Annapolis River Guardians
Volunteer Water Quality Monitoring Program
2002 – 2003 Annual Report

Matt Dill
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Acknowledgements

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Introduction

History

The Annapolis River Guardians volunteer monitoring program began collecting water quality data in the Annapolis River watershed in 1992. The Clean Annapolis River Project (CARP) started the program as a Public Awareness Project, and has had numerous volunteers test for a variety of parameters over the years. It is one of the longest running and most extensive volunteer based water quality programs in Eastern Canada. It is also CARP's only on-going project. At least 200 volunteers from the Annapolis Watershed community have participated in the program to date and over 3200 samples have been analyzed for at least one water quality parameter.

The program was initiated in the early 1990's by Dr. Graham Daborn and Dr. Mike Brylinsky of the Acadia Centre for Estuarine Research. Many groups were involved in the planning process for the program, including staff with the Nova Scotia Department of Health, the Nova Scotia Department of Environment, College of Geographical Sciences, and CARP. The hope was a program that delivered a consistent set of data, was financially reasonable, and tested an informative set of parameters could be achieved. Although the program has undergone slight changes over the last ten years, the basics remain the same, and the Annapolis River Guardians Program is still going strong.

Program Objectives

The Annapolis River Guardians Program has four objectives:

- To establish and support a regular observation system which will provide an early warning of environmental problems;
- To provide a long term record of the river's health;
- To develop interest in the Annapolis River and community stewardship to ensure a viable resource for future generations;
- To provide a knowledgeable group of local individuals who can promote the preservation, rehabilitation, and use of these estuarine resources in the future.

Program Scope

The program design called for 11 sites that were monitored by 17 volunteers. Initial response from the community was great and the project was significantly expanded between 1992 and 1994. In 1994, 38 sites were monitored by 43 River Guardians from 36 households (Pittman et al 2001). The enthusiasm has since faded, although a core group of dedicated volunteers still exists. Ten sites were sampled in 2002, with 15 volunteers involved in the program. The parameters that have been tested over the duration of the program are listed below. All the sites the River Guardians have sampled are also listed, with the ten current sites in bold font.

Parameters Tested

The River Guardians currently test these water quality parameters:
Fecal coliform densities (*Escherichia Coli*)
Dissolved Oxygen
Suspended Particulate Matter (Total Suspended Solids)
Temperature
Weather conditions
Colour

Parameters tested in the past, which have since been discontinued due to financial and logistical constraints are:

pH
conductivity
transparency
chlorophyll a
salinity

Sites Monitored

The following sites have been monitored at some point in the history of the Annapolis River Guardians Program. The ten sites that have consistently monitored are highlighted. These sites also have Global Positioning System coordinates given, in Universe Tranverse Mercators, as recorded on a hand-held GPS (Durland pers. comm. 2002).

SITE	LOCATION	Easting	Northing
A1	Aylesford East, Parker Road, bridge		
A21	Aylesford, Sun Valley Drive (by the Cranberry Farm)		
A22	Aylesford, Hwy 1, bridge over Patterson Brook		
00	**Aylesford, Victoria Road, bridge at the Post Office**	**353313.34**	**4985418.70**
01	Aylesford, Maple Ave. (bridge below Sewage Treatment Plant)		
A3	Millville, Bridge over South River		
A14	Auburn, Musgrave Road, bridge		
A5	Auburn, Sawmill, bridge		
A6	Greenwood, Hwy 201, (Glebe Road), bridge		
13	**Kingston, Bridge Street, bridge**	**346748.46**	**4982480.39**
14a	Kingston, Bridge St. bridge over Zeke Brook, below CFB Greenwood		

SITE	LOCATION	Easting	Northing
14b	Greenwood, hall Road culvert, above CFB Greenwood		
A8	Greenwood, Hwy 201, bridge over Fales River		
15a	Kingston, south from Hwy 1, railway bridge over Walker		
17a	Wilmot, south from Hwy 1, railway crossing over Wiswall Brook		
17b	Wilmot, Hwy 1, bridge over Wiswall Brook		
17e	Melverne Square, Spa Springs Road, bridge over Wiswall Brook		
A20	Wilmot, Dodge Road, river shore		
18	Wilmot, Old Mill Road, bridge		
19a	Wilmot, Todd Branch Road, bridge over Black River		
19b	**Meadowvale near Kingston, Torbrook Rd, bridge over Black River**	**343471.26**	**4979526.19**
19c	Torbrook, Uhlman Branch Road, bridge over Black River		
19d	Torbrook, Torbrook Road, bridge over Black River		
19e	Torbrook, Messenger Rd, bridge over Black River		
19f	Torbrook, Messenger Road, Black River tributary (W. of county line)		
19g	Torbrook, Messenger Road, Black River tributary (W. of R. Chase farm)		
19h	**Torbrook, Meadowvale Rd. Black River tributary (E. of county line)**	**346261.48**	**4979025.04**
19I	**Torbrook, Meadowvale Road, bridge over Black River**	**346967.55**	**4979305.53**
21	West Wilmot, Bayard (previously Carleton) Road, bridge		
24a	Nictaux, Hwy 201, bridge over Nictaux River at old sawmill dam		
24m	Nictaux, Nictaux River's mouth		
25	**Middleton, Highway 10, bridge**	**336981.58**	**4978044.59**
31	Brickton, Mount Hanley Road, bridge		
31-x	North Williamston, Keith Lane, bridge over Delancey Brook		
35	**Lawrencetown, Lawrencetown Lane, bridge**	**329581.15**	**4971984.70**
40	**Paradise, paradise Lane, bridge**	**325738.51**	**4970620.51**
49	**Bridgetown, Queen Street, bridge 318900**	**318900.00**	**4967621.30**
50a	Bridgetown, Highway 1, bridge over the Solomon Chute Brook		
50b	Bridgetown, Church St. bridge over the Solomon Chute Brook		

SITE	LOCATION	Easting	Northing
53	Bridgetown, below mouth of Bloody Creek, on the river from a boat		
53a	Bridgetown, Highway 201, bridge over Bloody Creek		
60	Centrelea, 300m below Britex, on the river from a boat		
A19	Belleisle, Hebb's Landing (picnic park), river shore		
64	Upper Granville, river shore or from a boat		
75.1	Granville Centre, on river from boat (surface water at the depth of 1 m)		
75.6	Granville Centre, on river from boat (subsurface water at depth of 6 m)		
75a	Granville Centre, Brun Creek		
80	Moschelle, above the mouth of the Saw Mill Creek, river shore		
81.a	Moschelle, Highway 201, bridge over the Saw Mill Creek		
81b	Moschelle, bridge over the Saw Mill Creek in South Mountain		
82	Moschelle, north of Hwy 201, Moschelle Brook mouth, river shore		
82b	Moschelle, Hwy 201, bridge over Moschelle Brook		

Funding

The Annapolis River Guardians Project, for 2002-2003, received funding from three sources:
Atlantic Coastal Action Program
Nova Scotia Department of Environment and Labour
Human Resources and Development Canada

Background on Fecal Coliforms and Dissolved Oxygen

Fecal coliforms have been identified in the past as a major cause of concern in the Annapolis River watershed (Pittman et al 2001). *E. coli*, the only true fecal coliform (Edberg et al. 2000), is the most widely used indicator species when dealing with water quality, and is the species enumerated in the Annapolis River Guardians Project and also Operation Sub-Watershed Investigative Monitoring (SWIM). This species is a thermo-tolerant, enteric, lactose fermenting, Gram-negative bacteria and is of fecal origin. Although not pathogenic themselves (excepting sub-species such as *E. coli* O175:H7), they are used as indicators of potentially pathogenic microbes. The source of the bacteria is the intestines of warm-blooded animals.

