Annapolis River 2012 Annual Water Quality Monitoring Report

Including results from the Annapolis River Guardians Volunteer Water Quality Monitoring Program

Clean Annapolis River Project

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Annapolis River Guardians Volunteer Water Quality Monitoring Program

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List of Acronyms

ACER	Acadia Centre for Estuarine Research
CABIN	Canadian Aquatic Biomonitoring Network
CARP	Clean Annapolis River Project
CCME	Canadian Council of Ministers for the Environment
CFU	Colony-Forming Units
DO	Dissolved Oxygen
DOSAT	Saturated Dissolved Oxygen
EC	Environment Canada
EPT	Ephemeroptera, Plecoptera, Trichoptera
FBI	Family Biotic Index
NO3-N	Nitrate-Nitrogen
NTU	Nephelometric Turbidity Units
OMEE	Ontario Ministry of Environment and Energy
P	Phosphorus
pH	Power of Hydrogen
QA/QC	Quality Assurance/Quality Control
RCA	Reference Condition Approach
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
TSS	Total Suspended Solids

Acknowledgements

River Guardians is a volunteer-based program that would not have been possible without the dedication of community members throughout the past 21 years. We would like to extend our deepest thanks and appreciation to the volunteers of 2012 who have contributed to the success of the project. The Annapolis River Guardians include:

Mike Brobbel

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Adrian DeMontfort

Claire Diggins

Matthew Guy

Daren Parks

Tami Parks

Vicky Parker

Frank Thomas

The success of the River Guardians program is in part due to its approach of bringing together a variety of stakeholders who have an interest in the health of the Annapolis River. We would like to thank the following partners who have worked with us to deliver the Annapolis River Guardians program:

Environment Canada – Atlantic Ecosystems Initiative

Shell Canada

Small Change Fund

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Art Cook – Environment Canada

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Executive Summary

In 2012, the Annapolis River Guardians completed their 21st year of continuous water quality monitoring on the Annapolis River. Nine volunteers monitored eight sites over the course of the season, which ran from April to October. In 2008, total suspended solids (TSS) and turbidity were added to the suite of parameters monitored, however TSS monitoring stopped in 2011. Others include dissolved oxygen, E. coli bacteria, air and water temperature, pH and conductivity, as well as local weather conditions.

E. coli bacteria levels along the Annapolis River during 2012 were similar to those observed in 2011, with 2012 medians being comparable or slightly lower at some locations. The amount of precipitation received in 2012 was lower than in 2011. As in previous years, *E. coli* counts increased between the sampling stations at Aylesford Road and Victoria Road, indicating a possibility of the introduction of fecal material between these two locations. In 2009, some additional sampling was performed between these two stations. The results were inconclusive due to the variability of the testing method and can be found in the 2009 River Guardian Report. Foot surveys were initiated along Patterson Brook in 2012. The results from these can be found in an internal report.

Over the 21 years of monitoring, mean dissolved oxygen saturation (DOSAT) levels have remained in the range of 80 to 94%. In 2012, the mean DOSAT level was 87.1% compared to 85.5% in 2011. Mean dissolved oxygen (DO) concentrations (mg/L) have remained in the range of 8.4 to 11.5 mg/L. In 2012, the mean DO concentration was 8.53 mg/L, compared to 8.76 mg/L in 2011. The maximum recorded DO and DOSAT levels in 2012 were 14.80 mg/L and 147%, respectively, at Paradise.

The mean summer water temperature for the Annapolis River during 2012 was 21.0ºC, 1.2ºC warmer than for the same period in 2011, and to date has been the highest recorded mean summer water temperature. As in previous years, water temperatures during the 2012 summer months continued to reach and exceed levels stressful to aquatic life ($>$20ºC). The maximum value recorded in 2012 was 26.6ºC at Paradise, 6.6ºC higher than the 20ºC threshold.

The pH levels at each of the River Guardian sites fell mostly within the recommended range for the protection of aquatic life (6.5-9.0). None of the pH readings fell below the lower limit of 6.5. Mean pH values for the eight monitoring locations along the Annapolis River ranged between 7.02 and 7.36. The maximum observed pH value was 8.92, recorded at Paradise.

Nitrogen and phosphorus levels were initially measured at Lawrencetown and Wilmot beginning in 2006, and Millville was added as a reference site in 2008. Lawrencetown sampling ceased in 2009. There is much controversy over the level at which nitrogen becomes harmful to aquatic life. For reporting needs, 0.9 mg/L of total nitrogen (Dodds and Welch, 2000) is used as the maximum concentration for preserving aquatic health and 2.9 mg nitrates-nitrogen/L (CCME, 2003) is used as the guideline for reporting nitrates. While elevated total nitrogen results were observed, phosphorus remains a significant concern. During the 2006 to 2012 period, all of the dissolved nitrate values fell well below the CCME guideline of 13.0 mg/L, which was determined to be too high of a threshold for the Annapolis River watershed. In the same period, 11% of total nitrogen results exceeded 0.9 mg/L while 41% of total phosphorus results exceeded the suggested guideline level of 0.030 mg/L (OMEE, 1994). These elevated phosphorus concentrations are believed to have a role in excessive periphyton growth along the main stem of the river and depression of dissolved oxygen levels in the tidal portion of the river.

Working in conjunction with Environment Canada, turbidity and total suspended solids (TSS) samples were collected in 2008 and 2009 as part of the regular bi-weekly sample collection and during high flow precipitation events. This sampling was part of a two-year effort to establish a baseline for turbidity and TSS in the Annapolis River and to develop a numerical relationship between these two parameters. In 2010 and 2011, samples were only collected after precipitation events of 15 mm or greater in order to assess peak sediment levels in the water column at Bayard Road in Wilmot, Middleton and Paradise. The Lawrencetown and Millville sites were also sampled more regularly

in 2011. TSS sampling was not continued in 2012, but TSS values were estimated from regular turbidity sample collection, based on a relationship developed from past TSS and turbidity sampling efforts. The maximum observed turbidity value in 2012 was 72.3 NTU, recorded at Aylesford.

CARP has collected benthic invertebrate samples in the Annapolis River watershed since 2002, using the protocol developed through the Canadian Aquatic Biomonitoring Network (CABIN). A total of three sites are monitored in the Annapolis River, two on the main stem of the river at Paradise and Wilmot, and one on the Southern branch at Millville. The site in Millville is used as a reference site as there are minimal human impacts at this site. The Family Biotic Index at the Paradise location has fluctuated between values of 4.01 and 5.29 since 2005, with a reported value of 4.96 in 2010. By comparison, the site at Wilmot has fluctuated between 4.62 and 5.65, exhibiting marginally worse water quality on average than the Paradise site. Samples from the Millville reference site have been collected since 2008, and have ranged from 3.39 to 3.78, indicating very good water quality. The results for 2012 CABIN monitoring had not been processed at the time of writing and were not included in this report.

As part of CARP's Quality Assurance Project Plan, regular quality control samples were collected. The accuracy of River Guardian dissolved oxygen readings were estimated at +/- 0.8 mg/L, compared with +/- 0.19 mg/L recorded in 2011. Travel and field blank samples, collected to check for cross contamination, consistently had E. coli counts of 0 cfu/100mL. *E. coli* split samples had a Relative Percent Difference of 18.5% compared to 15% in 2011 and 25% in 2010.

1.0 Introduction

1.1 History

The Annapolis River Guardian volunteers began collecting water quality data in the Annapolis River watershed in 1992. The Clean Annapolis River Project (CARP) initiated the program as a public awareness project, and has had numerous volunteers collecting samples 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 longest running project. At least 100 volunteers from the Annapolis Valley community have participated in the program over the years, and over 4,000 water samples have been collected and analyzed.

The program was initiated in the early 1990's by Dr. Graham Daborn and Dr. Mike Brylinsky of the Acadia Centre for Estuarine Research (ACER). Many groups were involved in the planning process for the program, including staff from the Nova Scotia Department of Health, the Nova Scotia Department of Environment, Nova Scotia Community College, and CARP. Some modifications have been made over the years, but the core has remained the same.

Originally, the design called for 11 sites to be monitored by 17 volunteers. However, the program was so well received by the community that it was significantly expanded between 1992 and 1994. In 1994, 38 sites were monitored by 43 River Guardians from 36 households (Pittman et al. 2001). This intensity of monitoring placed considerable strain on the capacity of CARP. While some of the initial enthusiasm surrounding the program has subsided, a core group of 8 to 15 dedicated volunteers has been maintained over the past years and eight sites remain actively monitored.

1.2 Program Objectives

The Annapolis River Guardians program has four objectives:

- To establish and support a regular observation system that provides 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 aquatic resources in the future.

1.3 Overview of 2012 Monitoring Season

Sample collection for the 2012 season ran from April 22nd to October 21st on a biweekly basis. The parameters monitored were E. coli bacteria, dissolved oxygen content, water temperature, air temperature, pH, conductivity, and turbidity. Total suspended solids (TSS) and turbidity event sampling was initiated in 2008, but was not performed in the 2012 monitoring season. Sampling of these parameters was part of a joint project between CARP and Environment Canada, in order to determine baseline levels in the Annapolis River and to establish a mathematical relationship between the two variables. TSS was estimated from the regular turbidity samples this year. Bacteria count, DO and temperature data have been collected since the inception of the River Guardians program in 1992, pH has been collected since 2003 and nutrients have been monitored by Environment Canada since 2006.

Eight stations were sampled along the Annapolis River. Further information on these sampling locations is contained in Appendix B. The monitoring sites for 2012 were all within the freshwater portion of the Annapolis River (Figure 1). The data collected by the volunteers is stored in a Microsoft Access database at the CARP office.

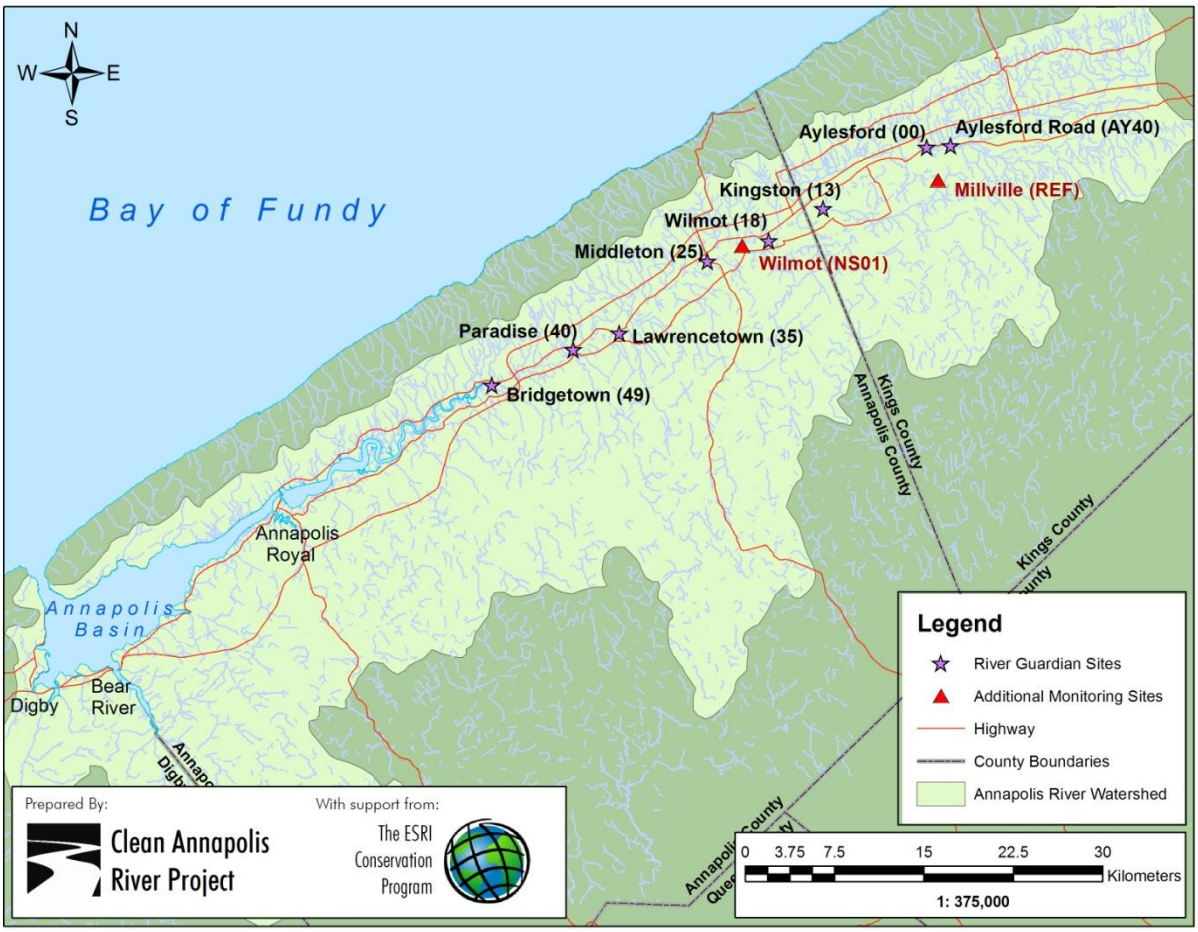

Figure 1. Annapolis River watershed with 2012 River Guardian monitoring sites identified by stars.

The 2012 River Guardian sampling locations (with their identification numbers) were:

49 – Bridgetown	40 – Paradise	35 – Lawrencetown	25 – Middleton
18 – Wilmot	13 – Kingston	00 – Victoria Road, Aylesford	AY40 – Aylesford Road, Aylesford

All sample sites are located on the main stem of the Annapolis River. With the exception of Aylesford Road (Site AY40), each location has a large River Guardians sign (Figure 2) that indicates E. coli contamination and overall water quality trends for that location. The signs are updated by the volunteers every two weeks and are on display from May through to November.

In addition to the regular River Guardians sites, site NS01 (Bayard Road in Wilmot) and REF (South Annapolis River at Millville) are shown in Figure 1. The River Guardians did not monitor these sites, but they were used for the monitoring of nutrients by Environment Canada, as well as for past TSS/Turbidity sampling by CARP.

As part of CARP's Quality Assurance/Quality Control (QA/QC) plan (Sharpe and Sullivan, 2006), additional samples were taken to ensure good data quality. The QA/QC measures taken are detailed in Appendix C.

Figure 2. River Guardian sign displaying the date, latest bacteria count, and overall water quality trend.

2.0 2012 Monitoring Results

2.1 *E. coli* Bacteria

2.1.1 Introduction

Escherichia coli (*E. coli*) are rod-shaped, aerobic, lactose fermenting bacteria that are present in the wastes of humans, animals, and even some fish (Valiela et al., 1991). The predominant sources of *E. coli* bacteria in a watershed include poorly maintained on-site septic systems, malfunctioning central sewage treatment plants, aquatic wildlife, domestic animals, and livestock. Because they occupy the same ecological niche as many human pathogens, such as Cryptosporidium, *E. coli* are used as indicators for the possible presence of other potentially dangerous pathogens. *E. coli* levels have been identified in the past as a major cause of concern in the Annapolis River watershed (Pittman et al., 2001).

Many factors in a particular ecosystem affect the abundance and persistence of *E. coli* in rivers. These include the type of contributing source, the transport mechanism with which the *E. coli* is deposited, and precipitation. The result is that *E. coli* densities in surface waters can be highly variable. Their survival in surface waters is not well understood, and is dependent on many factors. These include predation by other organisms, the amount and intensity of sunlight reaching the water surface, pH, salinity of the water, temperature, as well as composition and abundance of sediment (Wcisto and Chróst, 2000; Davies et al., 1995). The persistence of *E. coli* in river systems is also largely dependent upon the composition and type of media in which they are found. For example, there are a range of estimates for the survival times of the commonly monitored *E. coli* in various media:

Cow pats: 49 days at 37oC, 70 days at 5oC (also dependent on moisture content) (Chalmers et al., 2000)
Drinking water: Between 28 and 84 days (Edberg et al., 2000)
Soil cores with grass roots: 130 days (Chalmers et al., 2000)
Freshwater sediment: 57 days (Davies et al., 1995)

From 1992 to 2011, numerous initiatives were undertaken which have contributed to the improvement of water quality in the Annapolis River. For example, in the winter of 1994, 14 Wing Greenwood discontinued the discharge of untreated aircraft wash-water into a tributary of the Annapolis River. In August 1998, the base discontinued the operation of its own sewage treatment plant, redirecting its waste to the Greenwood municipal facility. In October of 2011, the Town of Middleton completed the construction of a new sewage treatment plant.

While the core River Guardian monitoring program has been maintained over the period of 1992 to 2012, a number of modifications have been made. For example, in 1996, the collection of *E. coli* samples was standardized to every two weeks. In the period from 1997 to 2002, fecal coliform numbers were determined using the IDEXX Colilert procedure, which specifically identifies *E. coli*. With the change to a new laboratory, the 2003 and 2004 samples were analyzed using the Membrane Filtration procedure, which enumerates fecal coliforms (see Appendix A). In 2005, the Science Advisory Committee for the Annapolis River Guardians advised that bacteria monitoring be switched from fecal coliforms to *E. coli*, to bring the program more in line with current guidance at a national level. To ensure the continuity of the historic dataset, it was decided to collect split samples for the first two months of the season, to allow parallel testing for fecal coliform and *E. coli*. This process confirmed that the two methods do not give statistically different results. Further information on the parallel testing and statistical analysis can be found in the 2005 Annual Report for the Annapolis River Guardians (Beveridge et al., 2006).

The sampling procedure for *E. coli* collection can be found in Appendix A.

2.1.2 Canadian Water Quality Guidelines

Various government agencies have developed 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 (CCME) has incorporated these guidelines in the comprehensive Canadian Water Quality Guidelines (CCME, 2002). There have been several different guidelines developed for different possible water uses, such as protection of aquatic life, agricultural uses, drinking or recreation. CARP has summarized some of these guidelines for *E. coli* bacteria contamination into a single table for public awareness purposes (Table 1).

Table 1. Summary of water quality guidelines and categories for *E. coli*.

cfu*/100ml	Water Use	Explanation/Source
0	Acceptable for drinking	*E. coli*/100ml. (Health Canada, 2010)
1-50	Acceptable for livestock watering	Interpretation of CCME narrative "high-quality water given to livestock" (cfu/100mL).
50-100	Acceptable for food crop irrigation	Tentative Maximum Concentration. CCME Guidelines (cfu/100mL).
100-200	Acceptable for recreational use	Interim category.
>200	Unacceptable for human recreational contact	Geometric Mean of 5 samples taken during a period not to exceed 30 days, should not exceed 200 cfu/100 mL (Health Canada, 1992).
>400	Unacceptable for human recreational contact	Single sample maximum concentration taken in a given period should not exceed 400 cfu/100 mL (Health Canada, 2012).

*cfu = colony forming units

2.1.3 Monitoring Results

The high variability of fecal bacteria measurements presents a number of challenges with respect to data analysis. Samples collected from a single site, on separate occasions, can vary by two and sometimes three orders of magnitude (e.g. 3 cfu/100 ml to 3000 cfu/100 ml). The use of standard data analysis methods, such as calculating and comparing mean values, inadequately describes the distribution of fecal bacteria results. The following analysis is therefore based on the proportion of samples analyzed that exceed particular water quality thresholds. This approach was chosen as it best presents to decision-makers and resource managers whether the water at a site is unsuitable for particular uses.

While this approach eliminates the bias of calculating means with highly variable data, it presents another type of bias. If the majority of samples one year fall slightly below a guideline threshold (e.g. 200 cfu/100 ml), a small increase in fecal coliform concentration the next year may cause the proportion of samples above 200 cfu/100 ml to increase significantly. This would give the appearance that the water quality had worsened considerably, when in fact the mean coliform concentration may have only increased slightly. In order to ensure the differences observed in the following analysis are real, a box-whisker plot was prepared to compare the distribution of the 2011 and 2012 *E. coli* results (Figure 3). The box plot shows the 25th and 75th percentiles as well as the median for each site. The minimum and maximum results are also shown. Note that the y-axis of the graph is plotted using a logarithmic scale (Log *E. coli*) and that the data is artificially capped at 2419 cfu/100mL, as this is the maximum possible value with the IDEXX Colilert testing system. From 1992 to 2012, approximately 2% of the data have exceeded this cap value.

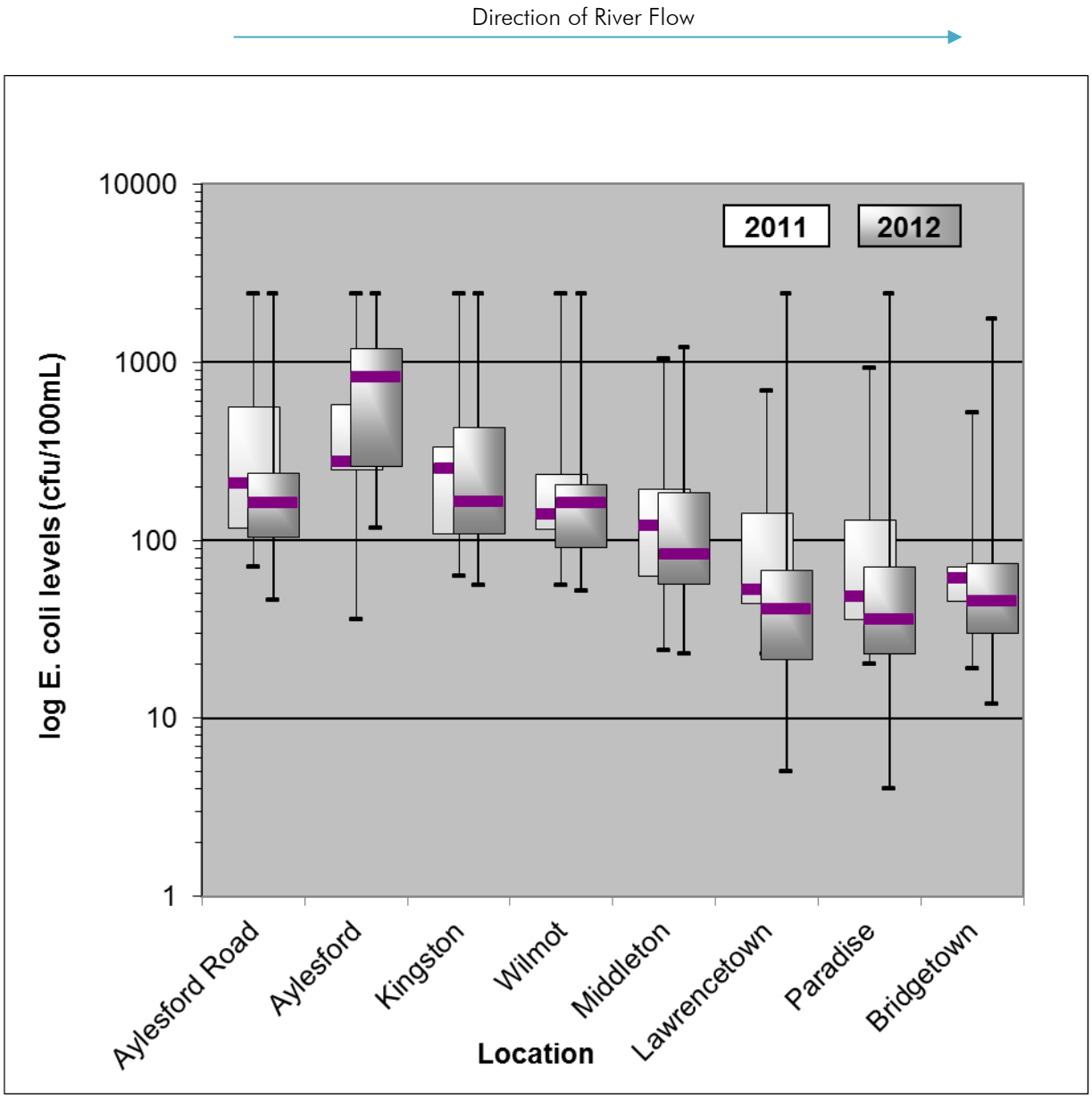

Figure 3. Box and whisker plots of Annapolis River Guardian *E. coli* bacteria results for 2011 and 2012.

