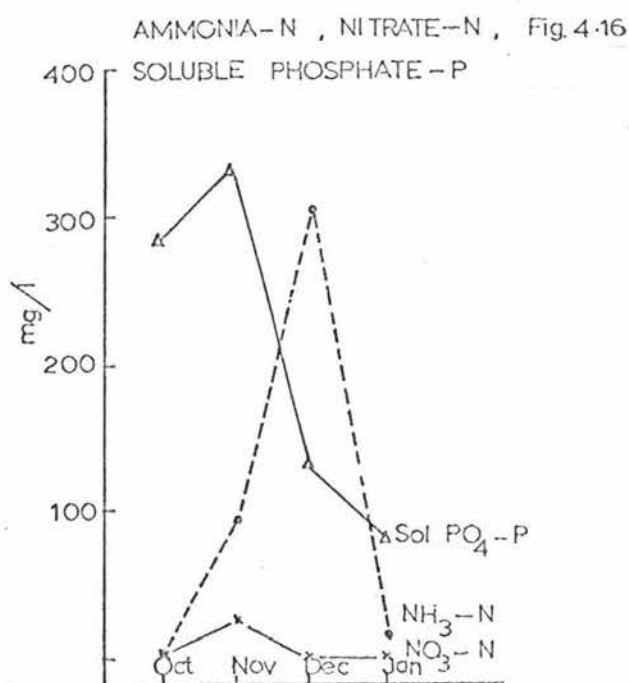
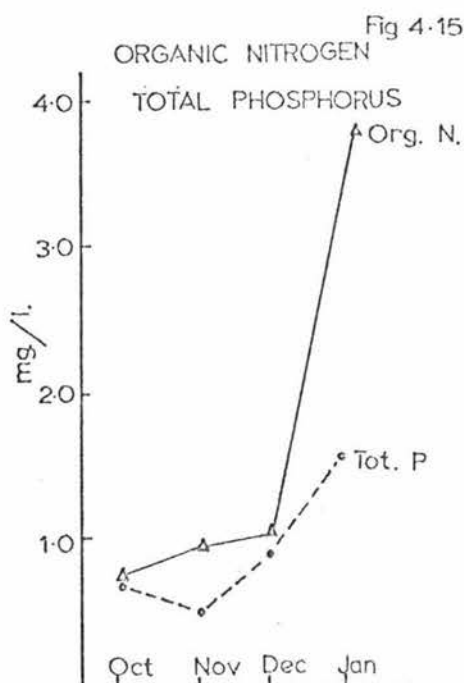


pH values were higher in the upper dam, increasing sharply in January, probably in response to the increase in photosynthesis.

Turbidity in the upper dam (Fig. 4.13) was higher than in the lower dam, and increased from October to January. The high summer values appeared to be the result of large algal populations in the water, since dense beds of filamentous algae were observed when sampling, and increasing D.O. concentrations (Fig. 4.14), pH values (Fig. 4.12) and BOD_5 (Fig. 4.11) were observed in January.



D.O. concentrations were high in October and January, with extreme supersaturation. In November and early December, low concentrations were recorded, associated with increasing BOD_5 and ammonia concentrations. The January increase in BOD_5 concentration (Fig. 4.11) was associated with increasing D.O. so was thought to be due mainly to algal cells and cell products.



Organic N and total P concentrations (Fig. 4.15) increased markedly from values similar to those in the lower dam in October, November and December, to much higher concentrations in January. While soluble phosphate concentrations (Fig. 4.16) were many times higher than those in the lower dam until the end of December, ammonia concentrations increased to higher values in December. Nitrate concentrations were similar to those in the lower dam in the spring but declined more rapidly to undetectable levels in December. Spring nitrite concentrations were higher in the upper dam, and trace concentrations were more prevalent in the summer.

While TPC results (Fig. 4.17) were about 10 times higher in the upper dam than in the lower dam, higher coliform and FS concentrations in October declined to low values in January, whereas in the lower dam coliform and FS concentrations increased in November and maintained high summer levels (Fig. 4.9). Although % FC/TC results were higher in the upper dam samples (Figs. 4.18, 4.10), FC/FS ratios were also higher. This may have indicated that FC organisms were able to survive slightly better than FS in the eutrophic conditions of the upper dam.

Fig 4-17

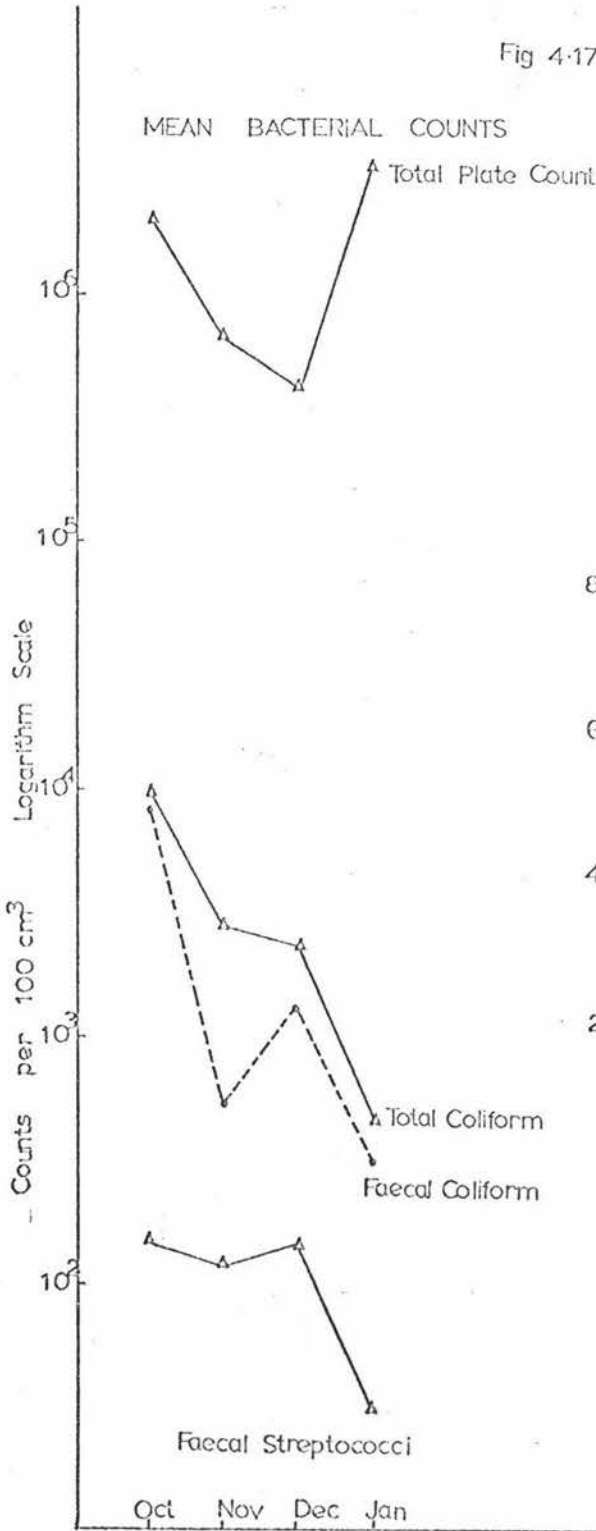
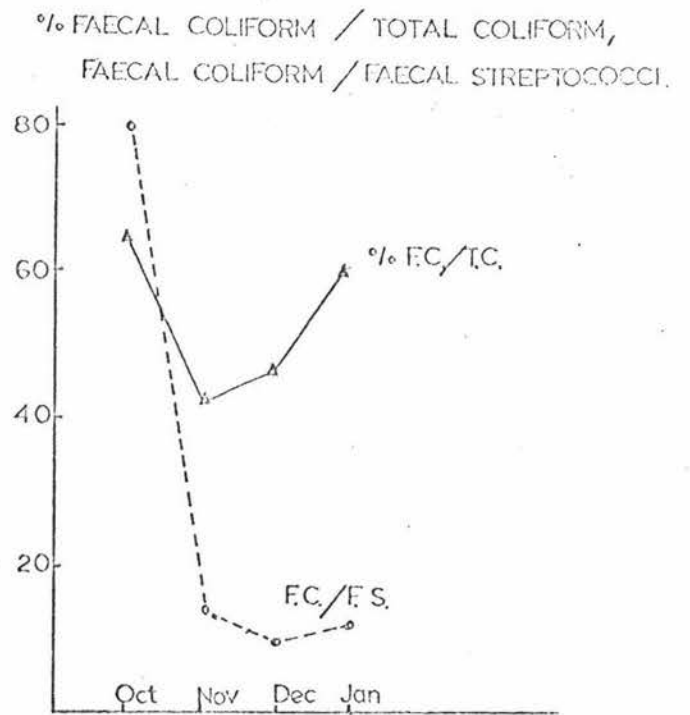


Fig 4-18



2. Statistical Analysis of Data:

2.1 The Effects of Animal Pollution:

Comparison between results for Animal-Polluted Samples (APS) and Un-Polluted Samples (UPS) (Table IX) showed that in 50% or more of comparable samples, turbidity, BOD₅, FS, water temperature and FC results were significantly greater in APS than in UPS. (Water temperature may have fallen into this group because stock tended to drink at stations where there was shallow water rather than steep banks. For example, the recent presence of animals was recorded at Stations 1, 3, 4, 9, and 10 on ten or more occasions. At such stations the water would heat up more rapidly during the day.) Animal pollution had less effect on the chemicals assayed, although total N and ammonia were significantly greater in APS than in UPS for more than 40% of comparable samples. The effects of animal pollution on other parameters was considered to be insignificant.

TABLE IX: Comparison between results for Animal-Polluted and Un-Polluted Samples. Parameters are listed in order of decreasing percentage of comparable sampling runs where APS > UPS at the 70% Confidence Interval.

Parameter	Runs where APS > UPS		Runs where APS ≈ UPS		Runs where APS < UPS		Total No. of Comparable Runs
	No.	%	No.	%	No.	%	
Turbidity	15	75	3	15	2	10	20
BOD ₅	16	57	7	25	5	18	28
Faecal Strep.	12	52	7	30	4	17	23
Water Temperature	15	52	6	21	8	28	29
Faecal Coliform	13	50	11	42	2	8	26
Total N.	9	43	7	33	5	24	21
NH ₃ -N	7	41	7	41	3	18	17
Total Plate Count	10	39	11	42	5	19	26
D.O. % Satn.	11	38	10	35	8	28	29
Total P.	8	36	9	41	5	23	22
Sol. P.	5	33	6	40	4	27	15
pH	8	20	9	33	10	37	27
D.O. mg/l	8	28	12	41	9	31	29
NO ₃ -N	4	27	9	60	2	13	15
Total Coliform	6	24	10	40	9	36	25
NO ₂ -N	1	7	14	93	0	0	15

There were seasonal* patterns in the differences between APS and UPS. Turbidity was consistently greater in APS in the winter, spring and summer, but not in the autumn. BOD₅ concentrations were generally higher in APS in the spring, summer and autumn but not in the winter samples. In spring samples FS and FC results were sometimes greater in UPS; at other times of the year APS results were generally higher.

2.2 The Effects of Rainfall and Drainage:

Correlations between most parameters and rainfall in the five days preceding sampling were generally high (Table X). Where the regression line had a covariance (CVR - correlation coefficient) of 0.65 or more, the parameters were considered to be well-correlated. Parameters not listed had CVR values of less than 0.50.

TABLE X: Correlations between water quality parameters and rainfall (mm) in the five days prior to sampling.

Parameter	Un-Polluted Samples			Animal-Polluted Samples		
	A	B	CVR	A	B	CVR
Water Temp. °C	23.0	-0.19	0.68	22.7	-0.21	0.66
Turbidity	0.09	0.0040	0.72	0.12	0.0044	0.66
NH ₃ -N ug/l	14.6	2.76	0.53	12.9	5.25	0.57
NO ₃ -N ug/l	-0.6	2.25	0.52	-6.2	2.34	0.53
TPC (log ₁₀)	4.98	0.026	0.82	5.01	0.026	0.71
Log ₁₀ TC/100 cm ³	3.01	0.022	0.73	3.11	0.022	0.52
Log ₁₀ FC/100 cm ³	2.40	0.022	0.73	2.65	0.017	0.52

2.3 Parameters Correlated with Water Temperature:

Parameters correlated with water temperature were D.O. as % saturation, ammonia, nitrate, log₁₀ TPC, and log₁₀ TC. Correlations for nitrate and TPC in both UPS and APS were weak, as were those for D.O. and TC in APS.

TABLE XI: Correlations between water quality parameters and water temperature (°C).

Parameter	Un-Polluted Samples			Animal-Polluted Samples		
	A	B	CVR	A	B	CVR
D.O. % Satn.	34.2	3.76	0.72	(66.34	1.96	0.37)
NH ₃ -N, ug/l	328.9	-14.45	0.76	464.2	-19.86	0.66
NO ₃ -N, ug/l	(175.6	-7.41	0.49)	179.4	-7.58	0.55
Log ₁₀ TPC/100 cm ³	6.43	-0.048	0.50	(6.50	-0.052	0.45)
Log ₁₀ TC/100 cm ³	4.86	-0.078	0.66	(4.23	-0.039	0.33)

*Seasons - Summer = November (1971) to January (1972); Autumn = February to April; Winter = May to July; Spring = August to October; Summer = November (1972) to January (1973).

2.4 Parameters Correlated with Turbidity:

Ammonia, nitrate, TPC and FS were the only parameters correlated with turbidity (Table XII). The correlations for nitrate and FS were weak, as was that for TPC in APS.

TABLE XII: Correlations between water quality parameters and turbidity.

Parameter	Un-Polluted Samples			Animal-Polluted Samples		
	A	B	CVR	A	B	CVR
NH ₃ -N, ug/l	-43.5	737.2	0.73	-58.9	992.9	0.72
NO ₃ -N, ug/l	-33.1	479.8	0.58	(-2.82	215.5	0.43)
Log ₁₀ TPC/100 cm ³	4.76	4.39	0.74	4.99	2.55	0.55
Log ₁₀ FS/100 cm ³	(1.33	3.32	0.45)	1.65	3.57	0.54

2.5 Correlations Between Non-bacterial Parameters:

Some correlations were observed between chemical parameters (Table XIII). The correlations between pH and D.O. as % saturation were weak, as were those between BOD₅ and total N, and total P and ammonia in APS.

TABLE XIII: Correlations between chemical parameters.

Dependent Parameter	Independ. Parameter	Un-Polluted Samples			Animal-Polluted Samples		
		A	B	CVR	A	B	CVR
pH	D.O.%Sat.	6.29	0.01	0.52	6.24	0.01	0.55
Tot.N. (ug/l)	Tot.P. (ug/l)	-594.9	5.68	0.72	472.9	1.31	0.82
BOD ₅ (mg/l)	Tot.N. (ug/l)	5.19	0.0012	0.70	(4.81	0.0019	0.39)
Tot.P. (ug/l)	NH ₃ -N (ug/l)	148.4	1.98	0.61	(358.5	1.38	0.18)
NO ₃ -N (ug/l)	NH ₃ -N (ug/l)	5.56	0.53	0.64	13.97	0.33	0.70
BOD ₅ (ug/l)	NO ₂ -N (ug/l)	-29.65	3.54	0.76	(6.84	-0.09	0.20)
Tot.P. (ug/l)	NO ₂ -N (ug/l)	-2.705	0.294	0.81	(0.269	0.002	0.03)
Tot.N. (ug/l)	NO ₂ -N (ug/l)	-31.495	3.218	0.99	(892.04	-6.31	0.06)

2.6 Correlations Between Bacterial and Chemical Parameters:

The only significant correlations observed were between TPC and ammonia and nitrate (Table XIV).

TABLE XIV: Correlations between bacterial and chemical parameters.

Dependent Parameter	Independ. Parameter	Un-Polluted Samples			Animal-Polluted Samples		
		A	B	CVR	A	B	CVR
Log ₁₀ TPC /100 cm ³	NH ₃ -N (ug/l)	5.18	0.044	0.65	5.19	0.003	0.66
Log ₁₀ TPC /100 cm ³	NO ₃ -N (ug/l)	5.27	0.005	0.63	5.28	0.006	0.62
Log ₁₀ FS /100 cm ³	NH ₃ -N (ug/l)	(1.56	0.004	0.48)	1.65	0.003	0.54

3. Bacterial Content of Animal Faeces and Littoral Sediments:

3.1 Bacteria in Animal Faeces:

Results appear in Table XV.

TABLE XV: Bacterial counts per gram dry matter of faeces, dry matter percentage, faecal coliform percentage and FC/FS ratio.

Species	% Dry matter	Tot.Pl. Count	Tot.Coli. Count	Faec.Coli Count	Faec.Strep. Count	% FC/TC	FC/FS
Cow	14	2.3x10 ⁸	2.2x10 ⁴	1.7x10 ⁴	1.1x10 ⁷	76	0.001
Sheep	16	3.1x10 ⁸	3.4x10 ⁷	3.4x10 ⁷	1.9x10 ⁶	100	18
Goose	13	4.8x10 ⁸	2.6x10 ⁶	1.8x10 ⁵	1.2x10 ⁷	11	0.024

While the results for cattle and goose faeces are similar to those reported in the literature (Geldreich & Kenner, 1969; Williams-Smith, 1961), the FC/FS ratios were much less than 0.7. The results for sheep faeces revealed a much higher FC/FS ratio than expected. This was found also in preliminary experiments. One reason could be that the samples were collected at a particularly dry time of the year when faecal streptococci may have died-off rapidly in faecal material, or may not have multiplied to such an extent as usual. It is also possible that with the organic matter present the FC counts could have been overestimated.

3.2 Bacteria in Littoral Sediments:

Bacterial counts varied from station to station (Table XVI). High indicator bacteria counts at Stations 2 and 10 with low FC/FS ratios indicated that stock had contaminated those stations recently. Upper dam sediments had lower coliform and streptococcal counts than lower dam sediments.

TABLE XVI: Bacterial content per gram dry matter of pond sediments, dry matter percentage, faecal coliform percentage and FC/FS ratio.

Station	Tot.Pl. Count	Tot.Coli. Count	Faec.Coli. Count	Faec.Strep. Count	% Dry matter	%FC/TC	FC/FS
1	2.0×10^6	4.6×10^3	1.8×10^2	46	44	40	40
2	2.6×10^6	4.6×10^4	2.4×10^2	2.2×10^3	54	0.5	0.11
3	2.3×10^6	5.2×10^2	3.5×10^2	3-	31	69	-
4	1.0×10^6	4.1×10^4	3.7×10^4	23	49	90	1700
6	2.5×10^6	2.0×10^4	1.6×10^4	35	49	77	450
7	1.6×10^6	2.4×10^3	5.9×10^2	4	51	25	150
9	2.9×10^6	8.3×10^3	8.3×10^2	4	48	10	200
10	4.0×10^5	4.2×10^3	1.3×10^3	2.3×10^3	69	31	0.56
11	1.4×10^6	$1.9 \times 10^3+$	1.9×10^3	2-	43	-	950+
12	7.6×10^6	6.0×10^2	3.6×10^2	4-	25	60	90+
Mean Lower Dam ^a	2.1×10^6	1.3×10^4	9.2×10^3	19	-	52	424
Mean Lower Dam ^b	1.5×10^6	2.5×10^4	7.7×10^2	2.3×10^3	-	18	0.34
Mean Upper Dam	4.5×10^6	4.0×10^2	2.8×10^2	3-	-	80	520+

a - Mean for unpolluted stations.

b - Mean for polluted stations (2 and 10).

