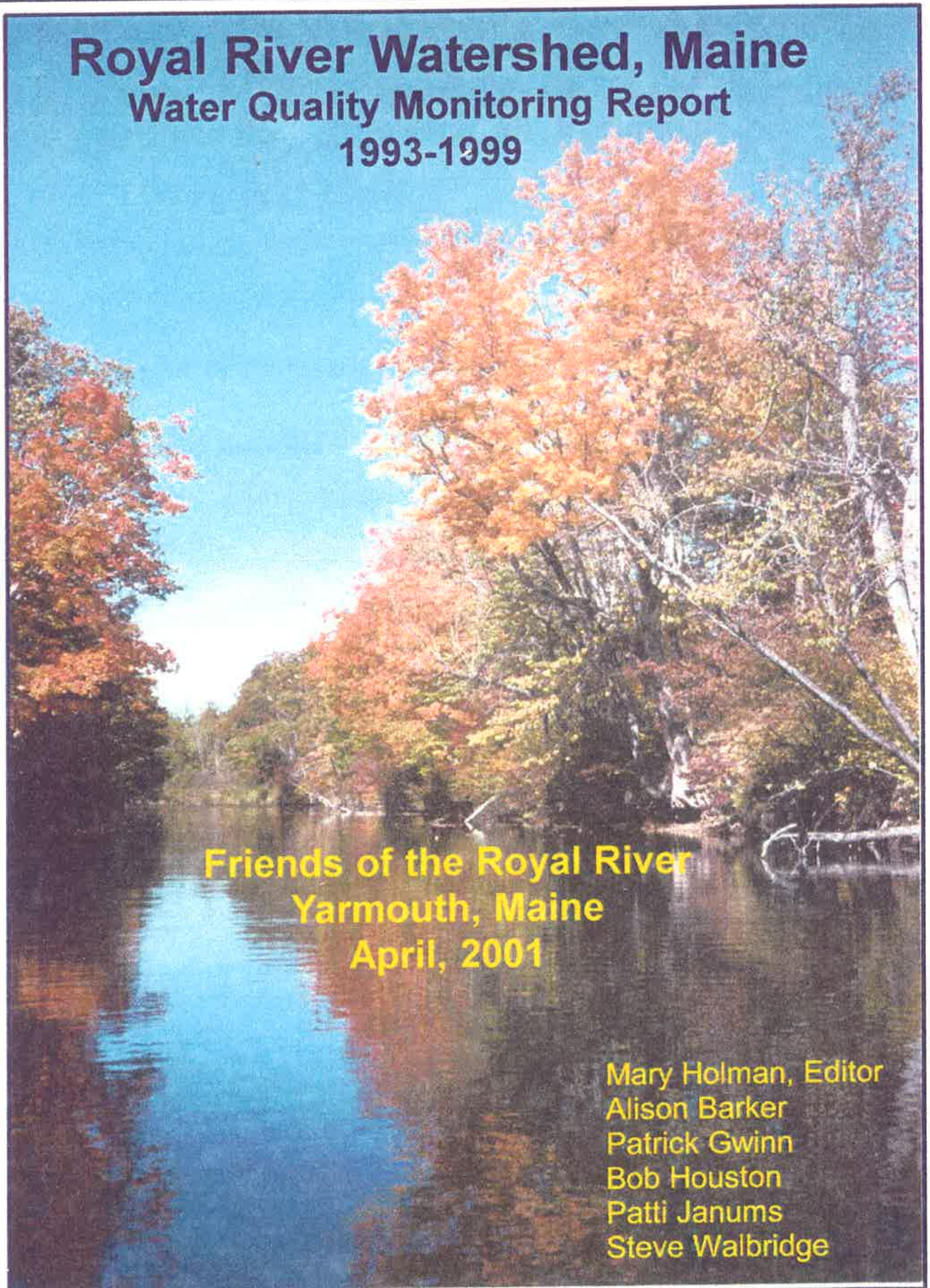
Royal River Watershed, Maine
Water Quality Monitoring Report
1993-1999



Friends of the Royal River
Yarmouth, Maine
April, 2001

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EXECUTIVE SUMMARY

The Friends of the Royal River, a non-profit river conservation group in southern Maine, conducted a bi-weekly volunteer water quality monitoring program during the spring, summer, and fall months of 1993 through 1999. The purpose of the monitoring program was to assess the health of the Royal River and some of its tributaries by measuring and documenting the levels of important water quality indicators. This report summarizes and explains the results of that program, which tested for dissolved oxygen (DO), turbidity and fecal coliform bacteria at a maximum of 28 sampling locations each year. The sampling sites were located throughout the Royal River watershed, encompassing seven of the twelve communities in the watershed.

The results indicate that the main stem of the river and large portions of the watershed are in generally good health and for the most part meet Maine criteria for a Class B river system (or Class A where applicable, see footnote p.3) for the parameters tested. However, certain areas warrant closer scrutiny to determine if preventative measures will prevent further degradation to the river system. These areas include- Collyer Brook subwatershed which had high bacterial counts, Chandler Brook subwatershed with low DO, and the East Branch of Chandler Brook subwatershed with consistently low DO and high bacterial counts. The only discernible trend in water quality was suggested by data from the East Branch of Chandler Brook in Pownal where the mean DO readings decreased over a period of four years.

Specific recommendations are made for actions that could be taken to further monitor and document water quality in the Royal River watershed, to evaluate sources of nonpoint source pollution, to improve certain areas of the watershed, and to continue to expand the efforts of the Friends of the Royal River to protect and preserve this valuable resource.

The complete set of sampling data can be found on the Friends of the Royal River website at:

www.cascobay.com/royal/royal.htm

1.0 PURPOSE

The purpose of this Watershed Monitoring Report is to publish the results of the water quality analyses conducted by the Friends of the Royal River (FORR) from 1993 to 1999. Each year, FORR volunteers collected specific water quality data during the spring, summer, and early fall months from many locations on tributaries and the main stem of the Royal River. The goal of the monitoring program was to develop an analytical database from which conclusions regarding the current health of the river system could be made, and to define a "baseline" to which future monitoring results can be compared. To that end, this report attempts to accomplish the following five goals:

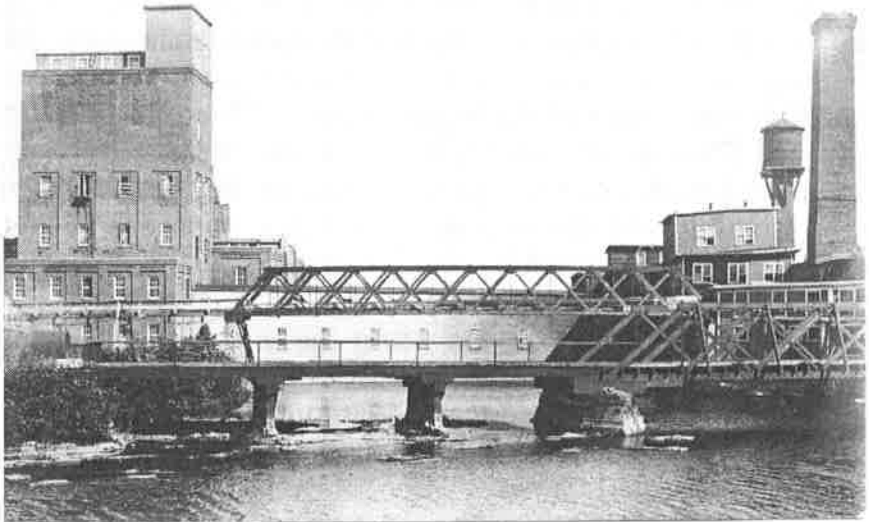
- assess the health of the watershed using the water quality data collected between 1993 and 1999,
- document baseline levels of important water quality indicators in the 1990s,
- identify areas of the watershed that are not meeting state-specified water quality criteria,
- if possible, identify trends for each water quality parameter measured, and
- serve as a source of baseline water quality monitoring data to compare against data collected in the future and/or to assess development and land use impacts.

2.0 INTRODUCTION

The Royal River is a quiet, meandering river about 39 miles long in southern Maine. It flows out of Sabbathday Lake in New Gloucester, winds its way through rural wooded areas and fertile farmlands, and eventually flows into an estuary before emptying into Casco Bay. The Royal River watershed drains a total of approximately 142 square miles (91,451 acres) of land from the towns of Auburn, Poland, Raymond, New Gloucester, Gray, Cumberland, Pownal, Durham, Brunswick, Freeport, North Yarmouth, and Yarmouth. An illustration of the watershed showing the portion of each town that it drains is provided in Figure 1.

The watershed comprises the main stem and three major tributaries, each draining a section of the total watershed. The three major tributaries or subwatersheds are Collyer Brook, Chandler Brook, and the East Branch of Chandler Brook. The Royal River watershed, its subwatersheds, and the tributaries on which sampling sites were located are shown in Figure 2.

Historically, the Royal River has influenced the growth of its watershed communities by transporting people and goods, providing hydroelectric power, and as a recreational resource. In the early 1800's, fourteen mills harnessed the power of the four falls in Yarmouth. From 1874 to 1923, the Forest Paper Company produced many tons per day of soda pulp with power generated from the third falls (Baker's Falls). The paper mill closed after World War I and the buildings burned in the 1930s. The falls area is now a public park where the stone foundations of the mill buildings are still visible.



Forest Paper Company, Yarmouth, Me. circa 1900. Photo provided by Yarmouth Historical Society

Today one sees surprisingly few signs of human development along the banks of the River, even along its most populated southern section. Even with the increasing residential population in the towns that make up the Royal River watershed, much of the land is still open field, forested, or otherwise undeveloped. Figure 3 is a land cover map of the Royal River Watershed derived from satellite imagery. It shows how much of the whole watershed and each individual subwatershed is composed of forested areas, agricultural and grassland areas, wetlands, open water, and developed land. Due to its relatively undeveloped condition, the watershed has the potential to support a diverse aquatic and terrestrial ecosystem. As such, it is significant in and of itself, but may also serve as a reference location for studies on similar habitats in other watersheds. Most of the land in the watershed is undeveloped, which provides great potential for continued increase in commercial development, residential housing, and their corresponding infrastructure (i.e., roads). The potential for growth is especially high along the banks of the Royal River and its tributaries as these provide a tranquil, aesthetically pleasing setting.

The State of Maine classifies the Royal River as a Class B river[1], meaning that the State's goal for this watershed is an "unimpaired" habitat that can be used for

[1] During review of the draft of this document it came to the authors' attention that in 1999, the main stem of the Royal River above Collyer Brook was reclassified to Class A. Since this change in classification applies to only 5 testing sites (RoR18.4, RoR28.9, RoR30.3, RoR34.3, and RoR36.3) and the desired DO concentration for Class A and Class B is essentially the same, the body of the report has not been amended to reflect this reclassification. Please refer to Appendix A and Title 38 Maine Revised Statutes Annotated, Section 467.

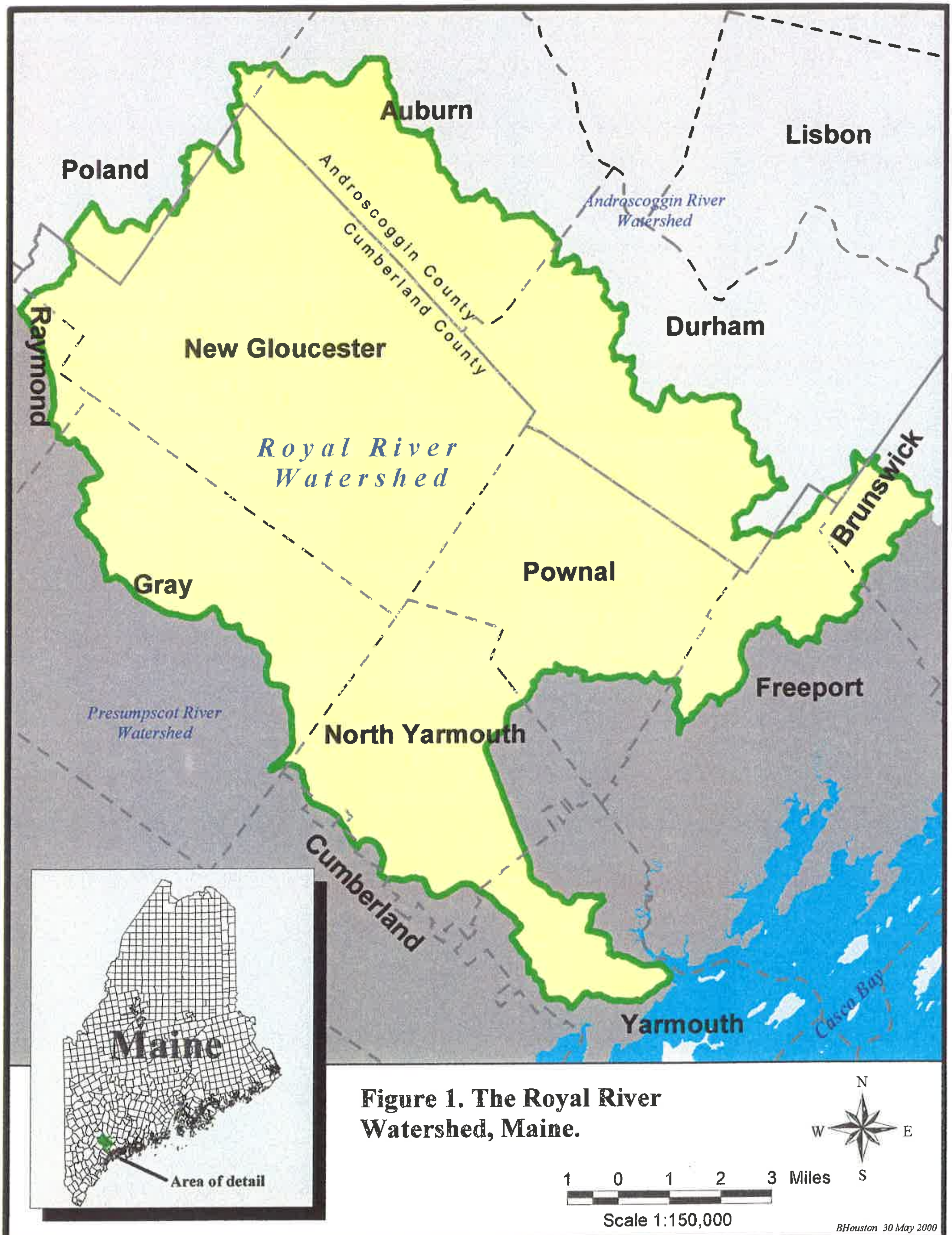


Figure 1. The Royal River Watershed, Maine.

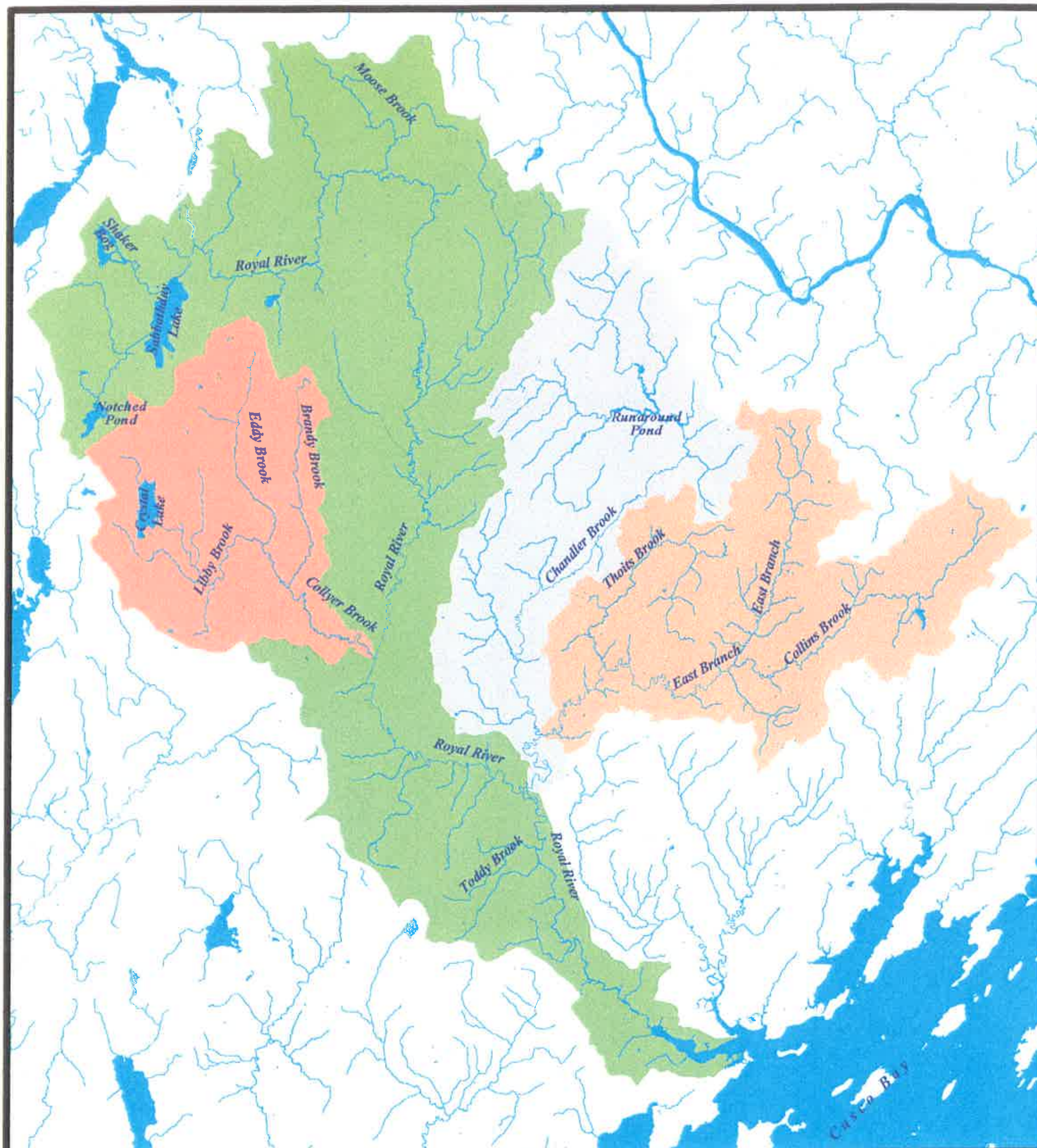


Figure 2. Royal River Watershed with subwatersheds and hydrologic features.

Legend

- Chandler Brook - 16,121 acres
- Collyer Brook - 11,993 acres
- East Branch of Chandler Brook - 17,607 acres
- Royal River - 45,725 acres

N / S / E / W

1 0 1 2 3 Miles

Scale 1:150,000

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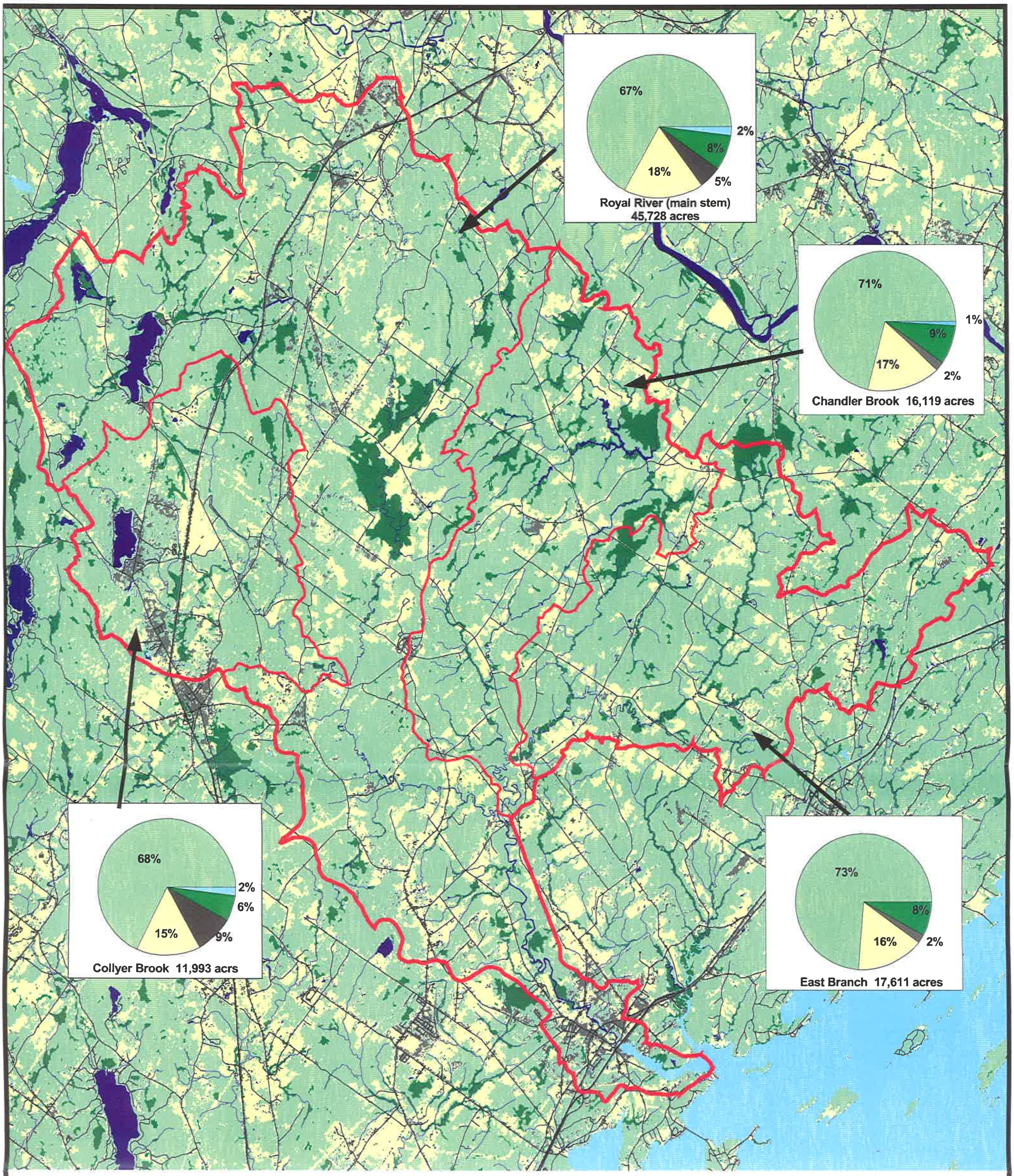


Figure 3. Land cover of the Royal River Watershed and its Subwatersheds.

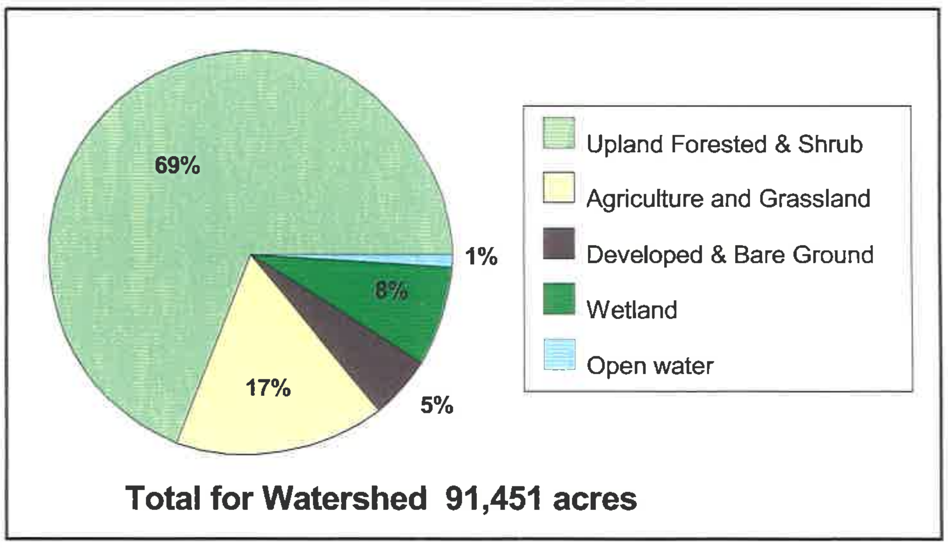
Landcover information is based on Landsat satellite image data from NOAA, University of Maine GAPS, and EPA during the early 1990's. Data was combined by U.S. Fish & Wildlife Service's Gulf of Maine Program. Landcover classes are summarized into 5 classes from the original 31 classes for the purposes of this map.

For display purposes, USGS 1:24,000 roads and hydro features are superimposed.

N W E S

1 0 1 2 3 4 5 Miles

Scale 1:110,000



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recreation and for power generation, and can be used as the source of a treated drinking water supply. The State of Maine water classifications and criteria are listed in Appendix A. Although the Royal River is not currently used as a source for municipal drinking water supplies, the Yarmouth Water District retains exclusive rights to the Royal River to supplement their existing groundwater sources, if necessary.

Lakes, rivers, and streams in southern Maine are increasingly coming under pressure as commercial and residential development and construction continue to burgeon in the region. In Durham, New Gloucester, North Yarmouth and Pownal combined, the number of new single-family units permitted per year during the period from 1990 to 1997 increased an average of eighty percent. In New Gloucester alone, which is almost entirely within the Royal River watershed, new single-family building permits rose by sixty-nine percent. The State Planning Office (SPO) estimates that Cumberland County grew approximately 5.5% from 1990 to 1998. It forecasts that it will grow at a rate of 8% from 1998 to 2010 (Maine State Planning Office, '99). One result of development in the Royal River watershed is the increase in impervious surfaces (e.g., roads, parking lots, and buildings). This means that rainwater and pollutants (e.g., silt, sand, fertilizers, pesticides, animal wastes etc.) will run more directly from these surfaces into the river as surface runoff, bypassing the important natural filtration usually performed by soil and vegetation. In addition, population growth around the Royal River has increased the use of the River for recreational activities such as boating, fishing, and swimming.

In response to the increased development and use of the Royal River, The Friends of the Royal River was founded in the early 1990's. FORR is a community-based, all volunteer organization that was founded to ensure the protection of this resource by promoting public awareness of the river and the quality of its water. Specifically, the three goals of FORR are:

- to promote public participation in the conservation of the Royal River watershed,
- to monitor and protect water quality and wildlife habitat,
- to preserve the scenic, historic and ecological integrity of the watershed.

Toward these ends, the Friends initiated a water quality monitoring program in 1993, drawing upon the volunteer resources of the surrounding communities. This program was supported by the FORR membership and by grants from charitable funding organizations. Organizations involved in supporting and funding the volunteer monitoring program are listed in Appendix B.

Seven years of water quality data have been collected (1993 – 1999) and the analysis of those data forms the basis of this report.

2.1 Scope of the Water Quality Monitoring

Initially, nineteen surface water sampling locations were identified and sampled in 1993. Sites were located throughout the watershed and were selected to give an overall picture of the watershed's water quality to the extent possible, given volunteer sampler availability. Each sampling site was named using a convention that uses a three letter code to denote the name of the stream followed by a number which is equivalent to the distance in miles from the mouth of the Royal River (midstream at the confluence with the Cousins River) to the site. The distance was calculated using geographic information system (GIS) mapping software. By 1999, the program had grown to include a total of 28 sites. Figure 4 and Table 1 present the locations of the testing sites and the years each site was tested.

Samples were collected during the early morning, on a bi-weekly basis during the months of June through September. Volunteers collected three water samples at each sampling station. The water quality parameters that were monitored included dissolved oxygen, turbidity, and fecal coliform bacteria. These parameters were chosen because the tests are relatively easy and inexpensive to do, and they are very good indicators of overall water quality (Potvin, 1992, USEPA, 1997). A summary of each of the monitoring parameters is provided below:

- **Dissolved oxygen** (DO) is the measure of oxygen dissolved in water, reported as milligrams per liter (mg/L) or as percent saturation (i.e., percent of the maximum amount of oxygen possible in the water). This test is used to assess the health of a river because it reflects the amount of oxygen available to aquatic life including animals, fish, insects, bacteria and protozoa. River water which is well-oxygenated (around 8 mg/L) will generally support a healthy and diverse population of aquatic organisms, which will in turn support a wider range of aquatic and terrestrial organisms in the local food chain. Waters with less than the Class B dissolved oxygen standard for long periods of time could suffer from the loss of preferred game fish species and smaller organisms that serve as their food sources.

  As mentioned above, dissolved oxygen levels may also be measured as a percentage of saturation at a given temperature. This unit of measure (percent saturation) is often used to determine compliance with a water quality standard. For example, the Maine Department of Environmental Protection (MEDEP) states that Class B waters should have a dissolved oxygen content of at least 75% saturation. That means that the water should have equal to or greater than 75% of the maximum amount of dissolved oxygen that it could possibly hold given the temperature of the water. Because DO is temperature dependent (colder water can contain more dissolved oxygen than warm water), the temperature of the surface water and overlying air were also measured and recorded during routine sampling.

Microorganisms are the major consumers of a river's dissolved oxygen, while aquatic plants reoxygenate the water daily through photosynthesis. During the course of a night, the population of microorganisms will use the river's oxygen without it being replenished by daylight/photosynthesis. In addition, plant respiration during the night can further deplete the dissolved oxygen of surface water. Therefore, by collecting water samples in the early morning, we are able to assess the minimum levels of a river's dissolved oxygen or the "worst case" condition in the river.

- **Turbidity** is the measure of the cloudiness of a sample of water. Suspended matter, such as clay, silt, fine organic and inorganic matter, soluble organic compounds, and microscopic organisms, increases the turbidity of the water.

  Turbidity is measured by recording the amount of light scattered when a light beam passes through a sample of water. The instrument used to measure turbidity is called a nephelometer, and it records turbidity in units of nephelometric turbidity units (NTUs). Values of less than 10 NTU are desirable. However, there currently is no turbidity standard for Class B waters in Maine.

  Turbidity usually rises following rainstorms due to soil erosion and the draining of runoff into the river where it can inhibit aquatic life. Excessive sediment produced by soil erosion can clog fish gills and smother bottom-dwelling organisms and spawning habitat. Increased sediment can also lead to warmer water by making the channel flow more slowly. Other mechanisms that increase sediment suspension, such as mechanical disturbances, also cause increased turbidity. Maintaining vegetated buffers along riverbanks helps to limit particle introduction to the river because the buffer zones act as filters. As vegetated buffers are reduced or removed, particle introduction and thus, turbidity can increase. Maintaining a vegetated buffer or riparian zone along a river's bank also can provide shade to the river, which helps keep the water cooler and capable of holding more oxygen (Welsch, 1991).

- **Bacterial** counts are an indication of the amount of bacteria that reside in surface water. The concentration of bacteria in surface water is measured in a laboratory by adding a small quantity of river water to a gel surface containing nutrients that allows the bacteria in the surface water to grow into larger "colonies". After a specific amount of growing time at a controlled temperature, the bacterial colonies are counted. The number of colonies counted, called the colony forming units (cfu), is indicative of the

Subwatershed	Stream	Site	Description	Town	'93	'94	'95	'96	'97	'98	'99
Royal River	Moose Brook	MoB31.8	Turkey Lane, NW side	New Gloucester	✓		✓	✓	✓	✓	✓
Royal River	Royal River	RoR1.9	Route 88, path from end of parking lot, NE side	Yarmouth	✓	✓	✓	✓	✓	✓	✓
Royal River	Royal River	RoR2.9	E. Elm Street off of Water District parking lot, NW side	Yarmouth	✓	✓	✓	✓	✓	✓	✓
Royal River	Royal River	RoR5.3	Behind end of Deer Run Road	North Yarmouth	✓	✓	✓	✓	✓	✓	✓
Royal River	Royal River	RoR7.3	At confluence with Toddy Brook	North Yarmouth	✓	✓	✓	✓	✓	✓	✓
Royal River	Royal River	RoR8.6	Route 9, NW side	North Yarmouth	✓	✓	✓	✓	✓	✓	✓
Royal River	Royal River	RoR12.1	Mill Road, NE side	North Yarmouth	✓	✓	✓	✓	✓	✓	✓
Royal River	Royal River	RoR14.8	Depot Road, under bridge, SW side	Gray	✓	✓	✓	✓	✓	✓	✓
Royal River	Royal River	RoR18.4	Penny Road, NE side	New Gloucester						✓	✓
Royal River	Royal River	RoR28.9	Browns Crossing Road, SW side	Auburn (Danville)			✓	✓	✓	✓	✓
Royal River	Royal River	RoR30.3	Danville Road, SE side	Auburn (Danville)	✓		✓				
Royal River	Royal River	RoR34.3	Bald Hill Road, SE side	New Gloucester	✓		✓	✓	✓	✓	✓
Royal River	Royal River	RoR36.3	Tobey Road, SW side	New Gloucester						✓	✓
Royal River	Royal River	RoR38.4	Sabbathday Lake near outlet	New Gloucester	✓		✓				
Royal River	Toddy Brook	ToB8.0	Sligo Road, NW Side	North Yarmouth	✓	✓	✓	✓	✓	✓	✓
Collyer Brook	Brandy Brook	BrB19.6	Morse Road, SE side	New Gloucester			✓	✓	✓	✓	✓
Collyer Brook	Brandy Brook	BrB20.6	Jack Hall Road, NW side	New Gloucester						✓	✓
Collyer Brook	Cole Brook	ClB23.8	Behind 80 Blueberry Lane	Gray							✓
Collyer Brook	Collyer Brook	CoB16.6	Merrill Road, SE side	Gray			✓	✓	✓	✓	✓
Collyer Brook	Collyer Brook	CoB18.3	Megquier Road, SE side	Gray							✓
Collyer Brook	Eddy Brook	EdB21.0	Fish Hatchery Road at gate, across from driveway to Deb's Barnyard	New Gloucester	✓		✓	✓	✓	✓	✓
Collyer Brook	Eddy Brook	EdB21.4	At Fish Hatchery, above dam at end of access road	New Gloucester	✓		✓	✓	✓	✓	✓
Collyer Brook	Libby Brook	LiB19.7	Mayall Road, NW side	Gray						✓	✓
Chandler Brook	Chandler Brook	ChB13.6	Milliken Road, NW side	North Yarmouth	✓	✓	✓	✓	✓	✓	✓
Chandler Brook	Chandler Brook	ChB14.7	Chadsey Road, SW side	Pownal	✓	✓	✓	✓			
Chandler Brook	Chandler Brook	ChB14.8	Chandler Brook, behind 22 Leighton Road	Pownal					✓	✓	✓
Chandler Brook	Chandler Brook	ChB19.1	Poland Range Road, N side	Pownal					✓	✓	✓
Chandler Brook	Chandler Brook	ChB20.4	Below Alder Brook, NW side	Durham	✓	✓	✓	✓			
Chandler Brook	Chandler Brook	ChB21.1	Below Runaround Pond dam, small pond area SE side	Durham	✓	✓	✓	✓	✓	✓	✓
Chandler Brook	Runaround Brook	RuB23.2	Auburn Road, SE side	Durham	✓	✓	✓	✓	✓	✓	
Chandler Brook	Runaround Pond	RuP22.3	Middle of Runaround Pond	Durham				✓			
East Branch Chandler Brook	Collins Brook	CnB20.4	Tuttle Road, just above confluence with East Branch, NE side	Pownal				✓	✓	✓	✓
East Branch Chandler Brook	E Branch Chandler Br.	EBr20.4	Tuttle Road, just above confluence with Collins Brook, SE side	Pownal				✓	✓	✓	✓
East Branch Chandler Brook	Thoits Brook	ThB15.8	South of Elmwood Road from path in cemetary	Pownal							✓

Figure 4. Water quality testing sites for Friends of the Royal River, 1993 - 1999, Royal River Watershed, Maine.

Base 1:100,000 scale USGS data from Maine Office of GIS

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amount of bacteria in the original surface water sample. In samples that have very high concentrations of bacteria, the colonies can overlap, rendering the number of colonies uncountable. These samples are termed too numerous to count (TNTC) by the laboratory.

The MEDEP provides upper-end limits for acceptable concentrations of *E. coli* in Class B water. Because *E. coli* are intestinal bacteria, their presence is a good indicator of fecal contamination. MEDEP's cutoff values for *E. coli* are determined by the geometric mean of a given number of samples taken. For Class B water to be used for recreation or as a treated drinking water source, the geometric mean of eight samples should not be over 125 cfu, which means a maximum of 125 bacterial colonies grown from a 100-milliliter (mL) sample of river water. In Class A waters in Maine, bacteria should be "as naturally occurs."

As discussed in detail in Appendices D and E, bacteria measurements were modified over the course of the seven-year watershed sampling program. At the outset of the watershed-monitoring program in 1993, water samples were collected for measurement of fecal coliform, the subgroup of coliform bacteria present in the gut and feces of warm-blooded animals. However, in 1997 funding was secured which allowed for the more costly measurement of *E.coli* in the water samples. *E.coli* is a type of fecal coliform bacteria. Measurements of *E. coli* were made from July 1997 through the end of 1999.

High bacterial readings can be found in water near failing septic systems, in agricultural areas where animals graze near the river, and sometimes after heavy rainstorms when fecal bacteria are washed from the riverbanks into the water. These bacterial impacts to surface water can be minimized if appropriate management practices are employed by the watershed community.

2.2 Sampling

Over the seven-year monitoring period some sites were relocated, discontinued, or added according to volunteer availability and concerns over potential "trouble spots" in the watershed. The maximum number of sites tested in a season occurred during the 1999 sampling season, when 28 sites were sampled. Over seven years, the Friends' water quality testing program was successful due to the donation of more than 3500 volunteer hours. The many volunteers involved in the program are listed in Appendix C.

All volunteers were trained in the correct sampling techniques to maintain the integrity of the data and to provide consistency across sampling times and locations. Details regarding volunteer sampler training are provided in Appendix D.

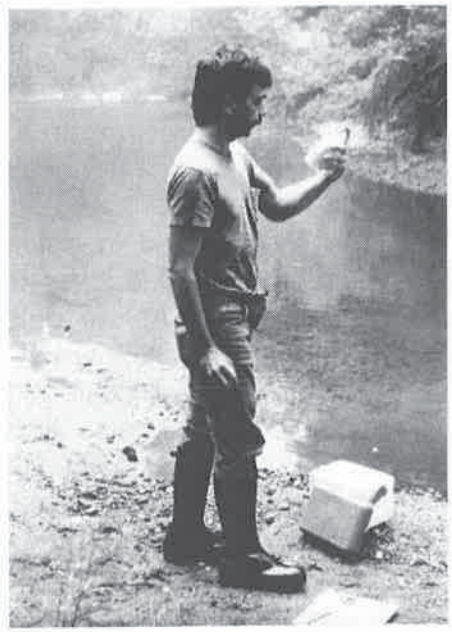
Following collection, all samples were kept cool and delivered to a lab for testing, recording, and, in the case of bacteria, were sent to another lab for further testing. Values derived from these many samples and tests were subsequently compiled, verified, and entered into a composite database. A description of analytical methods is provided in Appendix D.

3. QUALITY CONTROL AND QUALITY ASSURANCE

There were four main areas of quality control and quality assurance in the testing program run by the Friends of the Royal River:

- training of volunteers in water sampling technique,
- assurance of sample collection, storage and transport,
- training of laboratory personnel and assurance of strict laboratory quality control procedures verified by control samples,
- laboratory data calculation and entry validation.

Each of these areas is described in detail in Appendix D.



Brian Whitney collecting water samples

4.0 DATA ANALYSIS

The data generated from this seven-year water quality monitoring program were carefully studied to verify their validity and usability to draw conclusions regarding the general health of the watershed. In addition, the distribution best characterizing the data for each parameter was determined so that the correct types of statistics could be applied in analyzing the data. Appendix E addresses in detail the following aspects of data analysis:

- modifications of sampling and/or analytical measurements,
- data distributions,
- data preparation including data queries, outside data considered and data calculation.

5.0 RESULTS

What did we learn about the health of the Royal River watershed? In general, the results indicate that with respect to dissolved oxygen levels, turbidity and bacterial testing, water quality is generally acceptable for a Class B river indicating a healthy watershed. The results of the three test parameters (dissolved oxygen, turbidity, and coliform bacteria) have changed very little at the sites tested since the start of the monitoring program. However, they also show that water quality varies significantly among the different subwatersheds of the Royal River, and that degradation of water quality has occurred or is threatened at some individual test sites. These findings are presented in greater detail in this section of the report, which begins with a discussion of water quality for the entire Royal River watershed and then proceeds to presentations of the results for each individual subwatershed. The section ends with a discussion of individual sampling sites where testing results suggest potential problems.

5.1 Overall Watershed Health

Generally, the annual arithmetic mean values of dissolved oxygen and the geometric mean values of turbidity and coliform bacteria in the entire Royal River watershed have changed very little over the last seven years, and were consistently within the acceptable range for Class B fresh surface waters in Maine. Figure 5 shows the mean (arithmetic for DO and geometric for bacteria and turbidity), minimum, and maximum values for the entire Royal River watershed each year for dissolved oxygen, turbidity, and coliform bacteria, respectively. Appendix E discusses the use of mean versus geometric mean for each parameter.

Average dissolved oxygen values for the entire watershed have ranged from 75.9 to 80.9 percent of saturation. This range compares well with the Maine Department of Environmental Protection's (MEDEP) minimum Class B standard of 75 percent saturation. Class B water with dissolved oxygen concentrations in excess of the MEDEP standard are deemed to be in compliance for that criterion since they represent a higher (healthier) oxygen level than is required.

Time of sample collection is very important when comparing dissolved oxygen values. Very early in the morning, before there is enough sunlight penetrating the water to begin the process of photosynthesis, dissolved oxygen levels are at their lowest. Differences in sample collection times (i.e., 6:00 AM vs. 8:00 AM) in this study did not correlate with dissolved oxygen values (i.e. later tests did not correspond with higher DO). The annual mean time of sample collection over the seven years ranged from 6:29 AM to 7:01 AM. There were several sites where mean testing time changed over an hour from year to year due to changes in sampling volunteers or their schedules. However, the values for percent DO saturation at those sites did not appear to be affected by the difference in time of sample collection.

Annual geometric means of coliform bacteria counts for the entire watershed averaged between 35 and 79 colonies over the seven-year testing period, well below MEDEP's standard of 125 colonies (for a set of eight samples). Contrary to dissolved oxygen, coliform bacteria counts in excess of MEDEP's Class B standard renders the water at least temporarily out of compliance. However, because the geometric mean coliform bacteria counts have averaged less than MEDEP's Class B criterion, the Royal River watershed was generally in compliance with its water class designation.

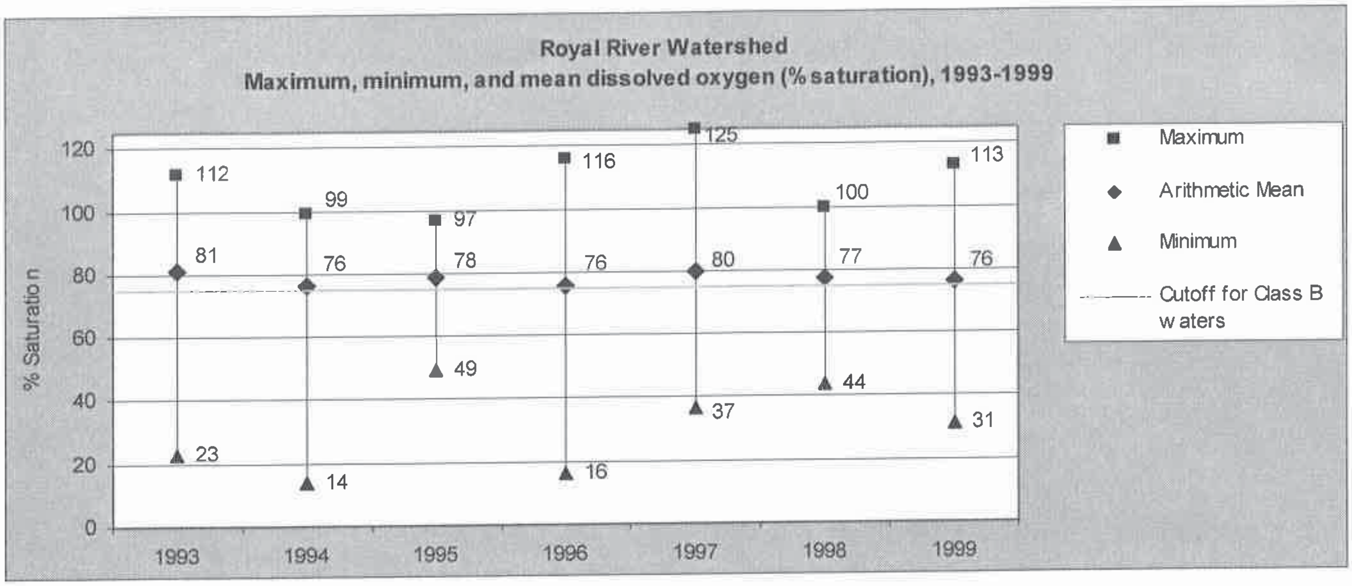
Although high coliform counts were very unusual, on two testing dates, September 16, 1998, and July 7, 1999, a third or more of *E. coli* measurements were reported as too numerous to count (TNTC). On the September 16, 1998, seven of eleven sites with TNTC bacterial results also recorded the highest turbidity readings for that year, showing a positive correlation that day between the two parameters. Although flow data from the Yarmouth station did not show a large increase in stream flow on these dates, 100% of sampling volunteers on September 16, 1998 and 74% on July 7, 1999 described weather for the previous 24 hours as "rain", "heavy rain" or "thundershowers" on their field observation sheets. Although elevated levels of bacteria due to storm runoff generally are not sustained for long periods of time, there would be potential risk to swimmers exposed to the short-term elevated levels.

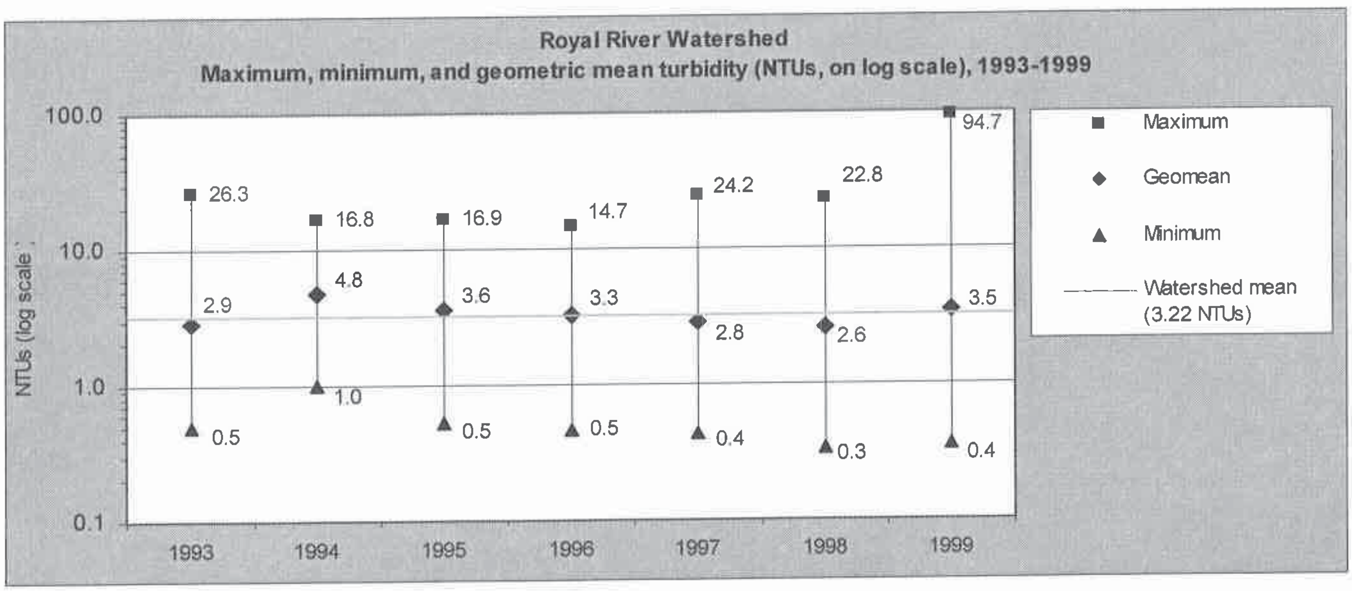
The geometric mean turbidity measurements for the entire watershed have consistently remained below 5 NTUs, and only two individual readings in seven years exceeded 30 NTUs. There is no turbidity criterion for waters in Maine. However, these values are generally very low, indicating that on the days tested, the surface water at the testing sites was relatively clear.