In the Annapolis River watershed, potential contamination sources are central sewage treatment plants, on-site septic systems, aquatic wildlife species (i.e. beavers, muskrats, waterfowl), agricultural livestock and manure. The survival of this indicator species in the wild is not well known, and is dependent on many factors. These include the rate of predation by other microbes, amount of sunlight, salinity of the water, and composition and abundance of sediment (Davies et al 1995). In scientific experiments done on the subject, estimated survival times of *E.coli* are as follows:

Cow pats: 49 days at 37°C, 70 days at 5°C (also dependent on moisture content) (Chalmers et al 2000)
Drinking water: Between 4 and 12 weeks (Edberg et al 2000)
Soil Cores with grass roots: 130 days (Chalmers et al 2000)
In situ Freshwater Sediment: 57days (Davies et al 1995)

Many factors in a particular ecosystem affect the abundance of *E. coli* in rivers. In addition to factors that affect die-off, mentioned above, other factors include the type of source, the transport mechanism with which the *E.coli* is deposited and soil types. The result is that *E.coli* densities are highly variable. This report attempts to use the River Guardians data, other supporting data sets, and aerial photographs to identify the status of each sampling site along the Annapolis River, and to identify potential remedial actions that would lead to decreases in *E.coli* densities in the Annapolis River.

Canadian Water Quality Guidelines

Various governmental agencies have created water quality guidelines to protect the safety of the general public. Health Canada is responsible for the guidelines for drinking and recreational waters. The Canadian Council of Ministers of the Environment have incorporated these guidelines with a multitude of other guidelines and give us the comprehensive Canadian Water Quality Guidelines (CCME 2002). CARP has summarized the guidelines for fecal coliform contamination into a concise table for public education purposes. The table is published in the local media monthly, and is represented on highway signs at River Guardian sampling sites. The table is also periodically presented in The River Guardian, the program newsletter. Liberties have been taken with the official Canadian Water Quality Guidelines so that the table effectively engages the public. The table is:

/100ml	Water Use	Source
0	Acceptable for drinking	Health Canada, no fecal coliforms/100ml.
$<$ 50	Acceptable for livestock watering	CARP interpretation of CCME Guidelines "high-quality water given to livestock."
$<$ 100	Acceptable for food crop irrigation	CCME Guidelines, maximum concentration/100ml.
$<$ 200	Acceptable for recreational use	Health Canada, Geometric Mean should not exceed 2000/L.

It should be noted that some guidelines are in maximum concentrations, while others are in geometric means over a period of time. Also, the numeric "50" in the table for acceptable livestock watering is based on rationale for coliforms from experiences in Ontario (CCME), not fecal coliforms.

Dissolved Oxygen

Dissolved oxygen (DO) is a widely used and important general indicator of the health of a river system (Addy et al 1997). Dissolved oxygen in solution is required by aquatic organisms, just as terrestrial organisms need oxygen for external respiration. Oxygen in the atmosphere, which is readily available to terrestrial organisms, must be dissolved into the water and is present at much lower concentrations. Wind, wave action, rainfall, and photosynthesis help aerate waterways and increase dissolved oxygen levels. Sewage, other high organic inputs and lower rates of photosynthesis due to ice cover can lead to decreased oxygen levels. Dissolved oxygen levels above 5 mg/l and above 60% saturation are acceptable for most aquatic life. Temperature also plays a large part in how much oxygen water can keep in solution, thus percent saturation is an important indicator. Lower temperature waters can hold more oxygen.

Methods

Fecal coliform enumeration

The fecal coliform samples are processed at the Valley Regional Hospital in Kentville, Nova Scotia. They use the commercial IDEXX Colilert Water Test for total coliforms and *E. Coli* in water. This method uses nutrient indicators that produce colour and/or fluorescence when metabolized by total coliforms and *E.coli*. This has been used as the method of choice at the hospital since 1997 (Doucette, pers. comm. 2003). Prior to this the membrane filtration technique was used. The two methods correlate well with each other (Desmarais et al 2002). The following is a summary of the Standard Operating Procedure for processing river waters in the microbiology laboratory at the Valley Regional Hospital (IDEXX).

The samples are decanted until 100ml remains in the sterile water collection bottle. The sample is then shaken well. The IDEXX Colilert reagent is added and the bottle shaken until fully dissolved. The solution is then added to the Quanti-Tray, sealed, and incubated at 35°C for 24 hours. Counts are given as Most Probable Number *E. coli* per 100ml of river water sample.

Dissolved Oxygen Content

Modified Winkler Titration - See Annapolis River Guardians Procedure Manual

This method enumerates dissolved oxygen content in water using known quantities of chemicals. It is the most accurate procedure to measure dissolved oxygen.

Suspended Particulate Matter

Vacuum Filtration - See Annapolis River Guardians Procedure Manual

In this method, a measured amount of water is passed though a pre-weighed glass fiber filter. The filter is dried and reweighed. The difference in weight corresponds to the amount of total suspended solids present in the water sample.

Results and Characterization of River Guardians Sites

Fecal Coliforms:

The River Guardians data from the last ten years is analyzed, primarily for fecal coliform densities. The data as a whole is summarized to identify trends, and each individual site is examined closely in terms of geometric means and medians, so that actions can be taken in problem areas. The data collected by the volunteers is currently stored in a MS access database, as well as in a database on the web-site fundybay.com.

Consistent and comparable data arises in 1997 when the current Most Probable Number technique was employed. This was also the year bimonthly sampling was implemented. As a result the majority of this report will concentrate on these six years of solid data, although years previous to this may be included in graphs and tables.

Fecal coliform densities are site and time specific (although to what extent is not known in the Annapolis Watershed) and are influenced by numerous factors. Thus, having an average for the program over the years does not identify problem sites or give an accurate indication of the health of the river, but it may give some indication as to the effectiveness of the program in lowering fecal coliform densities in the river, which is ultimately the goal. In Figure 1, it can be seen from 1997 on that the maximum geometric mean is 91, and the minimum is 60, occurring in 2000. The geometric means fluctuate between these values, and have risen the last two years. The medians for each year are also given and correlate closely with the geometric mean, although it is interesting to note that in the years 1993, 1994, 1996, and 1997, the median is slightly higher than the geometric mean, and in the years from 1998-2002, the median is equal to or lower than the geometric mean. These numbers are an indication of the relative distribution of densities over that particular year. When the median is higher than the geometric mean, the distribution of fecal coliform densities are relatively higher, and vice versa when the median is lower.

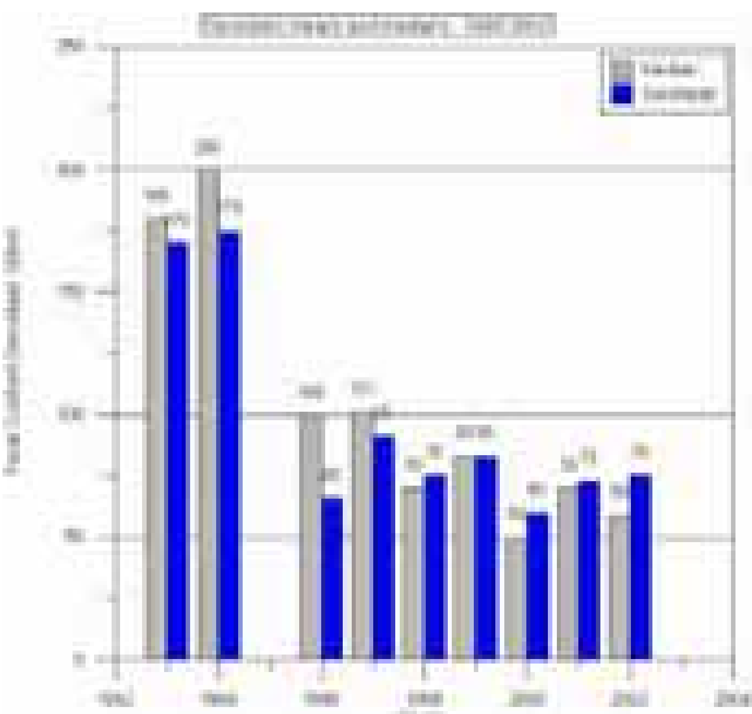

Figure 1
Geometric means and medians of the 7 main stem sites currently sampled River Guardians sites, from 1993 to 2002.

