



Review of existing data and reports on pathogen monitoring at Lake Eildon and Lake Eppalock

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EXECUTIVE SUMMARY

This review provides a summary of existing information relevant to pathogen monitoring at the Goulburn Murray Water (G-MW) assets, Lake Eildon and Lake Eppalock. The monitoring of water sources is necessary to ensure public health and the sustainability of valuable resources. Pathogens are microorganisms that can cause disease, often the result of human faeces entering the water, and include bacteria, viruses and protozoa.

Bacterial indicator species are monitored in waters used for potable water, recreational purposes and irrigation and provide useful information as to the presence of potentially pathogenic bacteria. The most commonly used bacterial indicators belong to the coliform group, of which *Escherichia coli* (*E. coli*) is used as the main indicator of faecal pollution.

Depending on the final use of the water, various established water quality guidelines are applicable. Guidelines relevant to the supply of potable water are covered in the Australian Drinking Water Quality Guidelines and the State Environment Protection Policy (SEPP) – Waters of Victoria. Current Victorian SEPP guidelines require that there is less than 100 *E. coli*/100 mL in a raw water supply.

Routine sampling of water from the lakes has taken place since the late 1960's. Water quality has been primarily assessed using total plate counts (TPC), total coliforms (TC) and *E. coli* however, testing for Enterococci and *Salmonella* spp. has occurred on occasion.

Compliance with SEPP guidelines was consistently maintained during 1981-2001 at Lake Eppalock, however, Lake Eildon exceeded the guideline values at times during the period from 1971-2001. Guidelines were surpassed during the period from May-June.

The historical data and reports show that levels of TC and *E. coli* increase in areas of known recreational activity, particularly in the summer months. Additionally, as a result of inflows from the catchment of sewage and/or animal faeces following rainfall, indicator counts rise. Current sampling consists of monthly samples taken at a single point near the outflow of each lake reservoir with greater emphasis placed on testing the quality of water following treatment. The nature of the lake catchments, existing data and how it was collected is not conducive to useful statistical analysis such as trend analysis, temporal variation or predictive modelling.

Whilst the presence of bacterial indicators such as *E. coli*, provides useful information as to likely presence of other bacterial pathogens, it fails to indicate the presence of other pathogens such as viruses and protozoa. *Giardia* and *Cryptosporidium* are becoming an increasing problem in the

contamination of raw water sources that are used for potable water, as tests for faecal indicators do not encompass protozoa.

Whilst rapid tests adopted by most diagnostic laboratories can produce results for *E. coli* within 18 h (Colilert[®] –18), tests for protozoa and viruses are still development, consequently it is imperative that the quality of the source water used for the potable water supply is of a very high standard.

A risk-based pathogen-monitoring program is required that clearly outlines G-MW policy and procedures that will be used to implement the quality assurance requirements necessary to document the reliability and validity of the data collected.

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Abbreviations and Acronyms

| | |
|-----------------------|--|
| <i>E. coli</i> | <i>Escherichia coli</i> |
| Colilert® | The Colilert system simultaneously detects and enumerates total coliforms and <i>E. coli</i> directly from water samples without the need for confirmation. Coliforms (including <i>E. coli</i>) metabolise ortho-nitrophenyl galactopyranoside using the enzyme β -galactosidase to produce ortho-nitrophenyl resulting in yellow colouration in the test well. Additionally <i>E. coli</i> also metabolises 4-methyl-umbelliferyl glucuronide using the enzyme β -glucuronidase to produce 4-methyl-umbelliferone which fluoresces under long wave (365 nm) ultra violet light. |
| G-MW | Goulburn Murray Water |
| FC | Faecal coliform |
| MF | Membrane filtration |
| MPN | most probable number |
| MTF | Multiple Tube Fermentation |
| org(s) | organism(s) |
| QA | Quality assurance |
| SEPP | State Environment Protection Policy |
| SR & WSC | State Rivers and Water Supply Commission |
| TC | Total Coliform |
| TPC | Total plate count |
| WHO | World Health Organization |

1.0 INTRODUCTION

G-MW provides water delivery services to a range of customers and is responsible for the management of headwork assets and the delivery of bulk water services over an area of 68,000 square kilometres, from the Great Dividing Range north to the River Murray and from Corryong down river to Swan Hill.

As a major water utility business, the management of water quality is of paramount concern to G-MW. While there are a number of ways that water quality can be characterised, an area essential to G-MW is that of public health microbiology.

1.1 Pathogenic microorganisms

Pathogenic microorganisms are able to cause disease, infection or intoxication in a susceptible host. Bacteria, viruses and protozoa are pathogens that can be spread through drinking water as a result of pollution with human or animal faeces. Recently, the identification of pathogens in drinking water such as the protozoa *Giardia* and *Cryptosporidium*, pathogenic *E. coli* and viruses of enteric origin has meant that the quality of water supplies has received greater attention. As a result traditional measures of the microbial quality of water are now coming under greater scrutiny.

1.2 Bacterial indicators of faecal pollution

It is not practical to test water samples for each specific pathogen so an indicator species is used to evaluate microbial water quality. An indicator species generally enters the water at the same time as faeces, but is easier to detect than the pathogens (Stevens *et al.*, 2001). The presence of faecal indicator organisms implies that faecal contamination of the water source has occurred and that pathogenic organisms may also be present.