In 2012, the median *E. coli* values for the monitoring sites were slightly lower than in 2011, except for two locations: Aylesford and Wilmot. Sites with lower median values were Aylesford Road, Kingston, Middleton, Lawrencetown, Paradise, and Bridgetown. Aylesford, Kingston, Lawrencetown and Bridgetown showed greater variability this season, while Aylesford Road and Paradise showed less. Wilmot and Middleton portrayed a similar variability to 2011. Contamination continues to be greatest in upstream river sites, and there appeared to be a greater difference in values between the Aylesford Rd and Aylesford sites.

The *E. coli* data for each River Guardian location was calculated as the percentage of samples that fell within each of the ranges specified in Table 1 (Tables 2 through 9). This allows easy visualization of how the *E. coli* readings have fluctuated for each station since CARP began monitoring the Annapolis River. All of the *E. coli* ranges are in units of cfu/100mL.

Table 2. *E. coli* percentages for Aylesford Road.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992				
1993				
1994				
1995				
1996				
1997				
1998				
1999				
2000				
2001				
2002				
2003	20	40	20	20
2004				
2005	33	13	27	27
2006	29	6	6	59
2007	20	20	33	27
2008	8	23	38	31
2009	29	14	36	21
2010	0	23	31	46
2011	0	21	21	57
2012	15	8	31	46

Table 3. *E. coli* percentages for Kingston.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	67	33	0	0
1993	21	21	36	21
1994	33	17	0	50
1995	86	0	0	14
1996	50	19	6	25
1997	19	38	31	13
1998	27	27	27	18
1999	35	18	18	29
2000	40	20	33	7
2001	24	29	18	29
2002	39	28	17	17
2003	13	13	40	33
2004	7	14	43	36
2005	33	7	33	27
2006	7	29	14	50
2007	14	29	14	43
2008	15	0	46	38
2009	0	29	43	29
2010	7	21	21	50
2011	0	14	28.6	57
2012	0	21	36	43

Table 4. *E. coli* percentages for Aylesford.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	0	0	50	50
1993	9	9	27	55
1994	17	17	17	50
1995	67	0	17	17
1996	62	0	0	38
1997	14	14	29	43
1998	15	8	23	54
1999	9	18	27	45
2000	40	0	20	40
2001	25	19	31	25
2002	6	11	33	50
2003	16	16	58	11
2004	6	0	24	71
2005	29	7	7	57
2006	8	23	8	62
2007	6	6	12	76
2008	0	23	8	69
2009	7	14	0	79
2010	0	21	7	71
2011	8	8	0	85
2012	0	0	15	85

Table 5. *E. coli* percentages for Wilmot.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	0	33	0	67
1993	19	13	19	50
1994	13	0	31	56
1995				
1996				
1997	28	11	44	17
1998	60	30	10	0
1999	31	25	19	25
2000	50	17	17	17
2001	25	31	25	19
2002	29	35	12	24
2003	20	47	13	20
2004	0	21	57	21
2005	27	7	60	7
2006	21	36	14	29
2007	27	27	27	20
2008	23	8	54	15
2009	15	8	23	54
2010	21	7	36	36
2011	0	21	43	36
2012	0	43	29	29

Table 6. *E. coli* percentages for Middleton.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	0	33	0	67
1993	14	14	43	29
1994	9	9	27	55
1995				
1996	40	10	20	30
1997	13	25	50	13
1998	50	0	25	25
1999	50	8	25	17
2000	60	20	7	13
2001	41	18	24	18
2002	65	29	6	0
2003	36	29	14	21
2004	15	23	38	23
2005	53	20	13	13
2006	43	21	7	29
2007	20	27	27	27
2008	14	36	21	29
2009	29	21	21	29
2010	21	14	36	29
2011	21	21	29	29
2012	21	36	14	29

Table 7. *E. coli* percentages for Paradise.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	0	0	67	33
1993	14	14	36	36
1994	14	29	0	57
1995	63	0	13	25
1996	29	18	12	41
1997	50	36	7	7
1998	22	44	22	11
1999	42	25	25	8
2000	33	17	8	42
2001	35	18	29	18
2002	59	6	18	18
2003	40	20	27	13
2004	14	21	21	43
2005	36	36	21	7
2006	33	7	13	47
2007	53	27	7	13
2008	54	23	15	8
2009	43	21	14	21
2010	36	29	7	29
2011	54	15	8	23
2012	64	14	0	21

Table 8. *E. coli* percentages for Lawrencetown.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992	0	33	33	33
1993	7	14	21	57
1994	24	6	41	29
1995	43	0	29	29
1996	13	13	33	40
1997	29	36	29	7
1998	42	25	25	8
1999	40	30	30	0
2000	53	20	7	20
2001	56	25	13	6
2002	50	11	17	22
2003	53	20	7	20
2004	21	29	21	29
2005	47	33	20	0
2006	40	7	13	40
2007	57	14	7	21
2008	54	23	8	15
2009	50	14	7	29
2010	50	7	14	29
2011	50	21	7	21
2012	50	36	0	14

Table 9. *E. coli* percentages for Bridgetown.

Year	% in 0 - 50	% 51 - 100	% 101 - 200	% >200
1992				
1993				
1994	14	21	21	43
1995	44	11	22	22
1996	29	18	18	35
1997	35	12	47	6
1998	44	38	13	6
1999	33	22	28	17
2000	60	27	13	0
2001	71	18	0	12
2002	41	35	12	12
2003	33	27	13	27
2004	14	7	50	29
2005	40	47	7	7
2006	27	20	20	33
2007	53	13	0	33
2008	50	29	7	14
2009	29	29	14	29
2010	29	14	14	43
2011	39	39	15	8
2012	57	21	7	14

There does not appear to be an indicative trend for *E. coli* as the values at all sites are quite variable (Tables 2 to 9). The percentage of samples that fell into the range 0-50 cfu/100 mL increased for Aylesford Road, Paradise and Bridgetown, remained the same for Kingston, Wilmot, Middleton, and Lawrencetown, and decreased for Aylesford. For the range 51-100 cfu/100 mL, percentages increased in Kingston, and decreased at Aylesford Road, Aylesford, Paradise, and Bridgetown. For the range 101-200 cfu/100 mL, Aylesford Road, Aylesford, and Kingston had more values fall into this range than in 2011, and Wilmot, Middleton, Lawrencetown, Paradise and Bridgetown had less. The percentage of values with >200 cfu/100 mL of *E. coli* increased for Kingston and Bridegetown, remained the same for Aylesford and Middleton, and decreased for Aylesford Road, Kingston, Wilmot, Lawrencetown, and Paradise.

The percentage of samples falling into the >200 cfu/100mL and 101-200 cfu/100mL category decreased in 2012 when compared to 2011, while both the 51-100 cfu/100mL and 0-50 cfu/100mL categories increased. Overall the changes were very minor between the two years, the observed differences likely attributable to a lower amount of summer precipitation in 2012. The percentage of data falling into each of these categories for all locations was compiled (Figure 4) as well as the number of samples taken in each year (Table 10).

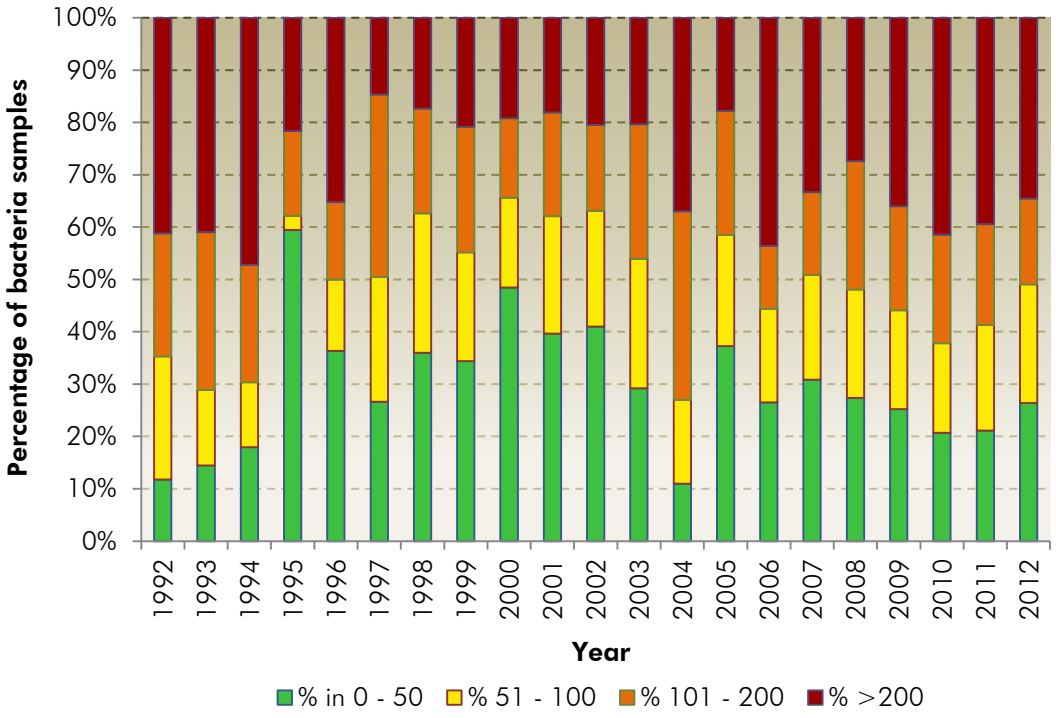

Figure 4. Percentages of *E. coli* samples (cfu/100mL) that fall into each water quality category by year.

Table 10. The number of *E. coli* or fecal coliform samples taken each year.

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Sample Count	17	83	89	37	88	109	75	96	99	116	122	113	100	118	117	120	106	111	111	110	111

It is important to note that in 1992 and 1995, a relatively small number of samples were collected. 1992 showed few sample proportions falling into the 0 – 50 cfu/100mL range, while 1995 revealed an extremely high proportion. However, due to the fact that there were so few samples taken in those years, the results may not adequately reflect actual water quality for those years.

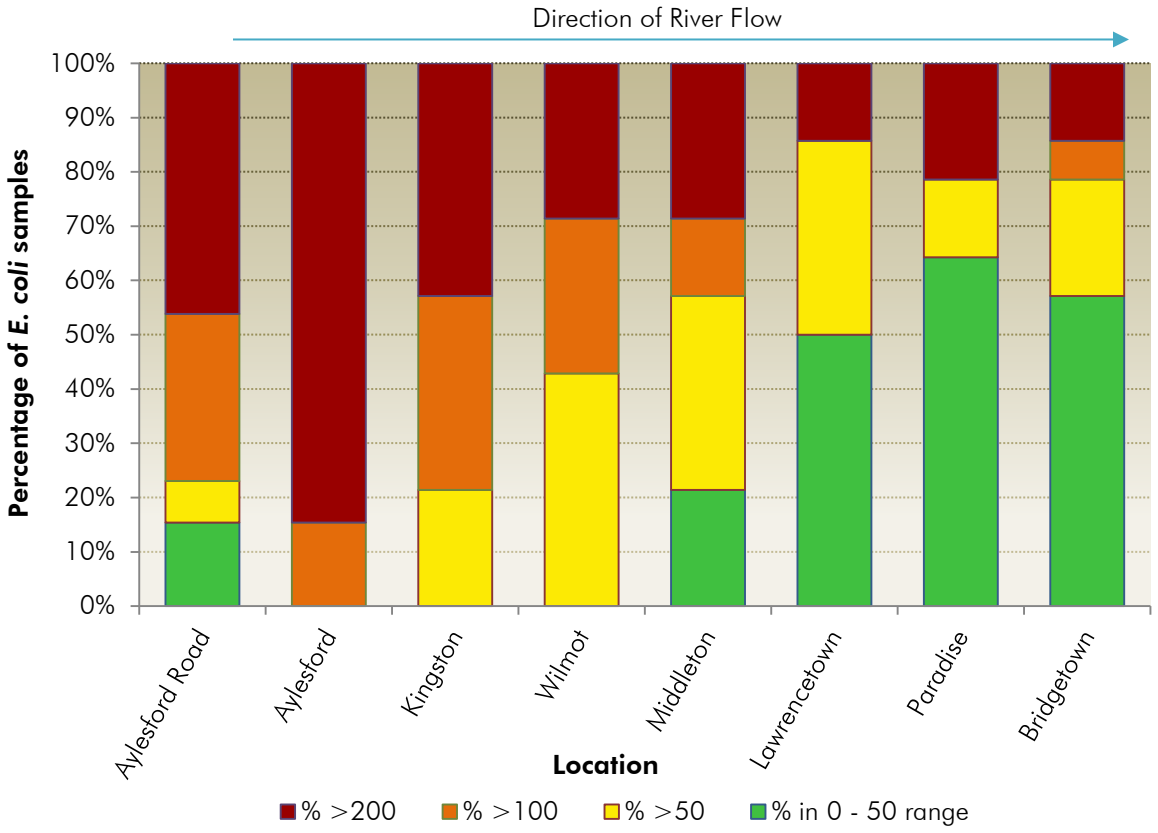

Figure 5. The percentages of 2012 samples falling into the different cfu/100mL ranges, organized by location.

Following a similar pattern as previous years, the highest bacteria counts occurred in Aylesford on Victoria road, while the lowest occurred at the Bridgetown, Paradise and Lawrencetown locations (Figure 5). In 2012, the lowest *E. coli* count was 4 cfu/100mL at Paradise, while the highest was 2419 cfu/100mL (artificially capped), recorded at several sites. There seems to be a source of contamination between the Aylesford Road and Aylesford sites, which may be coming in from one of several tributaries that join the main river between these two sites. In 2009, an attempt was made to identify possible sources of this bacterial contamination. These results were inconclusive based on the testing method and are detailed in the 2009 River Guardian Report. Further foot surveys were conducted along one of the tributaries (Patterson Brook) between the two sites in 2012. The results from this study are available internally.

2.1.4 *E. coli* Monitoring Recommendations

- Continue regular River Guardian *E. coli* monitoring at the eight main river sample locations.
- Contact livestock owners addressing the issue of restricting animals from the Annapolis River.
- Continue to investigate the potential source(s) of contamination between Aylesford Rd and Victoria Rd.
- Investigate correlation between precipitation amounts and *E. coli* levels in the river.

2.2 Dissolved Oxygen

2.2.1 Introduction

Dissolved oxygen (DO) is a widely used and important general indicator of the health of a river system (Addy et al., 1997). Aquatic organisms require oxygen in solution for internal 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, lower rates of photosynthesis, eutrophication and limited diffusion from the atmosphere due to ice cover can all lead to decreased oxygen levels.

As the temperature of water decreases, a greater concentration of oxygen is able to dissolve in the water. DO levels are also dependent to a lesser degree on atmospheric pressure and water salinity. The amount of oxygen in water can be reported in two ways, either as a concentration measurement (mg/L) or as percent saturation. Percent saturation represents the actual amount of dissolved oxygen in an amount of water compared to the maximum amount that can be dissolved. This value is given as a percentage. Water reaches its saturation point when it can no longer dissolve any additional oxygen for a given temperature. High levels of photosynthesis or turbulent conditions can "supersaturate" the water, resulting in saturation levels greater than 100%. Dissolved oxygen levels below 60% saturation are known to cause stress to aquatic life, particularly cold-water fish species (Mackie, 2004). Comparatively, CCME guidelines for concentrations of dissolved oxygen (mg/L) for the protection of freshwater warm-water species is 5.5 mg/L, while that for cold water species is 6.5 mg/L (CCME, 2002).

2.2.2 Monitoring Results

To better understand the status of dissolved oxygen levels in the Annapolis River, values for both percent saturation (DOSAT) and concentration (mg/L) were compared. During the period of 1992 to 2012, annual mean dissolved oxygen (percent saturation) levels have varied from a high of 94% in 1992, to a low of 80% in 1996 (Figure 6). Variation between DOSAT levels has had minimal variation over the past four years; however the 2012 mean was slightly higher than the previous 3 years. In 2012, the mean dissolved oxygen saturation was 87.1%, compared with 85.5% in 2011. This value is within the normal range of variability observed for the Annapolis River. The standard error of the mean is shown with error bars, which indicate that there was similar variability in 2012 as in 2011. The maximum DOSAT value recorded in 2012 was 147% on August 26th, in Paradise, while the lowest value was 57%, in Bridgetown, on August 12.

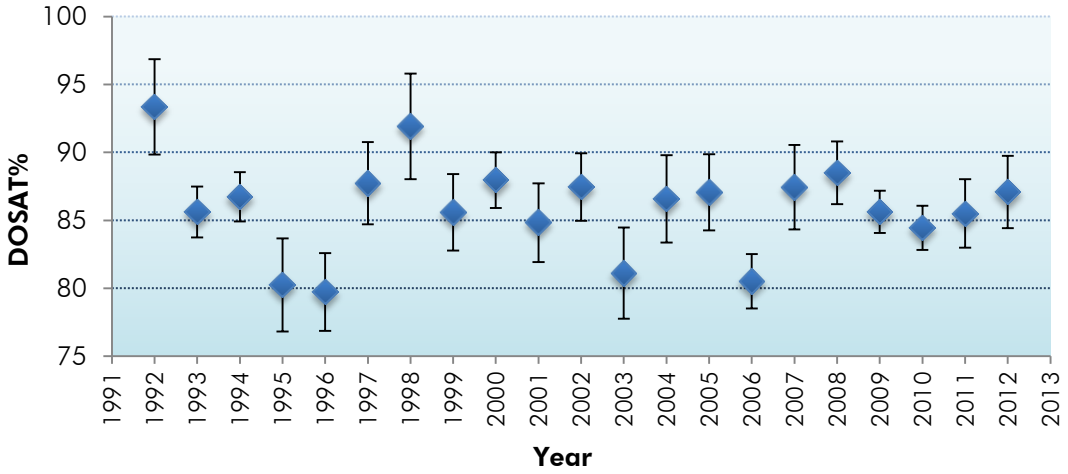

Figure 6. Mean dissolved oxygen saturation (DOSAT) by year, 1992 to 2012 (showing standard error of the mean).

Figure 7 shows the dissolved oxygen concentrations (mg/L) in the river from 1992 to 2012. As with the percent saturation, concentrations have remained fairly similar over the past several years. The mean DO (mg/L) level in 2012 was 8.53 mg/L, compared to 8.76 mg/L in 2011. The lower DO concentration, coupled with higher DOSAT levels suggests that there was a lower capacity for water to dissolve oxygen,

likely attributable to the higher observed water temperatures that year. The lowest DO (mg/L) value that was recorded in 2012 was 4.60 mg/L in Bridgetown on August 12, and the highest was 14.80 mg/L in Paradise on August 26.

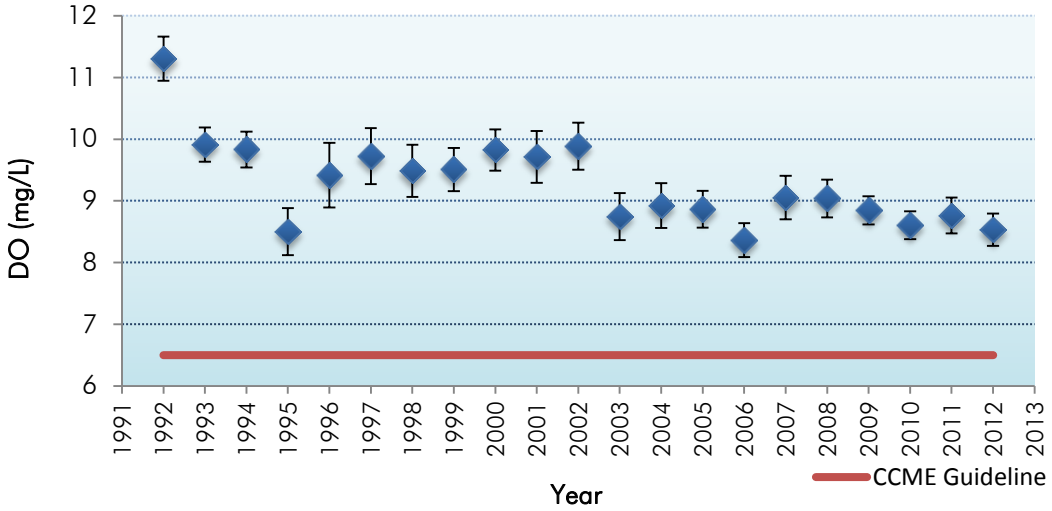

Figure 7. Mean DO (mg/L) by year, 1992 to 2012 (showing standard error of the mean). The red line represents the 6.5 mg/L threshold (CCME) below which cold water species will become stressed.

The 19-year mean dissolved oxygen values for both DOSAT and DO (mg/L) were calculated for each of the main river monitoring sites (Figures 8 and 9). The standard error of this mean is shown with error bars. This is overlaid with the mean values for the 2012 monitoring season. Paradise fell outside the normal DOSAT range, as shown by the bars indicating standard error of the mean. Conversely, Kingston, Wilmot, Middleton, Lawrencetown and Bridgetown fell outside the normal DO range. The 2012 averages at Kingston, Lawrencetown, and Bridgetown were slightly lower than the 19-year historical mean. The sampling sites at Aylesford Road and Paradise exhibited slightly higher oxygen saturation levels in 2012 as compared to the historical mean. Note that the average for Aylesford Road is only for 7 years, and that the Middleton and Wilmot averages are missing some data from 1995 and 1996. Mean oxygen saturation levels were comparable to the historic mean for Aylesford, Wilmot and Middleton.

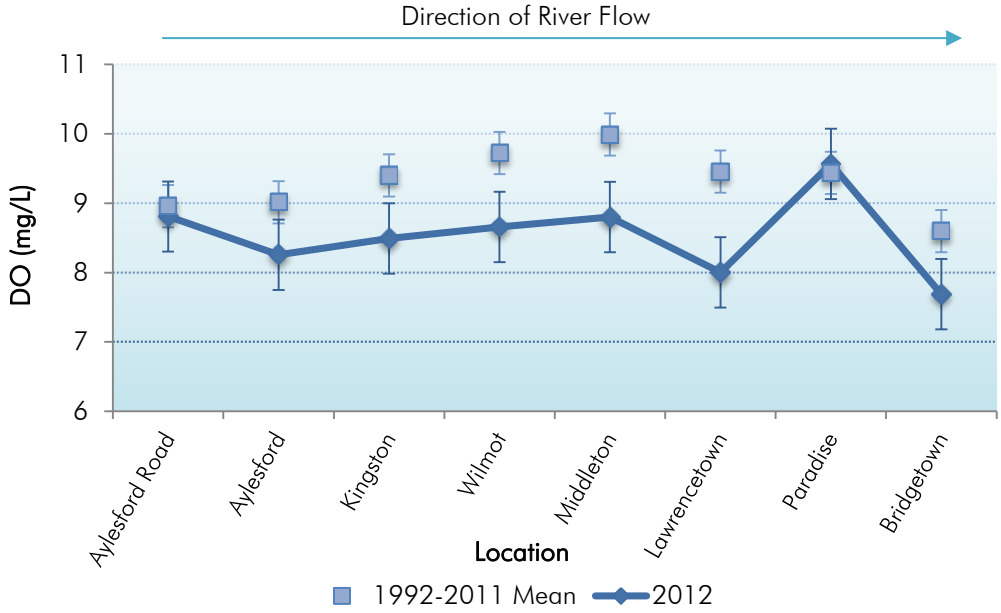

Figure 8. DO (mg/L) results for 2012 as well as mean dissolved oxygen (mg/L) from 1992 to 2011, organized by sample site. The error bars show standard error of the mean.

The DO (mg/L) results show a much different picture (Figure 8). All of the sites except for Aylesford Road and Bridgetown have significantly lower mean DO concentrations than the historical average. Paradise is slightly higher, and Aylesford is slightly lower. This vast difference observed between DOSAT and DO (mg/L) is likely attributable (in part) to the observed increase in water temperatures (see Figures 10 and 11). Although less oxygen would be able to dissolve in the water (Figure 8), the saturation levels would remain similar (Figure 9). The Paradise site illustrates this example well. In Figure 8, the 2012 average values are comparable to the historical mean DO (mg/L) values. Comparatively, the DOSAT results tell a different story for this same site, as in Figure 9, the 2012 results show a significantly higher DOSAT value when compared to the historical mean.