The total geometric means are broken down into the seven individual mainstem sites in Figure 2. It can be clearly seen that Aylesford is a persistent problem site, with Bridgetown giving consistently low densities. Excepting a few instances, the graph has a shape that indicates the further upstream on the Annapolis where the sample is taken, the higher the fecal coliform density.

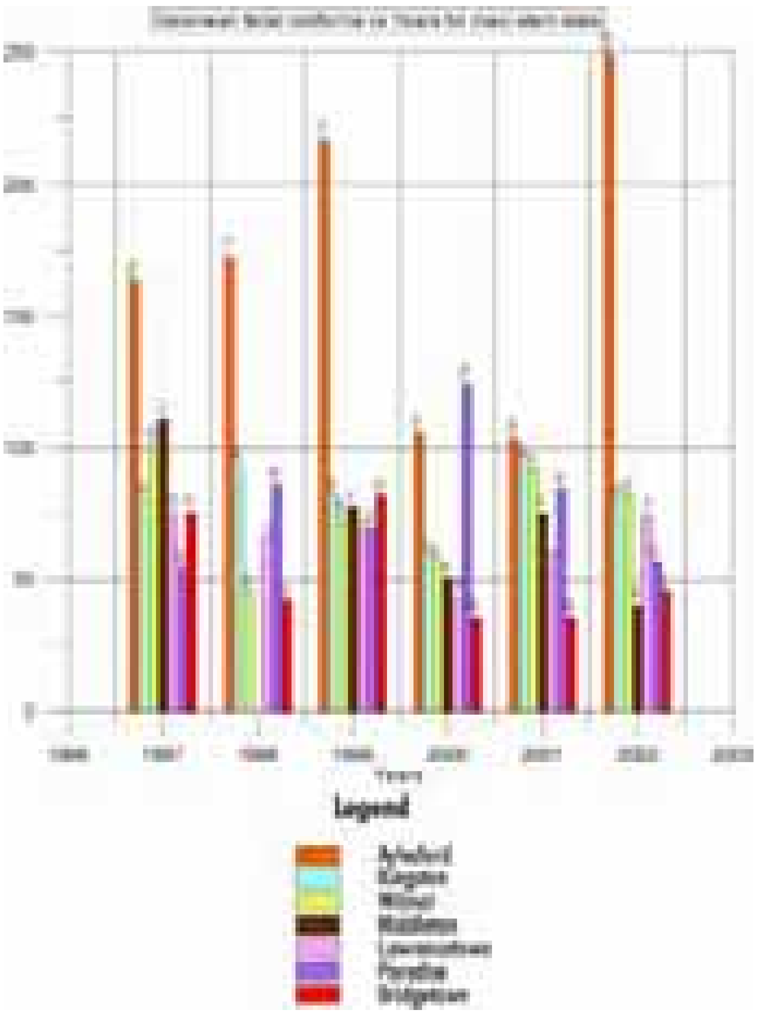

Figure 2
Geometric mean for main stem Annapolis River sites from 1997 to 2002. Black River sites have not been included.

The data for the 10 current River Guardians sites from 1992-2002 is summarized in Table 1. Summary statistics are given, including the percentages of times the samples exceed 50 and 200 fecal coliforms. It can be seen that the maximum in all cases is 2419 MPN/100ml. This has been artificially imposed. The current method of fecal coliform analysis is the statistical Most Probable Number method. The maximum number enumerated is 2419, and thus this number was imposed as the maximum in all cases. P90 stands for percentage 90, meaning ten percent of the samples are above the number listed. The 2002 sampling season is given below in Table 2 as a comparison. It can be seen that the 2002 sampling season have lower numbers than 1992-2002 counts, in the majority of cases.

Table 1 Annapolis River Guardian Sites - Fecal Coliform Summary Statistics

Site #	#Samples	Period	Min FC	Max FC	Gmean	Median	P90	%>=50	%>=200
00 Aylesford	132	1992-2002	0	2419	135	163.5	683	77	45
13 Kingston	146	1992-2002	0	2419	66	84	443	66	22
18 Wilmot	125	1992-2002	0	2419	99	105	555	72	28
19 B Black river	133	1993-2002	0	2419	77	84	387	71	23
19 H Black river	124	1994-2002	0	2419	101	143.5	1098	73	38
19 I Black river	125	1994-2002	0	2419	90	86	742	64	39
25 Middleton	119	1992-2002	0	2419	86	80	467	65	26
35 Lawrencetown	141	1992-2002	0	2419	85	90	387	66	26
40 Paradise	130	1992-2002	0	2419	87	96	542	66	27
49 Bridgetown	140	1994-2002	0	2419	58	63.5	300	61	21

Table 2 - 2002

Site#	# Samples	Year	Min	Max	Gmean	Median	P90	%>=50	%>=200
00 Aylesford	18	2002	19	2419	249	201.5	1091	94	50
13 Kingston	18	2002	13	1553	80	73.5	324	67	17
18 Wilmot	17	2002	11	770	82	58	361	71	24
19 B Black River	18	2002	11	1414	85	68	435	67	22
19 H Black River	18	2002	30	2419	156	145	590	94	33
19 I Black River	18	2002	6	2419	63	57.5	339	61	17
25 Middleton	17	2002	9	187	40	38	86	35	0
35 Lawrencetown	18	2002	10	548	75	54.5	394	56	22
40 Paradise	17	2002	6	816	57	38	391	41	18
49 Bridgetown	17	2002	3	326	45	57	208	65	12

Table 3 gives fecal coliform densities for each individual sampling day in 2002. Also included in this data are precipitation amounts from the weather recording station at Greenwood (MSC 2002). The precipitation amounts are given in millimeters for one, two and three days (given in 24 hour increments) before the sampling date. To supplement this data, the average weather observations are given, as recorded by the volunteers. This data is qualitative and varies between volunteers, depending on when and where the sample was taken. Of note are the sample days on June 23rd and 24th, in which sample site numbers 00, 18, 19B, 19H, 19I and 40 were taken the morning of June 24th. The samples for site numbers 13, 25, 35, and 49 were taken by the volunteers on June 23rd, before the rainfall event. Discharge data, obtained from the Nova Scotia Power recording site in Lawrencetown, is also provided to give insight as to the river level at the time of sampling (NSP 2002). Of note is the increase in discharge between the sampling days in July and the increase on the sampling days of Nov. 17th/18th. The fecal coliform densities also spike on these sampling days at the majority of the sites.

