Friends of the North Fork of the Shenandoah River
Science Committee Report
January 2014

Water Quality Monitoring in the Vicinity of Lake Laura (2010-2013)

Acknowledgments

Friends of the North Fork of the Shenandoah River (FNFSR) is a non-profit, volunteer-based organization. Our mission is to keep the North Fork of the Shenandoah River clean, healthy, and beautiful through advocacy, community action, education, and science. Without the efforts of our volunteers, most of what we do could not take place. In this project, H. B. Lantz was both instrumental and invaluable in the completion of this work. He identified the concern, prepared the draft request for funding, and led all of the water sampling over the four year period of the project. In his sampling efforts, he was assisted by other volunteers including Frank Hovermale, Michael Calhoun, Nancy Smaroff, and Joe Freund.

The water samples taken in this project were analyzed by the certified laboratory located at Shenandoah University that is operated by the Friends of the Shenandoah River. Karen Andersen directs the lab and is assisted by Molly Smith. They have been dedicated and diligent in working with our volunteers and providing high quality analytical results.

The costs for this project, which are primarily the fees paid for the laboratory analyses, were covered by a Minding the Planet grant received from the YSI Foundation, which is affiliated with YSI, a water monitoring equipment company.

1. Executive Summary

The sampling and analysis of water quality above, in and below Lake Laura between 2010 and 2013 indicates the following:

- Nutrients (ammonia, nitrates and phosphates) were at their highest concentrations at the beginning of the study period in an unnamed tributary feeding into Stoney Creek above the lake. In 2012, the Orkney Spring sewage treatment plant that discharged into that tributary was shut down and the wastewater was rerouted to a larger, more advanced treatment facility downstream of Lake Laura. The removal of that discharge had a significant positive impact on the quality of water in the Orkney Springs tributary. The nutrient reduction that occurred should have a favorable effect on algae growth downstream in Stoney Creek and in Lake Laura.
- There is no evidence that the removal of the Orkney Springs wastewater discharge has reduced E. coli levels on the tributary or at locations downstream. In fact, average and maximum E. coli levels are higher at all points sampled in 2013 than in 2010-2011. However, it is unclear whether this demonstrates a worsening of water quality or simply reflects inherent variability, because of the many factors influencing E. coli levels and the number of samples that were taken during 2013.
- The data indicate that the high levels of E. coli are correlated with rain events and storm runoff, suggesting that animal and human waste (flushed into the creeks and the lake in stormwater runoff) are an important contributing factor.
- Sampling and analysis for bacteria (E. coli) indicate that the waters above the lake and in the lake periodically exceed the state standard for recreational use and the exceedances are frequent enough to have these waterways classified as “impaired”. The data from this study are being provided to the Virginia Department of Environmental Quality.

Periodically the DEQ determines which water bodies in the state are officially impaired. Once an area is designated as impaired, actions are taken to reduce the contaminant in question to acceptable levels. The process takes years. In the meantime, users of the lake and the tributaries above the lake should be aware that E. coli levels are high from time to time, especially following rain events.

2. Background

In early 2010, concerns with water quality in Lake Laura were brought to the attention of the FNFSR. Lake Laura is part of the North Fork watershed. It is fed by and discharges into Stoney Creek, which flows into the North Fork. A project to collect and analyze water samples was developed and funding was sought. The goal of the project was to characterize the quality of the water in Lake Laura and the tributaries in the vicinity; to use those data to determine what level of pollution is present; and to gain insights into the sources of contamination. Funding was secured in 2010 and monitoring began in April of 2010 and was concluded in September of 2013.

3. Water Quality Sampling and Analysis

Chemical and Physical Parameters

The approach to water quality sampling for this project was to evaluate traditional contaminants at selected sites every two weeks (every other Friday). The traditional parameters that were evaluated include:

- Nitrates
- Ortho Phosphates
- Ammonia
- Turbidity
- Dissolved oxygen
- Temperature
- pH, which was replaced with conductivity in 2013

Periodic sampling for these parameters was carried out in 2010 and 2011. Periodic sampling was suspended in 2012 to preserve funding for sampling in 2013. The main motivation was to have funds to evaluate water quality after the discharge from the Orkney Springs sewage treatment plant had been eliminated.[1] Periodic sampling was restarted in March of 2013, with fewer sites due to budget limitations.

A general discussion of the impacts and the environmental importance of each of these contaminants can be found on the Friends of the Shenandoah River website at: http://fosr.org/water-quality-analysis-parameters/

[1] Until 2012, Shrine Mont operated a sewage treatment plant at Orkney Springs that discharged into a tributary of Stoney Creek above where Stoney Creek flows into Lake Laura. In 2012, their waste water was rerouted to the Stoney Creek Sanitary District treatment plant which has a more advanced treatment system and discharges well below Lake Laura.