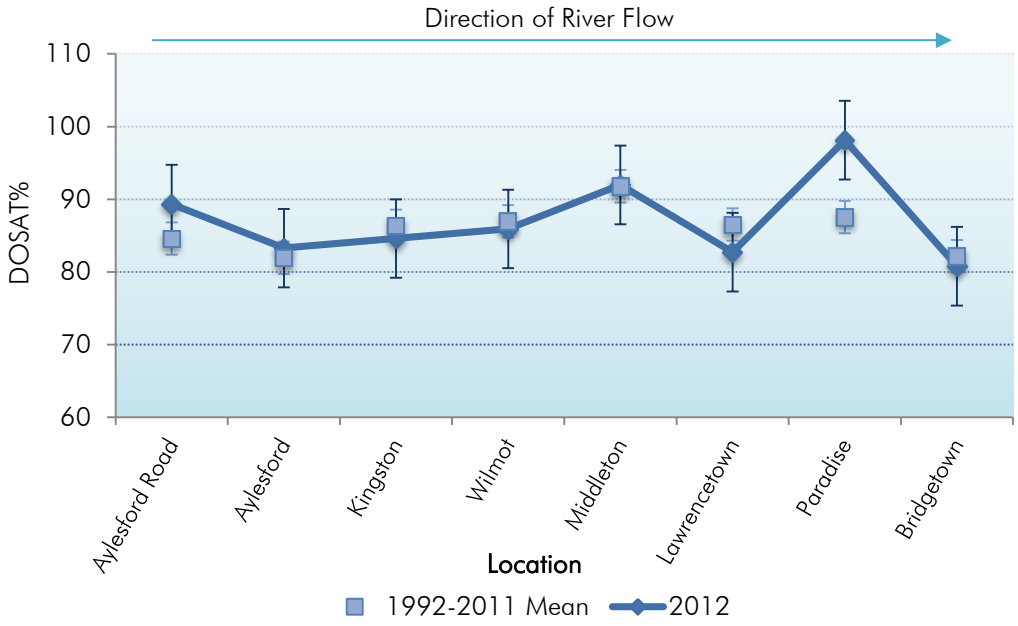

Figure 9. DOSAT results for 2012 as well as mean dissolved oxygen saturation (DOSAT) from 1992 to 2011, organized by sample site. The error bars show standard error of the mean.

Tables 11 and 12 show the distribution of samples for various DO and DOSAT categories. There was one recording below the 5.5 mg/L value in 2012 at Bridgetown, and a total of 5 recordings below 6.5 mg/L at the Aylesford, Lawrencetown, and Bridgetown sites (see Table 11). One of the samples collected had a DOSAT of 60% or less (Table 12). Out of 111 readings, 99 readings had DO saturation greater than 75%. The high levels of dissolved oxygen historically observed at Middleton are likely due to input from the Nictaux River tributary, which is fast flowing and well oxygenated. The Nictaux River joins with the Annapolis River approximately 400 m upstream from the Middleton site.

Table 11. Dissolved oxygen (mg/L) thresholds for the Annapolis River.

Site	<5.5 mg/L	5.5 to 6.5 mg/L	>6.5 mg/L	Total Samples 2012
Aylesford Road	0	0	14	14
Aylesford	0	1	13	14
Kingston	0	0	14	14
Wilmot	0	0	14	14
Middleton	0	0	14	14
Lawrencetown	0	1	13	14
Paradise	0	0	14	14
Bridgetown	1	2	11	14
Totals	1	4	107	112

Table 12. Dissolved oxygen percent saturation (DOSAT) thresholds for the Annapolis River.

Site	Samples less than 60%	Samples within 61-74%	Samples greater than 75%	Total Samples 2012
Aylesford Road	0	4	10	14
Aylesford	0	3	11	14
Kingston	0	0	14	14
Wilmot	0	0	14	14
Middleton	0	0	14	14
Lawrencetown	0	1	13	14
Paradise	0	0	14	14
Bridgetown	1	3	10	14
Totals	1	11	100	112

2.2.3 Dissolved Oxygen Monitoring Recommendations

- Continue regular River Guardian DO monitoring program at the eight main river sample locations.
- Undertake periodic DO monitoring of the Annapolis River estuary in the late summer and early autumn. These times are most likely to display depressed levels of DO. Depth profiling should be included as part of this monitoring.
- Investigate atmospheric pressure readings to determine whether or not they vary enough to affect dissolved oxygen readings.

2.3 Temperature

2.3.1 Introduction

Water temperature, like dissolved oxygen, serves as a broad indicator of water quality. The temperature of water has a direct bearing on the aquatic species present and their abundance. For example, trout and salmon species experience stress at water temperatures in excess of 20ºC, with lethality occurring after prolonged exposures to temperatures over 24ºC (MacMillan et al., 2005).

2.3.2 Monitoring Results

The mean summer water temperature for the Annapolis River in 2012 was 21.0 ºC, which is 1.2ºC warmer than the same period in 2011. As in previous years, water temperatures during 2012 continued to reach and exceed levels stressful to aquatic life during the summer months (see Figure 10). The 2012 season had the highest recorded mean summer water since the inception of the River Guardian program. The data had a similar range of variability as compared to data recorded in previous years. The mean summer water temperature (July, August, September) by year for the eight main River Guardian monitoring sites were compared to the 1992 to 2012 mean summer water temperature (18.7ºC). The average for 2012 is 2.3 ºC above this average.

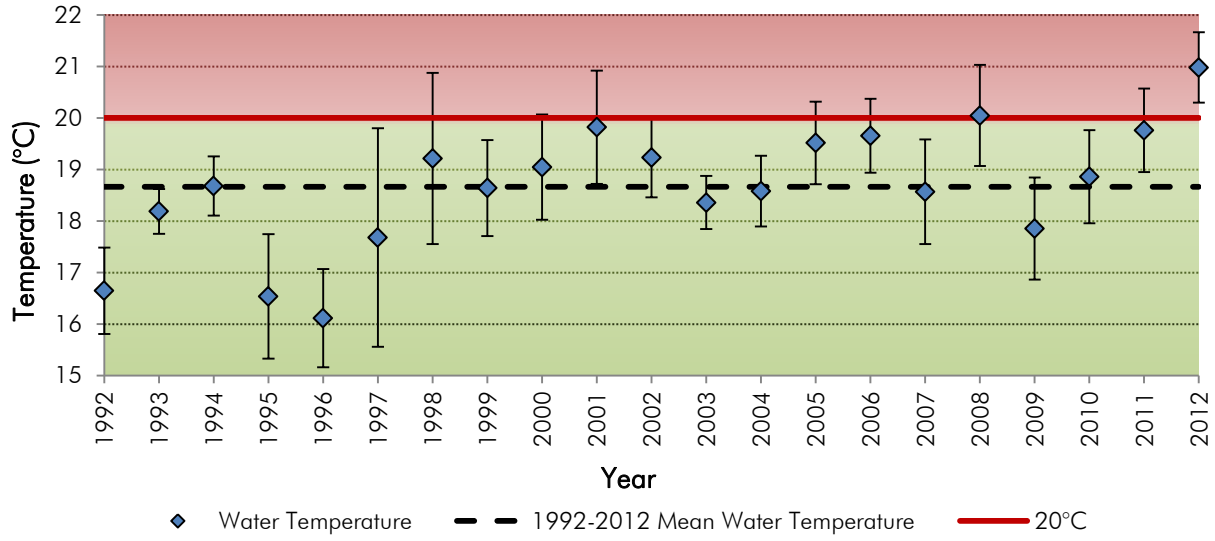

Figure 10. Mean summer water temperatures by year (showing standard error of the mean) with the 1992-2012 mean shown as a thick dashed line. The 20°C threshold where fish become stressed is shown as a thick red line.

The data from previous River Guardians annual reports suggested a gradual increase in temperature in the lower river sites, particularly in the summer data. The mean summer water temperature values along the main Annapolis River in 2012 were compared to the historical averages for those sites (Figure 11). At all sites, the 2012 average was higher than the average from 1992 to 2011. Kingston had the greatest deviation with an average temperature 2ºC warmer than the historical value.

Of the 111 discrete water temperature measurements recorded during the months of July, August and September in 2012, 58% exceeded 20ºC. The portion that exceeded 20ºC in 2011 was 29%. The maximum water temperature observed was 26.6ºC, recorded at Paradise on July 15th, 2012.

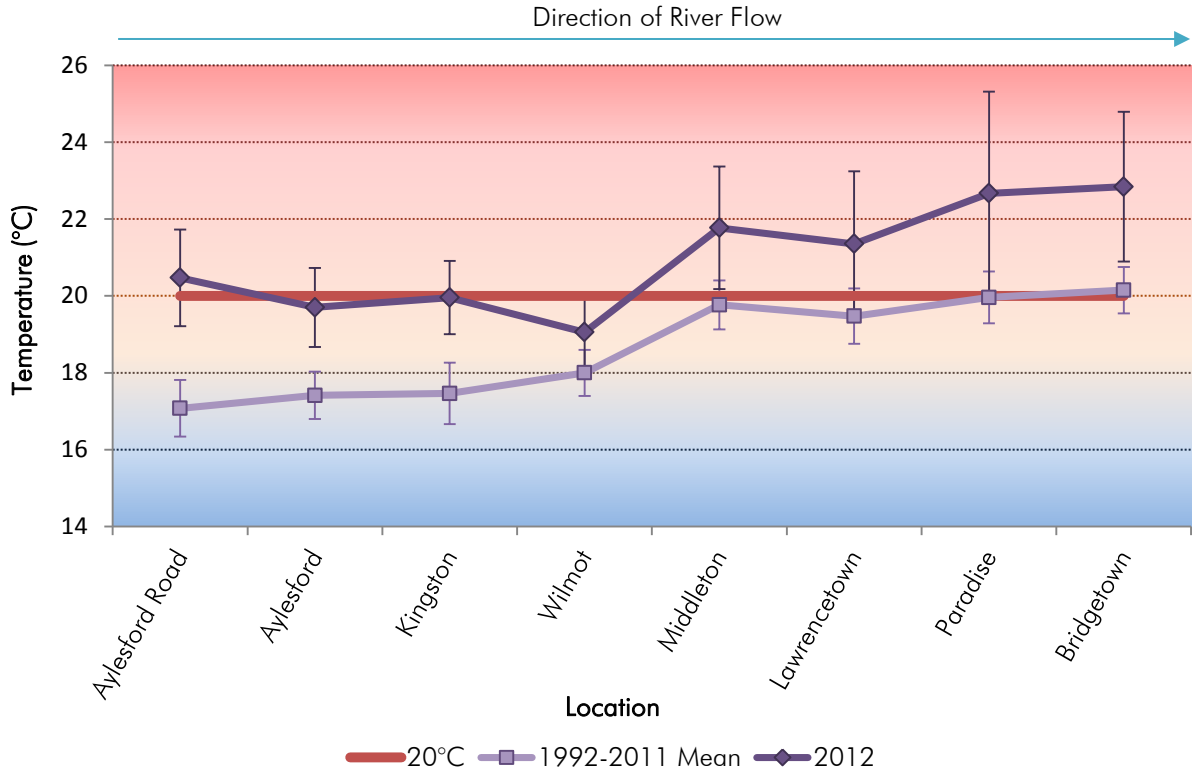

Figure 11. Mean 2012 summer water temperatures and historical average temperatures (1992-2011) by site, showing standard error of the mean. The 20°C threshold where fish become stressed is shown as a thick red line.

Figures 12 and 13 show the temperature data collected from dataloggers installed at the Aylesford Road and Kingston monitoring sites. These were installed partway through the season, and so did not capture the variations in temperature for the entire summer. Both sites exhibited similar datasets; however the Kingston site appeared to have a lower magnitude of diurnal fluctuations than Aylesford Road. The high summer water temperatures recorded by the River Guardians is also reflected in the data collected by the dataloggers, however the most stressful temperatures are not being captured by the regular River Guardian monitoring program. This is because the River Guardians data is collected at noon, whereas the peak daily temperatures were recorded at 3 pm by the dataloggers. A third logger was installed at Middleton, however this was lost and the data unrecoverable.

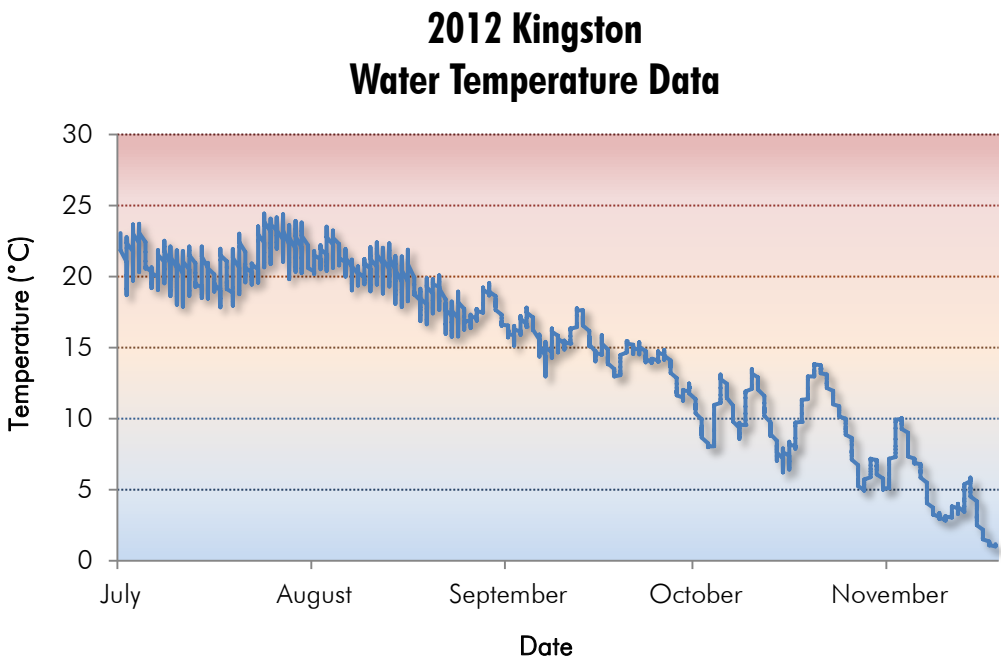

Figure 12. 2012 Logger water temperature data for Kingston (Site 13).

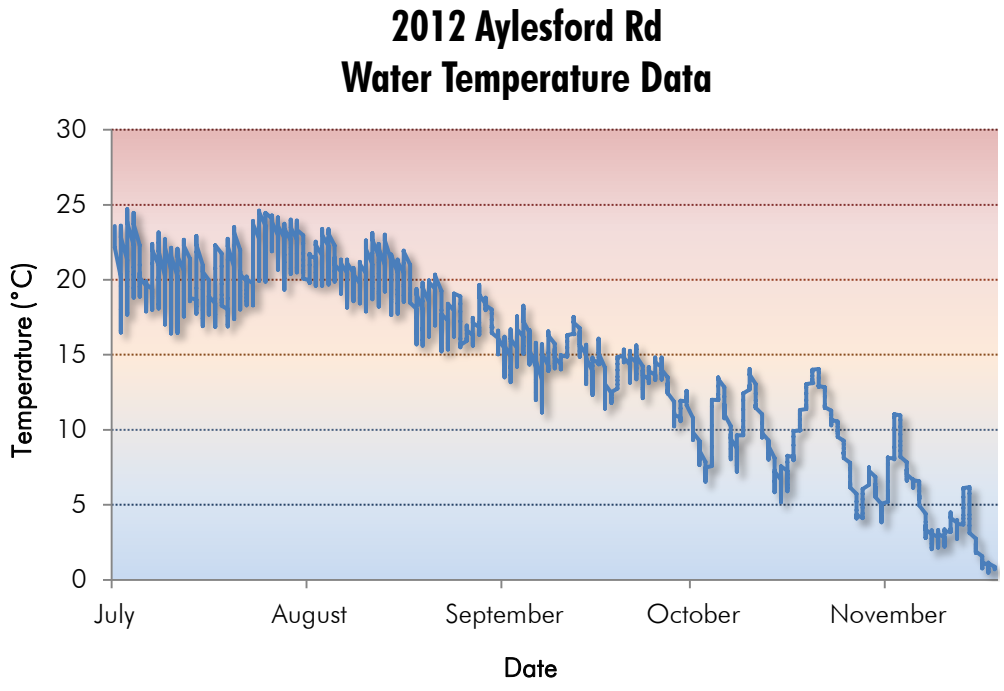

Figure 13. 2012 Logger water temperature data for Aylesford Road (Site AY40).

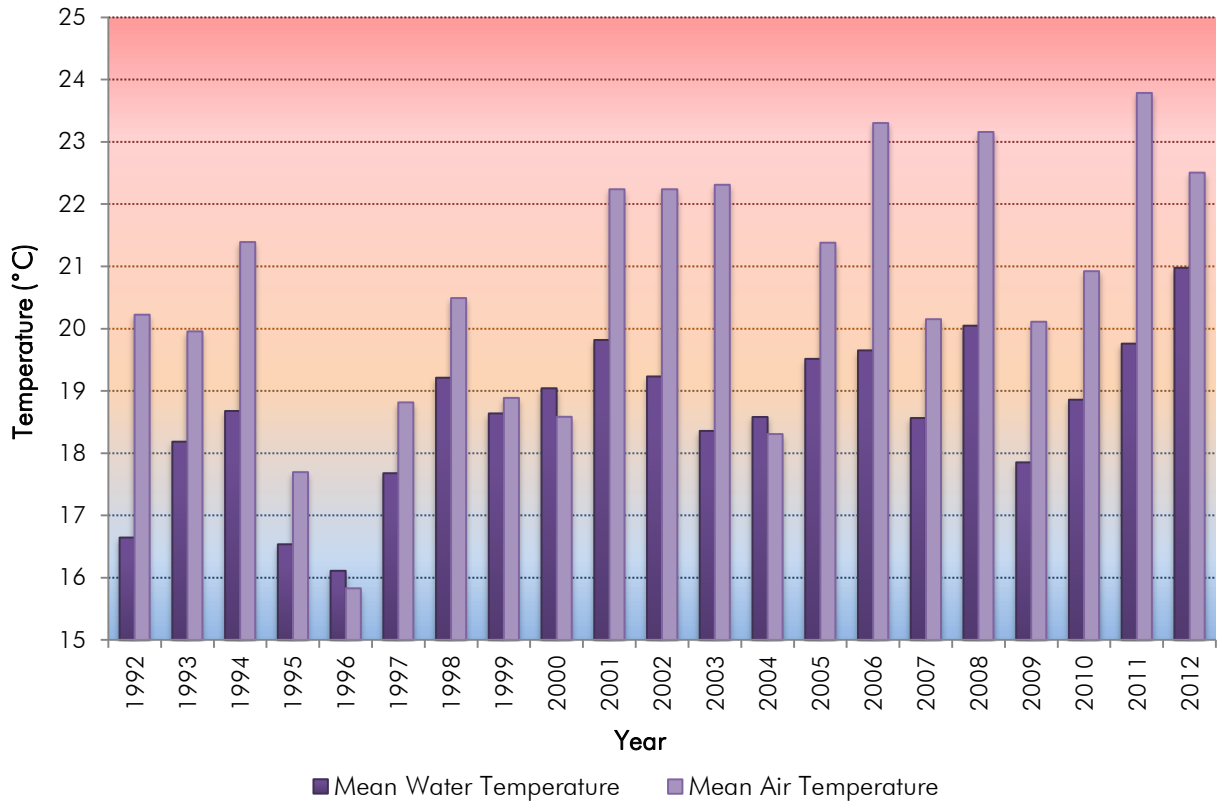

Figure 14. Mean summer air and water temperatures (1992-2012) by year.

The mean summer water and air temperatures are shown by year in Figure 14, for each year from 1992 to 2012. The coefficient of determination (R2) in Figure 15 denotes a value of 0.7461. This means that 74.6% of the variance in water temperature values can be explained by changes in air temperatures. A perfect correlation (data all on the trendline) would have an R2 of 1, while data with little to no correlation would have values closer to 0. Therefore, there is a strong positive correlation between the air and water temperatures (Figure 15). For the most part, higher air temperatures coincided with higher water temperatures, except in 1996, 2000 and 2004, where mean air temperatures were slightly below mean water temperatures. It is possible that River Guardian sampling dates in these years fell on colder days of the summer, which may explain the slightly lower air temperature values. The mean summer air temperature for 2012 was 22.5°C, which was 1.5°C higher than the mean annual water temperature of 21.0°C, and 1.3°C lower than the mean summer air temperature in 2011.

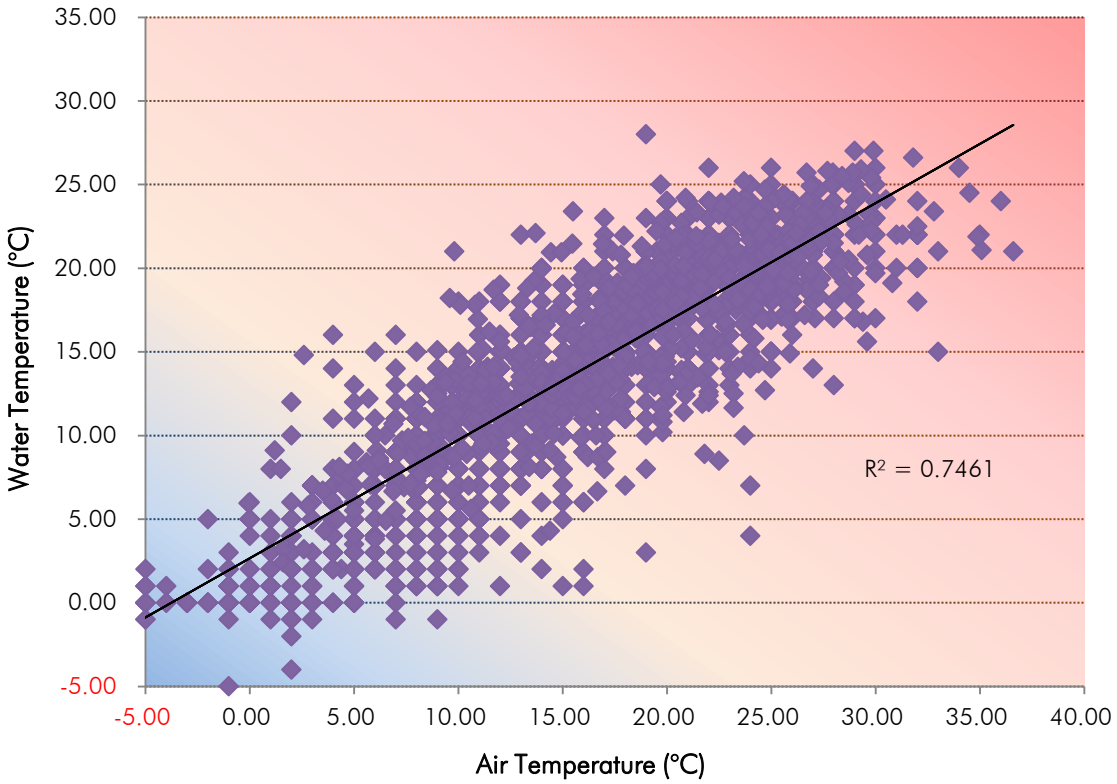

Figure 15. Correlation between air and water temperature values from 1992 to 2012.

2.3.3 Water Temperature Monitoring Recommendations

- Continue regular River Guardian temperature monitoring program at the eight main river locations.
- Continue temperature logger installations at regular monitoring sites along the Annapolis River.
- Install temperature loggers in candidate streams to assess for fish habitat improvements.
- Temperature data loggers should be calibrated immediately prior to deployment and at least once in situ. These procedures should be added to the QA/QC Project Plan.
- Investigate the temperature increase on the Annapolis River between Aylesford and Lawrencetown. This may include collection of thermal status data on tributaries to the Annapolis River.