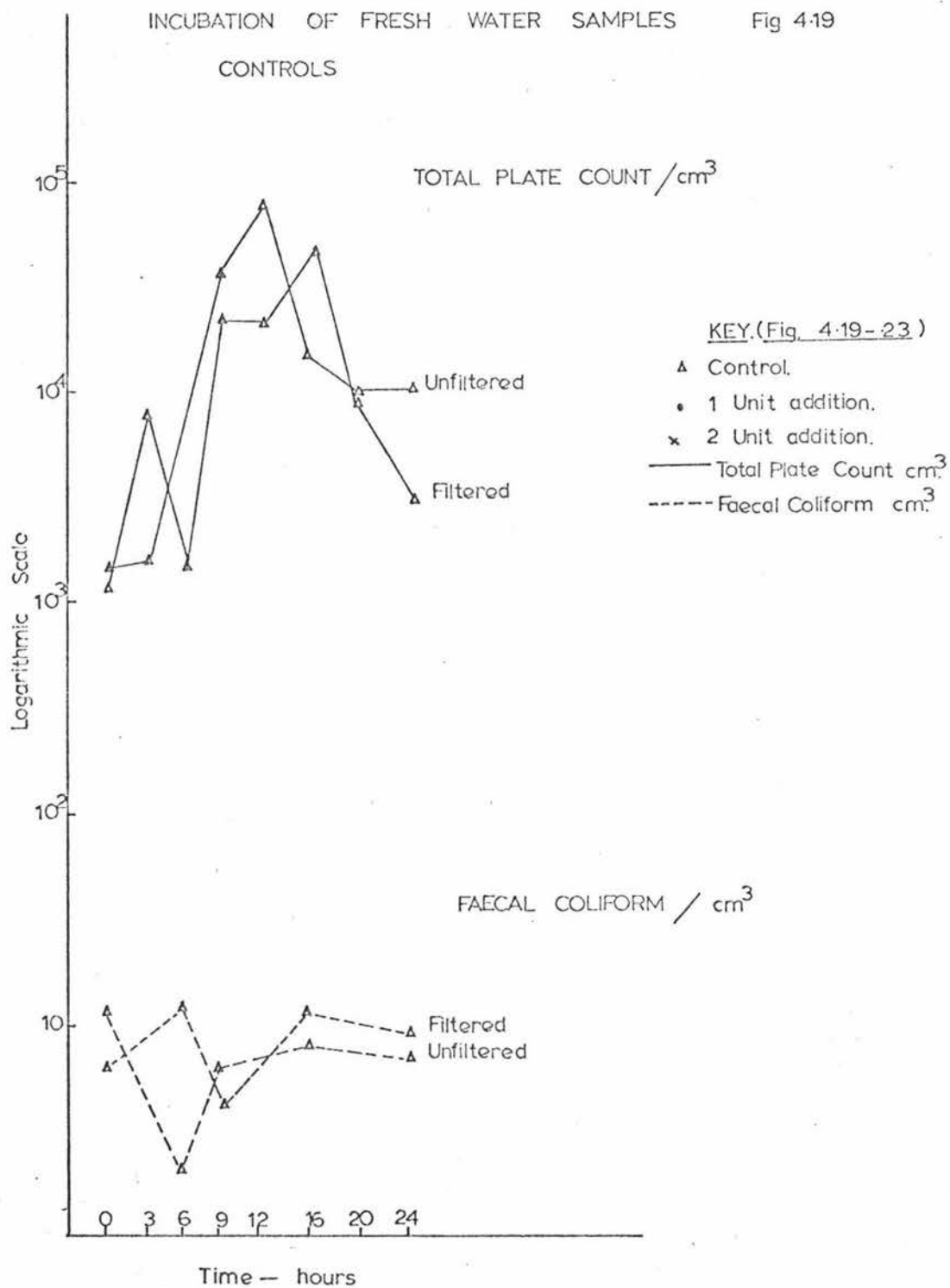
4. Bacterial Growth and Survival Experiments:

These were carried out with fresh and sterilized pond water, to some of which was added nitrate and/or phosphate solutions.

4.1 Growth and Survival in Fresh Water Samples:

A sample collected on 23/6/72 was subjected to various treatments (Table XVII). 500 cm^3 quantities were incubated in 2000 cm^3 flasks.

Bacterial counts are shown in Figs. 4.19 to 4.23. The main effect of filtration was to allow early bacterial growth and die-off. Coliform bacteria appeared to survive slightly better in filtered water. FS counts were initially approximately $10/100 \text{ cm}^3$ in both filtered and unfiltered samples, and increased slightly up to $20-30/100 \text{ cm}^3$ before dying off within 16 hours. The addition of phosphate at the higher level stimulated bacterial growth to a higher final cell concentration in unfiltered water, and the early growth was observed with both nitrate and phosphate addition at the higher level. All filtered samples showed early growth, and both phosphate and nitrate encouraged bacterial growth for a longer period.

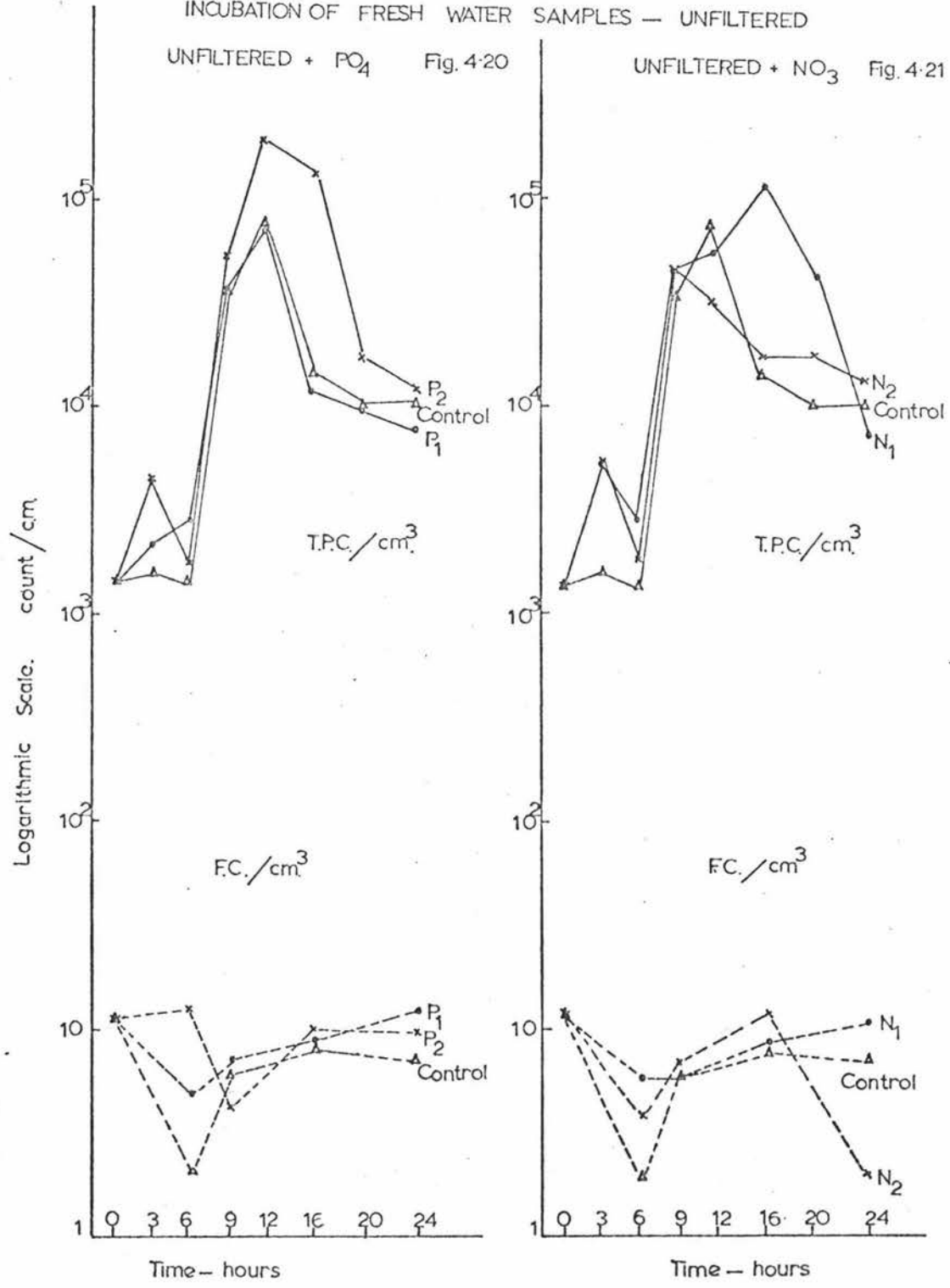


Turbidity (as absorbance at 420 nm) was about 0.11 in unfiltered samples and 0.09 in filtered samples throughout the experiment.

INCUBATION OF FRESH WATER SAMPLES — UNFILTERED

UNFILTERED + PO₄ Fig. 4-20

UNFILTERED + NO₃ Fig. 4-21



INCUBATION OF FRESH WATER SAMPLES — FILTERED

FILTERED + PO₄ Fig. 4·22

FILTERED + NO₃ Fig. 4·23

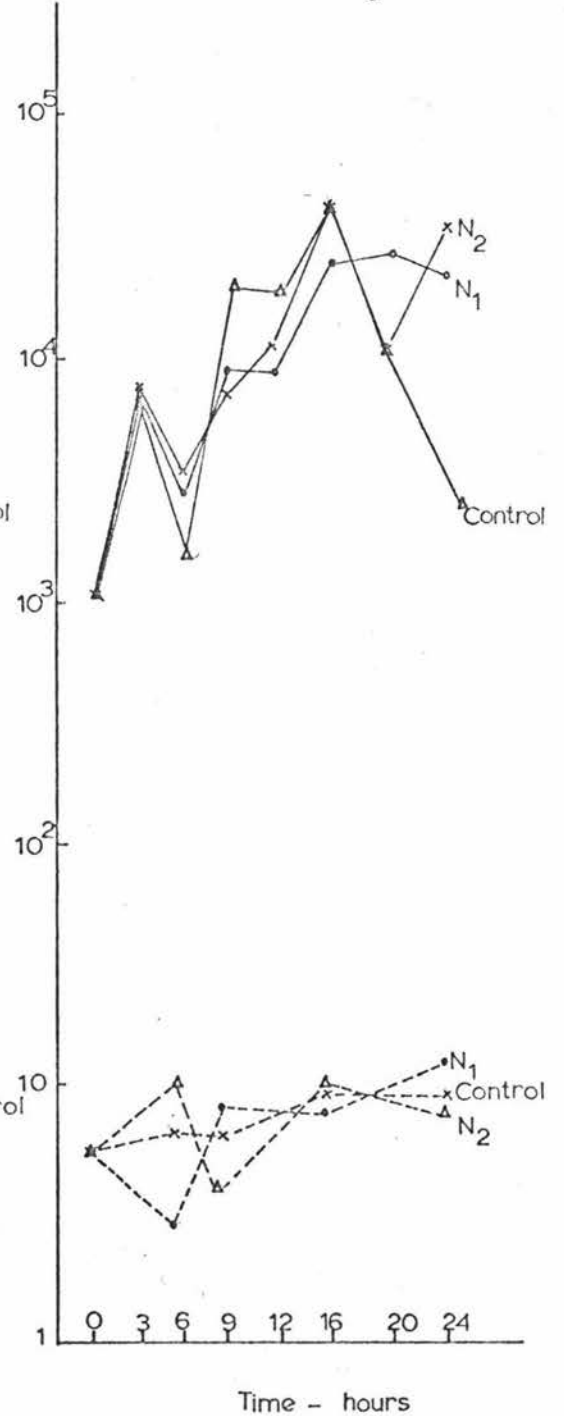
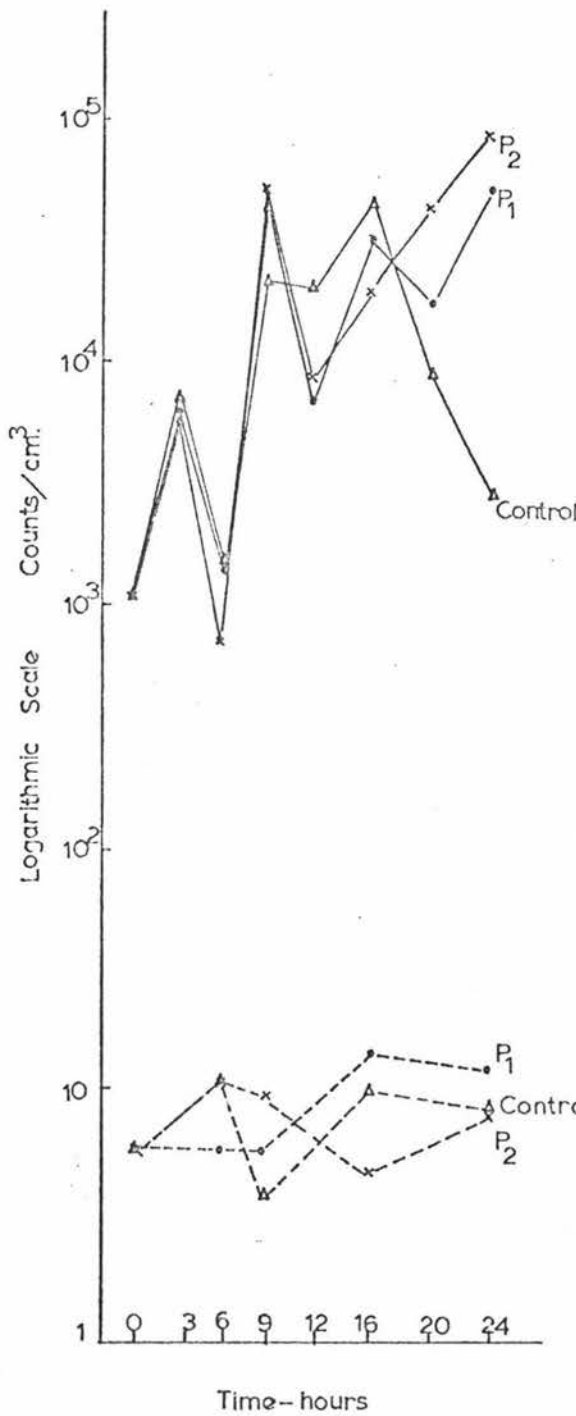


TABLE XVII: Nutrient levels in samples subjected to designated treatments before incubation for bacterial growth experiment.*

Description of Treatment	Tot.P. mg/l	Tot.N. mg/l	PO ₄ -P mg/l	NO ₃ -N mg/l
Unfiltered, no nutrient addition - Control	0.02	0.65	0.01	0.25
Unfiltered, 1 unit (2 mg/l) phosphate added	2.02	0.65	2.01	0.25
Unfiltered, 2 units phosphate added	4.02	0.65	4.01	0.25
" 1 unit (1 mg/l) nitrate added	0.02	1.65	0.01	1.25
Unfiltered, 2 units nitrate added	0.02	2.65	0.01	2.25
Filtered, no nutrient addition - Control	0.02	0.6	0.01	0.27
" 1 unit (2 mg/l) phosphate added	2.02	0.6	2.01	0.27
Filtered, 2 units phosphate added	4.02	0.6	4.01	0.27
" 1 unit (1mg/l) nitrate added	0.02	2.6	0.01	1.27
" 2 units nitrate added	0.02	2.6	0.01	2.27

*Other than for control flasks nutrient concentrations were calculated from known concentration and additions.

4.2 Growth of Pure Cultures in Sterilized Water:

Pure cultures of faecal coliform or faecal streptococcal isolates were inoculated into 50 cm³ aliquots of sterilized pondwater sample which was collected on 18/7/72 from Station 10. Details of the analysis of the fresh sample can be found in Appendix 3.19. The nutrient levels after autoclaving and the calculated levels after nutrient addition are shown in Table XVIII.

TABLE XVIII: Nutrient levels in autoclaved sample (control) and calculated levels after nutrient addition for experiments 1 and 2.

Treatment	NO ₃ -N mg/l	Sol. PO ₄ mg/l	Total Nitrogen mg/l	Total PO ₄ mg/l
Control	0.20	0.30	0.27	0.60
+ PO ₄	0.20	2.30	0.27	2.60
+ NO ₃	2.20	0.30	2.27	0.60
+NO ₃ + PO ₄	2.20	2.30	2.27	2.60

Autoclaving resulted in the loss of nitrogen, probably as ammonia. The sterilized sample was stored for future use. Subsequent analysis indicated

that although it remained sterile, increasing ammonia concentrations resulted in increased Total Nitrogen concentrations of 0.66 mg/l for Experiment 3 and 0.95 mg/l for Experiment 4. The Total Phosphorus concentration for Experiment 4 was increased to 0.63 mg/l by the addition of phosphate.

The resultant population growth rates are shown in Table XIX.

TABLE XIX: Population growth rates in generations/hours of pure faecal coliform and faecal streptococcal isolates in sterilized pond water, with or without the addition of nitrate (N) and phosphate (P), at a concentration of 2 mg/l.

Organism	Treatment				Expt. No.	Date	Times Sampled (hours)
	0	+P	+N	+P+N			
Faecal coliform	0.41	0.44	0.47	0.59	1	31/7	0,6,12,18
Faecal streptococci	-----contaminated-----				1	"	30,48
Faecal coliform	N.D.	0.40	0.43	0.46	2	8/8	0,4,16
Faecal streptococci	0.07	0.14	0.22	0.27	2	"	28,40
Faecal coliform	0.28	N.D.	N.D.	N.D.	3	20/9	0,12,18,24
Faecal streptococci	0.24	"	"	"	3	"	36,42,48,60
Faecal coliform	N.D.	0.36	"	"	4	7/12	0, 6, 12,24
Faecal streptococci	"	0.33	"	"	4	"	30,36,48,54

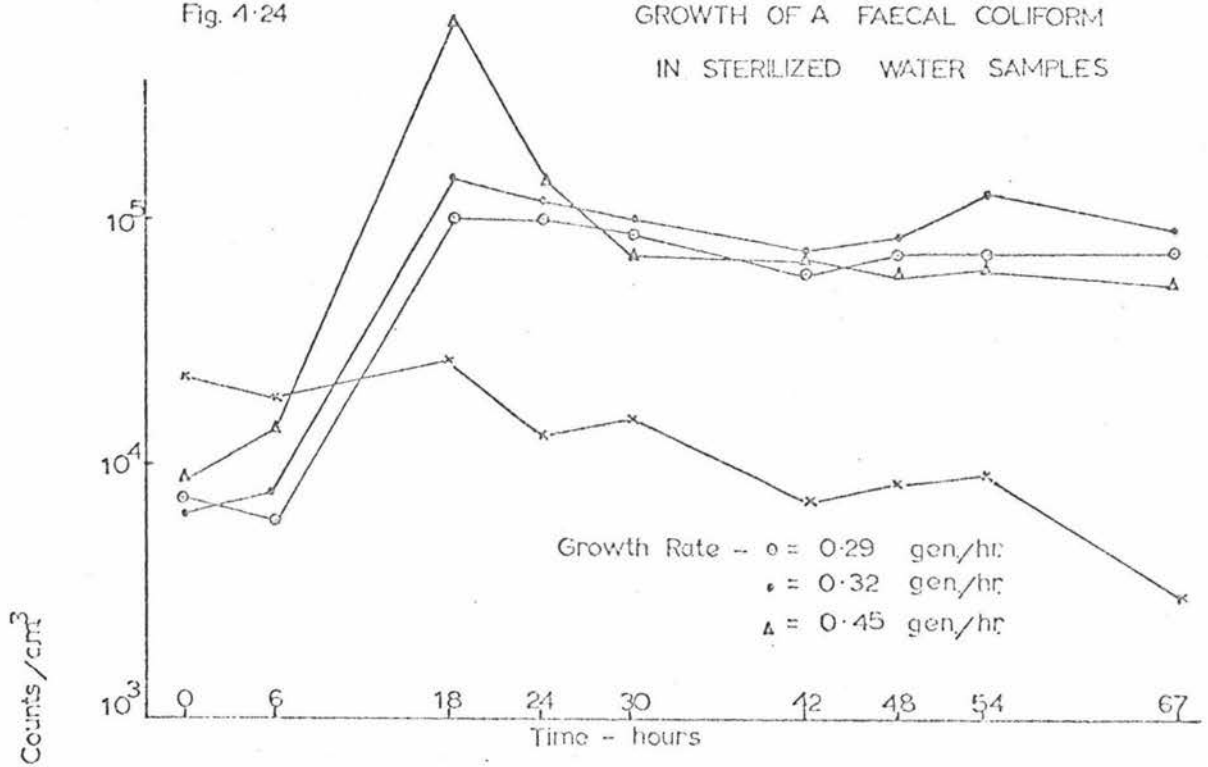
Two inocula of each organism were used for the experiments: the first for experiments 1 and 2, and the second for experiments 3 and 4. The first faecal coliform isolate had a higher growth rate than the second, while the first faecal streptococcal isolate had a lower growth rate than the second. Growth of the faecal streptococci on confirmatory agar indicated that the first isolate was probably Strep. bovis and the second was probably Strep. faecalis.