Table 3 **Fecal Coliform Densities per 100ml - 2002**

Sites	27-Mar-02	14-Apr-02	28/29-Apr-02	12-May-02	26-May-02	09/10-Jun-02	23/24-Jun-02	07/08-Jul-02	21/22-Jul-02
00 Aylesford	156	548	488	159	19	140	687	816	2419
13 Kingston	44	13	59	19	32	35	115	96	1553
18 Wilmot	548	770	45	11	16	59	189	52	127
19 B Black River	54	11	127	14	11	48	387	84	88
19 H Black River	53	155	153	30	64	548	2419	201	1414
19 I Black River	44	52	59	6	6	24	82	79	548
25 Middleton	53	na	18	9	25	35	38	25	548
35 Lawrencetown	328	387	158	33	37	18	10	124	411
40 Paradise	128	345	461	16	22	25	40	11	26
49 Bridgetown	52	291	152	17	59	3	20	50	149
Precip (mm)									
0-24 hrs	22	20.8	11.4	0	0	11.2	9.8	0.2	0
24-48 hrs	3	9.4	0.8	0	0	0	0	0	20.2
48-72 hrs	0	0	14	12	0.2	0	0	0	9.8
Observations	**Heavy**	**Heavy**	**Moderate**	**Drizzle**	**None**	**Drizzle**	**None**	**None**	**Heavy**
Discharge m^3/s	47.3	57.5	30.6	22.3	15.9	9.7	9.03	7.76	8.05

Sites	11/12-Aug-02	25/26-Aug-02	08/09-Sep-02	22/23-Sep-02	06/07-Oct-02	20/21-Oct-02	03/04-Nov-02	17/18-Nov-02	01/02-Dec-02
00 Aylesford	365	225	178	365	111	79	56	1733	127
13 Kingston	435	276	160	93	88	126	50	55	25
18 Wilmot	36	58	86	236	49	52	57	228	na
19 B Black River	365	65	131	152	59	48	43	548	24
19 H Black River	172	276	137	70	107	99	52	687	71
19I Black River	70	56	33	250	79	42	38	2419	55
25 Middleton	187	35	24	84	63	74	47	47	24
35 Lawrencetown	28	111	50	43	46	41	59	548	61
40 Paradise	6	159	184	30	32	38	63	816	na
49 Bridgetown	12	18	8	63	87	57	82	326	na
Precip (mm)									
0-24 hrs	0	4.6	0	0	0	0	0	46	6.6
24-48 hrs	0	4.4	0	0	6	4	3	0	0.2
48-72 hrs	0	1.8	0	0	0	0	4	0	2.8
Observations	**None**	**Moderate**	**None**	**None**	**Heavy**	**Drizzle**	**Drizzle**	**Heavy**	**Drizzle**
Discharge m^3/s	3	2.01	1.64	8.36	8.29	5.64	17.2	103	32.4

Individual Sites

Site 49 is taken from the bridge on Bridge Street in Bridgetown. It has historically shown the lowest counts over the period the River Guardians have been monitoring the site. It is also the only current River Guardians site that is tidal. The town has a central sewer and central water systems, and thus on-site septic system problems would not play a role in influencing the fecal coliform densities at this point. The central sewer discharges slightly upstream from where the sample is taken. There is some cleared land at the eastern end of the town that lacks adequate riparian zones. There has been no sustained improvement in fecal coliform densities over the years.

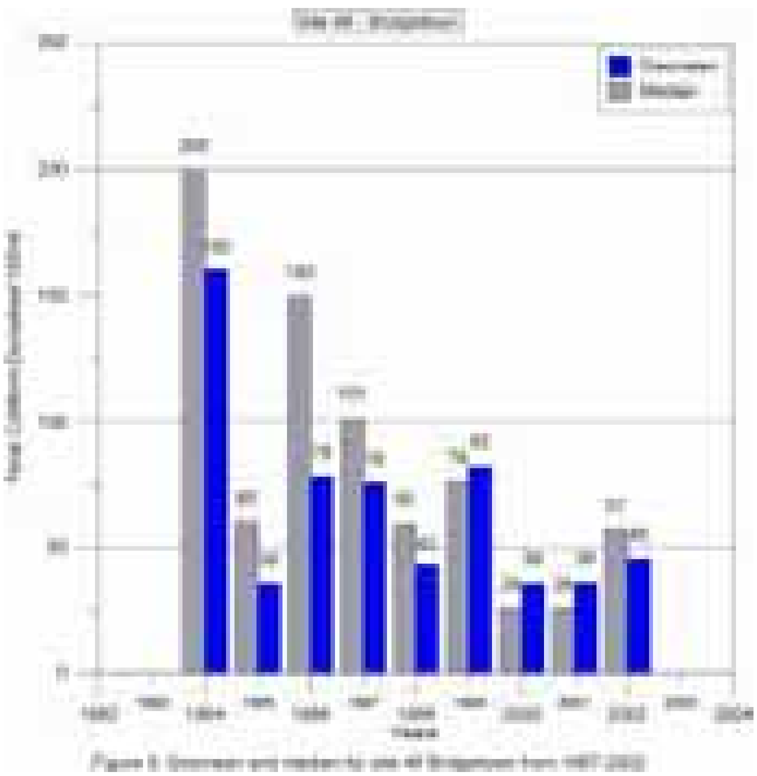

Figure 3
Geometric means and medians of fecal coliform densities for Site 49 Bridgetown, from 1994 to 2002.

Aerial Photograph 1 - Bridgetown

Site 40 is taken from the bridge in Paradise. Although the geometric mean was 57 in 2002, Paradise has fluctuated between 55 and 124 since 1997, a trend that differs from the other sites in proximity. Paradise has no central sewer system, and the majority of homes should have on-site septic systems. Potential sources of fecal coliforms in this area include possible malfunctioning septic systems from a row of houses on the northern bank, and also agricultural land that is immediately upstream on the southern bank. Leonard Brook, which has high fecal coliform densities (Montgomery 1998), enters the Annapolis upstream of this site. Wildlife may also contribute to the counts in this area. There has been no significant or sustained improvement in counts from 1997 onward.

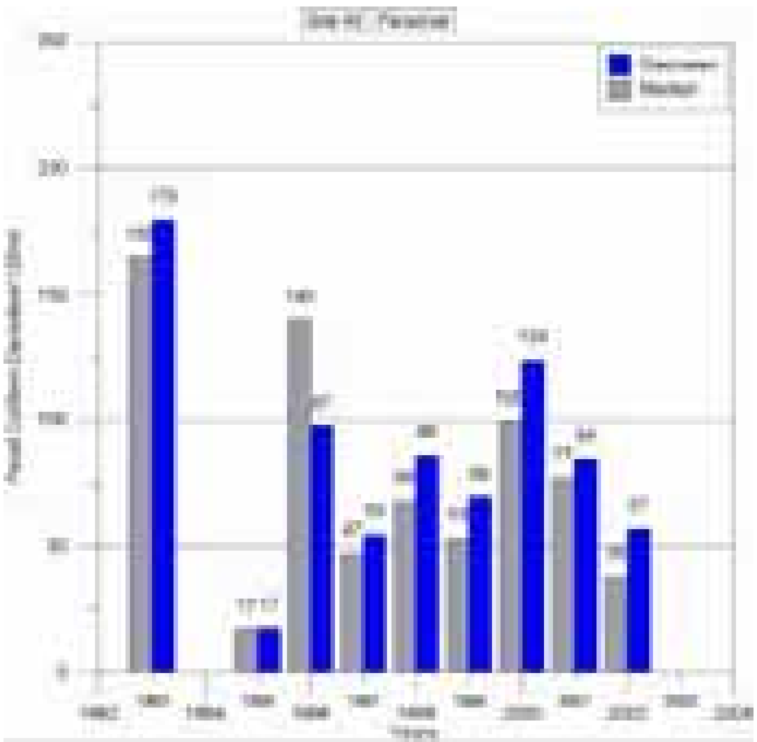

Figure 4
Geometric means and medians of fecal coliform densities for Site 40 Paradise from 1993 to 2002.