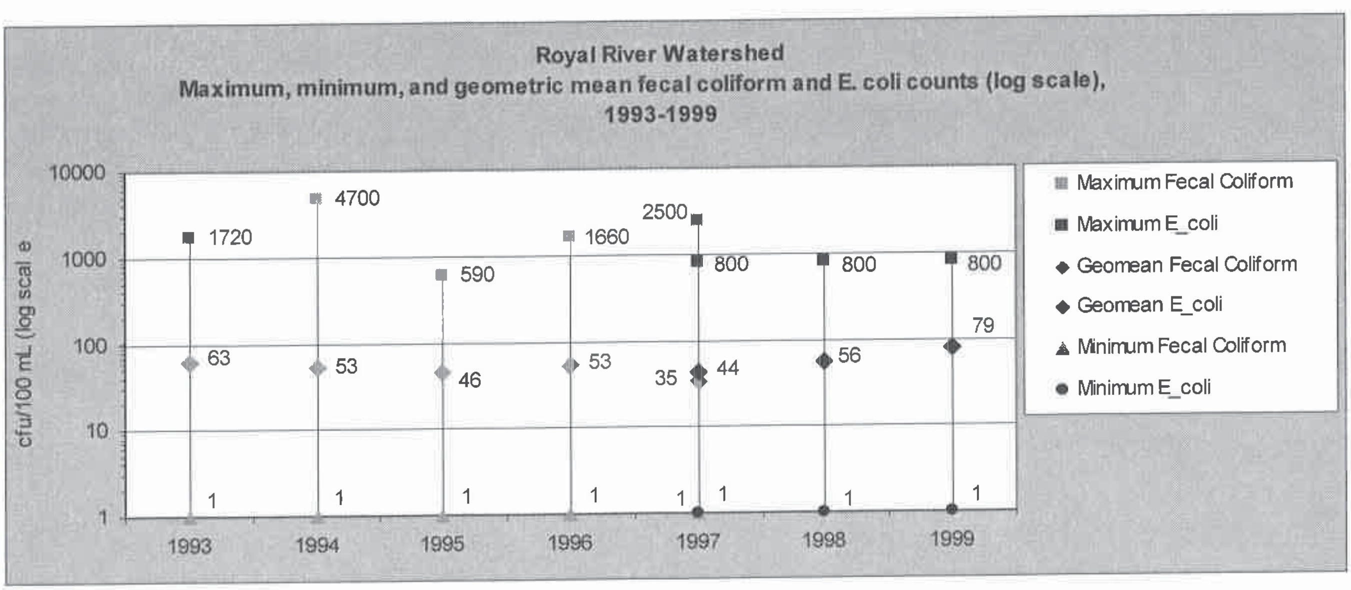
Figure 6 is a map of the sampling sites which displays the percent of years each site was in compliance with MEDEP Class B standards for fresh surface water for dissolved oxygen. Figure 7 is a similar map for turbidity showing for each site the percent of testing years that levels were below the watershed geometric mean of 10 NTUs. The use of this reference is discussed in Appendix E, Section 3.3. Figure 8 displays the sites with respect to the MEDEP Class B standard for *E. coli* counts. Note that Figure 8 represents only *E. coli* results and consequently only three years of data. Fecal coliform data for all sites for years 1993-1997 are included in Appendices F-I. The large red triangles in Figures 6, 7, and 8 indicate potential problem sites. Additional details regarding the results shown in Figures 6, 7, and 8 are provided below.

Although the main stem of the Royal River and the three subwatersheds were evaluated for significant trends (declining or increasing) for all water sampling parameters, no clear trends were observed. In fact, mean values for all parameters for the subwatersheds changed very little between 1993 and 1999. This indicates that the subwatersheds as a whole were fairly stable with respect to the parameters analyzed during the seven-year monitoring period.

Figure 5.


Royal River Watershed
Maximum, minimum, and mean dissolved oxygen (% saturation), 1993-1999
% Saturation
120
100
80
60
40
20
0
112
81
23
99
76
14
97
78
49
116
76
16
125
80
37
100
77
44
113
76
31
1993
1994
1995
1996
1997
1998
1999
Maximum
Arithmetic Mean
Minimum
Cutoff for Class B waters


Royal River Watershed
Maximum, minimum, and geometric mean turbidity (NTUs, on log scale), 1993-1999
NTUs (log scale)
100.0
10.0
1.0
0.1
26.3
2.9
0.5
16.8
4.8
1.0
16.9
3.6
0.5
14.7
3.3
0.5
24.2
2.8
0.4
22.8
2.6
0.3
94.7
3.5
0.4
1993
1994
1995
1996
1997
1998
1999
Maximum
Geomean
Minimum
Watershed mean (3.22 NTUs)


Royal River Watershed
Maximum, minimum, and geometric mean fecal coliform and E. coli counts (log scale), 1993-1999
cfu/100 mL (log scale)
10000
1000
100
10
1
1720
63
1
4700
53
1
590
46
1
1660
53
1
2500
800
35
44
1
1
800
56
1
800
79
1
1993
1994
1995
1996
1997
1998
1999
Maximum Fecal Coliform
Maximum E_coli
Geomean Fecal Coliform
Geomean E_coli
Minimum Fecal Coliform
Minimum E_coli

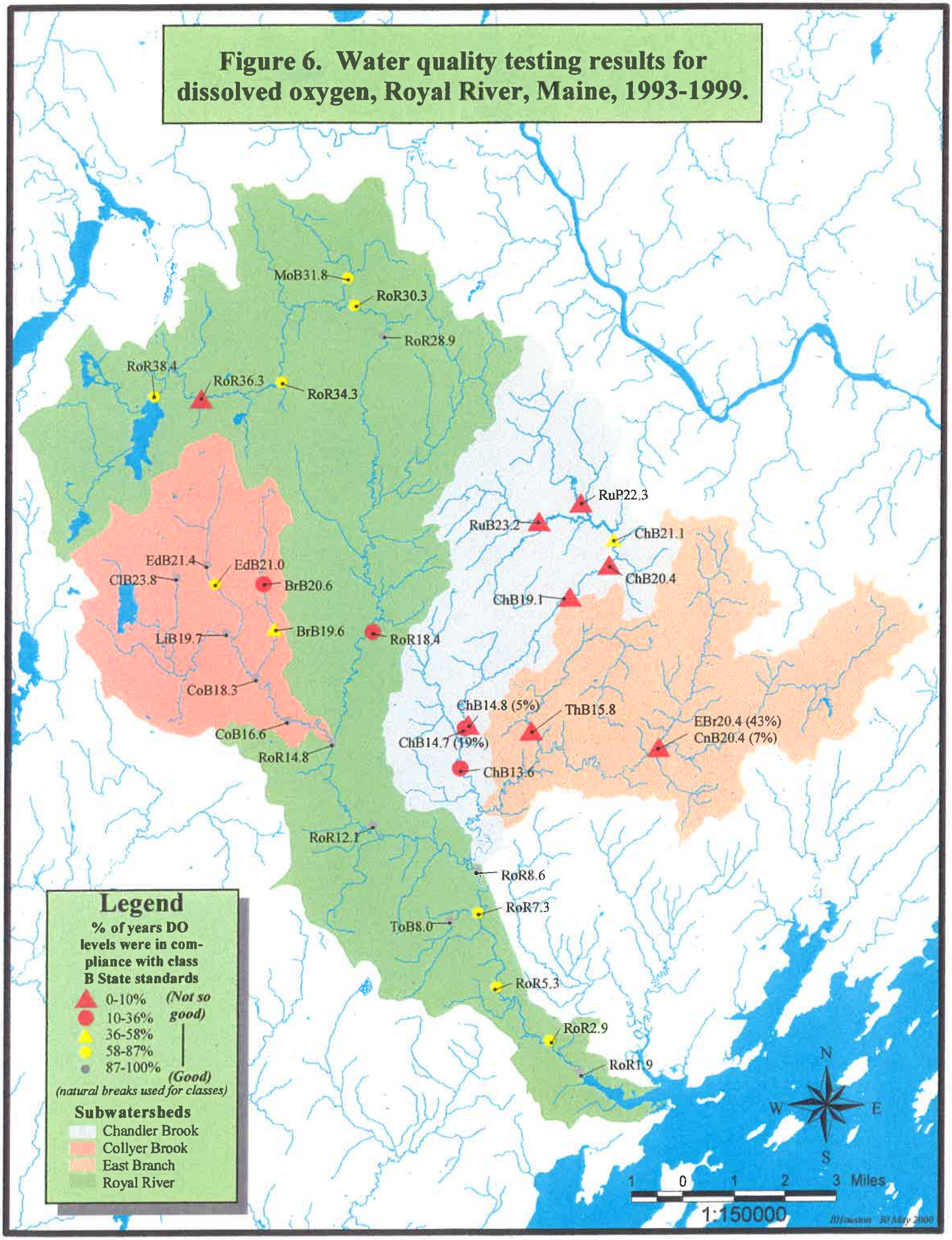


Figure 6. Water quality testing results for dissolved oxygen, Royal River, Maine, 1993-1999.
MoB31.8
RoR30.3
RoR28.9
RoR38.4
RoR36.3
RoR34.3
RuP22.3
RuB23.2
ChB21.1
EdB21.4
EdB21.0
ClB23.8
BrB20.6
ChB20.4
ChB19.1
LiB19.7
BrB19.6
RoR18.4
CoB18.3
ChB14.8 (5%)
ThB15.8
EBr20.4 (43%)
CnB20.4 (7%)
CoB16.6
ChB14.7 (19%)
RoR14.8
ChB13.6
RoR12.1
RoR8.6
RoR7.3
ToB8.0
RoR5.3
RoR2.9
RoR1.9
Legend
% of years DO levels were in compliance with class B State standards
0-10%
10-36%
36-58%
58-87%
87-100%
(Not so good)
(Good)
(natural breaks used for classes)
Subwatersheds
Chandler Brook
Collyer Brook
East Branch
Royal River
N
W
E
S
1 0 1 2 3 Miles
1:150000
BHouston 30 May 2000

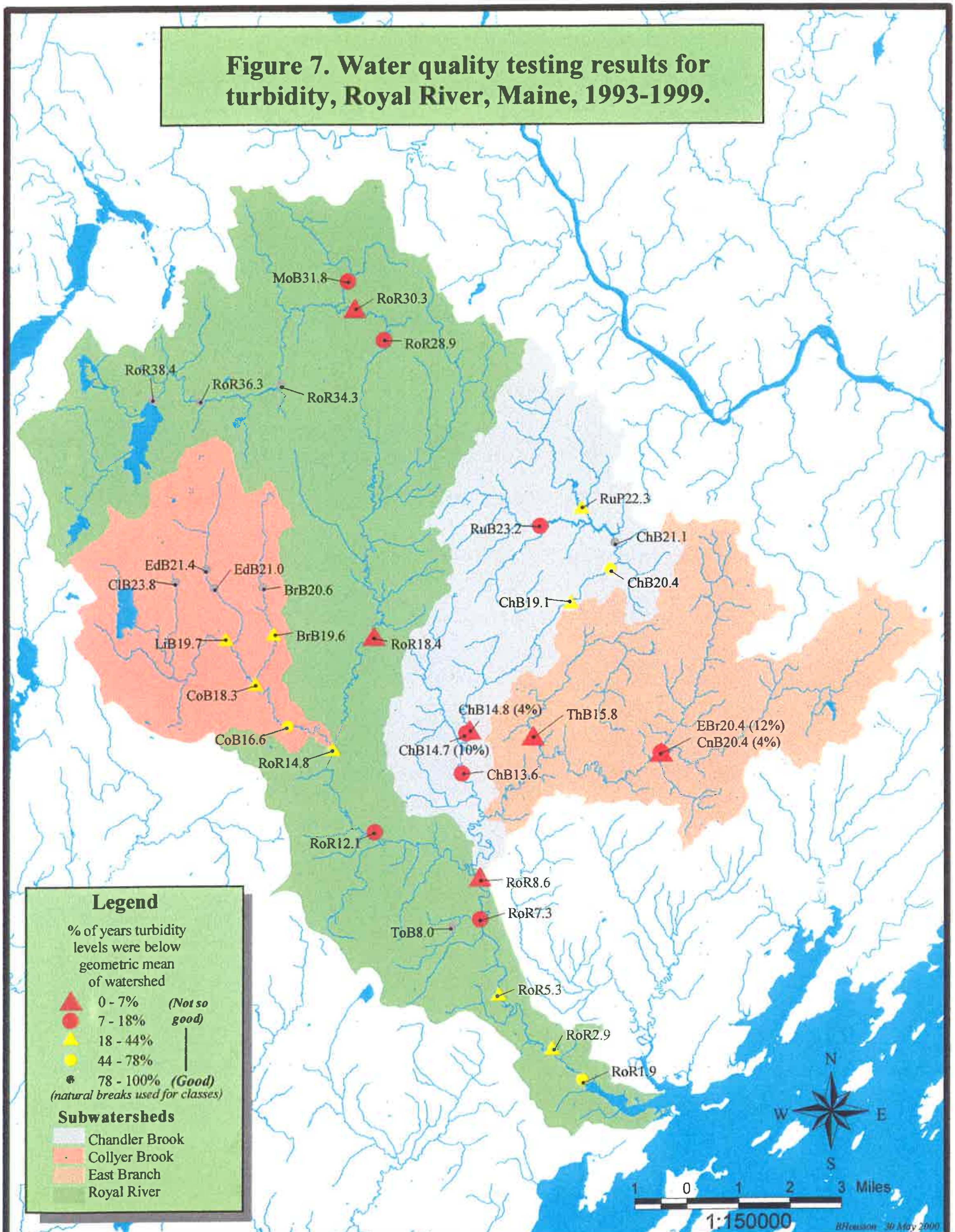


Figure 7. Water quality testing results for turbidity, Royal River, Maine, 1993-1999.
MoB31.8
RoR30.3
RoR28.9
RoR38.4
RoR36.3
RoR34.3
RuP22.3
RuB23.2
ChB21.1
EdB21.4
EdB21.0
ClB23.8
BrB20.6
ChB20.4
ChB19.1
LiB19.7
BrB19.6
RoR18.4
CoB18.3
ChB14.8 (4%)
ThB15.8
EBr20.4 (12%)
CnB20.4 (4%)
CoB16.6
RoR14.8
ChB14.7 (10%)
ChB13.6
RoR12.1
RoR8.6
RoR7.3
ToB8.0
RoR5.3
RoR2.9
RoR1.9
Legend
% of years turbidity levels were below geometric mean of watershed
0 - 7%
7 - 18%
18 - 44%
44 - 78%
78 - 100%
(Not so good)
(Good)
(natural breaks used for classes)
Subwatersheds
Chandler Brook
Collyer Brook
East Branch
Royal River
N
W
E
S
1 0 1 2 3 Miles
1:150000
BHousson 30 May 2000

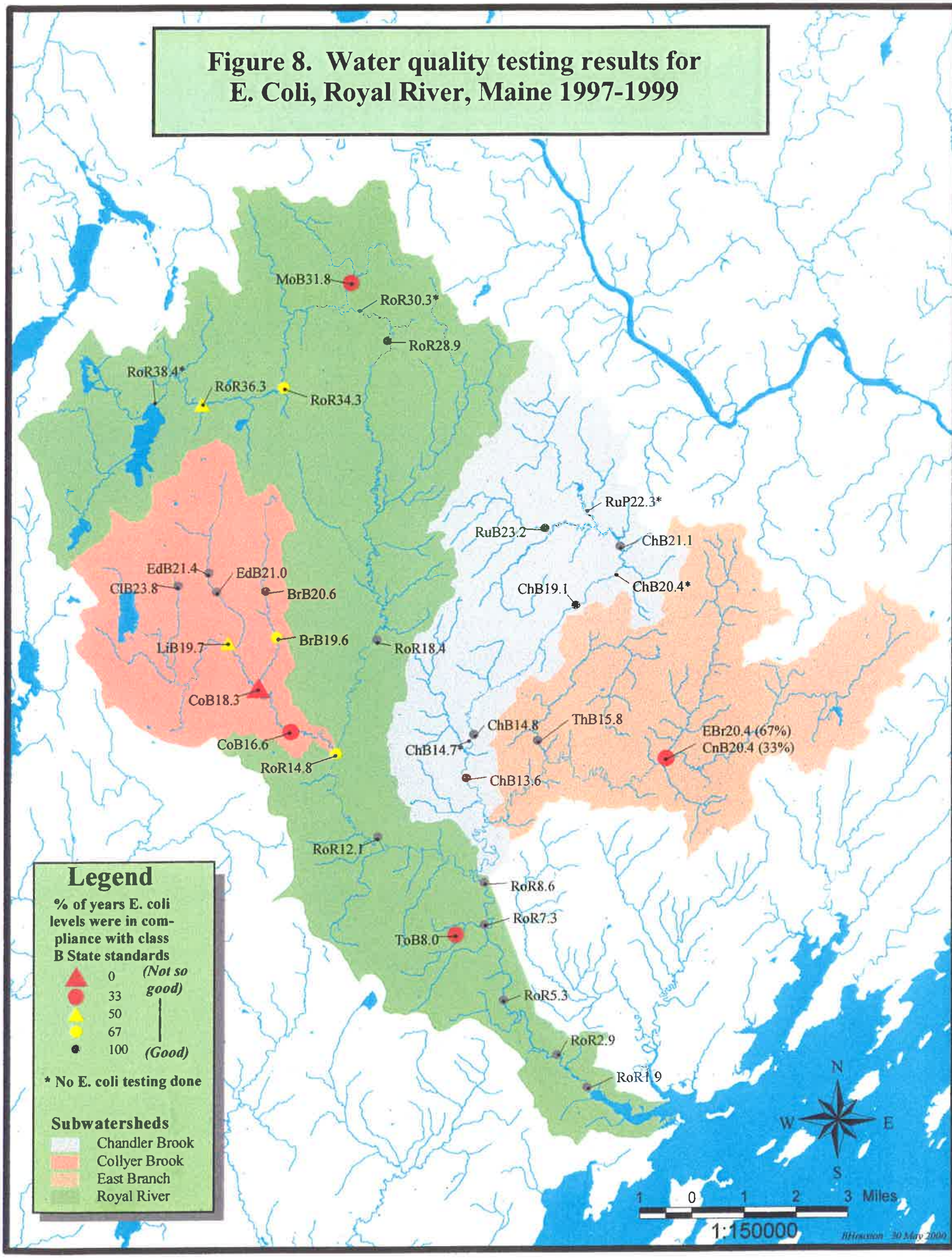


Figure 8. Water quality testing results for
E. Coli, Royal River, Maine 1997-1999
MoB31.8
RoR30.3*
RoR28.9
RoR38.4*
RoR36.3
RoR34.3
RuP22.3*
RuB23.2
ChB21.1
EdB21.4
EdB21.0
ClB23.8
BrB20.6
ChB19.1
ChB20.4*
LiB19.7
BrB19.6
RoR18.4
CoB18.3
ChB14.8
ThB15.8
EBr20.4 (67%)
CnB20.4 (33%)
CoB16.6
ChB14.7*
RoR14.8
ChB13.6
RoR12.1
Legend
% of years E. coli levels were in compliance with class B State standards
0
(Not so good)
33
50
67
100
(Good)
* No E. coli testing done
Subwatersheds
Chandler Brook
Collyer Brook
East Branch
Royal River
RoR8.6
RoR7.3
ToB8.0
RoR5.3
RoR2.9
RoR1.9
N
W
E
S
1 0 1 2 3 Miles
1:150000

The mean dissolved oxygen for the East Branch Chandler Brook subwatershed exhibited a slight downward trend over the sampling period (1996 to 1999). However, the shorter monitoring period for this subwatershed (only four years vs. seven years for other subwatersheds) makes this trend suspect as it is difficult to distinguish between natural variability and potentially declining dissolved oxygen concentrations with only four years of data. The sites in this subwatershed were added to the monitoring program in 1996.

Two of the four subwatersheds had annual mean dissolved oxygen levels below the Class B standard of 75 percent. Annual mean dissolved oxygen levels in Chandler Brook were consistently below 75 percent, ranging from 61.1 to 66.9 percent saturation, and in the East Branch Chandler Brook levels ranged from 57.6 to 69.3 percent. It is also important to note that the dissolved oxygen content within these subwatersheds has consistently been below the Class B standard for the entire seven-year monitoring period. The data do not suggest that the dissolved oxygen levels are necessarily decreasing or increasing. The fact that the dissolved oxygen is low in these subwatersheds could be due to many natural or anthropogenic factors, including, for example, low stream flow and lack of aeration, elevated levels of dissolved and suspended organic material, or inputs of runoff containing nutrient-rich material.

An effort was made to examine whether there was any relationship between the three water quality parameters measured and the seemingly low dissolved oxygen levels found in Chandler Brook. However, no clear associations were identified. For instance, Collyer Brook had the highest annual mean dissolved oxygen levels and lowest turbidity of all the subwatersheds, but had higher mean bacteria counts than Chandler Brook (the subwatershed with the lowest dissolved oxygen). The bacterial counts in Chandler Brook were also lower than those in the main stem of the Royal River subwatershed, which had mean dissolved oxygen levels nearly as high as Collyer Brook. The combination of low dissolved oxygen and relatively low turbidity and bacteria counts in Chandler Brook suggest that its water quality is being affected by different influences than the other subwatersheds. As discussed above, these impacts may be the result of natural and/or anthropogenic influences to the subwatershed.

The East Branch Chandler Brook intermittently had annual mean coliform (both fecal and *E. coli*) counts that failed to meet the Class B standard, suggesting possible non-point source impacts to water quality. However, it is important to note that all data for this subwatershed were collected from three sites, and thus provide a relatively narrow view of conditions throughout the subwatershed. In contrast, data sets for the main stem and the other two subwatersheds of the Royal each include samples from at least seven different sites.

The variations in water quality observed within each subwatershed are discussed in the following subsections.

5.2 Main Stem of the Royal River

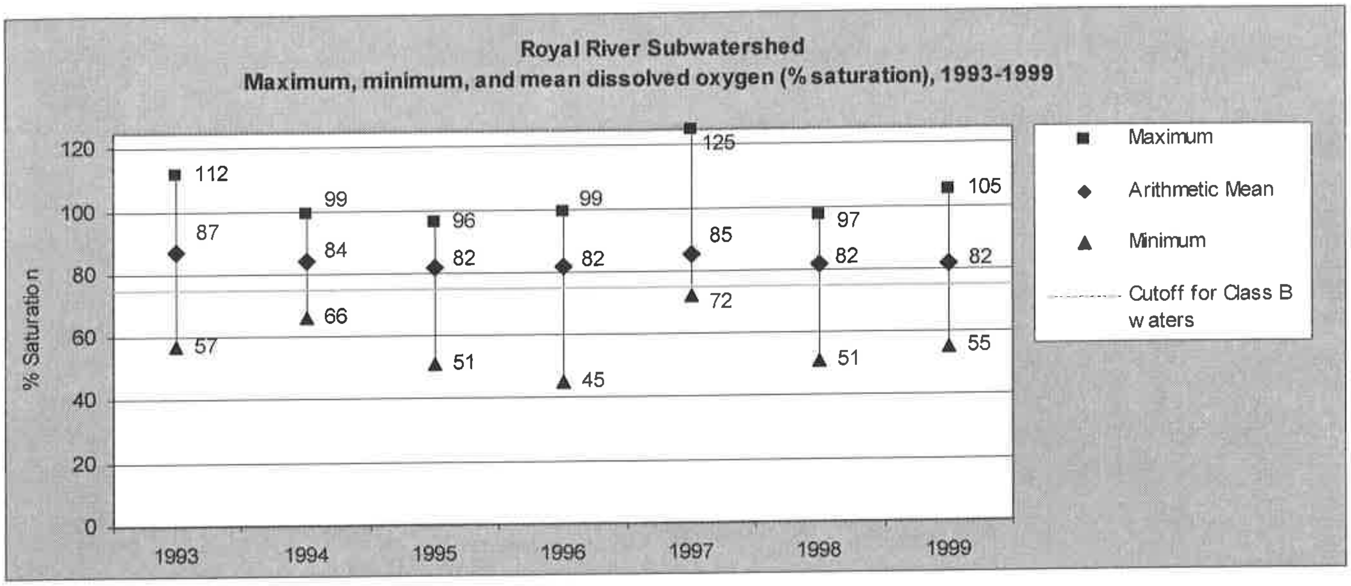
The minimum, maximum, and mean annual results of sampling done at sites in the main stem subwatershed of the Royal River are presented in Figure 9.

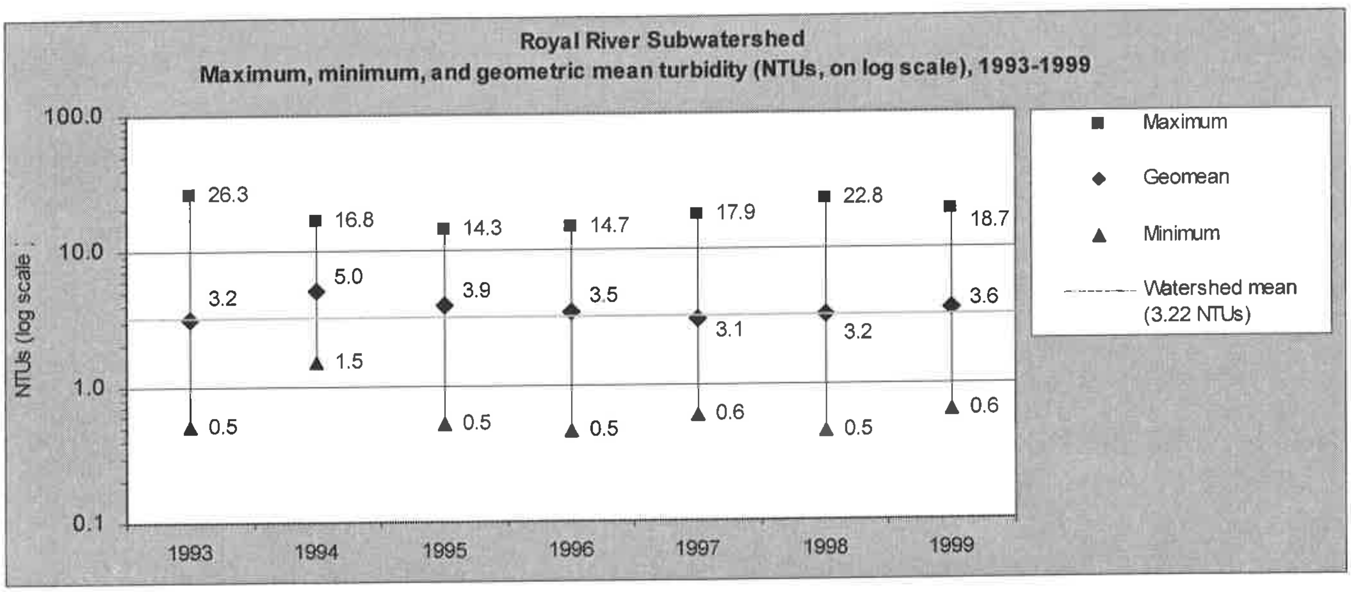
Most sites in the main stem had relatively high dissolved oxygen levels, but several sites had intermittently elevated bacteria counts. All but five of the 15 sites in the main stem maintained annual mean oxygen concentrations better than the 75 percent Class B standard every year. Appendix F includes individual graphs of annual means, minimums and maximums for the three testing parameters for each site within the main stem subwatershed. Two of the five sites that exhibited mean concentrations below 75 percent, RoR38.4, and RoR18.4, were each monitored for only two years and had mean concentrations well above 75 percent for one of the two years. RoR36.3 was monitored for only two years and its mean % DO saturation fell slightly below the cutoff both years. All three of these sites, which are located in the upper part of the watershed above any contributions from the other subwatersheds, had fairly low turbidity (less than 8 NTUs). Only one (RoR36.3) had an annual mean coliform count above the Class B standard in one of the two years it was tested. The other two sites with an annual mean oxygen concentration below the Class B standard, MoB31.8 and RoR5.3, were monitored for six and seven years, respectively, and had mean oxygen concentrations well above 75 percent of saturation in all years but one.

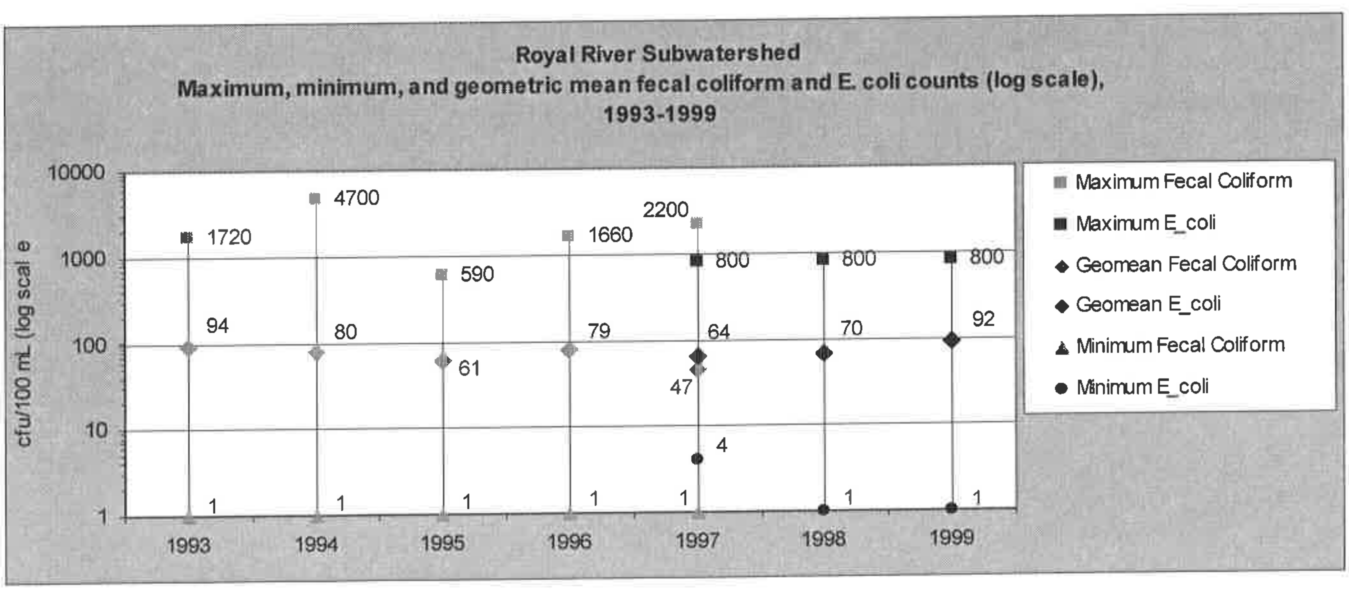
Five of the 15 sites in the main stem had an annual geometric mean *E. coli* count above the Class B standard in at least one of the monitored years. However, all of these sites (RoR36.3, RoR34.3, MoB31.8, RoR14.8, and ToB8.0) also had one or more years where the annual geometric mean was below the Class B standard. One other site, RoR30.3, had relatively high (greater than 100 colonies per 100 mL) annual geometric mean fecal coliform counts during the only two years it was monitored (1993 and 1995). The sources of the bacteria found at these sites are not known, but may include human influences such as discharges from septic systems or fertilizers (biosolids) or animal wastes carried by surface runoff.

Finally, it should be noted that the McKin Superfund Site in East Gray has an ongoing discharge to the surface water in this section of the watershed, near the confluence of Collyer Brook and the Royal River. The parameters for which the FORR tested (dissolved oxygen, turbidity, and fecal coliform bacteria) are not appropriate for estimating the potential threat to human health and the environment which may exist due to the continuing release of trichloroethylene (TCE, an industrial solvent) into the Royal River from the McKin Superfund Site (FORR, Spring 1996, FORR, Fall/ Winter 1996/1997, Cumberland County Soil and Water Conservation District 1998).

Figure 9.


Royal River Subwatershed
Maximum, minimum, and mean dissolved oxygen (% saturation), 1993-1999
% Saturation
120
100
80
60
40
20
0
112
87
57
99
84
66
96
82
51
99
82
45
125
85
72
97
82
51
105
82
55
1993
1994
1995
1996
1997
1998
1999
Maximum
Arithmetic Mean
Minimum
Cutoff for Class B waters


Royal River Subwatershed
Maximum, minimum, and geometric mean turbidity (NTUs, on log scale), 1993-1999
NTUs (log scale)
100.0
10.0
1.0
0.1
26.3
3.2
0.5
16.8
5.0
1.5
14.3
3.9
0.5
14.7
3.5
0.5
17.9
3.1
0.6
22.8
3.2
0.5
18.7
3.6
0.6
1993
1994
1995
1996
1997
1998
1999
Maximum
Geomean
Minimum
Watershed mean (3.22 NTUs)


Royal River Subwatershed
Maximum, minimum, and geometric mean fecal coliform and E. coli counts (log scale), 1993-1999
cfu/100 mL (log scale)
10000
1000
100
10
1
1720
94
1
4700
80
1
590
61
1
1660
79
1
2200
800
64
47
4
1
800
70
1
800
92
1
1993
1994
1995
1996
1997
1998
1999
Maximum Fecal Coliform
Maximum E_coli
Geomean Fecal Coliform
Geomean E_coli
Minimum Fecal Coliform
Minimum E_coli

5.3 Collyer Brook Subwatershed

The minimum, maximum, and mean annual results of sampling done in the Collyer Brook subwatershed of the Royal River are presented in Figure 10. Appendix G includes individual graphs of annual means, minimums and maximums for the three testing parameters for the eight sites within this subwatershed.

The Collyer Brook subwatershed generally had the highest mean oxygen concentrations of all the Royal River subwatersheds. Six of the eight sites had annual mean oxygen concentrations above the Class B standard every year they were monitored, in addition, 86% of the minimum DO values at these sites were still above the cutoff. A seventh site (BrB19.6) had a mean concentration below the standard in only one of the five years it was monitored. The lowest mean oxygen concentrations in the subwatershed were measured at BrB20.6, located near where Brandy Brook crosses beneath U.S Route 202 in New Gloucester. This site was only monitored in 1998 and 1999, but had annual mean concentrations below 75 percent in both years.

Turbidity values in the Collyer Brook subwatershed were the lowest of all the subwatersheds.

E. coli counts in the Collyer Brook subwatershed were relatively high, especially at those sites located in the lower parts of the subwatershed. Each of the four lowest sites (CoB16.6, CoB18.3, BrB19.6, and LiB19.7) had at least one year in which their annual mean *E. coli* count exceeded the Class B standard. CoB18.3, which was sampled for *E. coli* for only one year, was the only one of these sites to exceed the standard every year it was monitored. When considering these relatively high bacteria counts, it is of interest to note that Figure 3 shows that the Collyer Brook subwatershed has the highest percent of developed land of the four subwatersheds.

5.4 Chandler Brook Subwatershed

The minimum, maximum, and mean annual results of sampling done in the Chandler Brook subwatershed of the Royal River are presented in Figure 11. Appendix H includes individual graphs of annual means, minimums and maximums for the three testing parameters for the eight sites within this subwatershed.

Dissolved oxygen concentrations in the Chandler Brook subwatershed were almost uniformly low. Only one of the eight sites had a year in which its annual mean concentration met or exceeded the Class B standard. This site, ChB21.1, is located immediately below the outlet dam on Runaround Pond, where oxygen is likely introduced into the water as it cascades over the dam. Annual mean DO concentrations at ChB21.1 were generally above 75 percent, but fell below this standard in two of the seven monitored years. The annual mean concentrations at the other five sites were below the standard every year, with many of the values falling below 60 percent. The cause of the low oxygen concentrations in the Chandler Brook subwatershed is not known, but may be due to a combination of low flow/aeration and high levels of suspended and dissolved organic matter.

Turbidity results in this subwatershed were generally low. Site RuB23.2 had some high values from 1993-1995, which then dropped down in 1996-1999 to values more consistent with the rest of the subwatershed. The cause of this apparent change is unknown.

In 1999, the FORR monitoring program documented a sharp change in turbidity readings at ChB14.8. This coincided with two crossings of Chandler Brook by the Maritimes Northeast Natural Gas Pipeline construction project. Figure 12 graphs the turbidity readings at two sites on Chandler Brook in Pownal. ChB14.7 was tested from 1993 to 1996. In 1997, the sampling site was relocated 0.1 miles upstream to ChB14.8 due to a change in available volunteers. On June 21, 1999, the pipeline crossed Chandler Brook at Elmwood Road in Pownal (1.3 miles upstream from ChB14.8) and on August 23, it crossed Chandler Brook again 0.22 miles upstream of sampling site ChB14.8. These data strongly suggest that even with the use of best management practices (BMPs) to minimize erosion, the stream was impacted by soil and sediment erosion quite a distance below the construction sites for the entire summer of 1999[2].

E. coli counts in the Chandler Brook subwatershed were consistently very low, with no sites exhibiting annual mean counts exceeding the Class B standard.

5.5 East Branch Chandler Brook Subwatershed

The minimum, maximum, and mean annual results of sampling done in the East Branch Chandler Brook subwatershed of the Royal River are presented in Figure 13. Appendix I includes individual graphs of annual means, minimums and maximums for the three testing parameters for the three sites within this subwatershed.

With only three sites, one of which (ThB15.8) was monitored only in 1999, the East Branch of Chandler Brook had the fewest monitored sites of any of the subwatersheds. The results for these sites varied a great deal. The mean dissolved oxygen concentrations at EBr20.4 were consistently within one

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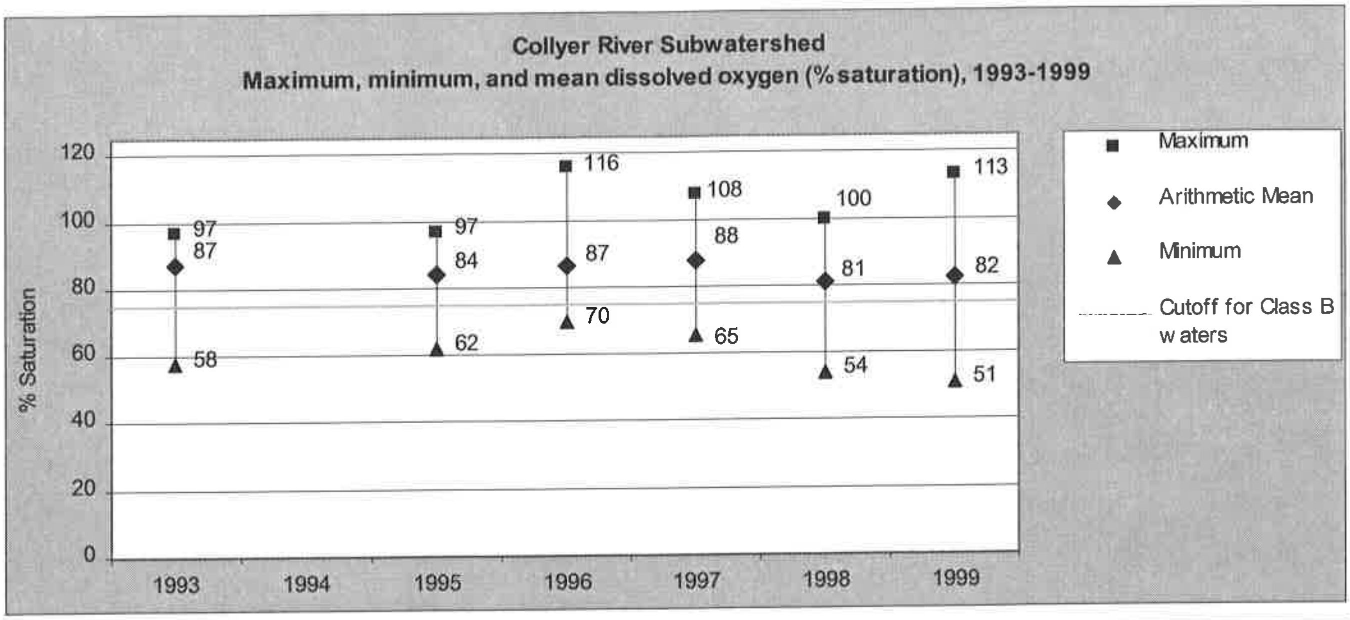
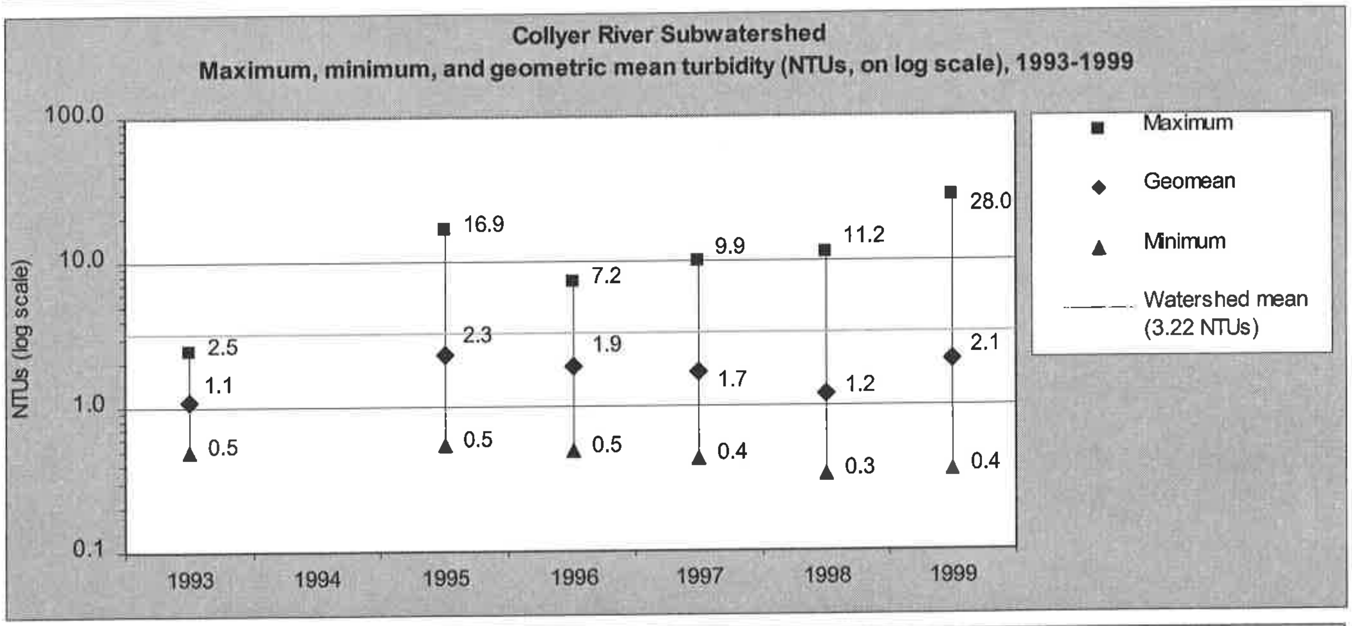
[2] The construction and maintenance of the BMPs used at the stream crossings were not observed or recorded by FORR. The purpose of BMP implementation is to prevent the short- and long-term degradation of the surface water. Therefore, the elevated turbidity cannot necessarily be attributable solely to BMP efficacy (or lack thereof). It is possible that the elevated levels of turbidity were the result of incorrect installation of BMPs, improper maintenance of the BMPs, or both.

Figure 10.


Collyer River Subwatershed
Maximum, minimum, and mean dissolved oxygen (%saturation), 1993-1999
% Saturation
120
100
80
60
40
20
0
1993
1994
1995
1996
1997
1998
1999
97
87
58
97
84
62
116
87
70
108
88
65
100
81
54
113
82
51
Maximum
Arithmetic Mean
Minimum
Cutoff for Class B waters


Collyer River Subwatershed
Maximum, minimum, and geometric mean turbidity (NTUs, on log scale), 1993-1999
NTUs (log scale)
100.0
10.0
1.0
0.1
1993
1994
1995
1996
1997
1998
1999
2.5
1.1
0.5
16.9
2.3
0.5
7.2
1.9
0.5
9.9
1.7
0.4
11.2
1.2
0.3
28.0
2.1
0.4
Maximum
Geomean
Minimum
Watershed mean (3.22 NTUs)

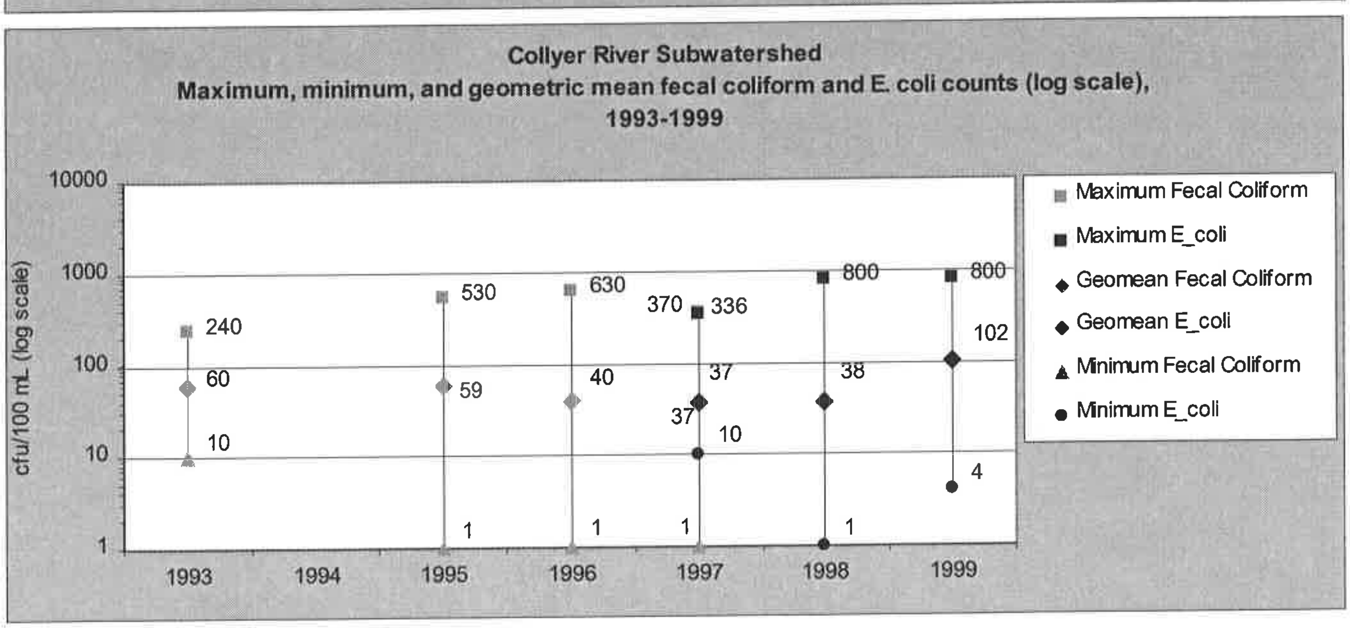
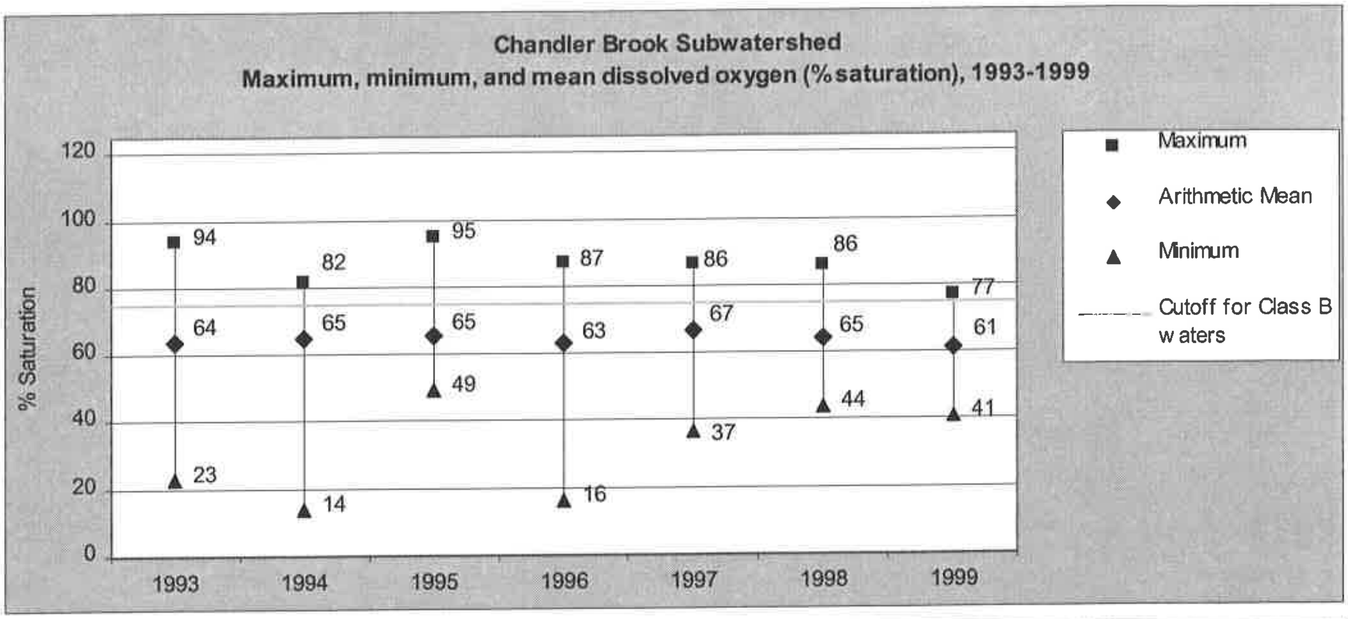
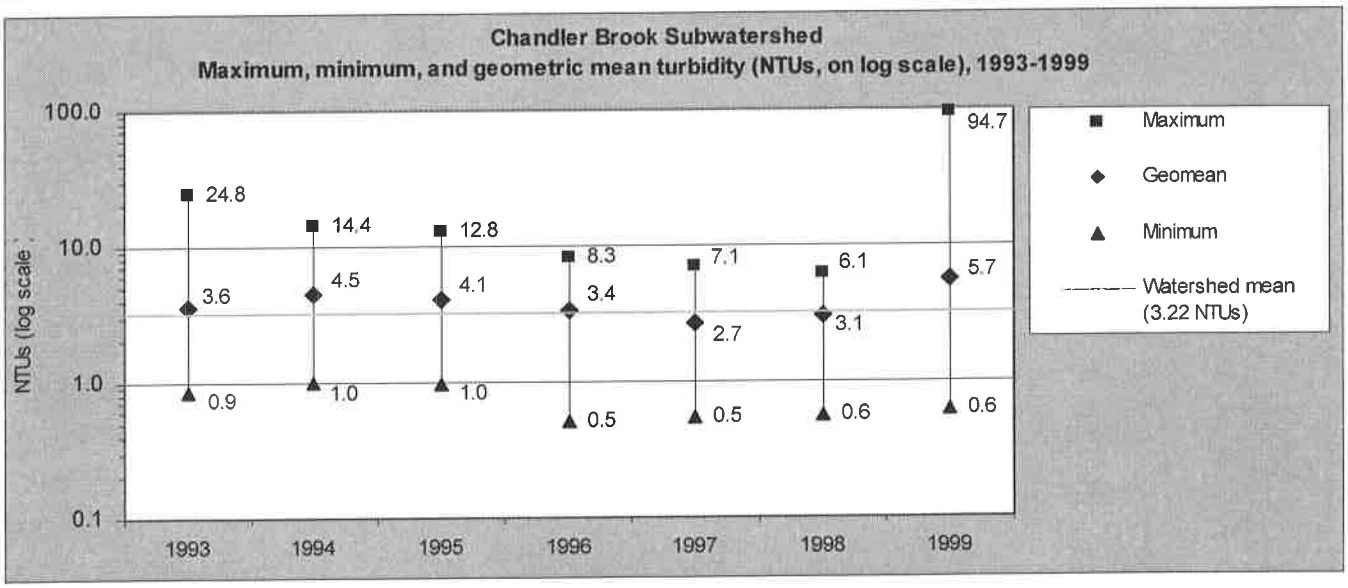
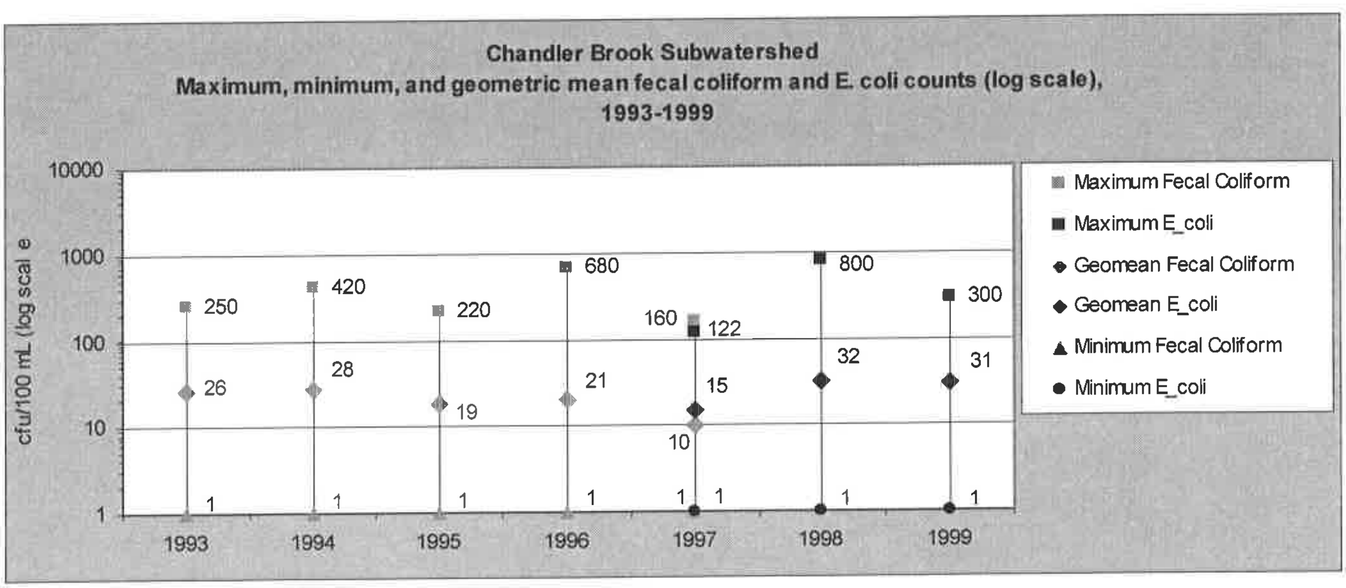

Collyer River Subwatershed
Maximum, minimum, and geometric mean fecal coliform and E. coli counts (log scale), 1993-1999
cfu/100 mL (log scale)
10000
1000
100
10
1
1993
1994
1995
1996
1997
1998
1999
240
60
10
530
59
1
630
40
1
370
336
37
37
10
1
800
38
1
800
102
4
Maximum Fecal Coliform
Maximum E_coli
Geomean Fecal Coliform
Geomean E_coli
Minimum Fecal Coliform
Minimum E_coli

Figure 11.