The most commonly used faecal indicator bacteria are *E. coli* and they are used to measure the sanitary quality of water for recreational, industrial, agricultural and water supply purposes. *E. coli* are natural inhabitants of the gastrointestinal tracts of humans and other warm-blooded animals. They are released into the environment with faeces, and are then exposed to a variety of environmental conditions that eventually cause their death. Due to the similar origin of *E. coli* and potentially pathogenic bacteria, it is assumed that the rate of decline in the environment will be similar.

Often TCs are measured in conjunction with the traditional indicator of faecal pollution, *E. coli*, however, their relevance is becoming of less importance where public health is concerned as their presence does not necessarily indicate a health risk.

Studies have shown that faecal indicator bacteria survive from a few hours up to several days in water, but may survive for days or months in sediments, where they may be protected from sunlight and predators (Drakas, 2001).

The survival time of faecal indicator bacteria in water is a function of many environmental influences and there is no number that applies to all water bodies, or even to all times of the year for a single body of water.

1.3 Lake Eildon and Lake Eppalock water quality

The management of water quality issues at lakes are of concern to G-MW as they are often a source of raw water for stock and domestic supply, irrigation, town water and for recreational purposes. The two lakes considered in this review are Lake Eildon, the source of the Goulburn River and Lake Eppalock, which is located on the Campaspe River.

Based upon the final use of the water, there are number of water quality guidelines that are relevant to G-MW. The Australian Drinking Water Quality Guidelines and the SEPP – Waters of Victoria are pertinent to the supply of potable water. Although G-MW supplies raw water only and the responsibility of water quality ultimately lies with the retail water authority, improved quality of the raw water source can only stand to provide a higher standard of potable. However, new Victorian Drinking Water regulations are being proposed which may see G-MW become more involved.

There is strong evidence to suggest that there is a causal dose-related relationship between gastrointestinal symptoms and recreational water quality measured by bacterial indicator counts (Prüss, 1998). As levels of faecal indicators increase in recreational waters, more people may fall ill as a result of pathogenic infection.

The recreation activities that people participate in involving the waters of Eildon and Eppalock can be considered as primary and secondary contact recreation. Primary recreational activities may include swimming and water-skiing and have a high likelihood of swallowing water. Secondary contact includes activities such as fishing, canoeing and boating where there is less contact with the water body.

A summary of the relevant microbial guidelines for the supply of potable water from the lakes and the use of the lakes for recreational purposes can be found in Appendix I. The current Victorian SEPP guidelines require that there is a concentration of less than 100 *E. coli*/100 mL in water that is a source of raw water supply.

2.0 PURPOSE & SCOPE

The purpose of this report is to review information collected by G-MW Water on faecal indicator bacteria and pathogenic microorganisms in their water supply sources, Lake Eildon and Lake Eppalock.

The study is important, as a comparison of the current water quality program with historical data and reports will provide useful information on microbiological trends in the lakes and help form the basis for future planning and more strategic monitoring programs.

The literature review will consist of a summary of the historical data and reports on the microbiological aspects of the lakes as well as an outline of the sampling methods and water analysis. Where possible comparisons will be made between current and historical information

The validity of the existing data on pathogen monitoring at the lakes will be reviewed against current literature so that recommendations for future pathogen monitoring programs can be drawn.

3.0 REVIEW OF EXISTING DATA AND REPORTS

3.1 Analysis of existing data and reports of Lake Eppalock

3.1.1 Summary of the sampling program at Lake Eppalock between 1972 and 1978 (SR & WSC, 1979)

Bacteriological sampling commenced at Lake Eppalock in December 1971 and continued up until April 1972. Weekly samples were collected at four popular recreation areas and a site near the outlet tower. Sampling was less frequent during the winter months. In July 1972 the program was revised to comprise a winter run of eight samples collected monthly from April to November and a summer run of 21 samples collected fortnightly.

In December 1976 a special collection of samples for *E. coli* in the surface water at fifteen recreational areas around the lake. Samples were collected at fortnightly intervals and during alternate weeks in addition to the routine program.

Surface water samples were collected, throughout the survey, from a boat, at a distance of 20 to 50 metres from the shore. The stream samples were collected from mid-stream and an estimate in Ml/d was made of the flow at the time of sampling.

Annual Reports produced by the Bendigo Regional Laboratory (Coliban Water) include bacteriological water quality results for headwork storages and main supplies. Between 1980 and 1994 samples were taken from Lake Eppalock and at the Eppalock pipeline in Bendigo. The annual figures reported include the number of samples taken, the mean and range of counts for TC and *E. coli*. Annual *E. coli* mean counts were less than 10 orgs/100 mL except for 1989-90 when 32 orgs/100 mL was recorded.

Monthly averages of raw bacteriological data from samples taken at the Lake Eppalock Tower exist, although incomplete, between 1997 and up until the time of this report. The results of TC and *E. coli* counts per/100 mL provide little trend information, only that TC increased during the summer months. The *E. coli* counts in February and March 2002 were very high, 7,700 and 13,000 orgs/100 mL respectively which may be related to unusually low water level at the Lake Eppalock in 2002 and recreational activities during the summer period.

E. coli count data from the raw water of Lake Eppalock has been summarised in Table 1, and Figure 1 presents the trends of *E. coli* at Lake Eppalock during 1981-2001. Both Table 1 and Figure 1 indicate the *E. coli* levels at Lake Eppalock are well below the guideline values of 100 orgs/100 mL recommended for raw water supply.