Aerial Photograph 2 - Paradise

Site 35 is taken from the bridge that crosses the Annapolis River in Lawrencetown. Lawrencetown is on a central sewer system that was improved in the mid-90s and consists of 3-cell aerated lagoons. Fecal coliform densities in this area since 1997 have been consistently under 75, and have been as low as 44, in 2000. The site recorded the third lowest maximum fecal coliform density in 2002, at 548. Of note is a storm drainpipe discharging immediately upstream of the sample site on the northern bank. Immediately upstream of this site the banks are lined with trees. Further upstream is cleared land, with some agriculture on both sides of the river.

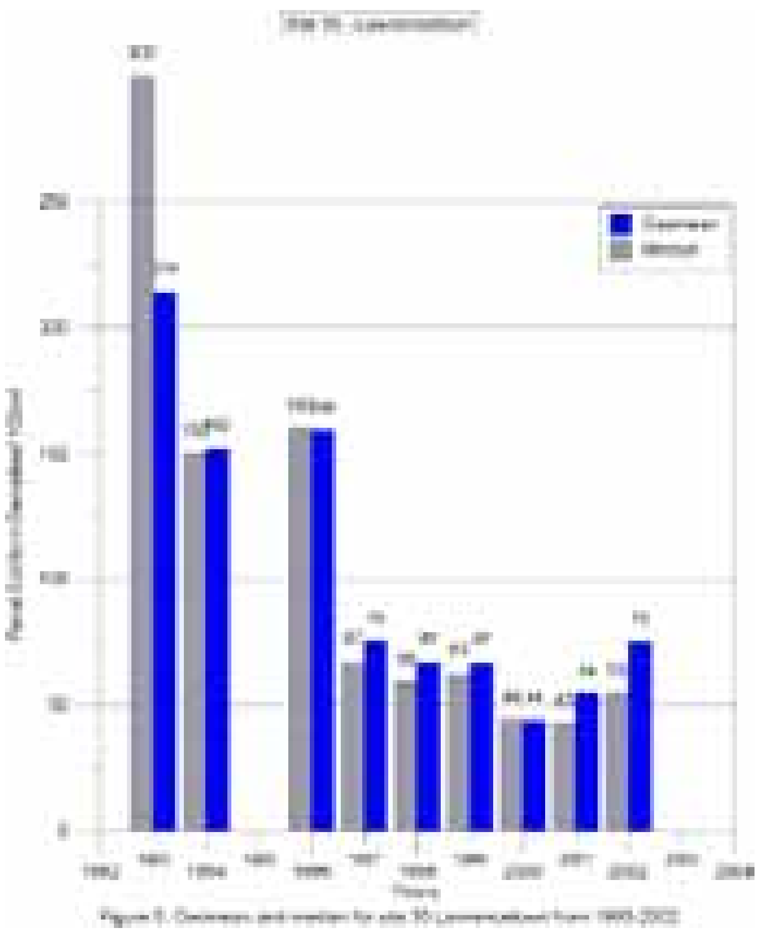

Figure 5
Geometric means and medians for Site 35 Lawrencetown, from 1993 to 2002.

Aerial Photograph 3 - Lawrencetown

Site 25 is taken from the bridge that crosses the Annapolis River in Middleton. This site has been variable since 1997, with a high of 111 that year, and a low of 40 in 2002. Unfortunately the site was not sampled in 1998. A sewage treatment plant (STP) services Middleton, and this discharges into Lily Lake Brook, which enters the Annapolis River downstream of the sample site. A STP also services the community of Nictaux. The Nictaux River discharges immediately upstream of the sample site. There is little development adjacent to the River upstream of this site, although there is some cleared land.

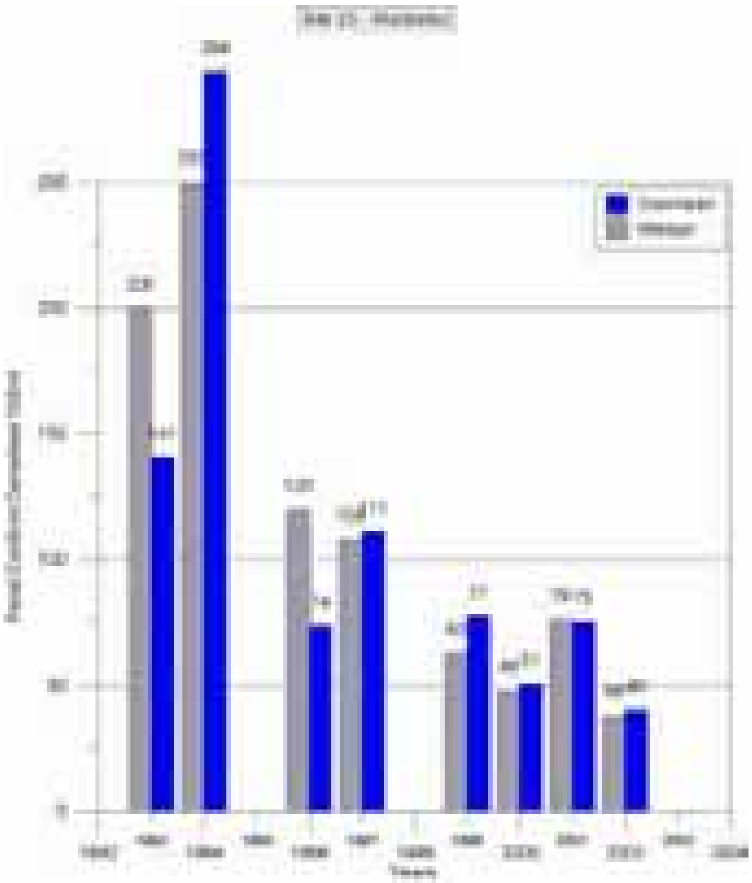

Figure 6
Geometric means and medians for Site 25 Middleton, from 1993 to 2002.

Aerial Photograph 4 – Middleton

Site 18 is taken from the bridge in Wilmot, and is upstream of the Black River entrance point. The counts vary from a geometric mean of 100 in 1997, down to 46 in 1998, and back up to 82 this past sampling year. Overall, the geometric mean is slightly higher than those downstream. It is the closest River Guardians sampling site downstream of two STP's, Greenwood and Kingston, although they both are at some distance upstream. There is little residential or agricultural development upstream.

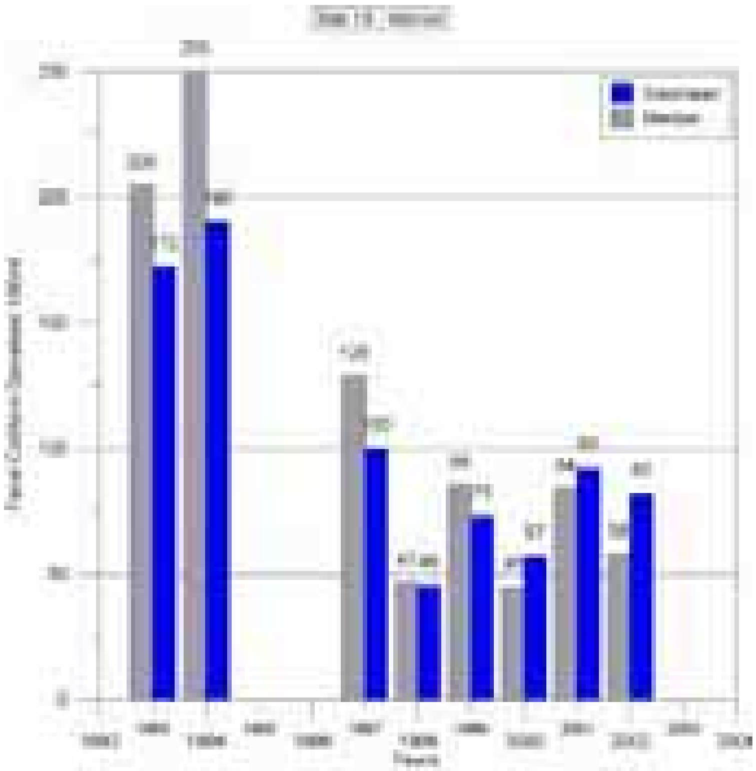

Figure 7
Geometric means and medians for Site 18 Wilmot, from 1993 to 2002.