4.3 Growth in Sterilized Water of Different Trophic Status:

Samples of water were collected from Station 10 (lower dam) and Station 11 (upper dam) on 12/12/72. The fresh samples were sterilized and the sample collected from Station 10 on 18/7/72 was re-sterilized with them. The analysis of the fresh samples can be found in Appendix 3. The concentrations of soluble nutrients in the three samples after autoclaving are given in Table XX. Sterile 25% Ringer's solution was inoculated as the control. Resultant growth of faecal coliform and faecal streptococcal isolates as pure cultures, and of the mixed population 'harvested inoculum' are shown in Figs. 4.24 to 4.28. While faecal coliform growth was increasingly stimulated by the increasing trophic status of the environment,

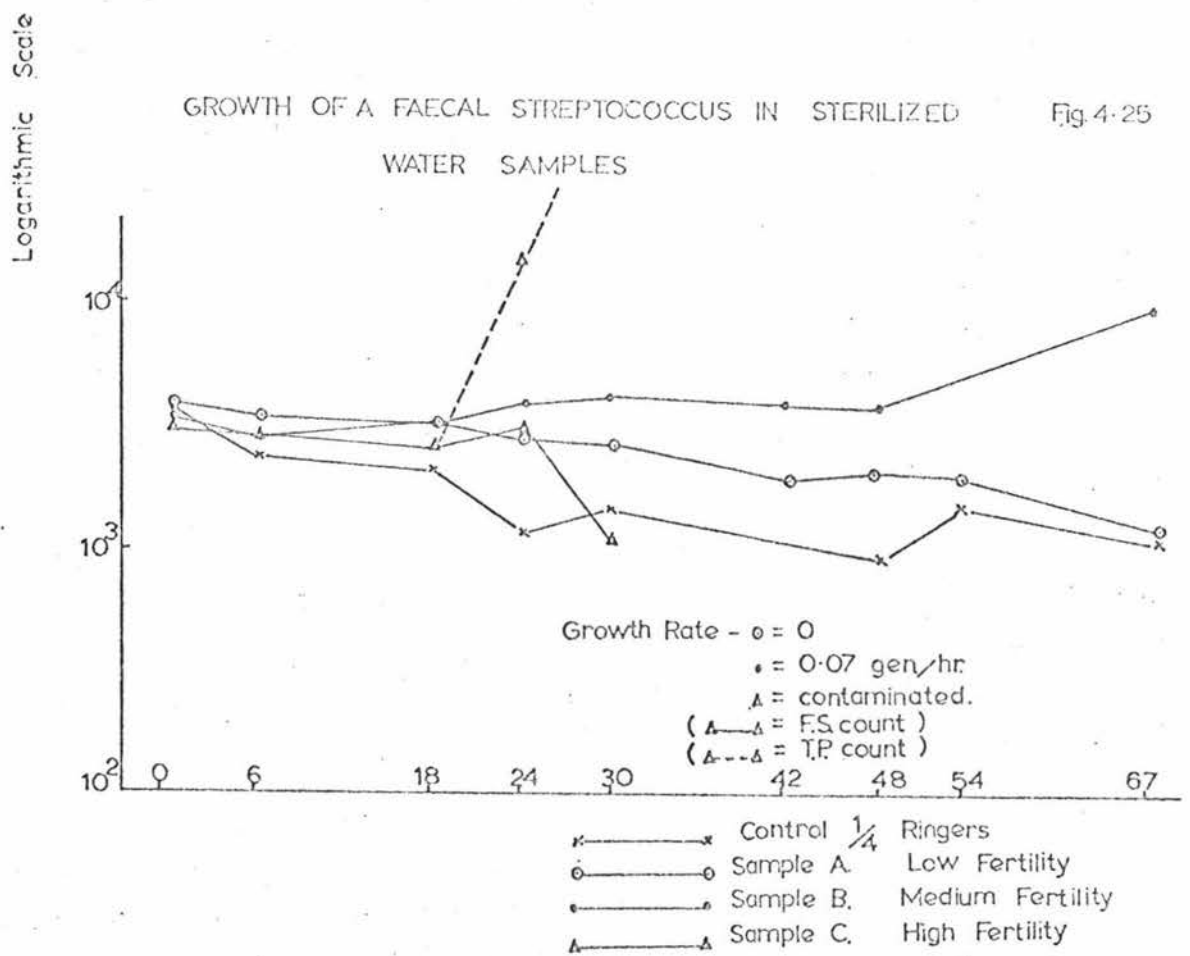
Fig. 4-24

GROWTH OF A FAECAL COLIFORM
IN STERILIZED WATER SAMPLES



GROWTH OF A FAECAL STREPTOCOCCUS IN STERILIZED
WATER SAMPLES

Fig. 4-25



GROWTH IN STERILIZED WATERS OF A MIXED CULTURE
HARVESTED FROM POND WATER.

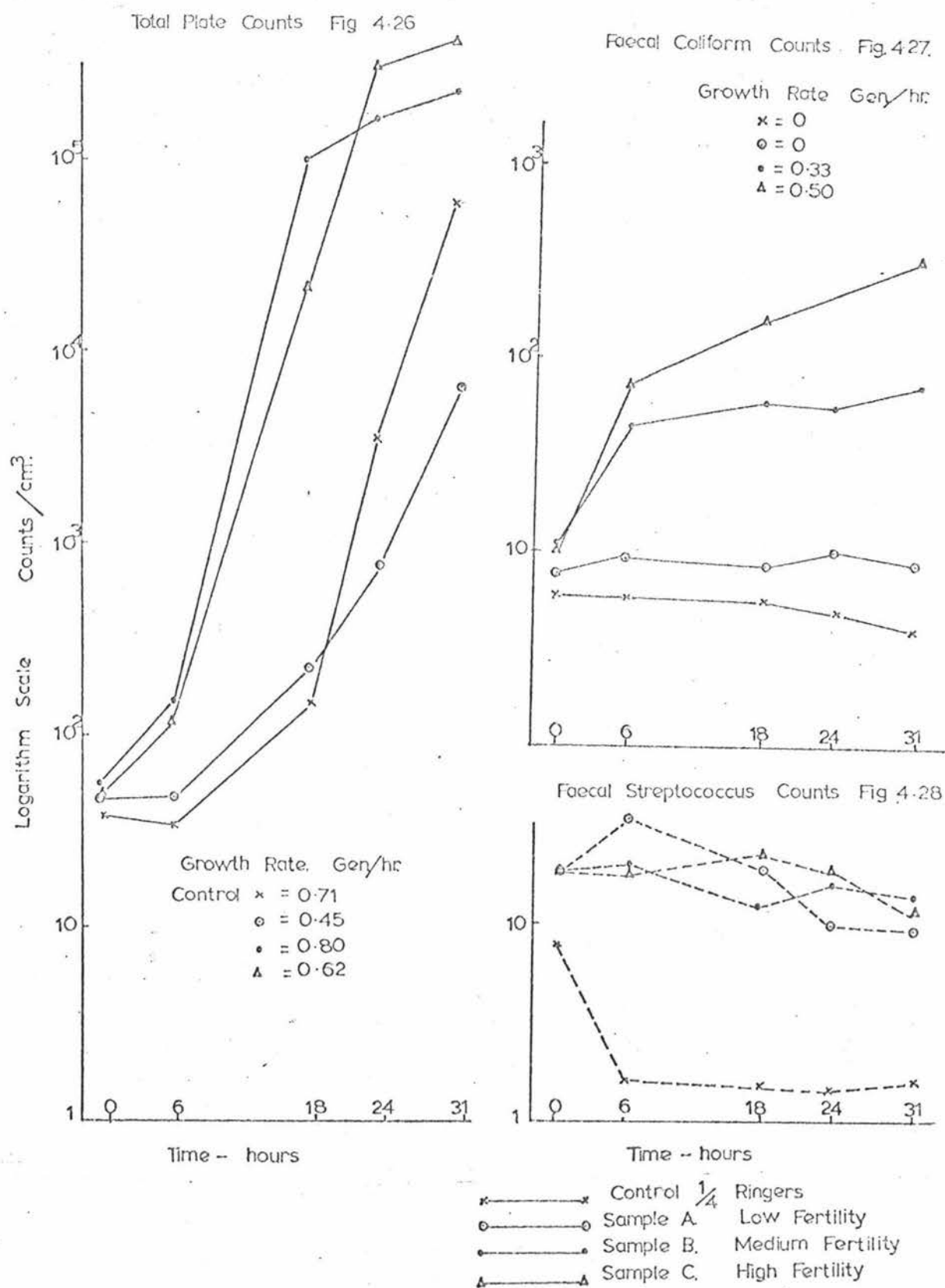


TABLE XX: Concentrations of soluble phosphate, ammonia and nitrate in pondwater samples after autoclaving for growth experiments.

Source	Date of Collection	Soluble PO ₄ mg/l	NH ₃ -N mg/l	NO ₃ -N mg/l	Designated Trophic Status
Station 9	18/7/72	tr	0.01	Not detected	Low
Station 10	12/12/72	0.013	0.01	tr	Medium
Station 11	12/12/72	0.34	0.12	tr	High

faecal streptococcal growth was only slightly stimulated by the environment of medium trophicity (the highly trophic culture was contaminated). Variable results for total bacterial population increase in the 'harvested innoculum' were observed, but faecal coliform bacteria were able to multiply at faster rates in the environments of higher trophic status. The survival of faecal streptococci was enhanced to a minor degree by all the sterilized water samples.

Further samples were collected from the lower and upper dams (Stations 10 and 11) on 4/3/73. The analysis of the fresh samples is given in Table XXI. While the upper dam sample had higher nutrient concentrations and a much higher BOD₅ than the lower dam sample, the total plate count was only marginally higher and the concentrations of indicator organisms were lower. Resultant growth rates for the various bacterial

TABLE XXI: Analysis of samples collected on 4/3/72 from Stations 10 and 11.

Constituent	Station 10	Station 11	Units
Turbidity	0.15	0.45	Absorbance
Dissolved Oxygen	4.7	11.8	mg/l
BOD ₅	2.8	24+	"
Water Temperature	20.5	23.0	° C
D.O. % Saturation	52	137	
Total PO ₄	0.23	1.3	mg/l
Soluble PO ₄	0.013	0.044	"
Total N.	0.71	3.7	"
NO ₃ -N	tr	=	"
Tot. Plate Count	5.4x10 ⁴	1.2x10 ⁵	bacteria/100 cm ³
Total Coliform	520	-	"
Faecal Coliform	310	120	"
Faecal Streptococci	240	10	"

groups in pure culture and mixed cultures are given in Table XXII.

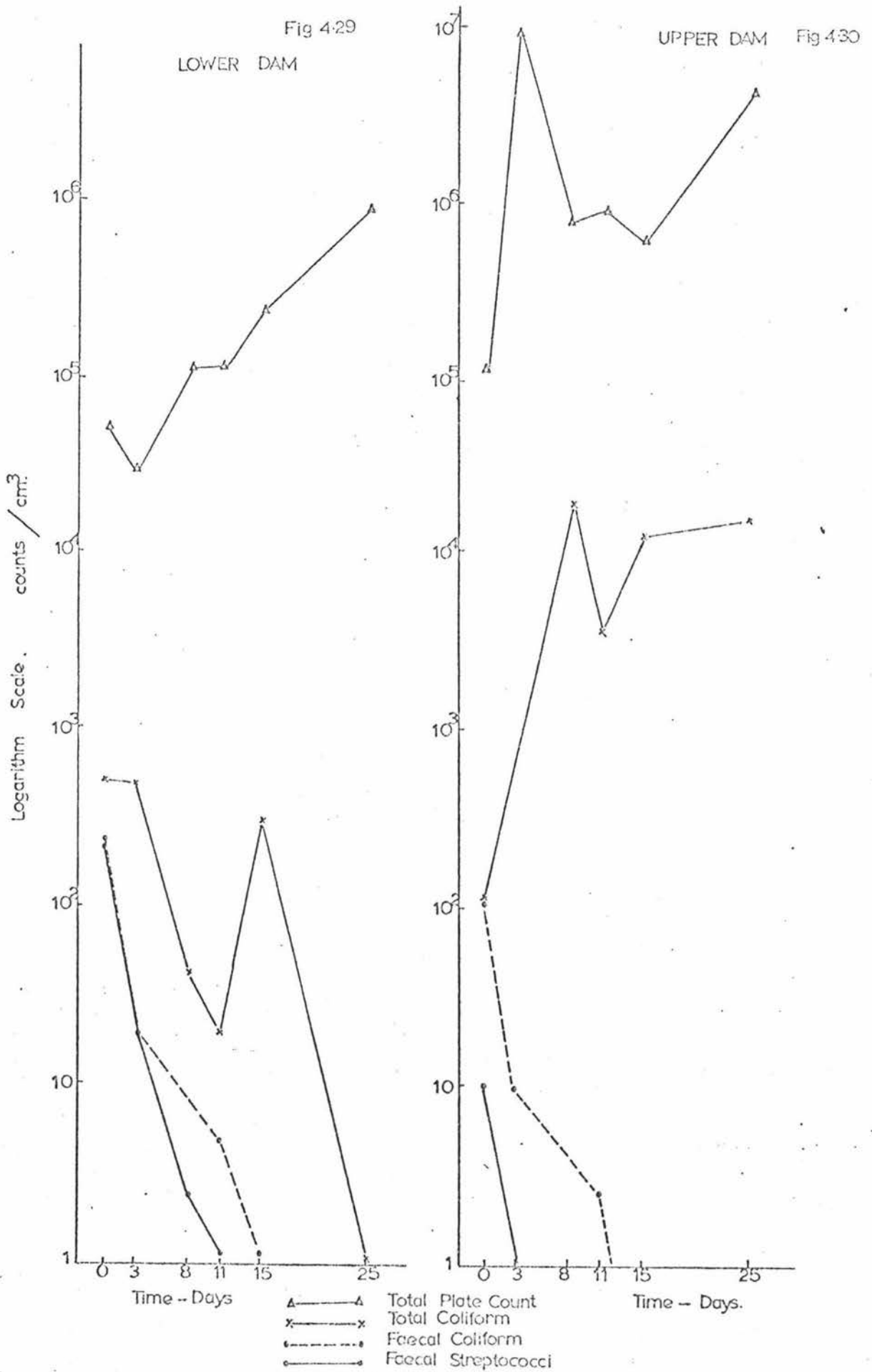
TABLE XXII: Growth rates in generations/hour of pure and mixed cultures of bacteria in sterilized pondwater collected 4/3/73.

Organism	System	Times Sampled	Control	Lower Dam	Upper Dam
Faecal Coliform	Pure Culture	0, 6, 18, 26, 30	0	0.35	0.42
Faecal Streptococcus	"	0, 6, 18, 24, 30, 42, 48	0	0.07	0.16
Total Count	Mixed Culture	0, 6, 18, 24, 30, 42, 48	0.43	0.78	0.89
Total Coliform	"	"	0	0.60	1.17
Faecal Coliform	"	"	0	0.35	0.50
Faecal Streptococcus	"	"	-	0.02	0.20

4.4 Long-term Bacterial Survival in Fresh Water Samples:

When samples were collected on 4/3/73 for the growth experiments described in section 3.3, samples were also collected in bottles and stored on the window-sill as described in Chapter 3, section 7.4. The results are shown in Figs. 4.29 and 4.30. While TPC concentrations tended to increase, coliforms and FS died-off in the lower dam samples, TC increased in the upper dam samples, while FC and FS died-off more rapidly than in lower dam samples.

CHANGES IN BACTERIAL POPULATIONS IN FRESH WATER SAMPLES,
STORED ON WINDOWSILL



CHAPTER FIVE

DISCUSSION

1. Chemical Enrichment:

The environmental features and agricultural practices investigated which resulted in chemical enrichment were grazing animals and the presence of wildlife, rainfall and drainage, and fertilizer application.

1.1 Grazing and Wildlife:

The only chemical parameter found in higher concentrations in APS was BOD₅ (Table IX). Less significant effects were observed with total N, ammonia, D.O. (% saturation), total P, and soluble P. pH, D.O. (mg/l), nitrate, and nitrite concentrations were not significantly affected by grazing and wildlife around the dam.

Fish (1971) recorded large increases in ammonia concentrations as a stream passed through farmland. The Ministry of Works (MOW), Hamilton, (1972) found that nitrate concentrations in drainage from pasture were particularly high, while drainage from a catchment carrying no stock and with no legumes had barely detectable nitrate. The soil was a light pumice where nitrogen fixation and cycling by legumes and nitrifying bacteria and the presence of grazing animals was thought to cause the increased nitrate concentration. In the present study the soil was heavier (silt-loam) and is characteristically gleyed (Cowie, 1972) so that accumulation of more ammonia than nitrate from ^{the breakdown of} dung and urine may have occurred.

Since the BOD₅ concentration was not correlated with rainfall, it would appear that the main effects of animal activities on BOD₅ were deposition of waste material in the dam and the resultant resuspension of littoral sediments as the stock drank. At Station 7 on Run 12 (23/3/72) the activities of sheep prior to sampling increased turbidity to 0.66, BOD₅ to 10.2 mg/l, and total N to 2.40 mg/l. A similar situation with cattle at Station 9 on Run 29 resulted in a turbidity of 0.93, BOD₅ of 4.8 mg/l and total N concentration of 0.74 mg/l.

1.2 Rainfall, Drainage and Seasonal Effects:

During the period of maximum rainfall and drainage in July, while soluble nutrients in the lower dam increased in concentration, the concentrations of total N and total P decreased. Total N and P concentrations reached a peak after the first autumn rainfall which produced runoff. This rainfall may have washed most of the loose particulate material from the surface soil so that subsequent drainage contained much lower concentrations of such material. In small agricultural catchments during

floods, the concentrations of total N and P increased, particularly as the streams were rising (MOW, Hamilton, 1972). It is also possible that sedimentation may have occurred as the dams filled, particularly in the upper dam.

Nitrate and ammonia concentrations increased with the rainfall and drainage in May. Along with soluble P, these nutrients reached peak concentrations in July. The autumn rain may have caused leaching of the upper soil layer, thus resulting in increased nitrate and ammonia runoff. Soluble P would not be expected to be leached from the soil due to possible adsorption and fixation effects (Metson, 1971). When the tile drains began to flow, maximum nitrate and ammonia runoff from leaching would have occurred. High turbidity in the July samples was thought to be due to the resuspension of dam sediments by the stormy weather and to water flowing through the dams. The dam sediments would have been well-decomposed, thus containing high concentrations of soluble nutrients and low concentrations of organic N and insoluble P compounds.

1.3 Fertilizer and Trophic Status:

After application of phosphate fertilizer on 23/10/72, 8 days later the concentration of soluble P had risen from undetectable amounts to an average value of 28 ug/l, and 16 days later the mean level had fallen slightly. Subsequent increases in soluble P concentration were concurrent with increases in ammonia and nitrate concentrations. No rainfall was recorded from 19/10/72 to 14/11/72, so it is probable that the increased phosphate concentrations were due to fertilizer which had been deposited in the dam. Pellets of fertilizer lay on the ground and in the littoral water for some time. The latter increases in soluble P concentration may have been due to mixing of the dam sediments since strong winds were experienced about that time.

Had there been significant rainfall following the fertilizer application, more rapid, larger increases in phosphate concentration would have been expected. Duncan (1973) monitored phosphate concentrations in runoff from experimental plots which were subjected to simulated rain storms. Runoff from silt-loam soils with ryegrass/white clover pasture which had not been fertilized for two years had a peak phosphate concentration of 0.5 mg/l after 20 minutes of the storm, resulting in a peak loss of 0.3 mg PO_4 per second. After the application of fertilizer, the peak concentration of 2.0 mg/l was reached immediately, and the rate of phosphate loss was about 1.0 mg/sec. Fish (1969) found that drainage from an agricultural catchment had 0.09 mg/l of phosphate before topdressing. The concentration rose to a peak of 8.6 mg/l after topdressing and 12 days later had returned

to 0.1 mg/l.

Peak phosphate concentrations in the lower dam were not as high as those reported by Fish or Duncan. However, upper dam soluble P concentrations reached a peak on Run 25 of 0.5 mg/l, which is similar to Duncan's results for unfertilized plots, and winter phosphate concentrations may have been much higher than this. There was evidence that the upper dam acted as a collecting reservoir for soluble and particulate matter in runoff. Higher nutrient concentrations, especially total and soluble P, total N and ammonia, and much higher concentrations of BOD₅ in the upper dam were observed. Dissolved oxygen concentrations were much higher in the upper dam in October and January when dense growths of filamentous algae were observed, but lower in November and December, probably because of the large amounts of oxidisable organic matter present due to mixing of dam sediments.

According to the trophic classification of Thomas (1969) cited by McColl (1972), both dams would be classified as eutrophic-mesotrophic, while McColl would class them as eutrophic because of their summer phosphate concentrations. The upper dam was more eutrophic than the lower.

2. Bacterial Pollution:

Interraction of environmental and agricultural factors affected the concentrations of bacteria in the dams. These factors included the presence of animals, rainfall and drainage, turbidity (as an index of particulate materials in suspension from dam sediments and soil), and factors affecting bacterial survival in the dams.

2.1 Grazing and Wildlife:

The bacterial groups most affected by animal activities were FS and FC. Concentrations of these bacteria were highest in the summer, autumn and winter, but FS in particular were present in lower concentrations in the spring. Both FC and FS concentrations were high during periods when stock were grazing around the dam, especially during the hot, dry months when sheep were present and would have been forced to visit the dam most frequently for water.

The expected inverse relationship was observed between the % FC/TC and the FC/FS ratio (Fig. 4.9). The mean FC/FS ratio was more closely related to the presence of animals than the % FC/TC, falling from 68 in November, 1971 to 17 in December, 2.5 in January, 1.2 in February, and 0.9 in March. From April onward the ratios tended to increase to reach high values again in September/November. With cattle grazing spasmodically the ratio did not reach such low levels in December, 1972 and January, 1973.

The coliform and streptococcal counts were in the same ranges as those

obtained by Weidner *et al* (1969). However, Geldreich and Kenner (1969) reported that in drainage from prairie watersheds with mainly grazing animals and low rainfall, FC and FS counts less than 200/100 cm³ and FC/FS ratios of 0.5 to 1.6 were observed. Even in UPS, concentrations of faecal indicator bacteria were extremely high. "Background" levels of such organisms in N.Z. agricultural drainage waters may be particularly high.

Determination of the bacterial content of animal faeces suggested that while cattle and goose faeces had a FC/FS ratio less than 0.01, similar to those reported in the literature (Chap.2, Section 1), the ratio in the sheep faeces sampled was about 18. The result for sheep faeces is dubious since the ratios observed in water when sheep were grazing were very low.