Virginia has freshwater quality standards[2] for ammonia that address impacts on fish life. For acute impacts, they are a function of the pH. For long term impacts, they are a function of temperature and pH. The ammonia, pH and temperature levels we observed indicate that the ammonia standards are not being exceeded. However, ammonia, ortho phosphates and nitrates are also important as nutrients that can lead to excessive algae growth and reduced dissolved oxygen levels. We did not observe depletions in dissolved oxygen but algae blooms do occur in these waters. The state has standards for nutrient impairment for specific lakes. Lake Laura is not listed. Impairment of a lake is normally based on the level of chlorophyll a in the water. The laboratory we worked with on this project was not equipped to run chlorophyll a in support of this study. Therefore, we are not able to quantify the level of impairment for algae. However, because we know that algae does occur in the lake, knowing the relative levels of nutrients and the trends in nutrients will help one understand the algae situation for Lake Laura.

Bacteria

Testing for bacteria levels was carried out every four weeks (every other time that the traditional contaminants were evaluated). Microbial water quality standards are based upon one of two indicator bacteria – fecal coliform in general, or Escherichia coli (E. coli) which is one of the coliform bacteria and is found in the intestinal tract of warm blooded animals. It is assumed that these bacteria “indicate” the presence of pathogens, in general, and associated human health risks. Microbial pollution sources include wildlife, humans, and livestock. In Virginia, the water quality standard for bacteria is based on E. coli. Therefore, this project examined E. coli levels. Virginia’s E. coli standard for recreational use (swimming) in a fresh water body such as Lake Laura is 126 “colony forming units” (cfu) per 100 ml for an average of 5 samples collected over 30 days, or 235 cfu per 100 mL for a single grab sample.[3] Because we did not collect samples as frequently as five or more samples over 30 days, we have applied the 235 cfu per 100 ml standard to our data.

There was limited sampling and analysis in 2012 focusing on the impact of rain events and storm runoff on E. coli levels in the lake. This was started because of a high reading of E. coli in the lake in December 2011. In this work, samples were taken right after significant rain events. There were five samples in 2012 and one in 2013.

[2] See: http://water.epa.gov/scitech/swguidance/standards/wqslibrary/upload/vawqs.pdf

[3] Colony Forming Unit (cfu) is an estimate of viable bacterial in a sample. Unlike direct microscopic counts where all cells, dead and living, are counted, cfu estimates viable cells. To determine the cfu, the sample is applied to a growth medium and it is analyzed for the formation of visible colonies of bacteria growth. The appearance of a visible colony requires significant growth of the initial cells plated. At the time of counting the colonies, it is not possible to determine if the colony arose from one cell or 1,000 cells. Therefore, the standard is expressed as cfu/ 100 mL (colony-forming units per 100 milliliters). The laboratory method used in this study has an automated counting system and the results are reported as the “Most Probably Number”(MPN) of viable cells. Most Probable Number reflects the fact that the method uses multiple cultures and a probability calculation to determine the approximate number of viable cells in a given volume of sample. The figures are comparable to cfu. For example: 50 MPN/100 mL means that the Most Probable Number of viable cells in 100 mL of sample is 50. You will see the use of MPN in the presentation of results in this report. It should also be noted that this analytical method for E. coli requires some prior knowledge of the range of result to be expected. In some instances the level of E. coli was higher than expected. In those instances the results are simply reported here as being at the maximum range of the test. This means that in some instances the reported levels are conservatively low.

Sampling Locations and Results

During this study, water samples were taken above, below and in the lake. Samples were collected and analyzed for the unnamed tributary associated with Orkney Springs (which flows into Stoney Creek above the lake), Stoney Creek above the lake, the lake itself, and Stoney Creek where it reforms below the dam. Table 3-1 lists the sampling sites during the project. It is followed by a map showing their locations.

The monitoring data from this project have been shared with interested parties in the community during the course of the study. In 2013, as new data were produced, an updated spreadsheet of results for the study was provided to community members.

Table 3-1: Sampling Locations for the Lake Laura Water Quality Study 2010-2013					
Site ID	**Site Description**	**Stream**	**Location**	**Latitude**	**Longitude**
OS01	Orkney Springs tributary at bridge on Rt. 263	Unnamed tributary hereafter known as Orkney Springs	This site is just upstream of the bridge on Rt. 263	38.474263N	78.484333W
OS02	Orkney Springs tributary downstream of sewage treatment plant	Unnamed tributary hereafter known as Orkney Springs	This site is just downstream of the Orkney Springs sewage treatment plant discharge	38.793611N	78.808056W
OS2A	Orkney Springs tributary downstream of sewage treatment plant	Unnamed tributary hereafter known as Orkney Springs - Replaced OS2 due to access considerations	This site is just downstream of the Orkney Springs sewage treatment plant	38 degrees 47' 34 01"N	78 degrees 48' 24 43"W.
OS03	Orkney Springs tributary before confluence with Stoney Creek	Unnamed tributary hereafter known as Orkney Springs	This site is between the road to Lake Laura and Stoney Creek	38.472598 N	78.475583W
OS04	Orkney Springs tributary just downstream of Shrine Mont pond	Unnamed tributary hereafter known as Orkney Springs	Orkney Springs Run just downstream of Shrine Mont pond	38.474830 N	78.485383 W
OS05	Orkney Springs tributary at culvert just upstream of hotel.	Unnamed tributary hereafter known as Orkney Springs	Orkney Springs run at culvert just upstream of hotel	38.474431 N	78490060 W
STY01	Stoney Creek upstream of Lake Laura	Stoney Creek	This site is on Stoney Creek just upstream of the gas pipeline clearing	38.472278 N	78.475614 W.
STY02	Stoney Creek below dam on Lake Laura	Stoney Creek	This site is just below the dam of Lake Laura as Stoney Creek reforms	38.481402 N	78.472679 W
STY03	Stoney Creek upstream of Lake Laura at Rt. 726	Stoney Creek	This site is upstream of STY01	38.46398N	78.475312W
LL01[4]	Lake Laura between two coves	Lake Laura	This site is at the mid-point between the two coves on the west side and in the middle of the Lake	38.475381 N	78.473504 W
LL02[4]	Lake Laura boat landing	Lake Laura	This site is in the middle of Lake Laura between the boat landing and the shore on the east side	38.473858 N	78.474077 W