Chandler Brook Subwatershed
Maximum, minimum, and mean dissolved oxygen (%saturation), 1993-1999
% Saturation
120
100
80
60
40
20
0
94
64
23
82
65
14
95
65
49
87
63
16
86
67
37
86
65
44
77
61
41
1993
1994
1995
1996
1997
1998
1999
Maximum
Arithmetic Mean
Minimum
Cutoff for Class B waters


Chandler Brook Subwatershed
Maximum, minimum, and geometric mean turbidity (NTUs, on log scale), 1993-1999
NTUs (log scale)
100.0
10.0
1.0
0.1
24.8
3.6
0.9
14.4
4.5
1.0
12.8
4.1
1.0
8.3
3.4
0.5
7.1
2.7
0.5
6.1
3.1
0.6
94.7
5.7
0.6
1993
1994
1995
1996
1997
1998
1999
Maximum
Geomean
Minimum
Watershed mean (3.22 NTUs)


Chandler Brook Subwatershed
Maximum, minimum, and geometric mean fecal coliform and E. coli counts (log scale), 1993-1999
cfu/100 mL (log scal e
10000
1000
100
10
1
250
26
1
420
28
1
220
19
1
680
21
1
160
122
15
10
1
1
800
32
1
300
31
1
1993
1994
1995
1996
1997
1998
1999
Maximum Fecal Coliform
Maximum E_coli
Geomean Fecal Coliform
Geomean E_coli
Minimum Fecal Coliform
Minimum E_coli

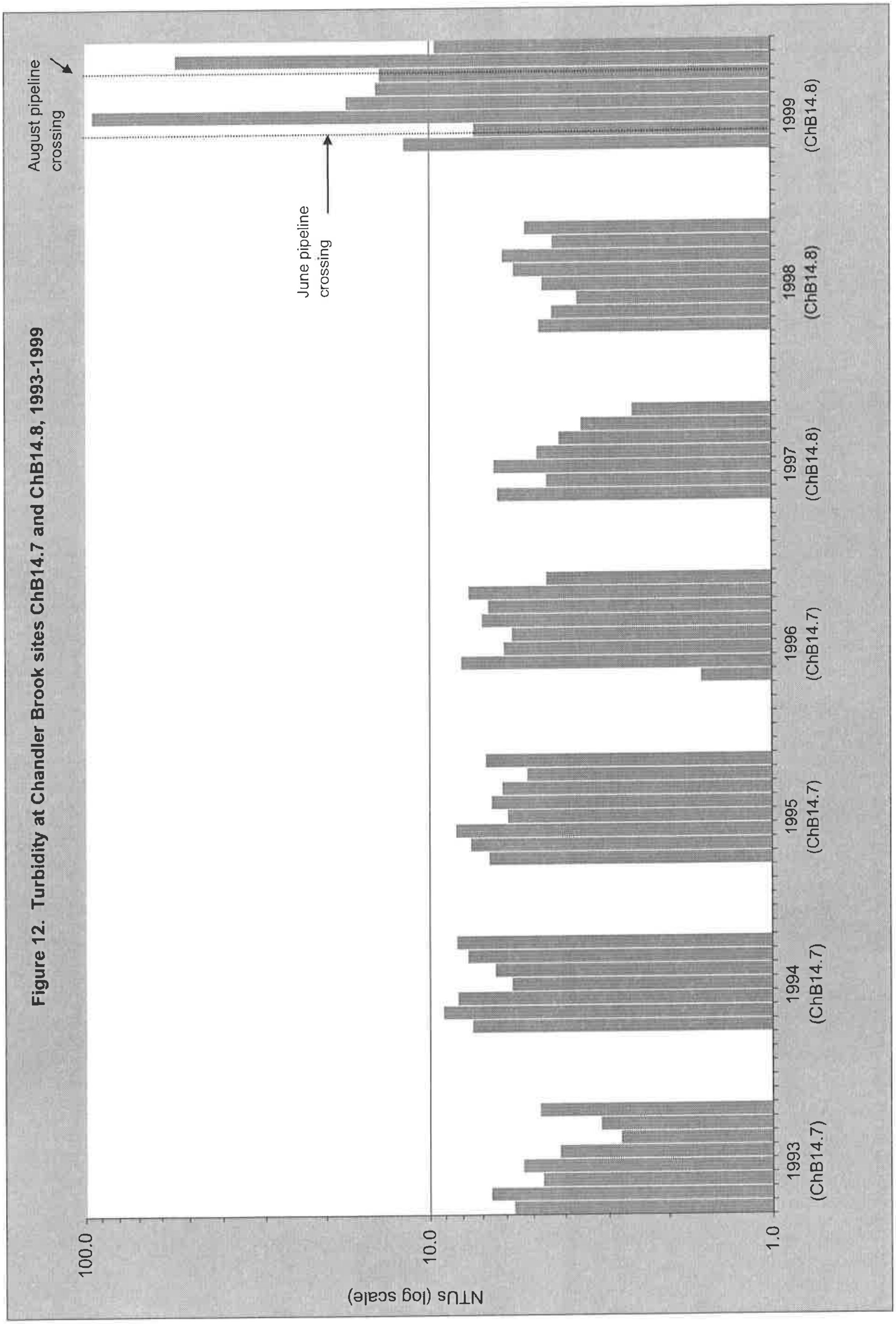
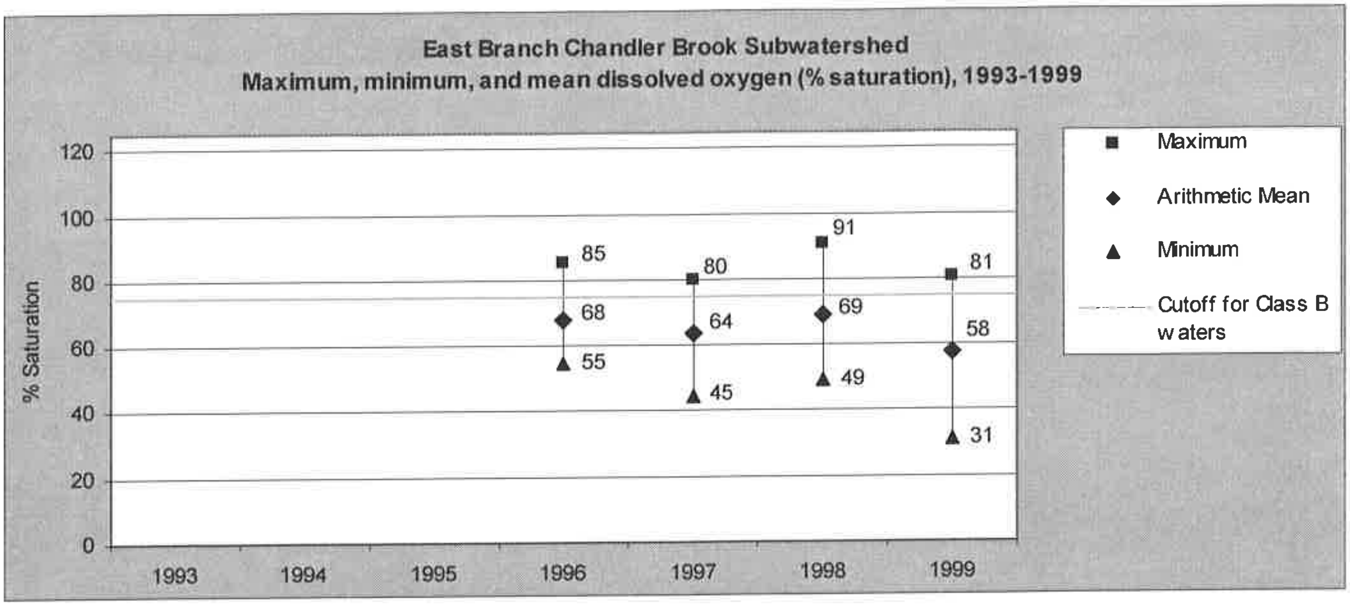
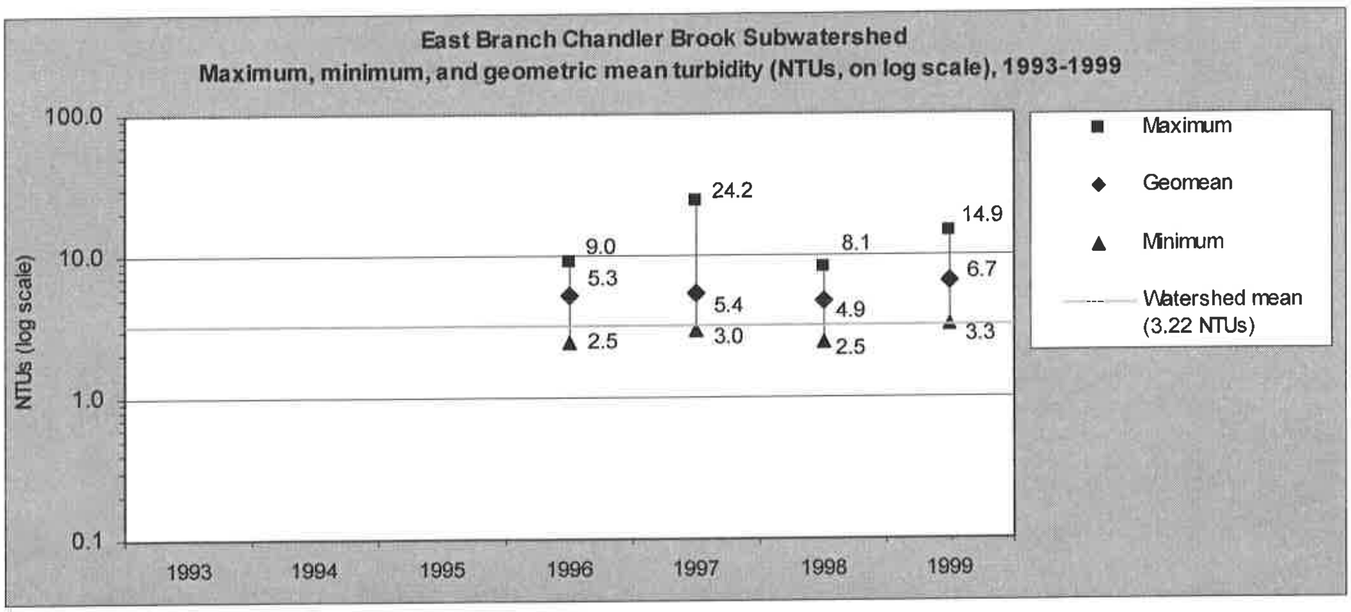
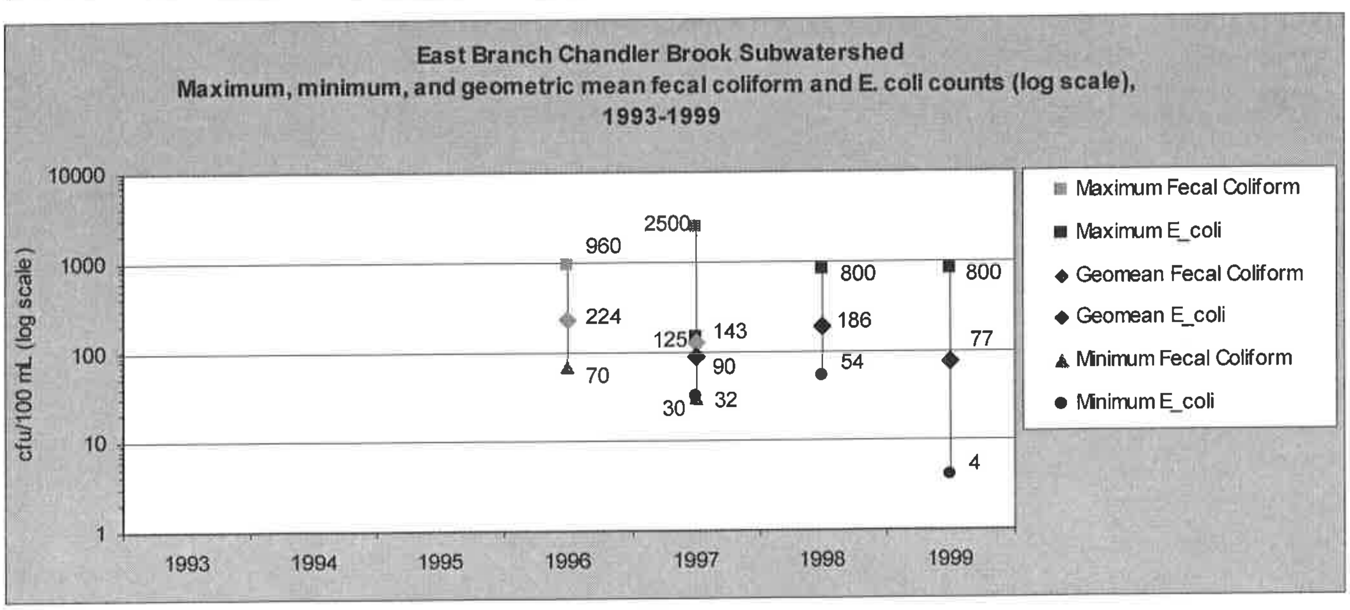


Figure 12. Turbidity at Chandler Brook sites ChB14.7 and ChB14.8, 1993-1999

Figure 13.


East Branch Chandler Brook Subwatershed
Maximum, minimum, and mean dissolved oxygen (% saturation), 1993-1999
% Saturation
120
100
80
60
40
20
0
1993
1994
1995
1996
1997
1998
1999
85
68
55
80
64
45
91
69
49
81
58
31
Maximum
Arithmetic Mean
Minimum
Cutoff for Class B waters


East Branch Chandler Brook Subwatershed
Maximum, minimum, and geometric mean turbidity (NTUs, on log scale), 1993-1999
NTUs (log scale)
100.0
10.0
1.0
0.1
1993
1994
1995
1996
1997
1998
1999
9.0
5.3
2.5
24.2
5.4
3.0
8.1
4.9
2.5
14.9
6.7
3.3
Maximum
Geomean
Minimum
Watershed mean (3.22 NTUs)


East Branch Chandler Brook Subwatershed
Maximum, minimum, and geometric mean fecal coliform and E. coli counts (log scale), 1993-1999
cfu/100 mL (log scale)
10000
1000
100
10
1
1993
1994
1995
1996
1997
1998
1999
960
224
70
2500
125
143
90
30
32
800
186
54
800
77
4
Maximum Fecal Coliform
Maximum E_coli
Geomean Fecal Coliform
Geomean E_coli
Minimum Fecal Coliform
Minimum E_coli

percentage point of the 75 percent standard, while all annual mean concentrations for the other two sites (ThB15.8 and CnB20.4) were below 65 percent.

The results for Site CnB20.4 are of particular concern, because they appear to indicate a trend of increasing impact to the stream. Over the four years that this site was monitored (1996 to 1999), mean oxygen concentrations have decreased while mean *E. coli* counts have increased. Mean *E. coli* counts at CnB20.4 have exceeded the Class B standard for the last two years. This is of particular interest since EBr20.4 is within a few hundred yards of CnB20.4 and the results for DO and *E. coli* appear to be stable at that site. This apparent degradation may be related to land use adjacent to the sites, where cattle have been observed to have unrestricted access to Collins Brook.

6.0 SUMMARY AND CONCLUSIONS

The volunteers of the FORR monitoring program collected seven years of baseline data on the quality of surface waters throughout the Royal River watershed, including samples from up to 28 different sites per year. The program's sampling parameters — DO, turbidity, and bacterial counts — provide a good indication of overall water quality. The monitoring data have been evaluated to assess the current health of the watershed and to identify any significant trends in water quality. The conclusions of this evaluation are summarized below.

- Major portions of the Royal River watershed were generally in compliance with water quality criteria for Class B waters for the parameters tested.
- Water quality varied significantly among the different subwatersheds and the main stem of the Royal River, but most parameters exhibited little change within a subwatershed or over the seven-year monitoring program.
- The main stem of the Royal River generally met the Class B criteria for dissolved oxygen and bacteria counts, but five of its sites intermittently failed to meet the bacteria criteria.
- The Collyer Brook subwatershed had the highest dissolved oxygen levels, most of which were well in compliance with the Class B criteria. However, Collyer Brook also had relatively high bacteria counts, especially in its lower reaches, where the mean annual bacteria count exceeded the Class B criteria for bacteria for at least one of the seven years it was monitored.
- The Chandler Brook subwatershed consistently failed to meet Class B dissolved oxygen criteria, but had consistently low turbidity and bacteria counts. The underlying cause of the low dissolved oxygen was not

determined, but may be due to a combination of low flow/aeration and high levels of suspended and dissolved organic matter.

- The East Branch Chandler Brook subwatershed consistently failed to meet Class B dissolved oxygen criteria, and also had relatively high bacteria counts. However, the relatively small number of sites (3) and duration of monitoring (4 years) for the subwatershed may provide a skewed picture of conditions.

- Site Cn20.4, located in the East Branch Chandler Brook subwatershed, was the only site where trends in the data suggesting possible water quality degradation were apparent. Specifically, a downward dissolved oxygen content and increasing fecal coliform bacteria trends were noted for this site. However, the site was only monitored for four years. A longer period of monitoring would be needed to confirm this trend.

6.1 Summary by Town

Watersheds and subwatersheds do not typically coincide with political boundaries, but individual town, county, state or even federal entities usually make regulations concerning land use. Thus it is important to mention the results of testing done at sites in each town within the Royal River watershed. Table 1 lists the location of each site and the town within which each site is located. The results of this monitoring program by town are summarized below:

Almost all of **New Gloucester** falls within the Royal River watershed. Nine sampling sites were monitored within the town limits. Eddy Brook, where the New Gloucester Fish Hatchery is located, is an exceptional stream. The two sampling sites located on Eddy Brook had very high DO, extremely low turbidity and bacteria for all seven testing years. Some of the main stem sites in New Gloucester had some years with low DO and high bacterial counts as discussed in section 5.2. The sites with the most problems in this town were the ones located on the Moose Brook and Brandy Brook tributaries as discussed in Sections 5.2 and 5.3. It is important to mention that New Gloucester has many smaller tributaries to the Royal River that were not tested and may have some of the same water quality problems as those documented on Moose and Brandy Brooks or, like Eddy Brook, may be in extremely good health and deserve protection. Also, during the 1990s, the Sabbathday Lake Association conducted water quality monitoring of Sabbathday Lake. As a result, remediation projects involving the Cumberland County Soil and Water Conservation District, MEDEP, and the Sabbathday Lake Association have been undertaken to attempt to control soil erosion and pollution from running into the lake. (Driscoll, 2000).

The two sampling sites in **Auburn** were both generally in compliance for all parameters. Although turbidity at RoR30.3 is represented by a red triangle on Figure 7, indicating that 0-7% of years tested were below the watershed median, the geomean turbidity values for this site were consistently low (5.3 and 5.4 NTUs) for the years tested. These values are just slightly above the watershed mean indicating acceptable turbidity. See discussion of turbidity data analysis in Appendix E3.3.

Five sites were tested in **Gray.** Results of testing at RoR14.8 are discussed in section 5.2. The other sites located in Gray are all on tributaries in the Collyer Brook watershed. These sites generally had high DO and low turbidity but CoB16.3, CoB18.3 and LiB19.7 all had at least one year when bacterial counts were out of compliance. Further studies should be conducted to determine the source of the bacteria and measures taken to protect these important tributaries.

Four sites were tested in the town of **Durham**. With the exception of ChB21.1, all of these sites regularly demonstrated DO levels well below the Class B standard as discussed in Section 5.4.

The six sampling sites within **North Yarmouth** generally were in compliance for DO and bacteria with a few exceptions for all years they were tested. Although turbidity at North Yarmouth sites has not been extremely high, the results merit further study in order to effectively implement preventive measures.

There were six sites tested in **Pownal,** all of which have some concerns. The three Chandler Brook sites had lower than desired annual mean DO values as discussed for this subwatershed as a whole in Section 5.4. The other sites in Pownal were the three tested in the East Branch subwatershed and are discussed in Section 5.5. The Collins Brook site is the only site where trends in data suggest possible water quality degradation.

The entire watershed drains through **Yarmouth**, and the readings at the two sites in Yarmouth indicate that the river has good recovery ability. The DO values at the Yarmouth sites are high, although the levels at RoR1.9 are in part due to the aerating effects of local dams and rapids. Bacterial counts and turbidity were generally low. No testing was done by FORR in the estuary below the last set of falls where water quality conditions may be very different.

There were several towns that are partly within the watershed but did not contain testing sites at any time during the monitoring program: **Brunswick, Freeport, Cumberland, Poland and Raymond**. No data were collected by the FORR from sites within these communities.

6.2 Considerations

The results discussed herein reflect only a partial picture of the health of the Royal River watershed. Particularly, the tests done on water samples taken at discrete sites on a given day provide a snapshot of what is going on in selected locations in the watershed at that moment. Nevertheless, the seven years of testing have provided us with sufficient data to conclude that conditions seem to be stable at the sites tested and that some tributaries are in better shape than others are.

This "snapshot" aspect of monitoring documented the impacts of some short-term events. In the summer of 1999, there were high turbidity readings at Chandler Brook, which correlated with the stream crossing dates and consequent disturbance of riverbanks and bottoms by the installation of the Maritimes Northeast pipeline. Likewise, those monitoring dates which closely followed heavy rains did document rises in *E. coli* and turbidity at some sites as would be expected from a surge of storm water runoff flushing sediment and bacteria into streams.

This report is not comprehensive in the sense that satisfactory DO, turbidity and coliform results are not guarantees that the river water is safe in all regards. As mentioned previously, the groundwater discharge of trichloroethylene into the river from the McKin Superfund site is potentially hazardous to human health and a very serious problem that is not reflected in the data presented here.

In a report by the Cumberland County Soil and Water Conservation District in 1998, a map of the Royal River watershed documents wood ash land application sites, surface petroleum spills, sludge land application sites and other potential threats to surface water quality. Tests other than those conducted by the FORR would be necessary to monitor water quality degradation by these potential pollution sources.

The testing program also did not include the Royal River estuary where water quality conditions may be quite different from those seen in the rest of the watershed due to tidal influences and the commercial and recreational uses of the estuary.

While it is reassuring to learn that the Royal River watershed appears to be generally healthy, the increased pressures on it from development and growing population require increased vigilance to protect this valuable resource. Federal assistance is available to communities and individuals through the Environmental Protection Agency and the National Resources Conservation Service. State support is provided through state regulations governing building setbacks and effluent requirements. State assistance is also available from MEDEP's Watershed Unit and the Non-Point Source Training Center. Assistance is also available through soil and water conservation districts, which roughly coincide with county political boundaries, such as the Cumberland County Soil and Water District (CCSWD). Technical assistance is available from any one of these organizations. Towns need to implement and enforce local ordinances and codes to encourage individuals and businesses to preserve their water resources.

All land use decisions come down to the individual level. Citizens need to recognize that decisions such as the choice to litter, to clean up after one's pets, choosing to use fertilizers and pesticides, choosing which products and the amount to use, are all land use decisions with consequences. Agricultural operations must utilize available measures which can minimize the amounts of livestock waste or soil loss via erosion which can contribute to poor water quality in rivers and streams. Many of these measures are low in cost and help to preserve farm resources.

Education at all levels involves citizens in the common ownership and responsibility of caring for the Royal River watershed. Education starts at home, extends through the schools, libraries, and organizations and carries on through the observation and support of other land stewards. The involvement of scouting programs and local naturalist organizations all foster a heightened awareness of our combined impacts.

7.0 RECOMMENDATIONS

Specific recommendations developed from this study of water quality of the Royal River are listed below.

- Conduct watershed surveys in the Chandler Brook and the Collyer Brook areas to determine the specific activities and mechanisms responsible for the low DO and high bacterial counts respectively in those streams.

- Continue water quality monitoring in problem areas to monitor any remediation efforts that result from watershed surveys of Chandler Brook and Collyer Brook areas.

- Incorporate the use of local rainfall gauges to further assess the effects of localized rainfall on stream water turbidity and bacteria counts.

- Expand monitoring on Collins Brook in Pownal above and below the 20.4 site to further document water quality in that tributary and to assess whether there is a trend toward worsening water quality.

- Monitor during storm events to identify problem areas in need of remediation (bank stabilization, planting of vegetated buffer zone etc.).

- Conduct biological monitoring in Chandler and Collyer Brooks. A comparison of the species of macroinvertebrates in the two streams may provide important information on whether the lower DO in Chandler Brook is having an impact on the diversity of organisms living there.

- Conduct planned periodic watershed-wide water quality monitoring to look for unrecognized water degradation.

- Support periodic inventories of macroinvertebrate populations and game fish species in the tributaries to document overall watershed health.

- Support water quality monitoring in the estuary in cooperation with the Friends of Casco Bay water quality monitoring program.

- Continue citizen and municipal involvement with the ongoing remediation of the McKin Superfund Site.

- Establish and maintain vegetative buffer strips along waterways to minimize erosion and provide shade.

- Evaluate and where necessary, improve maintenance of road crossings to reduce soil erosion into streams.

- Encourage town-, county-, and/or state-led demonstration projects of the use of best management practices in new stream crossings or repairs.

- Encourage municipal officials, especially Planning Board, Code Enforcement Officers, and Public Works Directors to take advantage of training available on soil and water conservation, to enforce local soil and water-related ordinances, and to use the CCSWCD Urban Conservation Review Program. (The Urban Conservation Review Program ensures that erosion and sedimentation control plans are reviewed and approved by the District's engineer prior to issuance of final permits.)

- Encourage active participation of conservation commissions, schools, and private groups in the education of the public in ways to protect streams.

- Encourage local communities to have riverside property set aside through protected land trusts.

- Promote to private landowners, agricultural producers, and businesses the technical assistance and incentives available for soil and water conservation.

- Facilitate public purchase of land easements adjacent to waterways to permanently safeguard those properties from potentially damaging development while simultaneously providing increased recreational opportunities for citizens.

- Actively solicit municipalities to develop a comprehensive watershed management plan.

Grant funding is available to support many of these efforts. For further information, contact:

Friends of the Royal River
P.O. Box 90
Yarmouth, ME 04097

This complete report is also located on the Friends of the Royal River website at:

www.cascobay.com/royal/royal.htm

All data gathered through this water quality monitoring program, including some data that are not included in this report, are available online through this website.

Riverside Farm in North Yarmouth from the bank of the river in winter

Appendix A

WATER CLASSIFICATION PROGRAM

Department of Environmental Protection State of Maine Article 4-A

§ 465. Standards for classification of fresh surface waters

The department shall have 4 standards for the classification of fresh surface waters which are not classified as great ponds.

Class AA waters. Class AA shall be the highest classification and shall be applied to waters which are outstanding natural resources and which should be preserved because of their ecological, social, scenic or recreational importance.

Class AA waters shall be such quality that they are suitable for the designated uses of drinking water after disinfecting, fishing, recreation in and on the water and navigation and as habitat for fish and other aquatic life. The habitat shall be characterized as free flowing and natural.

The aquatic life, dissolved oxygen and bacteria content of Class AA waters shall be as naturally occurs.

There shall be no direct discharge of pollutants to Class AA waters.

Class A waters. Class A shall be the 2nd highest classification.

Class A waters shall be of such quality that they are suitable for the designated uses of drinking water after disinfection, fishing, recreation in and on the water, industrial process and cooling water supply, hydroelectric power generation, except as prohibited under Title 12, Section 403, and navigation, and as habitat for fish and other aquatic life. The habitat shall be characterized as natural.

The dissolved oxygen content of Class A waters shall be not less than 7 parts per million or 75% of saturation, whichever is higher. The aquatic life and bacteria content of Class A waters shall be as naturally occurs.

Direct discharges to these waters licensed after January 1, 1986, are permitted only if, in addition to satisfying all the requirements of this article, the discharged effluent will be equal to or better than the existing water quality of the receiving waters. Prior to issuing a discharge license, the department shall require the applicant to objectively demonstrate to the department's satisfaction that the discharge is necessary and that there are no other reasonable alternatives available. Discharges into waters of this classification licensed prior to January 1, 1986, are allowed to continue only until practical alternatives exist. There may be no deposits of any material on the banks of these waters in any manner so that transfer of pollutants into the waters is likely.

Class B waters. Class B shall be the 3rd highest classification.

Class B waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment, fishing, recreation in and on the water, industrial process and cooling water supply, hydroelectric power generation, except as prohibited under Title 12, section 403, and navigation, and as habitat for fish and other aquatic life. The habitat shall be characterized as unimpaired.

The dissolved oxygen content of Class B waters shall be not less than 7 parts per million or 75% of saturation, whichever is higher, except that for the period from October 1st to May 14th, in order to ensure spawning and egg incubation of indigenous fish species, the 7-day mean dissolved oxygen concentration shall not be less that 9.5 parts per million and the 1-day minimum dissolved oxygen concentration shall not be less than 8.0 parts per million in identified fish spawning areas. Between May 15th and September 30th, the number of *Escherichia coli* bacteria of human origin in these waters may not exceed a geometric mean of 64 per 100 milliliters or an instantaneous level of 427 per 100 milliliters.

Discharges to Class B waters shall not cause adverse impact to aquatic life in that the receiving waters shall be of sufficient quality to support all aquatic species indigenous to the receiving water without detrimental changes in the resident biological community.

Class C waters. Class C shall be the 4th highest classification.

Class C waters shall be of such quality that they are suitable for the designated uses of drinking water supply after treatment, fishing, recreation in and on the water, industrial process and cooling water supply, hydroelectric power generation, except as prohibited under Title 12, section 403, and navigation, and as a habitat for fish and other aquatic life.

The dissolved oxygen content of Class C water may be not less than 5 parts per million or 60% of saturation, whichever is higher, except that in identified salmonid spawning areas where water quality is sufficient to ensure spawning , egg incubation and survival of early life stages, that water quality sufficient for these purposes must be maintained. Between May 15th and September 30th, the number of *Escherichia coli* bacteria of human origin in these waters may not exceed a geometric mean of 142 per 100 milliliters or an instantaneous level of 949per 100 milliliters. The board shall promulgate rules governing the procedure for designation of spawning areas. Those rules must include provision for periodic review of designated spawning areas and consultation with affected persons prior to designation of a stretch of water as a spawning area.

Discharges to Class C waters may cause some changes to aquatic life, provided that the receiving waters shall be of sufficient quality to support all species of fish indigenous to the receiving waters and maintain the structure and function of the resident biological community.

Appendix B - Funding Organizations

We are very grateful for the generous support from the following organizations without which this work could not have been accomplished.

BellAtlantic

Casco Bay Estuary Project

Davis Foundation of Maine

Maine Coastal Program, Maine State Planning Office

New England Grassroots Environment Fund

Patagonia

University of Maine Cooperative Extension

Appendix C - Volunteers

John Ackerman Jane Arbuckle Jim Attianese Jim Barker Jake Barker Alison Barker Anita Bernhardt ** Gil Birney ** David Bright Leonard Brooks Chris Buerkett Pat Christian Ray Clark Tom Connelly ** Dawna Coutant Avajit Dasgupta Binty Dasgupta Priya Dasgupta Caly Doran Linda Doran Samantha Dufresne Ngoc Duong Nghi Duong Judith Eycleshymer Dan Emery ** Program Director '93 Lynn Espy Fred Fellers Alex Finamore Pam Fischer Jackie Fournier Michelle Gurney Patrick Gwinn Phoebe Hardesty Bob Harradon ** Eric Holman David Holman Mary Holman ** Program Director '94-'99 Bob Houston ** Peter Ingraham Patti Janums	Tony Kariotis Carrie Kivela Jessica Kolda Nat Langer John Langlois Mary Larlee – Lab Coordinator '97-'99 Ron Letorneau Sherry Lewis Abbie Lumsden Mike Lyons Wells Lyons John MacKinnon ** Bruce MacNeill Karen Massey Bob Moore ** Rosita Moore Don Northrop Mary Northrup Gay Peterson Marilyn Porcaro Jennifer Pucci Sam Ristich Toby Schneider George Schneider Carl Shaw Deb Storey Greg Thaler Ted Tiedemann Jeff Tindall Dana Trask Barbara Trentacosta David Valyou Steve Walbridge ** Brian Whitney** Upper Watershed Coordinator Sheryl Wilkinson ** Wes Willink ** Kathy Wyatt David Zarinfar

**Special thanks to volunteers who have worked with the program for 5 years or more!

Appendix D - Quality Control and Quality Assurance

D.1 Training of Volunteers

Volunteers were provided with both written and personal instruction on the correct procedures for collecting surface water samples. All volunteers were supplied with a copy of the Friends of the Royal River Monitoring Program Field Water Sampling Manual for Volunteers. This manual was prepared by Geoff Dates of Riverwatch Network (Dates,'93) at the beginning of the program and was updated as needed. The manual outlines the expectations of the program, and includes detailed descriptions of each collection procedure. It was very important that all volunteers were collecting their samples in the same way so that the measurements of samples from one site could reliably be compared to measurements of samples from another site and to samples collected over the entire time period of the monitoring program. The Field Sampling Manual included sections on: preparation prior to sampling day, what to do before going to the first site, what to do at the site, how to collect water samples in Whirl-pak water sample bags, and how to collect and "fix" (or preserve) dissolved oxygen water samples in BOD bottles.

As part of the personal instruction, volunteers were interviewed to verify that they were able to conduct sampling at a specific site by the specified time (by 8 a.m. on the collection date). Volunteers either visited sites with the program coordinator or received detailed maps indicating easily identifiable roadside sampling sites. In addition, all volunteers attended a riverside training demonstration of techniques for sample collection, sample preservation and air and water temperature measurements. Hands-on training included collection and chemical preservation of samples of water in BOD bottles for determination of dissolved oxygen content, and the technique of reliably collecting water samples in sterile Whirl-pak bags for bacterial and turbidity determinations. Finally, volunteers were instructed on the preparation of Water Collection Field Data Sheets, which served as both a sample chain-of-custody and a field observation note sheet.

D.2 Sample Collection Technique Assurance

All samples were transported to Yarmouth High School by 9 a.m., either by the sample collector or by a designated volunteer courier, and time of arrival was noted. After collection, it was important that all samples were kept chilled and in the dark. A lab volunteer checked incoming samples.

The following criteria had to be met for samples to be accepted for testing:

- dissolved oxygen sample bottles were completely full without obvious trapped air bubbles,
- Water Collection Field Data Sheets were appropriately completed,
- samples had been transported on ice and in the dark,
- all sample containers were properly labeled.

If any of the above could not be verified, the samples were not tested.

D.3 Laboratory Procedures

All lab volunteers were trained by one of two laboratory coordinators in laboratory protocol for DO and turbidity. Each received copies of the Friends of the Royal River Laboratory Protocol Manuals for Dissolved Oxygen (Riverwatch, '95) and Turbidity (Riverwatch,'93), prepared by Geoff Dates of Riverwatch Network. A laboratory coordinator was present during all testing sessions.

DO was analyzed using the Hach Azide Modification Winkler Method with a digital titrator and an 0.2N $Na_2S_2O_3$ cartridge(Hach, '99) Each analytical run included a control saturated sample prepared the previous day. Reagents and technique were considered acceptable if the control was within 0.5mg/L of the expected value for a saturated sample collected at that sample's temperature at the time of the addition of chemicals to "fix" the sample. Field collected water temperatures were used to determine percent saturation of each sample using a standard chart of maximum dissolved oxygen concentration at specific water temperatures by degree provided by Riverwatch Network, Inc. Although DO results are presented as percent saturation in this report, please note that all water temperature and mg/L DO data are available on the Friends of the Royal River Website www.cascobay.com/royal/royal.htm.

Turbidity measurements were taken with a Hach 2100P Turbidimeter (Hach.'99). The turbidimeter was recalibrated before each testing season using dilutions of a 4000 NTU formazin standard. Three standard gel turbidity controls were read before each run of samples. Values were acceptable if within 5% of the NTU readings after the last calibration of the machine. Sample turbidity was determined as the average of two replicate readings after gently mixing the contents of the Whirl-pak surface water sample.

Fecal coliform counts were performed at the Town of Yarmouth, ME Waste Water Department Laboratory 1993-1997 using a standard protocol (Clesceri,9-). *E. coli* counts were performed at Wright-Pierce Engineers, Topsham, ME 1997-1999 using an USEPA approved method (USEPA,'86). All samples for bacterial counts were stored on ice and arrived at testing labs before 11 a.m. of the day collected. Constant chain-of-custody was documented.

D.4 Laboratory Data Validation

Two volunteers checked all of the arithmetic used in calculating final test results for each test completed on each sample. Transcription of water temperatures from Field Collection Data Sheets for determination of percent DO saturation were also checked by two volunteers. All data were completely verified by two volunteers after entry into computer spreadsheets and were again checked after migration into a Microsoft Access database. Once validated and in the database, data were analyzed for their usability for interpretation. Then, as described in Appendix E, data queries were constructed to create tables and graphs for interpretive purposes.

Appendix E - Data Analysis

This appendix summarizes the types and results of analyses that were applied to determine the usability of the data presented in the results and conclusion sections of the report. In addition, the data were evaluated in terms of their distribution characteristics, which determined the type of statistics applied to the data for further analyses of overall water quality. The following discusses the results of the data validation, the effect of modifications to analytical or sampling procedures during the seven year sampling period, and the determination of distribution of the data for each parameter.

E.1 Modification of Sampling and/or Analytical Measurements

Throughout the seven years of watershed monitoring, sampling and analysis of dissolved oxygen has remained consistent with respect to the sampling procedure and analytical method employed, so data are readily comparable from station to station (spatially) and from sampling event to sampling event (temporally). Therefore, the dissolved oxygen levels from different locations and/or time periods are easily compared to determine and evaluate differences or similarities in the data.

Similarly, the sampling and analysis methods for turbidity have remained constant for all sampling stations over the course of the seven-year watershed sampling program. Therefore, the turbidity data are also spatially and temporally comparable.

Unlike the previous two water quality parameters, measurements for bacteria were modified over the course of the seven-year watershed sampling program. At the outset of the watershed-monitoring program in 1993, water samples were collected for measurement of fecal coliform, the subgroup of coliform bacteria present in the gut and feces of warm-blooded animals. This testing was provided free of charge to FORR by the Yarmouth Maine Water Pollution Control Facility.

In July 1997, the FORR water quality program was successful in obtaining funding to cover the cost of having the samples tested for *E coli* by Wright Pierce Engineering in Topsham, Maine. *E.coli* is a type of fecal coliform bacteria. The change was made because the state of Maine uses *E. coli* as the indicator species for bacterial determinations in fresh waters. Measurements of *E. coli* were made from July 1997 through the end of 1999. Although fecal coliform measurements were discontinued after 1997, concurrent measurements of fecal coliform and *E. coli* were made by collecting duplicate whirlpaks at each sampling site for the five sampling days from July 23, 1997 to the end of September 1997.

Because the fecal coliform and *E. coli* measurements are not identical (*E.coli* is a subset of fecal coliform), direct comparison of these data may not be appropriate.

To determine if we could correlate the fecal coliform data with *the E. coli* data, the concurrent measurements from July to September 1997 (92 samples) were compared. This comparison indicated that there was not a significant difference between the fecal coliform and the *E. coli* populations measured at the same location at the same time. Because there was not a significant difference between the two types of bacterial measurements, they were assumed to be spatially and temporally comparable. However, it should be noted that although this comparison seemed to be appropriate for the concurrent data collected in 1997, it may not necessarily be so for other sampling times (i.e., pre-1997).

E.2 Data Distributions

Generally, environmental data follow two types of distributions, the normal and log-normal distribution. A normal distribution is typified by the bell-shaped curve where the mean and median of the data are equal and the distribution has equal tails at either end. For normal distributions the correct statistical measure of the average is the arithmetic mean.

A log-normal distribution is one where a preponderance of the data is weighted to an extreme (usually the low end), and is often truncated at the low end due to the inability to detect levels as they approach and go below the analytical detection limit. In the case of the log-normal distribution, the mean and the median are not equivalent. The correct statistical measure of the average in a log-normal distribution is the geometric mean.

The data sets for each water quality parameter were tested to determine the type of distribution that best represented the measured data. This analysis was performed so that the correct statistical measures could be used in summarizing, presenting and analyzing the data.

The dissolved oxygen, turbidity, and bacteria data were fitted to the appropriate distribution by creating a histogram of each data set, and visually evaluating the histogram with respect to a normal distribution. If the histogram appeared normally distributed, the data were tested using the Shapiro-Wilk W-test for normality (Gilbert, 1987). If the histogram did not appear normally distributed, the data were log-transformed and a histogram of the log-transformed data was analyzed. Similarly, the log-transformed data were tested for normality using the W-test.

This analysis showed that data for dissolved oxygen were normally distributed. The data for both turbidity and bacteria were lognormally distributed. These results were used to direct the analysis and interpretation of the data in subsequent sections.

E.3 Data Preparation

E.3.1 Data Queries

The data from 1999 were entered directly into a Microsoft Access database, prior years had been previously entered into Excel spreadsheets and were imported into Access. Data were validated against both Excel and field sheets, and a number of data-checking queries were written to validate data entry and manual calculations.

Over ninety database queries were written to import, verify, and analyze the data. Some of the queries that were conducted to analyze data are summarized below, the results are discussed in Section 5.

To quickly evaluate the water quality at each testing site year by year, the arithmetic or geometric means, maximum and minimum values, and number of observations were sorted from high to low, for each parameter (turbidity, dissolved oxygen, and bacteria).

Often, turbidity levels are positively correlated with water borne bacteria levels; as turbidity increases, bacterial levels increase. This phenomenon is typically due to the fact that surface runoff carries both suspended solids (silt, clay, and organic matter) as well as bacteria, so when it rains both the turbidity and the bacteria levels rise. To determine if a relationship between bacteria and turbidity exists for the Royal River watershed, *E. coli* and fecal coliform observations for all sites and dates were compared to the corresponding turbidity observation.

As mentioned in Section 2.0, the dissolved oxygen content of surface water is temperature dependent. Typically, the temperature of the water and air are coolest in the early morning hours (6-7 AM), and increase as the day progresses. Therefore, if a dissolved oxygen sample was collected from one station at 6 a.m. and from another station at 9 a.m., at least part of the difference in the dissolved oxygen content may be due to temperature changes that occurred during the 3 hour lag time between the sampling events. To assess whether variations in dissolved oxygen from site to site were due to differing sampling times, an analysis was conducted to evaluate the presence of a relationship between testing time and dissolved oxygen. In this analysis, the average, earliest, and latest testing time for each site, per year, were listed, alongside the mean dissolved oxygen measurement. A visual comparison was made to determine whether a relationship could be determined.

E.3.2 Outside Data Considered in the Study

Flow data for the Yarmouth gaging station on the Royal River are available on the Internet,
(http://waterdata.usgs.gov/nwisw/ME/data.components/hist.cgi?statnum=01060000).

Flow data were plotted against the minimum, maximum, and geometric mean of all turbidity and E. coli measurements for sampling dates in 1997 and 1998.

An examination of the data for a relationship between rainfall and turbidity and/or *E.coli* counts was also made. For this analysis relevant precipitation data was sought on the Internet, and was available from the National Oceanographic and Atmospheric Administration (NOAA) for the Portland International Jetport. However, during much of the sampling season, local water levels are often influenced by small to medium-sized storm systems which drop precipitation on all or only part of the watershed but no precipitation falls at the Portland Jetport (or vise versa). Therefore, this station was considered too far from the Royal River watershed to allow for a meaningful comparison.

E.3.3 Data Calculation

E. coli measurements of TNTC (too numerous to count) were entered into the database as 800, since the lab's upper detection limit of 80 cfu and the dilution factor of 10 meant that highest reliable count would be 800 cfu although the actual cfu might have been higher. There were no fecal coliform measurements of TNTC because multiple dilutions of river water were used to arrive at a final number of cfus.