2.2 Rainfall, Drainage and Seasonal Effects:

The concentrations of bacteria at the sampling stations increased with rainfall and subsequent drainage. The bacterial groups correlated with rainfall were TPC, TC and FC. TPC and TC concentrations reached a maximum in July. While FC and FS were present in large concentrations during the winter months, their concentrations in flood runoff did not increase.

TPC and TC concentrations were inversely related to water temperature. This could have been primarily because rainfall in the five days preceding sampling was inversely related to water temperature (a seasonal effect) or because the survival of these bacteria increased. In the winter there were higher levels of soluble nutrients which may also have prolonged bacterial survival. It was not thought that water temperature had a primary effect on bacterial populations. Although Brasfield (1972) observed some correlations between bacterial counts and environmental factors, such as phosphate and detergent concentrations in a sewage polluted river, no correlations with temperature were observed.

The autumn rainfall which resulted in increased concentrations of chemical constituents (1.2 above) also resulted in increased indicator bacterial concentrations. FC and FS counts were maximal at most sampling stations on Run 18 (16/5/72) due to the build-up of indicator organisms on the pasture and in surface soil over the summer/autumn period (Cuthbert, 1954). The natural soil pH of about 6.0 (N.Z. Soil Bureau, 1968) would have been increased by lime application (over the years prior to the survey) to nearer 7.0. This soil pH would allow prolonged survival of indicator bacteria (Cuthbert, 1955).

2.3 Turbidity and Sediment:

TPC counts were well correlated with turbidity, the linear regression relationships being $\text{Log}_{10}\text{TPC} = 4.76 + 4.386 \text{ turbidity (UPS)}$, and $\text{Log}_{10}\text{TPC} = 4.99 + 2.550 \text{ turbidity (APS)}$ (Table XII). Turbidity in APS was significantly higher than in UPS because the animals

stirred up the littoral sediments as they drank. A weak correlation was observed between FS and turbidity in APS and recently-polluted sediments had high FS counts.

The correlation between TPC and turbidity in UPS was expected because both these constituents were related to rainfall. In late autumn, turbidity values increased as runoff increased. High levels in July were attributed to resuspension of dam sediments (1.2 above) which resulted in increased TPC counts.

While the bacterial counts in littoral sediments were slightly higher than those in the water of the lower dam, sedimentation and adsorption onto bottom muds could result in a 100-fold increase in the concentrations of indicator bacteria as opposed to those in the overlying water (Van Donsel and Geldreich, 1970). Keeney et al (1970) reported evidence of higher TPC concentrations in eutrophic vs oligotrophic lake sediments. Comparison of results from the littoral sediments of the upper and lower dams showed that upper dam sediments contained about twice the concentration of TPC, but fewer coliforms and FS. Since some strains of FS, e.g., Strep. faecalis survive longer than other indicator organisms in soil and water (Evans and Owens, 1972; Geldreich et al, 1968; Geldreich and Kenner, 1969), it is probable that they would also survive longer in bottom sediments. Their numbers would thus build up in bottom sediments; this could explain the very weak correlation between FS and turbidity in UPS.

2.4 Bacterial Survival:

TPC concentrations were positively correlated with rainfall, turbidity, and nitrate and ammonia concentrations. These correlations can largely be explained by the concurrent increases in these parameters in the winter. Except turbidity, they were all negatively correlated with water temperature. Coliform bacteria were also positively correlated with rainfall and TC were negatively correlated with water temperature.

There is evidence in the literature that indicator bacteria and pathogens survived longer in winter samples incubated at 10°C than in spring, summer and autumn samples incubated at 20°C (Geldreich et al, 1968). Miura (1971) found that FS organisms die off neither in summer nor winter water samples, and Klock (1971) found that low temperatures limited coliform survival in sewage ponds. In summer, UV irradiation can be a major factor resulting in decreased bacterial concentrations in seawater (Gameson & Saxon, 1967). Low organic and inorganic nutrient concentrations are also claimed to limit bacterial survival (Carlucci & Pramer, 1960 a, b, c, d; Carlucci et al, 1961) although bacterial growth has been

observed in laboratory and field studies with extremely low concentrations of nutrients (Hendricks & Morrison, 1967; Hendricks, 1972; Garvie, 1955).

It is possible that organic compounds secreted by algae may support growth of some bacteria including E. coli (Davis and Gloyna, 1970) but extended survival may be limited by the increasing pH as the carbon dioxide concentration decreases because of photosynthesis (Parhad & Rao, 1972).

The results of laboratory growth experiments showed that both FC and FS bacteria could multiply in sterilized pondwater samples, and that in pure culture their growth was stimulated by the addition of nitrate and phosphate (Table XIX). Stimulation was greater when both nitrate and phosphate were added, and nitrate was more stimulatory than phosphate. In waters of differing trophic status (Figs. 4.24 and 4.25) pure cultures of both FC and FS multiplied at a faster rate in more eutrophic samples, and in a mixed culture of indigenous bacteria harvested from the water TPC and TC were stimulated most, although FC grew at similar rates as they had in mono-culture (Figs. 4.26 - 4.28, Table XXII). In the first experiment FS initially died off then survived at low concentrations in the control and survived in other samples. In the second experiment, they (FS) multiplied at a slow rate in the less eutrophic sample and at a faster rate in the more eutrophic sample.

Experiments with fresh water samples indicated that in unfiltered samples with the natural population of algae and protozoa, adding nitrate did not stimulate growth and the bacteria died off within 12 hours (Fig. 4.21), whereas phosphate at the higher concentration stimulated indigenous bacterial growth (Fig. 4.20). In samples filtered to remove most algae and protozoa, phosphate and nitrate stimulated growth of bacteria particularly after 20 hours when control populations were declining (Figs. 4.22 and 4.23). It was possible that limited numbers of small algae had passed the filter and that their multiplication had occurred after about 18 hours. The prolonged stimulation of bacterial populations in chemically enriched samples could have been partly due to the algal secretion of organic materials utilizable by the bacteria. Such stimulation may have occurred in addition to the direct stimulation of bacterial growth particularly by phosphate.

Further experiments to examine long-term survival showed that in the upper dam samples TPC and TC populations increased for up to 8 days, while FC and FS populations diminished within the first 3 days, the FS being undetectable* within 3 days and the FC after 11 days (Fig. 4.29). In the lower dam sample, the TPC initially decreased then began to increase after 8 days (Fig. 4.30) possibly as a result of cell products released and

*Not detectable in 100 cm³ of sample.

initial breakdown of difficultly-decomposed organic matter. Die-off of coliforms and FS was observed, the FS being undetectable after 8 days, the FC after 15 days and the TC after 25 days. While indigenous bacteria were able to multiply in the stored samples, indicator bacteria except TC disappeared more quickly in the more eutrophic sample. It is possible that in the more eutrophic sample inhibitory factors such as higher concentrations of bacterial predators were present, resulting in faster die-off of indicator bacteria. In the upper dam waters, while TPC concentrations were higher than those for the lower dam, indicator bacterial counts decreased over the summer.

2.5 Indicator Bacteria and Pathogens:

There is evidence that Sal. typhimurium can survive longer than Strep. bovis in summer or winter stormwater samples, and as long as FC in summer (Geldreich and Kenner, 1969). Sal. typhimurium has also been found to be more persistent than FC at lower temperatures (Gallagher & Spino, 1968). Salmonella organisms may be free-living pathogens (Cherry et al, 1972). The evidence of several authors (Chap.3, Section 5) shows that Salmonella isolation could be expected with coliform counts ranging from 10^4 to 10^5 , FC counts from 10^2 to 10^5 , and FS counts from 10^2 to 10^3 , where there was sewage pollution. In the Saline River, which flows through predominantly agricultural land and where the FC/FS ratio of 0.4 suggests that animal waste was the prime source of pollution, Salmonella isolation occurred in one sample with 11,000 TC/100 cm³, 1,100 FC/100 cm³ and 2,900 FS/100 cm³ (Smith and Twedt, 1971). A higher proportion of samples with a FC/FS ratio indicative of human faecal pollution yielded salmonellae. Claudon et al (1971) found that agricultural and urban runoff were safer than sewage in terms of pathogen contamination.

While it may be true that farm water supplies are seldom the primary source of Salmonella outbreaks (Salisbury, 1958), transmission through water is a distinct possibility. For example, carrier or infected animals may be brought onto a property with access to a water course or stock dams. Transmission of the disease to animals on the farm and on farms further downstream through the water would be likely. In acute cases of Salmonellosis in animals, millions of pathogenic organisms per gram of faeces may be voided, and leptospiral infections can result in large numbers of the organisms in urine (Diesch, 1970).

The concentrations of faecal indicator organisms encountered in lower dam samples indicate that Salmonella isolation would have been possible in some samples of littoral water and bottom sediments. (Hendricks (1971) found that Salmonellae were concentrated in bottom sediments of a river.) Other pathogenic organisms such as Leptospira and Brucella could also have

However, been present. A veterinarians did not consider that an outbreak of Salmonellosis in Mr. Clapperton's cattle after he took over the property where the dams were was due contaminated water. (Clapperton pers. comm.)

3. Summary:

Grazing and rainfall causing land drainage were the most important environmental factors affecting the concentrations of pollution indicators (BOD₅, FS, FC and turbidity) in the dams. The concentrations of indicator bacteria were low in the spring, rising sharply in the summer as the stock began to drink at the dam. Autumn rainfall produced drainage water containing high concentrations of particulate matter, which was rich in insoluble phosphorus, organic nitrogen, and indicator bacteria. Winter drainage contained high concentrations of ammonia and nitrate which had been leached from the soil, but low concentrations of insoluble P, organic N and indicator bacteria. Winter mixing of dam sediments caused by turbulent weather conditions and increased rate of flow through the dam, and increased outflow of nutrients from the upper dam resulted in increased soluble nutrients (phosphate, nitrate, ammonia) and indigenous bacterial concentrations.

Although laboratory experiments showed that organic and inorganic enrichment of the water stimulated bacterial growth, the main factors affecting bacterial concentrations in the dam appeared to be the environmental ones described above.

Laboratory experiments with filtered and unfiltered samples collected in the winter (Fig. 4.19) suggested that antibacterial effects such as inhibition, predation, and competition from other organisms were minimal. Long-term survival experiments with samples collected in the autumn suggested that such effects were present and were more significant in the more eutrophic samples.

Fertilizer application resulted in slightly increased phosphate concentrations but continued effects were not obvious because of mixing of bottom sediments in the spring, which also resulted in increased nitrate and ammonia concentrations. In the long term, phosphate in drainage waters could be increased due to the increased fertility of the surface soil.

Evidence from the literature suggested that pathogenic bacteria would be present in some samples of littoral water and bottom sediments because of the high concentrations of indicator bacteria.

4. Conclusions:

(a) That inorganic and organic enrichment of the dams studied was due mainly to erosion and leaching of the pasture soils and to resuspension of sediments which was caused by turbulence and the flow of water through the dams. Fertilizer application resulted in only small increases of phosphate concentrations.

(b) That the environmental factors of the presence of grazing animals and wildlife, rainfall, mixing of dam sediments, and erosion of the pasture soils affected indicator bacterial concentrations most.

(c) In laboratory experiments with mixed bacterial cultures, nitrate and phosphate enrichment was shown to stimulate growth of indigenous bacteria. In water samples of increasing trophic status, growth of indigenous bacterial and faecal coliforms was stimulated. With pure cultures of faecal coliforms and faecal streptococci enrichment with nitrate, particularly, and phosphate resulted in growth stimulation. Long-term survival of indicator bacteria was reduced in more eutrophic waters.

(d) The concentrations of faecal bacteria indicated that pathogenic organisms could be present in littoral waters and bottom sediments of stock dams.

APPENDIX 1.1

TABLE I : Nutrient Content in Fresh Animal Manures

	Species (av. size)		
	Hen	Pig	Cattle
Output lb/day	0.25	9.1	64
% Moisture	70	84	84
lb Major Nutrients/1000 gals			
Organic matter	1830	1130	1060
N	135	60	49
P ₂ O ₅	104	36	15
K ₂ O	48	57	40
lb Minor Elements/1000 gals			
Ca	300	47	17
Mg	24	6.6	8.7
S	26	12	5.8
Fe	3.9	2.3	0.33
Zn	0.75	0.50	0.12
B	0.50	0.33	0.12
Cu	0.12	0.13	0.14

(From Taiganides, 1964.)

TABLE II : Average Amounts of Major Nutrients per 100 lb Live Weight

	Species		
	Hen	Pig	Cattle
Wet Manure			
lb/day	56	70	64
lb/yr	32,200	22,400	20,600
Total Mineral Matter			
lb/day	3.9	1.8	2.1
lb/yr	1440	600	800
Organic Matter			
lb/day	12.2	9.4	8.2
lb/yr	4400	3400	3000
Nitrogen			
lb/day	0.93	0.50	0.38
lb/yr	333	185	138
Phosphate			
P ₂ O ₅ lb/day	0.69	0.26	0.11
lb/yr	253	110	40
Potassium			
K ₂ O lb/day	0.34	0.48	0.31
lb/yr	118	172	112

(From Taiganides, 1964.)

APPENDIX 1.2LOW FLOW SURVEY OF STREAMS ENTERING TASMAN BAY+

(February, 1971)

Catchment Type	Coliform MPN/100ml	NO ₃ -N mg/l	Dissolved Oxygen mg/l	Oxygen % Sat	React.P mg/l	Tot.P mg/l	K mg/l	Number of Samples
Native Bush (not predom. Beech)	446	.015	9.6	103*	.004*	.006	.61*	8
Beech Forest	329	.104*	10.6	109	.009*	.010	.49	9
Exotic Forest	821	.009	9.0	93	.013*	.011	.56	4
Forest + Extensive Farming	1038	.032	10.1	113	.006*	.009	.69	9
Exotic Forest + Farming	932	.215	9.6	100	.018	.018	.64	8
Farming/ Mixed Farming	1101	.096	8.6	93	.008*	.012	.83	13
Extensive Grazing	423	.202	9.0	94	-*	.016	.85	3
Forest	532	.043	9.7	102	.008	.009	.55	21
Forest + Farming	985	.124	9.9	107	.012	.014	.67	17
Wangapeka River	225	.066	10.5	115	.002	.004	.50	1
Collins River	550	.009	9.9	101	.005	.005	.75	1

*Some results omitted as they were recorded as being higher than Total P. results.

+ Summary of M.O.W. Results (Nelson), unpublished.

APPENDIX 1.3

ESTIMATED WASTE PRODUCTION BY MAN AND FARM ANIMALS

	Human	S p e c i e s				Sheep (e)
		Poultry (a)	Poultry (b)	Pigs (c)	Dairy Cow (d)	
Av. L.W. lb	150	5	5	100	1000	120
Pop. Equ. L.W. basis	1.0	0.03	0.03	0.66	6.6	0.8
Wet Manure lb/day/head	3.9	0.25	0.2	7.0	64.0	8.2
Pop. Equ. W.M. basis	1.0	0.06	0.05	1.9	16.4	2.1
Totl. solids % W.M.	-	29	30	16	16	12.5
Volat. solids % DM	-	76	78	85	80	80 ⁺
BOD lb/day per cap.	0.20*	0.017	0.015	0.34	1.38	0.017 ⁺
BOD lb per lb VS	-	0.313	0.227	0.354	0.156	0.2 ⁺
No. of Ans/Human (BOD)	1.0	12.0	12.0	0.6	0.14	12.0
Pop. Equ. BOD basis	1.0	0.08	0.08	1.7	7.0	0.1
COD lb/day per cap.	-	0.058	-	1.25	10.5	-
BOD/COD %	-	29.7	-	26.8	12.2	-

*Includes wash-waters - body waste production † 0.12 lb/day/capita.

⁺Interpolated from dairy cow (ruminant).

(a) and (d) Estimates based on Taiganides & Hazen, 1966; Taiganides, 1964; Brown, 1969.

(b) Patchell, pers. comm.

(c) Carr, pers. comm.

(e) Davey, pers. comm.

APPENDIX 1.4

ESTIMATED POLLUTION LOADS ON AVERAGE-SIZED NEW ZEALAND HOLDINGS

Farming System	Total Waste Prodn. per head per day			Waste Prod. during concn.	Waste Production/day/head at site			Days conc'd /year	Ave. Size Hold'g (head)	Waste Production /head/yr at site			Waste Production per Holding per year		
	lb	gal	BOD		lb	gal	BOD			lb	gal	BOD	lb	gal	BOD
<u>Dairy:</u>															
Milking Shed	64.0	7.7	1.38	5	3.2	0.39	0.07	300	100 ^b	960	140.5	21.0	96000	14050	2100
Wintering Pad ^a	64.0	7.7	1.38	100	64.0	7.7	1.38	65	100 ^b	10560	2800	72.5	1056000	280000	7250
<u>Piggery:</u>															
U.S.	7.0	1.1	0.34	100	7.0	1.1	0.34	365	150 ^c	2555	400	124	382000	60000	18600
N.Z. ^c															
Whey fed	6.0	0.9?	0.30	100	6.0	0.9	0.30	365	150	2190	329	110	328500	49359	16500
Meal fed	3.0	0.5?	0.30?	100	3.0	0.5	0.30?	365	150	1095	183	110	164500	27450	16500
<u>Poultry^d:</u>															
Layers 5lb	0.25	0.03	0.017	100	0.25	0.03	0.017	365	2000 ^e	91	11	6.2	182000	22000	12400
Broilers 3lb	0.15	0.02	0.01	100	0.15	0.02	0.01	365	2000?	55	7.3	3.7	110000	14600	7400

^aNo allowance for bedding or drainage.

^bN.Z. Meat & Wool Boards Statistics, 1970

^cCarr, pers. comm.

^dTaiganides, 1964, Table 2.

^eN.Z. Poultry Producers' Annual Report, 1971.

APPENDIX 2.1

SAMPLING DATE, TIME, WEATHER AND STOCK OBSERVATIONS

Run	Date	Time (hrs)	Weather Conditions	Air Temp. ° C	Stock
<u>1971</u>					
1	7/11	p.m.	-	-	-
2	4/12	p.m.	Fine	18	Sheep P3*.
3	16/12	1200	Fine, hot, no wind	18	Sheep P1.
4	24/12	1530	Fine, hot, breeze	-	Lambs, steers P1.
5	31/12	1630	Cloudy, showery, humid	24	Sheep P1, P3.
<u>1972</u>					
6	10/1	1230	Fine, cloudy, SW breeze	-	Ewes, Lambs P1; Hoggets P3.
7	24/1	p.m.	-	-	Sheep P1, P2.
8	31/1	p.m.	Fine, warm	-	Ewes P1, P2, P3.
9	21/2	1500	Humid, overcast, W wind	24	Ewes, Lambs P1, P2.
10	1/3	1400	Overcast, NW	22	Ewes P2.
11	9/3	1400	Raining, SE	18	Ewes P1, P2, P3.
12	23/3	1300	Fine, hot, NW	25	Sheep P3
13	30/3	1400	Overcast, slight W breeze	-	Sheep P1, P2, P3.
14	11/4	1600	Warm, Cloudy, S	-	Steers P1; Sheep P2, P3.
15	19/4	p.m.	Cool, W	-	Sheep, Steers P1; Sheep P3
16	25/4	1300	Sunny; wet morning; W	-	Sheep, Steers P1 Sheep P2, P3.
17	9/5	1400	Fine, W	15	Steers, Sheep P1; Sheep P2.
18	16/5	1400	Fine, W	-	Sheep P1, P3; Sheep, Steers P2.
19	26/5	p.m.	Fine, W; frost in a.m.	12	Steers P2; Sheep P3.
20	18/7	1430	Fine, W	-	Sheep P3.
21	28/8	1500	Fine, SSE; cold rain for 2 days	10	-
22	28/9	1300	Warm, overcast, wet, NW	-	Heifers P3.
23	19/10	1430	Warm, NW	18	Heifers P3.
24	23/10	p.m.	Fine, cool, NW	16	" "
25	31/10	1500	Overcast, windy, NNW	-	Fertilizer applied. = Fertilizer on ground
26	8/11	1100	Humid, overcast, NW	20	Cows P1; P2 recently grazed.
27	21/11	a.m.	Hot, humid, WNW	-	Heifers P3 + ploughing
28	1/12	1200	Cool, showery, SSE	15	P's 1, 2, 3 recently grazed.
29	12/12	a.m.	Overcast, WNW	18	Cattle P1; P3 sown.
30	21/12	a.m.	Warm, overcast, NNW	-	=
<u>1973</u>					
31	5/1	a.m.	Warm, overcast, NNW	-	=
32	15/1	1000	Warm, cloudy, NW	20	=
33	25/1	1030	Fine, warm, NW	20	Cattle P2.

*P1, P2, P3 refer to paddocks around the dams.
For key to other abbreviations see Appendix 3.0.