Giardia and *Cryptosporidium* cysts were tested for by Coliban Water between August 1994 and April 1995. Results for samples taken at the Eppalock

pipeline in Bendigo indicated that no *Giardia* were detected however, 1 *Cryptosporidium* cyst/L was recorded on September 11, 1994.

In 1982-83 Coliban Water tested for the presence of *Salmonella* spp. as part of their Salmonella surveillance program for reservoirs, service basins, tanks or reticulation samples which had an *E. coli* count greater than 20 org/100 mL. No Salmonella was tested for directly from Lake Eppalock samples.

Welsh (1989) reports that *E. coli* counts in the surface water of Lake Eppalock increase in response to large inflows from the catchment (Figure 2) confirming the SR & WSC (1979) report identifying the catchment as the major sources of bacteria to the lake. Both reports comment on the increase in *E. coli* counts during the summer months as a result of increased recreation activities in the foreshore areas that were unrelated to rainfall. Drew (1983) also highlights the effects of lakeside activity and recreation giving rise to high counts of *E. coli*. Drew (1983) points out that while under 'normal' conditions the lake can assimilate a large bacteriological load, however at specific times bacteria can survive up to the outlet tower. Thus highlighting the need to chlorinate the water prior to domestic supply purposes. However, water supplied for domestic use are for household purposes (washing, stock drinking, gardening) not for potable use.

Faecal bacteria are associated predominately with animal wastes on the land. They are also derived from human sources; septic tanks, urban storm water runoff, etc (Interdepartmental Committee Report, 1981)

Table 1. Statistical information of *E. coli* counts of raw water of Lake Eppalock at the Eppalock tower site.

| Category | Year | Sample Number | Range | Mean | SD |
|--------------------|----------------------------|----------------------|--------------|-------------|-----------|
| MOST RECENT | 2001 | 11 | 0-6 | 1.8 | 2 |
| | 2000 | 12 | 0-14 | 2.3 | 4.2 |
| | 1999 | 10 | 0-74 | 12.6 | 25.5 |
| | 1998 | 10 | 0-4 | 0.8 | 1.4 |
| | 1997 | 5 | 0-2 | 0.4 | 0.9 |
| Mean | 1997-2001 | 9.6 | | 3.6 | |
| RECENT PAST | 1985/86 | N/A | 0-2 | 0.6 | N/A |
| | 1984/85 | N/A | 0-2 | 0.8 | N/A |
| | 1983/84 | N/A | 0-15 | 1 | N/A |
| | 1982/83 | N/A | 0-15 | 3 | N/A |
| | 1981/82 | N/A | 0-7 | 1 | N/A |
| Mean | 1981-1986 | | | 1.3 | |
| PAST | Jan 1976 – Mar 1978* | 45 | 0-12 | 1.1 | N/A |
| | Dec 1971 – Dec 1975* | 55 | 0-230 | 8.5 | N/A |

N/A – not available

* Data from SR&WSC Report (1979)