Aerial Photograph 5 – Wilmot

Site 13 is taken at the bridge between Kingston and Greenwood. The geometric means for this site are consistently between 80 and 95 since 1997, excepting the low of 61 in 2000. The river upstream of this site is bound on the south bank by Canadian Forces Base Greenwood. From the aerial photo, there appears to be a pond that drains into the river from the south bank upstream of the sample site. Zeke Brook, which runs through CFB Greenwood, enters downstream of this site, as does the Kingston STP effluent.

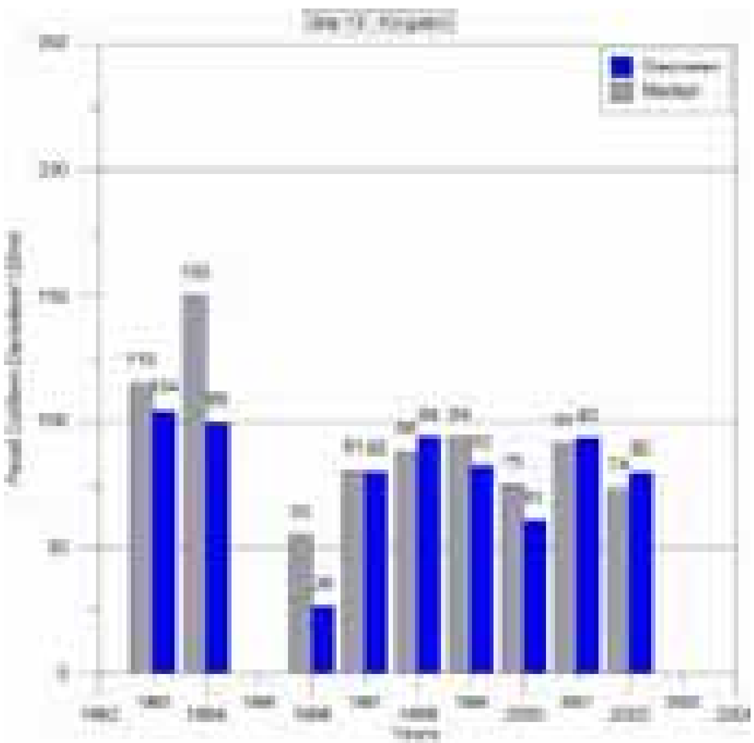

Figure 8
Geometric means and medians for Site 13 Kingston, from 1993 to 2002.

Aerial Photograph 6 — Kingston / Greenwood

Site 00 is taken at the Victoria Street bridge in Aylesford. This is the furthest upstream sampling location that the River Guardians sample, and thus the one with the lowest volume of water, relative to the other sites. This sampling site is also characterized by a silty substrate and slow moving water. Immediately upstream is a cow pasture with inadequate riparian zones, and suspected uncontrolled access to the river. Other pastures with known uncontrolled animal access are in close proximity to this site. The town of Aylesford is on a central sewer system with the effluent entering downstream of this sampling location. There are very few residences in immediate proximity upstream. Two small tributaries drain the north mountain upstream, which is characterized by large amounts of agricultural land. Figure 9 shows the continuing problem with fecal coliform contamination in this area. Since 1997, geometric means range from a high of 249 in 2002 to a low of 104 in 2001. The medians are also high.

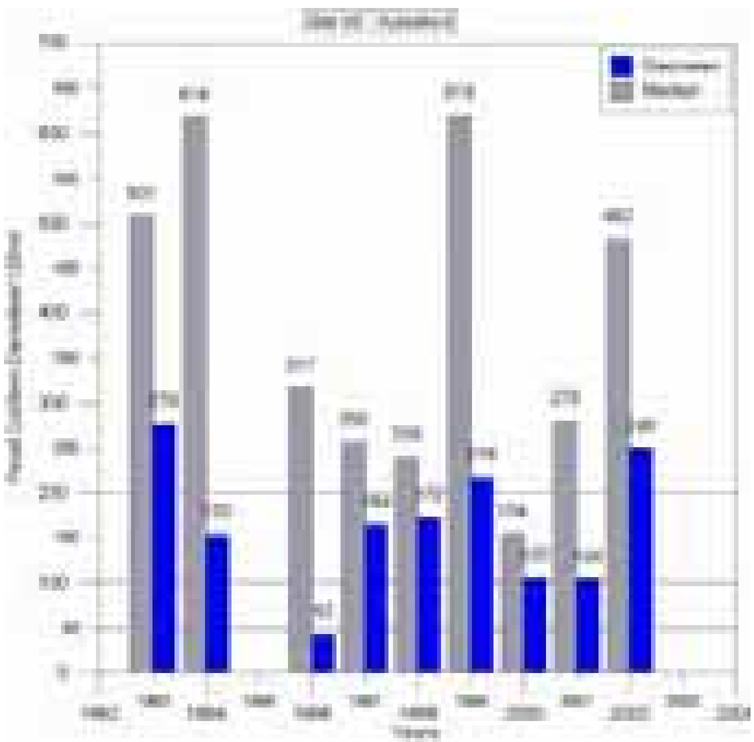

Figure 9

Geometric means and medians for Site 00 Aylesford, from 1993 to 2002. Note change in Y-axis maximum.

Aerial Photograph 7 – Aylesford

The Black River sites sampled by the River Guardians are 19B, 19H, and 19I. 19B is taken from the bridge on Torbrook Road, and is the furthest downstream site. Upstream of this site, there is little development to the north, although it should be noted that new suburban style communities are growing rapidly in this area, and may soon encroach on this part of this river. To the south, there are residential developments, most of which are set back from the river. There is at least one large beaver dam about 750 meters upstream of this site. The geometric means are highly variable, as can be seen in Figure 10, with a low of 43 in 1999, and a high of 180 in 1997, with no sustained improvements in fecal coliform densities.