APPENDIX 2.2

RECORD OF RAINFALL AND OBSERVATIONS OF DAMS

Run	Rainfall to 0900 mm	Rainfall Over Prev. 5 days mm	Inflow	Outflow	Other Observations
1		=	+	+	-
2	16.6	24.0	+	+	-
3	-	-	=	=	-
4	-	tr	=	=	Weed in upper area of dam
5	-	9.0	=	=	Surface weed
6	-	10.3	=	=	-
7	-	-	=	=	-
8	-	13.1	=	=	Dam choppy; weed blown to Station 2.
9	10.7	10.7	+	=	-
10	-	-	=	=	Weed blown to Stations 1, 3.
11	6.8	21.6	+	+	Dam choppy, weed blown to Station 10.
12	-	-	=	=	Calm
13	-	-	=	=	Weed blown to Stations 1 and 3.
14	-	24.7	+	+	Weed blown to Stations 7, 8, 9, 10.
15	-	29.7	+	+	Choppy
16	10.6	15.7	+	+	-
17	-	tr	++	++	Weed blown to Stations 1, 3.
18	16.1	43.9	++++	++++	Water silty, tiles running.
19	5.9	28.9	+++	+++	Weed blown to Station 2; tiles running.
20	10.1	69.4	++++	++++	Water silty, almost up to pasture.
21	0.2	22.3	+++	+++	Less silty; household scraps at Station 10.
22	0.3	0.6	+	+	-
23	tr	50.2	++	++++	Water up to pasture.
24	-	14.2	=	+	No tile inflow; dams lower.
25	-	-	=	=	Windy; choppy.
26	-	-	=	=	Dam levels falling.
27	tr	2.2	=	=	Weed increasing.
28	-	tr	=	=	Weed blown to Station 7.
29	-	-	=	=	Dams lower.
30	2	2	=	=	-
31	-	17.9	=	=	-
32	12.1	19.3	=	=	-
33	6.1	6.6	=	=	-

APPENDIX 2.3MONTHLY RAINFALL AT BUNNYTHORPE

Year	Month	Rainfall mm	Rain Days	Weather Conditions
1971	November	90.4	10	Cold, wet.
	December	41.3	4	Light rainfall.
1972	January	59.4	6	Cold, wet.
	February	49.0	5	Low rainfall.
	March	162.2	6	Dry.
	April	91.5	8	Dry, mild.
	May	98.9	11	Cold, wet.
	June	41.3	5	Severe frosts.
	July	109.2	8	Frosty, then wet late in month.
	August	32.5	7	Cold, dry.
	September	50.2	10	-
	October	71.8	7	Dry.
	November	6.2	2	Driest November known
	December	17.2	7	Dry.
1973	January	48.9	5	Hot, dry.

Supplied by courtesy of N.Z. Meteorological Service, Wellington.

APPENDIX 3.0

KEY TO ABBREVIATIONS IN RESULT SUMMARIES

Abbreviation	Meaning
Temp.	Temperature ($^{\circ}\text{C}$)
Turb.	Turbidity (as Absorbance at 420 nm)
D.O.	Dissolved Oxygen (mg/l)
D.O. % Sat.	Dissolved oxygen (% Saturation)
BOD ₅	5-day Biochemical Oxygen Demand (mg/l)
Tot.P.	Total Phosphorus (mg/l)
Sol.P.	Ortho-phosphate (ug/l)
Tot.N.	Total Nitrogen (mg/l)
Org.N.	Organic Nitrogen (mg/l)
NH ₃ -N	Ammonia Nitrogen (ug/l)
NO ₃ -N	Nitrate Nitrogen (ug/l)
NO ₂ -N	Nitrite Nitrogen (ug/l)
TPC	Total Plate Count (per 100 cm ³)
TC	Total Coliform Count (per 100 cm ³)
FC	Faecal Coliform Count (per 100 cm ³)
FS	Faecal Streptococcal Count (per 100 cm ³)
FC/TC	Faecal Coliform/Total Coliform percentage
FC/FS	Faecal Coliform/Faecal Streptococcal ratio
-	No observation or measurement
=	Below detectable level
tr	Present in trace amount
*	Less than 50 ug/l soluble phosphate
+	Greater than
-	Less than
±	Approximately
a	Sampled away from shore because of weed growth
b	Household scraps and rubbish in water
?	Animals present in paddock or near station but signs of recent presence at station not recorded.

APPENDIX 3.1 RESULT SUMMARY : STATION 1. PHYSICAL AND CHEMICAL RESULTS

Run	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	23.0			10.8	124	5.2							
2	16.0	7.0		7.4	74	2.8							
3	30.0	-		11.3	149	6.5							
4	29.0	7.0		14.4	185	8.9							
5	25.0	8.0+		10.4	124	6.0							
6	23.0	7.0		7.4	85	7.1							
7	21.0	7.2		10.2	114	5.0	0.15	*					
8	20.0	7.4		8.6	94	4.5	1.10	*					
9	24.0	7.6		10.2	120	10.1	0.125	*	1.05			=	=
10	24.0	7.0		11.0	130	9.7	0.15	*	0.20			=	=
11	17.0	7.2	.28	10.6	109	8.2	0.20	*	0.35			=	=
12	24.0	7.6	.31	13.6	160	11.4	0.25	*	1.10			-	-
13	22.0	7.9	.28	10.8	123	9.3	0.40	*	1.00			=	=
14	21.0	8.6	.22	14.0	156	7.6	-	*	2.50			=	=
15	16.0	8.2	.21	11.5	115	5.4	0.30	*	0.90			-	-
16	17.0	7.8	.23	9.8	101	6.0	0.45	*	2.65			-	-
17	16.0	7.5	.15	13.0	130	5.8	0.10	*	1.40	0.08	60	-	-
18	14.0	6.7	.48	8.2	79	-	0.50	150	1.50	1.14	360	300	-
19	10.5	6.9	.15	10.4	93	5.0	0.65	*	0.60	0.30	300	-	10
20	11.5	7.0	.39	8.8	80	8.6	0.50	26	0.44	0.21	234	168	tr
21	10.5	7.1	.30	10.0	90	7.4	0.30	40	1.20	0.95	247	105	tr
22	15.5	7.25	.17	11.0	109	9.1	0.34	30	0.42	0.33	90	tr	6
23	17.5	7.1	.19	8.8	92	8.7	0.27	=	0.52	0.52	=	10	=
24	18.0	7.1	.14	8.3	88	8.0	0.19	=	0.70	0.70	tr	tr	tr
25	16.0	7.0	.12	8.7	87	5.3	0.14	40	0.96	0.96	=	13	=
26	20.5	6.9	.11	7.6	84	4.8	0.15	22.5	0.34	0.34	=	20	tr
27	25.0	7.5	.11	10.9	130	4.7	0.15	52.5	0.74	0.74	=	36	tr
28	19.0	6.6	.16	6.2	66	2.6	0.24	37.5	1.20	1.16	27	46	8
29	18.5	6.8	.10	5.3	56	2.9	0.29	60	0.455	0.42	27	26	12
30	19.0	7.2	.10	8.3	88	3.5	0.15	25	0.155	0.04	113	8	6
31	24.0	7.2	.13	6.7	79	3.9	0.175	31	0.65	0.58	67	7	tr
32	23.0	7.3	.12	6.3	72	3.5	0.19	42	0.78	0.74	38	tr	=
33	23.0	6.8	.16	5.1	59	3.4	0.19	10	1.10	1.09	88	6	tr

APPENDIX 3.2 RESULT SUMMARY : STATION 1. BIOLOGICAL AND BACTERIAL RESULTS

Run	Biological Factors	TPC	TC	FC	FS	FC/TC ₈	FC/FS
1	-	1.8×10^5	2.4×10^2	9.3×10^1	4	39	23
2	-	2.1×10^5	$2.4 \times 10^3+$	1.1×10^3	1.3×10^2	46-	8.5
3	=	5.1×10^5	$1.3 \times 10^2+$	3.3×10^1	3-	25	111+
4	Water weed	-	-	-	-		
5	Water weed						
6	=						
7	Sheep						
8	Sheep		1.6×10^3	9.2×10^2	6.0×10^2	58	1.5
9	Sheep; Weed	3.2×10^5	1.6×10^3	5.4×10^2	7.5×10^2	34	0.7
10	Sheep; Weed	2.5×10^5	3.0×10^3	1.3×10^3	1.6×10^3	43	0.8
11	Sheep; Weed	-	1.6×10^4	5.0×10^3	1.4×10^4	31	0.4
12	=	3.2×10^5	9.4×10^2	2.2×10^2	6.0×10^2	23	0.4
13	Sheep; Weed	-	2.0×10^3	-	5.0×10^2	-	-
14	Sheep? Birds	2.1×10^5	7.0×10^3	2.4×10^3	1.0×10^3	34	2.4
15	Sheep? Birds	3.3×10^5	5.0×10^3	3.2×10^3	1.5×10^3	64	2.1
16	Sheep?	2.2×10^5	2.3×10^4	4.8×10^3	2.8×10^3	21	1.7
17	Sheep? Weed	2.2×10^5	4.0×10^3	1.1×10^3	1.0×10^2	26	2.2
18	Sheep; Cattle	$3 \times 10^{6+}$	7.8×10^4	3×10^4	2.4×10^4	38	1.3
19	Cattle	1.0×10^6	1.2×10^3	5.0×10^2	-	42	-
20	=	6.0×10^6	3.3×10^4	4.4×10^3	6.8×10^2	13	6.5
21	Geese?	4.4×10^6	1.6×10^4	7.1×10^3	2.7×10^2	44	26
22	Geese?	1.2×10^5	4.0×10^3	1.9×10^2	5	4.8	290
23	Weeds; Geese?	1.3×10^6	1.8×10^4	9.2×10^3	88	51	104
24	Birds	2.9×10^5	6.5×10^3	8.0×10^2	25	12	32
25	Birds	3.2×10^5	5.5×10^2	2.4×10^2	10	43	24
26	Cattle; Birds	6.5×10^4	1.5×10^3	3.2×10^2	26	21	12
27	Birds?	9.0×10^4	1.9×10^3	9.5×10^2	1.0×10^2	52	9.3
28	Cattle	1.7×10^5	2.3×10^3	1.7×10^3	2.8×10^2	74	6.2
29	Birds?	4.1×10^4	1.2×10^3	6.3×10^2	1.9×10^2	57	3.3
30	Birds	1.1×10^5	7.0×10^2	5.5×10^2	65	79	8.5
31	Birds	1.1×10^5	1.9×10^3	7.5×10^2	1.5×10^3	40	0.5
32	Birds	1.5×10^5	1.1×10^3	8.0×10^2	5.9×10^2	77	1.4
33	Cattle	3.7×10^5	6.6×10^3		4.2×10^3	-	-

APPENDIX 3.3 RESULT SUMMARY : STATION 2. PHYSICAL AND CHEMICAL RESULTS

Run	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	24.0			10.9	128	3.6							
2	16.5	7.7		11.6	118	4.4							
3	29.0			11.6	149	6.8							
4	29.0	7.0		13.0	167	8.8							
5	23.0	8 ±		8.8	101	5.4							
6	23.0	8 ±		11.2	109	10.8							
7	21.0	6.8		10.2	113	6.4	0.05	*					
8	20.0	7.4		9.8	106	2.4	0.10	*					
9	23.0	7.4		10.2	117	9.9	-	*	0.40			=	=
10	23.0	6.8		8.8	101	8.5	0.175	*	0.20			=	=
11	16.0	7.2	.30	10.4	104	7.4	0.25	*	0.55			=	=
12	23.5	7.4	.34	12.2	142	11.6	0.30	*	1.65			-	-
13	21.5	7.7	.25	9.5	107	8.6	0.15	*	1.50			=	=
14	19.0	7.9	.21	11.0	117	7.8	-	*	3.40			=	=
15	15.0	7.9	.22	10.6	104	4.0	1.00	*	1.00			-	-
16	16.5	7.8	.30	9.4	96	6.8	0.40	*	2.00			-	-
17	15.0	7.3	.17	10.2	100	19 +	6.80	*	8.80	8.0	80	-	-
18	13.0	6.6	.25	8.8	83	-	2.40	*	2.00	1.75	254	304	-
19	9.5	6.9	.16	3.2	28	27 +	2.00	*	2.00	-	254	82	16
20	11.0	7.0	.46	8.7	78	6.3	0.63	25	0.63	0.38	254	197	tr
21	10.0	7.2	.22	11.3	100	7.2	0.17	30	0.72	0.46	260	60	tr
22	14.5	7.2	.16	9.5	92	8.7	0.30	17	0.44	0.35	93	8	5
23	16.5	7.1	.17	9.1	93	7.2	0.18	=	0.50	0.50	=	12	=
24	17.0	7.0	.13	8.0	83	7.0	0.15	tr	0.48	0.48	tr	=	tr
25	15.5	6.9	.12	8.0	79	5.2	0.225	42.5	1.02	1.02	=	14	=
26	20.5	6.9	.10	7.7	85	5.2	0.16	12.5	0.17	0.17	=	14	tr
27	24.0	8.2	.10	11.9	140	4.5	0.15	42	0.69	0.69	=	34	tr
28	19.0	6.7	.10	9.5	101	5.4	0.175	62.5	0.92	0.83	87	62	5
29	18.0	7.0	.08	8.4	88	1.9	0.175	30	0.61	0.55	59	40	60
30	19.0	7.9	.10	10.1	107	3.4	0.13	tr	0.34	0.32	17	tr	=
31	24.0	8.3	.09	10.8	127	4.0	0.175	21	0.30	0.30	tr	tr	=
32	24.0	8.5	.12	12.1	144	4.3	0.13	tr	0.81	0.81	=	=	=
33	23.0	8.2	.10	12.8	147	3.7	0.17	14	0.96	0.96	=	tr	=

APPENDIX 3.4 RESULT SUMMARY : STATION 2. BIOLOGICAL AND BACTERIAL RESULTS

Run	Biological Factors	TPC	TC	FC	FS	FC/TC %	FC/FS
1	=	1.4×10^5	4.6×10^2	1.5×10^2	1	33	150
2	-	6.3×10^5	$2.4 \times 10^3+$	4.6×10^2	-	19	-
3	Sheep?	2.8×10^5	3.5×10^2	7.0×10^1	33	20	2.1
4	Sheep? Cattle?	-	-	-	-	-	-
5	=						
6	Sheep						
7	Sheep?						
8	Sheep? Weed		1.6×10^3	5.4×10^2	1.1×10^3	34	0.5
9	Sheep?	2.0×10^5	$2.4 \times 10^3+$	2.8×10^2	4.7×10^2	11-	0.5
10	=	3.0×10^5	1.3×10^3	3.3×10^2	1.4×10^3	25	0.6
11	Sheep? Weed	1.0×10^6	5.4×10^3	8.5×10^2	2.2×10^3	16	0.4
12	=	5.4×10^5	7.9×10^2	1.4×10^2	2.5×10^2	18	0.6
13	Sheep? Weed	-	3.0×10^3	-	1.0×10^2	-	-
14	Cattle; Weed	9.5×10^4	1.1×10^4	2.1×10^3	1.3×10^3	19	1.6
15	Cattle; Sheep?	1.9×10^5	1.1×10^4	2.2×10^3	1.3×10^3	22	1.7
16	Cattle; Sheep?	4.9×10^5	2.4×10^4	5.6×10^3	2.0×10^3	23	2.8
17	Cattle; Sheep? Weed	1.2×10^5	-	1.1×10^3	90	-	12
18	Sheep?	$3 \times 10^6+$	4.4×10^4	1.4×10^4	6.8×10^3	33	2.1
19	Weed	3.0×10^6	1.9×10^3	2.0×10^2	-	11	-
20	=	7.0×10^6	2.2×10^4	3.4×10^3	5.8×10^2	16	5.9
21	=	8.8×10^5	3.0×10^3	1.6×10^3	2.5×10^2	54?	6.4
22	=	1.5×10^5	3.5×10^3	1.3×10^2	2.5×10^0	3.7	52
23	=	1.2×10^6	9.0×10^3	4.0×10^3	1.3×10^2	44	31
24	=	2.7×10^5	8.0×10^3	1.0×10^3	4.3×10^1	17	23
25	=	3.3×10^5	1.3×10^2	1.2×10^2	1.0×10^1	9	12
26	Cattle? Slime	3.5×10^5	9.0×10^2	2.6×10^2	8.0×10^0	29	33
27	Weed ^a	1.8×10^5	2.4×10^3	2.4×10^2	1.2×10^2	10	2.0
28	Cattle? Weed ^a	7.0×10^4	1.1×10^3	5.9×10^2	2.0×10^1	53	3.0
29	Cattle? ^a	4.0×10^4	2.8×10^3	5.0×10^2	1.6×10^2	18	3.1
30	= ^a	6.6×10^4	2.3×10^3	1.0×10^2	1.1×10^2	4.5	0.9
31	= ^a	1.6×10^5	5.6×10^3	3.5×10^2	1.0×10^2	6.5	1.8
32	= ^a	5.8×10^4	1.4×10^3	3.0×10^2	1.4×10^2	22	2.1
33	= ^a	1.9×10^5	1.5×10^3	6.0×10^2	1.4×10^2	40	4.3

APPENDIX 3.5 RESULT SUMMARY : STATION 3. PHYSICAL AND CHEMICAL RESULTS

Run	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	26.0			10.5	128	5.2							
2	18.0	7.3		9.3	98	2.9							
3	29.0	-		10.5	140	5.2							
4	29.5	7.4		8.4	109	6.7							
5	21.0	7.2		4.0	44	4.0+							
6	21.0	7.5		3.8	42	3.8+							
7	21.0	7.4		8.0	89	1.2	0.30	*					
8	21.0	7.4		3.6	40	2.9	0.83	*					
9	24.0	6.9		0.2	2	-	0.80	*	1.30			=	=
10	22.0	6.8		1.9	22	-	0.20	*	1.20			=	=
11	16.0	6.8	.31	11.0	110	7.4	0.40	*	1.15			=	=
12	24.0	7.6	.44	10.0	117	9.8+	0.45	*	2.75			-	-
13	21.5	7.3	.30	5.7	64	5.7	0.35	*	1.40			=	=
14	19.0	7.9	.20	11.8	125	7.4	-	*	2.85			18	-
15	16.0	7.6	.19	9.8	98	2.2	0.50	*	1.80			-	-
16	17.0	7.8	.20	9.0	93	9.2	0.80	*	2.60			-	-
17	16.0	7.3	.20	6.8	68	16.4+	2.00	*	7.30	7.22	80	-	-
18	14.0	6.7	.52	9.0	87	-	1.95	125	1.40	1.12	320	304	-
19	9.0	6.7	.17	10.0	86	5.2	0.95	*	0.60	0.31	287	8	12
20	12.5	7.0	.46	8.9	86	4.9	0.50	26	0.80	0.59	207	179	tr
21	11.5	7.2	.32	9.5	87	7.4	0.30	40	1.52	1.29	233	150	tr
22	16.0	7.4	.18	11.3	113	8.9	0.47	30	0.70	0.61	87	tr	5
23	19.0	7.1	.19	9.0	96	8.2	0.26	tr	0.64	0.64	=	10	=
24	18.5	6.8	.25	7.9	84	7.6	0.30	tr	1.02	1.02	tr	7	tr
25	16.0	6.9	.15	9.0	90	5.0	0.21	28	1.02	1.02	=	26	=
26	21.0	6.9	.12	6.7	74	4.7	0.20	23	0.12	0.04	76	28	tr
27	27.0	7.2	.12	9.4	116	5.2	0.20	53	1.08	1.06	12	60	tr
28	19.5	6.7	.15	5.3	57	3.1	0.24	75	1.04	0.75	247	32	5
29	18.5	6.9	.12	5.6	60	3.2	0.19	60	0.63	0.41	220	17	8
30	21.0	7.4	.13	8.3	92	6.8	0.20	110	0.31	0.17	141	6	tr
31	26.0	7.4	.19	8.0	98	4.2	0.32	26	0.70	0.59	107	6	tr
32	24.0	7.2	.16	7.7	91	3.6	0.46	317	1.02	1.01	7	=	tr
33	25.0	7.0	.15	5.2	62	5.0	0.32	255	1.34	1.31	30	tr	=