Data from Coliban Water Annual reports

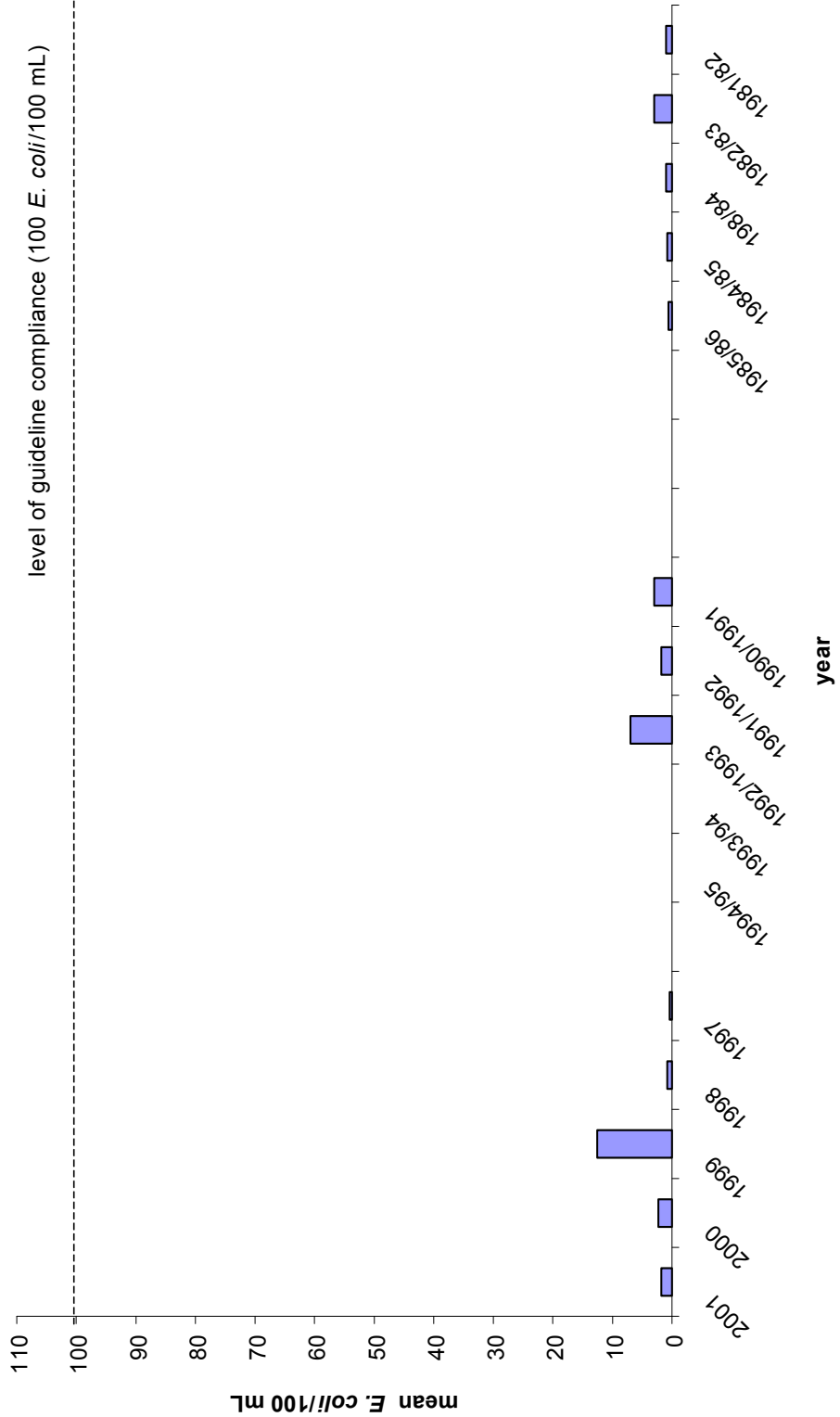


Figure 1. Mean *E. coli* counts recorded for raw water samples from Lake Eppalock during 1981-2002 at the Eppalock tower site

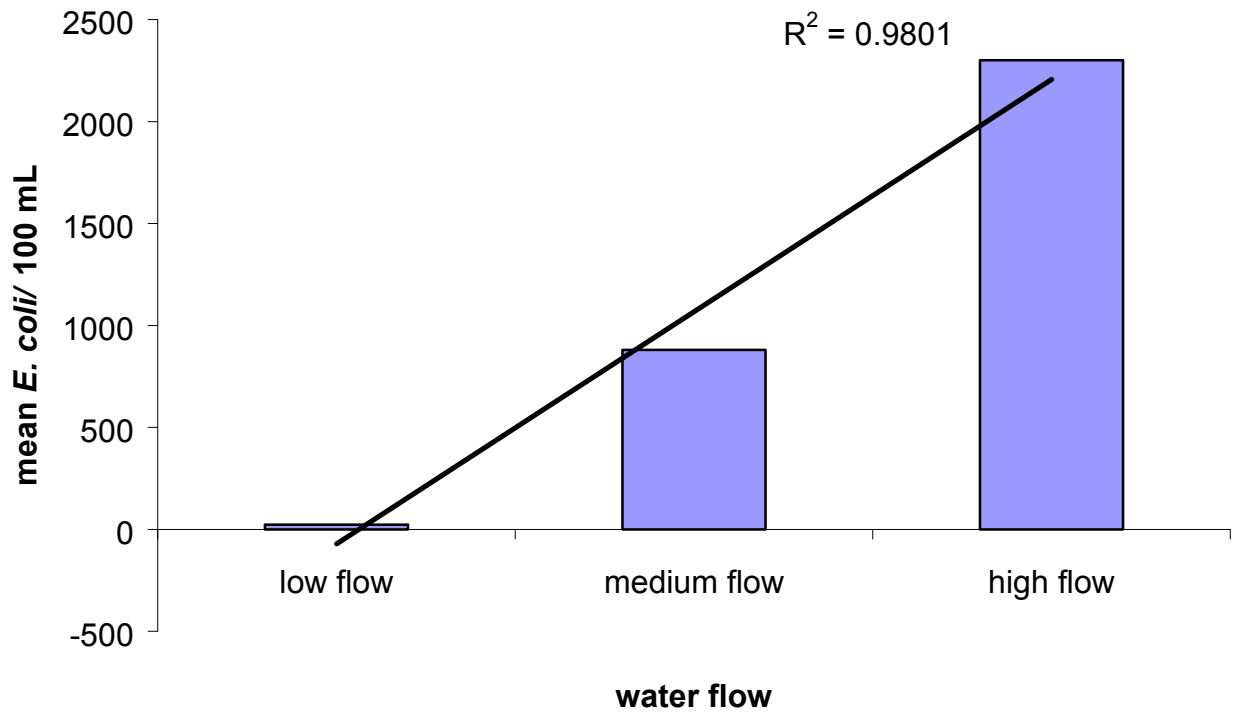


Figure 2. The relationship between water flow and *E. coli* numbers in rivers and creeks of Eppalock.

A measurable improvement in the bacteriological quality of the surface water between December 1975 and May 1978 was noted, probably due primarily to the low inflows and reduced rainfall during the period, and secondly to a decrease in pollutants from recreational areas (SR & WSC, 1979). This reduction may be attributed to measures taken in 1973 to reduced the adverse effects of recreational use and subdivisional development around the foreshore (SR & WSC, 1979).

Piani (1997) conducted a short report on water quality in Lake Eppalock by examining data collected by Coliban water between 1992 and 1996. The study found that 10% of the river and creek samples in the area tested positive to *Salmonella* spp. However, no *Salmonella* spp. were detected in Lake Eppalock.