[4] All samples at LL02 (Lake Laura boat landing) were taken at a depth of one (1) meter. The two samples taken at LL01 (between coves) were taken at either one (1) meter (coded "S" in the data base) or five (5) meters (coded "D" in the data base).

Figure 3-1 Location of Sampling Sites at Lake Laura

4. Review of the Data

This section presents our analysis of the data for evidence of contamination, trends and impacts.

4.1 Water Quality Data Analysis

The following tables identify and compare water quality in the areas we studied using five parameters – E. coli, nitrates, orthophosphates, ammonia and turbidity. The four areas are: the unnamed tributary associated with Orkney Springs, Stoney Creek above the lake, the lake, and Stoney Creek below the lake. This analysis uses all periodic sampling data (2010, 2011, and 2013) but none of the rain event data, which were evaluated separately because they were intentionally focused on the impact of rain events and do not portray the normal average conditions of these water bodies.

The tables present two types of comparisons. First, Table 4-1 compares all four areas on the basis of highest average and highest maximum parameter values. This gives a sense of which areas are most impacted and where the problems are for each parameter. Then, Tables 4-2, 4-3 and 4-4 present similar comparisons for each of the areas to identify the measurement points that are most impacted.

The following observations and conclusions are drawn from the tables:

- Based on average values, the Orkney Springs tributary was the most impacted area for E. coli and the nutrients, with its averages being significantly higher than the other areas for the nutrients. (That changed in 2013 and, later in the report, we address the impact of the removal of the discharge from the Orkney Springs wastewater treatment plant on water quality in the tributary.)

- The Orkney Springs tributary was also the most impacted area based on maximum parameter values for E. coli and nutrients, although it, Stoney Creek and Lake Laura all have at least one E. coli reading at 2,420 (the limit of measurement). High E. coli values have occurred below the dam as well.

- STY01 has the highest levels on Stoney Creek for all parameters, except for E. coli which is somewhat higher at STY03. The contaminant levels on the Orkney Springs tributary do not contribute to high levels at STY01, as STY01 is upstream about 75-100 meters from the confluence with the Orkney Springs tributary.

- Parameter levels in Lake Laura can be high for E. coli (approaching the levels upstream), but are generally lower for all other parameters. The lake has had one very high turbidity value that was about one-half the values upstream. This occurred at LL02, which is at the boat ramp area and in the middle of the lake.

Table 4-1: Identification and Comparison of Most-Impacted Locations for Five Parameters Using All Data (2010, 2011, 2013)

Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

	Orkney Springs Tributary		Stoney Creek (Above Lake)		Lake Laura		Stoney Creek (Below Dam)	
	Location	Level	Location	Level	Location	Level	Location	Level
Ranked Based on Average Levels								
E. coli (per 100 ml)	OS02	346	STY03	278	LL02	230	STY02	40
Nitrates (ppm)	OS02	1.80	STY01	0.21	LL01D	0.17	STY02	0.08
Orthophosphates (ppm)	OS02	0.33	STY01	0.02	LL02	0.02	STY02	0.01
Ammonia (ppm)	OS02	0.47	STY01	0.015	LL01D	0.05	STY02	0.16
Turbidity	OS04	39	STY01	9	LL01D	0.17	STY02	11
Ranked Based on Maximum Levels								
E. coli (per 100 ml)	OS02	2,420[5]	STY01,03	2,420[5]	LL02	2,420[5]	STY02	614
Nitrates (ppm)	OS02	8.24	STY01	1.31	ALL	0.41	STY02	0.46
Orthophosphates (ppm)	OS02	1.91	STY01	0.18	LL02	0.21	STY02	0.02
Ammonia (ppm)	OS02	5.16	STY01	0.10	LL01D	0.52	STY02	0.78
Turbidity	OS02	200	STY01	205	LL02	116	STY02	35

[5] This level is the limit of the measurement and, where it is presented, the actual level could be higher.