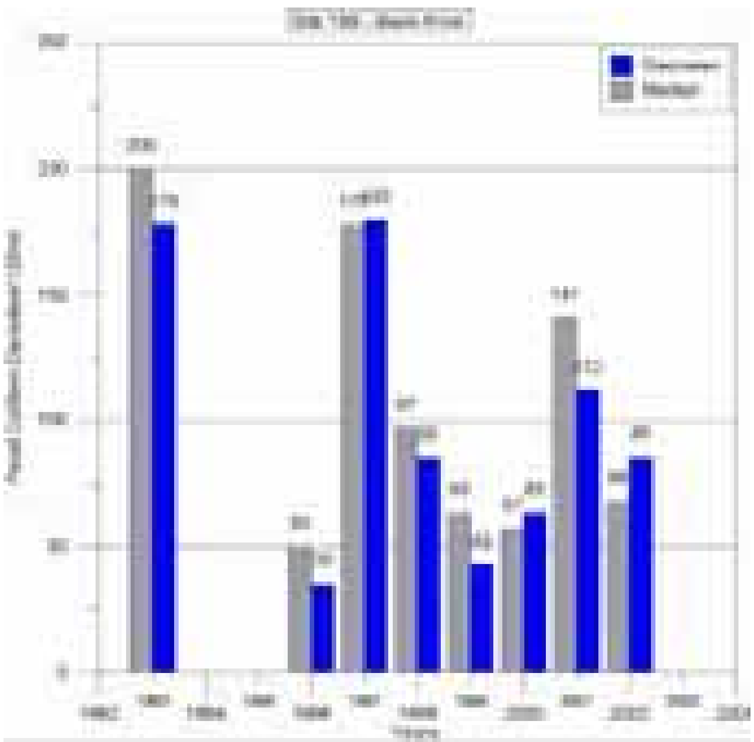

Figure 10
Geometric means and medians for Site 19B Black River, from 1993 to 2002.

Aerial Photograph 8 — Torbrook Road

19I is taken from a bridge on the Meadowvale Road on the main-stem of the Black River. Immediately upstream is forested land. Further upstream is pastureland where cattle have unrestricted access to waterways. The geometric means are again highly variable at this site, as can be seen in Figure 11, with no sustained improvement of fecal coliform densities.

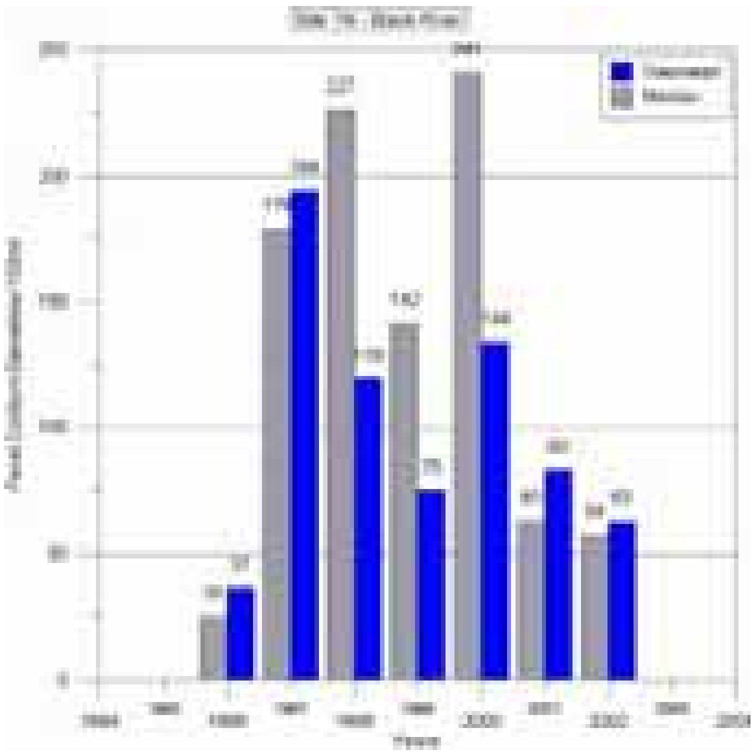

Figure 11
Geometric means and medians for Site 19I Black River, Meadowvale Road, from 1996 to 2002.

19H is taken from a bridge on the Meadowvale Road on a tributary of the Black River. The tributary does not run into the Black River in the summer. The sample location is characterized by stagnant, grey water. Upstream are two houses on either side of the stream, (not seen in aerial photograph) which are not on central sewer systems, and whose land appears to be in a flood plain. Further upstream is forested land. The geometric means are again variable over the last six years, but tend to be higher than most sites. In 2002 the geometric mean was 156.

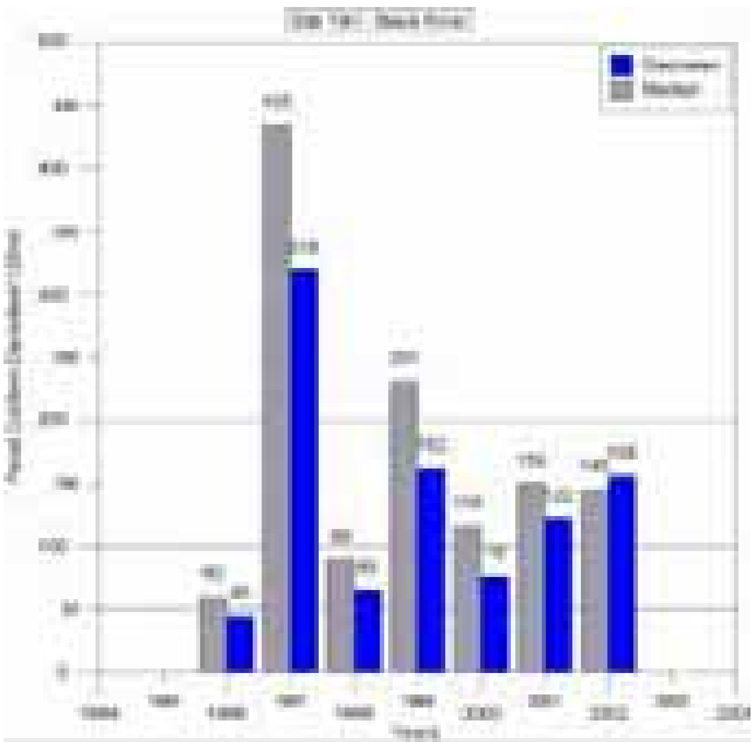

Figure 12

Geometric means and medians for Site 19H, Black River tributary, from 1996 to 2002. Note change in Y-axis maximum.

Aerial Photograph 9 – Black River

Dissolved Oxygen

Dissolved Oxygen has been analyzed 1081 times by the River Guardians. The Dissolved Oxygen content in milligrams/litre (mg/l) and the percent saturation are well within acceptable limits the majority of the time. The summary statistics are given in Table 4. The DO numbers for 2002 followed the same trend, with the majority being well within acceptable limits. Summary statistics for 2002 are given in Table 5.

Table 4- Summary Statistics DO

Count	1081 times
Min DO	3.20 mg/l
Min DO Sat	22.00%
Max DO	20.20mg/l
Max DO Sat	141.00%
Mean DO	9.98 mg/l
Mean DO Sat	87.59 %
Median DO	9.87 mg/l
Median DO Sat	86.00%
< 5 DO	8 times
< 8 DO	147 times
< 60% DO Sat	18 times
< 75% DO Sat	107 times

Table 5- Summary Statistics DO 2002

Count	80 times
Min DO	6.40 mg/l
Min DO Sat	58.00%
Max DO	18.00mg/l
Max DO Sat	119.00%
Mean DO	9.95 mg/l
Mean DO Sat	87.23 %
Median DO	10.10 mg/l
Median DO Sat	86.50%
< 5 DO	0 times
< 8 DO	11 times
< 60% DO Sat	1 times
< 75% DO Sat	8 times

Discussion and Recommendations – Individual Sites

Fecal Coliforms

Site 49 - Bridgetown

Bridgetown does and should, because of the volume of water and tidal effect, have the lowest fecal coliform densities of the sites monitored by the Annapolis River Guardians. This community should aim to keep the fecal coliform counts below 50 MPN/100ml on all samples. The volume of water in this part of the Annapolis dilutes the counts, so there is still significant input of coliforms into this region, despite the low numbers. Recommended actions in this area include lobbying for an upgraded sewage treatment plant, and improvements in the riparian zones of land upstream of the sampling site.