3.2 Analysis of existing data and reports of Lake Eildon

Bacteriological testing of water from a number of stations in Lake Eildon commenced in 1968 and has shown that, based on *E. coli* counts, faecal contamination occurs periodically (Caldwell Connell Engineers 1979). Water Supply Commission of Victoria Bacteriological Reports exist from 1968 through to 1979. The reports provide limited information regarding data collection including the date, name of the sampler, weather conditions, possible sources of pollution and treatment applied. The laboratory results section includes the locations of the samples, TPC information at 22°C and 37°C, TC and *E. coli* (orgs/100 mL). There is also a section for comments.

Table 2 provides a summary of *E. coli* counts of raw water obtained at the Rising Main. Figure 3 illustrates the trends in *E. coli* counts during the period 1971-2001, with *E. coli* levels peaking between May-June and exceeding the guidelines for raw water supply (100 orgs/ 100 mL).

Table 2. *E. coli* count of raw water from Lake Eildon at the rising main.

| Category | Year | Sample Number | Range | Mean | SD |
|--------------------|------------------|----------------------|--------------|-------------|-----------|
| MOST RECENT | 2001 | 8 | 0-64 | 16.1 | 22.3 |
| | 2000 | 15 | 0-4 | 1 | 1.3 |
| | 1999 | 12 | 0-910 | 84.6 | 260.4 |
| | 1998 | 12 | 0-240 | 24 | 68.4 |
| | 1997 | 12 | 0-70 | 8.8 | 21.8 |
| mean | 1997-2001 | 11.8 | | 26.9 | |
| RECENT PAST | 1985 | 12 | 0-138 | 12.3 | 39.6 |
| | 1984 | 11 | 0-26 | 3.1 | 8 |
| | 1983 | 10 | 0-4 | 0.5 | 1.3 |
| | 1982 | 12 | 0-0 | 0 | 0 |
| | 1981 | 11 | 0-2 | 0.4 | 0.7 |
| mean | 1981-1985 | 11.2 | | 3.26 | |
| PAST | 1971- | N/A | 0-0 | 0 | N/A |
| | 1975 | | | | |
| mean | 1971-1975 | | 0-0 | 0 | |

N/A – not available

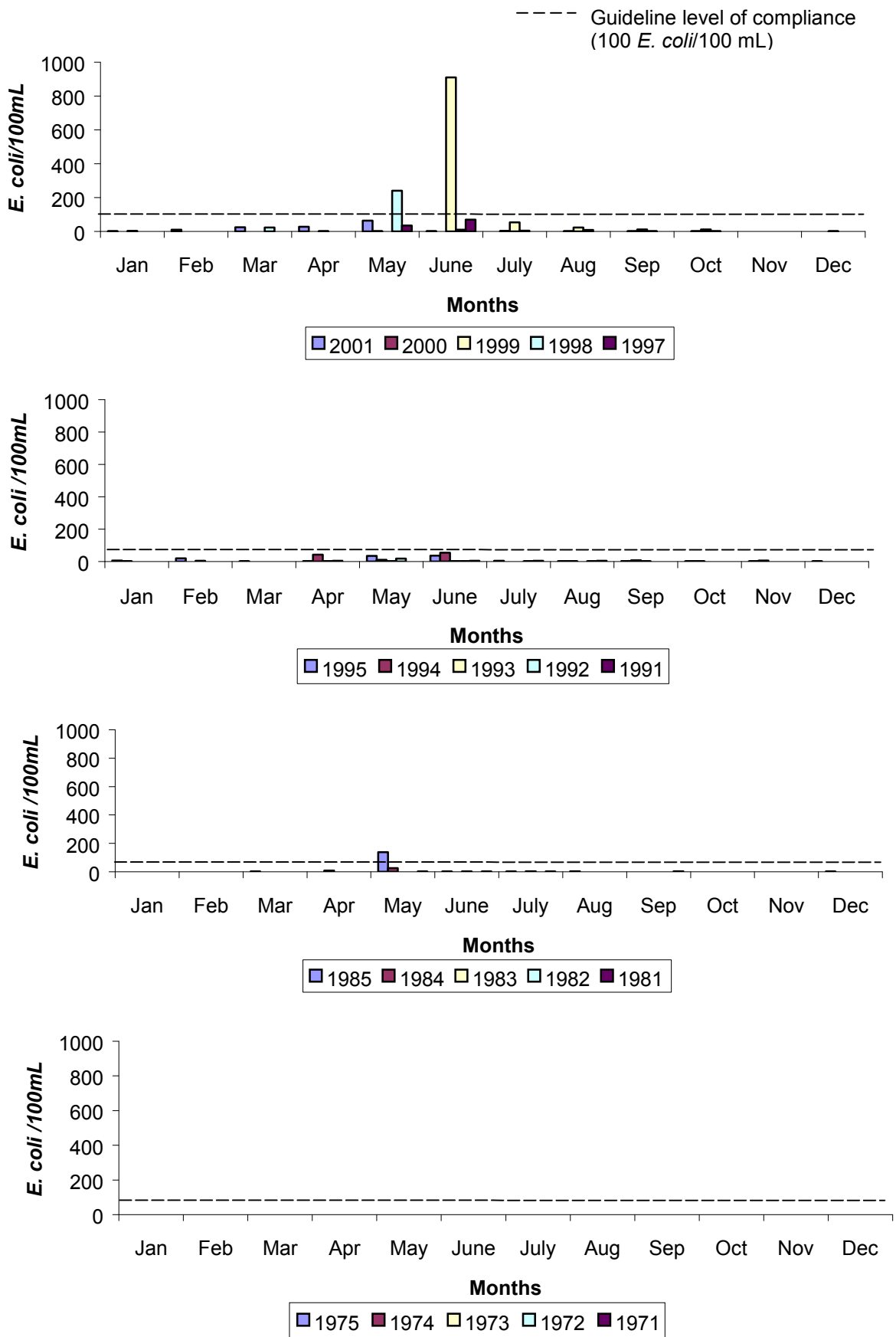


Figure 3. *E. coli* counts of raw water samples taken from Lake Eildon at rising main during the period 1971-2001.