2.4 pH

2.4.1 Introduction

pH is a measure of the acidic/basic nature of water and is determined by measuring the concentration of the hydrogen ion (H+). It is expressed on a logarithmic scale from 0 to 14, with zero being the most acidic and 14 the most basic. As pH is an inverse logarithmic scale, every unit decrease in the pH scale represents a tenfold increase in acidity. To ensure the health of freshwater aquatic life, pH levels should not fall outside the range of 6.5-9.0 (CCME, 2002). Levels below 5.0 are known to adversely affect many species of fish, including salmon and trout. pH varies naturally depending on a river system's underlying bedrock and soil composition, as well as by the amount of aquatic plants and organic material present, but can also be influenced by anthropogenic means such as acid precipitation and increased atmospheric CO2 concentrations (Dodds and Whiles, 2010).

pH values are measured on the day following River Guardian sample collection by CARP staff using the portable HydroLab Quanta water meter (see Appendix A for more details on sampling procedure and meter calibration).

2.4.2 Monitoring Results

Unlike a vast majority of river systems in Nova Scotia, pH values all along the Annapolis River are generally good, being only slightly acidic (Figure 16). The probable cause is the Torbrook Geological Formation, which is carved by many of the rivers tributaries, and contains limestone that helps buffer the watershed from acidification. Out of the 112 samples of 2012, the lowest value was 6.5 at Aylesford Road on September 10th while the highest was 8.92 collected in Paradise on July 20th. On average, pH was most acidic at Aylesford Road and Lawrencetown, whose average pHs were 7.01 and 7.06, respectively, which still fell within the range of 6.5 – 9.0 deemed safe for aquatic species by the CCME. There were no values that were recorded to be out of this range in the 2012 field season. The maximum recorded pH value was 8.92 at Paradise on July 30th, and the lowest recorded value was observed at Aylesford Road on September 10, with a value of 6.5.

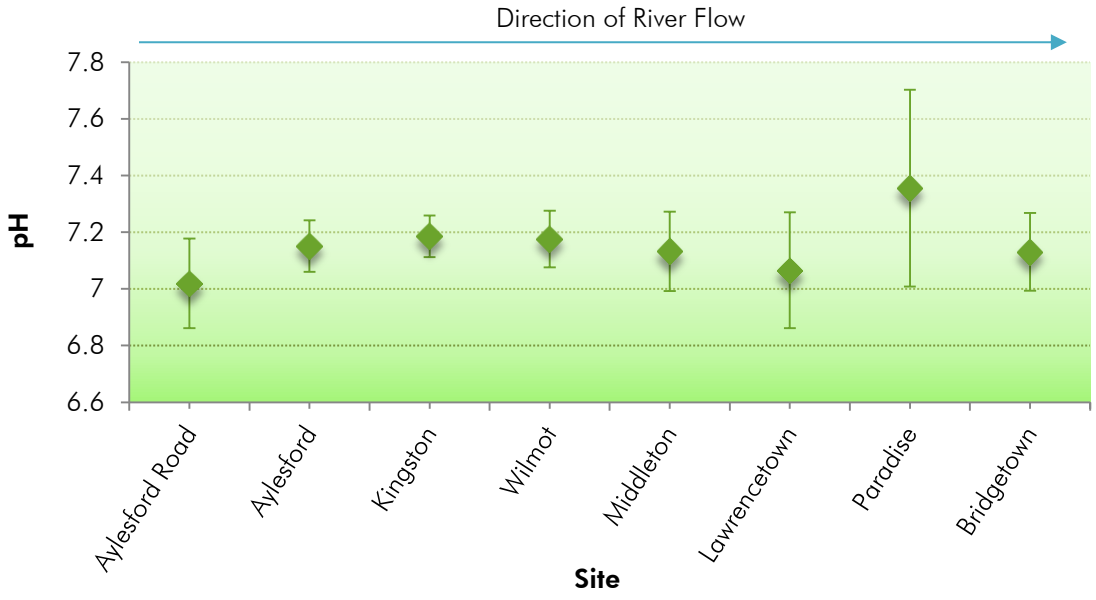

Figure 16. Average pH in 2012 for sampling locations along the Annapolis River (showing standard error of the mean).

Throughout the past 10 years, pH has been in the optimal range, except for 2005 when it fell on the lower end of the scale (Figure 17). The cause of this deviation may possibly have been acid rain and analysis can be reviewed in the 2005 River Guardians report. The pH has increased, becoming less acidic, from 2011 to 2012, across all sampling locations. During the early years of the Annapolis River Guardians program, pH was regularly measured at many of the main river sample locations. The average of this previous data was 6.9 and was based on 634 measurements. This historic pH is similar to that observed during the 2003 to 2012 period.

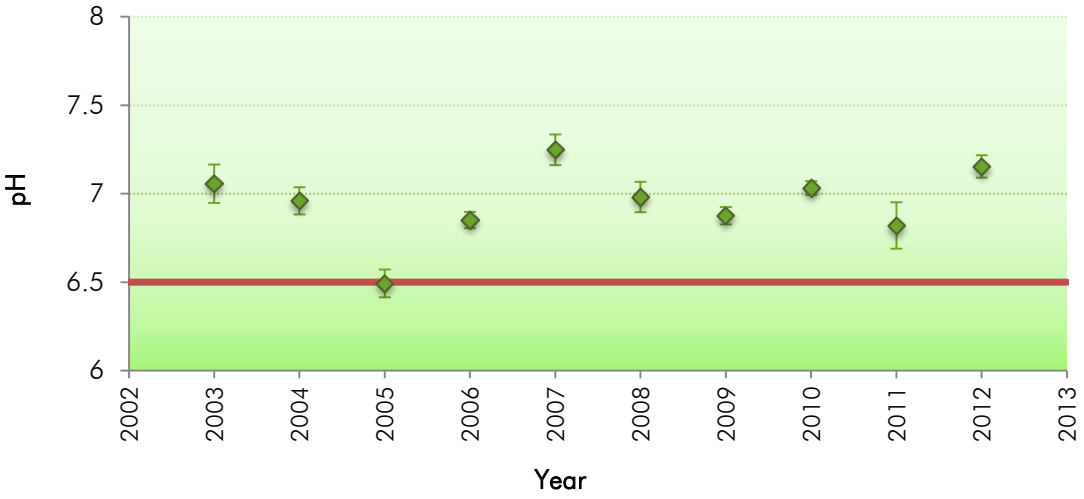

Figure 17. Average pH measured yearly along the Annapolis River (showing standard error of the mean) from 2003-2012. Shown by a thick red line is the lower threshold of 6.5 for fish species.

2.4.3 pH Monitoring Recommendations

- Regular pH monitoring should be continued at the eight Annapolis River Guardian monitoring locations.

2.5 Nutrients: Nitrogen and Phosphorus

2.5.1 Introduction

Nutrients are essential for the growth of both plant and animal life. They can occur naturally, or as a result of anthropogenic activities. Two nutrients commonly monitored in freshwater systems are nitrogen and phosphorus, which are often found to be the limiting factors of plant growth in aquatic systems. When the levels of these nutrients rise, either from natural inputs or from anthropogenic sources such as wastewater or agricultural runoff, excessive periphyton and macrophyton growth can result. Upon the death and decomposition of these plants, oxygen levels can become depleted to such an extent as to threaten aquatic life.

In 2006 and 2007, Environment Canada monitored two locations along the Annapolis River for a large range of water quality parameters including nitrogen and phosphorus. In 2008, a reference site on the South Annapolis River in Millville was added and in 2009, the Lawrencetown sample site was dropped. Nutrient monitoring is currently only carried out at Wilmot and Millville.

Dodds et al. (1998) compiled information from hundreds of streams in the US and from the EPA eutrophication survey in order to compare criteria for measuring nutrients in streams. As nitrogen can be present in various soluble and insoluble forms in freshwater systems, differing criteria for nitrogen have been outlined for both total nitrogen and dissolved nitrates. Dodds and Welch (2000) determined that acceptable total nitrogen criteria ranged from 0.25 mg/L to 3.0 mg/L, while for dissolved nitrates, criteria ranged between 0.02 mg/L to 1.0 mg/L. The CCME (2003) established a guideline of 13.0 mg/L for nitrates for the protection of aquatic life from direct toxic effects (equivalent to 2.9 mg NO3-N/L). This guideline, however, does not account for the effects of eutrophication, and was therefore determined to be too high for a threshold value in the Annapolis river watershed. An interim guideline of 0.9 mg/L total nitrogen was set as a criterion for the watershed, based on information obtained from Dodds and Welch (2000). It is believed that this value is more representative of that in which impairment through eutrophication is likely to occur. Total nitrogen was used as a threshold rather than dissolved nitrate as it measures all the nitrogen in a system rather than a portion of it.

In the case of phosphorus, there seems to be less variability between recommended criteria. The Ontario Ministry of Environment and Energy (OMEE) set a guideline of 0.03 mg/L total P, above which excessive plant growth occurs. Mackie (2004) suggested that total phosphorus levels in excess of 0.03 mg/L indicate that the surface waters are eutrophic. Dodds and Welch (2000) list upper limits ranging from 0.02 mg/L to 0.07 mg/L. For evaluation of phosphorus in the Annapolis River watershed, a criterion of 0.03 mg/L was used to indicate potential impairment through eutrophication.

2.5.2 Monitoring results

The nutrient results shown in this section were collected and analyzed by Environment Canada. Environment Canada collects regular water quality samples at one location on the Annapolis River and one location on the South Annapolis River. Grab sampling for 2012 was performed in Wilmot, near the bridge and gauging station on Bayard Road and in Millville, near the bridge on Victoria Road.

The results for monitoring of total nitrogen, nitrates and total phosphorus can be seen in Figures 18, 19 and 20 respectively.

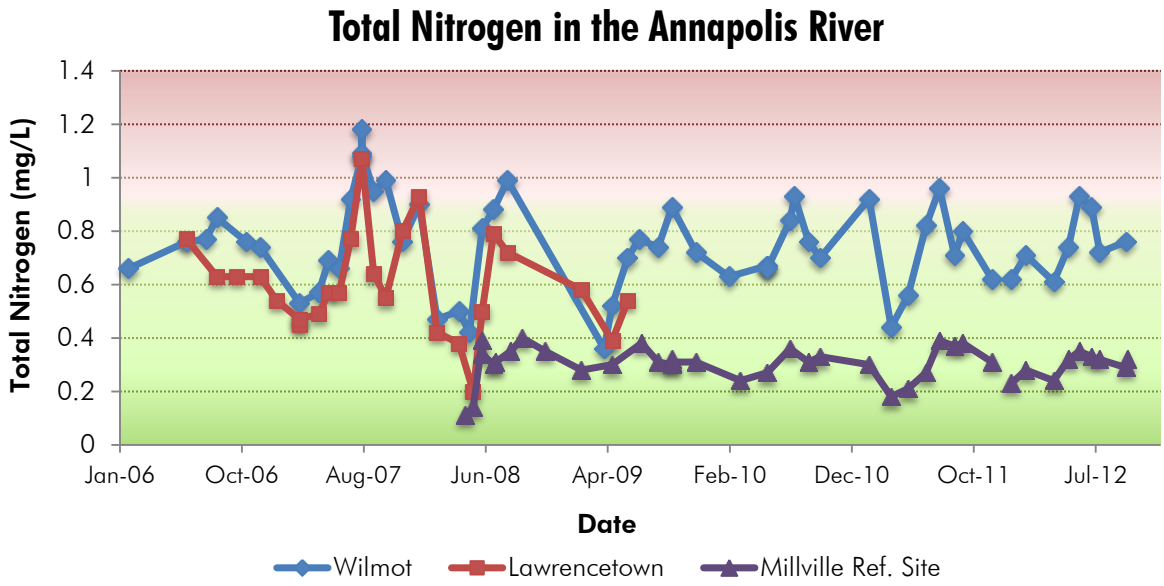

Figure 18. Total nitrogen results from 2006-2012 for Wilmot, 2006-2009 for Lawrencetown, and 2008-2012 for the Millville Reference Site. The solid black line represents the threshold value of 0.9 mg/L, above which conditions are deemed to be unacceptable.

Total nitrogen exhibits a wide range of values that appear to follow a slight annual trend. Wilmot and Lawrencetown values range from 1.18 mg/L on August 21st, 2007 in Wilmot to 0.2 mg/L on May 21st, 2008 in Lawrencetown. At the Millville Reference Site, the initial reading is the minimum recorded, at 0.11 mg/L on May 1st, 2008, with a peak reading on September 19th, 2008 at 0.4 mg/L. One sample taken in 2012 exceeded the 0.9 mg/L guideline, with a value of 0.93 mg/L, recorded at Wilmot on June 20, 2012. The sample taken at Wilmot on July 20th was also close to the threshold; at a value of 0.89 mg/L. Total nitrogen at all three sites exhibit seasonal fluctuations, with greater variability in the values from the Wilmot and Lawrencetown locations (Figure 18). Values at all three locations peak in the summer season and drop in the winter season. Total nitrogen starts to decrease around August and continues to decline until near April when values again climb to climax in early summer. This variation may be the result of agricultural fertilizers and other anthropogenic factors affecting land surrounding the river. Also, groundwater in the Wilmot area has been shown in the past to have elevated nitrate levels (Nova Scotia Environment, 2009). Most results fall above the upper limit of 0.25 mg/L to 3.0 mg/L that can causes adverse ecological effects, described by Dodds and Welch (2000).

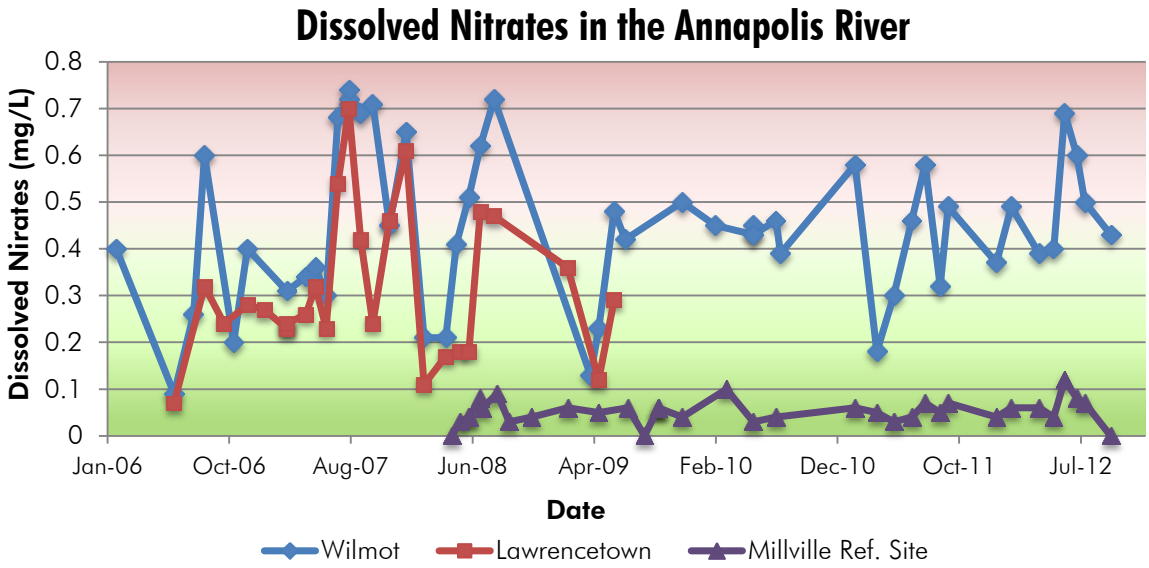

Figure 19. Dissolved nitrate results from 2006-2012 for Wilmot, 2006-2009 for Lawrencetown, and 2008-2012 for the Millville Reference Site.

Similar to total nitrogen in the Annapolis River (Figure 18), dissolved nitrates peak in the summer season and drop during the winter (Figure 19). The magnitude of variation is less than in Figure 18 as dissolved nitrates only contribute in part to the overall total nitrogen levels found in the river. The highest level of nitrate was observed at Wilmot on August 21st, 2007 at 0.74 mg/L while the lowest was 0.07 mg/L in Lawrencetown on June 16th, 2006. In 2012, a spike in nitrate levels was recorded at both the Wilmot and Millville sites. Nitrates at the Millville site were consistently measured between 0.03 mg/L and 0.10 mg/L. All of these levels are far below the CCME guideline.

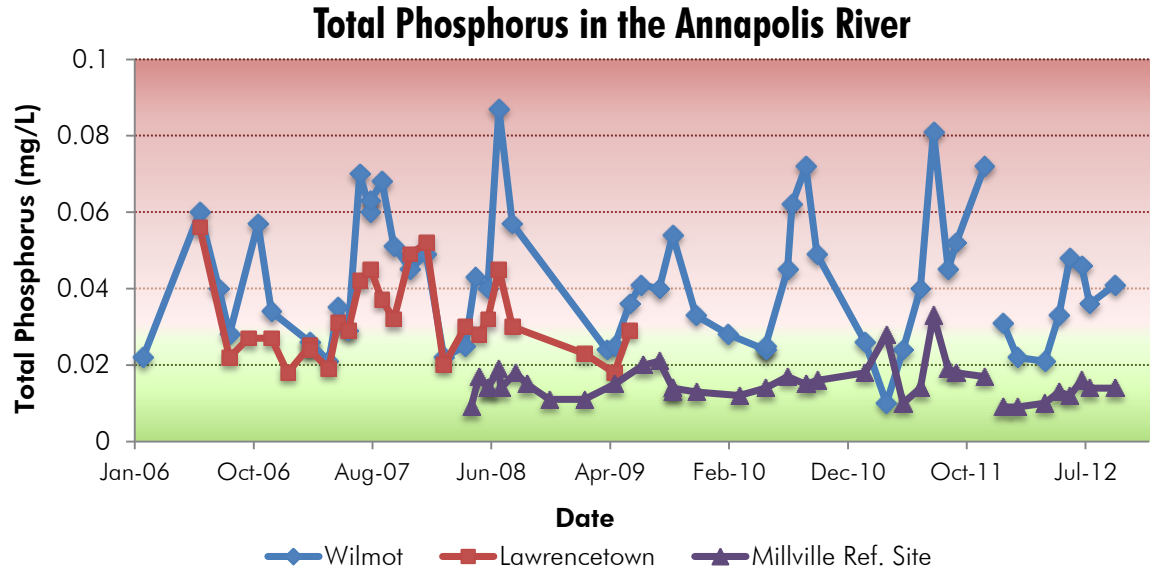

Figure 20. Total phosphorus results from 2006-2012 for Wilmot, 2006-2009 for Lawrencetown, and 2008-2012 for the Millville Reference Site. The solid black line represents the phosphorus guideline of 0.03 mg/L (Mackie, 2004).

The general trend of total phosphorus observed in the Annapolis River increases from spring to summer and decreases from summer to winter (Figure 20). Although Lawrencetown and Wilmot values follow a similar trend, the data is not as closely paralleled as seen with the nitrogen data. The maximum total phosphorus of 0.09 mg/L was observed at Wilmot on July 10th, 2008 and the minimum of 0.01 mg/L was in Wilmot on March 15th, 2011. Of all the data collected, 68% from Wilmot and 38% from Lawrencetown were above the recommended upper limit of 0.030 mg/L. Millville values were generally below this guideline however, on July 11th, 2011 a total phosphorus value of 0.33 mg/L was recorded at this site. The lowest value recorded at the Millville site was 0.009 mg/L on May 1st, 2008.

In the past, large algal blooms have occurred on the Annapolis River. On July 27th, 2008, the River Guardian volunteer for Bridgetown noted a green colour to the water. On August 1st, 2008, CARP staff observed a dark green colour to the water at this location only. This colour seems to be indicative of an algal bloom and may have been a result of excess levels of nitrogen and/or phosphorus. On the next collection day, August 10th, 2008, the green colour was no longer observable. No instances of an algal bloom have since been noted, although the river is not regularly monitored for this phenomenon.

Table 13. Mean, minimum, and maximum values for total nitrogen, dissolved nitrates, and total phosphorus at each location. Results are from 2008-2012 for Millville, 2006-2012 for Wilmot, and 2006-2009 for Lawrencetown.

Location	Total Nitrogen (mg/L)			Dissolved Nitrates (mg/L)			Total Phosphorus (mg/L)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Millville Ref Site	0.30	0.11	0.40	0.06	0.03	0.12	0.015	0.009	0.033
Wilmot	0.75	0.36	1.18	0.45	0.09	0.74	0.042	0.010	0.087
Lawrencetown	0.60	0.20	1.07	0.31	0.07	0.70	0.031	0.018	0.056

Table 13 summarizes the average, as well as maximum and minimum nutrient values recorded at each of the nutrient monitoring sites. Overall, Wilmot exhibited a higher nutrient concentration for total nitrogen, dissolved nitrates, and total phosphorus than either Lawrencetown or Millville (Table 13). Millville has the lowest average for all three nutrients when comparing all three sites. Therefore, the locations in order of increasing nutrients, and thus decreasing river health are Millville, Lawrencetown and Wilmot. Wilmot is located immediately upstream of Lawrencetown on the main stem of the Annapolis River. High *E. coli* values observed at Aylesford and Kingston may help explain the high nutrient values at Wilmot, as they both can be an indicator of a contamination source. Also, between Wilmot and Lawrencetown, the Nictaux River, Black River and other tributaries enter the Annapolis River, possibly diluting the nutrients resulting in lower concentrations at Lawrencetown.

2.5.3 Nutrient Monitoring Recommendations

- Work in collaboration with Environment Canada to ensure the continued collection of nitrogen and phosphorus samples at Millville and Wilmot.
- Examine flow rates in the Annapolis River near the nutrient sample collection points, as flow has a great influence on nutrient concentrations.
- Conduct analyses for traceable compounds found in fertilizers and wastewater treatment discharges to determine sources of nutrient inputs.
- Take more nutrient samples at various sites along the river. Add nutrient monitoring to the regular monitoring regime.

2.6 Benthic Invertebrates

2.6.1 Introduction

River systems are host to many different forms of life, and many of them can help indicate the river's water quality. Of particular interest are benthic invertebrates, which are small, relatively long-lived, sedentary aquatic organisms that live in the sediments, on woody debris, or rocks present on streambeds (Bouchard Jr, 2004). These include insects (e.g. mayflies), molluscs (e.g. clams) and other organisms that spend part or all of their life cycle on the bottom of watercourses. Some aquatic invertebrates are very sensitive to pollution, while others are pollution tolerant and can thrive in a contaminated environment. Measuring the relative abundance and diversity of both sensitive and tolerant invertebrates at a site can provide information on the water quality. For example, if species that are intolerant of pollution (e.g. mayflies and caddisflies) are either absent or present in low numbers at a site, whereas more tolerant species (e.g. midge larvae, snails, leeches) are abundant, it is highly likely that the site is polluted.

Benthic invertebrate sampling adds another dimension to ecological monitoring. While the measurement of physical and chemical parameters provides a picture of the river's health at a given time, the type of organisms existing in the system can provide a longer-term indication of its health. For example, a rainfall event can cause a river's total suspended solid count to spike for a short period and then quickly return to normal, whereas benthic life will show a greater sensitivity to long-term effects, because of the longer lifespan of some of these organisms.

Sampling of invertebrates is ideally performed in late summer or fall, during relatively low water levels when streams are safer to work in and when invertebrates have reached an optimal stage in their aquatic life cycles to facilitate capture and identification (Environment Canada, 2010). CARP makes use of the sampling and analysis procedure developed through the Canadian Aquatic Biomonitoring Network (CABIN).