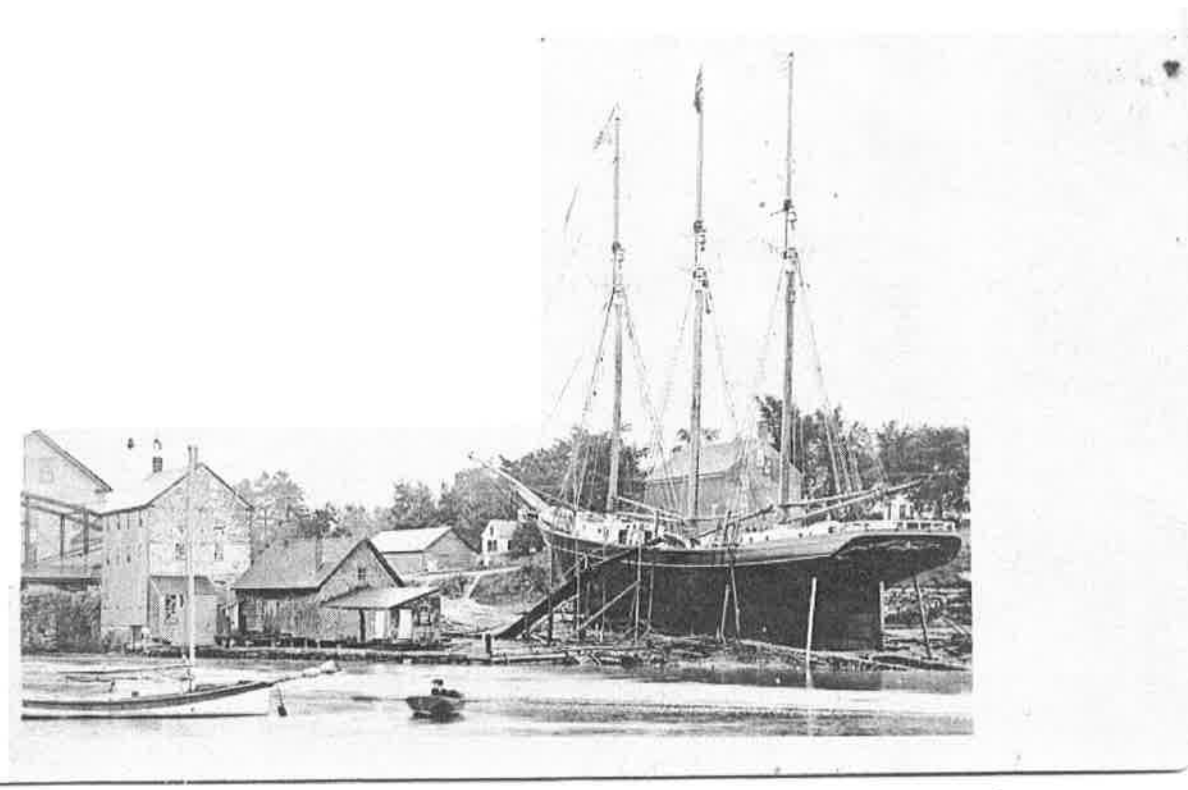
Geometric means were calculated for the *E. coli* data. However, several *E. coli* results were reported as zero because no bacterial colonies grew from the water sample. These data were changed from zero to one in order to calculate the geometric mean, since the calculation of a geometric mean cannot be done with values of zero. Changing the zero *E. coli* values from zero to one does not have a significant impact on the data, and thus, does not significantly effect its analysis.

Geometric means were calculated for the turdibity data. Since there is no criterion for turbidity in Maine waters, we decided to use the seven-year watershed geometric mean for a comparison level. By definition of a mean, some of the values would fall above that number and that alone does not mean the turbidity of the water sample was particularly high but merely higher than the watershed's geometric mean for seven years of testing.

Medians and geometric means were calculated via a Visual Basic program interface with Excel, since Access had no corresponding aggregate functions for those calculations.

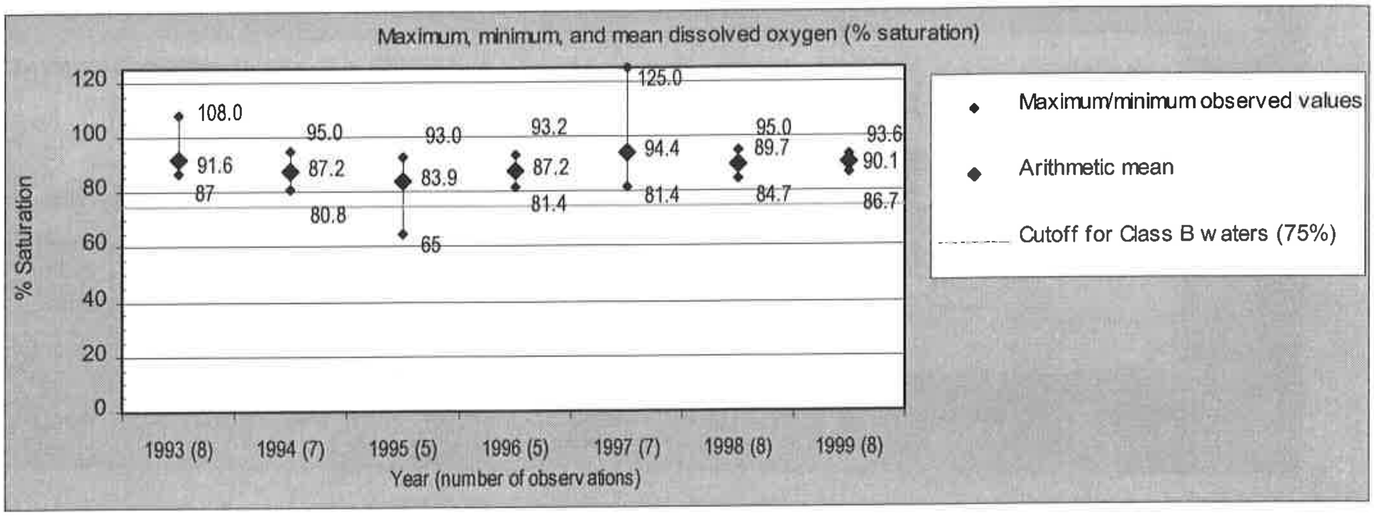
Appendix F

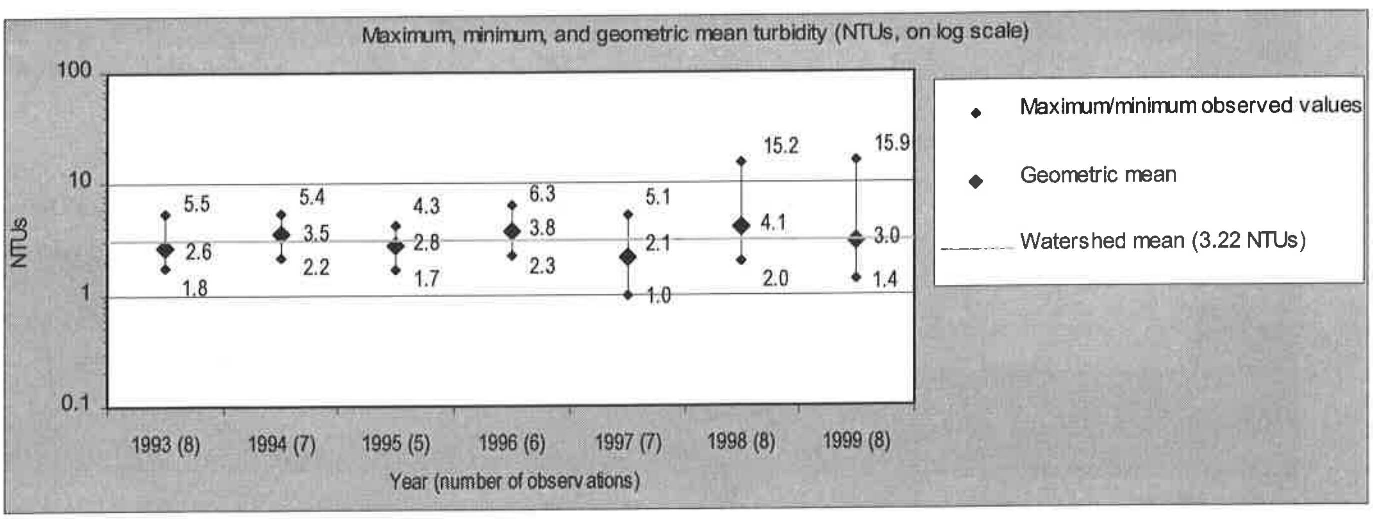
Monitoring Sites in the Main Stem of the Royal River Subwatershed

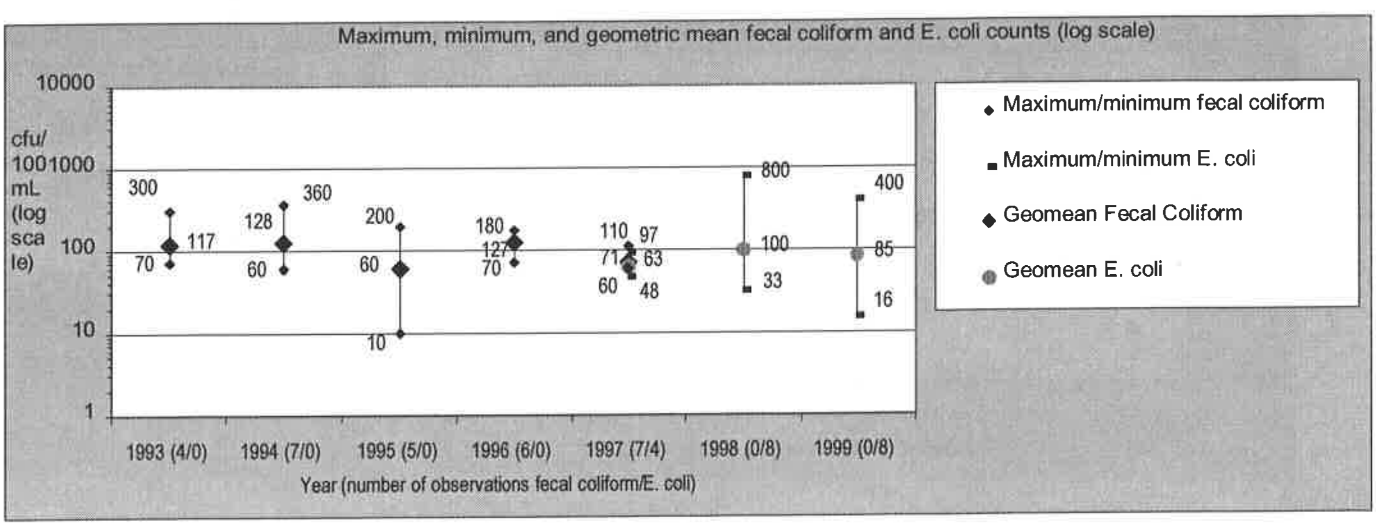


Royal River scene circa 1800s. Postcard provided by the Yarmouth Historical Society

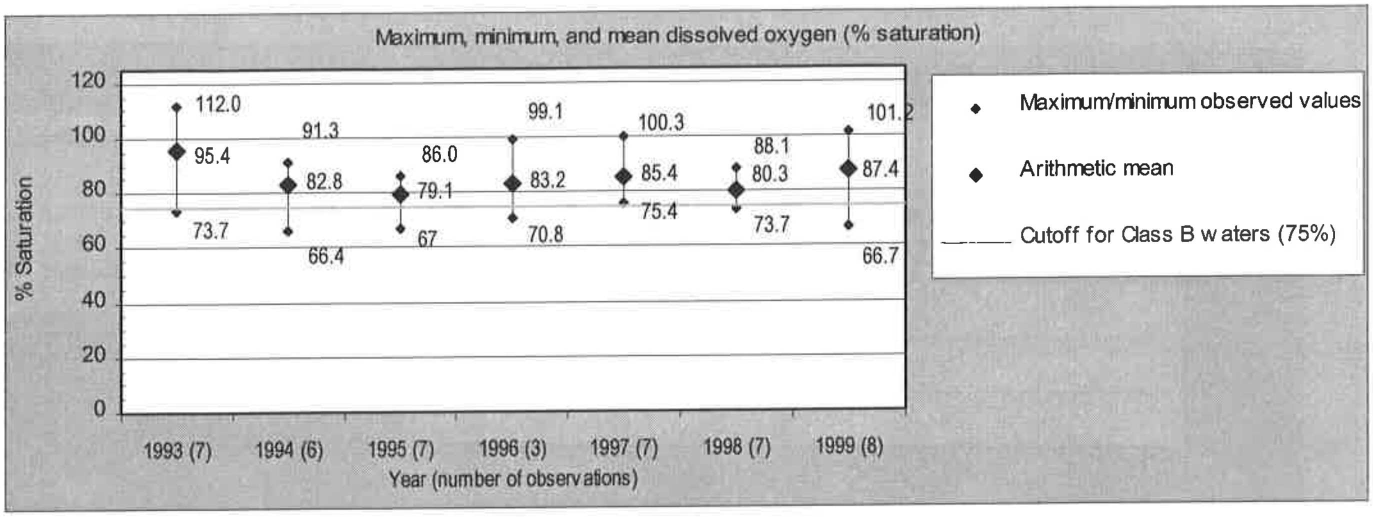
Site RoR1.9 (Royal River, in Royal River Subwatershed)

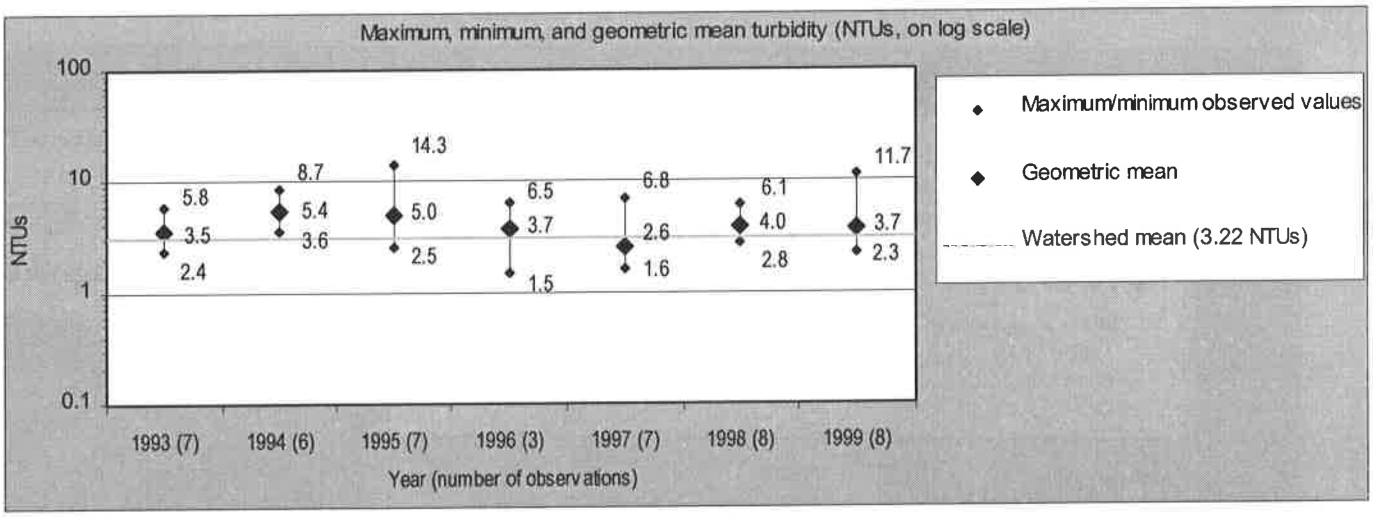


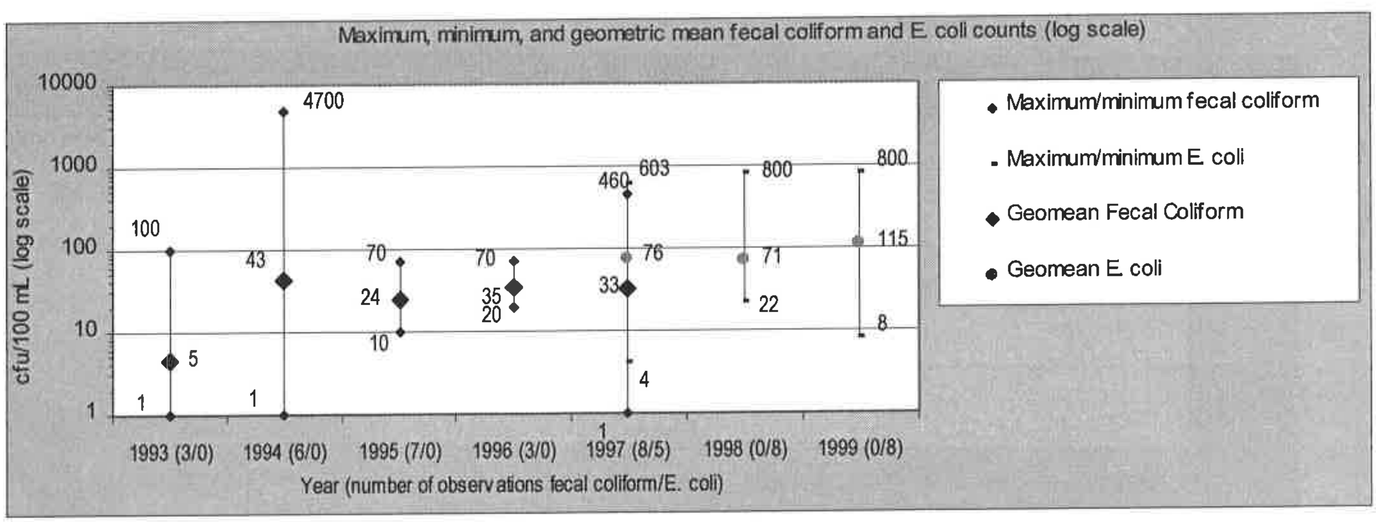




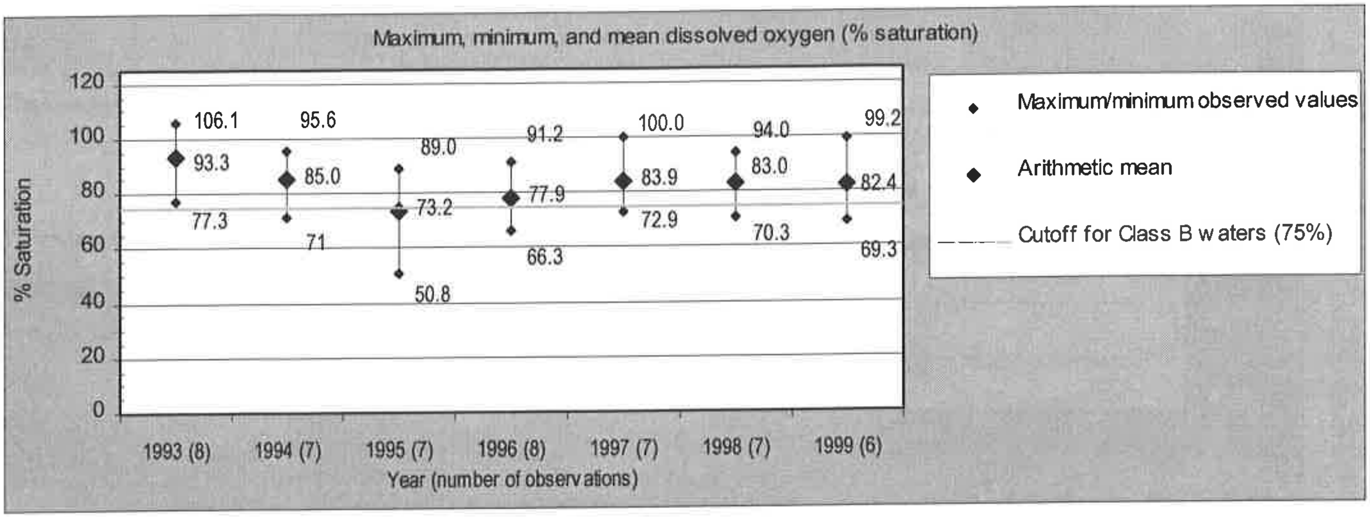
Site RoR2.9 (Royal River, in Royal River Subwatershed)

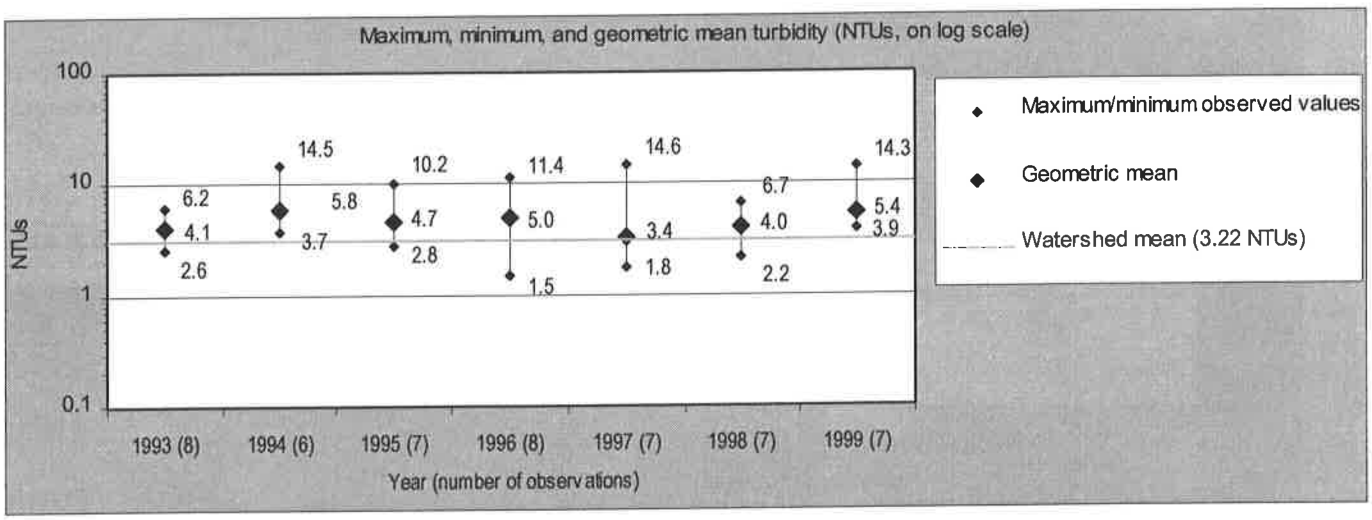


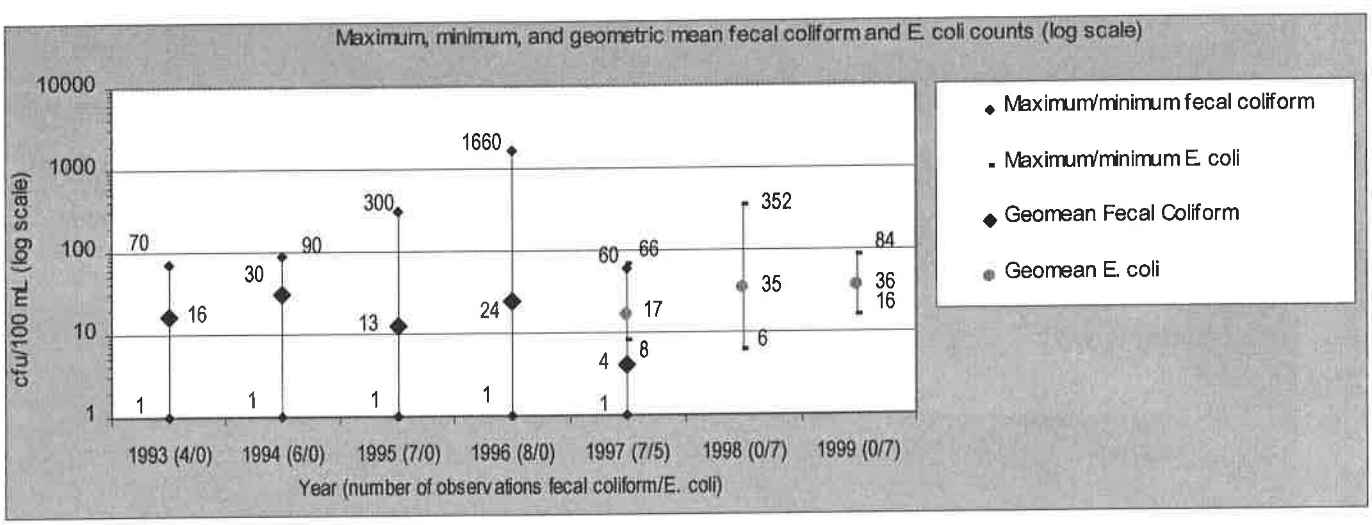




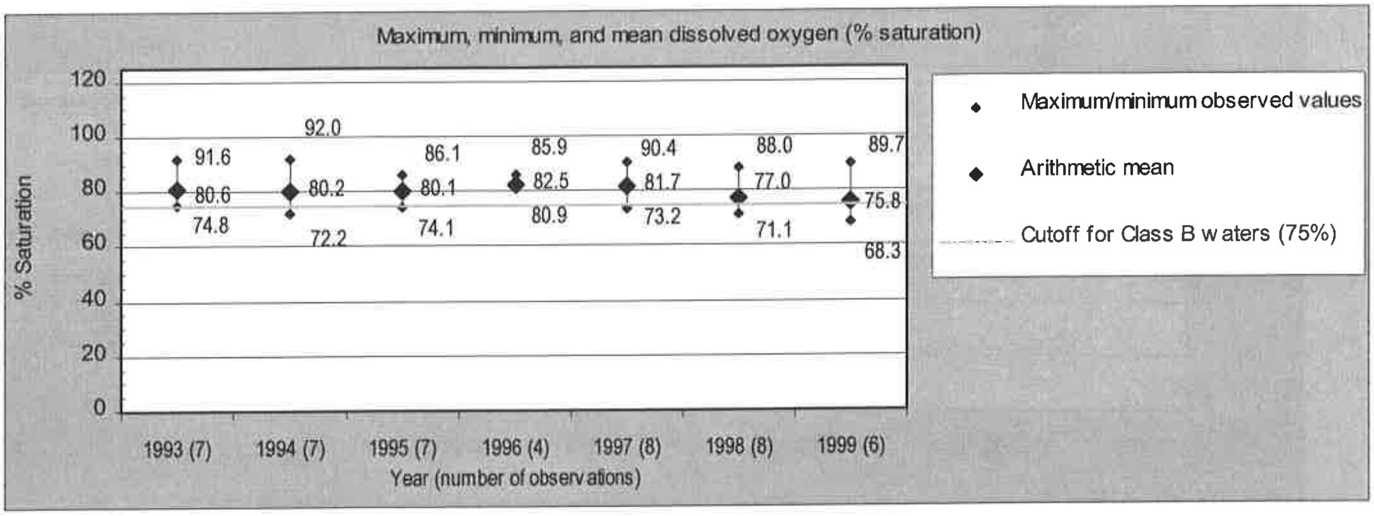
Site RoR5.3 (Royal River, in Royal River Subwatershed)

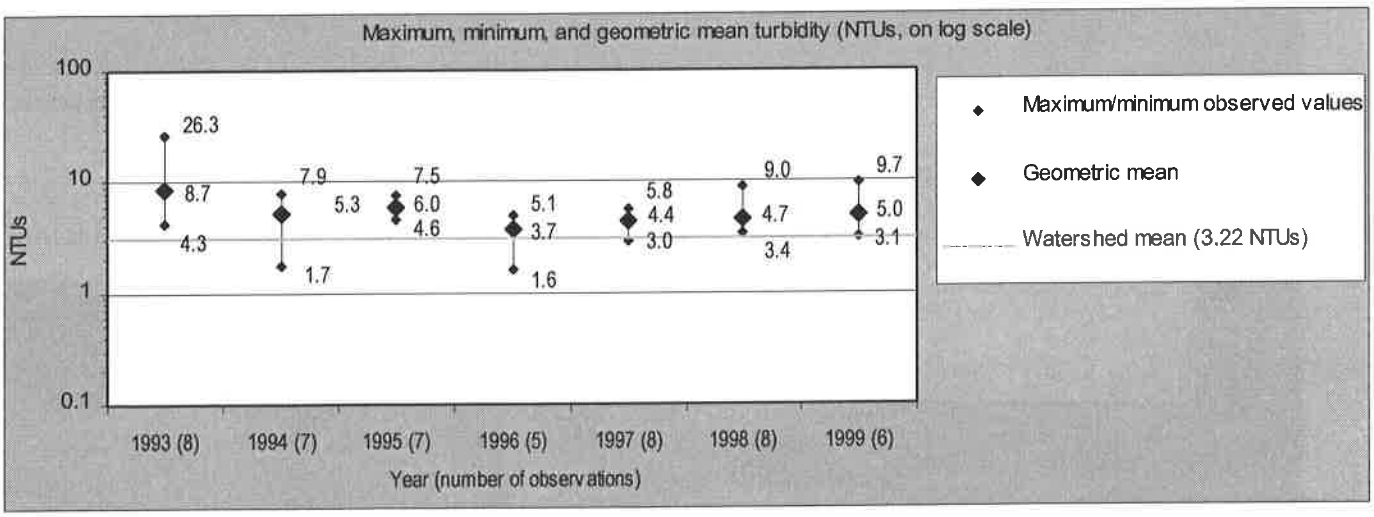


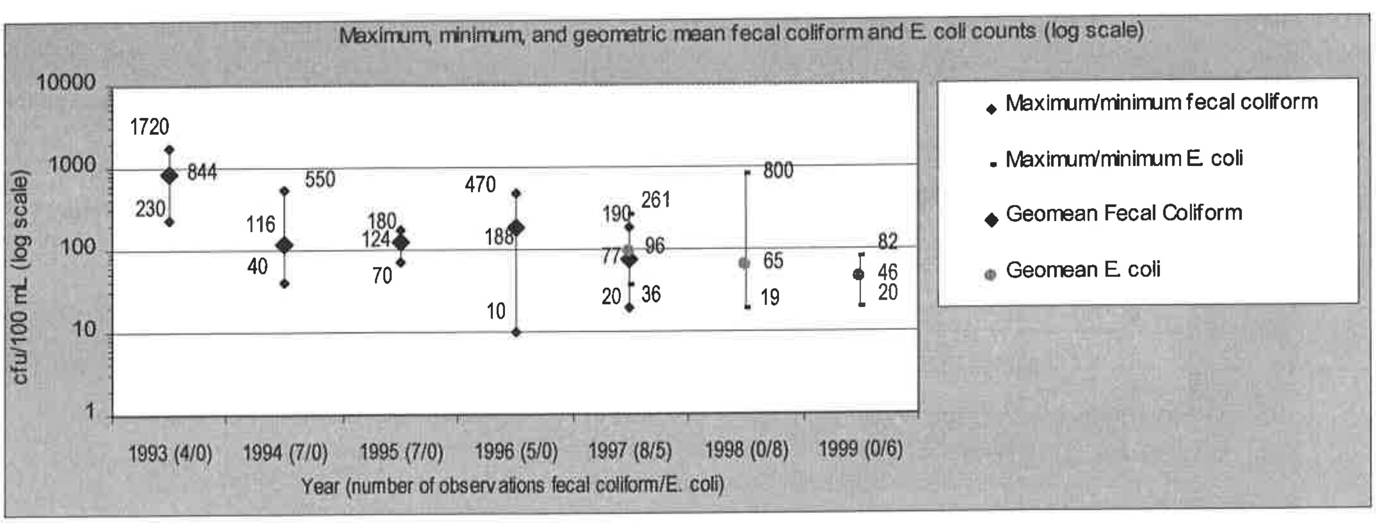




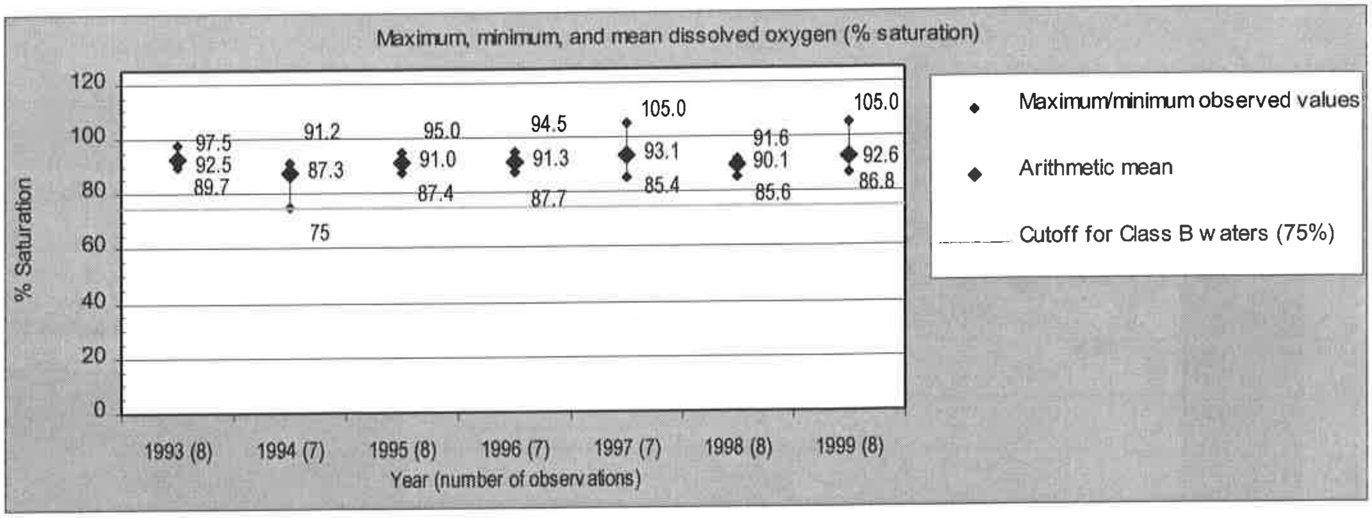
Site RoR7.3 (Royal River, in Royal River Subwatershed)

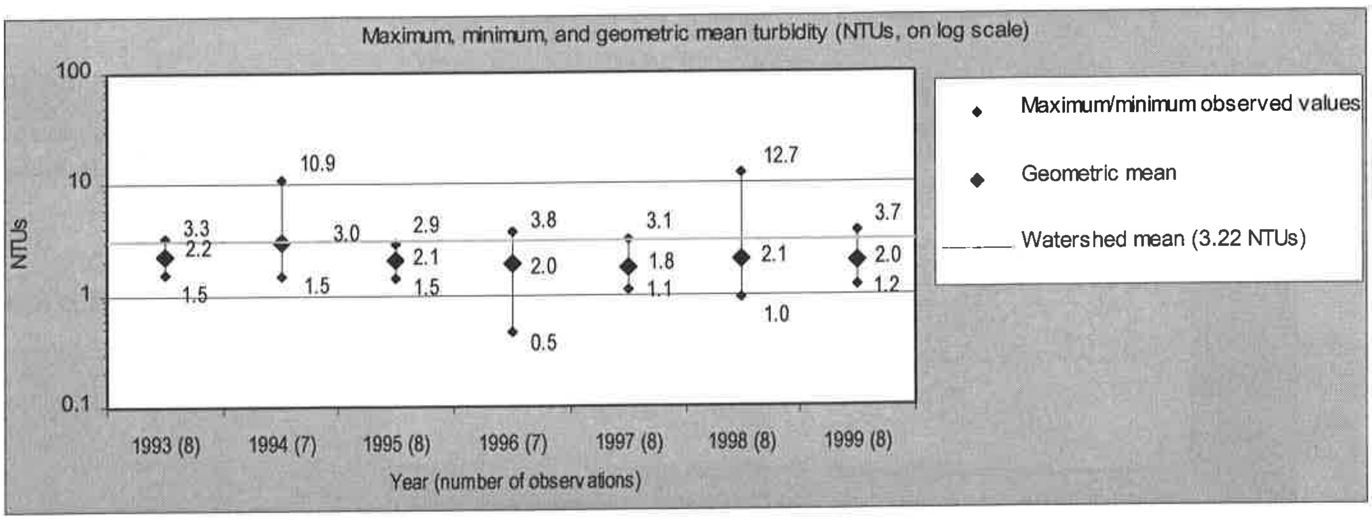


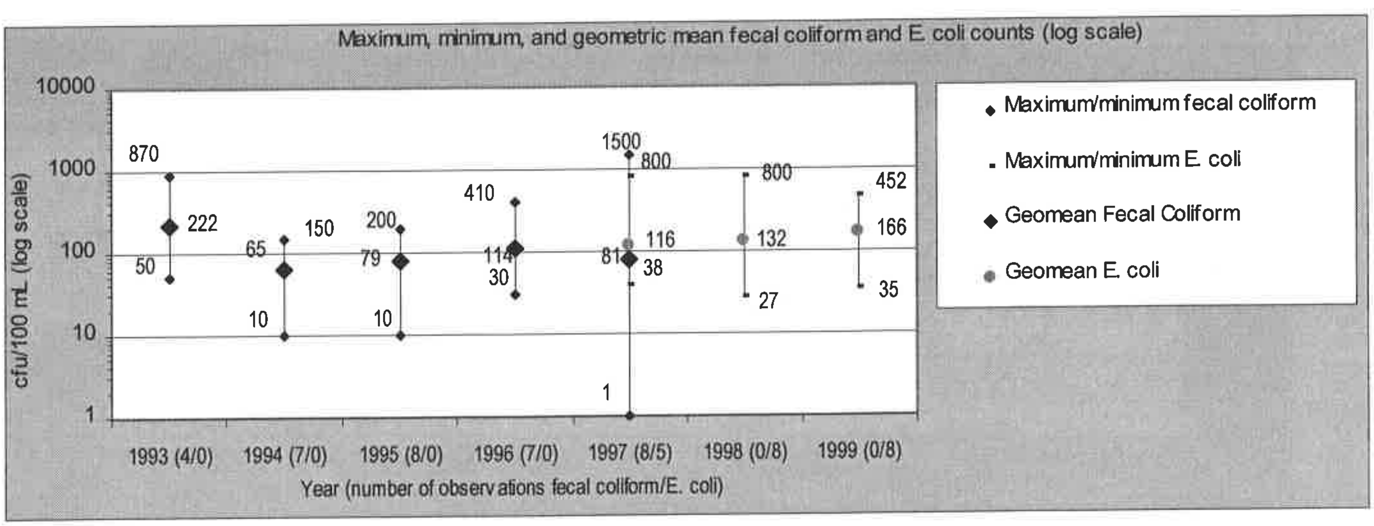




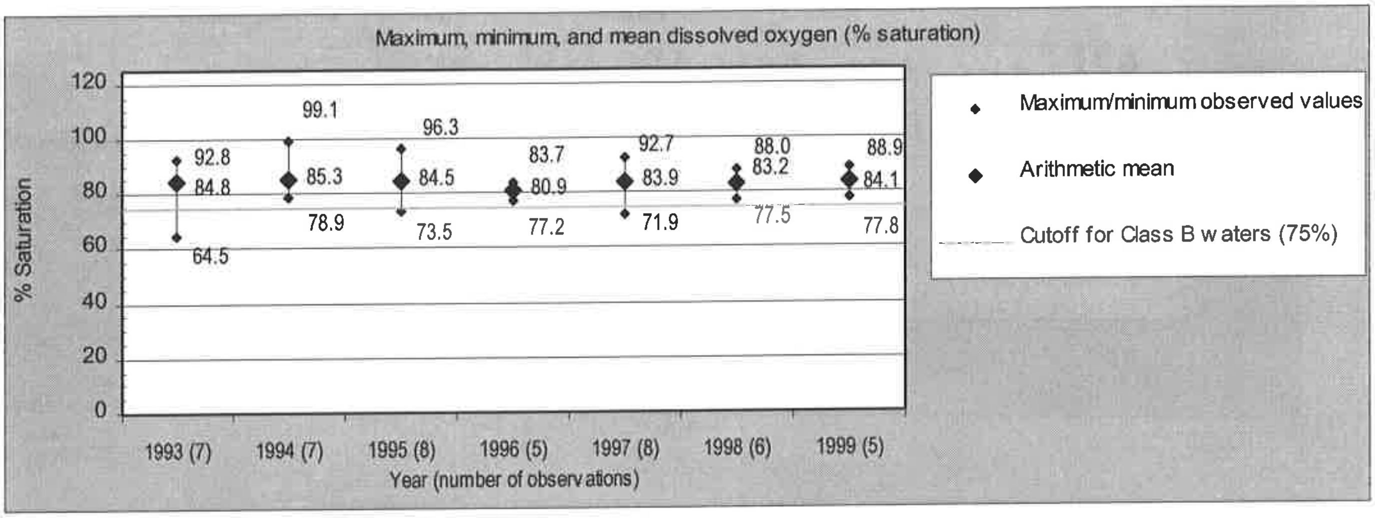
Site ToB8.0 (Toddy Brook, in Royal River Subwatershed)

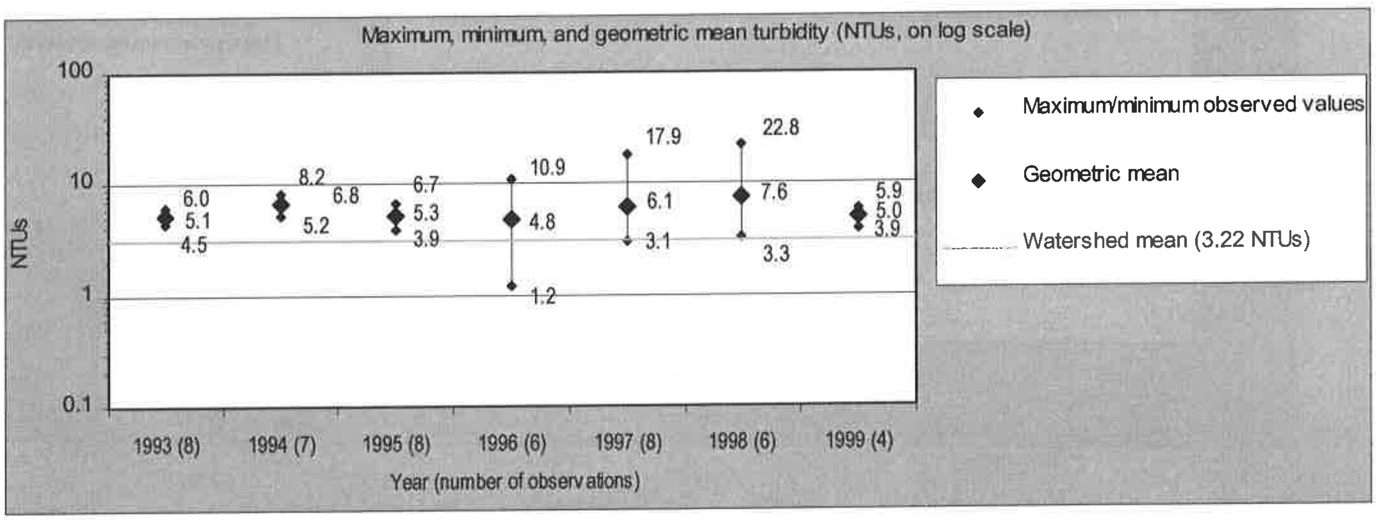


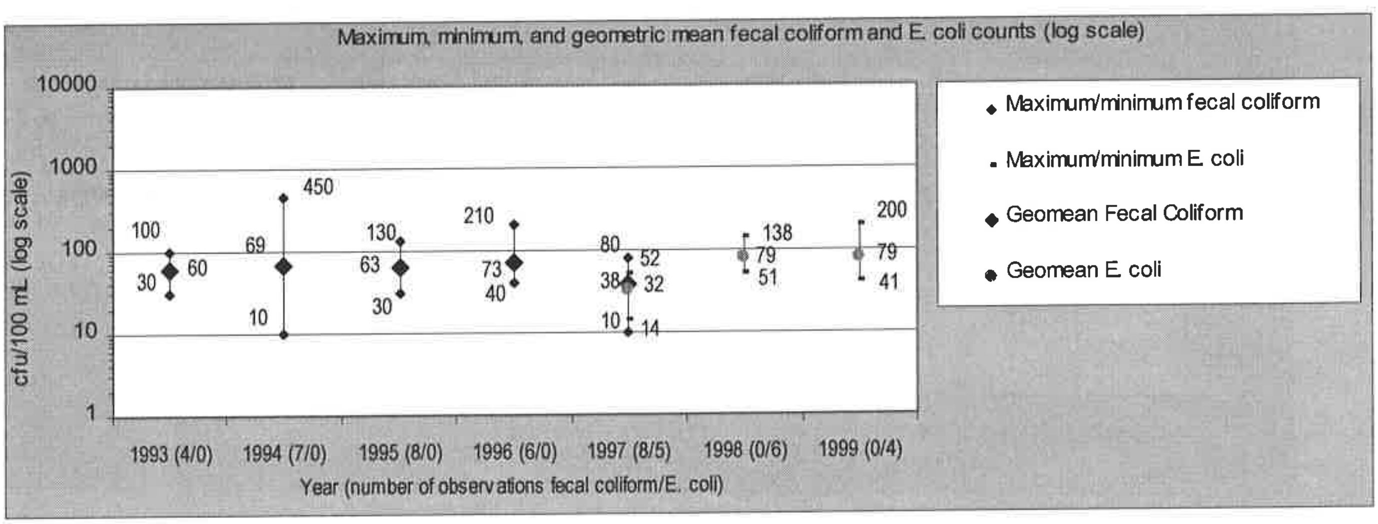




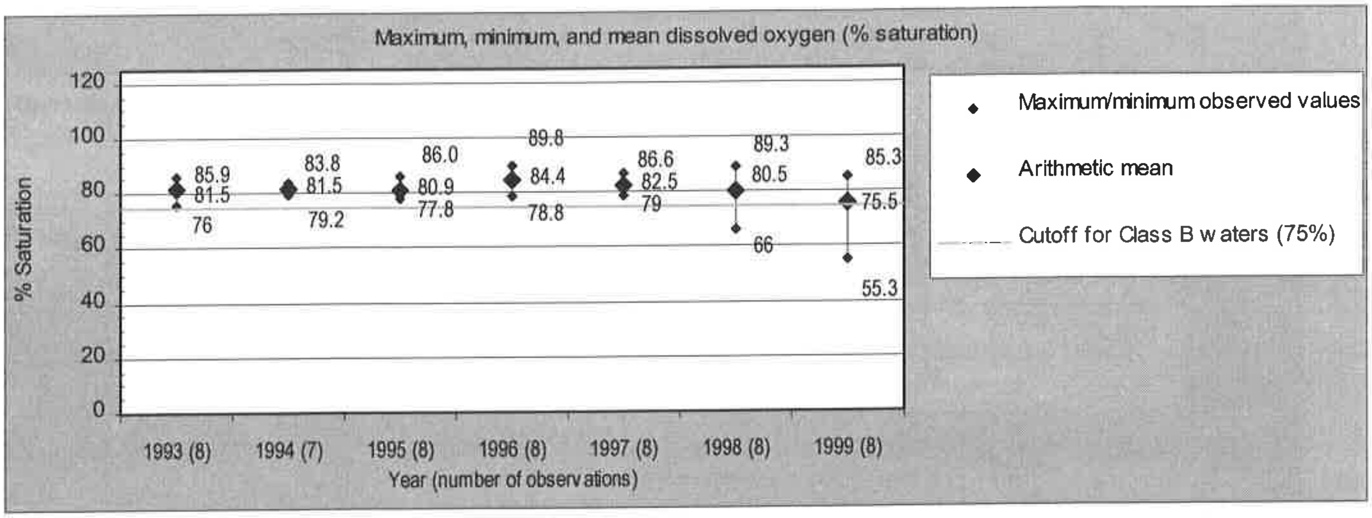
Site RoR8.6 (Royal River, in Royal River Subwatershed)