Site 40 - Paradise

Initially better riparian zones need to be established immediately upstream on the south bank. Functionality of on-site septic systems should be assessed for the residences in proximity to the river on the north bank. Further upstream, work to limit animal access to waterways is being undertaken. It is yet to be seen if this will lower the fecal coliform densities at this sample site. Leonard Brook probably also contributes to fecal contamination at this site (Montgomery 1998). The upper areas of this brook are agricultural, and best management practices should be encouraged at these sites. Aquatic wildlife also contributes fecal contamination to Leonard Brook.

Site 35 - Lawrencetown

Lawrencetown has fairly low fecal coliform densities. Water conservation technique promotion may be warranted to further improve the counts in the area. The function of the drainpipe immediately upstream should be further investigated. Upstream, there are tributaries (such as Millers Brook and Oak Hollow Brook) that drain agricultural areas. These areas need to be ascertained for riparian zones, and improvements made if necessary.

Site 25 - Middleton

Middleton has consistently shown low counts in the past few years. Possible sampling below the Nictaux STP is warranted to determine its effectiveness at reducing fecal coliform levels. Although counts are low, further investigation into the source of fecal coliform density is needed in this area. Densities are consistently low, and maintenance of these numbers should be a goal.

Site 18 - Wilmot

A detailed look at the portion of river upstream of this sampling location is warranted. The two main possibilities would seem to be failing on-site systems or agriculture, although at this point there is not enough information to speculate as to the cause of fecal coliform contamination. Other possibilities are aquatic wildlife or transport of fecal coliforms downstream from the two upstream STP's. A boat would be effective in examining upstream sources of fecal coliform contamination that may contribute to the relatively high fecal coliform densities at this site.

Site 13 - Kingston

This site has shown consistently relatively high densities, the cause of which is unknown as this time. The Annapolis River borders Canadian Forces Base Greenwood upstream of this sample site, and a collaborative effort to examine potential sources of fecal coliform contamination could be undertaken.

Site 00 - Aylesford

Initially, animal access to the river must be restricted and riparian zones must be established between Victoria Rd. and Aylesford East Rd. This is the most logical contributing factor to the large fecal coliform densities in this area. Bacterial zoonoses from nonpoint pollution sources (such as *E.coli* 0157) is a growing concern (Stelma et al 1992), and thus action should be taken as soon as possible. There are at least two pastures on the main stem of the river where cattle have unrestricted access, and efforts should be extended to the farmers in the area to help establish better fencing and riparian zones.

Sites 19B, 19H, 19I – Black River

19B, taken at the Torbrook Rd, has had varying counts over the years. Although no signs of septic system malfunction were visible in the area, this should not be discounted as a cause. A large beaver dam upstream may also contribute. This river has large amounts of sediment, and as such would facilitate transport of bacteria. Fecal coliforms may travel relatively long distances in this system, and thus sources may be far upstream.

19I is taken on the Black River at Meadowvale Road. Possible sources include aquatic wildlife, as the area upstream runs through a forested area. Further upstream of this is pastureland, with animals using the river as a watering source. Efforts should be made to establish riparian zones and restrict animal access in this area.

19H is taken at a tributary of the Black River. The counts are generally high here, and this is expected due to the nature of the stream. Possible sources include the usual suspects: septic systems, wildlife and agriculture. It is recommended that this sample site be dropped as a regular River Guardians sample. The volunteer that samples this site also sample the other Black River sites, so the program would not be losing volunteer participation. The site in question is not much more than a stagnant ditch that for large parts of the sampling season does not reach the main stem of the Black River.

Dissolved Oxygen:

Dissolved Oxygen content at the River Guardians sites is generally within acceptable limits. The dissolved oxygen is under the acceptable limits of 5mg/l and 60% saturation so few times that it is not significant. The low results are also not concentrated at a certain point in time or at a specific sample site. This parameter should continue to be monitored and any anomalies be reported to the appropriate authority. The River Guardians use the Winkler titration method, which is accepted as the most accurate. This method, done in home laboratories, allows the guardians to contribute valid scientific information and educates them as to the importance of dissolved oxygen in water.

Suspended Particulate Matter

Suspended Particulate Matter (SPM) has been a parameter tested by the River Guardians since the beginning of the program. This parameter, more so than the others tested, varies with large changes in rainfall amount and discharge rates of the river. Time series sampling protocol, such as with the River Guardians, is not usually employed with sediment monitoring (Thomas 1985). Different sampling protocols should be employed when analyzing suspended sediment, which cannot be accommodated in the River Guardians program. The current data in the River Guardians database is flawed by the fact that 15% of the samples have a negative value for SPM, which is not possible. The problem of negative values has occurred as recently as 2001 and is distributed through most of the years.

It is recommended that SPM be dropped from the River Guardians sampling regime, and that the money from this portion of the program be rerouted to other SPM sampling protocols, which can still have volunteer participation. Specialized total suspended solid protocols should be established, in conjunction with deposition of sediment monitoring, which has shown to be effective over a variety of flow scenarios (Larkin et al 1996).

General Recommendations for the River Guardians Program:

Overall, the River Guardians has adequately fulfilled its objective. However improvements could be made in the future to help further the program. These are listed below:

- Improvements in point of time sampling should be made, meaning all the volunteers sample as close to the same time of day as possible, on a consistent basis.
- The Hydrolab should be utilized at all sampling locations of the River Guardians. The Water Quality Coordinator can accomplish this task on the bi-monthly sample run. Important water quality parameters such as pH and conductivity can then be monitored.
- Monthly nutrient (nitrate and phosphate) sampling should be incorporated into the program. In the past, nutrient concentrations in the Annapolis have been higher than most mainland Nova Scotia rivers. (Dalziel et al 1998).
- Drop SPM from the River Guardians sampling protocol, and use funds for other sediment studies in the watershed.
- Add the Bridge in Brickton (31) and/or Wilmot (21) as a sampling site for better coverage of the river. Drop 19H as a sampling site for reasons mentioned in the main text.
- Consistent sampling depth should be established. Recommended depth is 30cm, or halfway to the bottom of the river, as is standard procedure.
- Consolidate the databases used in the program. Currently there are two, when only one is required.
- Compile a complete list of relevant scientific support, with contact information and area of expertise included.
- Drop sampling dates in December and March. This will save money and hopefully increase volunteer participation.

General Recommendations for CARP:

- This program should be used to direct remediation. This has to be based on good science. Volunteers will be attracted and committed to the program only if they can see some tangible improvements being made in the watershed, which thus far have been lacking.
- All information that the River Guardians have collected should be incorporated into a geographic information system.
- Action should be taken in the form of riparian zone restoration and restricting livestock access to waterways. There will be financial assistance for this in the near future. CARP should play a role in this area in facilitating financial, technical and educational resources for those that require it. Possible collaborations with Eastern Canada Soil and Water Conservation Centre and Department of Agriculture (both provincial and federal) could be helpful.
- Acquire use of a watercraft. It is essential to have a means to examine and monitor areas of the Annapolis River and its tributaries not accessible any other way.
- Annapolis Basin monitoring should be initiated (see previous recommendation). Possible avenues include collaboration with DFO and EC environmental protection branch.
- Transport and viability of fecal coliforms are not well understood in our watershed. A fecal coliform/sediment transport study would be beneficial in the understanding of this important factor.
- Overall, science and action must be used in order to achieve the desired results of improvement, education and stewardship within the watershed.

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IDEXX. 2003. Quanti-Tray Method for Total Coliform and Fecal Coliform Count.

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