Table 4-2: Summary of Contaminant Levels on Orkney Springs Tributary (2010, 2011, 2013 Data)

Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

	OS01	OS02	OS03	OS04	OS05	Orkney Springs
E. coli						
Samples (N)	30	31	21	2	2	86
Maximum	1,203	2,420	1,733	33	488	2,420
Average	230	346	209	21	275	263
Minimum	2	1	2	11	62	1.0
Nitrates						
Samples (N)	45	46	32	2	2	127
Maximum	0.36	8.24	7.87	0.02	0.08	8.24
Average	0.17	1.80	1.74	0.015	0.065	1.15
Minimum	0.01	0.08	0.01	0.01	0.05	0.01
Orthophosphates						
Samples (N)	45	46	30	2	2	125
Maximum	0.20	1.91	0.56	0.01	0.01	1.91
Average	0.01	0.33	0.11	0.01	0.01	0.15
Minimum	0.00	0.01	0.01	0.01	0.01	0.00
Ammonia						
Samples (N)	45	46	32	2	2	127
Maximum	0.22	5.16	0.15	0.12	0.01	5.16
Average	0.02	0.47	0.02	0.07	0.01	0.19
Minimum	0.01	0.01	0.01	0.02	0.01	0.01
Turbidity						
Samples (N)	36	39	26	1	1	103
Maximum	18.6	200	15	39	4.5	200
Average	7.5	11	5.4	39	4.5	8.5
Minimum	1.9	<1	<1	39	4.5	<1

Table 4-3: Summary of Contaminant Levels on Stoney Creek (2010, 2011, 2013 Data)

Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

	STY03	STY01	Stoney Creek Above Lake	Stoney Creek Below Dam
E. coli				
Samples (N)	18	30	48	23
Maximum	2,420	2,420	2,420	613
Average	278	246	258	40
Minimum	20	10	10	1
Nitrates				
Samples (N)	28	44	72	34
Maximum	0.29	1.31	1.31	0.46
Average	0.15	0.21	0.19	0.08
Minimum	0.05	0.01	0.01	0.00
Orthophosphates				
Samples (N)	28	44	72	34
Maximum	0.07	0.18	0.18	0.02
Average	0.013	0.02	0.018	0.01
Minimum	0.01	0.00	0.00	0.00
Ammonia				
Samples (N)	28	34	62	34
Maximum	0.01	0.10	0.10	0.78
Average	0.01	0.015	0.013	0.16
Minimum	0.01	0.01	0.01	0.01
Turbidity				
Samples (N)	23	37	60	28
Maximum	17	205	205	35
Average	4	9	7	11
Minimum	<1	<1	<1	1.4

Table 4-4: Summary of Contaminant Levels in Lake Laura (2010, 2011, 2013 Data) Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.				
	LL01D	LL01S	LL02	Lake Laura
E. coli				
Samples (N)	13	16	22	51
Maximum	201	201	2,420	2,420
Average	33	18	207	103
Minimum	1	1	2	1
Nitrates				
Samples (N)	24	23	35	82
Maximum	0.41	0.41	0.41	0.41
Average	0.11	0.08	0.10	0.09
Minimum	0.01	0.01	0.01	0.01
Orthophosphates				
Samples (N)	24	23	35	82
Maximum	0.02	0.01	0.21	0.21
Average	0.01	0.01	0.02	0.01
Minimum	0.00	0.00	0.00	0.00
Ammonia				
Samples (N)	24	23	35	82
Maximum	0.52	0.10	0.12	0.52
Average	0.05	0.02	0.03	0.04
Minimum	0.01	0.01	0.01	0.01
Turbidity				
Samples (N)	20	19	23	62
Maximum	115	22	116	116
Average	17	5	12	11
Minimum	2.4	<1	2	<1

4.2 Trends in Water Quality

This section looks at trends in contaminant levels over time by comparing levels measured in 2013 (after the shutdown of the Orkney Spring sewage treatment plant) to the corresponding levels measured during 2010-2011. The most-impacted sampling locations for each area are compiled in Table 4-5 (2010-2011 data) and Table 4-6 (2013 data). Appendix A presents the supporting data for all measurement points.

2010-2011 (Before Sewage Plant Shutdown)

- The Orkney Springs tributary is clearly the most impacted area in terms of both average and maximum values for all parameters except turbidity. Lake Laura is most impacted for turbidity (Table 4-5). Sampling location OS02 (downstream of the discharge of the sewage treatment plant) is the most-impacted location on the Orkney Springs tributary.
- Considering average values, E. coli levels on the Orkney Springs tributary are twice that of the next most-impacted area. Its average values for the nutrients are 11 times higher for nitrates; 22 times higher for orthophosphates; and 4 times higher for ammonia than the next most-impacted area.
- Considering maximum values, E. coli levels on the Orkney Springs tributary are 2.8 times that of the next most-impacted area. Its maximum values for the nutrients are 6 times higher for nitrates; 11 times higher for orthophosphates; and 10 times higher for ammonia.

The Orkney Springs tributary downstream of the sewage treatment plant was far and away the most-impacted area for E. coli and nutrients.