APPENDIX 3.6 SUMMARY SHEET : STATION 3. BIOLOGICAL AND BACTERIAL RESULTS

Run	Biological Factors	TPC	TC	FC	FS	FC/TC %	FC/FS
1	-	3.2×10^5	4.6×10^2	1.5×10^2	50	33	3
2	Sheep?	2.6×10^5	2.4×10^3	1.1×10^3	56	46-	20
3	=	5.6×10^5	2.2×10^2	1.7×10^2	63	78	2.7
4	=			2.6×10^3			
5	Sheep?						
6	Sheep? Weed						
7	Weed						
8	Weed; Sheep?		1.4×10^3	5.4×10^2	2.0×10^2	39	2.7
9	Weed; Birds?	4.3×10^5	1.6×10^3	9.2×10^2	2.1×10^3	58	0.4
10	Weed; Birds?	3.7×10^5	1.4×10^4	5.4×10^3	1.0×10^4	39	0.5
11	Sheep?	1.9×10^6	1.5×10^4	6.1×10^3	1.4×10^4	42	0.5
12	Sheep? Birds? Weed	5.8×10^5	2.4×10^3	4.9×10^2	7.0×10^2	20	0.7
13	Sheep? Weeds	-	3.5×10^3	-	2.7×10^2		
14	Sheep?	1.0×10^5	5.5×10^3	2.3×10^3	4.1×10^2	42	5.6
15	Sheep?	3.0×10^5	1.6×10^4	1.7×10^3	8.8×10^2	10	2.9
16	Weed; Birds; Sheep?	6.4×10^5	2.4×10^4	5.6×10^3	4.5×10^3	24	1.3
17	Weeds; Birds	1.7×10^5	3.5×10^3	8.0×10^2	1.4×10^2	23	1.7
18	Sheep? Flood	3×10^6	9.5×10^4	4.0×10^4	3.5×10^4	42	1.1
19	Sheep	1.1×10^6	9.0×10^2	7.5×10^2	-	83	
20	Sheep	1.0×10^7	2.2×10^4	3.9×10^3	6.3×10^2	18	6.2
21	Birds	3.3×10^6	$3.6 \times 10^3+$	3.6×10^3	3.5×10^2	?	10
22	Cattle; Birds	1.4×10^5	3.3×10^3	2.3×10^2	28	7	8.4
23	Cattle? Birds	1.9×10^6	3.0×10^4	9.6×10^3	64	32	150
24	Cattle? Birds	2.7×10^5	8.0×10^3	1.0×10^3	43	17	23
25	Birds	2.7×10^5	1.1×10^3	4.1×10^2	16	37	26
26	Weed; Birds	9.8×10^4	1.4×10^3	1.3×10^3	1.1×10^2	93	12
27	Birds; Cattle?	1.5×10^5	2.0×10^3	1.1×10^3	1.7×10^2	55	6.3
28	Cattle? Birds	1.5×10^5	-	1.5×10^3	1.1×10^2	-	13
29	Birds	5.5×10^4	1.9×10^3	7.8×10^2	2.0×10^2	41	3.9
30	Birds; Very shallow	1.7×10^5	1.2×10^3	1.1×10^3	65	88	16
31	Birds; Very shallow	8.7×10^5	1.9×10^3	1.3×10^3	5.7×10^2	66	2.2
32	Weed; Birds	2.5×10^5	$2.0 \times 10^2 \pm$	1.0×10^2	30	$50 \pm$	3.3
33	Shallow - sediment in sample	7.3×10^5	1.5×10^2	1.2×10^2	10	80	12

APPENDIX 3.7 RESULT SUMMARY : STATION 4. PHYSICAL AND CHEMICAL RESULTS

Run	Temp O C =	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	24.0			11.4	122	5.0							
2	17.5	8.3		11.2	117	3.5							
3	30.5	-		14.4	192	7.0							
4	30.0	7.0		13.8	182	5.4							
5	23.0	8 ±		8.6	99	6.2							
6	22.0	7.8		9.0	102	7.5							
7	21.0	7.4		12.2	136	5.4							
8	19.0	7.6		9.8	104	4.8	1.10	*					
9	23.0	7.2		10.4	120	10.1	0.10	*	0.30			=	=
10	22.0	6.8		9.4	107	7.8	0.125	*	-			=	=
11	16.0	7.2	.28	10.6	106	8.3	0.40	*	0.95			=	=
12	23.0	7.4	.40	13.4	154	11.3	0.25	*	1.75			-	-
13	21.0	7.8	.25	10.2	113	8.7	0.10	*	1.40			=	=
14	19.0	8.3	.21	13.1	148	7.0	-	*	2.65			18	-
15	15.0	7.9	.22	10.9	107	4.8	1.40	*	1.30			-	-
16	17.0	7.9	.22	9.6	99	6.4	0.425	*	2.15			-	-
17	14.0	7.2	.17	12.2	117	6.8	0.40	*	1.50	1.40	100	-	-
18	13.0	6.7	.22	9.8	92	-	0.30	*	1.90	1.65	247	87	-
19	10.0	6.9	.16	10.6	94	5.1	0.11	*	0.45	0.16	287	119	11
20	11.0	7.0	.54	9.0	81	5.9	0.57	250	0.26	0.07	194	183	tr
21	10.5	7.2	.21	10.6	95	6.5	0.20	30	0.92	0.73	190	115	tr
22	15.0	7.1	.17	10.5	103	8.3	0.30	8	0.60	0.51	87	5	6
23	16.0	7.1	.18	9.8	98	7.8	0.18	=	0.48	0.48	=	5	=
24	17.0	6.8	.14	9.0	93	7.2	0.125	=	0.48	0.48	=	=	tr
25	15.5	7.0	.13	8.2	81	4.9	0.175	28	0.94	0.94	=	13	=
26	20.5	6.9	.10	8.6	95	4.4	0.15	18	0.10	0.10	=	18	tr
27	25.5	8.1	.10	10.6	128	4.2	0.12	42	0.88	0.88	=	56	tr
28	19.5	7.4	.14	10.3	111	2.1	0.19	120	0.75	0.69	57	40	5
29	18.5	8.5	.12	13.2	140	2.2	0.13	30	0.54	0.48	55	6	5
30	21.0	8.2	.16	10.5	117	2.7	0.10	25	0.34	0.34	=	=	=
31	24.0	8.0	.10	9.8	115	4.1	0.15	21	0.27	0.27	=	tr	=
32	23.0	8.2	.12	10.0	115	4.5	0.19	10	0.74	0.74	tr	=	tr
33	22.0	8.2	.09	10.4	118	2.7	0.17	20	1.00	1.00	=	tr	=

APPENDIX 3.8 RESULT SUMMARY : STATION 4. BIOLOGICAL AND BACTERIAL RESULTS

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Run	Biological Factors	TPC	TC	FC	FS	FC/TC %	FC/FS
1	Geese?	1.8×10^5	4.6×10^2	2.9×10^2	1	63	290
2	Sheep?	1.9×10^5	2.6×10^3	1.1×10^3	69	42	16
3	Geese	7.5×10^4	1.4×10^3	5.4×10^2	2.3×10^2	39	2.3
4	-						
5	Weed, Sheep?						
6	Sheep?						
7	=						
8	Sheep		$2.4 \times 10^{3+}$	$2.4 \times 10^{3+}$	2.0×10^2		12+
9	=	1.9×10^5	$2.4 \times 10^{3+}$	$2.4 \times 10^{3+}$	5.0×10^2		4.8+
10	Geese?	9.6×10^4	1.3×10^3	4.9×10^2	6.0×10^2	38	0.8
11	Sheep?	1.6×10^6	3.8×10^3	9.3×10^2	5.5×10^3	25	0.2
12	Sheep	5.8×10^5	2.2×10^3	2.6×10^2	1.0×10^2	12	2.6
13	Sheep? Geese?	-	1.5×10^2	-	1.2×10^2		
14	Sheep? Weed	9.0×10^4	1.1×10^4	2.1×10^3	3.2×10^2	19	6.6
15	Sheep?	2.4×10^5	1.3×10^4	2.6×10^3	6.2×10^2	20	4.1
16	Sheep?	3.5×10^5	1.2×10^4	1.3×10^3	8.1×10^2	11	1.6
17	Birds	1.8×10^5	4.5×10^3	6.0×10^2	2.1×10^2	13	1.8
18	Sheep?	2.2×10^6	2.3×10^4	8.0×10^3	4.2×10^3	32	1.9
19	Birds, Sheep?	1.3×10^6	6.5×10^2	3.5×10^2	-	54	
20	Sheep? Birds	8.2×10^6	2.4×10^4	5.6×10^3	8.6×10^2	24	6.5
21	Birds?	4.0×10^5	3.0×10^3	2.5×10^3	95	83	27
22	Cattle? Birds?	1.8×10^5	2.0×10^3	2.5×10^2	2.5	5	100
23	Cattle?	1.4×10^6	8.0×10^3	4.4×10^3	96	55	46
24	Cattle?	2.8×10^5	3.5×10^3	4.0×10^2	10	11	40
25	Weed	3.1×10^5	1.0×10^3	1.6×10^2	8	16	20
26	Weed, Bird?	1.1×10^5	4.0×10^2	3.1×10^2	12	77	26
27	Cattle? Weed	1.1×10^5	4.0×10^2	2.1×10^2	2	53	105
28	Cattle; Birds	1.2×10^5	4.4×10^2	3.0×10^2	20	68	15
29	Birds	1.2×10^5	1.4×10^3	6.0×10^2	3.3×10^2	43	1.8
30	Birds	2.2×10^5	9.0×10^2	7.0×10^2	30	78	23
31	Birds	1.5×10^5	1.9×10^3	4.0×10^2	2.0×10^2	21	2.0
32	Birds	3.2×10^5	1.1×10^3	6.0×10^2	2.4×10^2	55	2.5
33	Birds?	2.8×10^5	5.5×10^2	4.0×10^2	95	73	4.2

APPENDIX 3.9 RESULT SUMMARY : STATION 5. PHYSICAL AND CHEMICAL RESULTS

Run	Temp °C	pH	Turb	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	24.0			12.1	144	2.5							
2	17.5	8.2		11.4	119	4.3							
3	30.5	-		13.5	180	7.8							
4	30.0	7.5		14.2	187	6.4							
5	23.0	8 ±		8.6	100	5.4							
6	23.0	7.5		9.4	109	8.6							
7	21.0	6.8		11.2	126	5.4							
8	19.5	7.5		10.0	109	5.0	0.95	*					
9	22.5	6.9		10.0	116	9.6	0.125	*	0.40			=	=
10	21.5	6.8		8.6	102	7.1	0.075	*	-			=	=
11	16.0	7.2	.29	9.8	99	6.7	0.45	*	1.40			=	=
12	23.5	7.6	.33	12.8	151	10.8	0.275	*	2.25			-	-
13	21.0	7.7	.24	9.1	102	7.1	0.15	*	1.00			=	=
14	19.0	8.1	.23	11.9	128	8.6	-	*	2.85			21	-
15	15.0	7.9	.23	10.5	104	4.2	1.40	*	1.50			-	-
16	16.0	7.9	.24	9.2	98	6.6	1.80	*	2.45			-	-
17	14.0	7.3	.14	12.0	117	6.2	0.90	*	1.40	1.29	107	-	-
18	13.0	6.9	.19	10.2	97	-	0.95	*	1.85	1.76	87	45	-
19	10.0	6.9	.15	9.8	87	4.6	0.38	*	.25+	-	247	120	10
20	11.0	7.1	.56	9.2	84	5.8	0.53	260	.70±		700	187	tr
21	11.0	7.2	.21	12.4	113	6.4	0.19	30	1.08	0.87	207	75	tr
22	15.0	7.2	.16	10.7	106	9.3	0.26	17	0.32	0.23	87	tr	5
23	16.0	7.2	.18	10.2	103	8.3	0.20	=	0.72	0.72	=	tr	=

APPENDIX 3.10 RESULT SUMMARY : STATION 5. BIOLOGICAL AND BACTERIAL RESULTS

Run	Biological Factors	TPC	TC	FC	FS	FC/TC %	FC/FS
1	-	1.4×10^5	4.6×10^2	1.7×10^2	2	37	85
2	Sheep?	1.1×10^5	2.6×10^3	1.1×10^3	46	42	24
3	Weed	1.6×10^5	9.2×10^2	5.4×10^2	60	59	9
4	=						
5	Weed; Sheep?						
6	Weed; Sheep						
7	Weed						
8	Sheep		2.2×10^3	9.2×10^2	4.0×10^2	42	2.3
9	=	2.3×10^5	1.6×10^3	2.2×10^2	5.6×10^2	14	0.4
10	=	2.1×10^5	1.7×10^3	7.0×10^2	1.1×10^3	41	0.7
11	Sheep?	1.2×10^6	1.3×10^3	4.9×10^2	2.2×10^3	38	0.2
12	Sheep?	6.9×10^5	2.4×10^3	4.9×10^2	4.0×10^2	20	1.3
13	Weed; Sheep?	-	2.5×10^3	-	1.1×10^2		
14	Sheep?	2.4×10^4	7.0×10^3	2.1×10^3	3.0×10^2	30	6.8
15	Sheep? Weed	3.7×10^5	8.0×10^3	2.1×10^3	1.1×10^3	26	1.9
16	Weed; Sheep? ^a	4.3×10^5	2.1×10^4	2.8×10^3	8.2×10^2	13	3.4
17	Weed ^a	2.1×10^5	4.5×10^3	2.0×10^2	90	4.5	2.1
18	Sheep? Flood	2.7×10^6	3.1×10^4	4.5×10^3	3.2×10^3	15	1.4
19	Sheep?	9.7×10^5	9.0×10^2	1.5×10^2	-	17	
20	Sheep? Ducks?	1.1×10^7	2.6×10^4	3.6×10^3	9.1×10^2	14	40
21	Ducks	7.1×10^5	1.5×10^3	1.4×10^3	1.6×10^2	94	8.8
22	Cattle?	1.7×10^6	3.8×10^3	1.2×10^2	2.5	3.2	48
23	Cattle?	1.4×10^6	5.5×10^3	3.9×10^3	74	72	53

APPENDIX 3.11 RESULT SUMMARY : STATION 6. PHYSICAL AND CHEMICAL RESULTS

Run	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	26.0			11.0	134	3.9							
2	17.0	7.8		10.7	110	4.5							
3	30.0	-		11.9	157	6.6							
4	30.0	-		13.0	171	5.2							
5	31.0	8 ±		8.6	114	5.4							
6	21.0	7.5		8.6	96	6.5							
7	21.0	7.4		12.0	133	6.4							
8	19.5	7.6		9.8	105	5.4	0.75	*					
9	22.0	7.1		9.6	109	9.2	0.28	*				=	=
10	22.0	6.8		9.4	107	7.9	0.10	*	0.80			=	=
11	16.0	7.1	.29	10.4	104	7.0	0.40	*	1.23			=	=
12	23.5	7.6	.56	10.6	147	10.2	0.35	*	1.75			-	-
13	21.0	7.8	.25	10.1	112	7.8	0.25	*	1.70			=	=
14	20.0	8.4	.22	13.1	143	7.8	-	*	3.00			15	-
15	14.0	8.0	.24	10.6	102	5.8	1.40	*	1.25			-	-
16	16.5	7.9	.28	9.4	96	6.0	0.70	*	2.00			-	-
17	14.0	7.4	.15	11.8	113	6.2	0.85	*	1.60	1.41	93	-	-
18	13.0	6.4	.18	9.2	87	-	0.25	*	1.20	1.01	193	300+	-
19	10.0	6.9	.16	10.0	88	5.2	0.05	*	0.35	0.08	274	180	15
20	10.5	7.1	.46	9.2	82	6.0	0.57	250	0.80+	-	800	195	tr
21	11.5	7.3	.20	12.1	111	7.1	0.20	30	1.20	1.01	190	70	tr
22	15.0	7.1	.17	10.1	99	8.8	0.95	28	1.20	1.10	100	tr	5
23	16.0	7.2	.18	9.8	98	7.1	0.22	=	0.56	0.56	=	10	=
24	17.0	6.7	.15	9.0	93	6.9	0.15	=	0.46	0.46	=	tr	=
25	15.5	7.0	.13	8.0	79	4.8	0.19	22.5	0.98	0.98	=	12	=
26	20.5	7.0	.10	8.3	91	4.9	0.18	17.5	0.43	0.43	=	16	tr
27	25.5	8.8	.09	13.9	168	4.1	0.13	31	0.72	0.70	17	56	=
28	19.0	7.5	.10	9.8	104	3.0	0.17	95	0.79	0.74	47	26	5
29	18.0	7.3	.08	8.4	89	2.7	0.20	50	0.59	0.50	90	35	6
30	19.0	7.7	.11	8.1	86	4.1	0.15	31	0.22	0.21	12	=	=
31	23.0	7.7	.10	7.9	91	4.3	0.16	20	0.45	0.45	=	tr	=
32	24.5	8.5	.11	10.8	129	4.2	0.13	=	0.91	0.91	tr	=	tr
33	24.0	8.4	.10	11.7	138	2.9	0.16	25	1.09	1.00	=	=	=

APPENDIX 3.12 RESULT SUMMARY : STATION 6. BIOLOGICAL AND BACTERIAL RESULTS

Run	Biological Factors	TPC	TC	FC	FS	FC/TC %	FC/FS
1	-	1.3x10 ⁵	4.6x10 ²	1.6x10 ²	6	35	27
2	Sheep?	8.5x10 ⁴	1.1x10 ³	4.6x10 ²	28	24	16
3	=	9.5x10 ⁴	2.4x10 ²	1.3x10 ²	23	55	5.7
4	=						
5	Sheep						
6	Sheep?						
7	Sheep?						
8	Sheep?		9.2x10 ²	3.5x10 ²	4.0x10 ²	38	.9
9	=	2.3x10 ⁵	9.7x10 ²	5.4x10 ²	5.7x10 ²	59	1.0
10	=	1.4x10 ⁵	4.9x10 ³	1.3x10 ³	1.3x10 ³	27	1.0
11	Sheep?	5.1x10 ⁵	1.3x10 ²	4.6x10 ²	1.6x10 ³	35	0.3
12	Sheep?	3.9x10 ⁵	7.9x10 ²	2.3x10 ²	3.0x10 ²	28	0.8
13	Sheep?	-	1.0x10 ³	-	1.0x10 ²		
14	Sheep?	1.1x10 ⁵	1.0x10 ⁴	1.7x10 ³	1.5x10 ²	17	1.1
15	Sheep?	2.9x10 ⁵	9.0x10 ³	2.1x10 ³	7.9x10 ²	23	2.6
16	Sheep?	3.8x10 ⁵	1.8x10 ⁴	2.4x10 ³	5.9x10 ²	14	4.0
17	=	2.0x10 ⁵	6.7x10 ³	3.0x10 ²	3.8x10 ²	5	0.8
18	Sampled tile outflow	5.4x10 ⁶	1.1x10 ⁴	6.7x10 ³	4.6x10 ³	61	1.5
19	Sheep?	6.9x10 ⁵	1.1x10 ³	5.0x10 ²	-	45	
20	Sheep? Ducks? Sediment	1.5x10 ⁷	3.4x10 ⁴	4.3x10 ³	8.7x10 ²	13	4.9
21	Ducks	8.0x10 ⁵		1.8x10 ³	1.6x10 ²	-	11.3
22	Cattle? Ducks?	2.1x10 ⁶	3.7x10 ³	1.7x10 ²	43	5	4.0
23	Cattle?	1.7x10 ⁶	8.0x10 ³	4.9x10 ³	88	61	56
24	Cattle?	2.5x10 ⁵	4.0x10 ³	2.5x10 ²	15	6	17
25	=	3.5x10 ⁵	5.0x10 ²	2.3x10 ²	10	46	23
26	=	8.9x10 ⁴	8.0x10 ²	2.7x10 ²	8	34	34
27	Cattle?	1.4x10 ⁵	1.5x10 ²	20	2	13.5	10
28	= ^a	7.1x10 ⁴	8.0x10 ²	3.2x10 ²	28	40	11.6
29	= ^a	4.8x10 ⁴	6.0x10 ²	5.0x10 ¹	26	8	1.9
30	= ^a	7.0x10 ⁴	6.0x10 ²	1.5x10 ²	68	25	2.2
31	Weed	4.0x10 ⁴	2.8x10 ³	1.5x10 ²	1.3x10 ²	9	1.2
32	Geese?	1.6x10 ⁵	1.2x10 ³	5.0x10 ²	90	44	5.5
33	=	2.4x10 ⁵	-	5.0x10 ²	1.4x10 ³	-	0.4

APPENDIX 3.13 RESULT SUMMARY : STATION 7. PHYSICAL AND CHEMICAL RESULTS

Run	Temp °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	26.0			10.6	131	2.2							
2	18.0	8.6		11.8	124	4.8							
3	29.5	-		12.3	162	6.8							
4	30.5	8.0		11.0	147	6.6							
5	22.0	7.2		8.4	97	5.8							
6	23.0	7.5		7.8	91	5.4							
7	22.0	6.8		10.2	117	5.0	0.70	*					
8	19.0	7.4		10.0	108	6.0	0.95	*					
9	23.0	6.9		9.6	111	9.2	0.30	*	0.70			=	=
10	22.0	6.8		9.6	110	7.8	0.125	*	0.70			=	=
11	16.0	7.2	.33	10.6	107	6.9	0.35	*	1.70			=	=
12	27.0	7.6	.66	11.2	140	10.2	0.40	*	2.40			-	-
13	22.0	7.7	.50	9.1	105	7.8	0.125	*	2.00			=	=
14	21.0	8.3	.26	12.2	137	7.4	-	*	2.75			15	-
15	15.0	8.0	.24	10.9	108	6.0	1.60	*	0.90			-	-
16	17.0	8.0	.40	9.8	101	6.0	0.90	*	1.60			-	-
17	15.0	7.5	.15	11.7	116	8.6	0.10	*	1.80	1.69	113	-	-
18	12.0	6.5	.18	9.9	92	-	0.90	*	1.50	1.28	220	44	-
19	9.0	6.9	.20	10.1	87	5.5	0.15	*	0.85	0.58	267	125	15
20	10.5	7.2	.47	9.1	82	4.5	0.60	290	0.56	0.08	480	174	tr
21	11.0	7.2	.21	12.0	109	6.7	0.16	160	1.08	0.89	193	65	tr
22	15.0	7.1	.17	10.5	104	8.7	0.26	17	0.80	0.70	100	tr	tr
23	16.5	7.3	.18	10.0	102	6.9	0.19	=	0.50	0.50	=	12	=
24	18.0	6.8	.18	9.9	104	6.9	0.15	tr	0.62	0.62	=	tr	=
25	16.0	7.0	.16	9.0	91	4.9	0.21	23	1.06	1.06	=	5	=
26	21.0	7.1	.10	10.0	112	4.8	-	28	-	-	=	16	tr
27	26.0	9.1	.11	12.1	150	4.1	-	31	-	-	=	44	tr
28	20.0	8.1	.17	12.9	142	1.9	0.23	75	0.63	0.57	40	22	tr
29	19.0	7.2	.08	8.4	91	2.4	0.12	50	0.46	0.37	85	42	5
30	19.0	7.6	.11	8.3	89	4.4	0.18	19	0.41	0.40	12	=	=
31	23.5	8.3	.10	9.9	116	3.8	0.14	20	0.55	0.55	=	tr	=
32	24.0	8.6	.11	10.7	127	3.7	0.13	tr	0.85	0.85	tr	=	tr
33	24.0	8.2	.10	11.3	135	3.6	0.16	25	0.88	0.88	=	tr	=