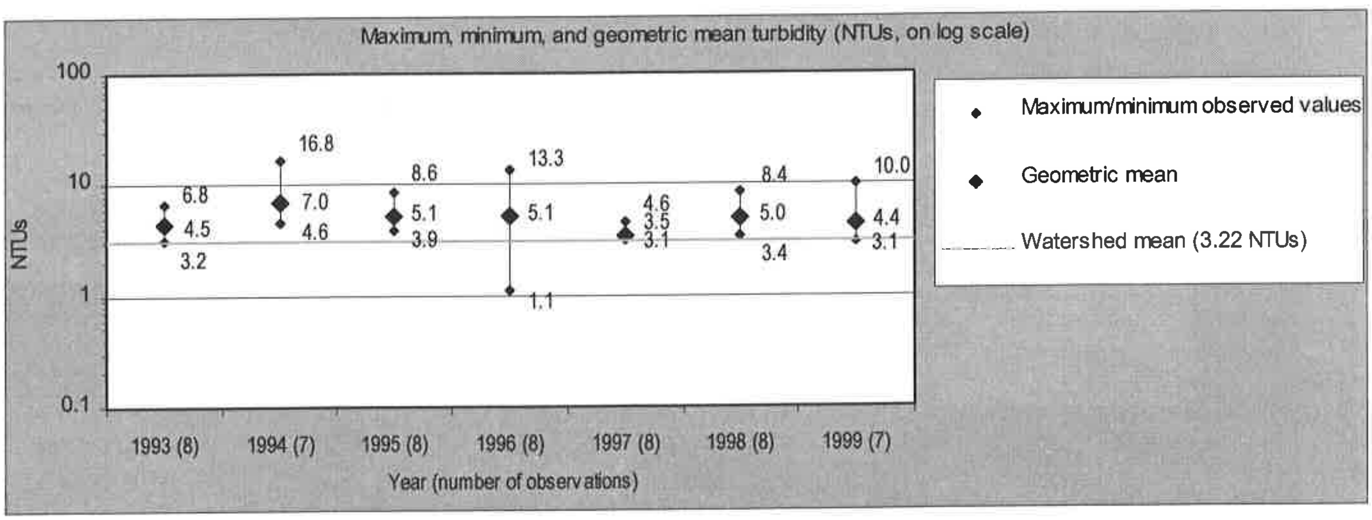


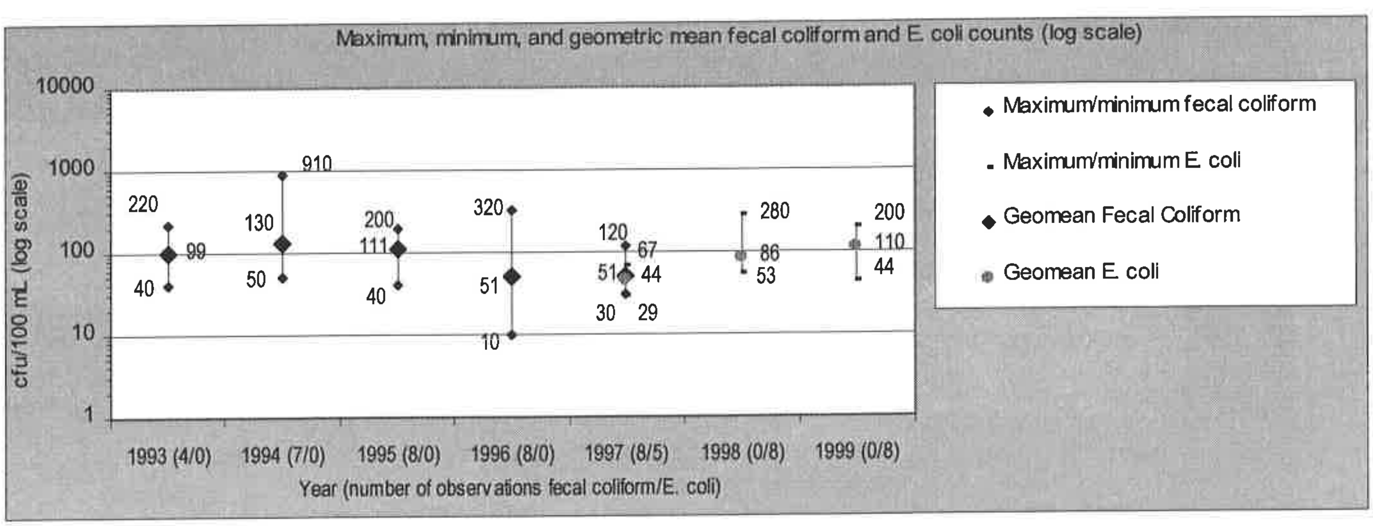




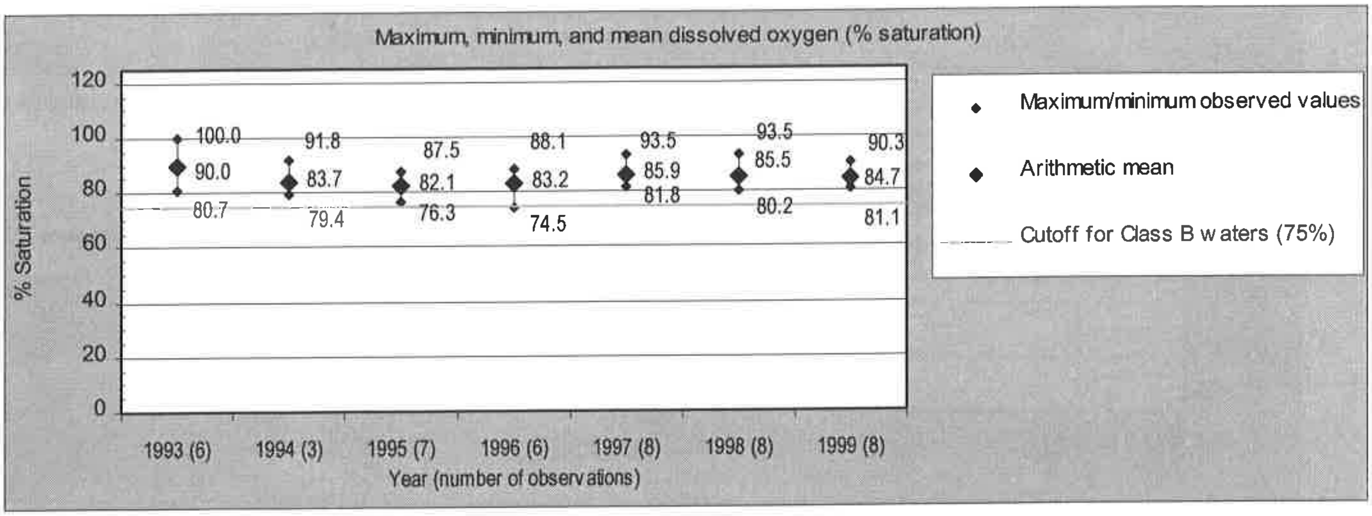
Site RoR12.1 (Royal River, in Royal River Subwatershed)

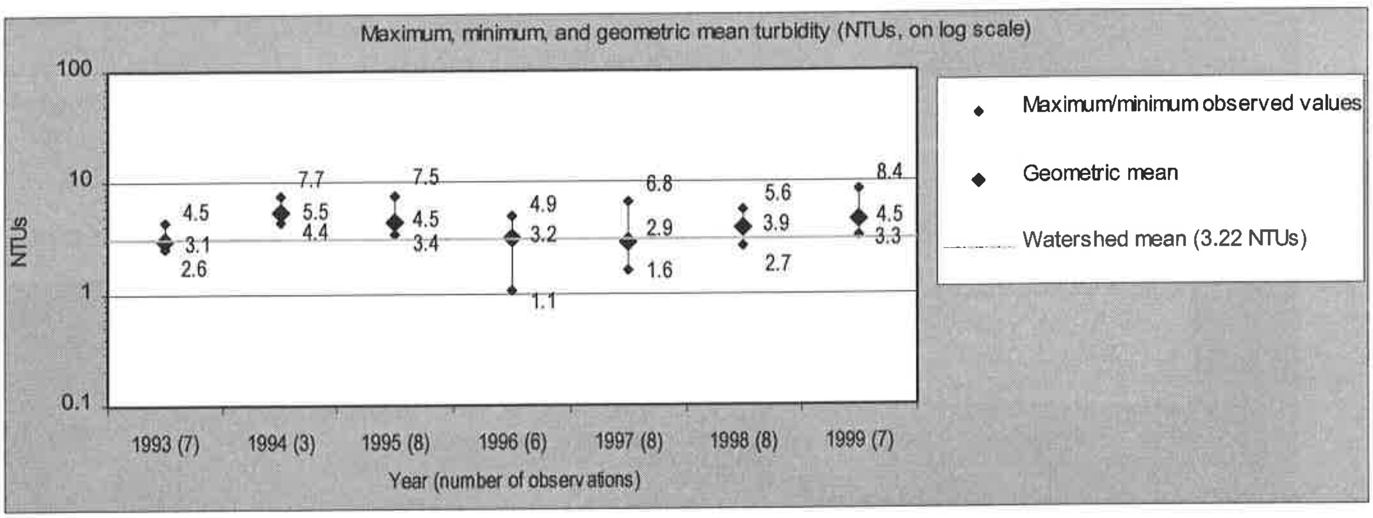


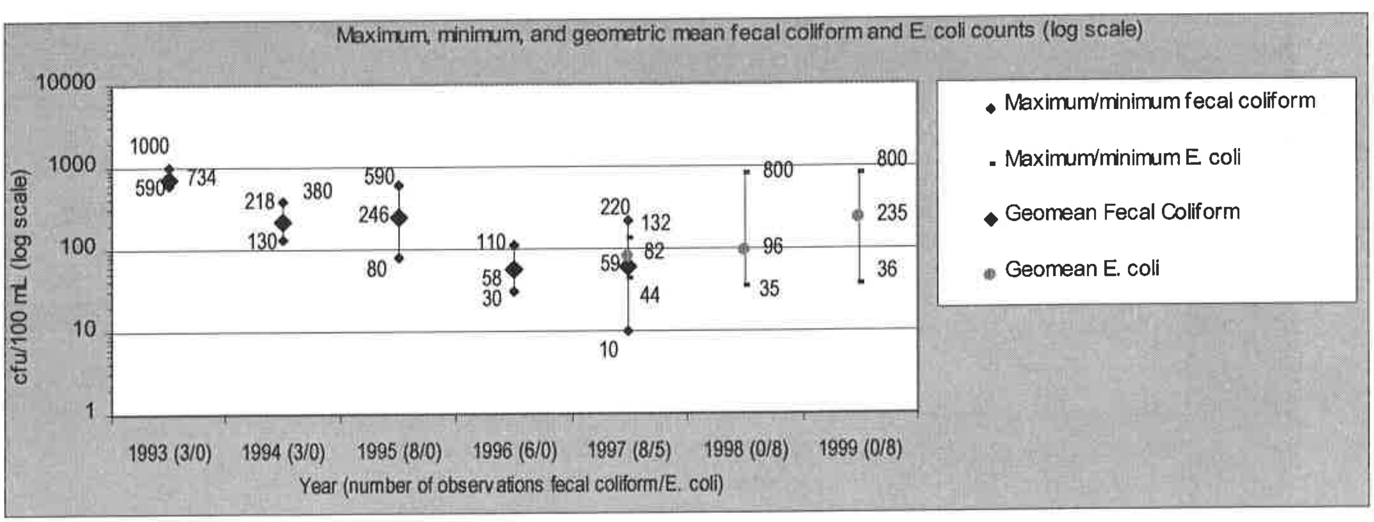




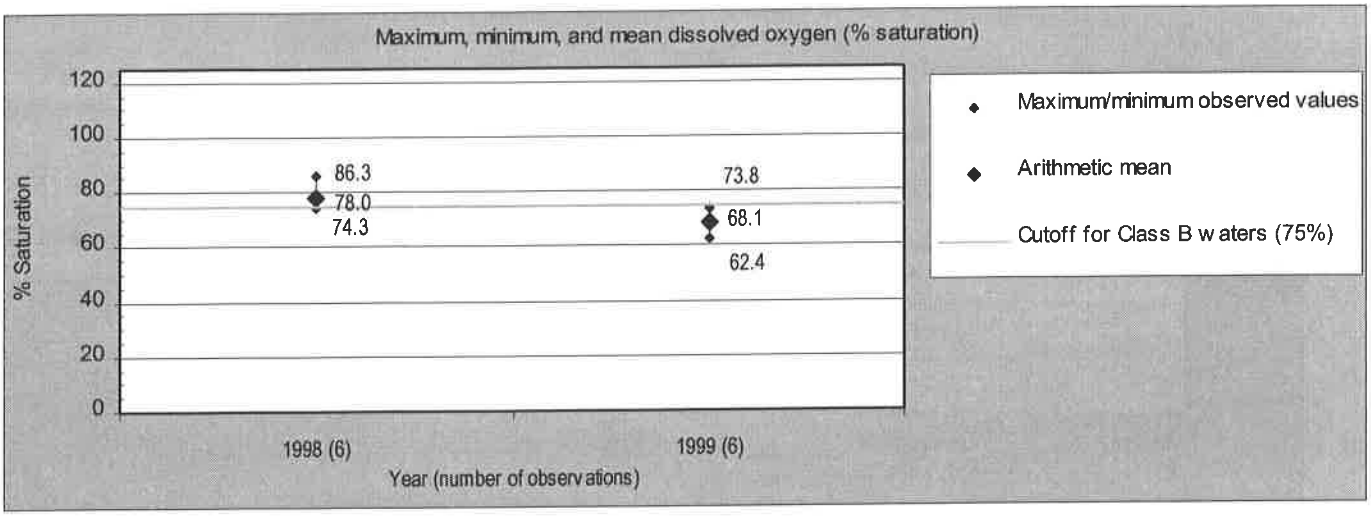
Site RoR14.8 (Royal River, in Royal River Subwatershed)

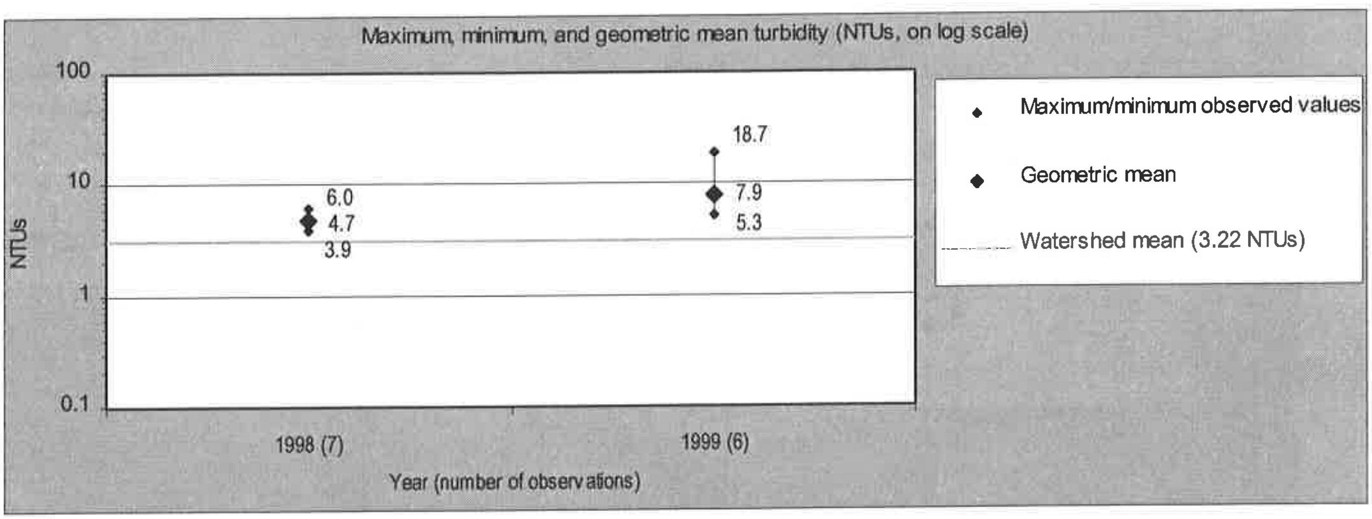


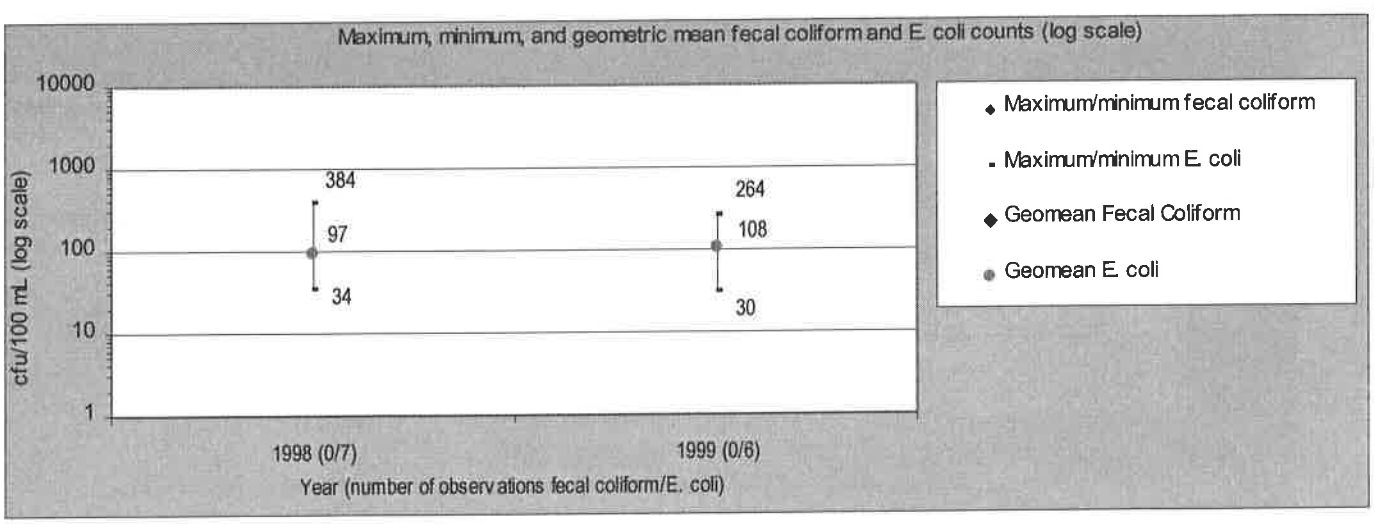




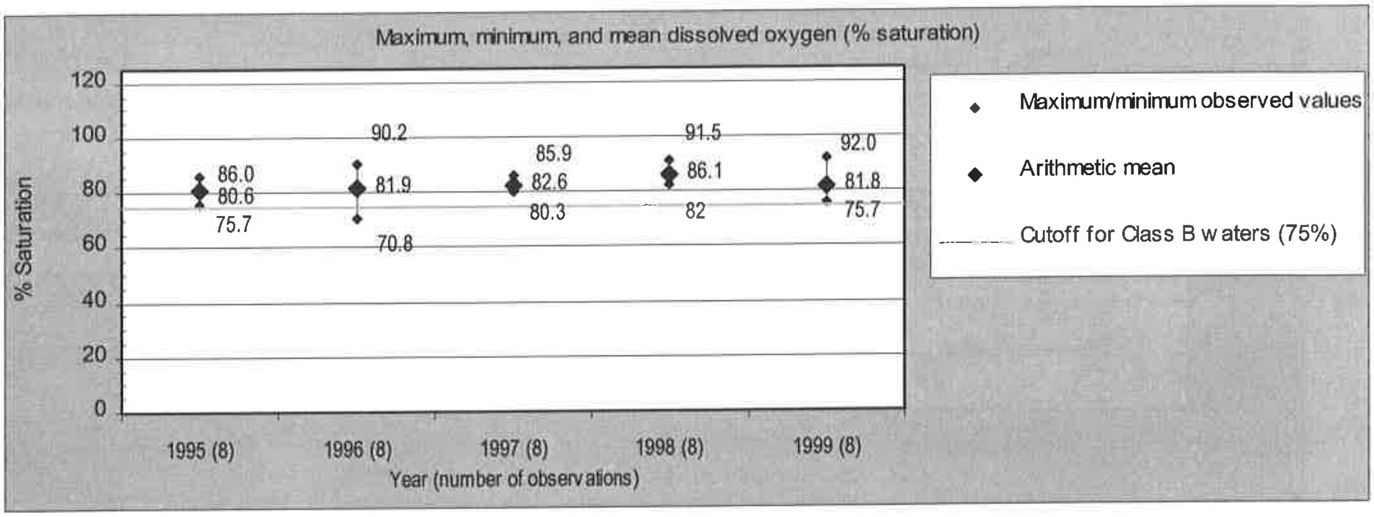
Site RoR18.4 (Royal River, in Royal River Subwatershed)

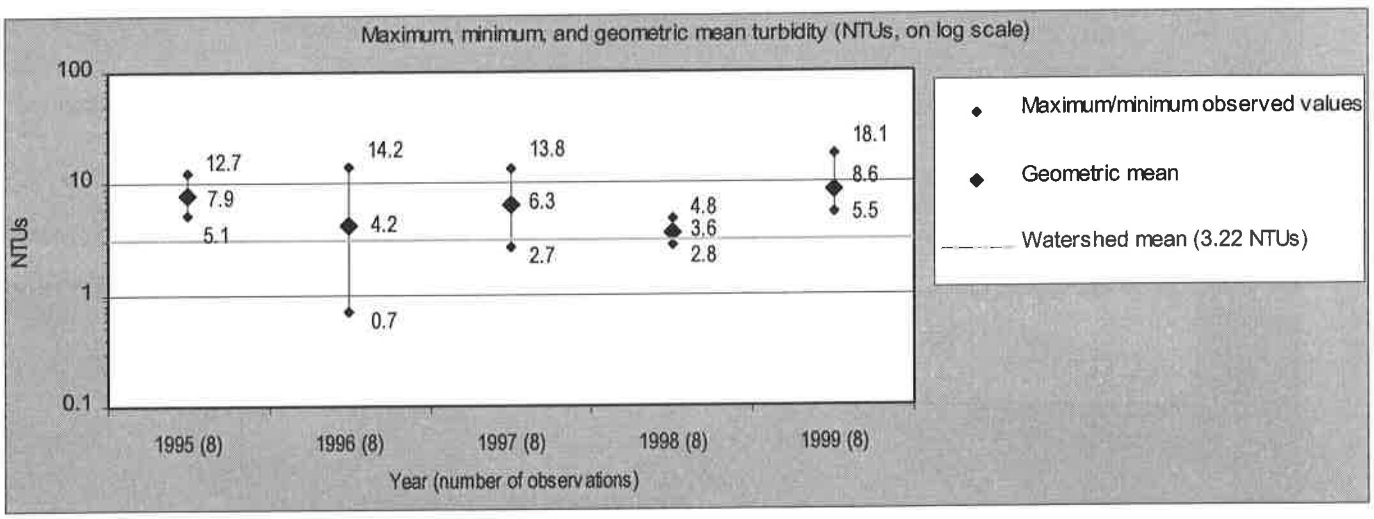


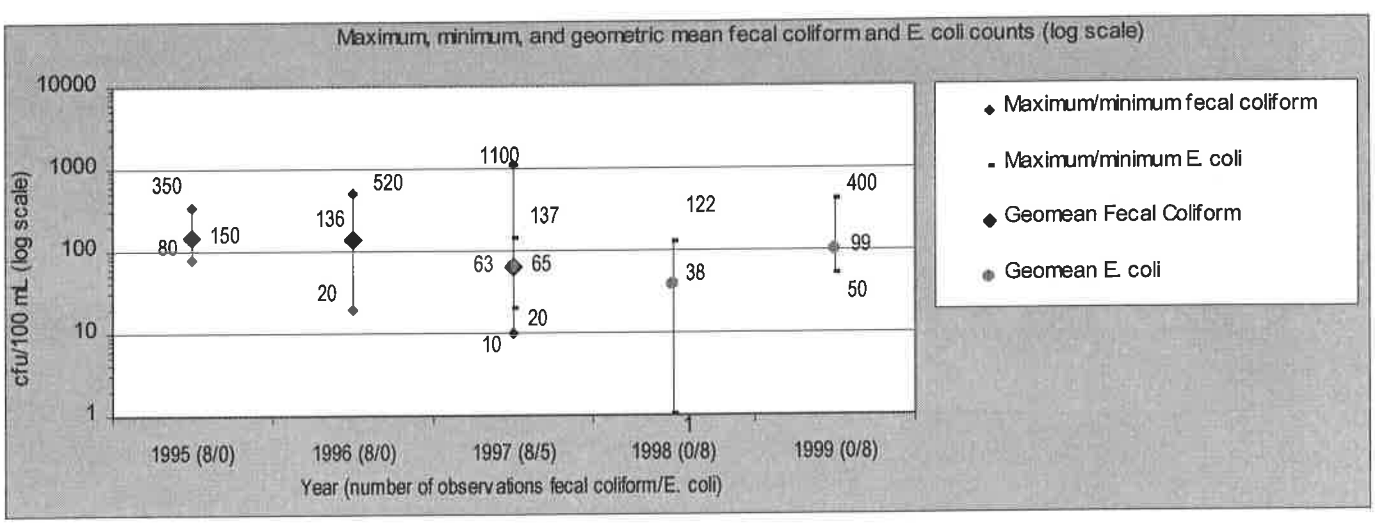




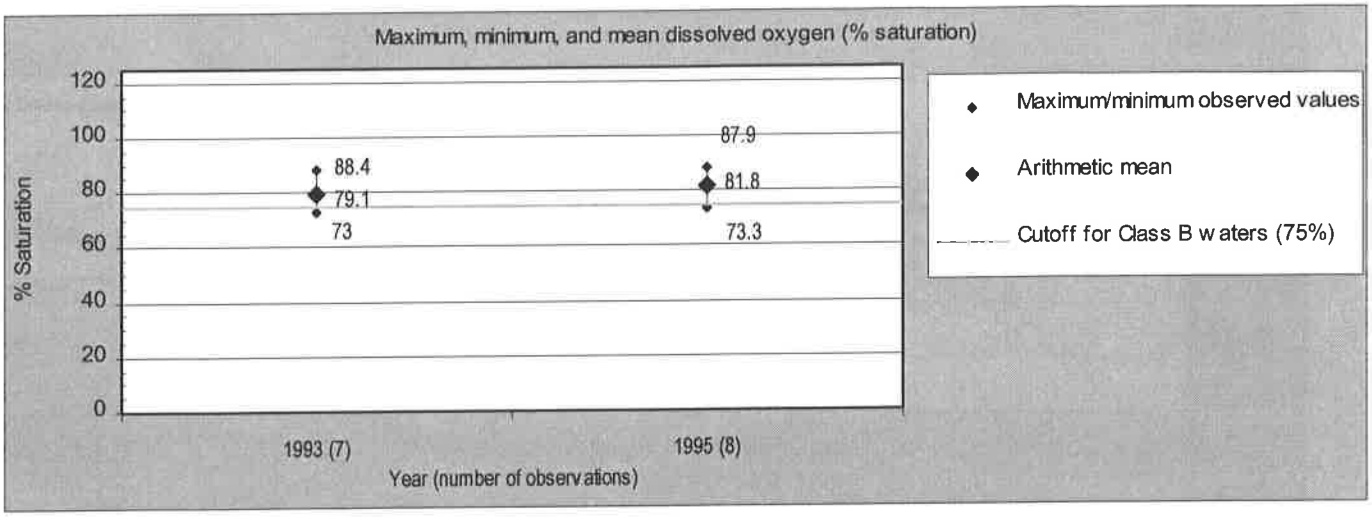
Site RoR28.9 (Royal River, in Royal River Subwatershed)

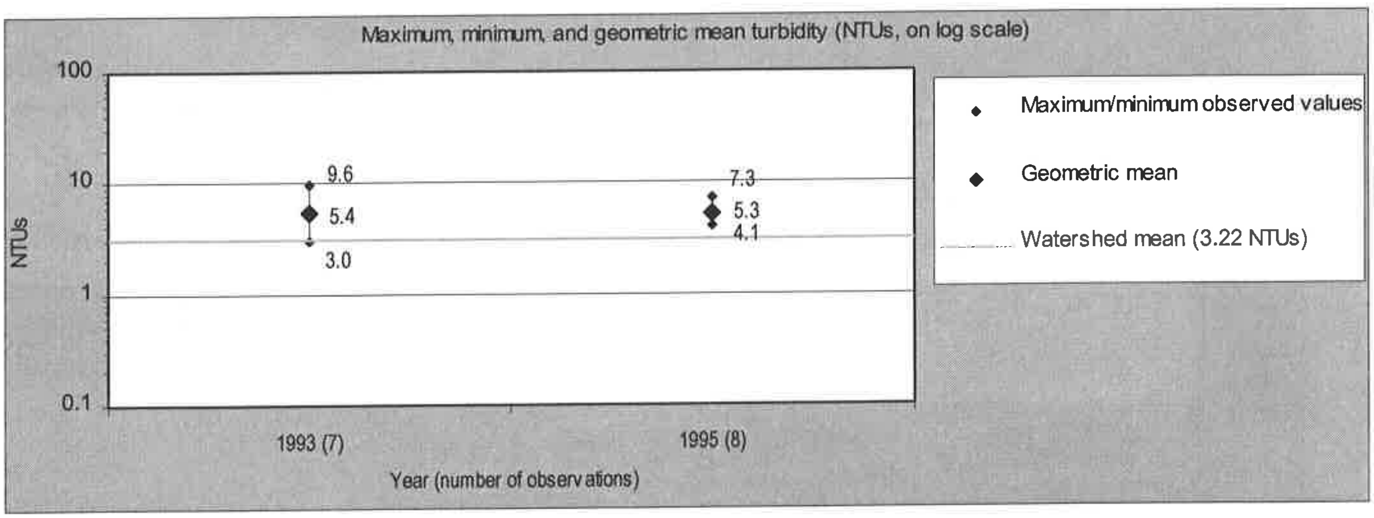


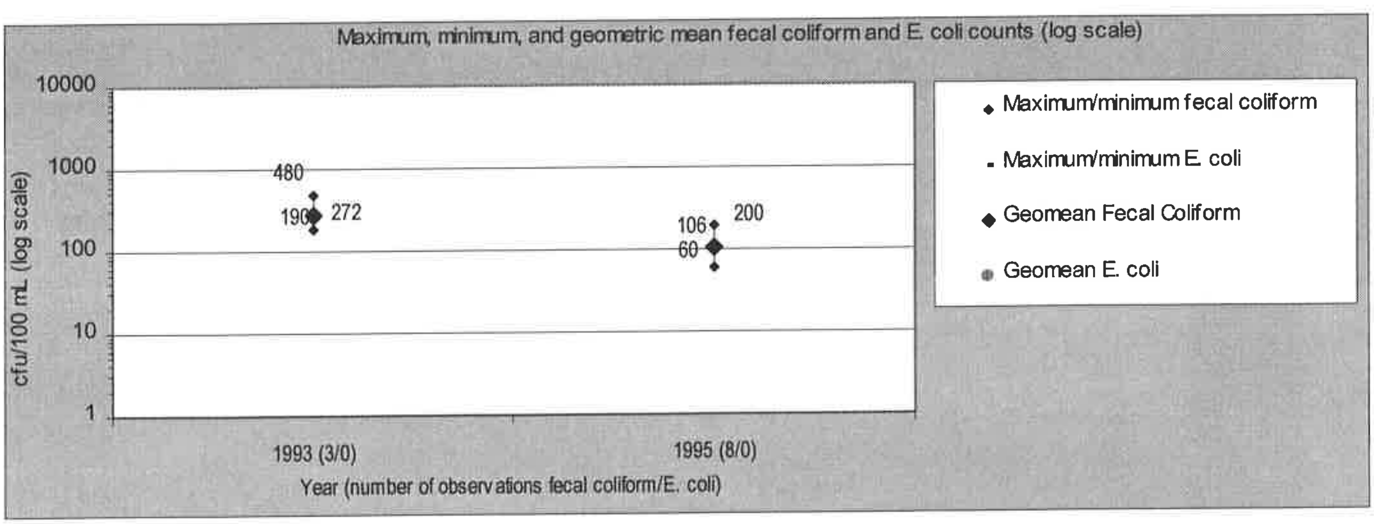




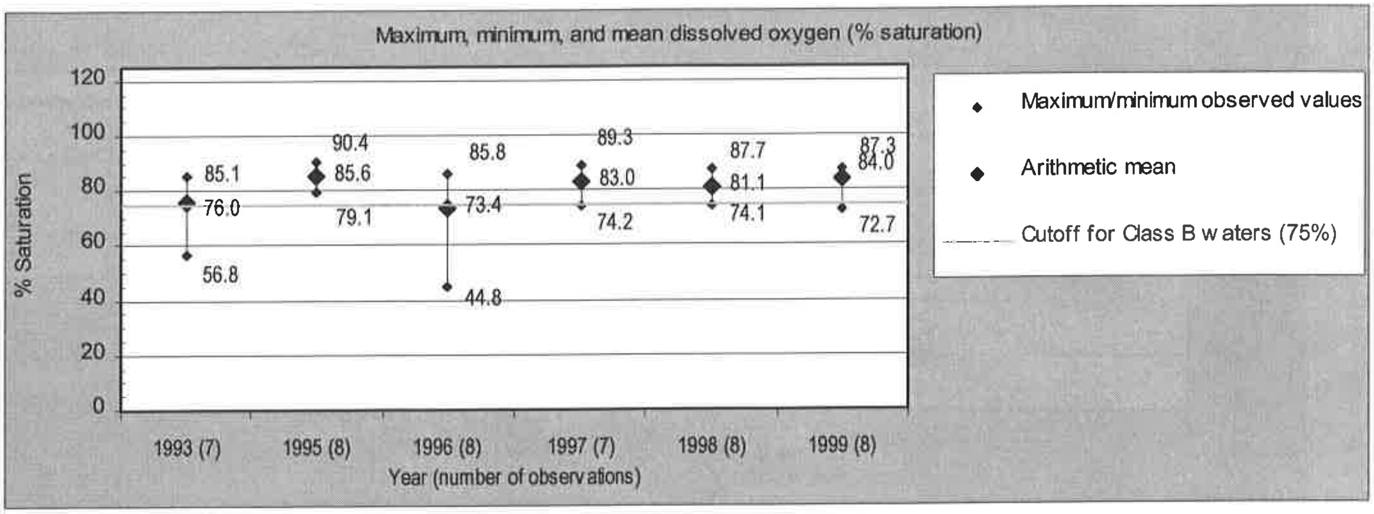
Site RoR30.3 (Royal River, in Royal River Subwatershed)

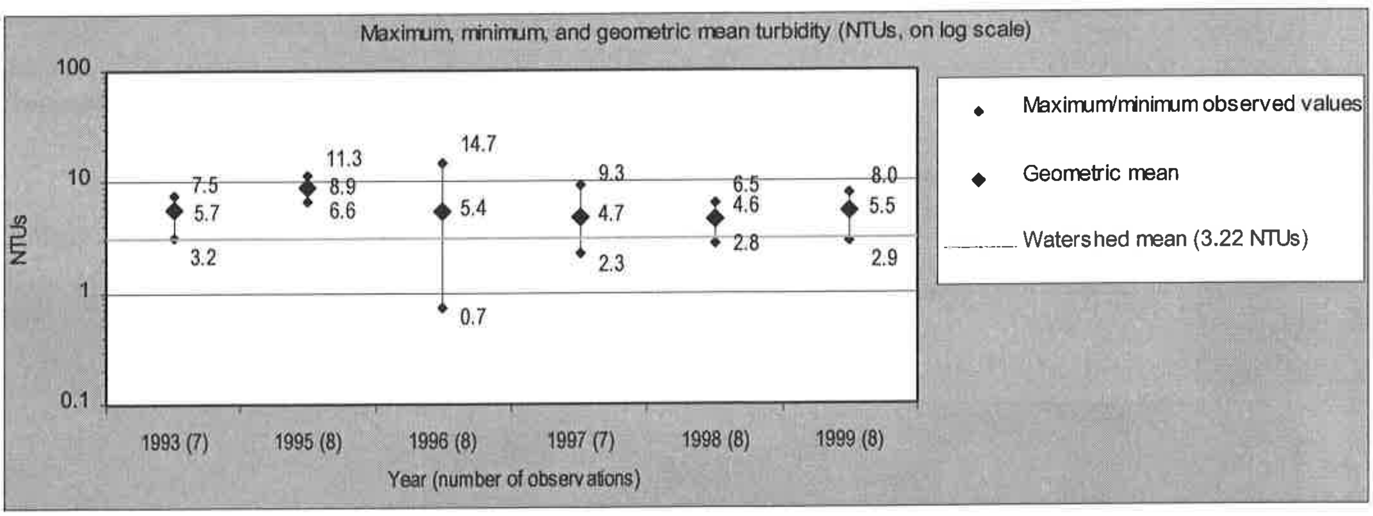


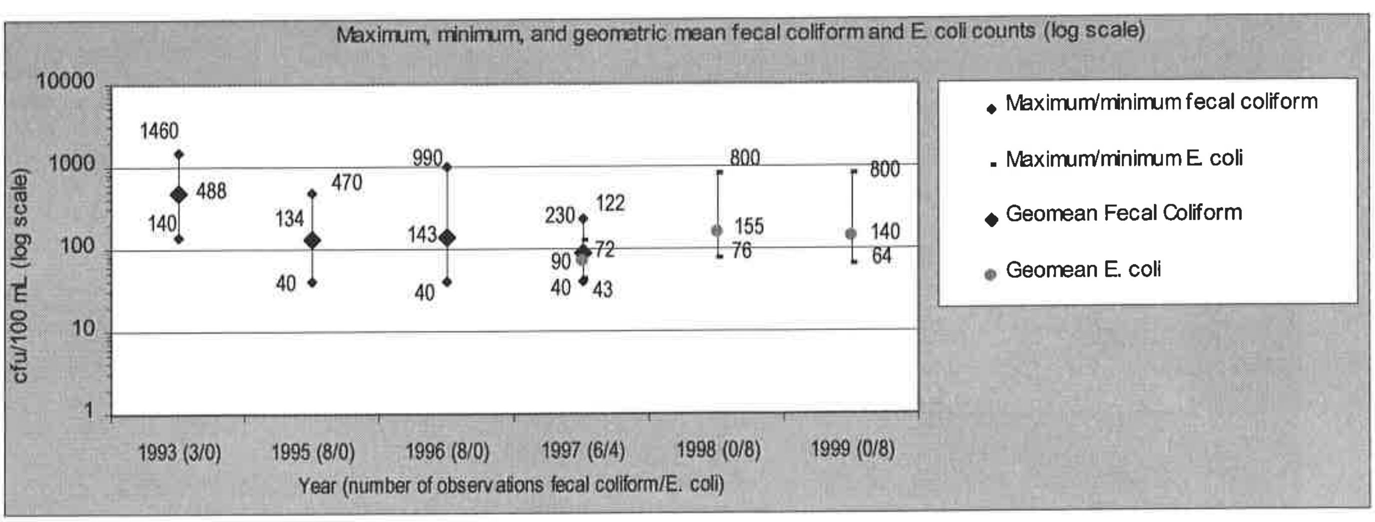




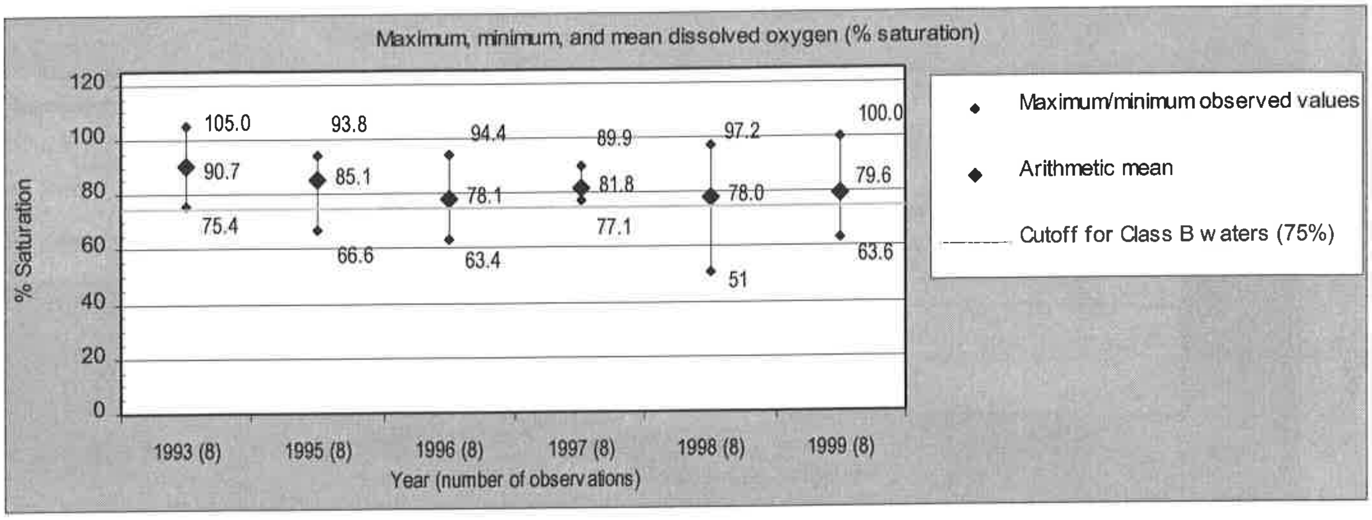
Site MoB31.8 (Moose Brook, in Royal River Subwatershed)

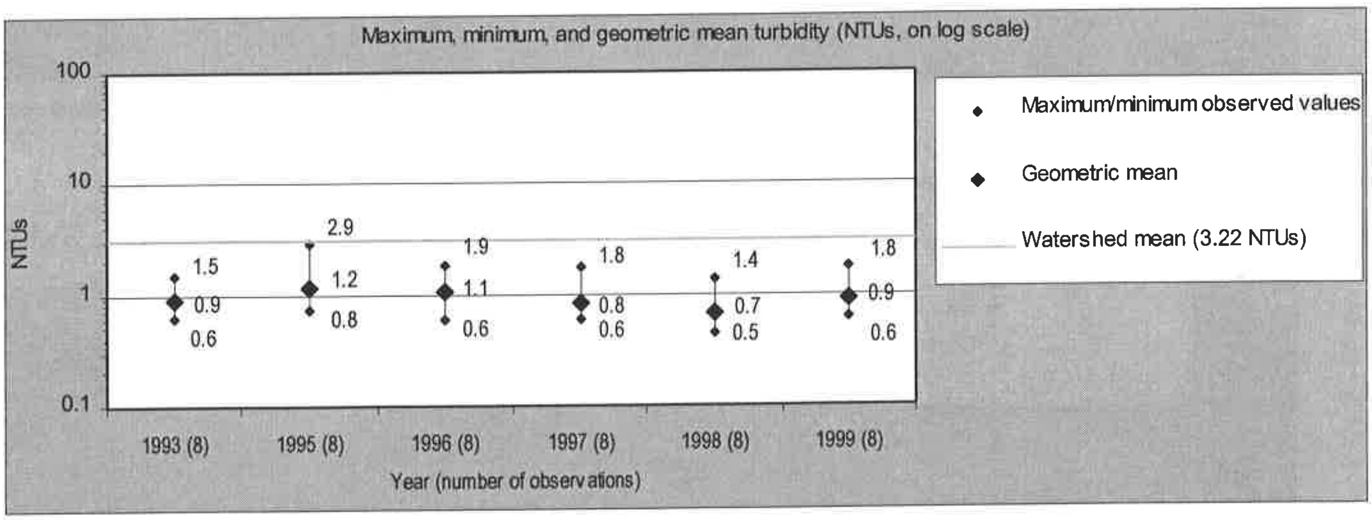


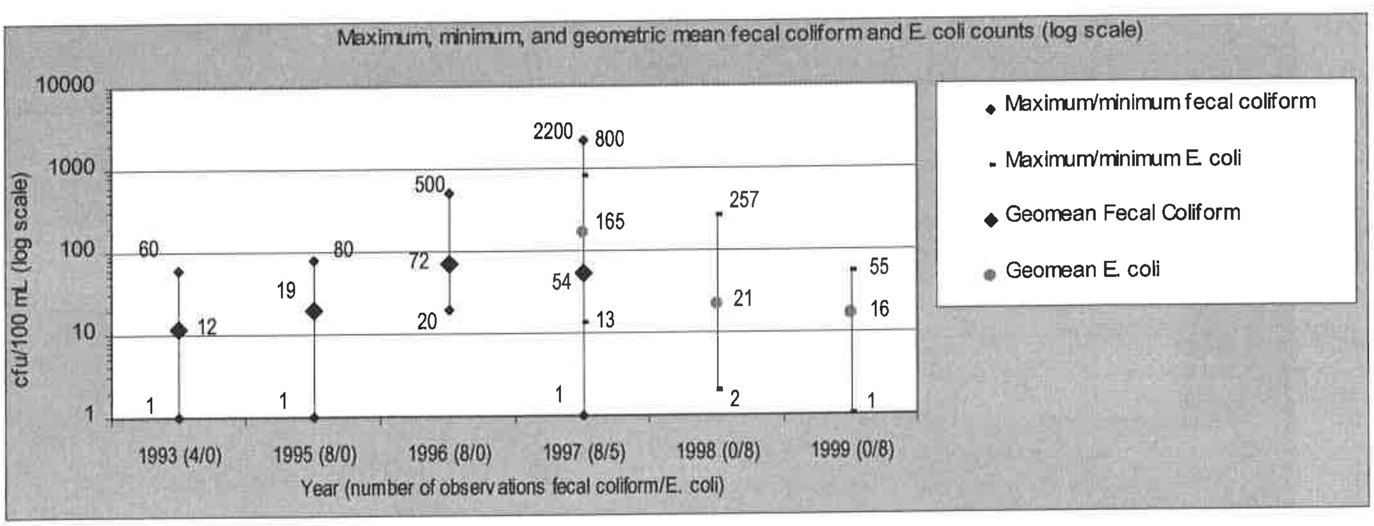




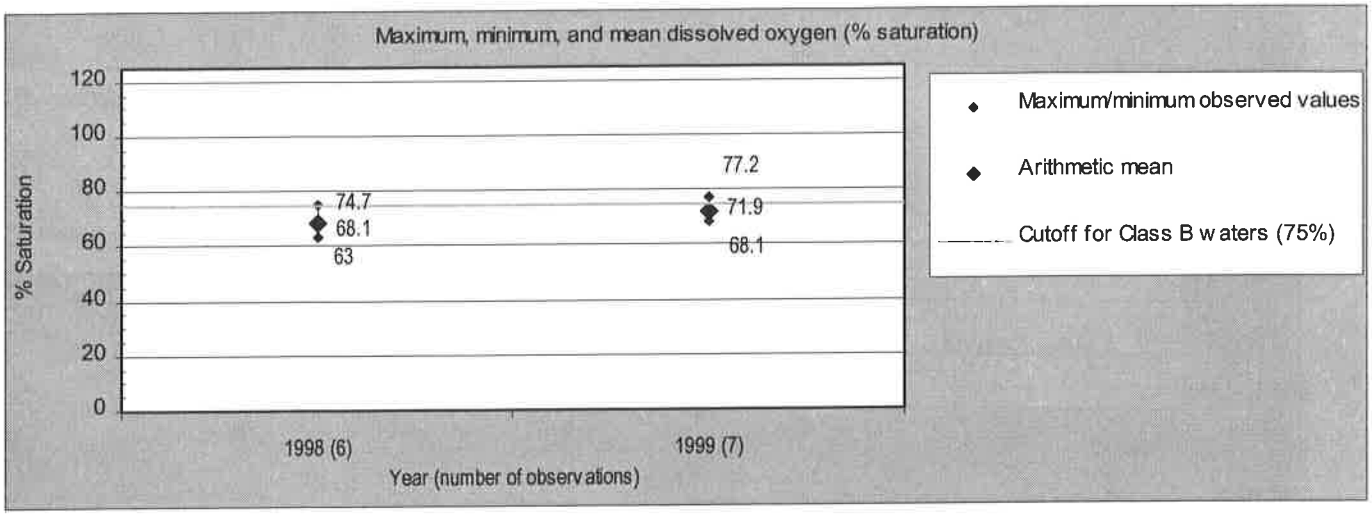
Site RoR34.3 (Royal River, in Royal River Subwatershed)