2013 (After Sewage Plant Shutdown)

The sampling in 2013 covered fewer sampling locations than before, due to budget constraints and in light of what was observed in the earlier sampling. Specifically, it included:

- The primary locations OS01 and OS02a on the Orkney Springs tributary that bracket the location of the sewage treatment plant discharge point.
- The primary locations STY03 and STY01 on Stoney Creek that bracket the junction of the Orkney Springs tributary.
- One sampling location LL02 in Lake Laura taken at the boat landing in the middle of the lake.

No measurements were taken on Stoney Creek below the dam in 2013.

There is also less data for 2013. There are 6 or 7 measurements for E. coli, 10 or 12 measurements for the nutrients, and 4 to 11 measurements for turbidity. Some caution is warranted in the interpretation of absolute levels because of the smaller sample sizes.

Table 4-5: Identification and Comparison of Most-Impacted Locations for Five Parameters

Using 2010-2011 Data

Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

	Orkney Springs Tributary		**Stoney Creek (Above Lake)**		**Lake Laura**		**Stoney Creek (Below Dam)**	
	Location	Level	Location	Level	Location	Level	Location	Level
Ranked Based on Average Levels								
E. coli (per 100 ml)	OS02	260	STY03	135	LL01D,02	33	STY02	40
Nitrates (ppm)	OS02	2.35	STY01	0.22	LL01D	0.11	STY02	0.08
Orthophosphates (ppm)	OS02	0.43	STY01	0.02	ALL	0.01	STY02	0.01
Ammonia (ppm)	OS02	0.64	STY01	0.016	LL01D	0.05	STY02	0.16
Turbidity	OS01	7	STY01	3	LL01D	17	STY02	11
Ranked Based on Maximum Levels								
E. coli (per 100 ml)	OS02,03	1,733	STY01	613	LL01D,1S	201	STY02	613
Nitrates (ppm)	OS02	8.24	STY01	1.31	ALL	0.41	STY02	0.46
Orthophosphates (ppm)	OS02	1.91	STY01	0.18	LL01D	0.02	STY02	0.02
Ammonia (ppm)	OS02	5.16	STY01	0.10	LL01D	0.52	STY02	0.16
Turbidity	OS04	39	STY01	13	LL01D	115	STY02	11

Table 4-6: Identification and Comparison of Most-Impacted Locations for Five Parameters Using 2013 Data

Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

	Orkney Springs Tributary [a/]		**Stoney Creek** [a/] **(Above Lake)**		**Lake Laura** [b/]		**Stoney Creek (Below Dam)**	
	Location	Level	Location	Level	Location	Level	Location	Level
Ranked Based on Average Levels							NO DATA	
E. coli (per 100 ml)	OS02	640	STY01	857	LL02	580		
Nitrates (ppm)	OS02	0.21	STY01	0.20	LL02	0.10		
Orthophosphates (ppm)	OS01	0.03	STY01,03	0.02	LL02	0.03		
Ammonia (ppm)	OS02	0.02	STY01	0.04	LL02	0.03		
Turbidity	OS02	24	STY01	28	LL02	32		
Ranked Based on Maximum Levels								
E. coli (per 100 ml)	OS02	2,420	STY01,03	2,420	LL02	2,420		
Nitrates (ppm)	OS02	0.46	STY01	0.43	LL02	0.36		
Orthophosphates (ppm)	OS02	0.20	STY01	0.08	LL02	0.21		
Ammonia (ppm)	OS02	0.22	STY01	0.04	LL02	0.12		
Turbidity	OS02	200	STY01	205	LL02	116		

Notes:
[a/] Two sampling locations in 2013.
[b/] One sampling location in 2013.

The following observations and conclusions are drawn from the tables:

- Nutrient levels in the Orkney Springs tributary are much lower than before the sewage treatment plant closed. (Table 4-6)

- Considering average values, Stoney Creek (above the lake) is the most-impacted for E. coli, with levels 34% higher than on the Orkney Springs tributary. The Orkney Springs tributary is most-impacted for nitrates but only by the narrow margin of 0.01 ppm over Stoney Creek (0.21 and 0.20 ppm, respectively). The Orkney Springs tributary and Lake Laura tie for most-impacted for orthophosphates (at 0.03 ppm). Stoney Creek is most-impacted for ammonia by a narrow margin (0.04).

- Considering maximum values for E. coli, all three areas recorded maximum values of 2,420 (the upper limit of measurement) during 2013. These occurred on 7/12 and 8/23. Because rain events lead to increased E. coli levels, the high levels observed on these dates are probably due to rain events.[6]

- Considering maximum values for the nutrients, the Orkney Springs tributary is most-impacted for nitrates, but by a small margin over Stoney Creek (0.46 and 0.43 ppm, respectively). Lake Laura is most-impacted for orthophosphates by a small margin over the Orkney Springs tributary (0.21 and 0.20 ppm, respectively). The Orkney Springs tributary is most-impacted for ammonia at nearly twice the level of Lake Laura (0.22 and 0.12 ppm, respectively).