APPENDIX 3.14 RESULT SUMMARY : STATION 7. BIOLOGICAL AND FACTERIAL RESULTS

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Run	Biological Factors	TPC	TC	FC	FS	FC/TC %	FC/FS
1	-	1.4x10 ⁵	4.6x10 ²	80	5	17	16
2	Sheep?	1.9x10 ⁵	2.6x10 ³	1.1x10 ³	27	42	41
3	"	2.8x10 ⁵	3.4x10 ²	1.1x10 ²	3	32	37
4	"						
5	Sheep						
6	Sheep? Weed						
7	"						
8	Sheep?		4.2x10 ³	1.6x10 ³	1.1x10 ³	38	1.5
9	" ^a	1.8x10 ⁵	2.4x10 ³ ⁺	3.5x10 ²	1.1x10 ³	14-	0.3
10	" ^a	1.5x10 ⁵	3.0x10 ³	3.4x10 ²	1.5x10 ³	11	0.5
11	Sheep?	2.8x10 ⁵	1.6x10 ³	2.1x10 ²	2.5x10 ²	13	0.9
12	Sheep	1.6x10 ⁶	2.2x10 ³	1.7x10 ³	1.6x10 ³	77	1.1
13	Sheep? Geese?	-	1.8x10 ⁴	-	2.1x10 ²		
14	Sheep? Weed	1.9x10 ⁵	8.5x10 ³	1.3x10 ³	1.3x10 ²	16	1.0
15	Sheep? Weed	2.5x10 ⁵	2.5x10 ⁴	1.6x10 ³	6.7x10 ²	7	2.4
16	Weed	3.4x10 ⁵	2.6x10 ⁴	2.6x10 ³	7.5x10 ²	10	3.5
17	Sampled outflow	2.1x10 ⁶	3.5x10 ³	4.0x10 ²	1.7x10 ²	11	2.1
18	Sampled outflow	2.3x10 ⁶	2.3x10 ⁴	5.1x10 ³	1.8x10 ³	22	2.8
19	Sheep? Outflow	1.1x10 ⁶	1.1x10 ³	2.5x10 ²	-	23	
20	Sheep? Ducks? Sed.outflow	1.2x10 ⁷	2.3x10 ⁴	4.8x10 ³	7.8x10 ²	21	6.1
21	Ducks? Outflow	6.0x10 ⁵	-	1.6x10 ³	1.3x10 ²	-	12.8
22	Cattle? Ducks	1.8x10 ⁵	3.0x10 ³	1.8x10 ²	15	6	11.6
23	Cattle? Outflow	1.5x10 ⁶	1.6x10 ⁴	4.1x10 ³	1.0x10 ²	26	41
24	Cattle?	1.8x10 ⁵	2.5x10 ³	2.0x10 ²	23	8	9
25	Weed	3.3x10 ⁵	4.5x10 ² ⁺	4.2x10 ²	48	-	12
26	Geese?	7.2x10 ⁴	1.3x10 ³	4.5x10 ²	16	4	28
27	Cattle? Weed	5.6x10 ⁵	5.0x10 ²	2.0x10 ²	8	40	50
28	Cattle? Ducks	3.7x10 ⁴	7.0x10 ²	2.0x10 ²	20	29	10
29	Weed ^a	3.6x10 ⁴	5.0x10 ²	50	36	10	1.4
30	Weed ^a	7.0x10 ⁴	8.0x10 ²	1.0x10 ²	28	13	3.6
31	Weed ^a	9.2x10 ⁴	1.1x10 ³	1.5x10 ²	1.1x10 ²	14	1.4
32	Weed ^a	1.3x10 ⁵	7.2x10 ³	5.8x10 ³	63	81	92
33	Weed	2.0x10 ⁵	5.5x10 ²	4.0x10 ²	93	73	4.3

APPENDIX 3.15 RESULT SUMMARY : STATION 8. PHYSICAL AND CHEMICAL RESULTS

Run	Temp °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	25.0			10.3	124	4.1							
2	18.0	8.4		11.4	120	4.5							
3	29.0	-		11.8	153	6.3							
4	30.0	8.0		11.0	145	5.2							
5	22.5	7.4		8.6	100	6.2							
6	21.0	7.0		6.3	76	5.0							
7	21.5	7.0		10.6	120	5.0							
8	19.0	7.4		9.6	103	2.6	0.93	*					
9	23.0	6.9		10.0	110	9.7	0.50	*	0.25			=	=
10	20.0	6.8		7.6	84	6.6	0.13	*	0.60			=	=
11	16.0	7.2	.29	10.4	106	7.7	0.50	*	1.05			=	=
12	22.0	7.6	.34	12.0	138	9.2	0.32	*	1.50			-	-
13	21.0	7.6	.28	8.8	99	7.9	0.125	*	0.65			=	=
14	22.0	8.1	.22	11.2	117	8.0	-	*	2.00			11	-
15	15.0	7.9	.23	10.4	103	6.2	1.55	*	1.15			-	-
16	16.5	8.0	.23	9.0	92	5.8	0.45	*	1.15			-	-
17	13.0	7.4	.15	11.6	110	6.6	0.10-	*	1.25	1.14	107	-	-
18	13.0	6.7	.23	10.1	96	-	0.45	*	1.70	1.48	220	21	-
19	9.0	7.0	.18	9.6	83	4.6	0.23	*	0.70	0.40	300	110	15
20	10.2	7.2	.48	8.8	78	4.5	0.57		310	-	-	174	tr
21	11.0	7.2	.26	11.7	106	8.5	0.20		40	0.92	200	73	tr
22	14.5	7.2	.16	10.0	98	8.7	0.66		59	1.20	133	tr	tr
23	16.0	7.3	.18	9.3	94	6.5	0.17		=	0.74	0.74	=	8
24	17.0	6.9	.14	8.3	96	6.7	0.14		tr	0.46	0.46	=	=
25	16.0	7.0	.12	8.1	82	2.3	0.18		28	1.12	1.12	=	12
26	20.0	7.1	.10	8.3	91	5.0	0.23		23	0.12	0.12	tr	18

APPENDIX 3.16 RESULT SUMMARY : STATION 8. BIOLOGICAL & BACTERIAL RESULTS

Run	Biological Factors	TPC	TC	FC	FS	FC/TC %	FC/FS
1	-	7.4×10^4	4.6×10^2	80	-	12	
2	=	1.0×10^5	2.4×10^3	4.6×10^2	26	19	18
3	=	5.7×10^5	7.5×10^2	2.4×10^2	23	32	11
4	=						
5	=						
6	=						
7	= ^a						
8	= ^a	4.0×10^6	1.6×10^3	5.4×10^2	5.0×10^2	34	1.1
9	=	1.5×10^5	2.4×10^3 ⁺	3.5×10^2	5.6×10^2	15	0.6
10	Weed	1.3×10^5	4.9×10^3	1.1×10^3	1.3×10^3	22	0.9
11	Sheep?	8.3×10^5	1.7×10^3	7.0×10^3	6.0×10^2	27	0.2
12	Sheep?	6.6×10^5	1.4×10^3	2.2×10^2	5.0×10^2	16	0.4
13	Sheep?	-	2.5×10^3	-	98		
14	Sheep?	3.4×10^5	5.5×10^3	8.5×10^2	90	15	9.4
15	Sheep?	2.8×10^5	1.3×10^4	2.1×10^3	8.9×10^2	16	2.3
16	=	2.8×10^5	2.5×10^4	2.5×10^3	6.1×10^2	10	4.0
17	Weed	2.0×10^6	5.5×10^3	6.0×10^3	7.4×10^2	11	0.8
18	Weed; Sheep?	2.1×10^5	2.2×10^4	4.7×10^3	2.8×10^3	21	1.7
19	Weed; Sheep?	8.7×10^7	6.5×10^4 [±]	5.0×10^3 [±]	-	74 [±]	
20	Sheep? Ducks? Sediment	1.1×10^5	2.8×10^4	4.7×10^3	8.2×10^2	17	5.7
21	Ducks? Bank eroding	7.3×10^5	2.5×10^3	1.4×10^3	1.3×10^2	56	11
22	=	1.7×10^5	4.3×10^3	1.4×10^2	3	3	56
23	=	1.8×10^6	9.0×10^3	3.2×10^3	1.2×10^2	36	28
24	=	2.8×10^5	4.0×10^3	4.0×10^2	10	10	40
25	Slime growth	5.2×10^4	-	-	-		
26	Weed	9.7×10^4	-	-	-		

APPENDIX 3.17 RESULT SUMMARY : STATION 9. PHYSICAL AND CHEMICAL RESULTS

Run	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	25.0			12.5	151	4.2							
2	17.5	8.3		11.3	118	4.1							
3	29.0	-		11.7	152	10.0							
4	30.0	8.0		9.4	124	7.0							
5	23.0	7.1		7.6	88	4.8							
6	22.0	7.0		7.8	90	6.1							
7	22.0	7.0		8.8	101	6.9							
8	20.0	7.6		10.0	111	5.8	0.85	*					
9	23.0	7.0		10.2	119	9.8	0.10	*	0.70			=	=
10	21.0	6.8		9.0	91	8.1	0.625	*	-			=	=
11	16.0	7.2	.32	10.6	107	7.9	0.40	*	0.95			=	=
12	22.0	7.6	.35	13.0	150	13.0+	0.40	*	1.25			-	-
13	21.0	7.4	.29	8.1	91	6.0	0.30	*	1.60			=	=
14	21.0	8.1	.27	10.4	117	20.0+	-	*	3.65			15	-
15	15.0	7.8	.19	10.7	106	6.2	2.50	*	0.50			-	-
16	16.5	7.9	.21	9.2	94	6.6	1.65	*	1.40			-	-
17	14.0	7.5	.16	11.6	113	18.0	0.70	*	2.00	1.89	107	-	-
18	13.0	6.9	.22	10.2	97	-	0.10	*	1.20	0.95	254	24	-
19	9.5	7.0	.25	9.9	87	5.4	0.80	*	0.60	0.26	340	130	10
20	10.5	7.1	.52	8.7	78	4.6	0.60	270	0.64	0.41	234	183	tr
21	11.0	7.2	.20	11.9	108	8.1	0.22	40	2.62	2.43	193	83	tr
22	15.0	7.0	.17	10.6	105	8.1	0.28	17	0.88	0.65	133	tr	tr
23	16.5	7.3	.17	9.6	98	7.3	0.20	=	0.90	0.90	=	8	=
24	17.0	7.0	.14	8.7	90	6.6	.12	tr	0.86	0.86	=	=	=
25	16.0	6.9	.12	9.2	93	4.7	0.19	28	0.76	0.76	=	9	=
26	21.0	7.1	.09	8.6	97	4.5	0.26	28	0.17	0.16	13	20	tr
27	25.0	8.7	.09	13.9	168	4.8	0.12	53	0.94	0.94	=	36	=
28	19.5	7.8	.10	12.0	130	2.1	0.16	75	0.57	0.51	57	46	5
29	19.0	7.8	.93	11.3	122	4.8	0.20	20	0.74	0.74	-	15	=
30	23.0	7.8	.11	7.9	92	0.8	0.19	25	0.51	0.47	40	tr	=
31	25.0	8.3	.09	10.2	123	4.0	0.15	30	0.37	0.37	tr	tr	=
32	25.0	8.6	.11	11.4	142	3.3	0.14	tr	0.80	0.80	=	=	=
33	25.0	8.4	.09	11.5	139	2.6	0.15	30	1.12	1.12	tr	tr	=

APPENDIX 3.18 RESULT SUMMARY : STATION 9. BIOLOGICAL AND BACTERIAL RESULTS

Run	Biological Factors	TPC	TC	FC	FS	FC/TC %	FC/FS
1	-	1.1x10 ⁵	93	40	7	43	5.7
2	=	3.1x10 ⁵	2.6x10 ³	1.1x10 ³	52	42	21
3	Sheep	2.2x10 ⁶	2.4x10 ³⁺	2.4x10 ³⁺	6.4x10 ³	-	
4	Sheep; Cattle?						
5	=						
6	Weed; Sheep?						
7	Sheep						
8	Sheep		1.0x10 ³	3.5x10 ²	4.0x10 ²	35	0.9
9	Sheep	2.2x10 ⁵	1.6x10 ³	2.8x10 ²	5.5x10 ²	18	0.5
10	=	1.3x10 ⁵	7.5x10 ³	1.3x10 ³	1.4x10 ³	17	0.4
11	Sheep	2.4x10 ⁵	1.7x10 ³	4.6x10 ²	2.6x10 ³	27	0.2
12	=	6.7x10 ⁵	4.6x10 ²	50	3.0x10 ²	11	0.2
13	Sheep?	-	6.0x10 ³	-	1.5x10 ³		
14	Weed; Sheep? Cattle?	8.8x10 ⁵	7.0x10 ³	2.3x10 ³	2.8x10 ²	32	0.8
15	Weed; Cattle? Sheep	1.4x10 ⁵	5.0x10 ³	1.4x10 ³	7.1x10 ²	27	1.9
16	Cattle? Sheep?	3.1x10 ⁴	9.5x10 ³	1.9x10 ²	8.1x10 ²	20	2.4
17	Cattle; Sheep? Weed	9.9x10 ⁶	3.0x10 ⁴	2.5x10 ³	2.8x10 ³	8	0.9
18	Sheep? Flood	1.9x10 ⁵	2.8x10 ⁴	6.2x10 ²	3.5x10 ³	22	1.8
19	=	7.6x10 ⁶	5.0x10 ²	2.5x10 ³	-	50	
20	Sediment	8.8x10 ⁶	3.1x10 ⁴	4.6x10 ³	7.5x10 ²	15	6.1
21	=	7.3x10 ⁵	-	2.0x10 ³	1.4x10 ²	-	14
22	=	1.8x10 ⁶	2.0x10 ³	1.9x10 ³	-	10	
23	= d	1.4x10 ⁵	1.6x10 ⁴	3.2x10 ³	1.2x10 ²	20	27
24	Weed	2.1x10 ⁵	-	5.0x10 ³	10	-	50
25	Weed; Algae; Rubbish ^b	6.6x10 ⁴	2.9x10 ⁴	5.1x10 ²	10	18	510
26	Weed; Rubbish; Cattle ^b ?	1.6x10 ⁴	4.0x10 ²	1.3x10 ²	6	33	22
27	Weed	8.0x10 ⁴	-	1.4x10 ²	8	-	18
28	Weed; Cattle?	7.9x10 ⁴	7.3x10 ²	1.2x10 ³	30	16	4.0
29	Cattle	1.5x10 ⁵	6.4x10 ²	2.6x10 ²	9.7x10 ³	41	0.3
30	Shallow	1.3x10 ⁵	8.0x10 ²	3.5x10 ²	7.5x10 ²	44	0.5
31	=	1.2x10 ⁵	1.0x10 ³	1.5x10 ²	10	15	15
32	Weed; Shallow	1.4x10 ⁵	6.5x10 ²	3.0x10 ²	1.0x10 ²	46	3.0
33	Weed; Shallow	3.9x10 ⁵	7.0x10 ²	3.7x10 ²	2.4x10 ²	53	1.5

APPENDIX 3.19 RESULT SUMMARY : STATION 10. PHYSICAL AND CHEMICAL RESULTS

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Run	Temp °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	26.0	-		9.7	120	4.5							
2	18.0	8.4		10.9	115	4.7							
3	28.5			12.6	162	7.1							
4	30.0	8 ±		9.0	118	8.4							
5	22.0	7.1		7.8	90	7.0							
6	20.0	7.0		7.8	86	5.7							
7	21.0	7.0		10.6	119	5.0		*					
8	19.5	7.0		9.0	98	6.2	0.72	*					
9	22.0	7.5		9.4	108	9.1	0.05	*	0.50			=	=
10	21.0	7.0		7.4	83	6.3	0.175	*	-			=	=
11	16.0	7.3	.30	10.2	103	7.4	0.40	*	0.70			=	=
12	21.0	7.6	.31	12.4	139	9.9	0.28	*	1.50			-	-
13	21.0	7.4	.29	7.9	89	7.9+	0.195	*	1.30			=	=
14	22.0	7.5	.22	4.6	53	8.6	-	*	2.25			18	=
15	15.0	7.9	.23	10.4	103	5.2	1.50	*	0.80			-	-
16	16.0	7.9	.22	9.2	93	6.0	1.70	*	1.00			-	-
17	13.0	7.4	.16	11.3	108	5.6	0.50	*	0.80	0.69	107	-	-
18	13.0	6.8	.39	3.6	34	-	8.00	14	-	-	254	tr	-
19	9.0	7.0	.28	9.2	79	4.6	0.75	*	0.40+	-	394	133	12
20	10.5	7.1	.46	8.8	79	4.8	0.60	290	0.38	0.11	267	190	tr
21	11.0	7.2	.21	11.2	102	8.2	0.20	40	0.92	0.73	193	65	tr
22	15.0	7.1	.17	10.0	100	7.5	0.43	17	0.36	0.25	113	tr	tr
23	16.0	7.3	.18	9.4	95	6.6	0.20	=	0.60	0.60	=	10	=
24	17.0	6.9	.14	8.2	85	6.4	0.17	tr	0.72	0.72	=	tr	=
25	16.0	7.0	.13	7.3	74	4.6	0.175	13	0.92	0.92	=	12	tr
26	20.0	7.1	.11	6.5	72	4.3	0.30	23	0.24	0.24	=	14	tr
27	25.5	8.0	.11	9.7	118	4.1	0.13	42	0.89	0.89	=	56	=
28	19.0	7.6	.11	8.3	89	2.4	0.225	63	0.61	0.55	63	52	6
29	19.0	7.4	.10	8.4	90	2.2	0.13	20	0.24	0.08	157	22	tr
30	21.0	7.9	.09	9.5	107	2.9	0.20	30	0.44	0.42	17	tr	=
31	24.0	7.9	.08	8.8	105	3.8	0.14	40	0.34	0.33	11	tr	=
32	23.0	8.2	.13	9.8	114	3.4	0.19	36	1.11	1.10	12	=	=
33	25.0	8.1	.09	10.0	122	2.4	0.16	33	0.84	0.82	24	=	=

APPENDIX 3.20 RESULT SUMMARY : STATION 10. BIOLOGICAL AND BACTERIAL RESULTS

Run	Biological Factors	TPC	TC	FC	FS	FC/TC %	FC/FS
1	-	1.9×10^5	4.4×10^3	1.2×10^2	3	27	40
2	"	2.7×10^5	$2.4 \times 10^{3+}$	1.1×10^3	56	-	20
3	Sheep	1.6×10^5	$2.2 \times 10^{3+}$	9.2×10^2	23	42	40
4	Sheep; Cattle?						
5	Sheep?						
6	Sheep?						
7	Sheep?						
8	Sheep (mud stirred up)	-	1.6×10^3	9.2×10^2	5.0×10^2	57	1.8
9	Sheep	2.2×10^5	4.3×10^3	1.5×10^3	7.0×10^2	38	2.3
10	-	1.3×10^5	4.9×10^3	1.1×10^3	8.0×10^2	22	1.4
11	Weed; Sheep?	1.4×10^6	1.1×10^3	3.1×10^2	1.5×10^3	28	0.2
12	-	6.1×10^5	7.9×10^2	2.7×10^2	50	34	5.4
13	Sheep	-	2.0×10^3	-	78		
14	Weed; Cattle?	4.3×10^5	6.5×10^3	1.8×10^3	5.1×10^2	28	3.5
15	Cattle; Geese? Sheep?	1.4×10^5	8.5×10^3	1.8×10^3	9.5×10^2	21	1.9
16	Cattle; Geese; Sheep?	3.1×10^5	2.1×10^4	4.0×10^3	7.9×10^2	19	5.1
17	Cattle; Sheep?	1.2×10^5	2.5×10^3	7.0×10^2	7.3×10^2	28	1.0
18	Weed; Sheep?	2.6×10^5	9.0×10^2	2.0×10^2	-	22	
19	Geese	1.7×10^6	$4.0 \times 10^{2+}$	$2.0 \times 10^{2+}$	-	50±	
20	Silt in water	1.2×10^7	3.3×10^4	5.9×10^3	7.1×10^2	18	8.3
21	-	6.6×10^5	-	1.9×10^3	1.7×10^2		12
22	Rubbish ^b	1.5×10^5	7.0×10^3	2.1×10^2	5	3.0	42
23	Rubbish ^b	8.0×10^5	2.9×10^4	4.2×10^3	1.7×10^2	15	25
24	Rubbish ^b	2.1×10^5	5.5×10^3	4.5×10^2	10	8	45
25	Shallow; Rubbish ^b	2.3×10^5	5.0×10^2	1.5×10^2	4	30	38
26	Cattle?	1.3×10^5	7.8×10^3	7.3×10^3	1.0×10^2	93	73
27	-	1.5×10^5	1.3×10^3	3.4×10^2	18	26	18
28	Cattle? (sediment in sample)	1.0×10^5	3.3×10^3	4.8×10^2	16	15	30
29	Cattle? Shallow	3.8×10^4	2.0×10^3	1.0×10^3	5.7×10^2	50	1.8
30	-	9.8×10^4	$7.0 \times 10^{2+}$	$5.0 \times 10^{2+}$	73	72±	6.9±
31	-	9.4×10^4	1.3×10^3	4.0×10^2	2.3×10^2	31	1.7
32	Geese	1.7×10^5	1.6×10^3	4.5×10^2	95	29	4.5
33	Shallow	1.4×10^5	1.4×10^3	9.2×10^2	93	66	10