2.6.2 Benthic Invertebrate Monitoring in the Annapolis River Watershed

The CABIN sampling program undertaken by CARP has pursued three objectives:

- To collect a sufficient number of samples from reference, or pristine, sites in order to allow the development of a reference condition approach model (RCA) for Nova Scotia or Atlantic Canada. The development of a RCA model is a long-term objective, requiring contributions from many partners and the collection of samples from across the region.
- To annually collect benthic invertebrate samples from water quality monitoring sites along the main Annapolis River in order to allow a time series analysis to be performed, highlighting temporal changes. This objective has been undertaken with the view that the CABIN analysis will compliment CARP's traditional chemical and physical water quality monitoring activities.
- To utilize benthic invertebrates as a tool to assess before and after changes in aquatic quality at sites undergoing habitat restoration activities.

CARP has worked with Environment Canada since 2002 to build a network of benthic invertebrate sample stations in the Annapolis watershed. Table 14 describes the location and status of CABIN samples collected in the Annapolis watershed by CARP, with CABIN samples collected by Environment Canada staff shown in Table 15. The locations of these samples are shown in Figure 21.

Table 14. CABIN samples collected by CARP (continued on page 31).

Site Code	Date Sampled (dd/mm/year)	River	Number of Samples	Reference or Test	Comments
ANN01	9/5/2002	Fales River	1	Reference	
ANN02	9/24/2002	East Round Hill River	1	Reference	
ANN03	9/24/2002	West Round Hill River	1	Reference	
ANN04	9/25/2002	Black River	1	Reference	
ANN05	10/11/2002	South Annapolis River	1	Reference	
ANN07	10/8/2003	Skinner Brook	1	Test	
ANN08	10/8/2003	Leonard Brook	1	Test	
ANN09	10/8/2003	Leonard Brook	1	Test	
ANN10	10/9/2003	Slokum Brook	1	Reference	
ANN01	10/9/2003	Fales River	1 + 2	Reference	Repeat of 2002 Reference Site; QA/QC samples collected
ANN11	10/18/2004	Annapolis River at Aylesford	1	Test	Long-term monitoring site
ANN12	10/19/2004	Acacia Brook	1	Reference	
ANN13	10/19/2004	West Branch Bear River	1	Reference	
ANN14	10/20/2004	Annapolis River at Kingston	1	Test	Long-term monitoring site
ANN15	10/20/2004	East Round Hill River	1	Reference	Repeat of 2002 Reference Site
ANN16	10/21/2004	West Branch Moose River	1	Reference	
ANN17	10/21/2004	West Branch Moose River	1	Reference	
ANN18	10/21/2004	East Branch Moose River	1	Reference	
ANN11	9/13/2005	Annapolis River at Aylesford	1	Test	Long-term monitoring site
ANN14	9/13/2005	Annapolis River at Kingston	1	Test	Long-term monitoring site
ANN19	9/13/2005	Annapolis River at Middleton	1	Test	Long-term monitoring site
ANN20	9/14/2005	Annapolis River at Paradise	1 + 2	Test	Long-term monitoring site; QA/QC samples collected
ANN20	11/10/2006	Annapolis River at Paradise	1	Test	Long-term monitoring site
ANN21	11/10/2006	E. Branch of S. Annapolis @ Morristown	1	Reference	
ANN22	11/10/2006	Annapolis River at Wilmot	1	Test	Co-located with EC gauging & Hydrolab placement
ANN20	11/9/2007	Annapolis River at Paradise	1	Test	Long-term monitoring site
ANN21	11/9/2007	Annapolis River at Wilmot	1	Test	Co-located with EC gauging & Hydrolab placement
ANN23	11/9/2007	Fash Brook	1	Test	
ANN20	17/9/2008	Annapolis River at Paradise	1	Test	Long-term monitoring site
ANN22	17/9/2008	Annapolis River at Wilmot	1	Test	Co-located with EC gauging & Hydrolab placement
ANN23	9/9/2008	S. Annapolis River at Millville	1 + 2	Reference	Co-located with EC turbidity & TSS station; QA/QC samples collected
ANN24	8/9/2008	Thornes Brook at Karsdale	1	Reference	
ANN25	8/9/2008	Fash Brook-West Branch	1	Reference	
ANN26	9/9/2008	Shearer Brook	1	Reference	
ANN20	13/9/2009	Annapolis River at Paradise	1	Test	Long-term monitoring site
ANN22	13/9/2009	Annapolis River at Wilmot	1	Test	Co-located with EC gauging & Hydrolab placement
ANN23	13/9/2009	S. Annapolis River at Millville	1	Reference	Co-located with EC turbidity & TSS station
ANN20	13/9/2010	Annapolis River at Paradise	1	Test	Long-term monitoring site
ANN22	13/9/2010	Annapolis River at Wilmot	1	Test	Co-located with EC gauging & Hydrolab placement

Site Code	Date Sampled (dd/mm/year)	River	Number of Samples	Reference or Test	Comments
ANN23	13/9/2010	S. Annapolis River at Millville	1	Reference	Co-located with EC turbidity & TSS station
ANN27	14/9/2010	Moose River – upstream of dam	1	Reference	Pre-removal monitoring sample
ANN28	14/9/2010	Moose River – dam impoundment	1	Test	Pre-removal monitoring sample
ANN29	14/9/2010	Moose River – downstream of dam	1	Test	Pre-removal monitoring sample
ANN20	10/10/2011	Annapolis River at Paradise	1	Test	Long-term monitoring site
ANN22	4/10/2011	Annapolis River at Wilmot	1	Test	Co-located with EC gauging
ANN23	4/10/2011	S. Annapolis River at Millville	1	Reference	Co-located with EC turbidity & TSS station
ANN27	10/10/2011	Moose River – upstream of dam	1 + 1	Reference	Post-removal monitoring sample; QA/QC samples collected
ANN28	10/10/2011	Moose River – dam impoundment	1	Test	Post-removal monitoring sample
ANN29	10/10/2011	Moose River – downstream of dam	1	Test	Post-removal monitoring sample

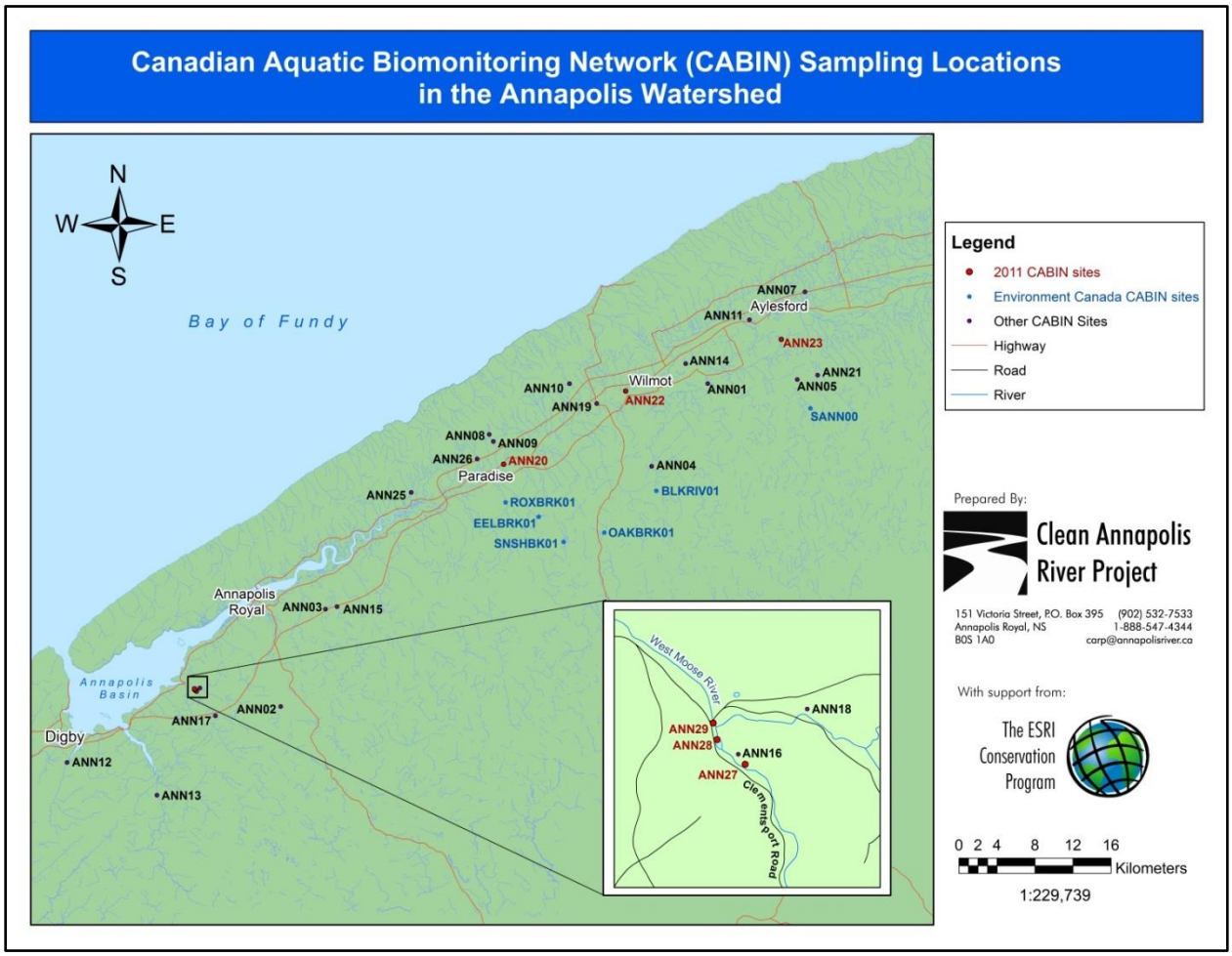

Figure 21. CABIN sample locations in the Annapolis River watershed (collections by CARP and Environment Canada).

Table 15. CABIN samples collected by Environment Canada.

Site Code	Date Sampled (dd/mm/year)	River	Number of Samples	Reference or Test
EELBRK01	3/10/2006	Eel Weir Brook (inflows to Annapolis River near Lawrencetown)	1	Reference
ROXBRK01	3/10/2006	Roxbury Brook (inflow to Annapolis River near Paradise)	1	Reference
OAKBRK01	4/10/2006	Oakes Brook (inflow to Nictaux River near Albany)	1	Reference
BLKRIV01	5/10/2006	Black River (inflow to Annapolis River)	1	Reference
SNSHBK01	6/10/2006	Snowshoe Brook south of Lawrencetown on the South Mountain	1	Reference
SANN01	7/10/2006	South Annapolis River	1	Reference

2.6.3 Monitoring Results

Benthic invertebrate samples have been collected from the Annapolis River at Paradise since 2005 and at Wilmot since 2006. To present these results, the Family Biotic Index has been used, as indicated by the CABIN analysis procedure. The index produces a value from 0 to 10, 0 being excellent water quality and 10 being poor water quality. The CABIN procedures outline categories for evaluation of water quality using the Family Biotic Index (Reynoldson et al., 2004). These categories are presented below, in Table 16.

Table 16. Evaluation of water quality using the Family Biotic Index.

Family Biotic Index	Water Quality	
0.00 – 3.75	Excellent	
3.76 – 4.25	Very Good	
4.26 – 5.00	Good	
5.01 – 5.75	Fair	
5.76 – 6.50	Fairly Poor	
6.51 – 7.25	Poor	
7.26 – 10.00	Very Poor	

The tolerance values for the Family Biotic Index calculation were taken from Applied Aquatic Ecosystem Concepts (Mackie, 2004). If they were not listed there, the values were taken from either the CABIN procedures (Environment Canada, 2010; Reynoldson et al., 2004) or from the Quality Assurance Work Plan for Biological Stream Monitoring in New York State (Bode et al, 1991); or from the University of Minnesota's Guide to Aquatic Invertebrates of the Upper Midwest (Bouchard Jr., 2004).

Figure 22 presents the results for the Family Biotic Index calculations for the Paradise site from 2005-2011. The result for 2011 was 4.01, which is the lowest score yet recorded at the site. The result for each year falls between 4.01 and 5.29, which are either 'very good', 'good', or 'fair' scores, according to the above table.

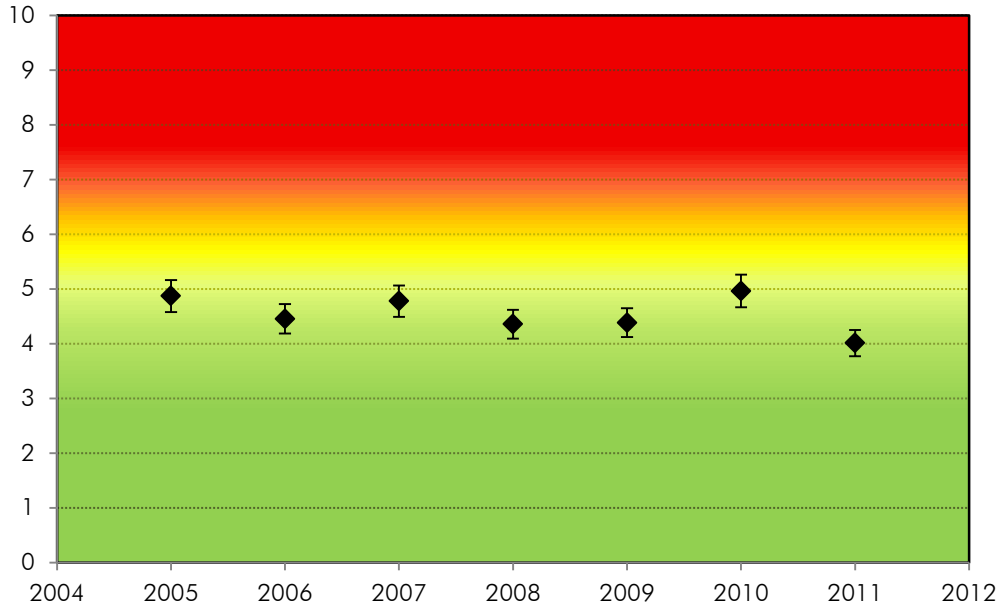

Figure 22. Family Biotic Indices for 2005-2011 for the Paradise location. The error bars display a 12% error, which was calculated using the QA/QC replicate data.

The 2006-2011 index results for Wilmot are presented below in Figure 23. The 2006, 2009 and 2010 indices fall into the 'fair' category while the results for 2007, 2008, and 2011 fall into the 'good' category. The Family Biotic Index for Wilmot in 2011 was 4.78.

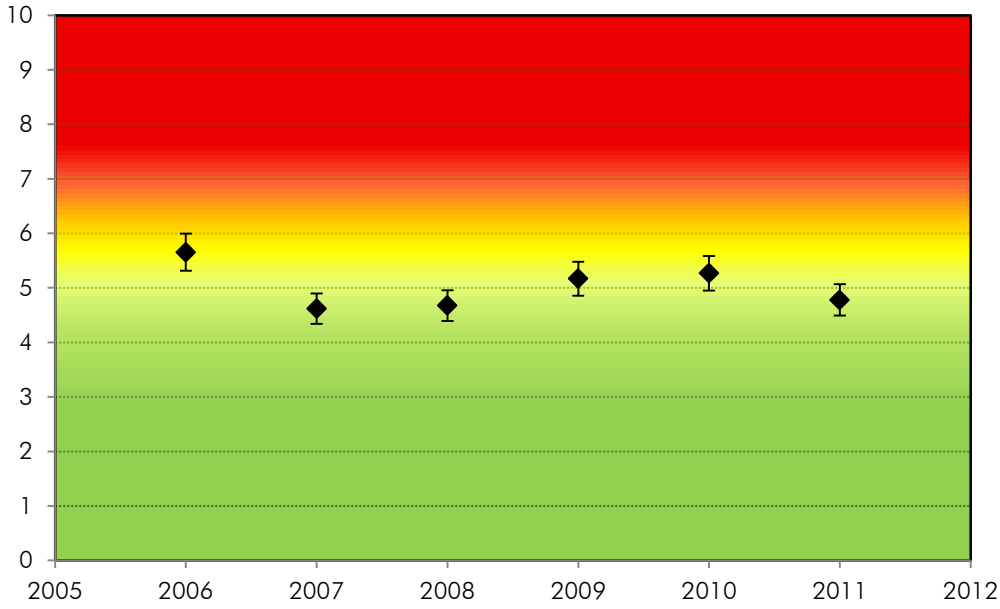

Figure 23. Family Biotic Indices for 2006-2001 for the Wilmot location. The error bars display a 12% error, which was calculated using the QA/QC replicate data.

Figure 24 illustrates the Family Biotic Index results for the reference site at Millville. CABIN sampling at this site began in 2008, and results to date indicate slightly better water quality than at the Paradise and Wilmot locations, with the Family Biotic Index values falling either into the 'excellent' or 'very good' categories. The Family Biotic Index value for Millville in 2010 was 3.53.

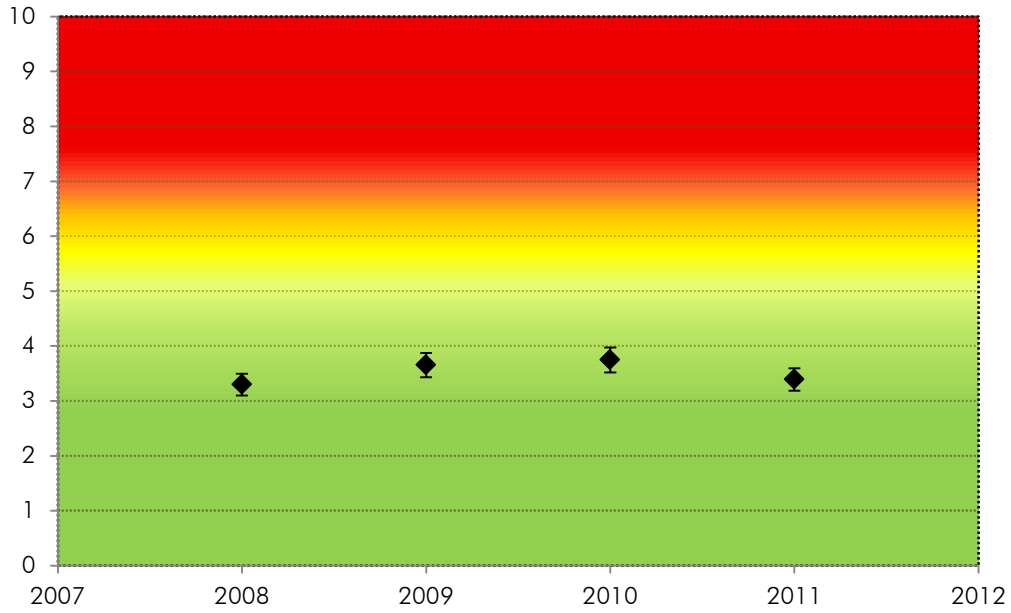

Figure 24. Family Biotic Indices for 2008-2011 for the Millville Reference site. The error bars display a 12% error, which was caluclated using the QA/QC replicate data.

Results calculated from 2005-2006 were completed using identifications performed by CARP and verified by Environment Canada scientists. Those calculated from 2007 through 2011, were done using identifications performed by Craig Logan, a certified taxonomist from Craig Logan Consulting. Taxa that were not part of CABIN monitoring were excluded from the calculations.

In addition to the Family Biotic Index, several other measures were used to characterize the benthic invertebrate samples for Paradise, Wilmot and Millville. The tables displaying these results are below (Tables 17, 18 and 19).

Table 17. Benthic invertebrate results for Paradise.

	2005	2005 QA1	2005 QA2	2006	2007	2008	2009	2010	2011
Family Biotic Index	4.87	5.29	5.27	4.45	4.78	4.35	4.37	4.96	4.01
Taxonomic Richness	29	32	24	23	19	28	25	26	26
Total EPT	284	430	147	95	208	291	243	153	199
Percentage EPT in sample (%)	49.05	37.46	41.18	32.65	44.26	57.62	54.36	36.96	56.86
Diversity	3.15	2.53	2.83	2.99	3.08	3.26	3.44	3.26	3.72
Hmax	-3.37	-3.47	-3.18	-3.14	-2.94	-3.33	-3.29	-3.26	-3.26
Evenness	0.94	0.73	0.89	0.95	1.05	0.98	1.07	1.00	1.14
Intolerant Organism Count	85	78	24	71	84	94	136	81	119
Tolerant Organism Count	6	5	12	12	11	10	5	16	13
Tolerant - Intolerant Ratio	0.07	0.06	0.5	0.17	0.13	0.11	0.04	0.2	0.11

Table 18. Benthic invertebrate results for Wilmot.

	2006	2007	2008	2009	2010	2011
Family Biotic Index	5.65	4.62	4.68	5.17	5.27	4.78
Taxonomic Richness	19	21	32	30	28	26
Total EPT	42	73	164	60	150	92
Percentage EPT in sample	11.23	25.44	31.6	17.29	19.01	31.94
Diversity	1.55	2.48	3.23	2.77	2.73	3.34
Hmax	-2.94	-3.04	-3.47	-3.4	-3.33	-3.26
Evenness	0.53	0.82	0.93	0.82	0.82	1.02
Intolerant Organism Count	31	64	109	46	88	68
Tolerant Organism Count	32	0	30	11	18	20
Tolerant - Intolerant Ratio	1.03	0	0.28	0.24	0.2	0.29

Table 19. Benthic invertebrate results for Millville.

	2008	2009	2010	2011
Family Biotic Index	3.3	3.65	3.75	3.39
Taxonomic Richness	33	35	27	27
Total EPT	266	320	159	216
Percentage EPT in sample	64.88	60.61	57.61	66.67
Diversity	3.61	3.55	3.76	3.86
Hmax	-3.5	-3.56	-3.3	-3.3
Evenness	1.03	0.99	1.14	1.17
Intolerant Organism Count	222	257	119	177
Tolerant Organism Count	10	26	6	31
Tolerant - Intolerant Ratio	0.05	0.1	0.05	0.18

The different measurements are described below.

- **Taxonomic Richness** refers to the number of different families of invertebrates in the sample.
- **Total EPT** refers to the number of organisms in the sample that come from the orders of Ephemeroptera (mayflies), Plecoptera (stoneflies) or Trichoptera (caddisflies). These organisms tend to have low pollution tolerance, so larger relative numbers of them tend to indicate less contaminated waters.
- The **Diversity Index** measures the relative abundance of each family. Mackie (2004) describes guidelines for using the species diversity index in assessing water quality. Since the samples taken by CARP were not identified to species, the index was modified to be used at the family level. A diversity index of <1 indicates polluted water, an index result of 1-3 indicates sub-polluted water and an index of >3 indicates clean water. However, Mackie does emphasize that these results treat all organisms as identical and does not take into account the pollution sensitivity of each different taxonomic grouping. The test is also optimized for analysis at the genus level of taxonomy and loses reliability at higher levels, such as family.
- **Evenness** also measures how the organisms are distributed between families. The closer the sample is to an even distribution, the closer this value will be to 1. Stresses to the aquatic environment tend to cause some taxa to shrink in number or disappear while causing others to increase in population resulting in populations skewed toward a small number of taxa. Thus, evenness results close to 1 tend to indicate a relatively uncontaminated environment.
- **Intolerant organism counts** measure the amount of organisms that come from families with a Hilsenhoff tolerance value of 3 or less; **tolerant organism counts** measure the amount of organisms that come from families with a Hilsenhoff tolerance value of 7 or greater.

2.6.4 Benthic Invertebrates Monitoring Recommendations

- Continue to collect annual benthic invertebrate samples from the Paradise, Wilmot, and Millville locations.
- Continue to collect QA/QC benthic samples every 10th sample.

2.7 Total Suspended Solids and Turbidity

2.7.1 Introduction

Total suspended solids (TSS) and turbidity are both terms that describe the amount of suspended particulate matter in water, although they are measured in different ways. TSS describes the physical mass of the particulate matter, while turbidity refers to the extent that light will penetrate the sample. Highly turbid waters have poor light penetration, which can hinder the growth of aquatic plants and can affect the health of aquatic animals.