- For turbidity, Lake Laura is most impacted on an average basis by small margins over Stoney Creek and the Orkney Springs tributary. Stoney Creek recorded the highest turbidity value (205) followed by Orkney Springs (200) and Lake Laura (116).

With the shutdown of the Orkney Springs sewage treatment plant, the Orkney Springs tributary has been restored to a status that is comparable to other locations within the area. E. coli levels can be high throughout the area, particularly after rain events, but the Orkney Springs tributary no longer stands out as clearly having the highest levels. Nutrient levels are down throughout the area below the old discharge point and the Orkney Springs tributary does not consistently have the highest levels.

The impact of the plant shutdown is also apparent on the Orkney Springs tributary itself (see Appendix A, Tables A-1 and A-4). Nutrient levels below the plant discharge point (OS02) are no longer consistently higher than above the plant (OS01) and the average levels above and below the plant discharge point are now quite similar. Average E. coli levels in 2013 are about twice as high below the plant as the levels above; a similar result was seen in the 2010-2011 data where average levels E. coli were also higher below the plant (but by a smaller margin).

Considering these results, it appears that E. coli levels are the most pressing problem that remains in the area. E. coli levels are explored in more detail in the next section.

[6] We were not able to address the impact of rain events on E. coli levels quantitatively because the rain events and their impact on runoff is both variable and localized, and we were not able to locate rain gauge data for a relevant location upstream of this part of the watershed. However, the persons taking the samples did observe the effects of rain on water flow and clarity on the days with higher E. coli levels.

4.3 E. Coli Levels and Impairment Implications

Table 4-7 below provides an "unofficial" classification of each sampling location and the four composite areas according to the criteria used by the state when it determines impairment[7]. An exceedance is a measured value greater than 235 cfu per 100 ml (E. coli in fresh water). To classify a waterway as "impaired," there must be at least two exceedances when the sample is small (2-9) or, for larger samples, two or more exceedances that amount to more than 10.5% of the samples.

For 2013 on a composite basis (all sampling locations), the Orkney Springs tributary remains impaired even after shutdown of the sewage treatment plant. Stoney Creek (upstream) is also impaired in 2013. There are insufficient data to make an official determination for Lake Laura, but the lake's one sampling location recorded 3 exceedances in 7 samples during 2013. No exceedances of the 235 level were recorded at Lake Laura during the 2010-2011 period.

Table 4-7: Waterway Classification for E. coli Impairment

	Using All Data (2010, 2011, 2013)			Using 2013 Data Only			
	Number of Exceedances	Pct of Samples	Impaired?	Number of Samples	Number of Exceedances	Pct of Samples	Impaired?
Orkney Springs Tributary	**24**	**28%**	**Yes**	**13**	**4**	**31%**	**Yes**
OS01	10	33%	Yes	6	2	33%	Yes
OS02/02A	9	29%	Yes	7	2	29%	Yes
OS03	4	19%	Yes	No Data			
OS04	Insufficient Data (2 samples)			No Data			
OS05	Insufficient Data (2 samples)			No Data			
Stoney Creek Upstream	**8**	**17%**	**Yes**	**13**	**4**	**31%**	**Yes**
STY01	3	10%	No	6	2	33%	Yes
STY03	5	28%	Yes	7	2	29%	Yes
Lake Laura	**3**	**6%**	**No**	**7**	**3**	**43%**	**Yes**
LL01D	0	0%	No	No Data			
LL01S	0	0%	No	No Data			
LL02	3	14%	Yes	7	3	43%	Yes
Stoney Creek Downstream (STY02)	**1**	**4%**	**No**	**No Data**			

[7] DEQ Document: "Water Quality Assessment Guidance Manual for Y2010, 305(b)/303(d) Integrated Water Quality Report"

The impairment classification made by the State is based on all available measurements for the most recent 6 year period. Trends over time will also be examined. The testing performed by FNFSR indicates that E. coli levels are higher in 2013 than during 2010-2011. In fact, average and maximum E. coli levels are higher at all sampling locations in 2013 compared to previous years. We are concerned that the data suggest a worsening of the problem. However, given the many factors that influence E. coli levels and the smaller number of measurement points and samples that were taken during 2013, we are not ready to conclude that it has worsened.

4.4 Impact of the Shutdown of the Orkney Springs Sewage Treatment Facility

The Orkney Springs sewage treatment plant was shut down during calendar year 2012[8]. Our water quality data allow us to compare E. coli and nutrient levels above the plant's discharge (sampling location OS01) with levels below the plant discharge (sampling locations OS02/02A). The difference in levels below the discharge point compared to levels above the discharge point on each sampling day gives the best basis for determining the sewage treatment plant's contribution to contaminant levels and the effect on water quality.

This view of the data leads to the following conclusions.