APPENDIX 3.21

RESULT SUMMARY : STATION 11 (UPPER DAM). PHYSICAL AND CHEMICAL RESULTS

Run	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
23	16.0	7.4	.21	9.0	91	7.8	0.32	125	0.40	0.40	23	=	=
24	18.5	9.4	.10	17.9	191	8.5	0.15	105	0.84	0.84	=	tr	=
25	15.0	8.7	.14	13.8	137	9.5	0.50	163	0.58	1.58	=	=	15
26	20.0	8.7	.41	17.0	187	10.5	0.475	213	0.57	0.57	=	18	tr
27	26.0	7.4	.36	8.7	107	9.4	0.53	225	1.13	1.13	=	50	=
28	19.5	7.3	.17	7.5	82	4.8	0.36+	363	1.26	1.19	67	=	8
29	17.0	6.9	.22	3.0	31	13.4	0.42	140	0.94	0.70	243	=	tr
30	19.0	7.2	.23	9.2	99	16+	1.90	355	1.80	1.79	12	=	=
31	21.0	7.9	.39	11.3	127	24.6	2.025	55	2.16	2.15	11	=	tr
32	22.0	8.4	.57	11.0	127	36	2.44	33	4.14	4.12	22	=	=
33	20.0	8.4	.37	12.1	133	42	1.1	20	4.5	4.5	tr	=	=

RESULT SUMMARY : STATION 11. BIOLOGICAL AND BACTERIAL RESULTS

Run	Biological Factors	TPC	TC	FC	FS	FC/TC	FC/FS
23	Outflow; Cattle?	2.2x10 ⁴	2.6x10 ⁴	2.3x10 ⁴	90	90	74
24	Fil. Algae; Water brown; Trickle o'flow; Cattle?	6.0x10 ³	50 ⁻³	50 ⁻²	50 ⁻		
25	No o'flow; Algae	3.5x10 ⁴	1.0x10 ³	3.1x10 ²	2 ⁻	31	155+
26	Geese	1.5x10 ⁵	4.0x10 ²	2.6x10 ²	56	65	4.6
27	Cattle?	8.7x10 ⁵	3.0x10 ²	1.7x10 ²	4	57	43
28	Sediment in sample	1.6x10 ⁵	6.3x10 ²	4.2x10 ²	18	68	23
29	a	9.7x10 ⁴	2.0x10 ²	50	3	25	17
30	Weed ^a	2.2x10 ⁵	50 ⁻	50 ⁻	5		
31	Weed ^a	3.3x10 ⁵	1.0x10 ²	80	10	80	8
32	Weed; Algae ^a	6.7x10 ⁵	6.5x10 ²	5.2x10 ²	32	80	16
33	=	5.2x10 ⁵	8.0x10 ²	3.5x10 ²	1.0x10 ²	44	3.4

APPENDIX 3.22

RESULT SUMMARY : STATION 12 (UPPER DAM). PHYSICAL AND CHEMICAL RESULTS

Run	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
24	15.0	6.6	.17	8.7	86	8.2	0.465	387	1.12	1.12	=	tr	113
25	12.5	6.8	.26	10.4	98	8.7	0.36	340	0.80	0.80	tr	=	tr
26	17.0	6.2	.18	0.4	4	12.6+	0.52	490	0.96	0.76	197	=	=
27	22.5	6.3	.28	0.4	5	12.8	0.45	363	1.54	1.35	186	42	
28	19.0	6.4	.27	1.0	11	15.8	.95	530	2.44	2.25	190	=	8
29	17.5	6.9	.44	9.5	99	14.8	0.84	110	0.88	0.13	750	=	tr
30	20.0	8.8	.35	10.8	119	15.8+	1.00	119	1.50	1.50	=	=	=
31	27.0	9.9	.74	13.0	163	27.7	1.95	30	3.98	3.96	23	=	=
32	24.0	9.2	.48	14.0	167	23.6	1.18	50	3.80	3.78	15	=	=
33	25.0	8.7	.34	13.5	163	19.6	0.90	30	3.80	3.80	=	=	=

RESULT SUMMARY : STATION 12. BIOLOGICAL AND BACTERIAL RESULTS

Run	Biological Factors	TPC	TC	FC	FS	FC/TC	FC/FS
24	Water brown; Cattle?	7.7×10^6	2.0×10^3	8.0×10^2	3.0×10^2	40	2.7
25	Weed; Odour; Cattle?	3.8×10^5	$2.2 \times 10^{3\pm}$	$2.2 \times 10^{3\pm}$	14	100-	170-
26	Weed	2.7×10^5	1.0×10^3	5.5×10^2	42	30	13
27	Weed	1.6×10^6	9.2×10^3	1.2×10^3	4.2×10^2	13	0.3
28	Water greyish-black	1.4×10^6	1.2×10^3	6.2×10^3	6.6×10^2	52	9.5
29	=	3.2×10^5	1.5×10^3	1.3×10^2	85	9	1.5
30	Shallow	6.0×10^5	2.2×10^3	1.4×10^3	1.3×10^2	64	1.1
31	Shallow; Algae ^a	1.7×10^7	$2.0 \times 10^{2\pm}$	80	10	40	8
32	Shallow; Weed; Algae ^a	1.9×10^6	$3.0 \times 10^{2\pm}$	2.2×10^2	12	73	18
33	Weed; Shallow	6.8×10^5	8.5×10^2	3.5×10^2	20	41	18

APPENDIX 3.23 RESULT SUMMARY : LOWER DAM MEAN RESULTS - PHYSICAL AND CHEMICAL RESULTS

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Run	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
1	25.0			11.0	133	4.0							
2	17.0			11.0	113	3.9							
3	30.0			12.2	161	7.0							
4	30.0	7.6		11.8	153	6.9							
5	23.0	7.5		8.2	95	5.8							
6	22.0	7.4		8.1	93	7.0							
7	22.0	7.1		10.4	120	5.2							
8	20.0	7.4		9.0	99	4.6	.82						
9	23.0	7.2		9.2	107	9.0	.27		0.62			=	=
10	22.0	6.8		8.2	94	7.8	.175	*	0.46			=	=
11	16.0	7.2	.30	10.5	106	7.3	.375	*	1.00			-	-
12	23.5	7.6	.40	12.3	145	10.7	.32	*	1.79			=	=
13	21.3	7.6	.29	8.9	101	7.7	.20	*	1.36			=	=
14	20.3	8.2	.23	11.3	133	9.0	-	*	2.79			13	-
15	15.1	7.9	.22	10.6	105	4.7	1.47	*	1.11			-	-
16	16.6	7.7	.25	9.3	95	6.5	.93	*	1.90			-	-
17	14.4	7.4	.16	11.2	110	9.9	1.25	*	2.79	2.41	96	-	-
18	13.1	6.7	.29	9.2	88	-	1.48	11	2.93	1.35	256	126	-
19	9.6	6.9	.17	9.3	83	7.2	0.71	*	0.53+	0.30+	295	102	13
20	10.9	7.1	.48	8.9	81	5.2	.57	270	0.59+	0.30	374	183	tr
21	10.9	7.2	.23	11.5	105	7.3	.21	40	1.22	1.00	211	86	tr
22	15.0	7.2	.17	10.4	103	8.5	.42	23	0.69	0.57	103	tr	tr
23	16.5	7.2	.18	9.5	94	7.5	.21	-	0.62	0.62	31	9	=
24	17.5	7.0	.15	8.6	90	7.0	.17	tr	0.64	0.64	=	tr	tr
25	15.8	7.0	.13	8.4	85	4.6	.19	28	0.98	0.98	=	13	=
26	18.6	7.0	.10	8.0	95	4.3	.20	22	0.19	0.18	10	18	tr
27	25.5	8.2	.11	11.6	142	4.5	.15	43	0.86	0.84	4	47	tr
28	19.3	7.3	.13	7.3	79	2.8	.20	85	0.81	0.73	104	40	5
29	18.6	7.4	.20	8.6	92	2.8	.18	40	0.53	0.44	130	25	5
30	20.0	7.8	.11	8.9	98	3.6	.17	30	0.34	0.30	40	tr	tr
31	24.0	7.9	.11	9.0	107	4.0	.18	26	0.45	0.43	24	tr	tr
32	24.0	8.1	.12	9.9	118	3.8	.20	50	0.88	0.87	7	=	=
33	24.0	7.9	.11	9.8	117	3.3	.18	50	1.03	1.02	18	2	=

APPENDIX 3.24 RESULT SUMMARY : LOWER DAM MEAN RESULTS - BACTERIAL RESULTS

Run	TPC	TC	Counts per 100 ml		FC/TC%*	FC/FS*
			FC	FS		
1	2.9×10^5	3.5×10^2	2.0×10^2	8	30 (57)	68 (25)
2	2.3×10^5	$2.4 \times 10^3+$	1.1×10^3	54	33 (46-)	21 (20)
3	4.8×10^5	$8.9 \times 10^2+$	5.2×10^2	6.9×10^2	42 (58)	13 (.8)
4-7						
8		1.8×10^3	9.1×10^2	5.3×10^2	41 (50)	2.5 (1.7)
9	2.3×10^5	$2.1 \times 10^3+$	$7.5 \times 10^2+$	7.9×10^2	34 (36)	1.2 (1.0+)
10	1.9×10^6	4.7×10^3	1.3×10^3	2.1×10^3	29 (28)	0.8 (0.6)
11	1.2×10^5	4.9×10^3	1.6×10^3	4.6×10^3	28 (33)	0.4 (0.4)
12	6.5×10^5	1.4×10^3	4.1×10^2	4.8×10^2	26 (29)	1.4 (0.9)
13	-	3.9×10^3	-	1.6×10^2	-	-
14	2.3×10^4	8.0×10^3	1.9×10^3	7.0×10^2	25 (24)	3.9 (2.8)
15	2.5×10^5	1.1×10^4	2.1×10^3	9.3×10^2	24 (19)	2.4 (2.3)
16	3.7×10^5	2.0×10^4	3.3×10^3	1.4×10^3	17 (17)	3.0 (2.4)
17	1.7×10^5	4.0×10^3	6.0×10^2	2.9×10^2	14 (15)	1.5 (2.1)
18	2.6×10^6	3.6×10^4	1.2×10^4	8.7×10^3	31 (33)	1.7 (1.4)
19	1.2×10^6	9.2×10^2	3.7×10^2	-	42 (40)	-
20	1.0×10^6	2.7×10^4	4.5×10^3	8.3×10^2	17 (17)	6.0 (5.4)
21	1.3×10^5	3.7×10^3	2.5×10^3	1.8×10^2	66 (68)	14 (14)
22	1.7×10^6	3.5×10^3	1.6×10^2	6	5.1 (4.6)	68 (26)
23	1.5×10^5	1.5×10^4	5.2×10^3	1.0×10^2	41 (35)	56 (50)
24	2.4×10^5	4.2×10^3	4.0×10^2	16	11 (10)	31 (25)
25	3.2×10^5	4.2×10^3	8.5×10^2	15	28 (20)	83 (57)
26	1.3×10^5	1.8×10^3	1.3×10^3	36	48 (80)	30 (37)
27	1.8×10^4	1.1×10^3	4.0×10^2	54	34 (36)	27 (7.4)
28	9.9×10^4	1.4×10^3	6.3×10^2	66	42 (45)	12 (9.5)
29	5.5×10^5	2.1×10^3	8.3×10^2	1.4×10^3	34 (40)	2.2 (0.6)
30	1.2×10^5	9.8×10^2	4.4×10^2	64	47 (45)	7.0 (7.0)
31	2.1×10^5	2.2×10^3	4.6×10^2	3.7×10^2	25 (21)	3.2 (1.2)
32	1.7×10^5	1.8×10^3	1.1×10^3	1.7×10^2	50 (62)	14 (6.6)
33	3.2×10^5	$1.5 \times 10^3?$	1.2×10^3	7.9×10^2	64 (83)	5.2 (1.6)

*Figures without brackets refer to means calculated from ratios for each station; those in brackets refer to ratios calculated from mean counts.

APPENDIX 3.25

RESULT SUMMARY : UPPER DAM MEAN RESULTS - PHYSICAL AND CHEMICAL RESULTS

Run	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
23	16.0	7.4	.21	9.0	91	7.8	0.32	125	0.40	0.38	23	=	=
24	16.8	8.0	.13	13.3	137	8.4	0.31	246	0.98	0.98	=	1	57
25	15.8	7.8	.20	12.1	122	9.1	1.40	550	1.19	1.19	2	=	tr
26	18.5	7.5	.29	8.7	93	11.6	0.50	350	0.76	0.67	98	9	tr
27	24.0	7.0	.28	4.6	55	11.1	0.50	320	1.34	1.24	93	46	=
28	19.0	6.9	.22	4.3	46	10.3	0.63	415	1.85	1.67	489	=	tr
29	17.3	6.9	.33	6.3	66	14.1	0.63	125	.91	0.42	448	=	tr
30	20.0	8.0	.29	10.0	110	16+	1.45	237	1.65	1.65	6	=	=
31	24.0	8.9	.57	12.2	145	26.2	1.99	178	3.47	3.06	17	=	tr
32	23.0	8.9	.53	12.5	145	29.8	1.81	42	3.97	3.95	19	=	=
33	25.0	8.7	.34	12.8	154	30.8	1.00	24	4.15	4.15	=	=	=

RESULT SUMMARY : UPPER DAM MEAN RESULTS - BACTERIAL RESULTS

Run	TPC	TC	FC	FS	FC/TC%	FC/FS
23	2.2x10 ⁶	2.6x10 ⁴	2.3x10 ⁴	3.1x10 ²	90	74
24	3.9x10 ⁶	1.3x10 ³	4.3x10 ²	1.4x10 ²	40	2.7
25	1.9x10 ⁵	1.6x10 ³ ±	1.3x10 ³ ±	8	66 (81±)	63± (160±)
26	2.1x10 ⁵	7.0x10 ²	4.1x10 ²	49	48 (58)	8.8 (8.3)
27	1.2x10 ⁶	4.8x10 ³	6.8x10 ²	2.1x10 ²	35 (14)	22 (3.1)
28	7.8x10 ⁵	6.3x10 ³	3.3x10 ³	3.4x10 ²	60 (52)	16 (9.8)
29	2.1x10 ⁵	8.5x10 ²	90	44	17 (11)	9.3 (2.0)
30	4.1x10 ⁵	1.1x10 ³	7.0x10 ²	65	64 (64)	5.6 (10)
31	8.7x10 ⁶	1.5x10 ²	80	10	60 (53)	8.0 (8.0)
32	1.3x10 ⁶	4.8x10 ²	3.7x10 ²	22	77 (77)	17 (17)
33	6.0x10 ⁵	8.3x10 ²	3.5x10 ²	60	43 (42)	11 (5.8)

APPENDIX 4.1

RESULT SUMMARY : MEAN MONTHLY RESULTS - LOWER DAM
PHYSICAL AND CHEMICAL RESULTS

Month	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
<u>1971</u>													
November	25.0	-	-	11.0	133	4.0							
December	25.0	7.6	-	11.3	131	5.9							
<u>1972</u>													
January	23.1	7.3	-	9.2	98	5.6	0.82						
February	23.0	7.2	-	9.2	103	9.0	0.27	*	0.62			=	=
March	20.7	7.3	.27	10.0	86	8.4	0.27	*	1.15			=	=
April	17.3	7.9	.23	10.4	105	6.7	0.80	*	1.93			13	-
May	12.4	7.0	.21	9.9	62	8.6	1.15	11	2.10+	1.53	216	114	tr
June	-	-	-	-	-	-	-	-	-	-	-	-	-
July	10.9	7.1	.48	8.9	81	5.2	0.57	270	0.59+	0.31	374	183	tr
August	10.9	7.2	.23	11.5	102	7.3	0.21	40	1.22	1.00	211	86	tr
September	15.0	7.2	.17	10.4	93	8.5	0.42	23	0.69	0.57	103	3	tr
October	16.6	7.1	.15	8.8	94	6.4	0.19	14	0.75-	0.74	11	8	tr
November	22.1	7.6	.11	9.8	120	4.4	0.18	33	0.63	0.51	38	33	tr
December	19.3	7.5	.15	8.3	96	3.1	0.18	52	0.49	0.49	91	23	tr
<u>1973</u>													
January	24.0	8.0	.11	9.6	113	3.7	0.19	42	0.79	0.77	16	1	tr

APPENDIX 4.2

RESULT SUMMARY : MEAN MONTHLY RESULTS - LOWER DAM

BACTERIAL RESULTS

Month	TPC	TC	FC	FS	FC/TC%*	FC/FS*
<u>1971</u>						
November	2.9×10^5	3.5×10^2	2.0×10^2	8	30 (57)	68 (25)
December	3.6×10^5	1.7×10^3	8.1×10^2	3.7×10^2	38 (52)	17 (10.4)
<u>1972</u>						
January	-	1.8×10^3	9.1×10^2	5.3×10^2	41 (50)	2.5 (1.7)
February	2.3×10^5	$2.1 \times 10^3+$	$7.5 \times 10^2+$	7.9×10^2	34 (36)	1.2 (1.0+)
March	6.9×10^5	3.7×10^3	1.1×10^3	2.9×10^3	28 (30)	0.9 (0.4)
April	1.5×10^5	1.3×10^4	2.4×10^3	1.0×10^3	22 (18)	3.1 (2.4)
May	1.3×10^6	1.4×10^4	4.3×10^3	4.5×10^3	29 (31)	1.6 (1.0)
June	-	-	-	-	-	-
July	1.0×10^7	2.7×10^4	4.5×10^3	8.3×10^2	17 (17)	6.0 (5.4)
August	1.3×10^6	3.7×10^3	2.5×10^3	1.8×10^2	66 (68)	14 (14)
September	1.7×10^5	3.5×10^3	1.6×10^2	6	5.1 (4.6)	68 (26)
October	6.9×10^5	7.8×10^3	2.2×10^3	44	27 (28)	57 (50)
November	1.6×10^5	1.5×10^3	8.5×10^2	45	41 (57)	29 (19)
December	9.1×10^4	1.5×10^3	6.3×10^2	5.1×10^2	41 (42)	7.1 (1.2)
<u>1973</u>						
January	2.3×10^5	1.8×10^3	9.2×10^2	4.4×10^2	46 (51)	7.5 (2.1)

*Results in brackets refer to monthly mean calculated from monthly mean bacterial results.

APPENDIX 4.3

RESULT SUMMARY : MONTHLY MEAN RESULTS - UPPER DAM

Month	Temp. °C	pH	Turb.	D.O. mg/l	D.O. %Sat	BOD ₅ mg/l	Tot.P. mg/l	Sol.P. ug/l	Tot.N. mg/l	Org.N. mg/l	NH ₃ -N ug/l	NO ₃ -N ug/l	NO ₂ -N ug/l
<u>1972</u>													
October	16.2	7.7	.18	11.5	121	8.4	0.68	290	0.86	0.78	8	tr	22
November	21.3	7.3	.28	6.7	76	11.8	0.50	335	1.05	0.95	96	28	tr
December	18.7	7.3	.28	6.9	74	13.5	0.90	136	1.47	1.06	311	=	tr
<u>1973</u>													
January	24.0	8.8	.48	12.5	148	28.9	1.60	81	3.86	3.85	12	=	tr

Month	TPC	TC	FC	FS	FC/TC%**	FC/FS*
<u>1972</u>						
October	2.1×10^6	9.6×10^3	8.3×10^3	1.2×10^2	65 (83)	80 (69)
November	7.1×10^5	2.8×10^3	5.5×10^2	1.3×10^2	42 (20)	15 (4.2)
December	4.7×10^5	2.2×10^3	1.4×10^3	1.5×10^2	47 (64)	10 (9.3)
<u>1973</u>						
January	8.7×10^6	1.5×10^2	80	10	60 (53)	12 (8.0)

*Results in brackets refer to monthly mean calculated from monthly mean bacterial results.

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