Throughout 2008 and 2009, CARP and Environment Canada worked together in order to establish baseline levels of TSS and turbidity for the Annapolis River, to be used in determining a water quality objective for these parameters. This water quality objective could then be used in the calculation of a water quality index for the Annapolis River, which would be useful for annual reporting. The monitoring was also conducted to help determine the relationship between TSS and Turbidity. The two measurements are related, but this relationship is unique for every waterway and must be determined. In order to develop this relationship, TSS and turbidity samples were taken simultaneously for each station along the Annapolis River for the duration of the 2008 and 2009 sampling season. In 2010, samples were only taken at Bayard Road, Wilmot, Middleton, and Paradise after 15 mm of precipitation had fallen to assess peak sediment levels in the river. In 2011, event samples were taken from Lawrencetown and Millville in addition to the other sites.

TSS was measured by the River Guardian program from 1992 to 2002. Although it was recognized that TSS is an important parameter for the Annapolis River, sampling was discontinued in 2003. It was felt that the procedure was time-consuming, failed to record the inherent variability of the parameter and was producing unreliable results (Dill, 2003). The revised protocol used in 2008 and 2009 required biweekly sample collection in addition to samples gathered after events of significant rainfall or snowmelt. These event readings were taken by either CARP staff or volunteers. At first, event samples were gathered after rainfall amounts of at least 5 – 10 mm, but it was found that this amount of rainfall had very little effect on the TSS and turbidity readings. The collection protocol was subsequently revised, with samples only being collected for rainfall amounts of at least 20 – 30 mm. In 2010 and 2011, samples were taken after at least 15 mm of precipitation had fallen.

Event samples were not collected in 2012, however the relationship curve developed for the Annapolis River (Figure 25), was used to estimate TSS loadings to the river. Past sampling results of TSS and turbidity data collection can be found in Appendix C.

2.7.2 Monitoring results

Turbidity data has been gathered as part of the regular biweekly monitoring regime of the River Guardian program since 2009. Turbidity data collected from April to October can be found in Figure 26. TSS values in Figure 26 were estimated based upon the preliminary relationship developed for the river with a best fit line equation. The best-fit line and equation generated from historical data is illustrated in Figure 25. The R2 value derived from the regression analysis was determined to be 0.71, meaning that 71% of the variance in TSS readings can be explained by changes in turbidity. More data should be collected however to improve the accuracy of this relationship and to test the validity of the best fit equation.

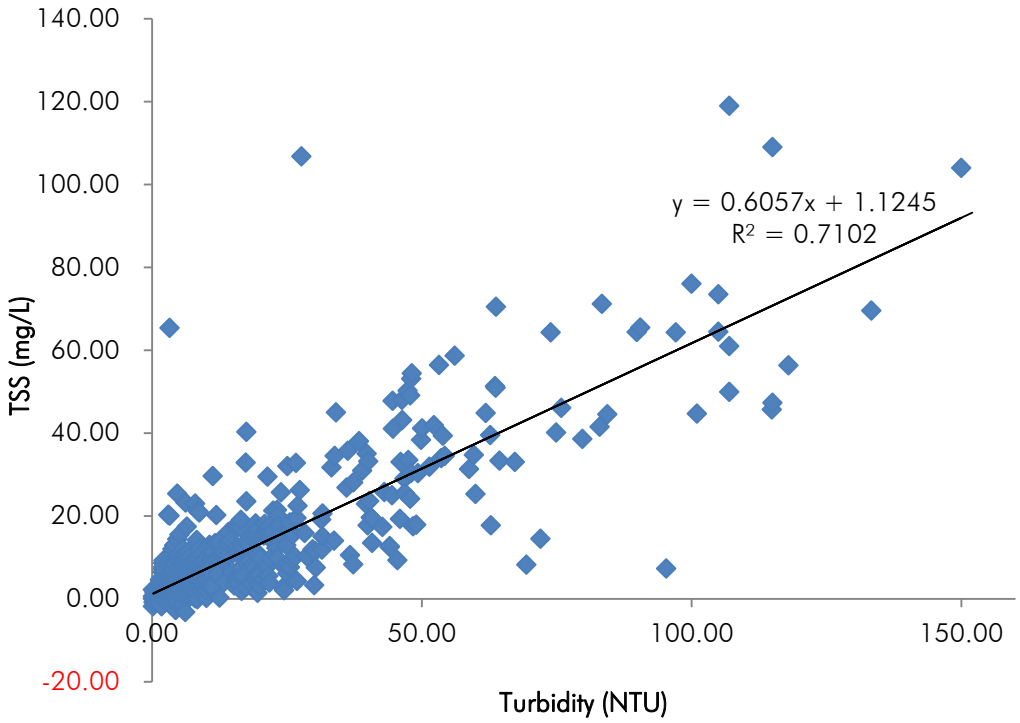

Figure 25. TSS in mg/L vs. turbidity in NTU for all sampled locations along the Annapolis River with the best-fit line and equation.

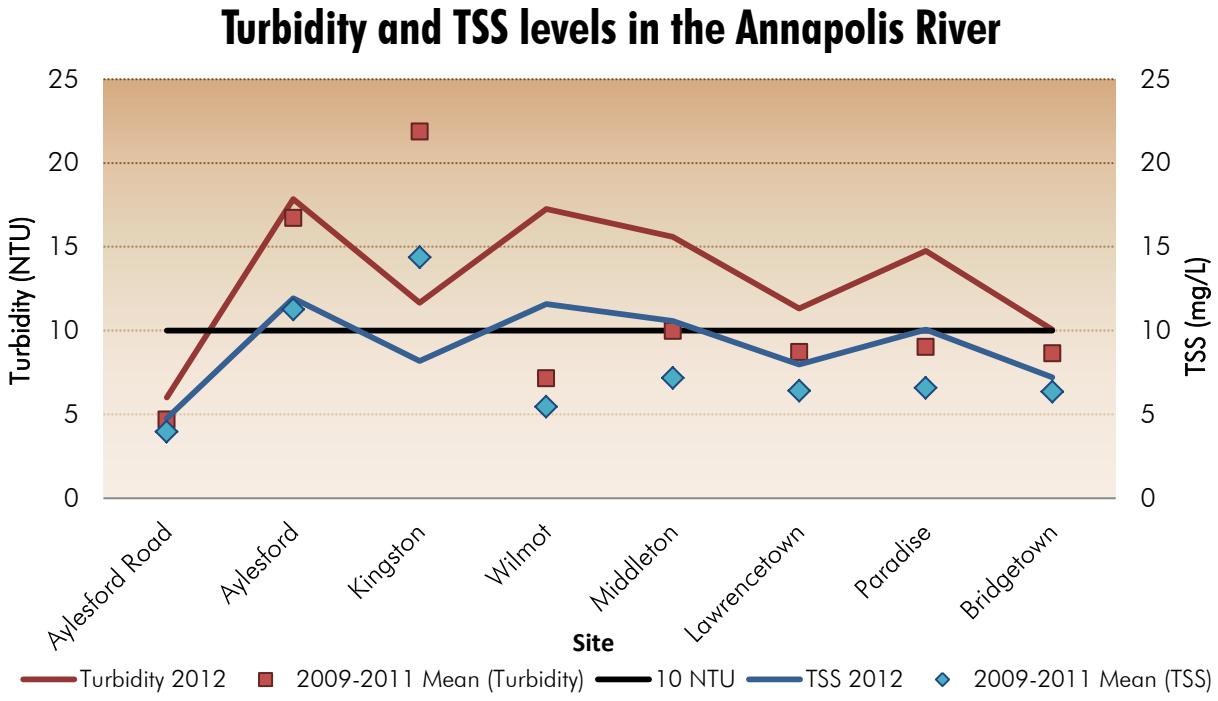

Figure 26. Turbidity and TSS levels at specified River Guardian monitoring sites, with the mean values obtained from 2009-2011 displayed (data is preliminary). The interim turbidity guideline of 10 NTU is denoted by the thick black line.

Turbidity levels in the river to date have ranged from lows of 0 NTU on August 13, 2012 to a high 398 NTU on October 18, 2010. The maximum turbidity value observed in 2012 was 72.3 NTU, recorded at Aylesford on September 10. Figure 26 shows turbidity fluctuations between individual sites, as compared to TSS values derived from the regression analysis (Figure 25). Mean turbidity levels in the Annapolis River rose beyond the determined safe level (interim guideline of 10 NTU) for all sites except Aylesford Road. Aylesford and Wilmot had the highest mean turbidity values in 2012, at 17.85 NTU and 17.27 NTU, respectively.

While the historical values for monitoring sites from 2009-2011 are displayed in Figure 26, these were highly variable datasets, with large standard error values (not displayed in the chart below). These results should therefore be viewed as preliminary until the dataset can be enlarged with more values. Aylesford Road, Kingston, Lawrencetown and Bridgetown had the lowest mean turbidity values. Conversely, Aylesford, Wilmot and Bridgetown had some of the highest turbidity values.

2.7.3 TSS/Turbidity Monitoring Recommendations

- Continue Event sampling after precipitation amounts greater than 20 mm
- Continue assessment to establish an accurate relationship between TSS and turbidity, which can be used to calculate TSS from the biweekly turbidity readings in the River Guardian Program
- Investigate possible correlations between TSS/Turbidity data, *E. coli* readings and rainfall amounts.

3.0 Trend Analysis

3.1 Purpose

Trend analyses have been completed for several of the water quality monitoring parameters since 2006. The results of these analyses are included as part of the annual River Guardians Report Card. Trends have been calculated since 2008 using a Shapiro-Wilks parametric analysis test and a Mann-Kendall or seasonal Kendall non-parametric test. If trends were found, they were reported as either increasing or decreasing, otherwise the parameter was reported as having no discernible trend.

3.2 Background Information

There are several different ways of reporting trends in a series of data, depending on the nature of the data set. Many of the statistical methods fall under two broad categories, parametric and non-parametric. Parametric methods are used for normally distributed data, while non-parametric methods are suited for non-normally distributed data. Methods of each type were attempted for the trend analysis of the water quality data.

The parameters assessed using these two methods were bacteria counts, DOSAT, temperature and pH. DOSAT was selected over DO because DO values are dependent on temperature, therefore, temperature trends might cause DO trends to be masked or indicated when they are not appropriate. Nutrient trends were also analyzed for Wilmot using parametric methods.

The procedure used for the non-parametric analysis was based on a procedure provided by D. Parent of Environment Canada and used by Glozier, Crosley, Mottle and Donald (2004). This procedure involved:

- separation of the data by station for each parameter
- a visual assessment of the data time series, which includes dividing the data into season according to the box-plot
- checking outliers for errors in measurement
- the Kruskal-Wallis test for seasonality
- either the Seasonal Kendall test or the Mann-Kendall test depending on whether the data displayed seasonality.

The Kruskal-Wallis test was performed using Systat 8.0 and the Kendall tests were performed using a free DOS-based computer program for the Kendall family of trend tests developed by the United States Geological Survey. The program is available at http://pubs.usgs.gov/sir/2005/5275/downloads/ (Helsel, Mueller and Slack, 2006)

The parametric procedures that were performed on the data were suggested by Drs. Y. Zhang and M. Brylinsky of Acadia University (pers. comm, December 2008). This procedure involved:

- separation of the data by station for each parameter
- a visual assessment for correlations between locations using scatterplot matrices
- a check for autocorrelation for each parameter and location
- an assessment for normality using the Shapiro-Wilks test
- transformations of the data if the parameter was found to be non-normal
- a linear regression of the data to determine whether a trend was present.

Systat 8.0 was used to produce scatterplot matrices and autocorrelation plots; the Analyse-It add-on for Microsoft Excel was used to perform the Shapiro-Wilks test and regression analyses.

The analysis procedures for parametric, non-parametric, and autocorrelation tests can be found in Appendix A.

3.3 Results

The results for the non-parametric tests (Table 20) and the results for the parametric tests (Table 21) were compiled. Autocorrelation tests were performed on all of the parameters to test for significant serial dependence, and none of the individual sites were found to exhibit significant serial dependence, while all sites together exhibited dependence. Therefore, trend analysis was performed on individual sites only.

Table 20. Statistically significant trends* and rates of change using non-parametric procedures.

	Bacteria Count	DOSAT (%)	DO (mg/L)	pH	Water Temperature	Air Temperature
Aylesford Road	Yes (+ 14 cfu/100mL/year)	No	No	No	No	Yes (+ 1.75°C/year)
Aylesford	Yes (+ 19.4 cfu/100mL/year)	No	Yes (- 0.03 mg/L/year)	Yes (+ 0.02/year)	No	Yes (+ 0.16°C/year)
Kingston	Yes (+ 5.9 cfu/100mL/year)	Yes (- 0.4 %/year)	Yes (- 0.11 mg/L/year)	Yes (+ 0.03/year)	Yes (+ 0.15° C/year)	Yes (+ 0.22°C/year)
Wilmot	Yes (+ 4.8 cfu/100mL/year)	Yes (+ 0.2 %/year)	Yes (- 0.07 mg/L/year)	No	No	No
Middleton	No	No	Yes (- 0.09 mg/L/year)	Yes (+ 0.04/year)	No	No
Lawrencetown	No	Yes (- 0.1%/year)	Yes (- 0.11 mg/L/year)	Yes (+ 0.03/year)	Yes (+ 0.11° C/year)	No
Paradise	No	No	Yes (- 0.05 mg/L/year)	Yes (+ 0.03/year)	No	Yes (+ 0.36°C/year)
Bridgetown	No	Yes (- 0.3 %/year)	Yes (- 0.06 mg/L/year)	No	No	No

*Statistically significant trends ($p < 0.05$) using Seasonal Kendall and Mann-Kendall tests.

Table 21. Statistically significant trends* and rates of change using parametric procedures.

	Bacteria Count	DOSAT (%)	DO (mg/L)	pH	Water Temperature	Air Temperature	Total Nitrogen	Total Phosphorus
Aylesford Road	Yes (+ 21.5 cfu/100mL/year)	No	No	No	No	Yes (+ 1.95°C/year)		
Aylesford	Yes (+ 20 cfu/100mL/year)	No	Yes (- 0.04 mg/L/year)	No	No	Yes (+ 0.18°C/year)		
Kingston	Yes (+ 10 cfu/100mL/year)	Yes (- 0.5 %/year)	Yes (- 0.12 mg/L/year)	Yes (+ 0.02/year)	Yes (+ 0.23°C/year)	Yes (+ 0.23°C/year)		
Wilmot	Yes (+ 7.4 cfu/100mL/year)	Yes (+ 0.2 %/year)	Yes (- 0.07 mg/L/year)	No	No	No	No	No
Middleton	Yes (+ 4.1 cfu/100mL/year)	No	Yes (- 0.08 mg/L/year)	Yes (+ 0.03/year)	No	Yes (+ 0.03°C/year)		
Lawrencetown	No	No	Yes (- 0.11 mg/L/year)	No	Yes (+ 0.14°C/year)	Yes (+ 0.15°C/year)		
Paradise	No	No	Yes (- 0.06 mg/L/year)	No	Yes (+ 0.11°C/year)	Yes (+ 0.34°C/year)		
Bridgetown	Yes (+ 2.2 cfu/100mL/year)	Yes (- 0.3 %/year)	Yes (- 0.07 mg/L/year)	No	Yes (+ 0.11°C/year)	No		

*Statistically significant trends ($p < 0.05$, residual plot randomly distributed, initial confidence interval range does not overlap with final confidence interval range) using linear regression fit.

Table 22. Non-parametric trend interpretations of water quality.

	Bacteria Count	DOSAT (%)	DO (mg/L)	pH	Water Temperature	Air Temperature
Aylesford Road	↓	↔	↔	↔	↔	↓
Aylesford	↓	↔	↓	↑	↔	↓
Kingston	↓	↓	↓	↑	↓	↓
Wilmot	↓	↑	↓	↔	↔	↔
Middleton	↔	↔	↓	↑	↔	↔
Lawrencetown	↔	↓	↓	↑	↓	↔
Paradise	↔	↔	↓	↑	↔	↓
Bridgetown	↔	↓	↓	↔	↔	↔

↑ Improving ↓ Declining ↔ No trend detected

Table 23. Parametric trend interpretations of water quality.

	Bacteria Count	DOSAT (%)	DO (mg/L)	pH	Water Temperature	Air Temperature	Total Nitrogen	Total Phosphorus
Aylesford Road	↓	↔	↔	↔	↔	↓		
Aylesford	↓	↔	↓	↔	↔	↓		
Kingston	↓	↓	↓	↑	↓	↓		
Wilmot	↓	↑	↓	↔	↔	↔	↔	↔
Middleton	↓	↔	↓	↑	↔	↔		
Lawrencetown	↔	↔	↓	↔	↓	↓		
Paradise	↔	↔	↓	↔	↓	↓		
Bridgetown	↓	↓	↓	↔	↓	↔		

↑ Improving ↓ Declining ↔ No trend detected

Values resulting from these calculations indicate a statistically significant trend as a rate of change, with a positive value as an increasing trend and a negative value as a decreasing trend (see Tables 22 and 23). The two test types generate slightly different results, but were mostly consistent. Both indicate decreasing water quality, with worsening bacteria trends upriver, at Wilmot, Kingston, Aylesford and Aylesford Road. The parametric tests also produced a worsening bacteria trend at Middleton and Bridgetown. Both methods displayed a decreasing saturated DOSAT trend at Kingston and Bridgetown, and an increasing trend at Wilmot, but disagree slightly in the magnitude. The non-parametric showed a decreasing DOSAT trend for Lawrencetown, and the parametric revealed no trend. For DO (mg/L), both tests found a statistically significant decreasing trend for all the tested sites except Aylesford Road, which may be partly due to a smaller dataset for that site. A small increase in pH was found at the Aylesford, Kingston, Middleton, Lawrencetown, and Paradise sites using non-parametric analysis, while parametric results displayed a small increasing trend for the Kingston and Middleton sites.

Increasing water temperature trends were recorded at Kingston and Lawrencetown using both parametric and non-parametric analyses. However, parametric analyses also detected increasing trends for Paradise and Bridgetown. The rate of change of the trends was also greater in the parametric analysis for water temperature. For air temperature, both the parametric and non-parametric analyses showed an increasing trend at the Aylesford Road, Aylesford, Kingston, and Paradise sites, with the highest increase at the AY40 site. The parametric

procedure also detected slightly increasing trends for Middleton and Lawrencetown. No nutrient trends were shown for either nitrogen or phosphorus at Wilmot. The Aylesford Road site has only been monitored since 2003, and was only monitored sporadically until 2006, so there is not a large amount of data for that location. Similarly, nutrient data has only been collected since 2006, usually with 6 – 8 samples at one location per year, which may be why no trends were concluded for these parameters.

When compared to the results of the 2011 trend analysis, the results are fairly consistent, but there are many more new additions and analyses. The non-parametric method indicated the same trends were present and Temperature in 2012 as in 2011. For DOSAT analyses, the non-parametric method detected one additional trend compared to the 2011 dataset, for Lawrencetown. All others displayed the same trends, but of slightly different magnitudes. In 2012, there was an increasing trend for bacteria counts at Wilmot, which hadn't been found in 2011, and no decreasing trend was found at Lawrencetown in 2012. pH increased at five sites in 2012, however it was only found to increase at one site in 2011. The parametric methods indicated an overall greater magnitude of increase in *E. coli* in 2012 than 2011, except for the Aylesford Road and Kingston sites, which had similar or slightly lower magnitudes of change. The same sites were detected to have a trend for DOSAT in 2012 as in 2011; however the Wilmot site registered an increasing trend rather than a decreasing one. Two additional sites were determined to have an increasing water temperature trend, as compared to 2011. Lastly, nearly all sites were detected to have decreasing trends for DO (mg/L) and increasing trends for air temperature, but no analyses are available for comparisons to the 2011 dataset.

4.0 Recommendations

4.1 Summary of Recommendations for the River Guardians Program

- Continue regular River Guardian *E. coli,* DO, temperature, pH, and turbidity monitoring at the eight main river sample locations.
- Address the issue of restricting animals from the Annapolis River.
- Investigate correlation between precipitation amounts and E.coli levels in the river.
- Undertake periodic DO monitoring of the Annapolis River estuary in the late summer and early autumn. These times are most likely to display depressed levels of DO. Depth profiling should be included as part of this monitoring.
- Install temperature loggers in candidate streams to assess for fish habitat improvements.
- Temperature data loggers should be calibrated immediately prior to deployment and at least once in situ. These procedures should be added to the QA/QC Project Plan.
- Investigate the temperature increase on the Annapolis River between Aylesford and Lawrencetown. This may include collection of thermal status data on tributaries to the Annapolis River.
- Work in collaboration with Environment Canada to ensure the continued collection of nitrogen and phosphorus samples at Millville and Wilmot.
- Examine flow rates in the Annapolis River near the nutrient sample collection points, as flow has a great influence on nutrient concentrations.
- Conduct analyses for traceable compounds found in fertilizers and wastewater treatment discharges to determine sources of nutrient inputs.
- Continue event TSS/Turbidity sampling after high precipitation amounts
- Continue analysis of TSS/Turbidity to establish an accurate relationship, which can be used to calculate TSS from the biweekly turbidity readings in the River Guardian Program
- Investigate possible correlations between TSS/Turbidity data, *E. coli* readings and rainfall amounts.
- Review current and historic air photos of the Aylesford area to identify land use changes and possible sources of contamination.
- Conduct a foot survey along the Annapolis River between Victoria Road and Aylesford Road as well as along Patterson, Parker and Skinner brooks to identify possible contamination sources.
- Research and implement a more definitive test for autocorrelation.
- Regularly perform volunteer training and overview before each season to ensure proper technique and sampling consistency

4.2 Recommendations for CARP

- Continue to implement the Quality Assurance Project Plan for all of CARP's Water Quality monitoring programs.
- Calibrate the Quanta Hydrolab every two or three weeks for pH, conductivity, dissolved oxygen and turbidity.
- Continue to update the manual for the River Guardian facilitator to ensure consistency in analysis and reporting.
- Continue to update the Annapolis River Guardian Procedures Manual on a continual basis.
- Continue to ensure QA/QC protocols are implemented yearly throughout the entire sampling season, including an information session before the first sampling date.

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6.0 Appendices

A.0 Appendix A

A.1 Parameters Tested and Methodologies

Table A1. Current and previous parameters measured throughout the program.

Parameters Analyzed in 2012	Additional Parameters Analyzed in Previous Years of the Program
E. coli bacteria densities	Salinity
Dissolved Oxygen	Chlorophyll a
Temperature (Water and Air)	Nitrate-N, Chloride, Sulphate, Total Phosphate
Weather conditions	Colour
pH, Conductivity, Total Dissolved Solids	Transparency
Nitrate, Nitrite, Phosphate	
Turbidity	

A.1.1 Water Collection for *E. coli* Bacteria Analysis

Following the contamination of some sampling equipment in 2003, a new collection procedure for fecal coliform samples was developed and used during the 2004 through 2012 seasons. The sampling units (Figure A1) allow for representative sampling from mid-span of bridges at the sampling sites.

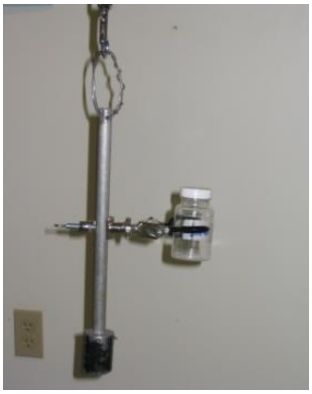

Figure A1. Collection unit used for *E. coli* samples in 2012.

The open sample bottle is secured in the clamp, and lowered from the mid-span of the bridge into the river, to a depth of 1 meter. Samples are collected on the upstream side of bridges, where a safe pedestrian walkway exists. After collection, water samples are refrigerated until delivery to the lab, typically within 24 hours of collection.

A.1.2 Enumeration of *E. coli* Bacteria

Prior to the 2005 season, bacterial samples collected by Clean Annapolis River Project's Annapolis River Guardians program were tested for Fecal Coliforms (FC) using the membrane filtration method. During the winter of 2005, the program's Science Advisory Committee suggested that the program switch to testing for *E. coli* (EC) using the Most Probable Number method (used in the Valley Regional Hospital), to bring testing more in line with national guidelines. In order to ensure the continuity of the dataset, a period of duplicate analysis with the two methods was conducted. Duplicate samples were analysed using both methods over a two-month period (four biweekly sample events at eight locations along the river). Analysis of the paired results indicated no significant difference between the two testing methods. Further information on the comparison of the two testing methodologies is presented in the 2005 Annapolis River Guardian Report, Appendix C, which is available at the CARP office.