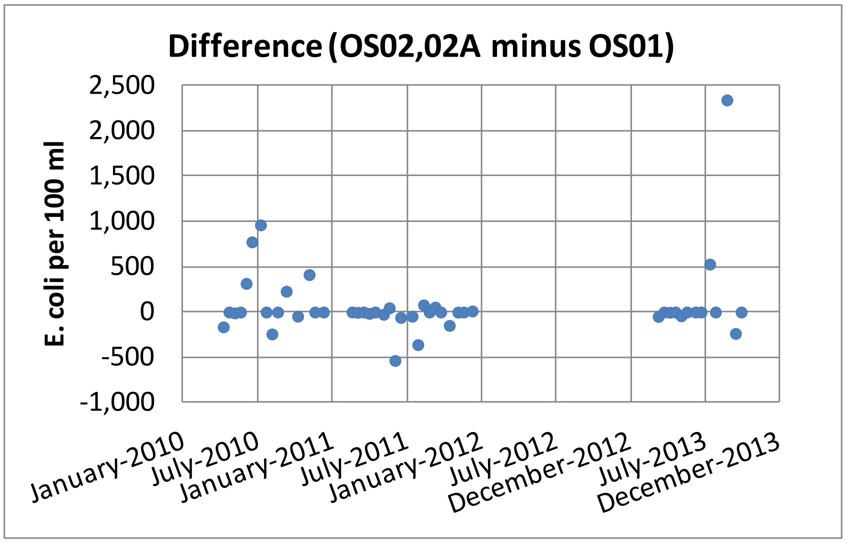
- The plant shutdown has not improved (reduced) E. coli levels downstream. E. coli levels downstream were substantially higher than upstream levels on 5 sampling days during 2011-2012 and on 2 sampling days during 2013.
- Shutting down the plant has significantly reduced nutrient (nitrate, ortho-phosphate, and ammonia) levels downstream. Nutrient levels are uniformly low upstream of the plant throughout the 2011-2013 data period.
- During 2011-2012, nutrient levels below the plant spiked in summer months when the seasonal facilities generating the wastewater were most active. In 2013, nutrient levels downstream have remained uniformly low throughout the summer months.

[8] The sewage has been rerouted to a more advanced sewage treatment plant operated by the Stoney Creek Sanitary District, which discharges downstream of this area.

Trends in Contaminant Levels Downstream minus Upstream

Figure 4-1 shows the differences in E. coli levels for matched pairs of samples (sample time and day) between the upstream site (OS01) and the downstream site (OS02/02A). A positive value indicates that the E. coli level increased in the segment where the Orkney Springs wastewater plant discharge was located. The E. coli difference does not systematically increase during summer months when the treatment plant would be most active, and there is no discernible change between the period when the Orkney Springs plant was in operation (2010/2011) and when it was not (2013). Average E. coli levels are consistently higher downstream of the treatment plant, but the data suggest that sources other than the treatment plant are responsible.

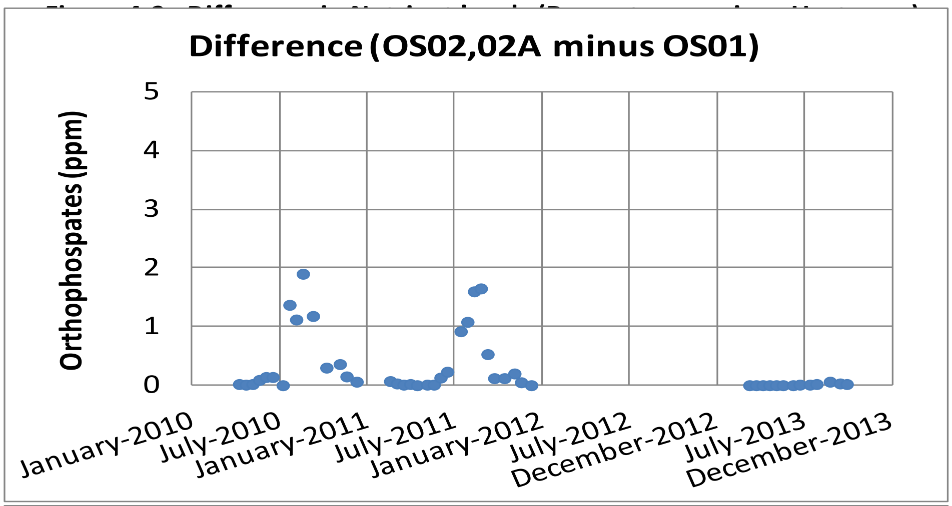
Figure 4-1: Difference in E. coli levels (Downstream minus Upstream)