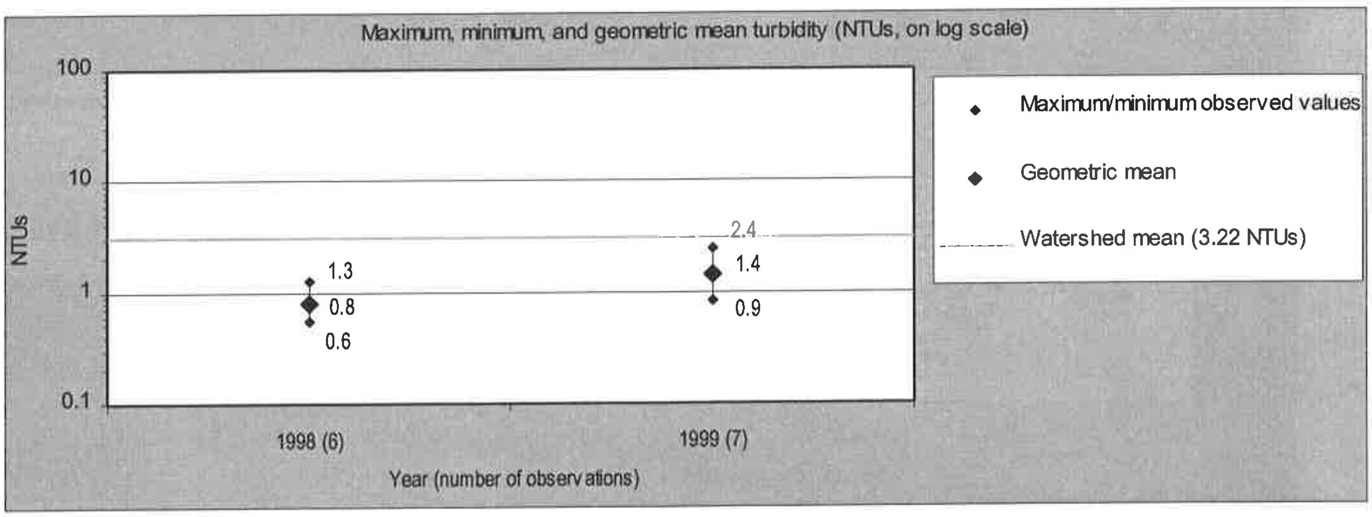


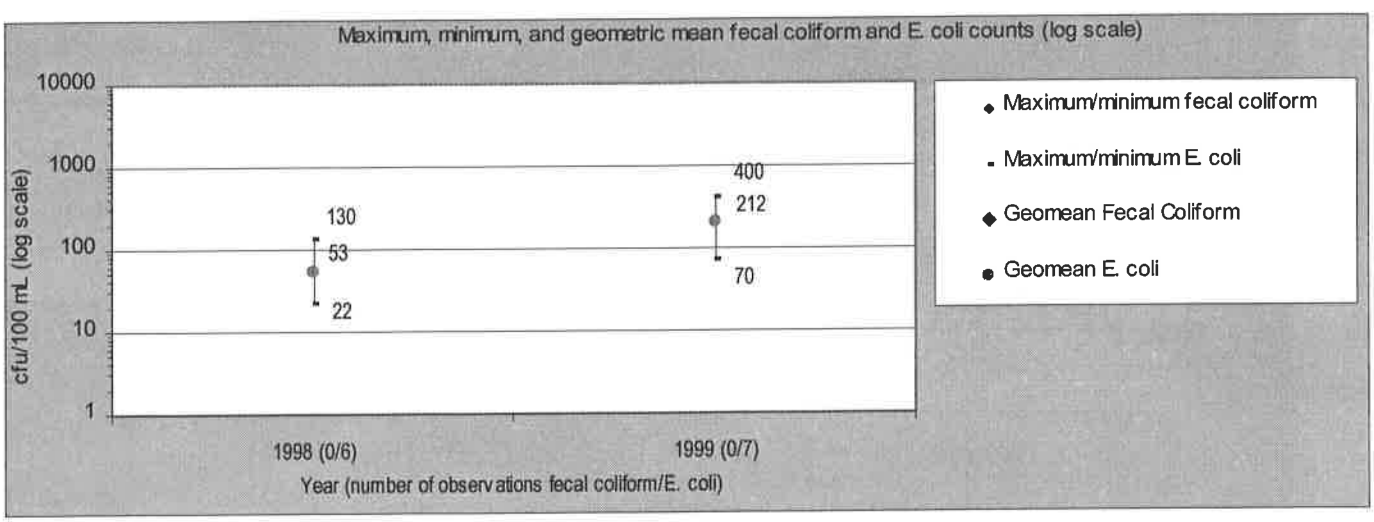




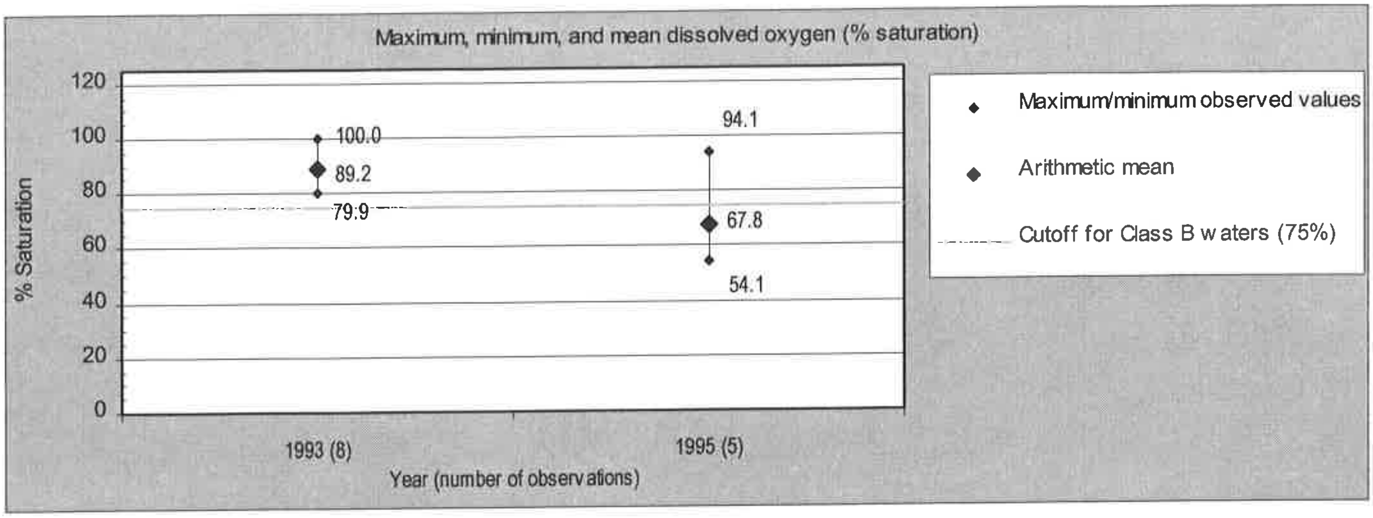
Site RoR36.3 (Royal River, in Royal River Subwatershed)

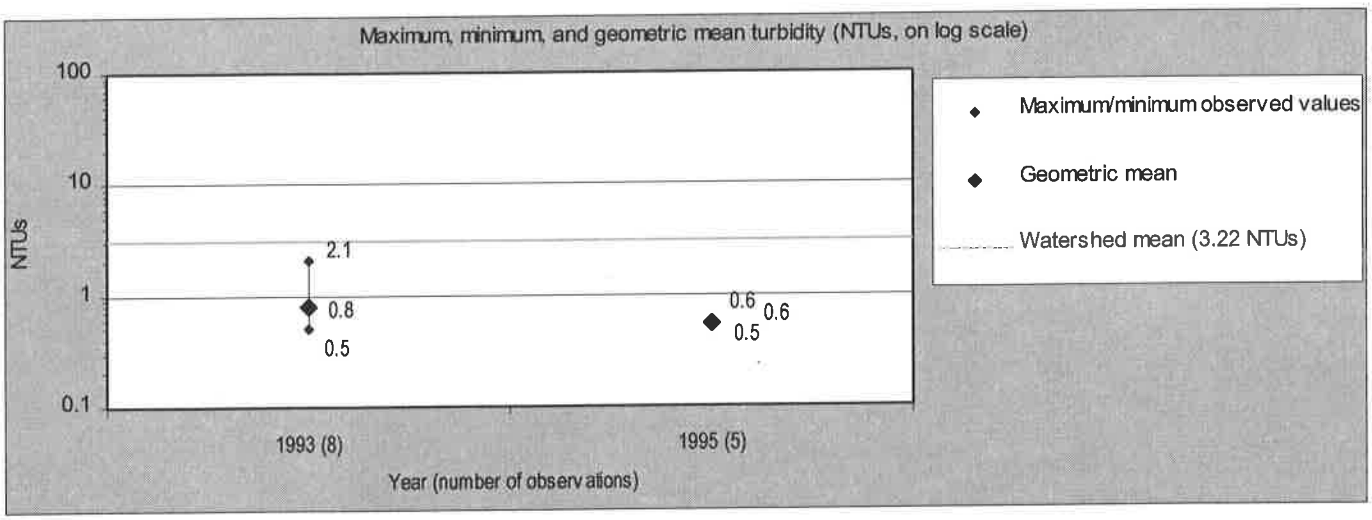


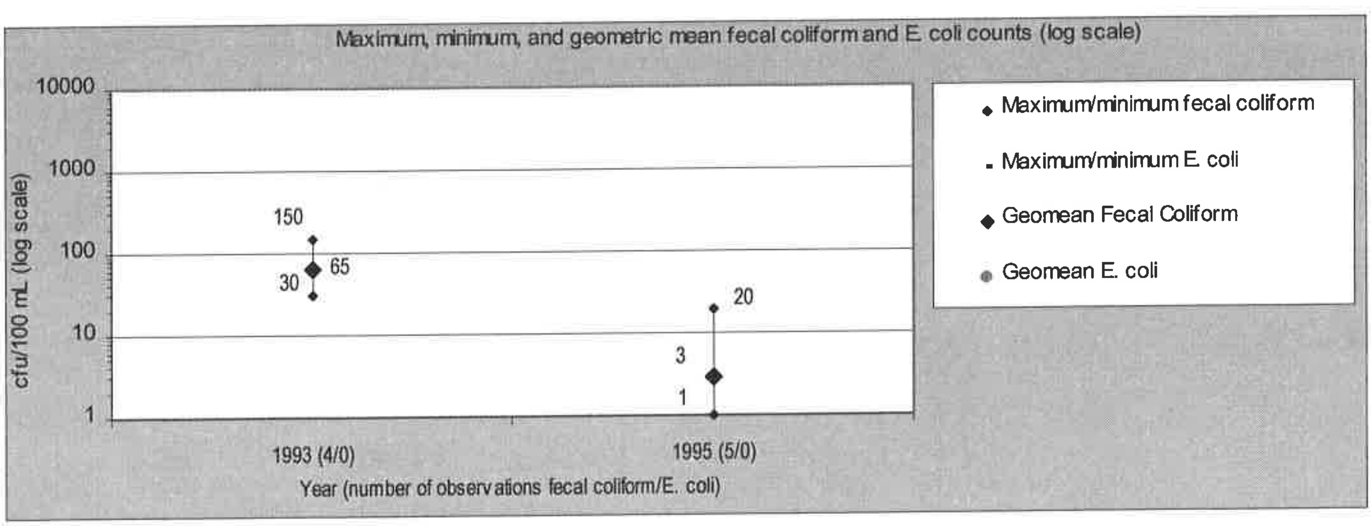




Site RoR38.4 (Royal River, in Royal River Subwatershed)





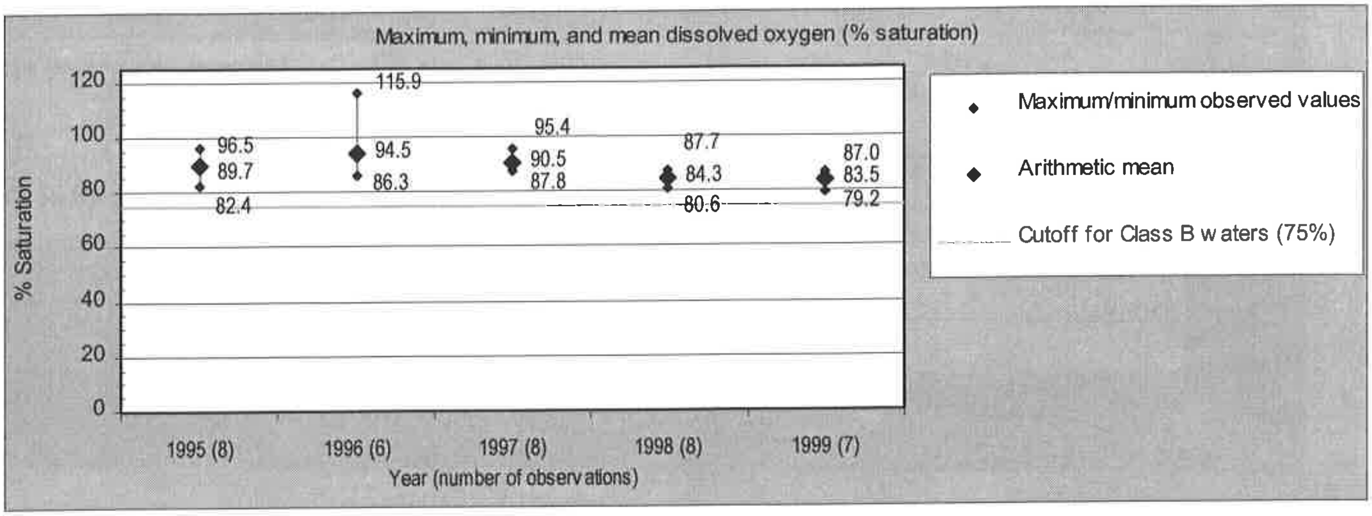


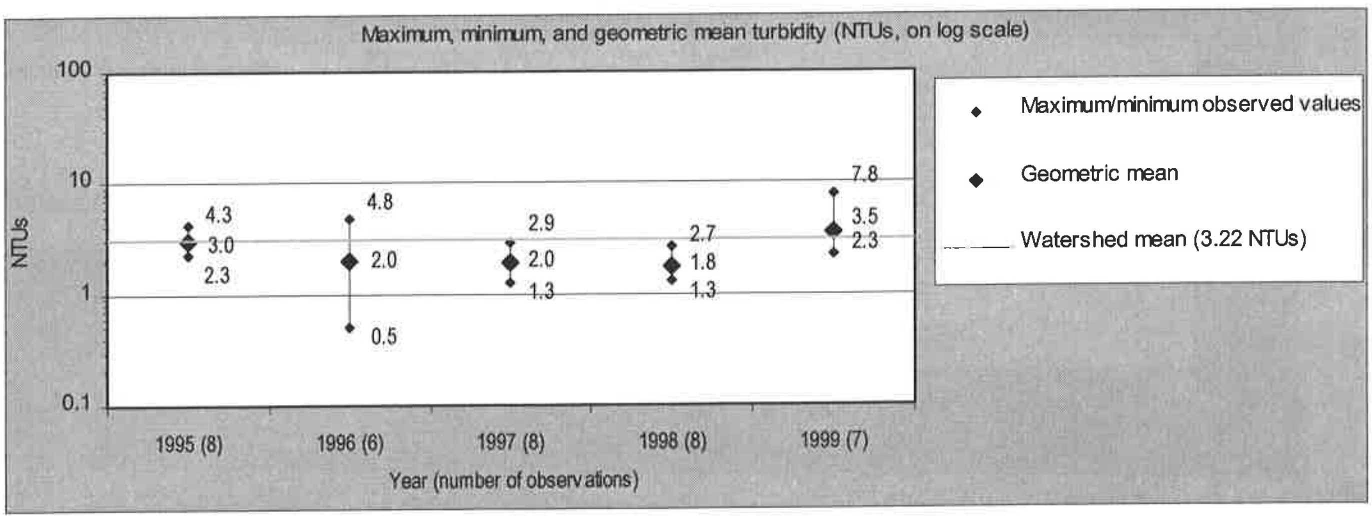
Appendix G

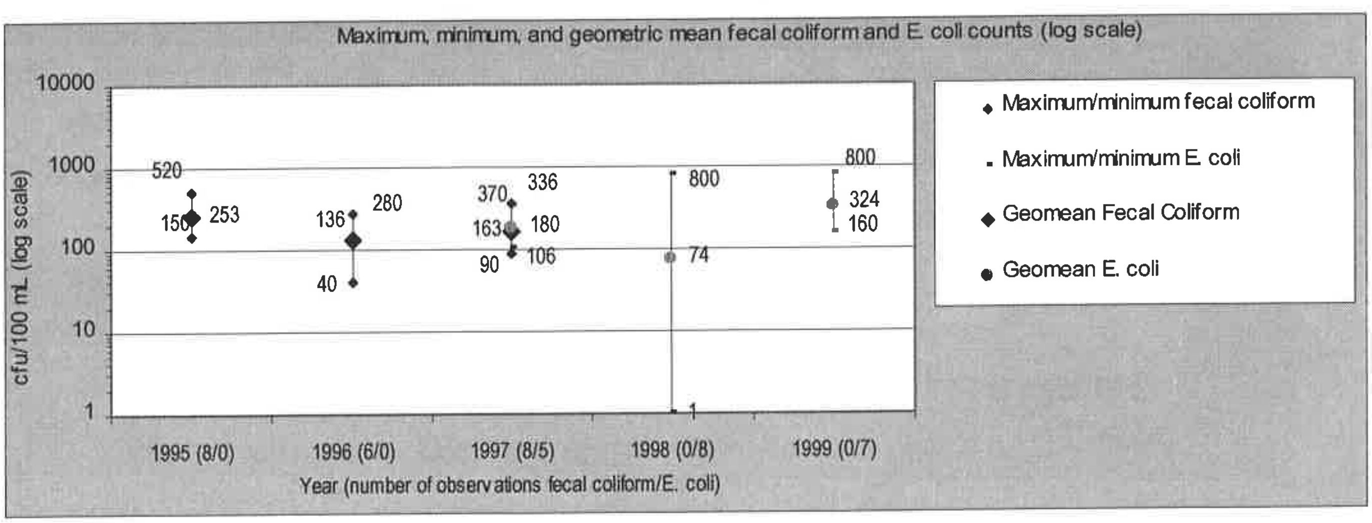
Monitoring Sites in the Collyer Brook Subwatershed

Below the first dam in Yarmouth during flood of 1989

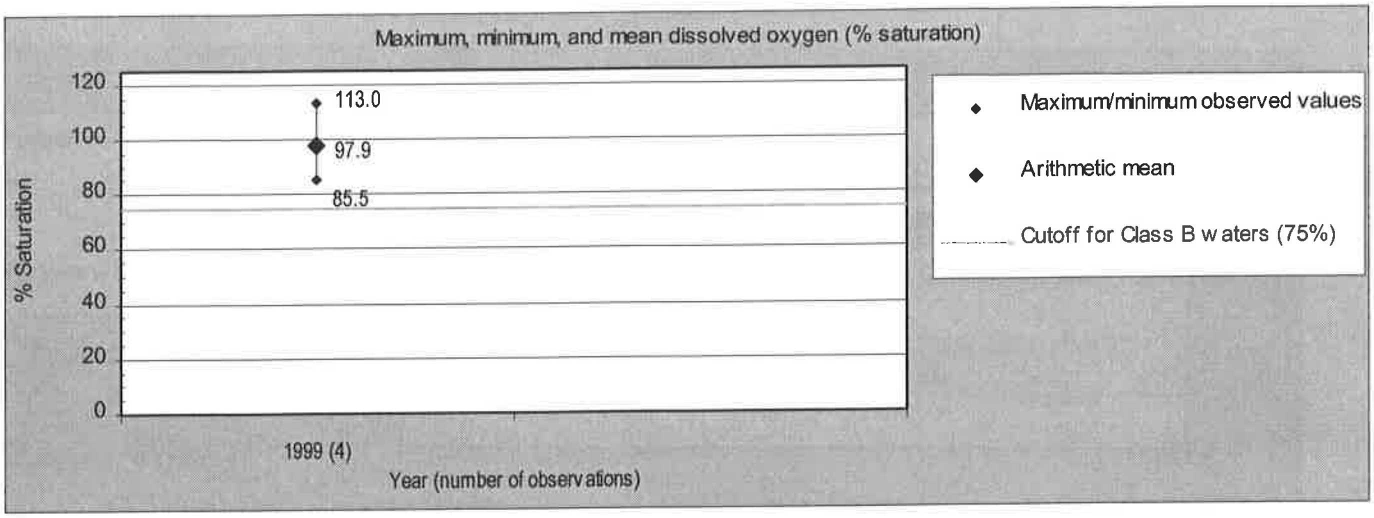
Site CoB16.6 (Collyer Brook, in Collyer Brook Subwatershed)

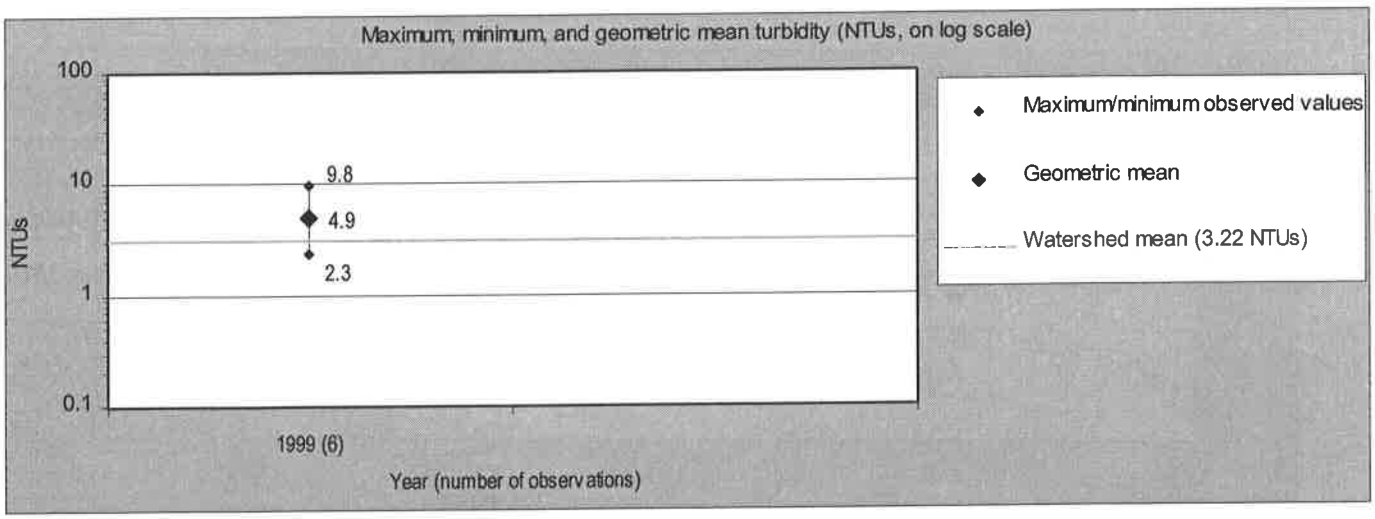


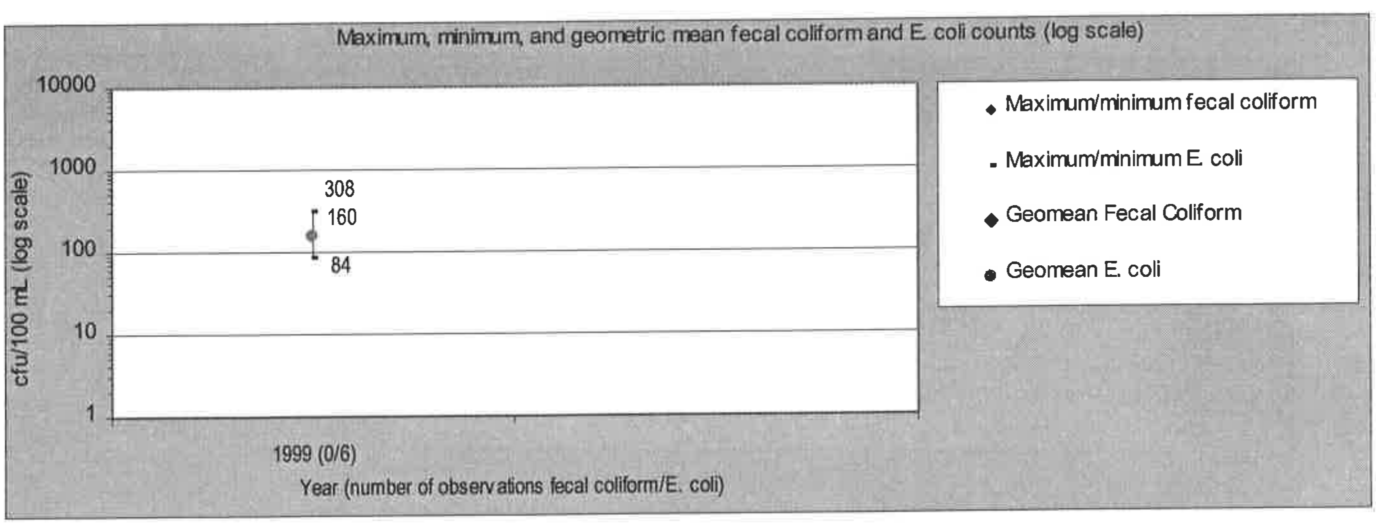




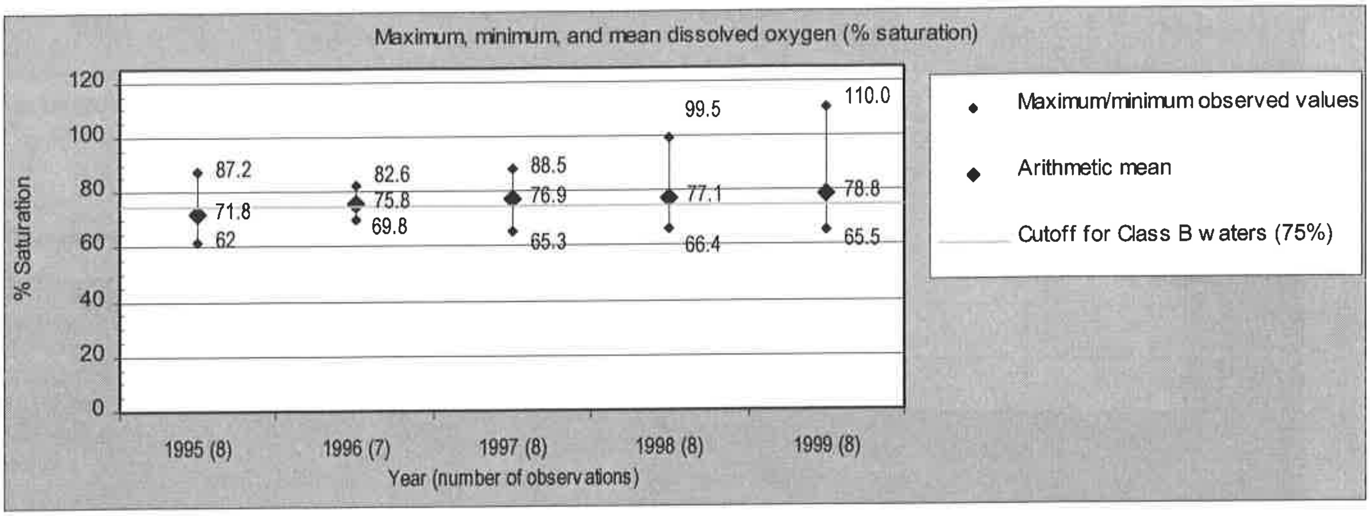
Site CoB18.3 (Collyer Brook, in Collyer Brook Subwatershed)

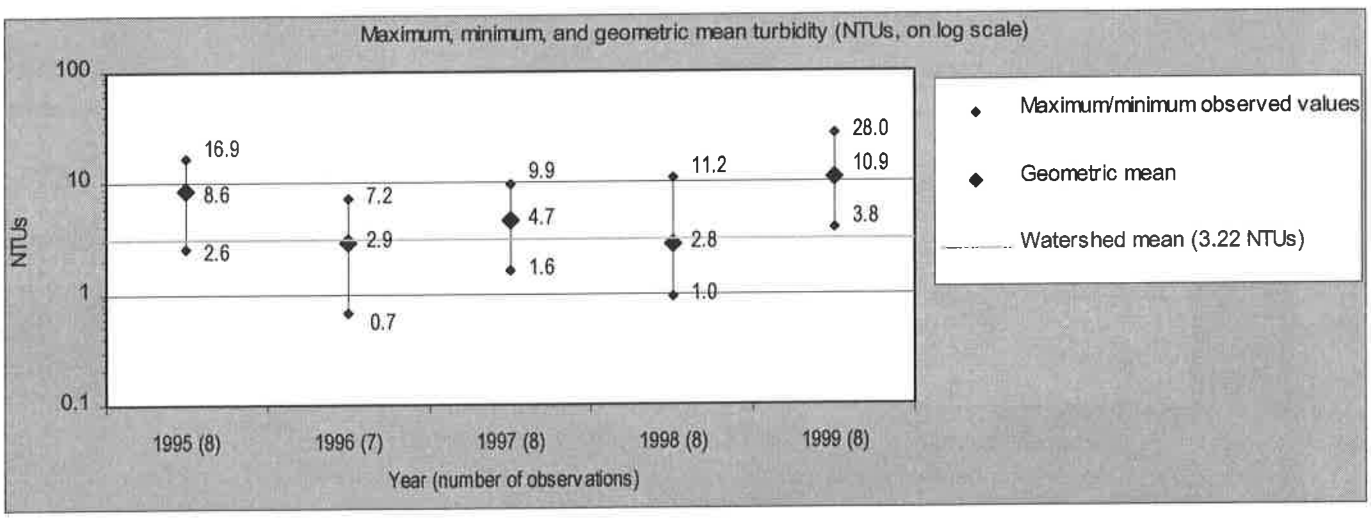


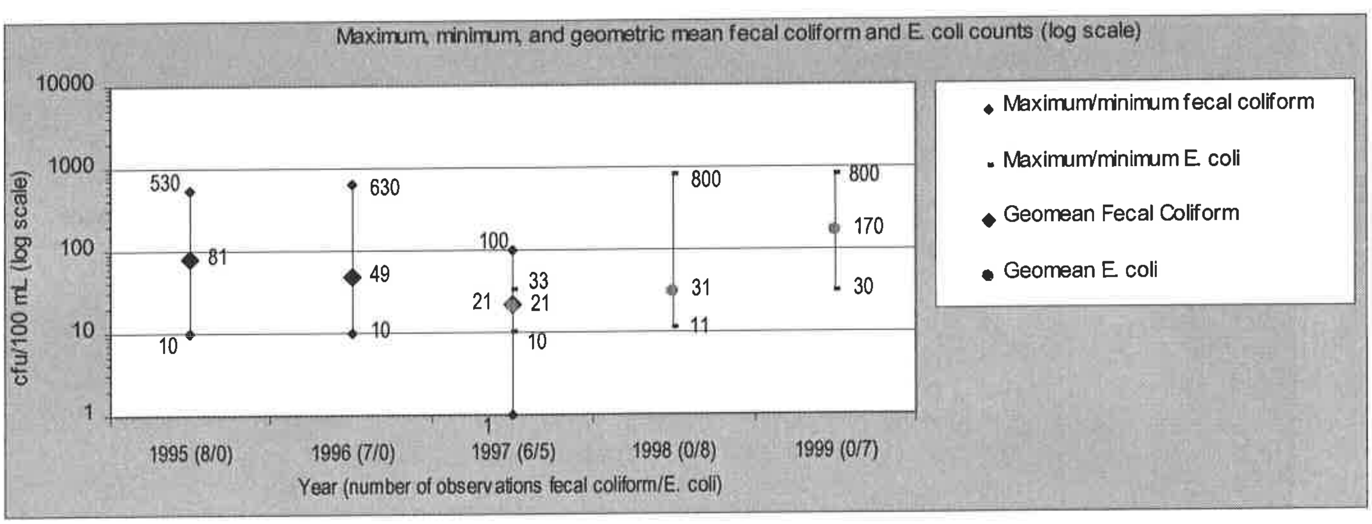




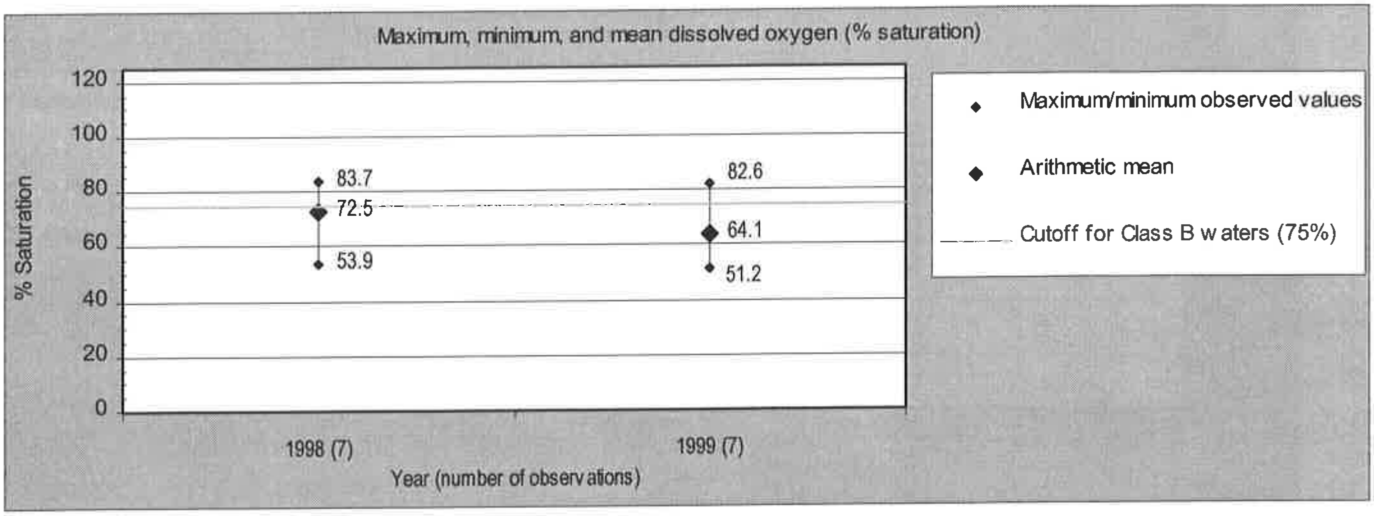
Site BrB19.6 (Brandy Brook, in Collyer Brook Subwatershed)

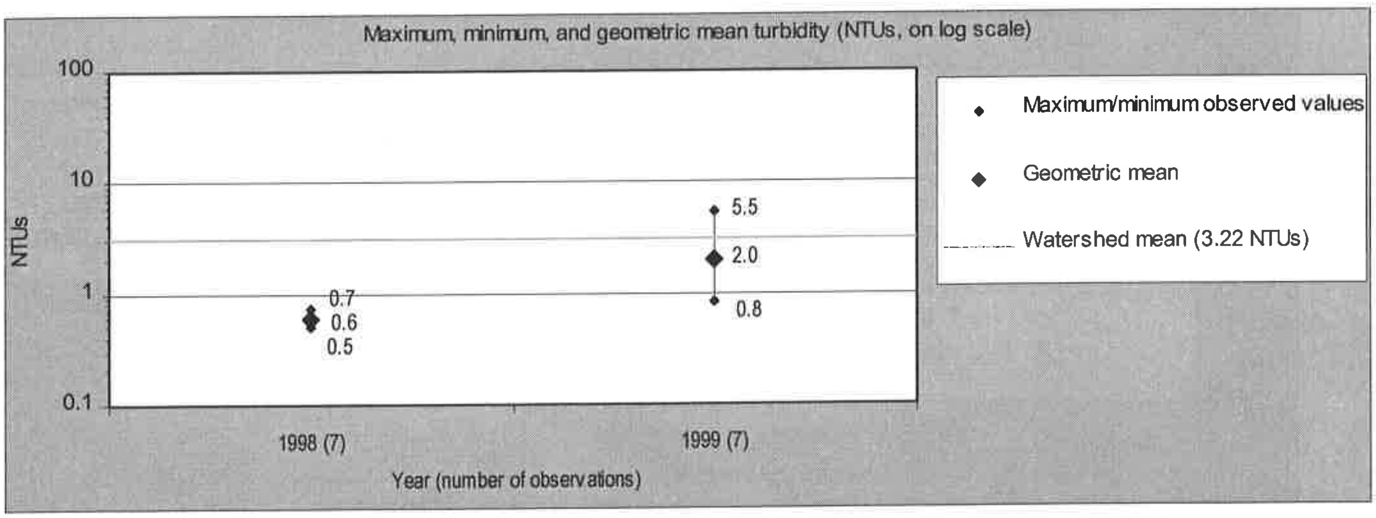


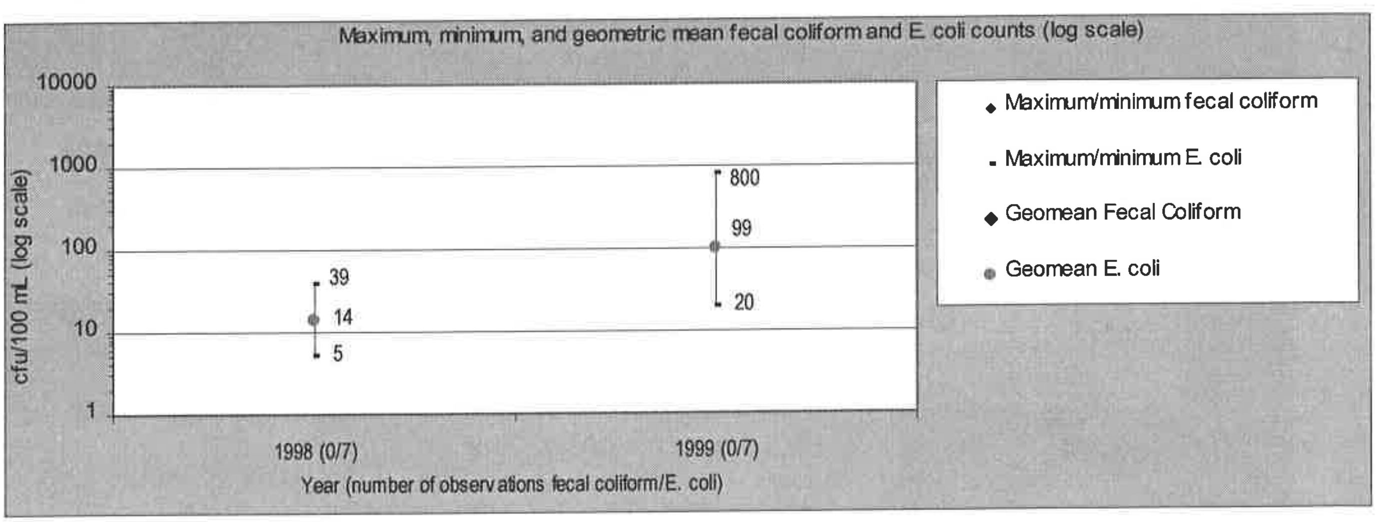




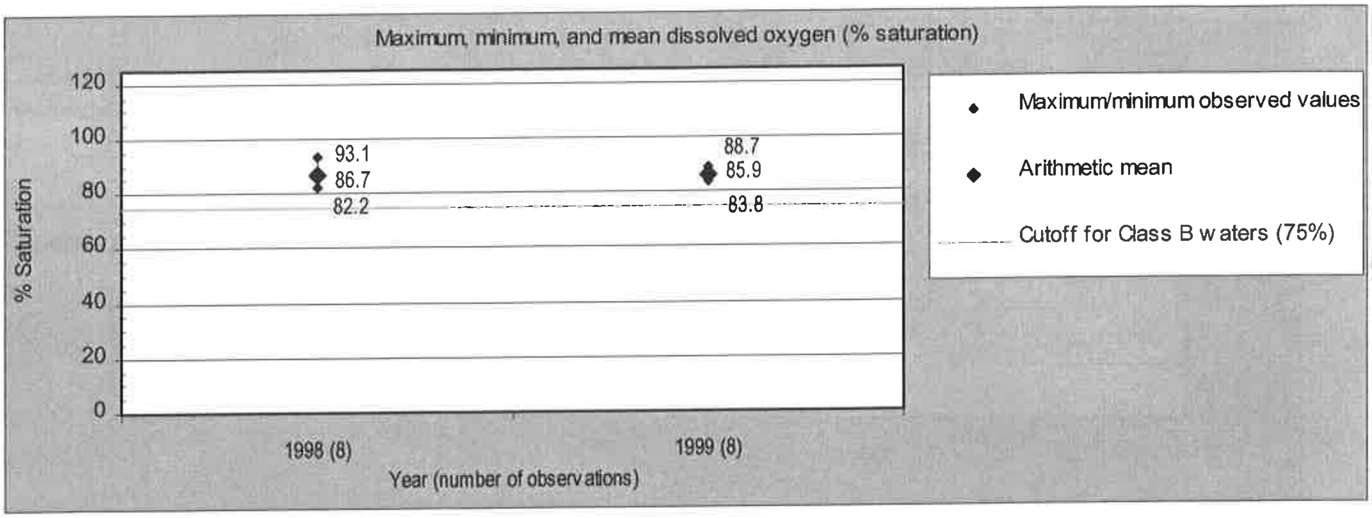
Site BrB20.6 (Brandy Brook, in Collyer Brook Subwatershed)

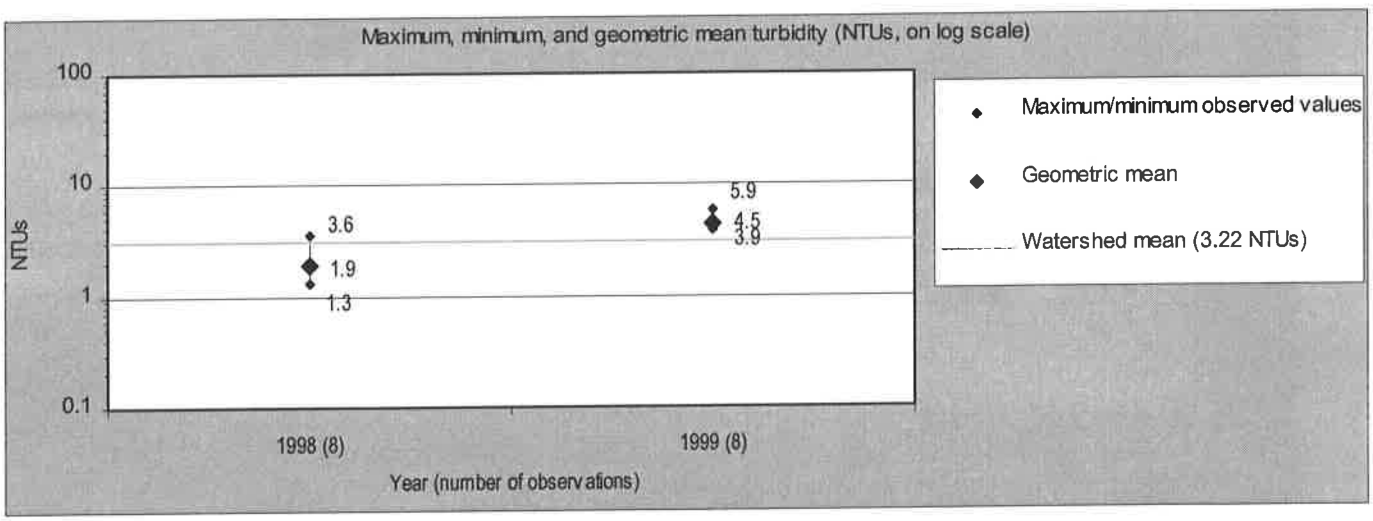


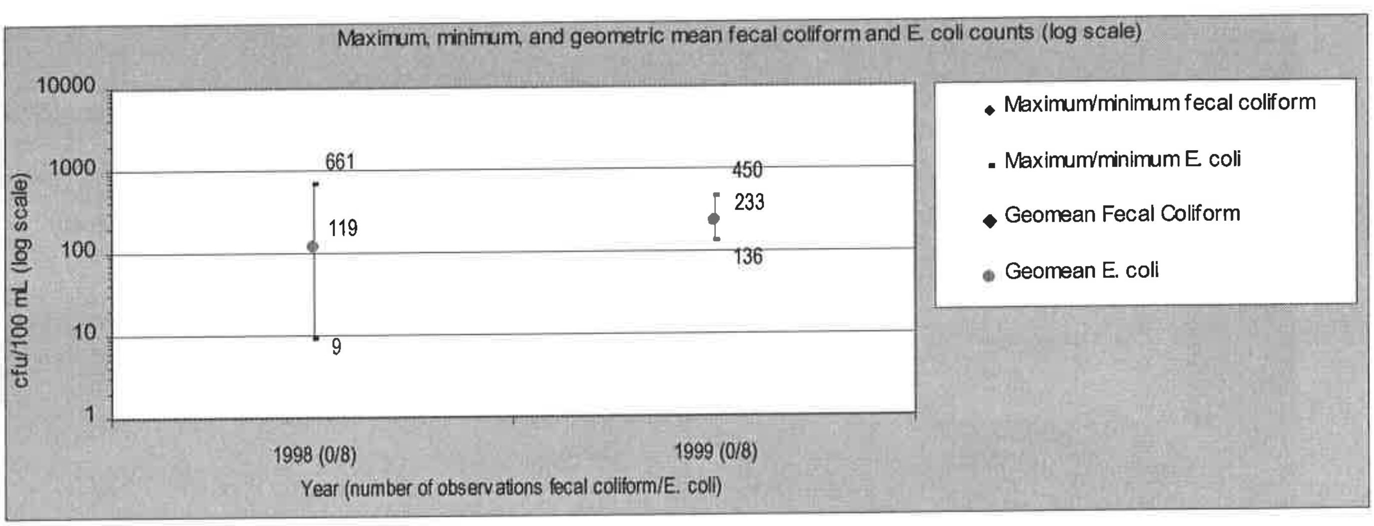




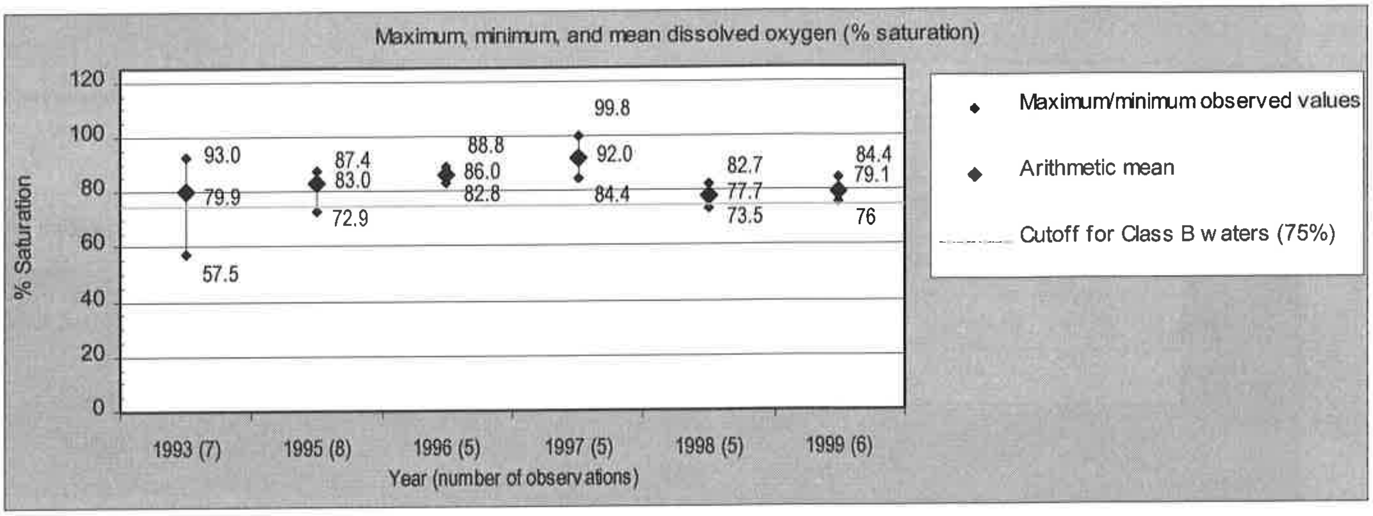
Site LiB19.7 (Libby Brook, in Collyer Brook Subwatershed)

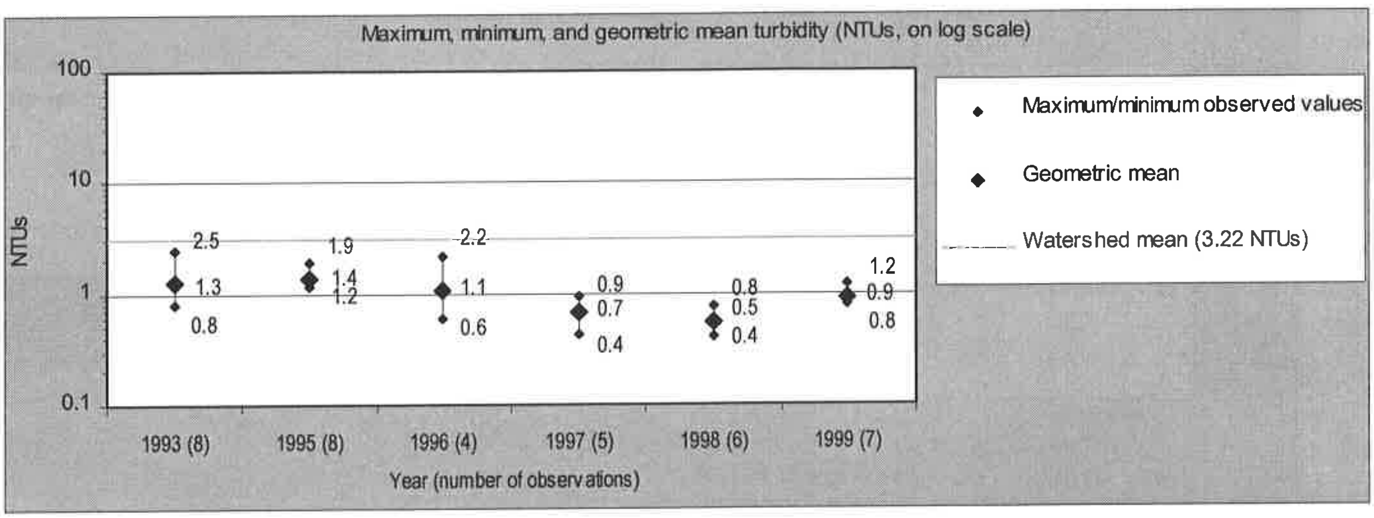


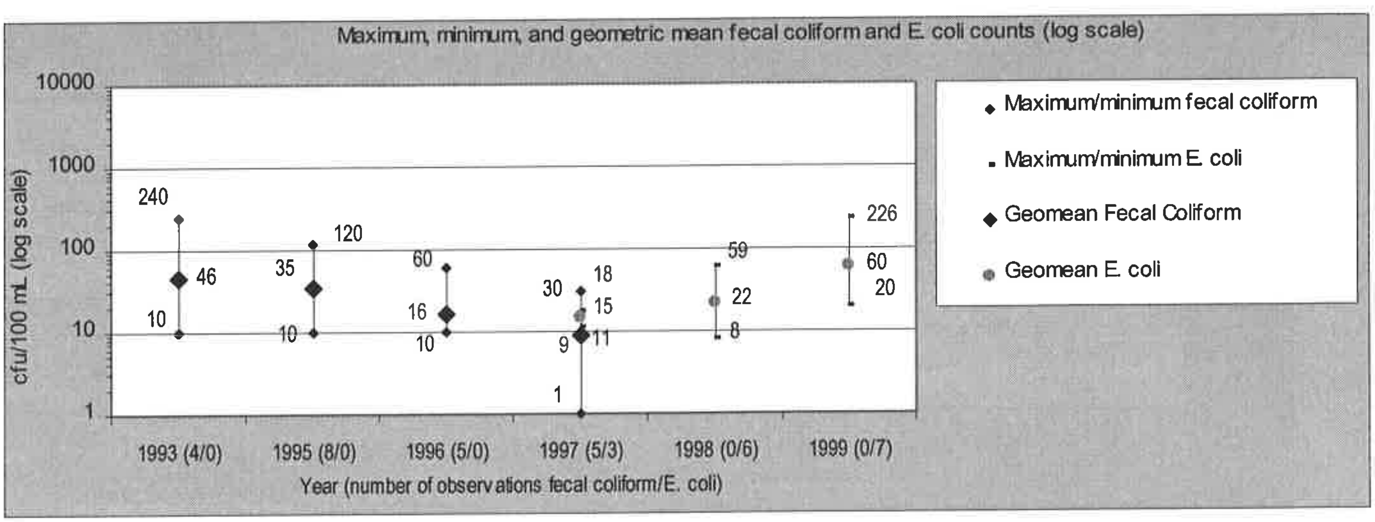




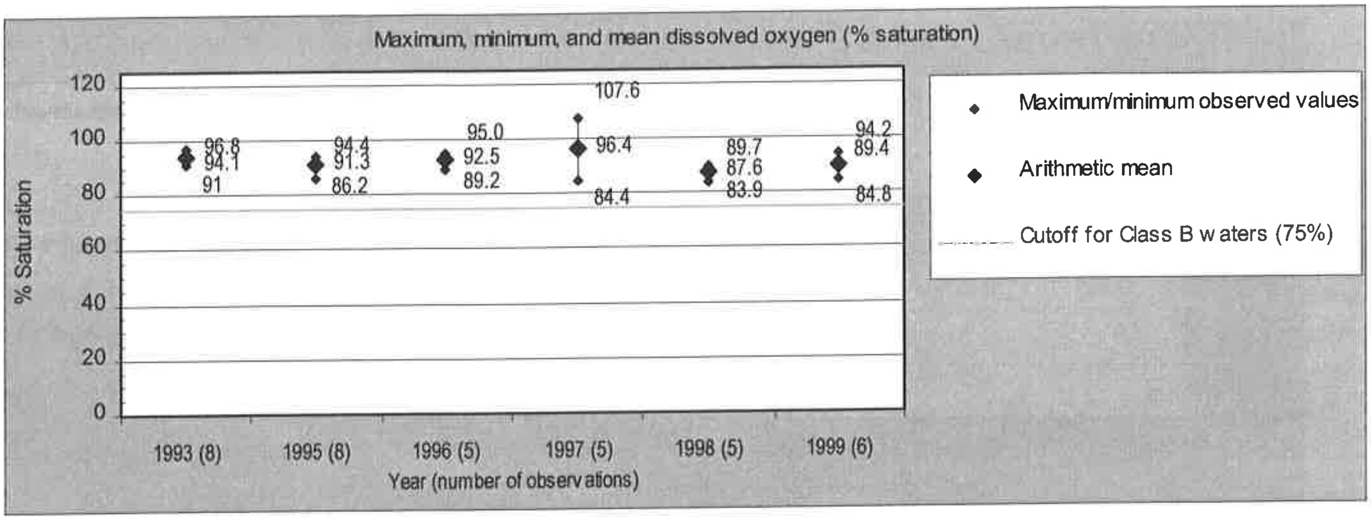
Site EdB21.0 (Eddy Brook, in Collyer Brook Subwatershed)