All *E. coli* bacteria samples are submitted to the Valley Regional Hospital Microbiology Laboratory in Kentville, Nova Scotia. The Valley Regional lab is accredited by Nova Scotia Environment to perform bacterial water quality analysis. From 1997 to 2003 and again since 2005, fecal bacteria densities were determined using the IDEXX Colilert procedure, to give a Most Probable Number of *E. coli* bacteria present. For the 2004 sample season, analysis was performed using the membrane filtration method.

A.1.3 Dissolved Oxygen Content

Dissolved oxygen samples are collected from the mid-span of bridges using a horizontal van Dorn sampler, at a depth of 1 meter. Dissolved oxygen in mg/L is determined using the modified Winkler titration using pre-packaged Hach reagents. The Winkler titration procedure is a widely recognized standard for determining dissolved oxygen. The procedure is reported to have an accuracy of at least +/- 1 mg/L. Dissolved oxygen as percent saturation is determined using Rawson's nomogram. Further information on the collection and analysis procedure for dissolved oxygen can be found in the Annapolis River Guardians Procedure Manual, which is available at the CARP office.

A.1.4 Temperature

Van Dorn samplers collect water at 1m depth, and temperature readings are immediately taken directly from the Van Dorn or from a 1L plastic bottle. The Annapolis River Guardians used a combination of glass/alcohol and digital thermometers during 2012. Prior to the start of the season, all thermometers were compared with the temperature reading from CARP's HydroLab Quanta water meter. This unit had recently been serviced and calibrated, with a reported accuracy of +/- 0.10 ^{o}C. From this comparison, a correction factor was determined for each River Guardian thermometer. These correction factors were applied to all River Guardian temperature measurements.

A.1.5 pH and Conductivity

Water chemistry data, including pH and conductivity, was collected using CARP's portable HydroLab Quanta water quality monitoring meter. Data was collected on a biweekly basis by CARP staff, typically the day following the volunteers' sampling day, at a set location on the riverbank at each River Guardian site. The meter was placed in the river approximately 1 to 2 meters away from the bank, and allowed to stabilize, usually for two to three minutes before a reading was taken. Once stabilized, the values were stored in the meter's memory and recorded on the data sheets upon return at the CARP office. The data is stored using an in-house Microsoft Access database. The multi-sensor water meter was calibrated for pH, conductivity and dissolved oxygen approximately every two to three weeks according to the directions in the Operating Manual (Hydrolab Corporation, 2002).

A.1.6 Procedures for TSS/Turbidity collection and processing

Samples were taken using either van Dorn Samplers or by hand from the shore near the bridge. If a van Dorn sampler was used, it was used mid-span of the bridge at a depth of approximately 30 to 60 cm. If taken from the shore, the bottle was dunked in an area where the water's flow was constant and at a depth the length of a forearm, approximately 30 to 40 cm. The collection method was not recorded for particular samples. A collection of approximately 1 litre of water was attempted for each collection. Field Turbidity was assessed using the Quanta Hydrolab at the time of collection. The collection sites for after April 2010 were NS01, 25, and 40. Some collection at other River Guardian sites occurred as well.

TSS data was processed through filtration. Filters were stored in a desiccator for at least 24 hours and were then weighed in a weighing boat on an analytical balance. The weight of the filter paper and the weighing boat together were recorded on the weighing boat. The filters used were Ahlstrom brand, grade 161, 4.7 cm in diameter, or Whatman brand, grade 934AH, 4.7 cm in diameter. The water sample was passed through one of the pre-weighed filters using a suction filtration procedure. The filter paper was carefully placed back in its weighing boat and dried in an oven at ~90 degrees Celsius before being stored back in the desiccator. After remaining in the desiccator for approximately 24 hours, the filters and boats were removed and reweighed. The original weight was subtracted from the new weight of the filter and boat, and this number was divided by the sample volume to give a g/L TSS reading. The balance used was an A&D Electronic Balance ER-120A.

A.1.7 Trend Analysis

Before any trend analyses were performed, outlier tests were conducted. The mean and standard deviation of a particular data set were calculated and each value was compared to the mean. If any value differed from the mean by more than twice the standard deviation, it was considered an outlier and was checked against the original data sheets. If there was reason to suspect the data point of being invalid, the data was not included in the trend analysis. If no notes or calculation errors were made on the original data sheet, the outlier value was retained in the data set. The analysis for the temperature data was performed only on data from the summer months (July, August and September), as elevated water temperatures that occur in the summer months are the principal concern. The outlier analysis was not performed on the bacteria data, as the nature of the data is not conducive to outlier analysis. The data is highly variable with a wide range of 0 to 2419 cfu/100 mL and is capped at 2419 cfu/100 mL. The cap of 2419 cfu/100 mL is due to method limitations; the IDEXX Colilert testing method will not produce a reading greater than this number. Some of the earlier data was analyzed using a different method that was not capped, so any data point above the 2419 cfu/100 mL threshold was artificially capped at 2419 cfu/100 mL for consistency purposes.

A.1.7.1 Non-Parametric Analysis

In 2008, a box and whisker plot was made for each parameter, with the data grouped by month. For the temperature, bacteria and pH data, months of January through March were excluded, as very little data was recorded for those months. The box plots were then visually assessed for similarities across months. Adjacent months with similar medians and ranges were grouped together as a season (Figure A2).

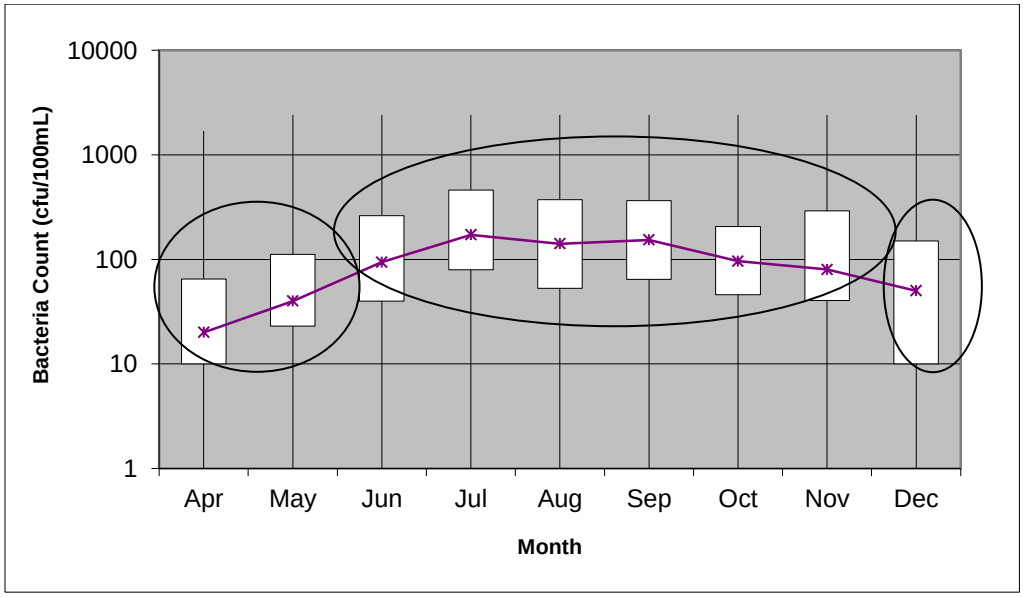

Figure A2. Bacteria count data for all years grouped by month. The circles indicate the seasons that were determined from this plot. There was very little data for the January to March period; these months were not used in the analysis. A 'dummy season' containing no data was used in the analysis to represent the January to March period.

Three seasons were indicated by the bacteria count box plot shown above and a fourth season was included in the analysis to represent the January to March months. The bacteria data was grouped according to these seasons and the Kruskal-Wallis for seasonality test was performed. Bacteria count data was indicated as being seasonal, while the pH, DOSAT and summer temperature data were not. Based on this, the Seasonal Kendall test was performed on the bacteria count data and the Mann-Kendall test was performed on pH, DOSAT and temperature data. These tests produce a linear trend equation and a probability statistic (p-value), which indicates whether or not the trend is statistically significant. A trend was considered significant if the p value was less than 0.05. Non-parametric analyses were not performed on the nutrient data as there was not enough data to assess the seasonality of the data set.

A.1.7.2 Parametric Analysis

The data was grouped by parameter and location, and the Shapiro-Wilks test was performed on each data set. The Shapiro-Wilks test is a test for non-normality and produces a histogram of the data overlaid with a normal distribution curve as well as some significance and probability statistics. For this procedure, the histogram and normal curve are examined to determine whether the data visually resembles a normal distribution. If the data does not resemble a normal distribution (in the case of *E. coli*), the data set can be transformed until it resembles a normal distribution. CARP's *E. coli* data distribution resembled a logarithmic distribution, so the data was transformed by taking the base-10 logarithm of the bacteria results. The logarithmic transformation produced a normally distributed data set (Figure A3).

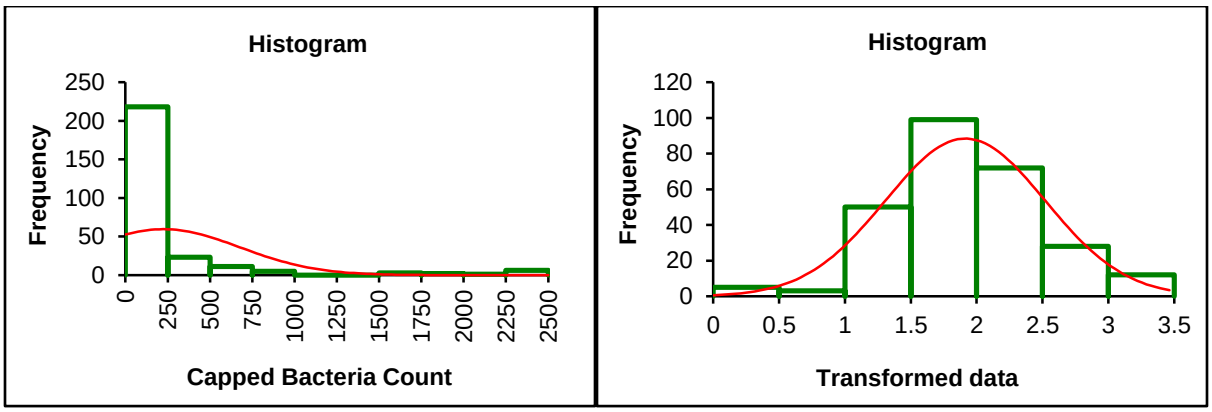

Figure A3. Lawrencetown (#35) bacterial count data distribution before transformation (left) and after transformation (right).

The transformed data much more closely resembles a normal distribution and can be used for the regression analysis. The data for DO, temperature and pH did not require transformation to resemble a normal distribution. After the trend analysis procedure below was completed, the bacteria data trend results had to be transformed back using an inverse logarithmic function.

After normality was established for each parameter, a linear regression was performed on its data set. This produced a linear slope of the trend, as well as a confidence interval, prediction interval, probability value and residual histogram. The trend slope provides the rate of change of the variable by year, the confidence interval and probability value allow for the determination of statistical significance of the trend and the residual plot and histogram indicate whether the data set varies in a non-linear fashion, which would indicate that the linear regression calculation is not appropriate for the data set. For the determination of statistical significance, three tests were performed. If any of these tests were failed, the trend was not considered significant. The three tests included:

- verification of the slope's p value. If the value was less than 0.05, this test was passed.
- examination of the confidence intervals of the regression plot. If the confidence interval range at the beginning of the data set overlaps with the range at the end of the data set, this test was passed (Figure A4).
- examination of the residual plot and distribution. If the residual scatterplot was randomly distributed and the associated histogram resembled a normal distribution, this test was passed. Non-linear correlation of the data would be indicated if this test was failed (Figure A5).

As an example, the DOSAT data for the Kingston location is displayed below. The p value for the slope produced by the regression analysis was <0.0001. This value is less than the 0.05 threshold, therefore, the data passed this significance test. Figures A4 and A5 below show that the Kingston data set passed the other two significance tests as well, therefore the trend slope of –0.5 %/year was accepted as significant. This indicates that dissolved oxygen levels are decreasing at the Kingston location.

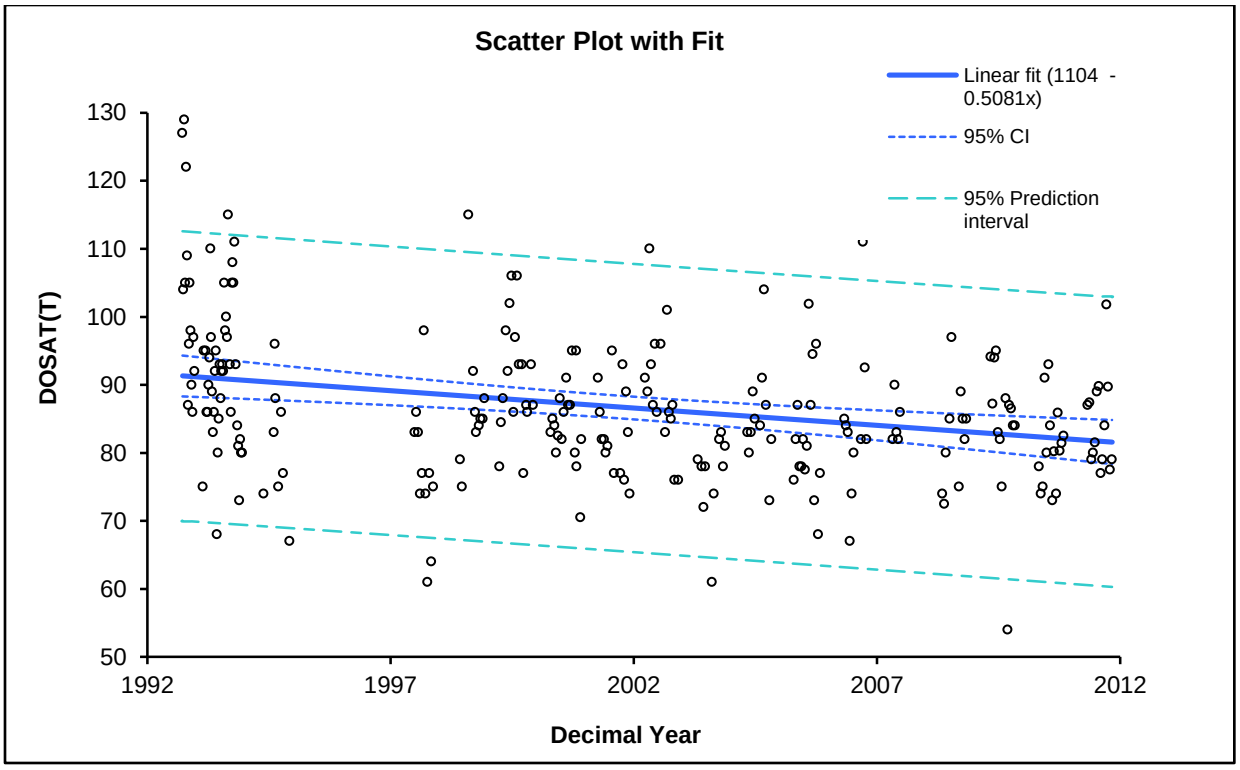

Figure A4. Linear regression for DOSAT data at the Kingston location. The thick dashed line is for the purpose of comparing the confidence interval range at the beginning and end of the dataset. If this horizontal line had remained within the confidence interval range for the entire domain of the dataset, a trend could not be concluded. This did not occur for the Kingston DO dataset; this dataset passed this significance test.

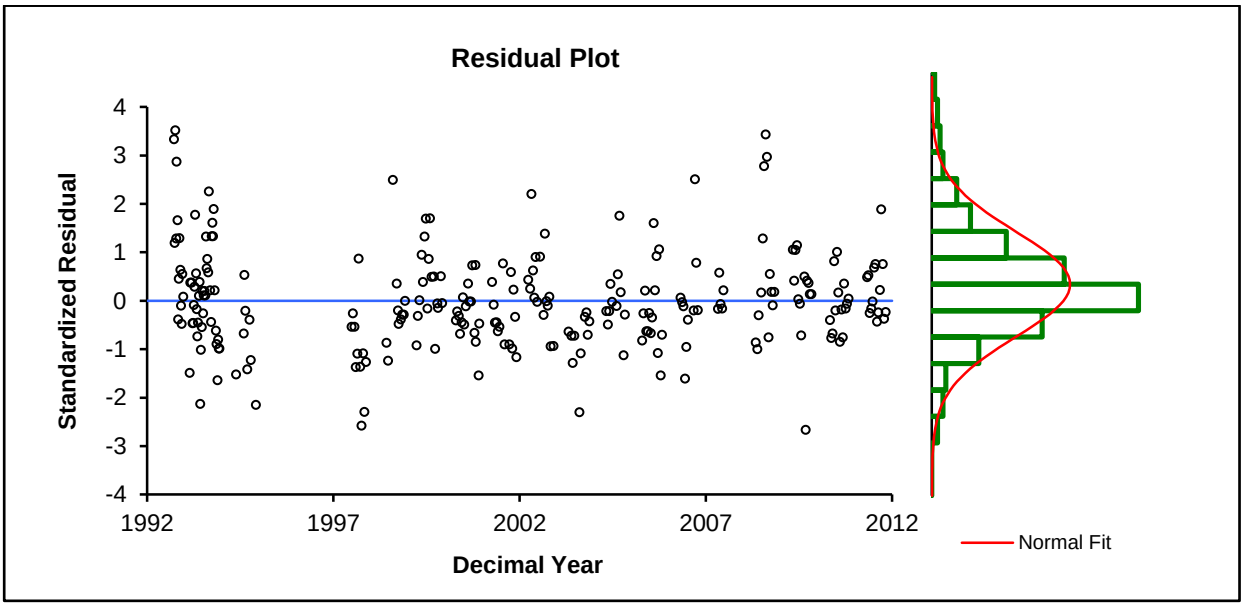

Figure A5. Residuals plot for the DOSAT regression for the Kingston location. The scatterplot does not display significant clustering and appears to be randomly distributed. Although the histogram displays a small spike around the center, it still resembles a normal distribution; therefore this test is passed for the Kingston DO data.

A.1.8 Autocorrelation and Serial Dependence

Autocorrelation is an important consideration for both parametric and non-parametric statistical trend analyses (Helsel and Hirsch, 2002) because its existence invalidates most statistical tests, as they assume data points to be independent and uncorrelated to one another. Autocorrelation refers to the correlation of a set of data points across either space or time. If a set of data displays temporal autocorrelation, (a.k.a. their data points, when separated by a unit of time, known as a lag, demonstrate a correlation) they are said to show serial dependence (Australian and New Zealand Environment and Conservation Council, 2000). For example, if a turbidity sample was taken during a storm event, and then another taken a few hours later, the likelihood of the readings for both samples being affected by this event is high, and so the sample values are not independent from one another. To test for autocorrelation, a data series is plotted against a time lagged version of itself (Figure A6), and the correlation value between the data points measured. These values are then plotted on an Autocorrelation plot (Figures A7 and A8) for each lagged unit of time, and compared against a 95% confidence interval to test for serial dependence. (Meko, 2011; Janssen, 2010). Significant serial dependence is indicated when the vertical bars extend beyond the 95% confidence curves.

The linear regression fit assumes that there must be no correlation between data points. In the case of water quality data, the potential existed for data points collected temporally close or along the same stretch of river to be correlated. To assess whether the data was affected by this serial dependence, an autocorrelation plot for each variable at each location was performed (Figure A7), as well as for the entire data set for each parameter (Figure A8). In the Paradise plot, most of the bars do not extend beyond the confidence interval, thus serial dependence is not indicated. When an autocorrelation plot was made for all locations, significant serial dependence was displayed; therefore a trend analysis was not performed on the data for all locations (Figure A8).

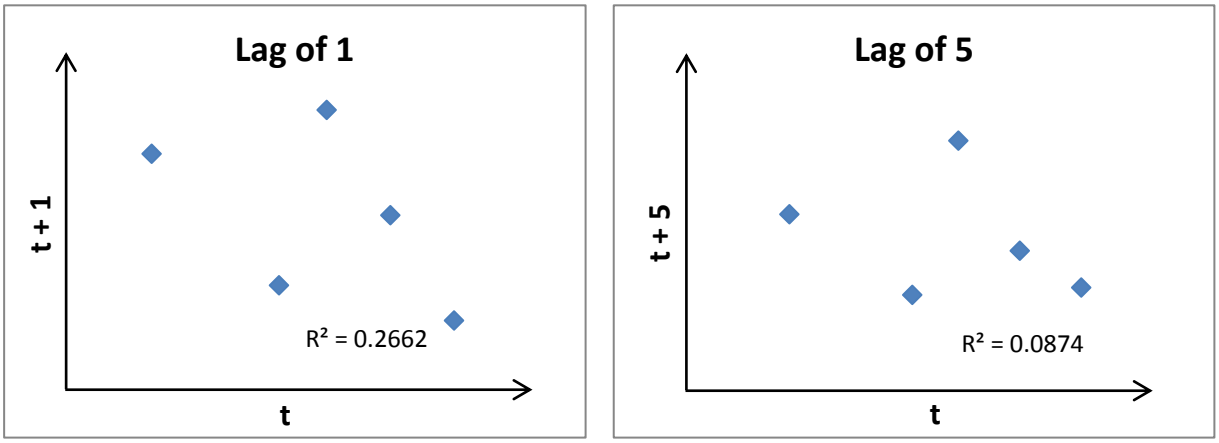

Figure A6. Time lag plots for autocorrelation analysis. To test for autocorrelation, data sets are plotted against themselves, offset by a unit of time (lagged), and the correlation between the data points taken.

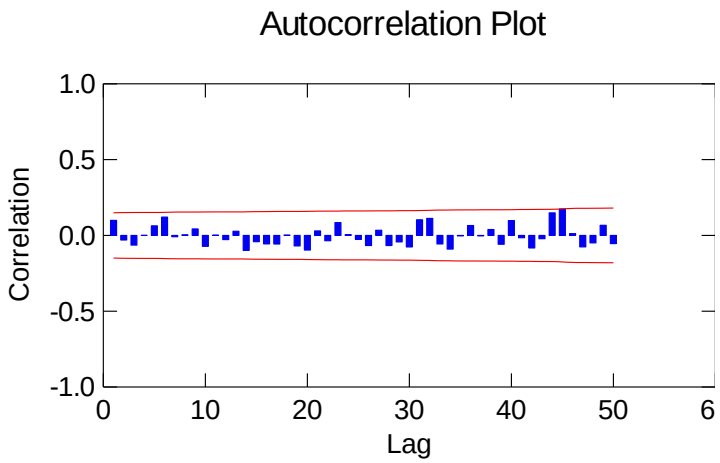

Figure A7. Autocorrelation plot for *E. coli* at the Paradise site.

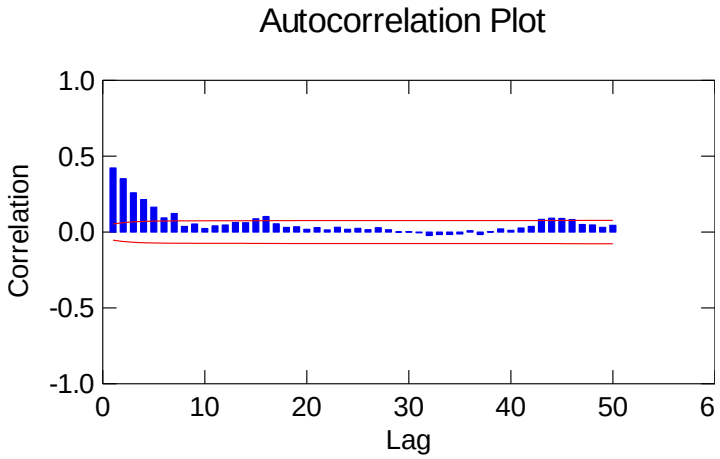

Figure A8. Autocorrelation plot for the entire *E. coli* dataset. Several of the bars extend beyond the confidence interval range; therefore significant serial dependence is indicated.