Powling (1972) reports on the surface water quality, as measured by the TC group of bacteria for the period August 1970 to July 1971 from 16 samplings sites (Appendix I). The report identified that the majority of sampling locations had zero FC counts in the winter months however, as a reflection of the extent of boating and other recreational activity together with drainage from small townships, camp sites or toilet blocks, FC levels rose to a maximum in summer.

In summary Powling's (1978) report states that:

1. The surface waters of Lake Eildon are periodically subject to faecal contamination.
2. During the summer months contamination was most marked in bays and inlets used intensively for recreational purposes.
3. The open waters of the lake do not show significant faecal contamination in summer.
4. The summer months of 1970 and 1971 were particularly bad for faecal contamination but the installation of the Sanitation Barge at point Worner may have helped reduce this after 1971.
5. The highest *E. coli* and faecal streptococci counts over the long term can be attributed directly to heavy rainfall and high natural flows to the reservoir.

Powling (1978) suggests that bacteriological monitoring should continue at monthly intervals and it should be considered at the five major inflowing streams as well. The report also suggests that a more intensive monitoring program should be carried out at weekly intervals at the recreational areas during summer. The value of Sanitation Barges is also emphasised. The report states that barges were installed at Jerusalem creek and Fords Inlet in 1976 and 1977 respectively and calls for barges to be installed at Bonnie Doon and Howqua Inlet.

The Caldwell Connell Engineers (1979) report contains microbiological studies including a water quality survey and an investigation of dieoff rates for indicator organisms. The water quality survey concentrated on determining *E. coli* levels in different sections of the lake representing a wide range of recreational uses.

Samples were collected every Sunday and Tuesday at ten locations between 14 December 1977 and 6 February 1978. Samples were collected at four points in most locations, the first point was normally where the pollutant levels were expected to be near maximum and the other three points were generally located in a line between the first point and the mouth of the bay or inlet. The only location to have very high *E. coli* counts was Brankeet Inlet adjacent to the town of Bonnie Doon. Up to 72,000 orgs/100 mL were obtained within 50 m of the point where effluent from the caravan park septic tank entered the lake.

The Caldwell Connell Engineers (1979) report draws four major conclusions based on their bacteriological survey:

1. Based on the WHO 1971 standards for non-disinfected drinking water, which specify that no *E. coli* should be present in 100 mL, water from the lake should not be used for potable supplies without suitable treatment or detention;
2. With the exception of the area adjacent to the Bonnie Doon caravan park, the waters of the lake are judged to be of excellent quality for all forms of recreational activity;
3. The impact of the level of recreational use of the lake and its shoreline on water quality during the study period was minimal except in the case of the Bonnie Doon caravan park; and
4. Contamination of the lake with *E.coli* from the rural runoff and waterfowl would prevent water quality in the lake achieving the WHO standard for non-disinfected drinking water, even in the absence of any recreational activity.

The SR & WSC (1982) report on a proposed development at Goughs Bay used information on *E. coli* counts from water samples to identify the need for chlorination of the water before its use domestically. The report also outlines the issue of increased bacterial counts as a result of effluent discharge into the bay and states that sewage, regardless of the level of treatment, should not enter the lake.

Samples in the Powling (1972) report were collected by boat in the middle of each of the bays or inlets to avoid shore contamination and to provide a better indication of the surface water quality mid-reservoir where the water is well mixed.

The Powling (1972) report does not provide details about sample analysis stating only that the methods are unchanged and consist of TPCs at 22°C and 37°C, a membrane coliform count using Teepol broth (3T) and a FC count using MacConkey membrane broth with final incubation at 44°C.

Water Supply Commission of Victoria Bacteriological Reports consist of TPC (orgs/mL at 22°C and 37°C), presumptive and confirmed TC and *E. coli* counts (orgs/100 mL) for several sampling locations around Lake Eildon. The reports also include information that has been filled out intermittently on weather conditions, possible sources of pollution, boating activities and wild life. Bonnie Doon appears to be the area where the highest levels of *E. coli* counts were observed in 1968.

In 1972 testing for faecal streptococci began. Extremely high counts resulted following heavy rainfall during the summer holiday period when human effluent entered the reservoir. This occurred in 1973 and was particularly bad at Bonnie Doon.

3.3 Analysis of existing methods of sampling/analysing at Lake Eppalock

The current sampling regime at Lake Eppalock consists of monthly sampling from a single location. During the period December through May, a dip sample is collected from the Eppalock Reservoir outlet to the Campaspe River. Between June and November the dip sample is taken from the wall of the reservoir near the outlet tower.