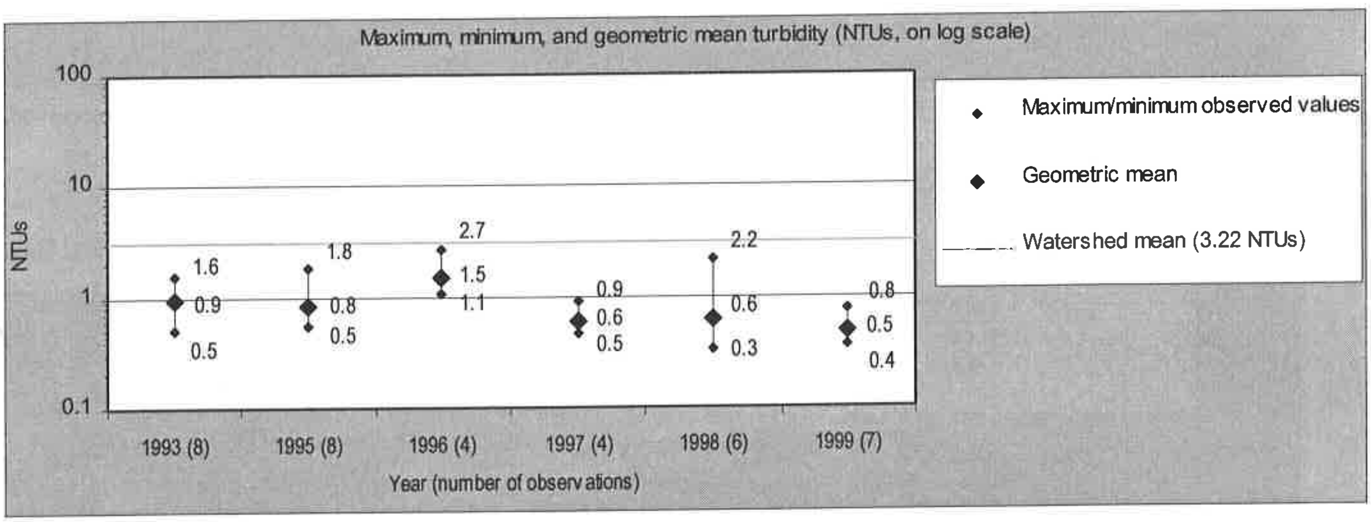


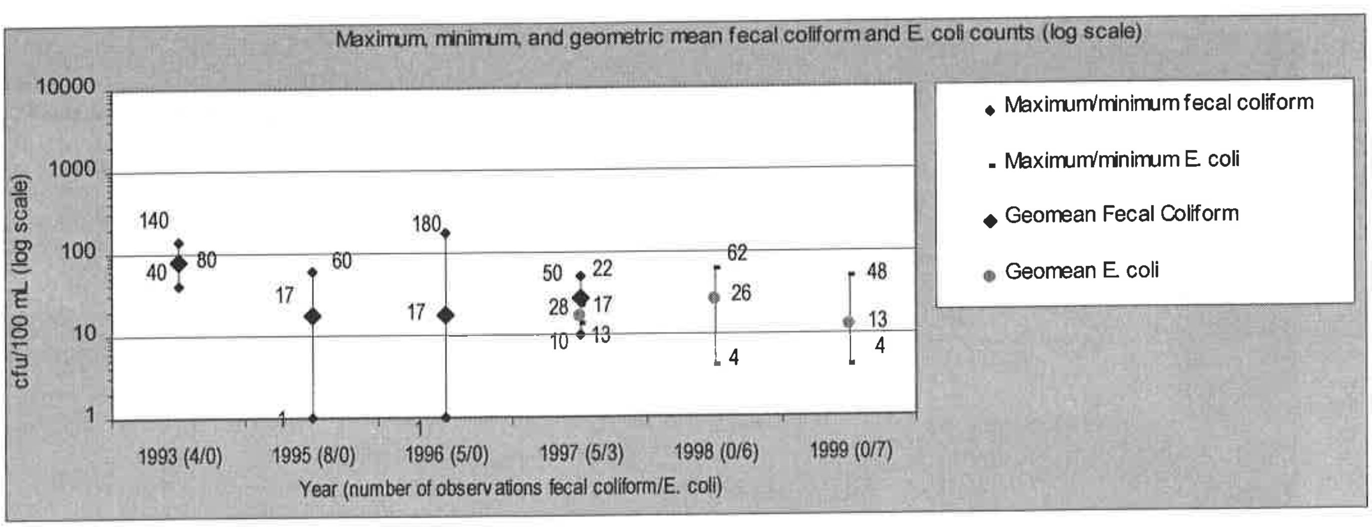




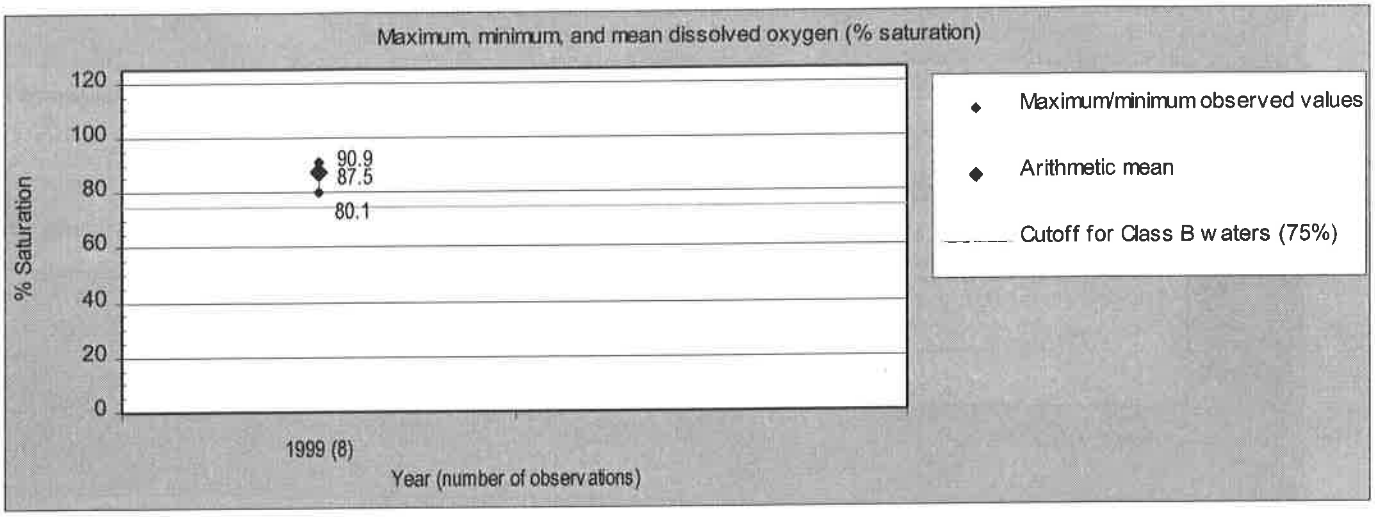
Site EdB21.4 (Eddy Brook, in Collyer Brook Subwatershed)

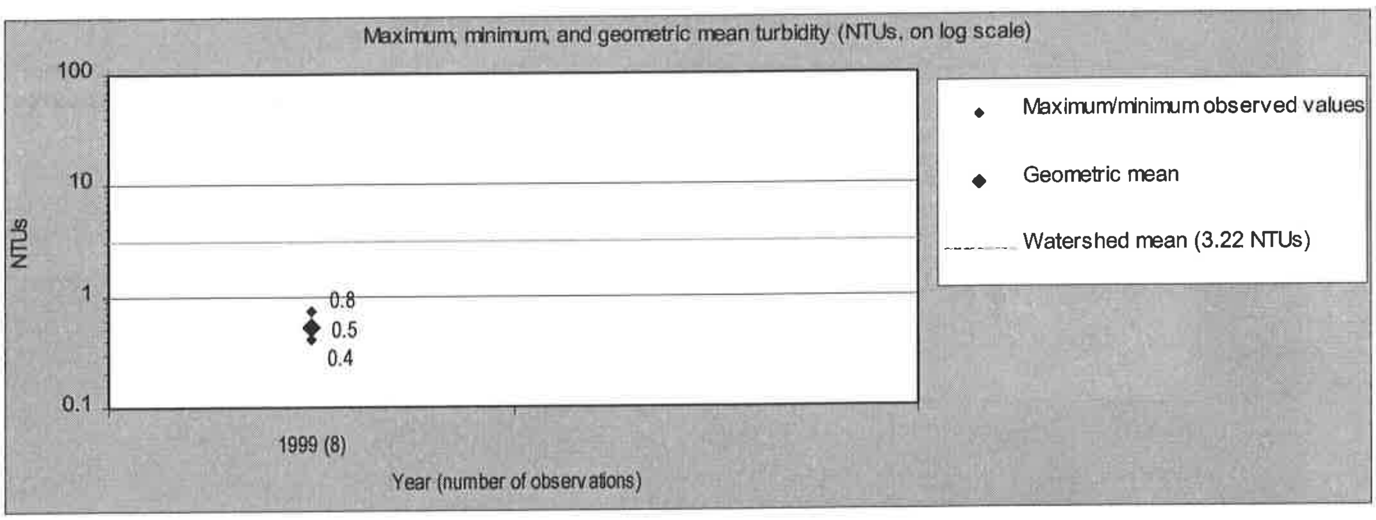


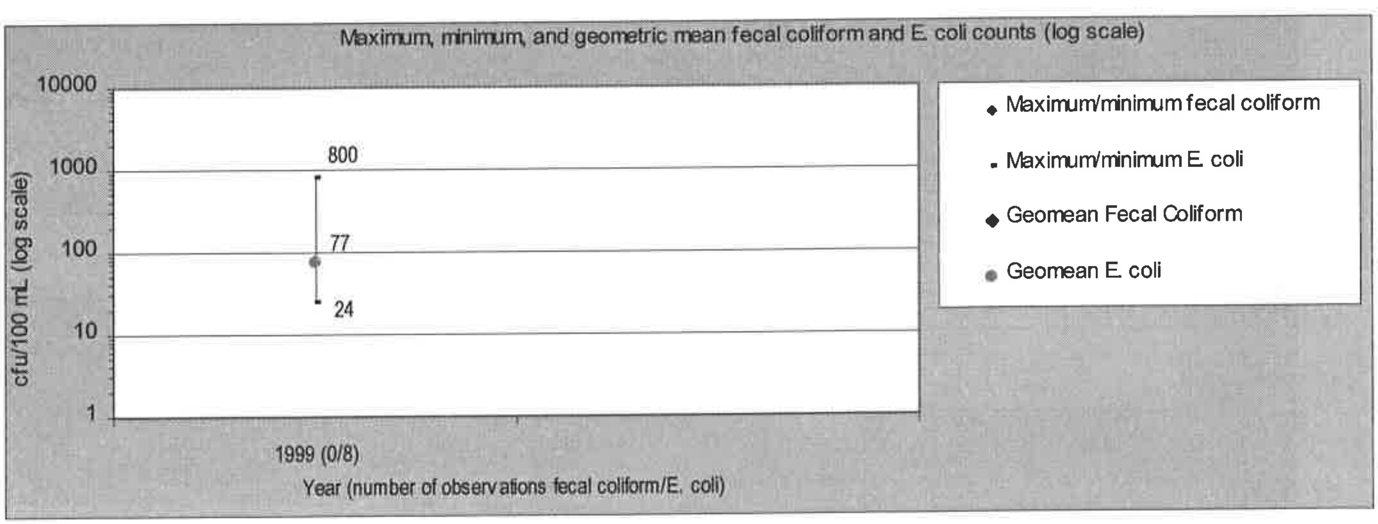




Site CIB23.8 (Cole Brook, in Collyer Brook Subwatershed)





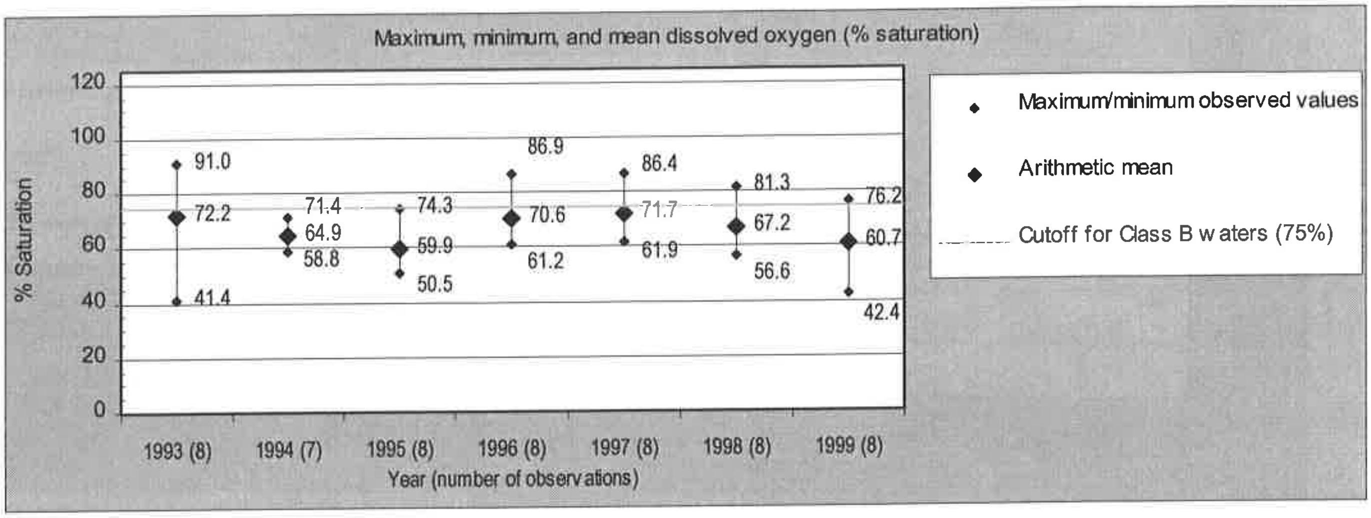


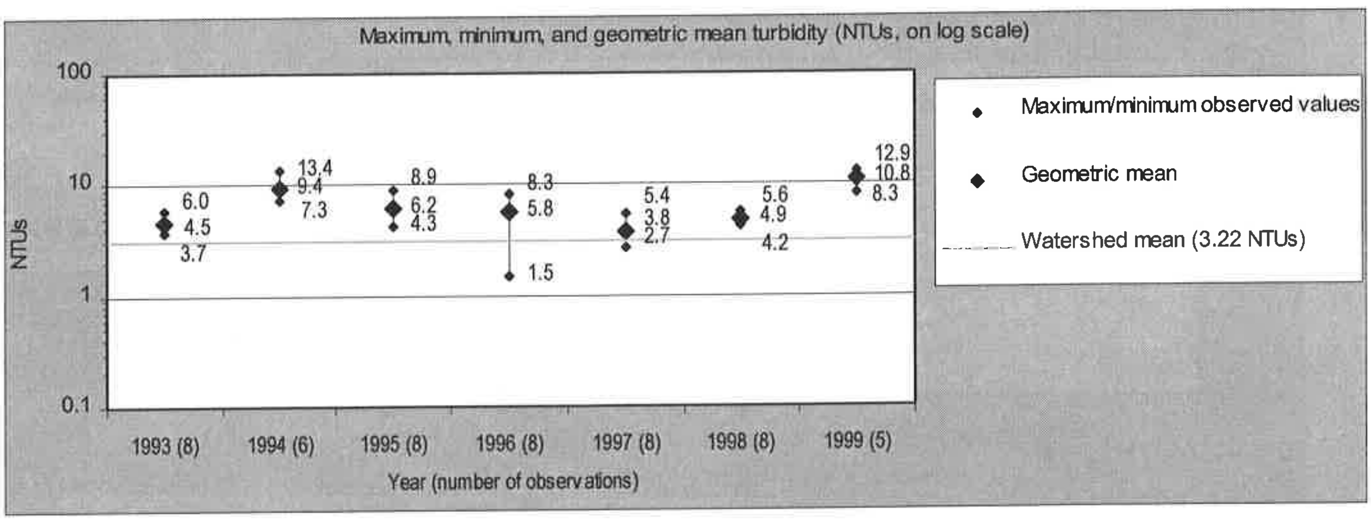
Appendix H

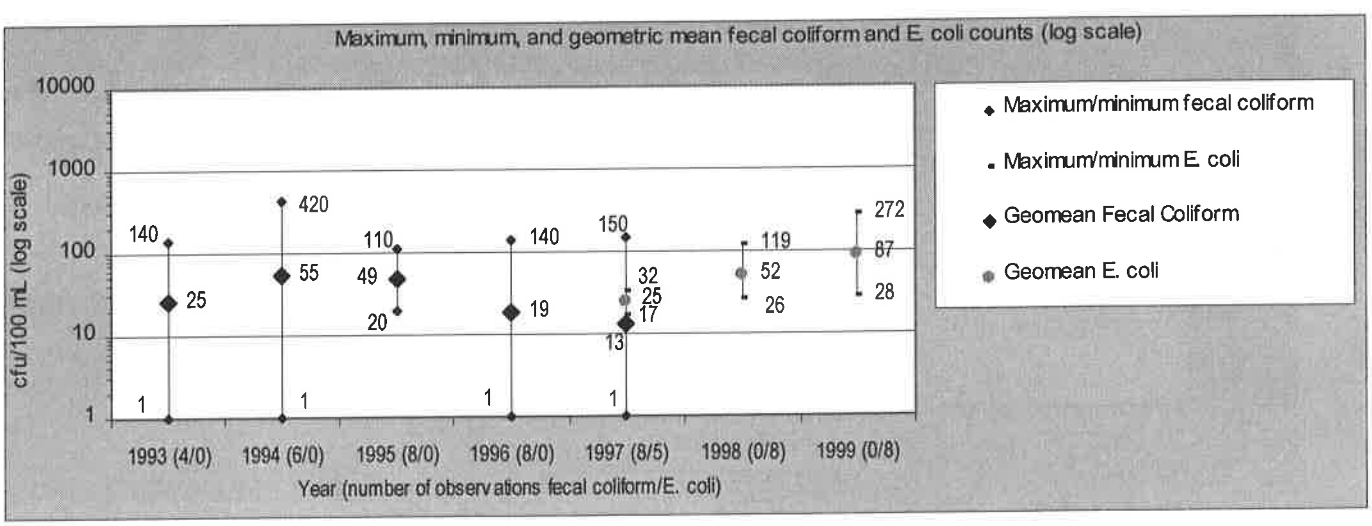
Monitoring Sites in the Chandler Brook Subwatershed

Alison Barker checking water temperature

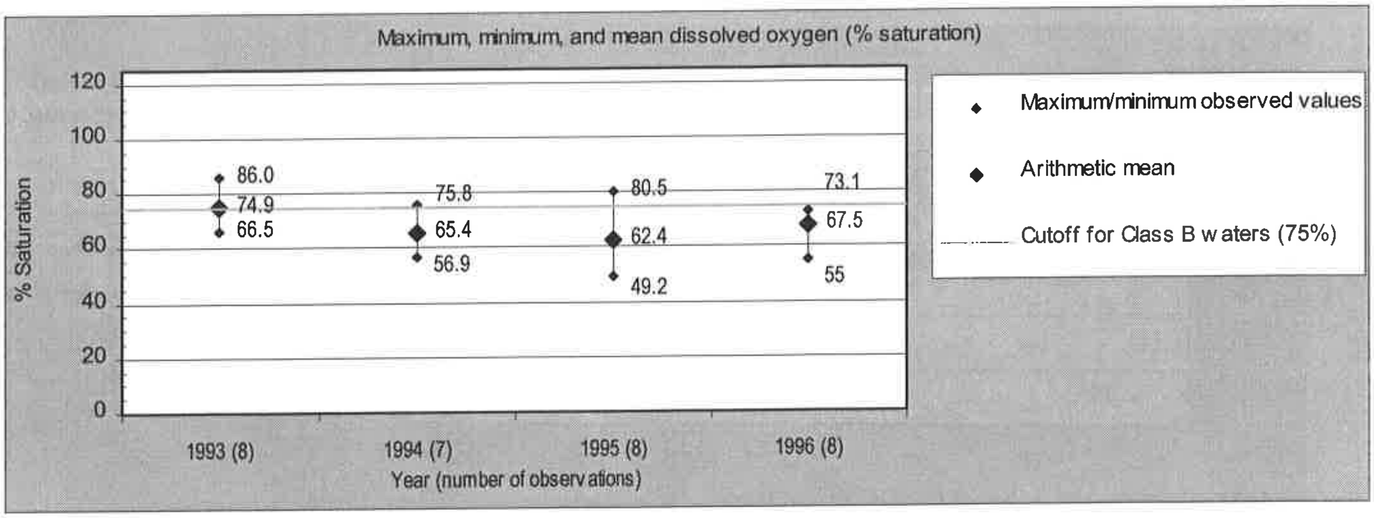
Site ChB13.6 (Chandler Brook, in Chandler Brook Subwatershed)

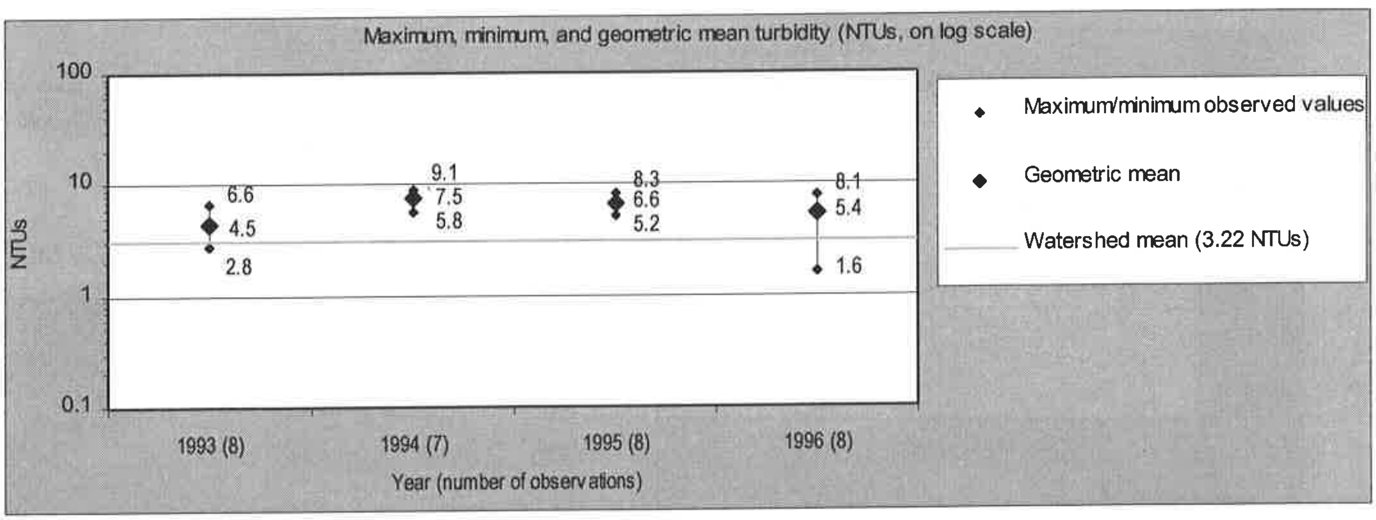


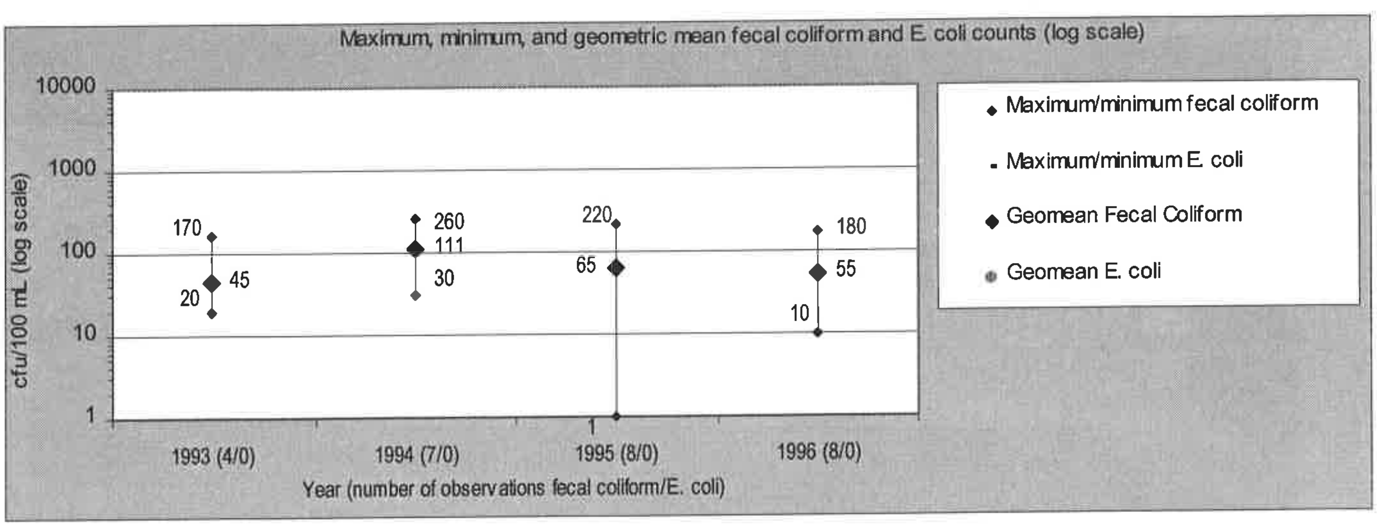




Site ChB14.7 (Chandler Brook, in Chandler Brook Subwatershed)







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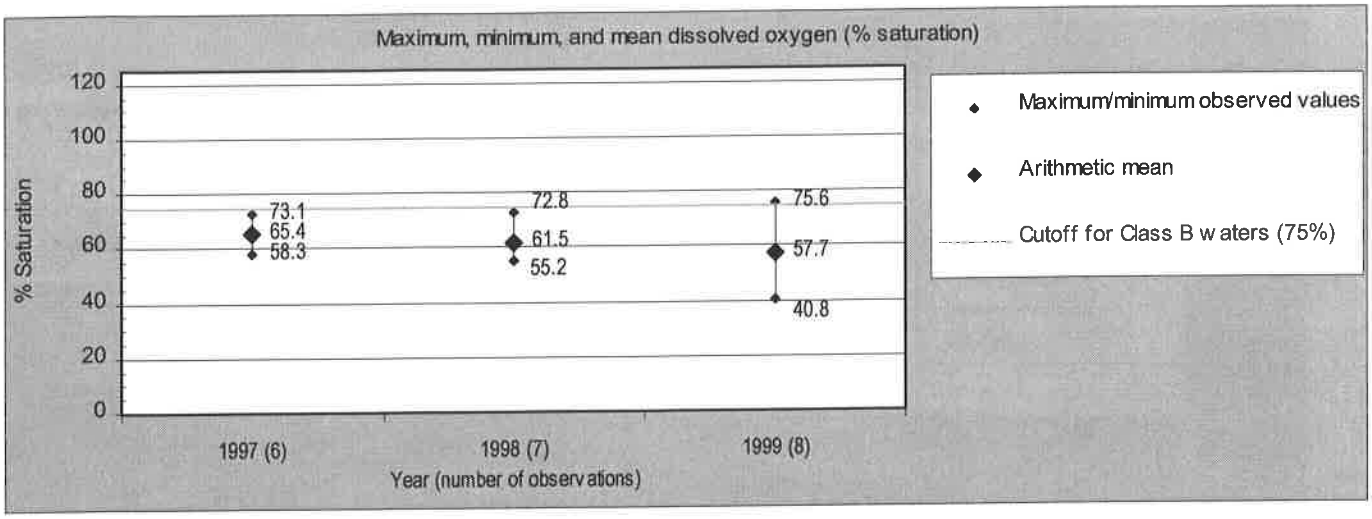

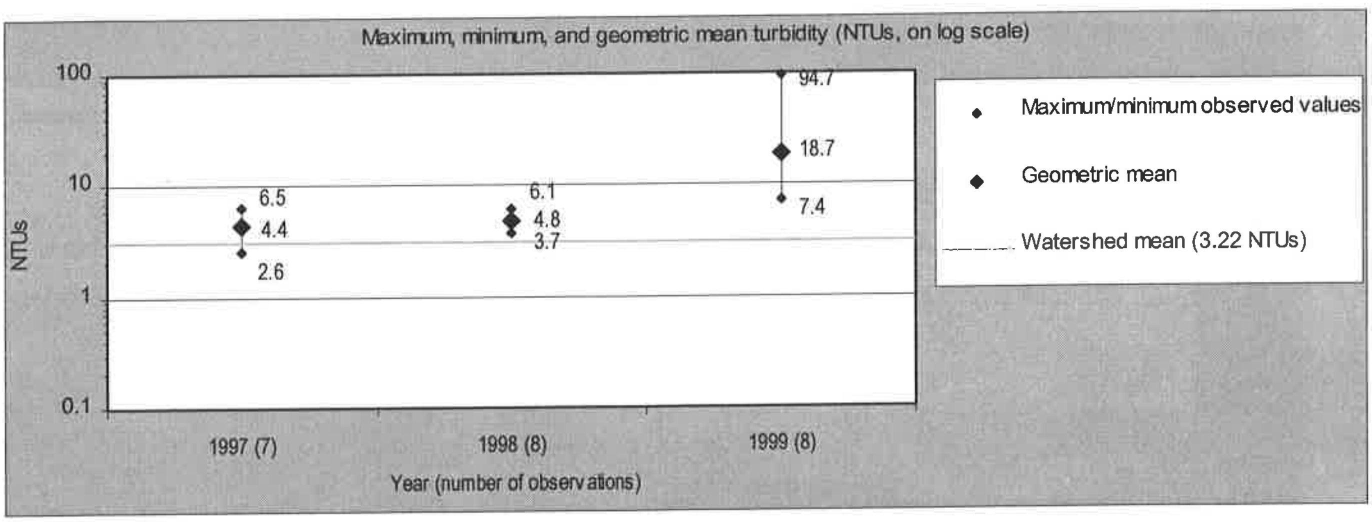

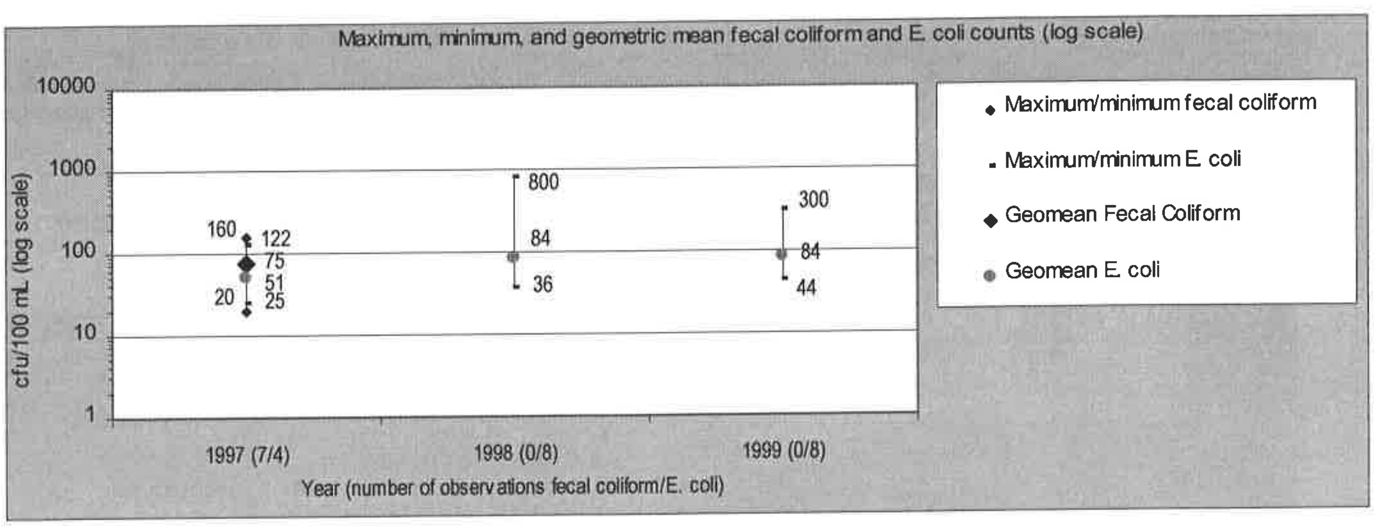

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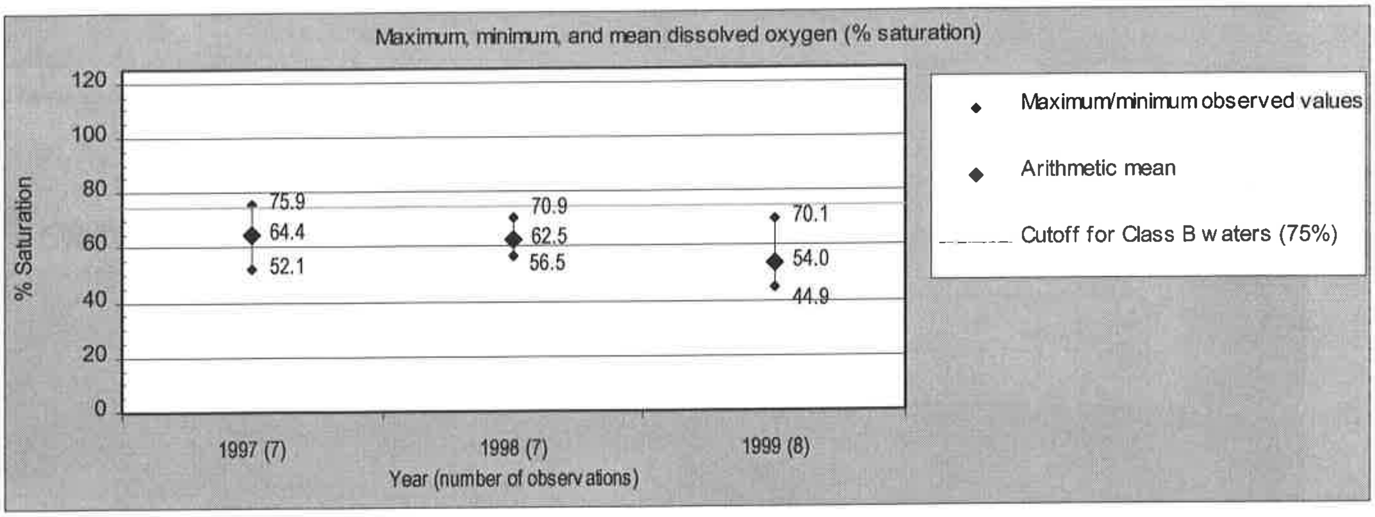

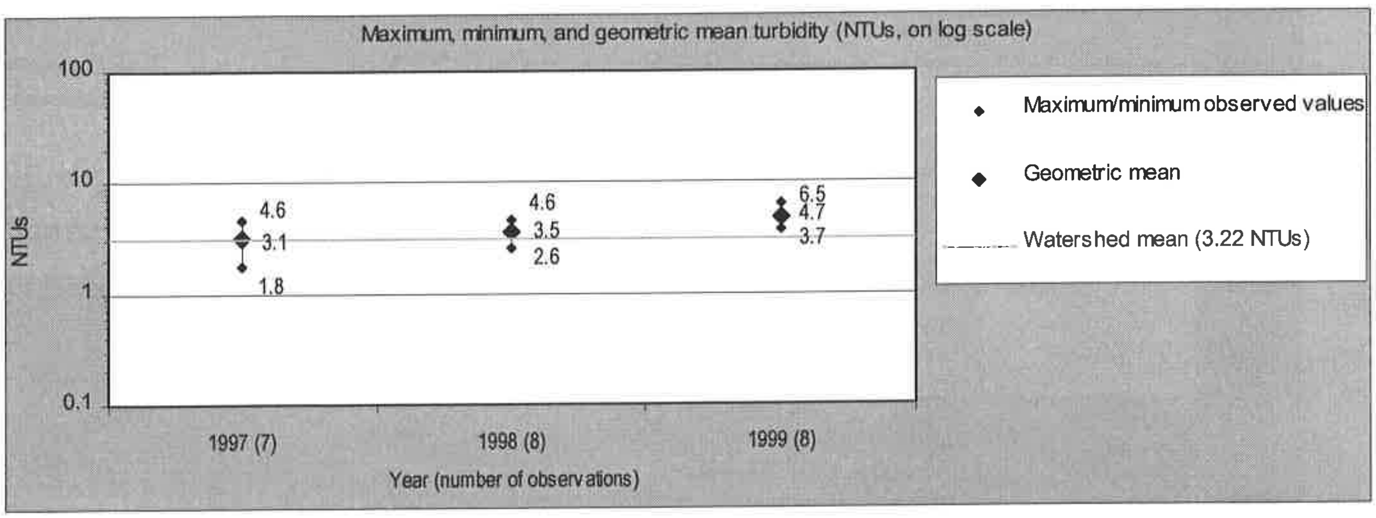

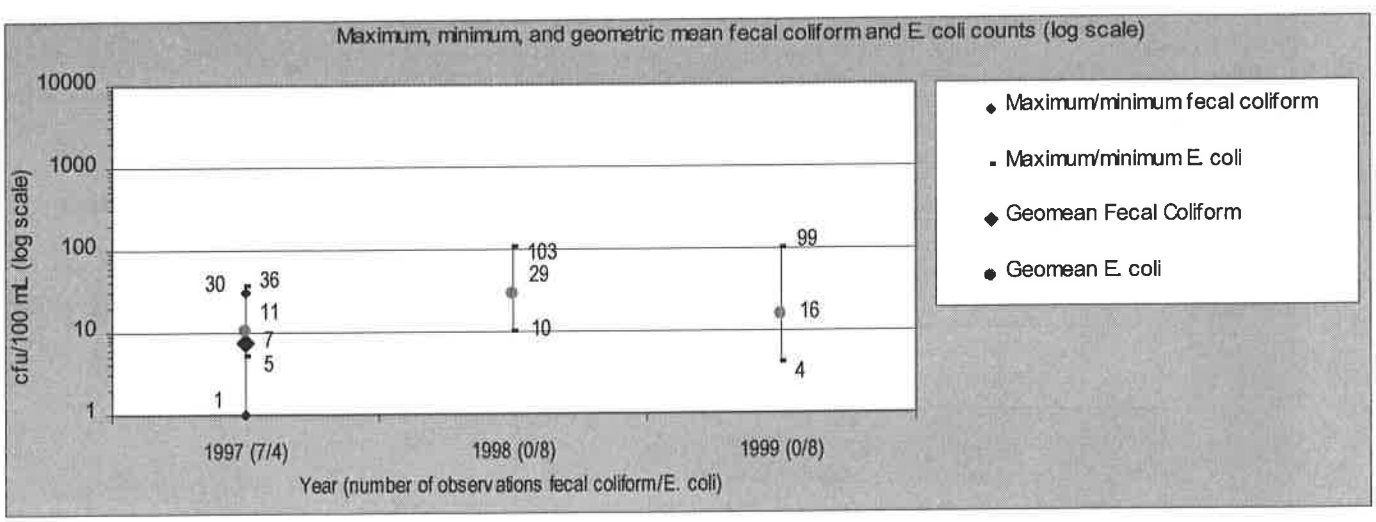

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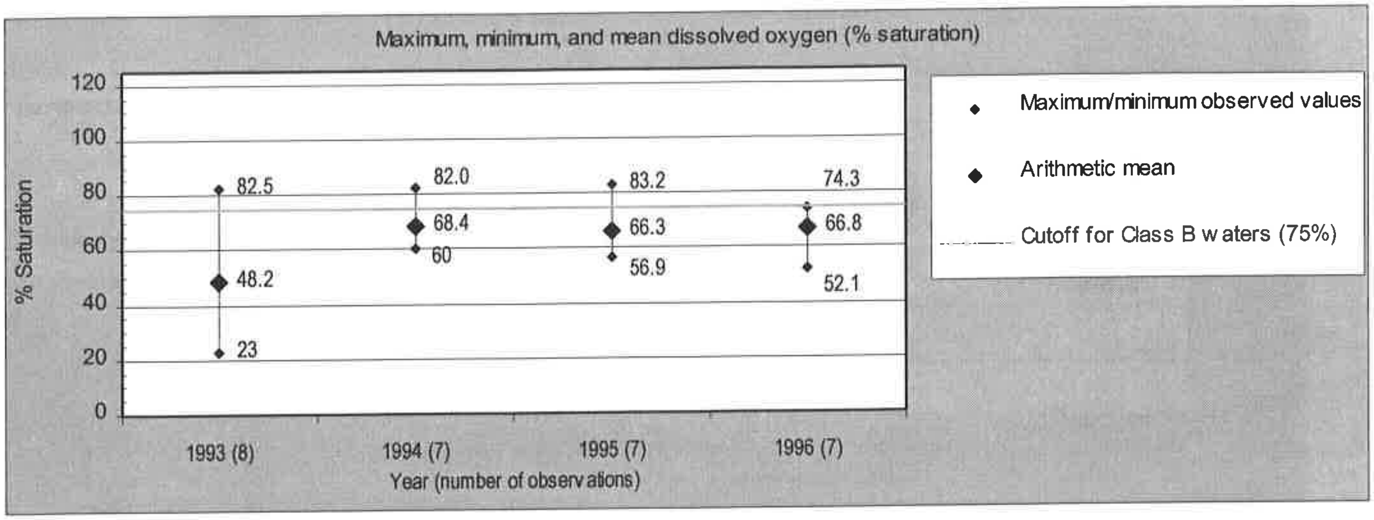