B.0 Appendix B

B.1 Sites Monitored

Water samples were collected during 2012 by the Annapolis River Guardians program at several different locations (Table B1). Coordinates are reported in latitude and longitude, as recorded on a hand-held GPS unit.

Table B 1. Coordinates and descriptions for Annapolis River Guardian and TSS/turbidity sample locations.

Site Code	Latitude	Longitude	Site Name	Site Name (Long with Reference Points)
AY40	N45 01.699	W64 48.617	Aylesford Road	Bridge at Aylesford Rd, near Hwy 1
Ref	N45 00.122	W64 49.381	Millville	Bridge on Victoria Rd, South Annapolis River
00	N45 01.606	W64 50.148	Aylesford	Bridge on Victoria Rd, near Hwy 1
13	N44 58.713	W64 56.663	Kingston	Bridge on Bridge St. near Stronach Park
18	N44 57.199	W65 00.096	Wilmot	Bridge on Old Mill Road
NS01	N44 56.942	W65 01.769	Wilmot	Bridge on Bayard Road
25	N44 56.213	W65 03.969	Middleton	Bridge on Hwy 10, near Riverside Park
35	N44 52.850	W65 09.476	Lawrencetown	Bridge on Lawrencetown Lane
40	N44 52.045	W65 12.384	Paradise	Bridge on Paradise Lane
49	N44 50.335	W65 17.492	Bridgetown	Bridge on Queen Street

The NS01 and Ref sites were sampled for nutrients by Environment Canada.

C.0 Appendix C

C.1 Historical TSS/Turbidity Results

Turbidity and TSS data collected May through to December in 2008-2011 along the Annapolis River is compiled in Figures C1 and C2. There are several spikes in the data throughout each year, which correspond to major precipitation events. The most notable occurred in September 2008, March 2009, July 2009, February 2010, December 2010 and October 2011 (Figures C1 and C2). All of these dates correspond to rainfall amounts of greater than 50 mm with the exception of March 30, 2009 when only 17 mm of rainfall was recorded. It is possible that there was significant snowmelt in occurrence with the rainfall, which led to high and turbid river levels.

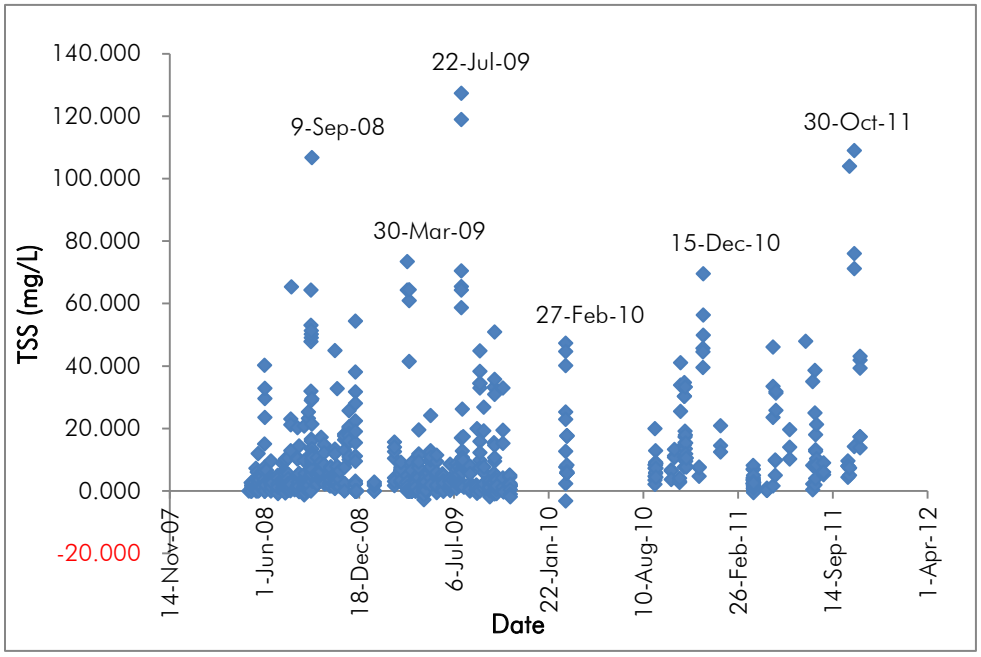

Figure C1. 2008-2011 Total Suspended Solids (TSS) results in mg/L by date.

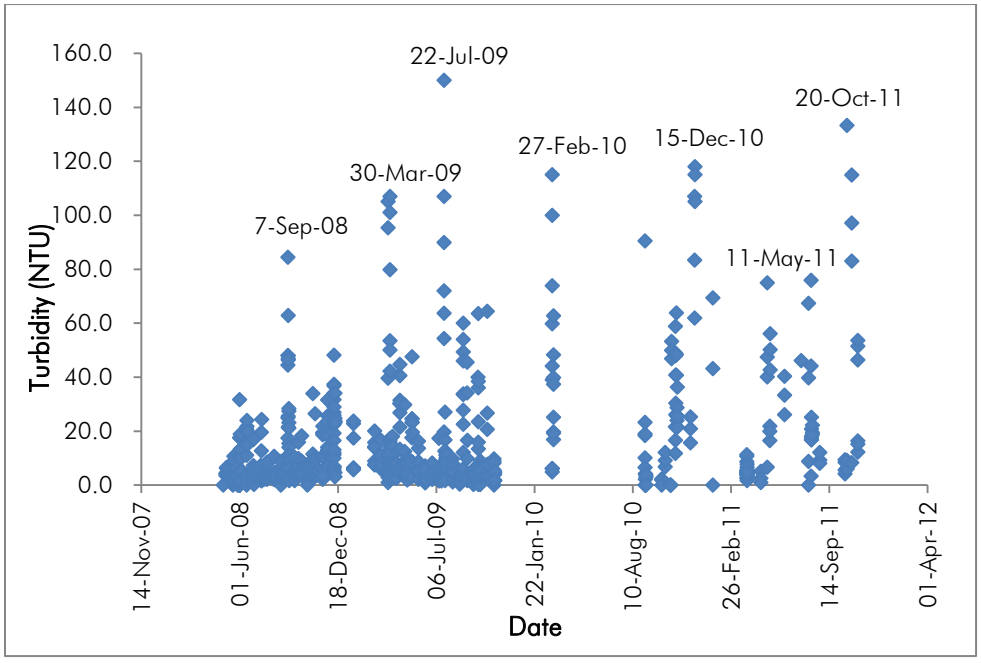

Figure C2. 2008-2011 Turbidity results in Nephelometric Turbidity Units (NTU) by date.

Data for the turbidity and TSS sample grabs for 2008-2011 were compiled in box and whisker plots to show the variability of the parameters between stations (Figures C3 and C4). Event grabs were overlaid onto the routine grabs to demonstrate how peak sediment in the river compares to baseline concentrations. The results have a large range and are shown in a logarithmic scale.

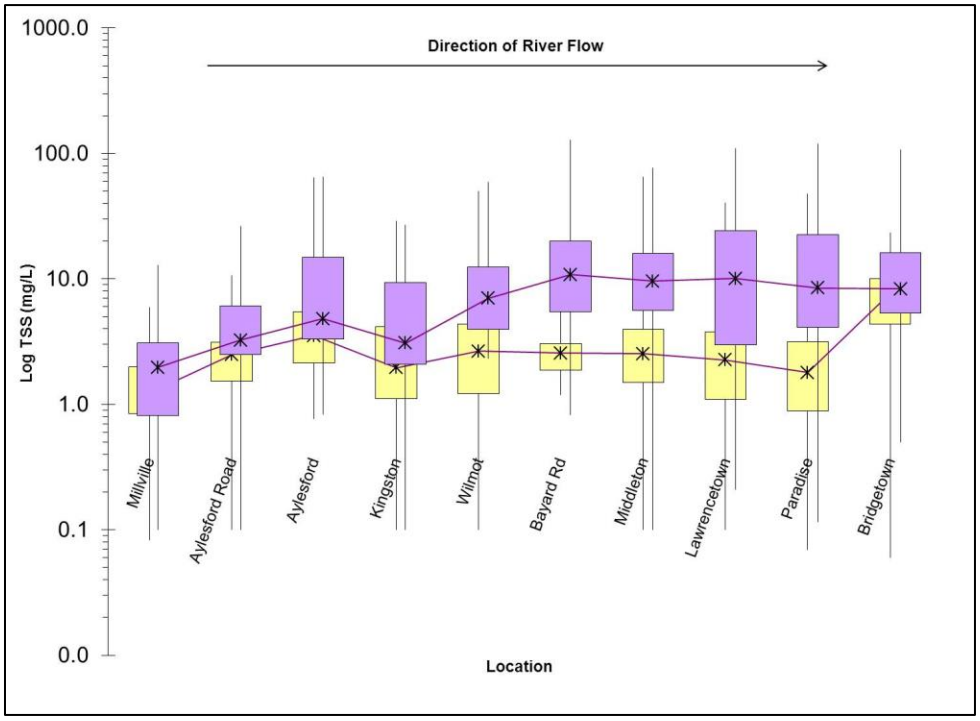

Figure C3. Routine (yellow) and Event (purple) TSS (mg/L) samples gathered at all locations from 2008-2011.

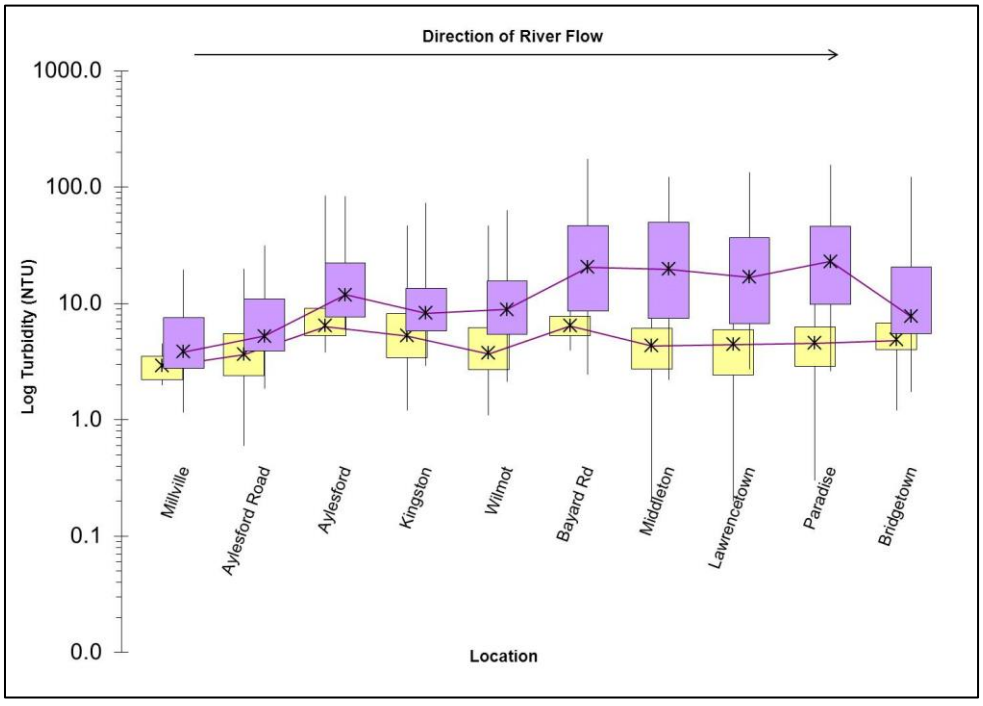

Figure C4. Routine (yellow) and Event (purple) Turbidity (NTU) samples gathered at all locations from 2008-2011.

Event grabs showed an overall higher TSS (mg/L) average than routine grabs, as is expected. Maximum levels reached over 100 mg/L with the highest value of 127.32 mg/L from Bayard Road, Wilmot on July 22, 2009. The Millville reference site has the lowest amounts of suspended solids in the water column for both routine and event samples. The samples for turbidity follow the same general trend. The highest turbidity measured was 150 NTU and was taken from the same sample that produced the highest TSS value. Note that the Bridgetown location shows high TSS readings when compared with the other sites, which is not reflected in the turbidity results. The Bridgetown location is the only monitored location that periodically has salt water due to tidal influence, which may be a possible explanation for this discrepancy.

One of the purposes of measuring these two parameters was to establish a relationship between TSS and turbidity (Figure 25). Upon visual examination, it seems as though these two variables are directly correlated. Continued collections and analyses under the direction of Environment Canada are required to accurately verify the validity of this relationship, as the data only encompasses a four-year period.

Although the best-fit straight line and equation are included in Figure 29, this relationship will be modified and adjusted as CARP continues to collect TSS and turbidity samples along the Annapolis River. Once sufficient data is collected, a more accurate relationship will be developed to enable Total Suspended Solids to be calculated from turbidity readings.

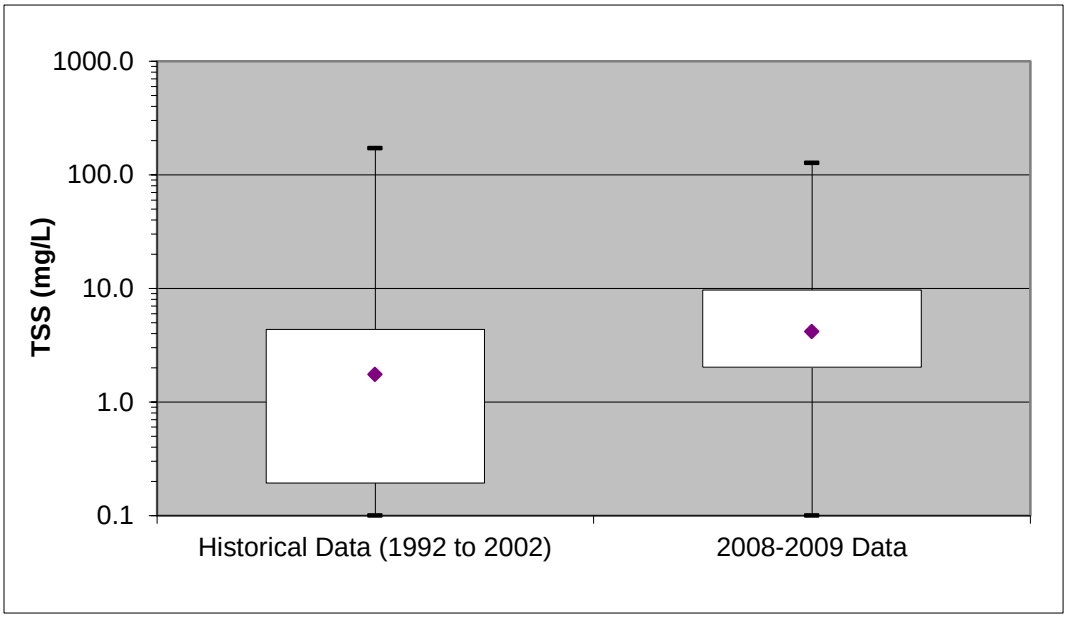

Figure C5. Comparison of the historical River Guardians TSS data (1992-2002) and the 2008/2009 TSS data collected as part of the TSS/Turbidity project.

TSS data from 1992 to 2002 was compared to data from 2008 and 2009 gathered during routine biweekly collections (Figure C5). The medians of the two data sets are similar, but the spread of the original data is larger and has a greater number of small values (between -15 and 1 mg/L). This might be due to the size of the original data set, which contains 9 years of data, whereas the 2008/2009 data set is only for 2 years. Note that the scale of the y-axis is logarithmic, therefore, negative values cannot be shown. However the minimum values for both sets of data are negative: -78.0 mg/L for the historical data and –3.21 mg/L for the 2008/2009 data.

The data collected in the period from 1992 - 2002 may not be usable. With regards to this data, Dill (2003) stated:

> The current [TSS] data in the River Guardians database is flawed by the fact that 15% of the samples have a negative value for [suspended particulate matter], which is not possible. The problem of negative values has occurred as recently as 2001 and is distributed through most of the years.

The data taken from 2008-2011 also contained negative values. Before correction, approximately 10% of the data was negative. However, as part of the project's Quality Assurance/Quality Control (QA/QC) plan (see Appendix D), blank samples were also processed. Many of the blank samples produced negative numbers as well, and using these results as a correction factor, the sample data was adjusted. The result was that only approximately 3% of the corrected data was negative. The absence of similar QA/QC data for the original data set makes it difficult to work with the results. In addition, although some of the 2008-2011 data was negative, the 1992 to 2002 data tended to be negative to a much greater degree (as much as –78.0).

D.0 Appendix D

D.1 Quality Assurance / Quality Control Data

D.1.1 Introduction

Following a bacterial contamination event in 2003, CARP initiated a number of procedures to ensure the quality of data collected. In addition to instituting a new collection procedure for fecal bacteria, CARP has put in place a program of regular quality control checks on sampling equipment and methods. Further information on the quality assurance/quality control (QA/QC) program can be found in CARP's draft QA/QC Project Plan (Sharpe and Sullivan, 2006). An important initial step in the QA/QC program is the training of volunteers. CARP staff conducted visits with each of the Annapolis River Guardian volunteers on collection days in order to both collect a series of blank and split samples, as well as to ensure the consistency in collection procedures. In total, forty-five QA/QC samples were collected during the 2012 season. These were, in summary:

- 9 Dissolved oxygen split samples
- 4 *E. coli* travel blanks
- 8 *E. coli* duplicate samples
- 8 *E. coli* field samples

D.1.2 Background

For the purposes of CARP's water quality monitoring programs, a blank sample is a sample that is known not to contain any of the substance in question. For CARP's monitoring of *E. coli* bacteria, either distilled or un-chlorinated tap water is added to the sample bottle. There are two types of blank samples that are collected for QA/QC analysis:

- Travel blanks are obtained by filling the sample bottle with distilled/tap water before the start of a sampling day, and placing them in the same cooler among other surface water samples. Travel blanks are used to ensure there is no cross-contamination between samples while they are being transported in the same cooler. They should always produce plates with no fecal bacteria growth.
- Field blanks are obtained by performing the entire sampling protocol (i.e.: attaching the bottle to the clamp, removing the cap and lowering the apparatus to the water surface) but NOT submerging the bottle. The bottle is instead lifted up empty and filled with distilled/tap water on the bridge. This type of blank sample is used to test the sampling procedure and should also always produce plates with no fecal bacteria growth. A positive result on a field blank would lead to further investigations to determine the source of contamination (for example: operator, equipment, distilled water, etc.).

Split samples are used to measure both precision and accuracy. Precision is expressed as the degree of agreement among repeated measurement of the same parameter and provides information on the reproducibility and consistency of the methods used. Accuracy, on the other hand, consists of how close a measurement is to the "true" value.

A split sample is a single sample volume that is divided in two samples that are analysed separately. Split samples can provide information on the precision of the lab method (i.e.: the precision of Valley Regional Hospital's *E. coli* analysis). Split samples can also provide information on the accuracy of the method used (i.e.: the accuracy of volunteers at the Winkler titration compared to staff).

The degree of variability between two split samples can be evaluated by calculating their relative percent difference (RPD). The RPD is expressed as the absolute difference of the two measurements multiplied by 100 and divided by the average of the two values:

$$RPD = \frac{|X_1 - X_2| \times 100}{(X_1 + X_2) \div 2}$$

When more than two samples are to be compared, the degree of variability is estimated by calculating their Relative Standard Deviation (RSD). Both the RPD and the RSD are expressions of precision, the smaller the value, the greater the precision.

$$RSD = \frac{s}{X_m} \times 100$$

s = standard deviation
Xm = mean of duplicate samples

Accuracy is estimated by taking the absolute difference between the "true" value and the "test" value. When there are multiple measurements, the true value is subtracted from the average of the test measurements. The result is compared to acceptable accuracy standards for each individual method. The staff value is considered the "true value" for the purpose of comparison.

Accuracy = Test/Average value – True Value

D.1.3 Dissolved Oxygen

Dissolved oxygen split samples were taken in 2012 using a single volume of water from a van Dorn sampler. The accuracy of volunteer DO measurements was assessed through the collection of seven split samples. The Winkler titration (described in Appendix A) is widely recognized has a standard for determining dissolved oxygen and is reported to have an accuracy of at least +/- 1 mg/L. Results from the split samples (Table D1) indicate that the volunteers attained an average accuracy of +/- 0.84 mg/L (RPD = 9.9%). For comparison purposes, the average DO accuracy for 2011 was +/- 0.19 mg/L (RPD = 2.2%).

Table D1. Volunteers' level of accuracy at measuring dissolved oxygen using Winkler titration.

Site #	Date	Volunteer Result	QA/QC Result	Accuracy	% Difference
49	9-Sep-12	8.0	9.0	1.0	11.76
40	12-Aug-12	11.3	11.4	0.07	0.62
35	12-Aug-12	7.4	8.4	1.0	12.92
25	29-Jul-12	8.8	9.1	0.3	3.35
18	9-Sep-12	7.2	9.1	1.9	22.77
13	29-Jul-12	10.4	8.4	2.0	21.51
00	15-Jul-12	8.1	8.4	0.3	3.04
AY40	15-Jul-12	8.2	8.5	0.3	3.11
			Mean	0.8	9.88

D.1.4 *E. coli* Bacteria

Throughout the sampling season, a series of blank samples were submitted blind for analysis to the microbiology laboratory at Valley Regional Hospital. The five travel blanks analyzed all had coliform counts of 0 cfu/100ml, which indicates that no cross-contamination was occurring during transportation of the samples. A field blank was collected at each River Guardian site and all eight samples showed 0 cfu/100m, indicating that the sample collection procedure was not contaminating the samples.

Throughout the 2012 sampling season, a total of eight split samples were collected during the sampling visits with the volunteers. These samples were submitted to the Valley Regional Hospital Microbiology Laboratory under fictitious sample identification numbers. The

purpose of this was to assess the reproducibility of the *E. coli* MPN analysis method used. The mean RPD for these split samples in 2012 was 18.5% (Table D2). The mean RPDs for the 2010 and 2011 seasons were 25.0% and 15.1%, respectively.

The 2010 RPD mean is slightly higher than the 2011 value, which in turn is lower than the 2012 value. This seems to indicate that the testing precision has been improving over the last few years. The test performed is the Colilert Most Probable Number analysis, and it is performed at the Microbiology Laboratory at Valley Regional Hospital.

Table D2. Relative percent difference in duplicate samples analyzed for *E. coli.*

Site #	Date	Volunteer Result	QA/QC Result	Accuracy	% Difference
49	9-Sep-12	35	44	9	22.8
40	12-Aug-12	76	88	12	14.6
35	12-Aug-12	60	58	2	3.4
25	29-Jul-12	114	93	21	20.3
18	9-Sep-12	79	80	1	1.26
13	29-Jul-12	649	1046	397	46.8
00	15-Jul-12	1203	1553	350	25.4
AY40	15-Jul-12	219	192	27	13.1
			Mean	102.4	18.5

All analysis methods have inherent variability; this is particularly the case with IDEXX, as the Most Probable Number result is statistically derived (Table D3). The variability values are taken from the IDEXX Quanti-Tray®/2000 MPN Table (per 100mL) with 95% Confidence Limits (no date). For each volunteer result, the 95% confidence range was found and compared to the confidence range of the QA result. If these ranges overlapped, then the variability between the two results can be explained by the inherent variability of the procedure. None of the volunteer results had a value whose confidence range that did not overlap with that of the QA result, however, the Kingston and Aylesford volunteer results just bordered the 95% confidence interval of the QA/QC result.

Table D3. Confidence interval limits for IDEXX Colilert Most Probable Number procedure.

MPN	95% Confidence	
	Lower Limit	Upper Limit
0	0	3.7
10	5	18
50	36	69
100	81	121
150	124	181
200	166	242
500	405	619
1000	740	1320
1500	1010	2350
2000	1220	3300
>2419	1440	infinite