Coliban Water are responsible for the current sample collection and the method employed is documented in their Laboratory - Operations Sampling Manual (1998) and is based on the following documents:

1. Standard Methods for the Examination of Water and Wastewater (1995).
2. Australian Standard - AS 5667 (1998).

3.4 Analysis of existing methods of sampling/analysing at Lake Eildon

The current location for the monthly raw water sample is taken from a tap on the rising raw water main prior to it entering the raw water storage. The pump station is located in the Southern Hydro generator building on the outside face of the reservoir wall.

Goulburn Valley Water are responsible for the sampling at the rising main and Water Ecoscience Pty Ltd, Melbourne are responsible for the current bacteriological analysis for Lake Eildon. While the aforementioned location is the only raw water sample taken at the lake, Water Ecoscience also sample at three storage tanks in Eildon and at four customer taps. Whilst the methods used are documented in their "Collection of Samples for Microbiological Examination Instruction Sheet", TPC (37°C), TC MPN Colilert[®] and *E. coli* MPN Colilert[®] form the basis of the microbiological analysis.

Recent data (2000 – 2002) for TC and *E. coli* counts from samples taken at the rising main have been recorded in electronic form (Excel spreadsheet). Additional information includes the date and name of the sampler, however no units are indicated. Although, as the standard units are orgs/100 mL, results recorded show that all monthly samples were compliant with SEPP guidelines for raw water supply (Appendix I). The counts were highest between February and April of 2001.

Accepted methodologies

Whilst traditional methods for TC and FC detection involve techniques such as the multiple-tube fermentation (MTF) method, newer and more specific methods are readily adopted and approved for use in the microbiological analysis of water. Membrane filtration (MF), whilst being a standard technique has been improved following the development of chromogenic media that are based on the presence of enzymes specific to TC and FC. Another method, Colilert[®], approved by the US EPA for the analysis of water and wastewater, also relies on enzyme activity unique to TC and FC. Despite the problems experienced when culturing environmental isolates, these methods offer relatively rapid results compared to traditional techniques.

4.0 DISCUSSION

4.1 Validity and Results Summary

In summary, the limited information available on the sampling methods and techniques used to analyse the historical samples places limitations on the validity of the data and how it can be used. This is particularly the case when trying to compare relatively recently collected data with historical information (Tables 1 & 2). Issues of data precision, accuracy, comparability and completeness prevent a great deal of valid statistical trends to be drawn from existing data.

The current sampling regime at both lakes consists of one monthly sample, which may not be sufficient to represent the lakes. Any one sample point can really only represent the bacteriological activity in the vicinity of that particular location. Also, lakes are subject to runoff following rainfall, faecal pollution from birds, varying rates of mixing within the water column, sediment disruption depending on lake activities and environmental conditions.

Changes in techniques used both in sampling and analysis place further limitations on the direct comparability of data sets. Studies have shown that faecal indicator bacteria survive from a few hours up to several days in surface water, but may survive for days or months in lake-sediments, where they may be protected from sunlight and predators (Darakas, 2001). Historically, sample collections appear to have been taken from surface waters.

Despite factors such as sunlight, salinity, toxic agents, predation and parasitism and reduced nutrient concentrations, faecal bacteria have demonstrated the ability to survive and, to a certain degree to grow in sediments (Hood & Ness, 1982). Another study inferred that the persistence of bacteria in sediments at fairly stable levels might be the result of equilibrium between growth rate and predation (Marino & Gannon, 1991). A study conducted in Israel found that high pH values and algal activity played a significant role in the reduction of coliforms in stabilisation reservoirs for wastewater storage suggesting that additional factors may influence survival (Liran *et al.*, 1994).

Taking into consideration the limitations associated with the pathogen monitoring programs at Lake Eppalock and Eildon some general findings and trends can be drawn. Indicator counts appear to be higher at known recreational sites and relates to the summer vacation periods when people are frequenting the lakes. This may be due to sediment disruption as result of activities within the lake, a finding supported by Ashbolt *et al.* (1993). This study observed that sediments may contain 100 to 1,000 times as many faecal indicator bacteria as the overlying water inferring that weather conditions may reflect fluctuations in population numbers due to stirring up of the sediment. Additionally, indicator counts at both lakes are higher after rainfall a result of surface water flows entering the reservoirs, runoff or sewage overflow. Several studies have reported significant correlations between increases in bacterial numbers with major rainfall patterns (Hagedorn *et al.*, 1978; Roll & Fujioka, 1992, Ashbolt *et al.* 1993).

5.0 CONCLUSIONS & RECOMMENDATIONS

Bacterial indicators whilst providing information on faecal pollution do not identify the source of the pollution, however, enumeration of TC and FC is necessary to ensure public health

Identification of faecal indicator organisms indicates the presence of other potentially pathogenic enteric microorganisms but do not indicate the presence of other pathogens such as viruses and protozoa

Tests for protozoa are expensive and time consuming, however, experience has shown that FC are an inadequate measure for protozoa such as *Giardia* and *Cryptosporidium* which were detected in raw and filtered water in Sydney during 1998 (Hawkins *et al.*, 2000).

It has been proposed that pathogen monitoring for protecting public health be replaced by alternative strategies such as optimising treatment and maintaining water quality throughout storage and distribution (Allen *et al.*, 2000).

Any pathogen-monitoring program established should clearly delineate G-MW QA policy, management structure, and procedures that will be used to implement the QA requirements necessary to document the reliability and validity of the data collected.

In summary it can be concluded that:

- The graphical data in this report should be considered as pictorial representations only. Data averages are based upon invalid statistical and scientific interpretations.
- Overall water quality or trends within the lakes should not be assessed based on the data in this report.