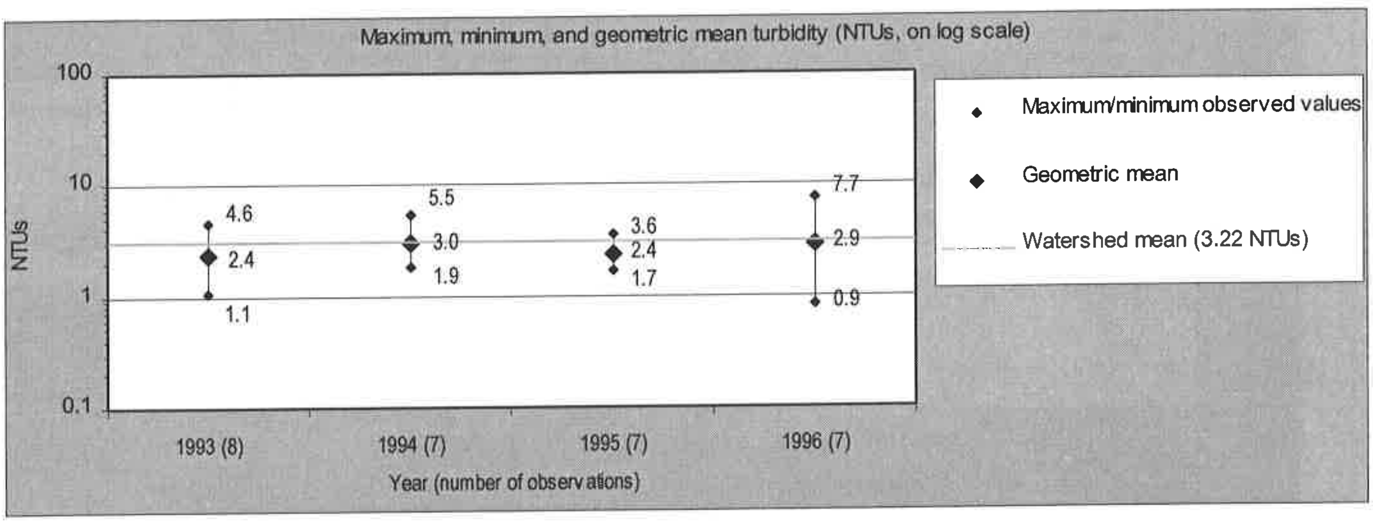

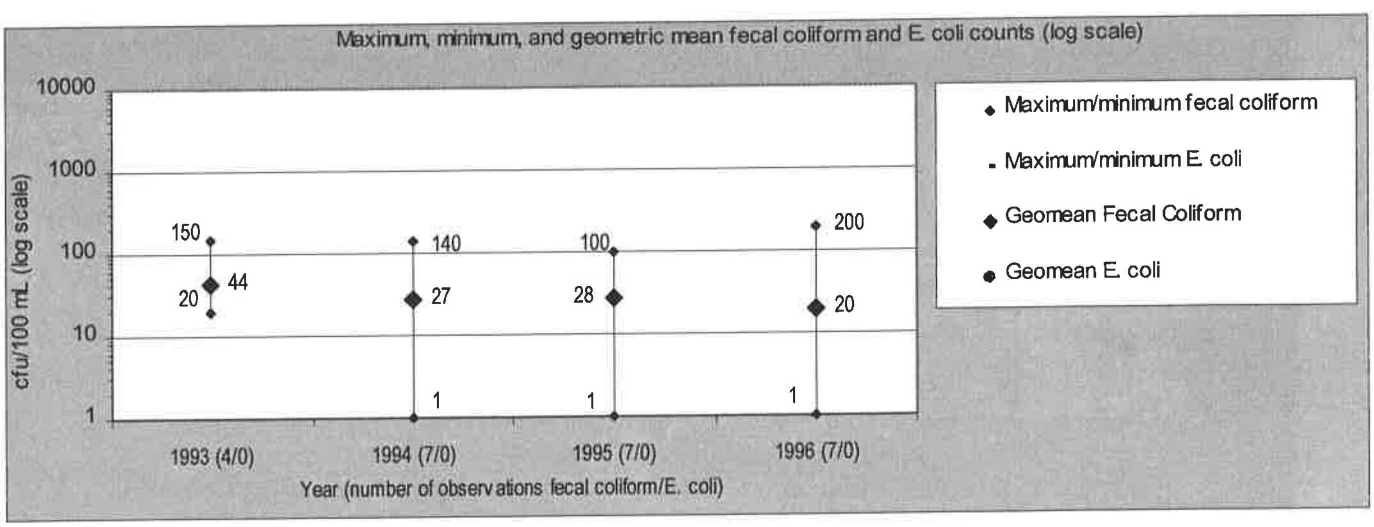

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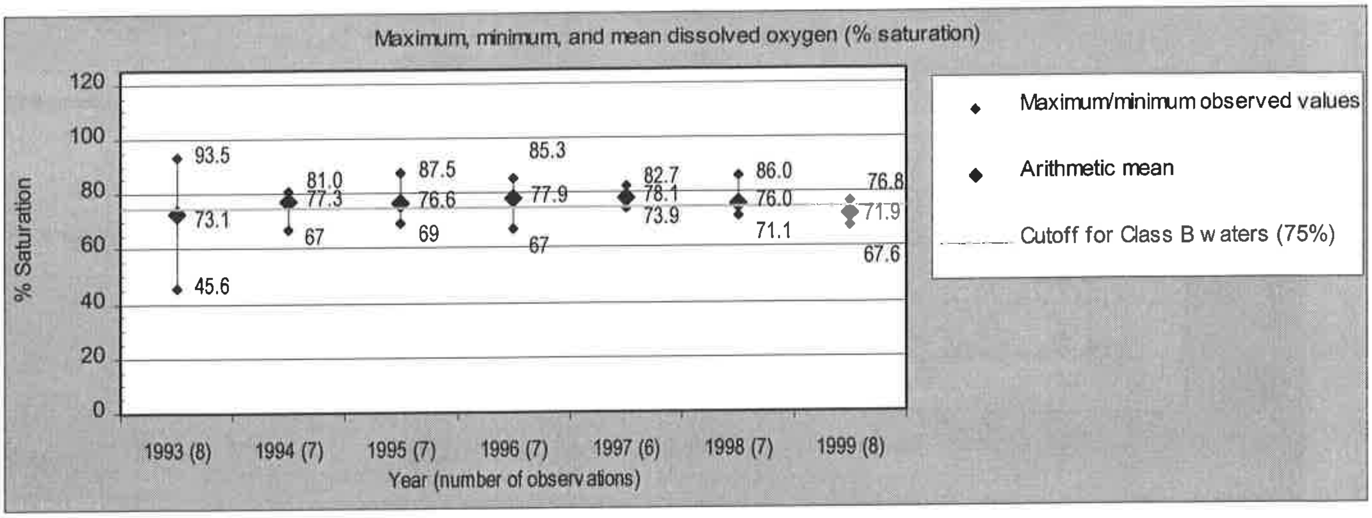
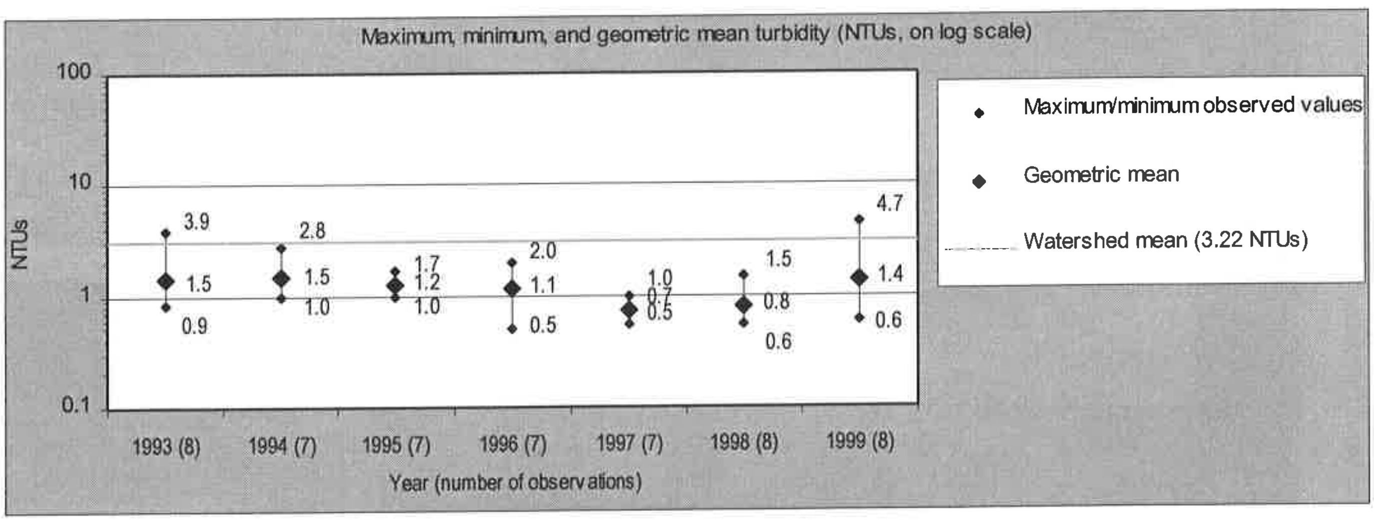
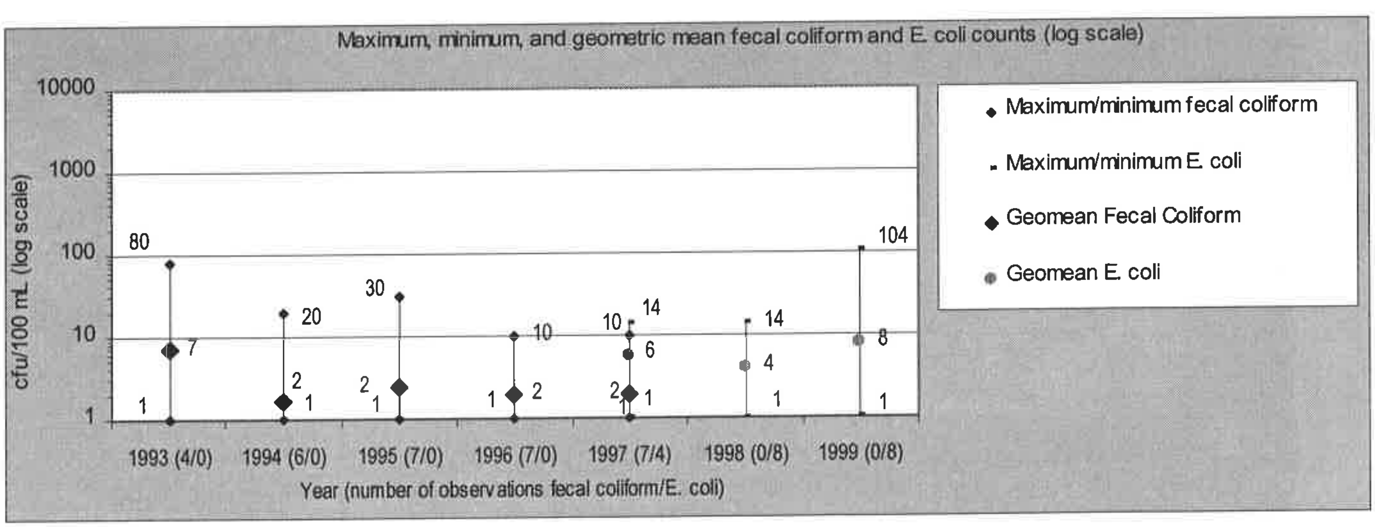
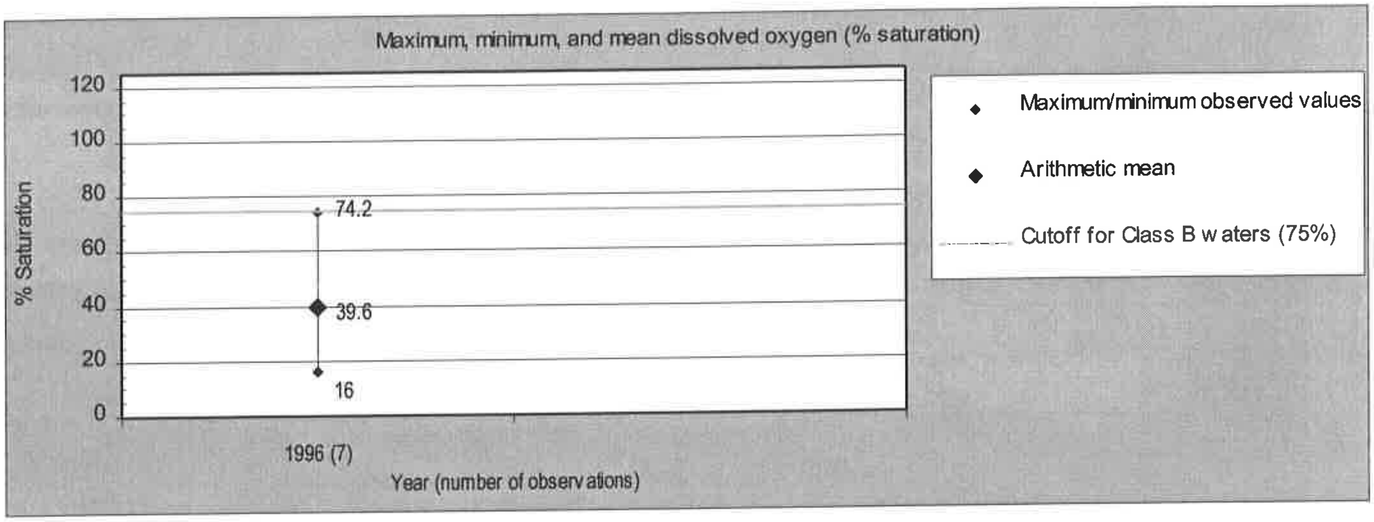
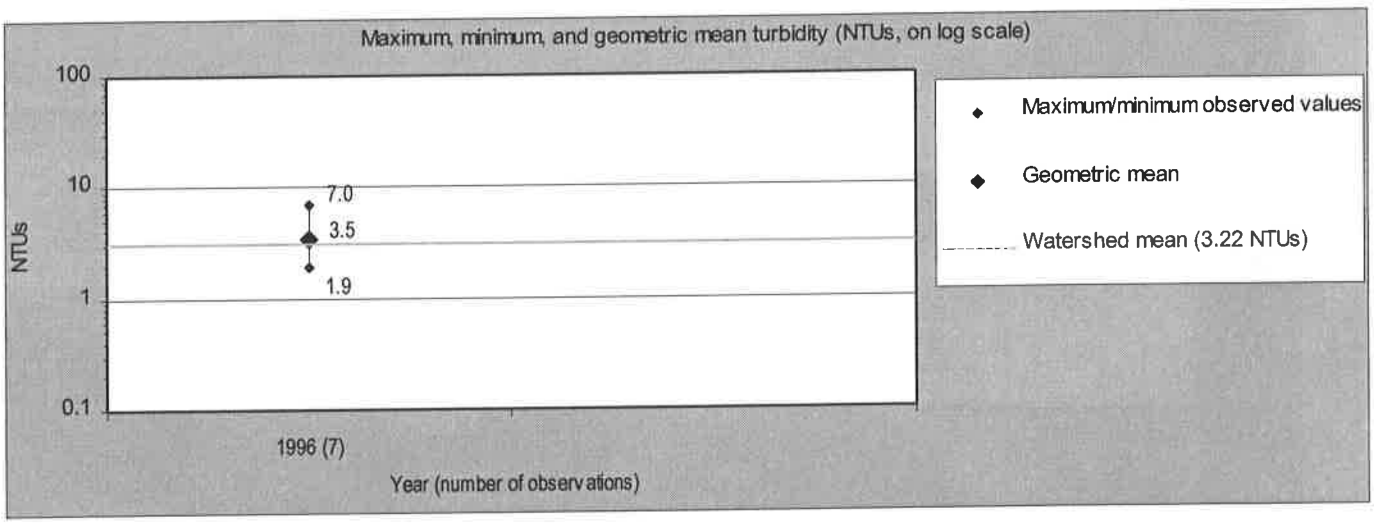


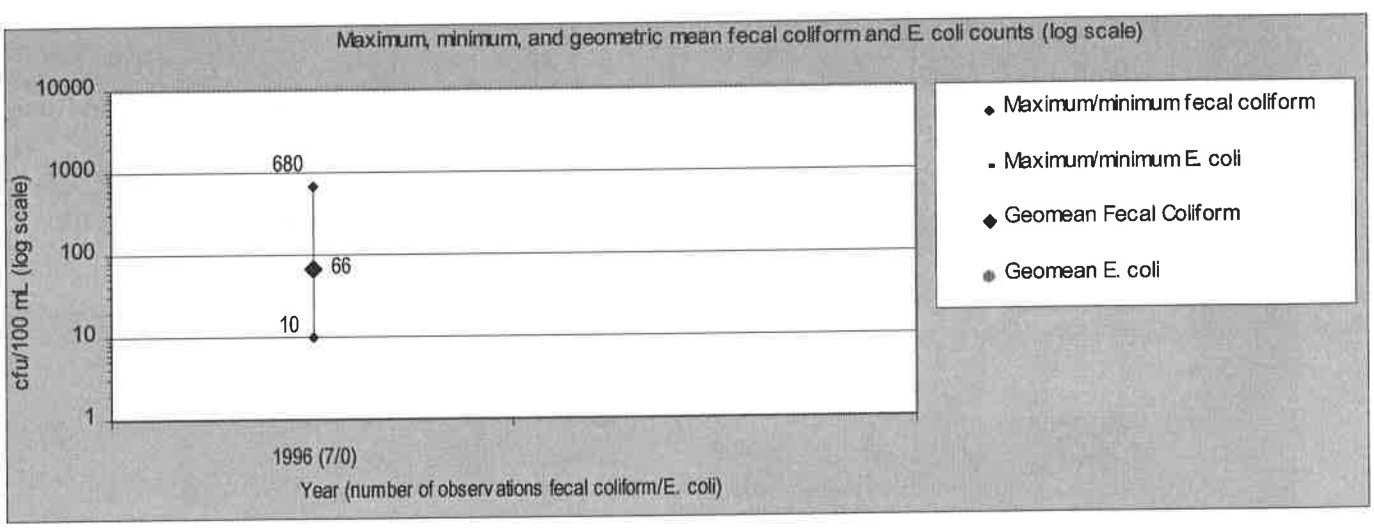




Site RuP22.3 (Runaround Pond, in Chandler Brook Subwatershed)







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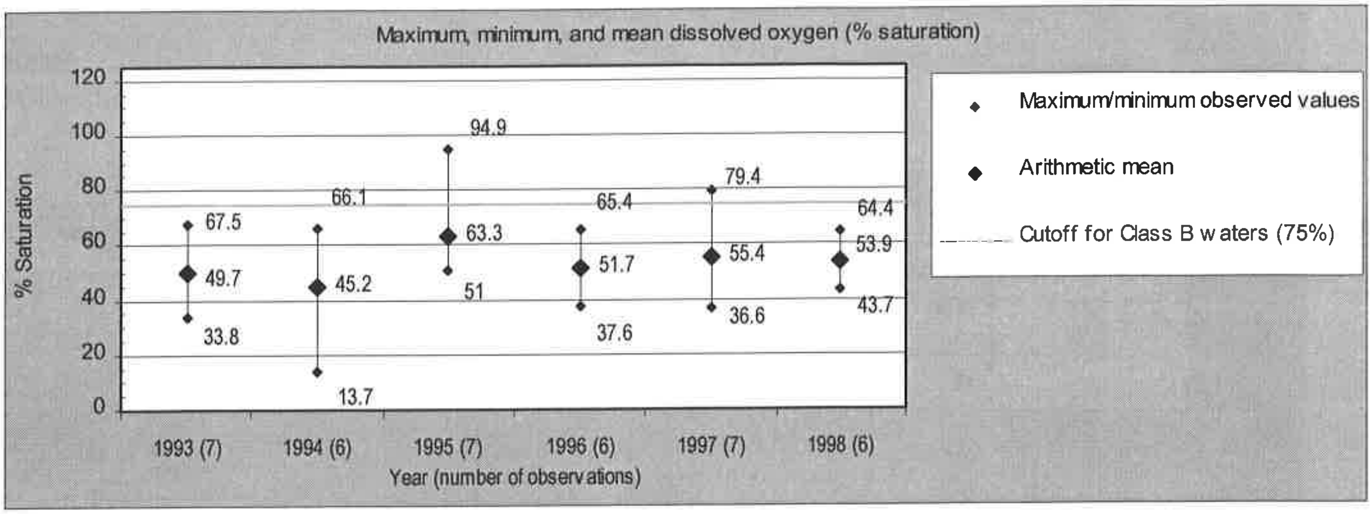
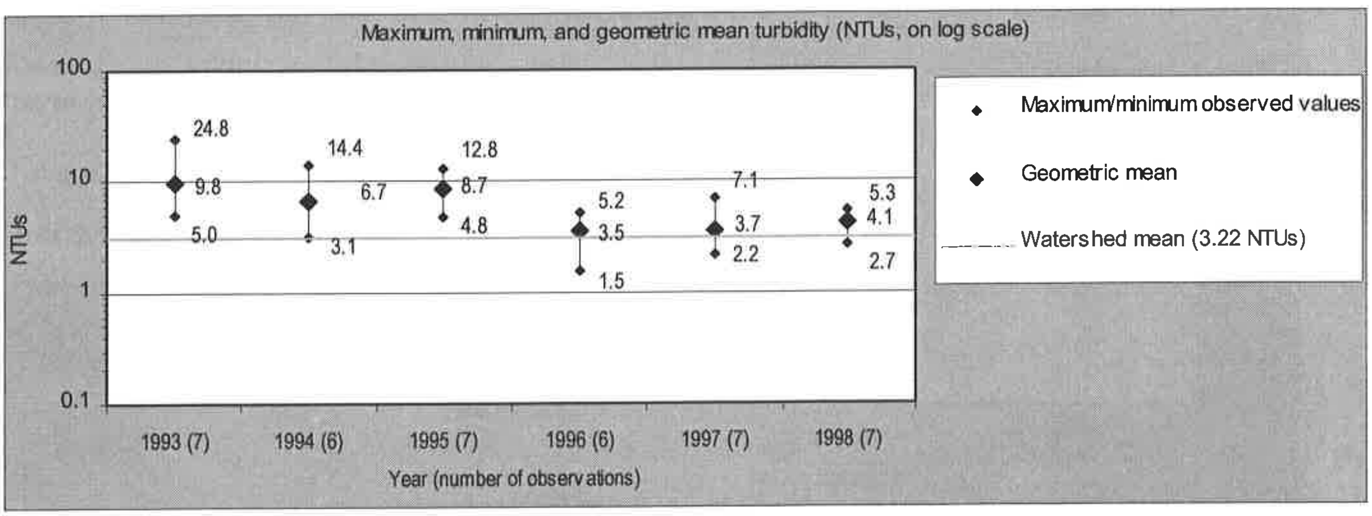
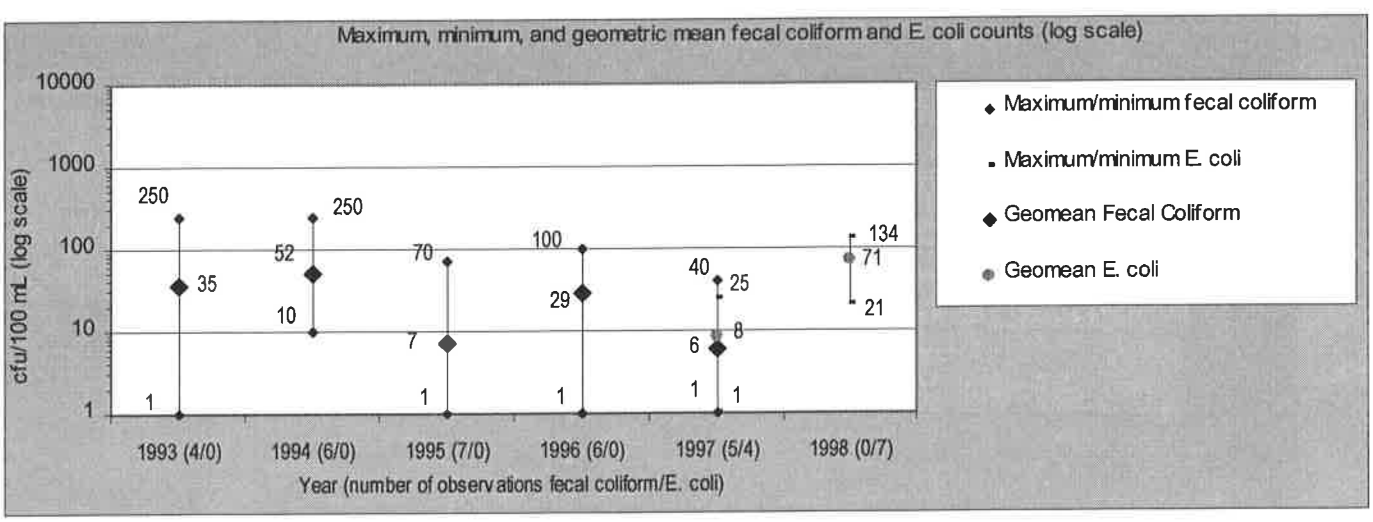




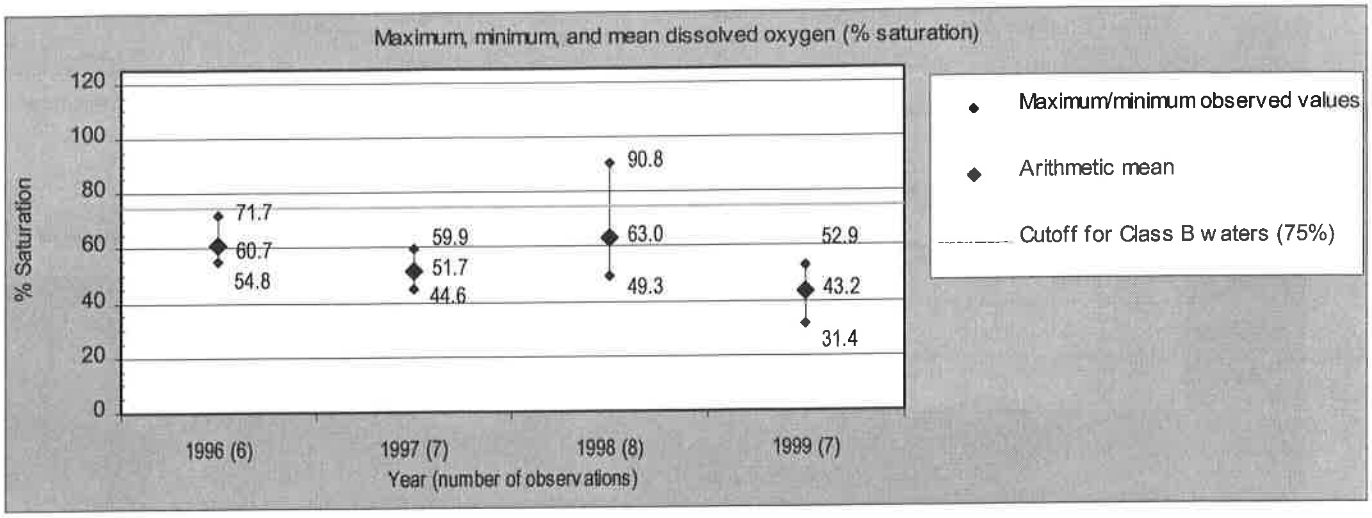


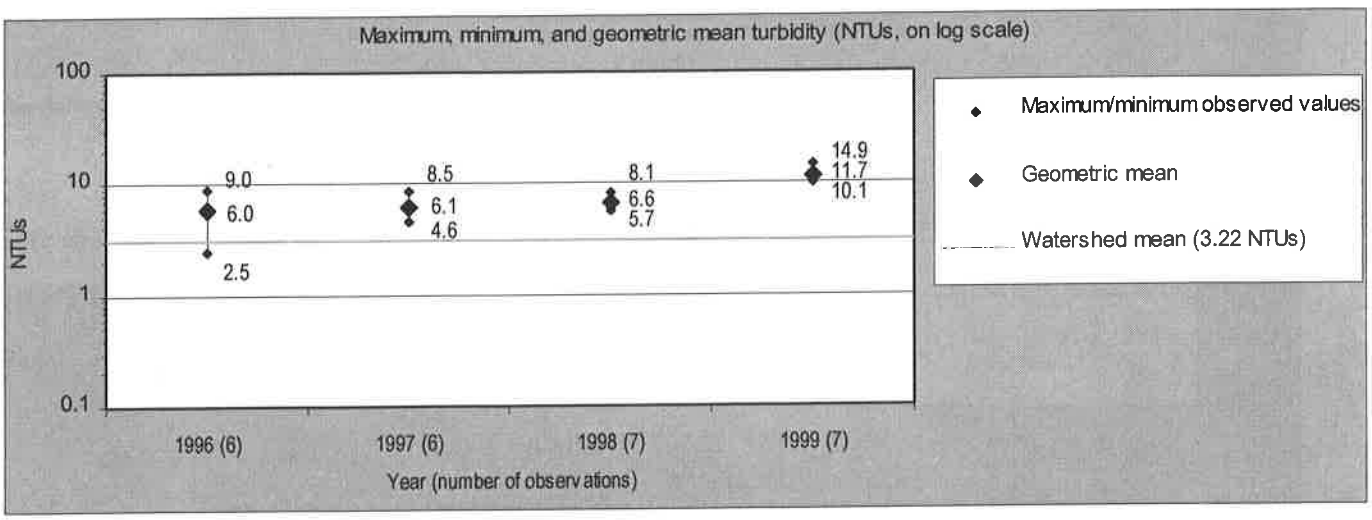
Appendix I

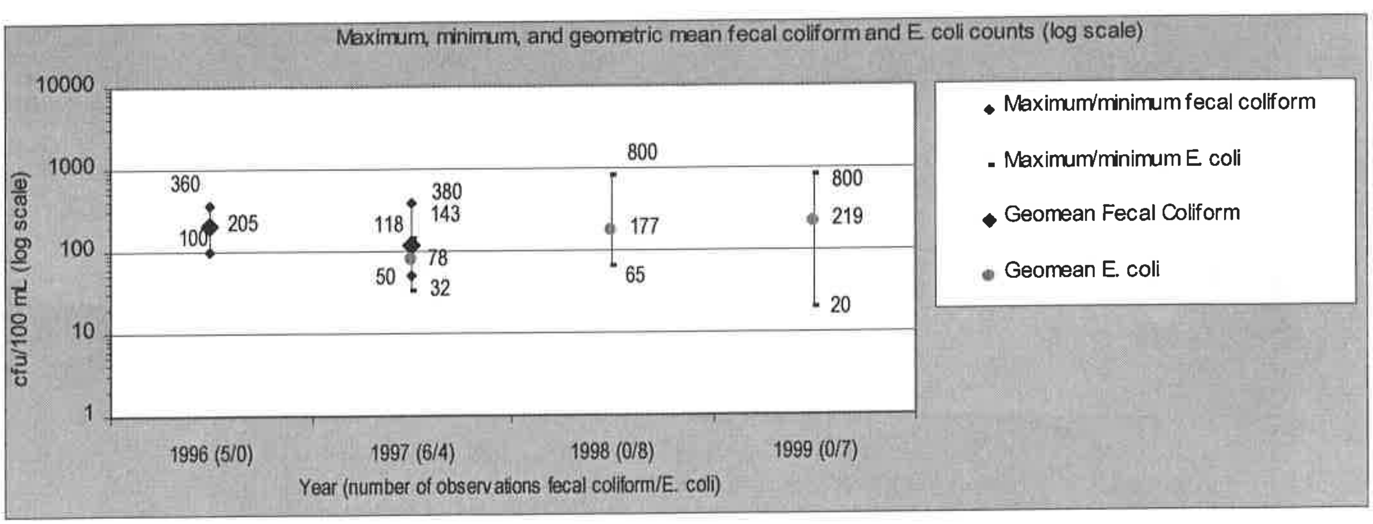
Monitoring Sites in the East Branch Chandler Brook Subwatershed

Dan Emery and friend enjoying some perfect ice

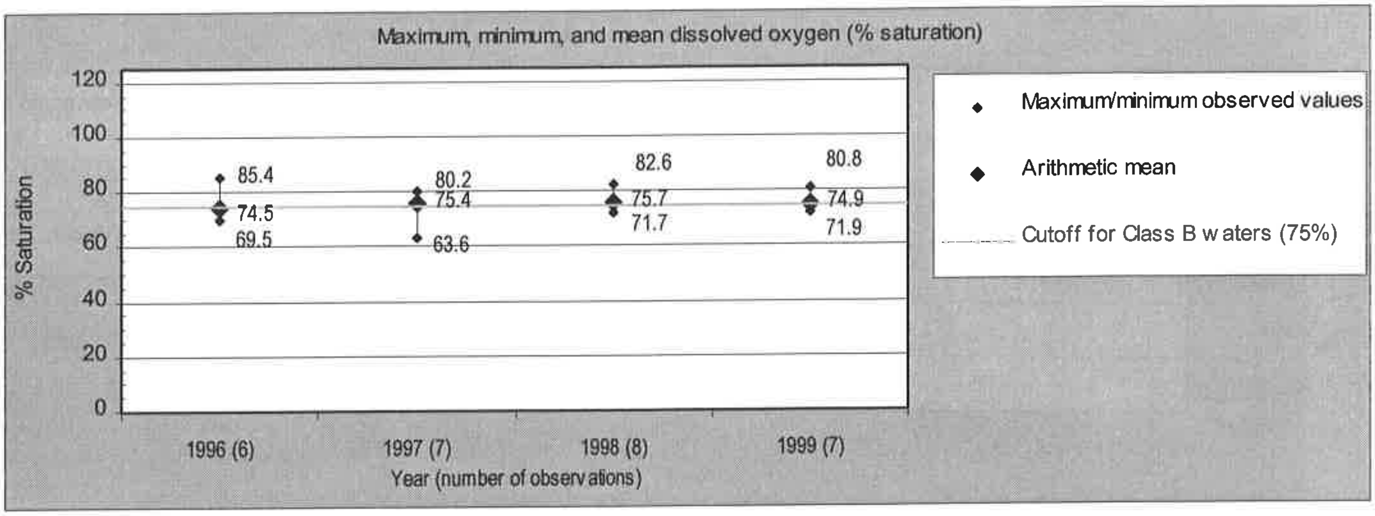
Site CnB20.4 (Collins Brook, in East Branch Chandler Brook Subwatershed)

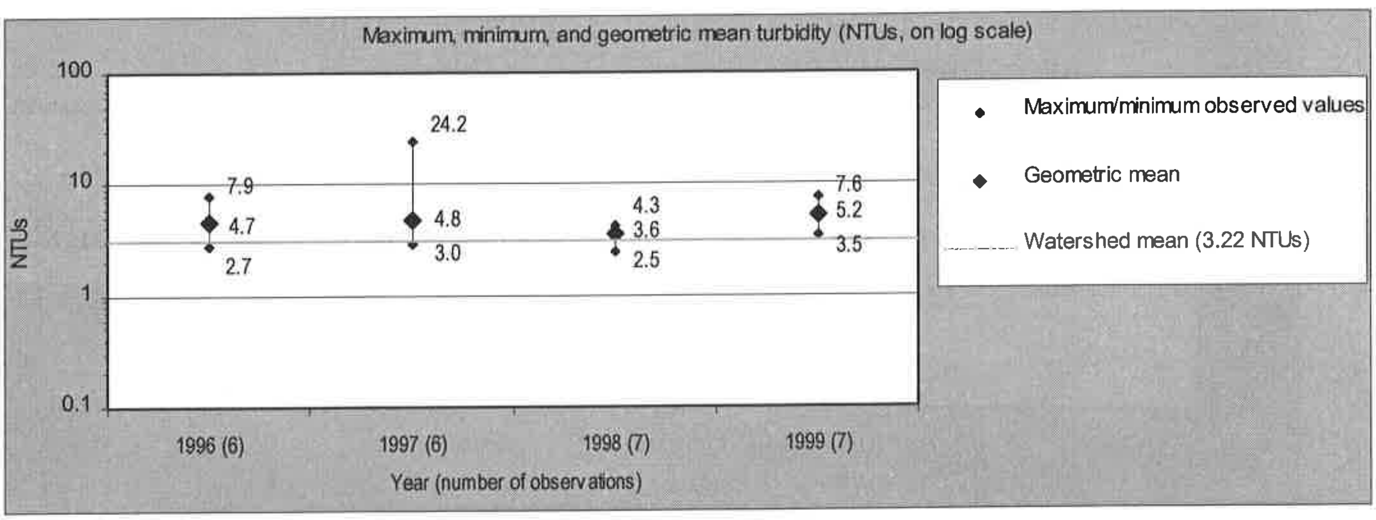


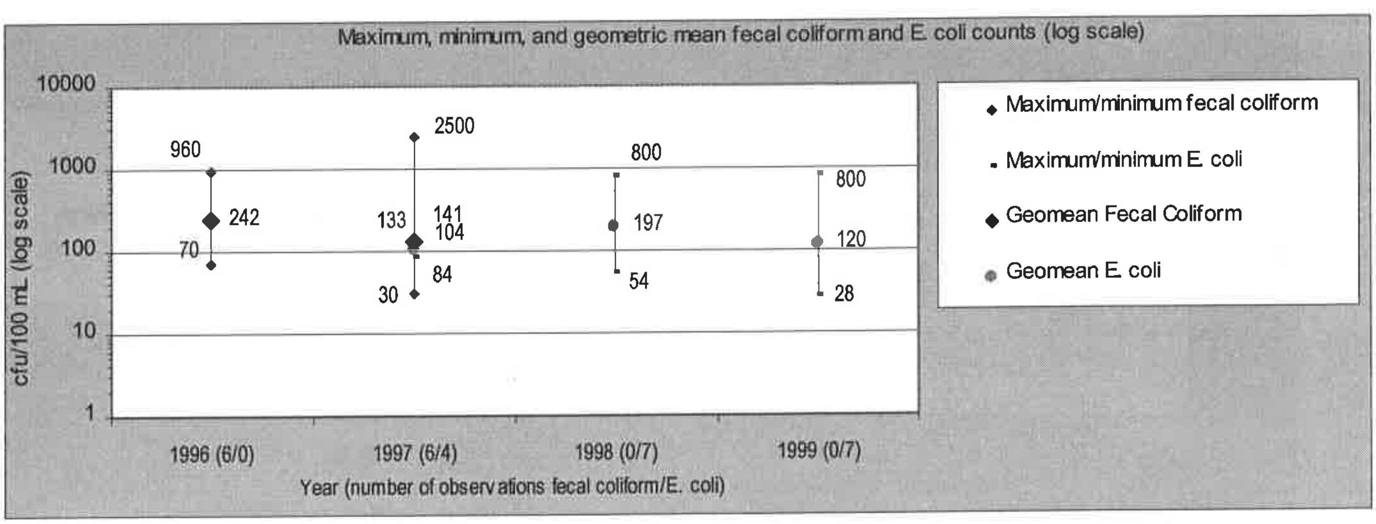




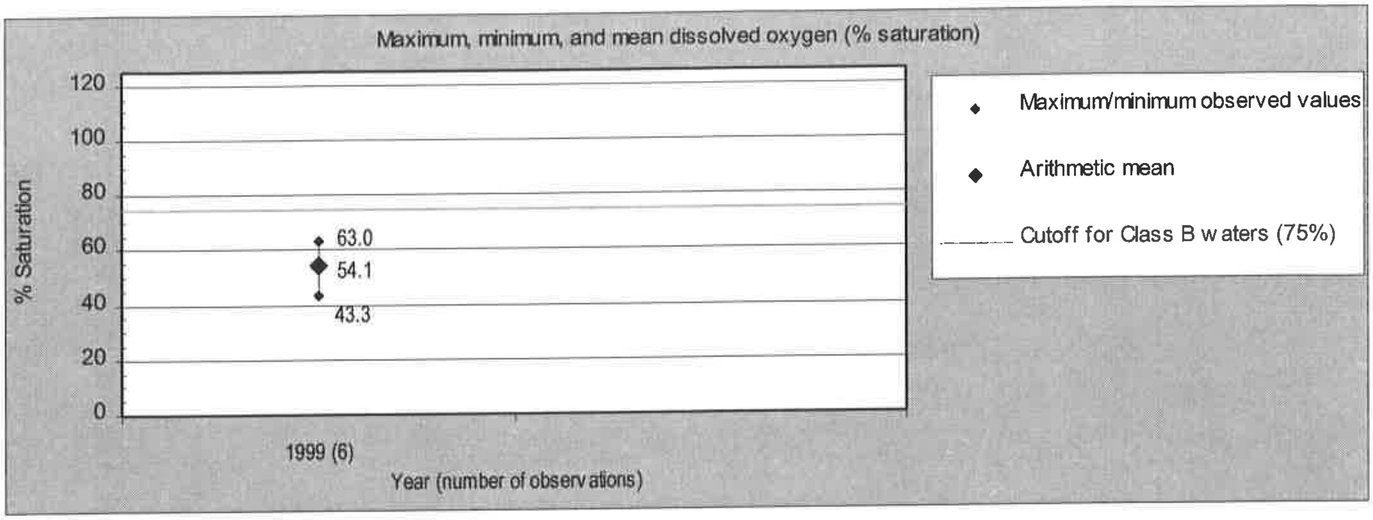
Site EBr20.4 (East Branch Chandler Brook, in East Branch Chandler Brook Subwatershed)

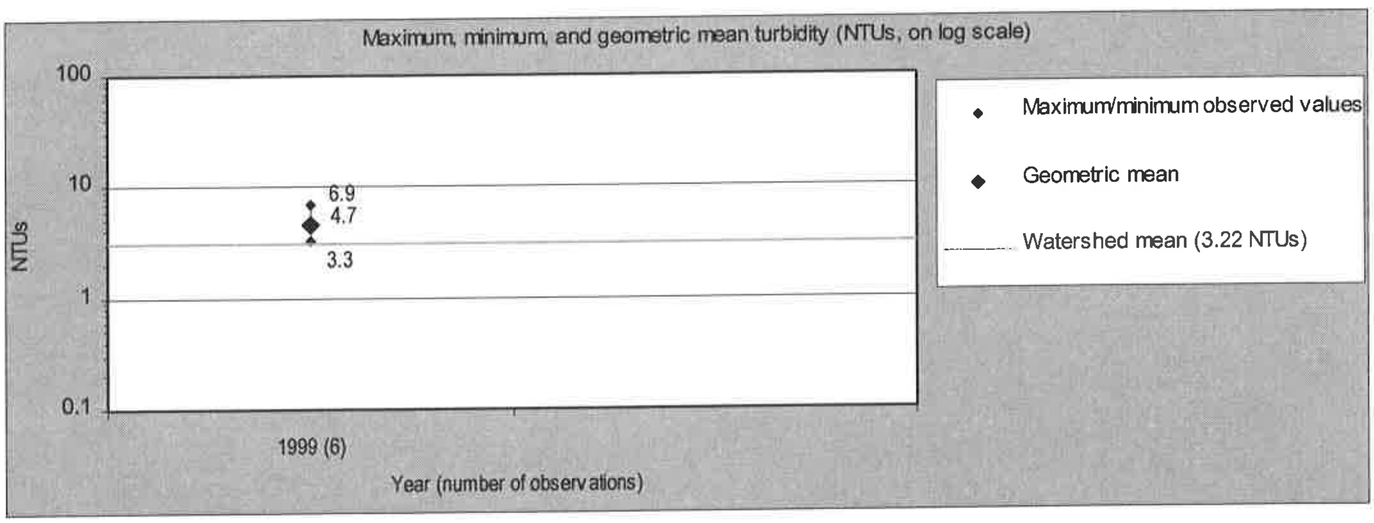


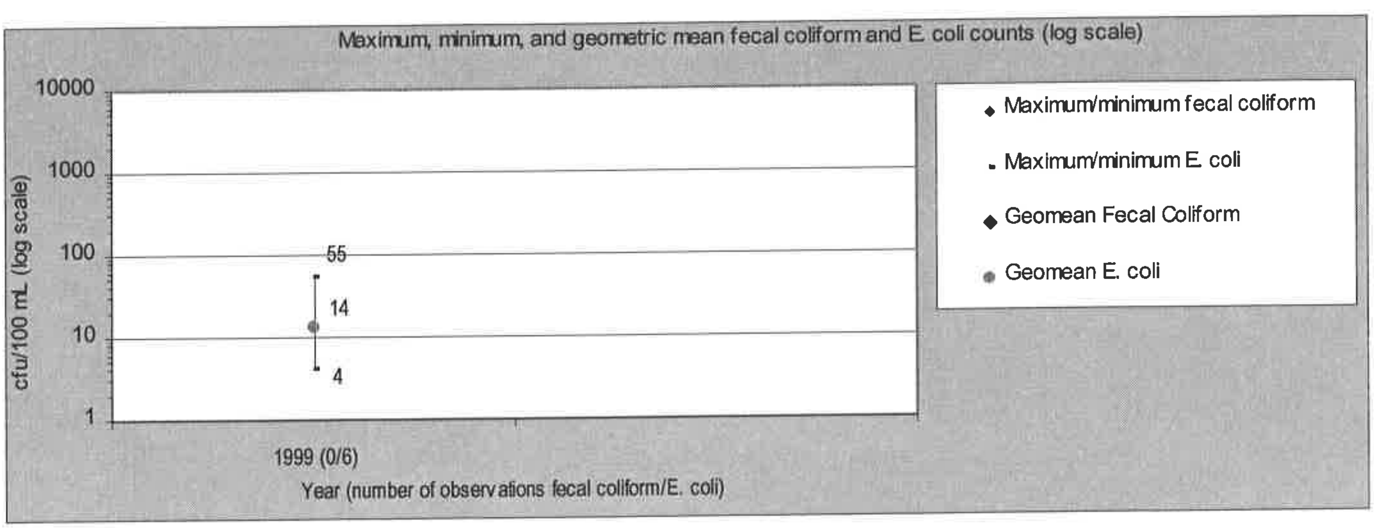




Site ThB15.8 (Thoits Brook, in East Branch Chandler Brook Subwatershed)







Appendix J - Glossary

Algae: Small simple chlorophyll-containing plants without roots, that grow in water. Blue-green algae are typically found in water with high concentrations of phosphorus.

Anthropogenic: Change brought about by actions of human beings.

Arithmetic mean: The average of all values in a data set computed as the sum of all values divided by the total number of values.

Basin (drainage basin): The area drained by a given river, also called a watershed.

Best Management Practices (BMPs): Techniques to reduce nonpoint-source impacts from construction, agriculture, timber harvesting, marinas, and stormwater. Manuals describing these techniques have been developed.

Buffer (vegetated buffer): Areas of vegetation that are left undisturbed or are planted between a developed area and a body of water to minimize the potential adverse effect of land use on water quality. Buffer vegetation can include trees, shrubs, bushes, and ground cover plants.

Colony Forming Unit (cfu): A bacterial colony that grows when a sample of surface water incubates under specific lab conditions. The number of cfu's counted after a specific amount of time is indicative of the amount of bacteria in the original water sample.

Dissolved Oxygen (DO): Oxygen dissolved in the water is essential for all plants and animals living in the water. DO is the measurement of the amount of oxygen in the water that is available for plant and animals to utilize. The amount of DO is used as an indicator of water quality and the level of life that the water can support.

E. coli (Escherichia coli): A specific type of fecal coliform bacteria which has been reliable in indicating the risk of illness in humans from water contact.

Estuary: A semi-enclosed body of water, which is the consequence of freshwater flowing into and mixing with tidal influxes of saltwater. This typically occurs where the lower part of a river meets and mixes with sea water.

Erosion: Wearing away of rock and soil by the gradual detachment of soil and rock fragments caused by water, wind, ice, and other mechanical and chemical forces. Human activities may greatly speed this detachment.

Erosion controls: Physical measures installed prior to and through the duration of filling or grading activities in order to prevent soil erosion. A silt fence is an example of an erosion control; it is a physical barrier installed along the perimeter of an earth moving activity. Water can pass through the fence but soil cannot. Hay mulch is another example; when spread over the soil it prevents rainwater from eroding the soil.

Fecal coliform bacteria: A type of bacteria found in the digestive tracts of warm-blooded animals. The presence of fecal coliform bacteria in a water sample indicates that there has been a recent contamination event but does not necessarily indicate that disease-causing organisms are present.

Geometric mean: The average of all the values in a log-normally distributed data set. Computed as the inverse natural logarithm of the sum of all natural log-transformed data divided by the number of samples.

GIS (Geographical Information System): A computerized system that allows users see their data distributed geographically by blending digital maps with databases and then generating color coded maps of the information being analyzed.

Habitat: A place used by plants and animals to live, feed, find shelter and reproduce.

Impervious Surface: A surface, such as a roof or pavement, that cannot be easily penetrated by water. A hard surface that either prevents or retards the entry of water into the soil as it would under natural conditions prior to development and/or a hard surface area that causes water to run off the surface in greater quantities and at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include but are not limited to rooftops, walkways, patios, driveways, parking lots, storage areas, concrete or asphalt paving, and gravel roads.

Log normal distribution: A curve on a graph whose x-coordinates increase by a constant value while the y-coordinates increase by factors of 10.

Macroinvertbrate: Animals without backbones which can be seen with the naked eye, specifically aquatic species which are used as a food source by larger vertebrates such as fish. These include insect larvae, snails worms etc.

Management Options: Suggestions and/or strategies for citizens, municipalities, agencies or other groups to consider for the preservation and protection of a watershed.

Mean (arithmetic mean): The average of all values in a data set computed as the sum of all values divided by the total number of values.

Median: The middle value of a group of numbers that have been ordered from lowest to highest.

Monitoring (water quality monitoring): Assessing the condition of a water body over time by the collection of physical, chemical, or biological information.

Mulch: A layer of hay or other material covering the land surface that holds soil in place to prevent it from eroding. It aids in the establishment of vegetation by holding the soil in place, conserving moisture, and minimizing temperature fluctuations.

Nonpoint Source Pollution (NPS): An indirect discharge, not from a pipe or other specific source but from a broad area, usually as a result of storm water runoff.

Nitrogen: An element found throughout the environment. A nutrient required for plant growth, often present in limited supply in the ocean during growth season. Nitrogen is present as organic nitrogen or in the inorganic forms of ammonia, nitrite, and nitrate. The inorganic forms are available to marine plants, while most other forms of organic nitrogen must be broken down by bacteria before they can be used for plant growth.

NTU: Nephelometric Turbidity Units. The units used to measure the turbidity of a sample of water. The units are based on measuring the amount of light that is scattered when a beam of light is passed through a certain volume of water.

Nutrients: Any substance required by plants and animals for normal growth and maintenance. Enriched nutrient loads of nitrogen and phosphorous from land runoff, sewage, septic systems, and atmospheric deposition can result in excessive growth of algae and lead to degradation of water quality.

Organic: Anything matter that originated from something that was once alive.

Parameter: One of a set of measurable factors that may be variable and helps define a system.

Pathogen: An agent such as a virus, bacterium, or fungus that can cause diseases in humans.

Phosphorus: An element found throughout the environment. It is a nutrient essential to all living organisms. Phosphorus binds to soil particles and is found in fertilizers, sewage, and motor oil, and in high concentrations in storm water runoff. The amount of phosphorus present in a lake determines the lake's production of algae. A very small change in phosphorus levels can dramatically increase algal growth.

Point Source of Pollution: Any confined and discrete conveyance (usually a pipe) from which pollutants are or may be discharged into a body of water.

Polluted Runoff: Runoff that has picked up contaminants or nutrients from the landscape (or air) as it flows over the surface of the land to a water body.

Remediation: Treatment of contaminated sediments so that the sediments are no longer toxic.

Riparian: Located or living along or near a stream, river, or body of water.

Runoff: Water that drains or flows off the surface of the land.

Sediment: Mineral and organic soil material that is transported in suspension by wind or flowing water, from its origin to another location.

Septic System: An individual sewage treatment system that typically includes a septic tank and leach field that are buried in the ground. The septic tank allows sludge to settle to the bottom and a scum of fats, greases, and other lightweight materials to rise to the top. The remaining liquid flows to the leach field where it is dispersed through soil in order to reduce the number of bacteria and viruses.

Stormwater runoff: Runoff of water from rain or snow storms.

Subwatershed: A small watershed that nests inside of a larger watershed

Tributaries: Smaller streams or rivers that flow to a larger body of water.

Turbidity: The reduced clarity of water caused by the presence of suspended matter.

Vegetated Buffer: Areas of vegetation that are left undisturbed or are planted between a developed area and a body of water to minimize the potential adverse effect of land use on water quality. Buffer vegetation can include trees, shrubs, bushes, and ground cover plants.

Water Quality: Pertaining to the ability of water to support life and the presence and amount of pollutants in water. The quality of water is measured in terms of its physical, chemical and biological characteristics.

Watershed: The geographic region within which water drains into a particular river, stream, or body of water. A watershed includes hills, lowlands, and the body of water into which the land drains. Watershed boundaries are defined by the ridges of land separating watersheds.

Watershed Management: The long-term management of the watershed through phases of assessment, planning, implementation and evaluation. Through these phases education plays a major role in reaching set goals.

Watershed Survey: A qualitative and quantitative process of determining the extent of pollution in a watershed by identifying existing non-point sources of pollution and inspecting the point sources of pollution.

Wetlands: Low lying areas inundated or saturated by water at a frequency and duration sufficient to support wetland vegetation. Wetlands can be swamps, marshes, bogs, wet meadows, etc. Some of their valuable functions include holding runoff, and removing pollutants through a series of chemical, physical, and biological mechanisms.

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