As an outcome of this report some recommendations can be made:

- *E. coli* is still the best organism to indicate water quality, even though it indicates faecal contamination only.
- If the priority is to assess the safety of water as a drinking supply then sampling at one location near the outlet should be satisfactory.
- If the priority is to assess the safety of the water for recreational purposes as well then sampling should occur at all the prime recreational locations.
- The frequency of the sampling at locations needs to be increased to ideally weekly.
- The number of water samples taken at each sampling point should not be less than three. Taking five individual samples would ensure accurate trend data and future statistical comparisons.

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Glossary

Coliform - A group of bacteria found in the intestines of warm-blooded animals (including humans). The family Enterobacteriaceae consists of Gram-negative facultatively anaerobic non-spore forming bacteria. The group is subdivided into a number of genera, namely *Escherichia*, *Shigella*, *Salmonella*, *Citrobacter*, *Klebsiella*, *Enterobacter*, *Erwinia*, *Serratia*, *Hafnia*, *Edwardsiella*, *Proteus*, *Providencia*, *Morganella*, *Yersia* and others. Based on the ability to ferment lactose, the group can be further divided. Lactose fermenters are referred to as coliforms and of the coliforms, *E. coli* is the most widely documented. The presence of coliform bacteria indicates that the water is polluted and may contain disease causing organisms.

Cryptosporidium - Intestinal protozoa that can cause gastrointestinal illness (e.g., diarrhea, vomiting, cramps)

Faecal coliform – *Escherichia coli* is the most common faecal coliform and produces acid and gas at 44.5°C.

Faecal indicators – microorganisms such as *E. coli* that indicate the presence of faecal contamination

Giardia lamblia - intestinal protozoa that can cause gastrointestinal illness (e.g., diarrhea, vomiting, cramps)

Protozoa - unicellular eukaryotic microorganisms that move by either protoplasmic flow (amoebae), flagella (flagellates) or, cilia (ciliates). Most species feed on bacteria, fungi, or detrital particles

Potable – water suitable for drinking

Pathogenic microorganisms – microorganisms that cause disease in a susceptible host.

Appendices

Appendix I

Table 1. Conventional microbial water quality guidelines applicable to Lake Eildon and Eppalock for potable supply.

| | Guideline level/concentration | Relevant Guideline |
|------------------------|--|--|
| Treated Drinking Water | <ul style="list-style-type: none"> • 0 Thermotolerant coliforms or <i>E. coli</i>/100 mL • 0 TC/100 mL | Australian Drinking Water Quality Guidelines |
| Raw Water | <ul style="list-style-type: none"> • ≤ 100 <i>E. coli</i>/100 mL | State Environment Protection Policy – Waters of Victoria |

Table 2. Conventional microbial water quality guidelines applicable for primary contact recreation at Lake Eildon and Eppalock.

| Guideline level/concentration | Relevant Guideline |
|---|--|
| Median bacterial counts taken over bathing season should not exceed: <ul style="list-style-type: none"> • ≤ 150 FC orgs/100 mL; or • ≤ 35 enterococci orgs/100 mL • Pathogenic free-living protozoa should be absent | ANZECC Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Recreation) |
| <ul style="list-style-type: none"> • ≤ 200 <i>E. coli</i>/100 mL (geometric mean) | SEPP – Waters of Victoria (1988) |
| <ul style="list-style-type: none"> • ≤ 150 <i>E. coli</i>/100 mL | SEPP – Waters of Victoria (2001 Draft) |
| <ul style="list-style-type: none"> • < 40 organisms/100 mL – 95th percentile value for < 1 % risk of gastrointestinal illness | WHO Draft Recreational Water Quality Guidelines (2001) |

Table 3. Conventional microbial water quality guidelines applicable for secondary contact recreation at Lake Eildon and Eppalock.

| Guideline level/concentration | Relevant Guideline |
|---|--|
| Median bacterial counts taken over the bathing season should not exceed: <ul style="list-style-type: none"> • ≤ 1000 FC orgs/100 mL; or • ≤ 230 enterococci orgs/100 mL | ANZECC Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Recreation) |
| <ul style="list-style-type: none"> • ≤ 400 <i>E. coli</i>/100 mL (80th percentile) | SEPP – Waters of Victoria (1988) |
| <ul style="list-style-type: none"> • ≤ 1000 <i>E. coli</i>/100 mL | SEPP – Waters of Victoria (2001 Draft) |

Appendix II

Lake Eildon Sampling Locations – Powling (1978)

- Howqua Inlet
- Goughs Bay
- Jerusalem Creek Inlet
- Gerraty Bay (Jerusalem Ck)
- SR&WSC Marker Buoy
- Eildon Boat Harbour
- Eildon Boat Club
- Spade Cove
- Taylor Bay
- Bolte Bay
- Coller Bay
- Brankeet Inlet
- Fords Creek Inlet
- Burnt Creek Inlet
- Howes Inlet
- Fraser national Park reticulation Devils Cove, Coller Bay

Lake Eildon Sampling Locations – Caldwell Connell Engineers (1979)

- Delatite Arm
- Upper Delatite Arm
- Ford Inlet
- Brankeet Inlet
- Aird Inlet and Stone Bay
- Coller Bay
- Taylor Bay
- Anderson Harbour
- Goughs Bay
- Gerraty Bay