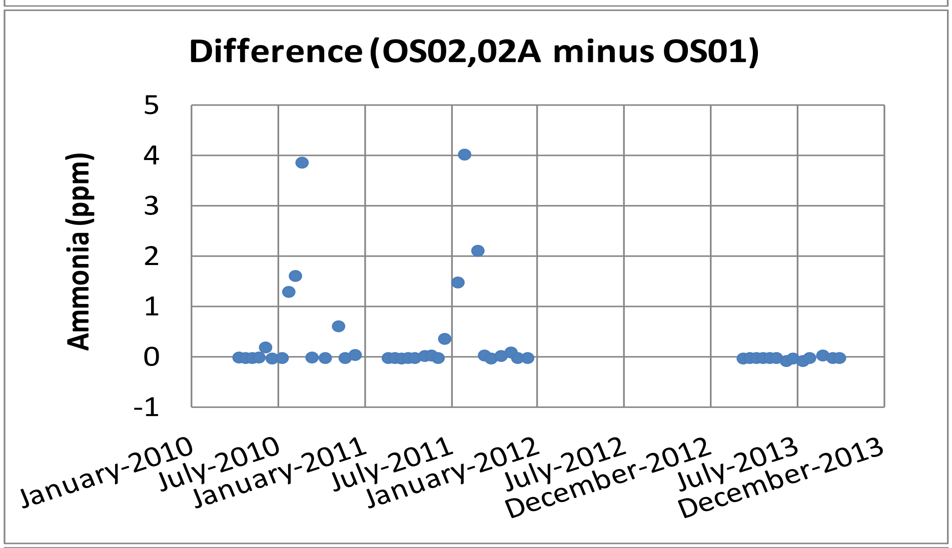


The same comparison for nutrients is very different. Figure 4-2 shows that the nutrient loading was much higher downstream when the Orkney Springs wastewater plant was operating in summer months. After the Orkney Springs wastewater discharge was eliminated, there is no discernible difference between the upstream and downstream readings. This indicates that the Orkney Springs wastewater discharge had been a significant source of nutrients.

4.5 Impact of Rain Events

Water quality sampling at regular intervals was suspended during 2012 to reserve funds for sampling after the Orkney Springs sewage treatment plant was shut down. In its place, limited sampling was done to address Lake Laura E. coli levels during rain events. Rain event sampling occurred five times in 2012 and was repeated during one rain event in 2013. The resulting data set covering six rain events is summarized in Table 4-7 at the end of this section.


Difference (OS02,02A minus OS01)
Orthophospates (ppm)
5
4
3
2
1
0
January-2010
July-2010
January-2011
July-2011
January-2012
July-2012
December-2012
July-2013
December-2013


Difference (OS02,02A minus OS01)
Ammonia (ppm)
5
4
3
2
1
0
-1
January-2010
July-2010
January-2011
July-2011
January-2012
July-2012
December-2012
July-2013
December-2013

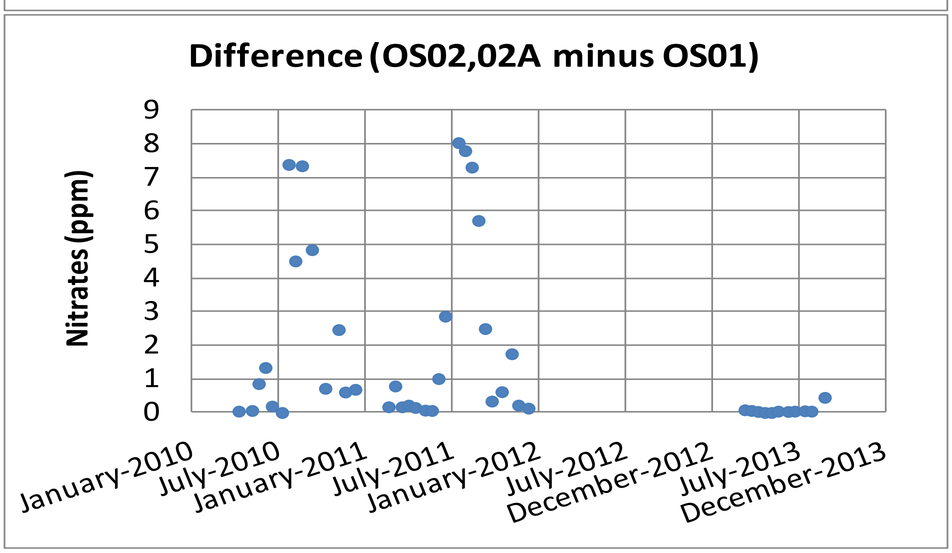

Difference (OS02,02A minus OS01)
Nitrates (ppm)
9
8
7
6
5
4
3
2
1
0
January-2010
July-2010
January-2011
July-2011
January-2012
July-2012
December-2012
July-2013
December-2013

Figure 4-3 shows the E. coli levels in Lake Laura during the rain events in comparison to the 2011-2013 average levels determined through the periodic interval sampling. Individual rain events can greatly elevate E. coli levels in the lake, although our data do not indicate that every rain event elevates the levels above the long-term average observed in the interval sampling (shown in red at the right). This may be because of the timing of our sampling.

The impact of rain events also tends to be location-specific:

- The LL01D measurements are deep samples taken 5 meters below the surface at a location between the coves. At this depth, only the 9/19/2012 rain elevated E. coli above the long-term average while the other four events did not cause elevated levels.
- The LL01S measurements are taken at the same location as LL01D, but at the usual depth of 1 meter below the surface. At this depth, four of the five rain events in 2012 had elevated E. coli above the long-term average.
- At LL02 (in the middle of the lake, also at 1 meter below the surface), E. coli levels were above the long-term average for three events, below (but close to) the average for two events, and well below the average for one event.

The impact of individual rain events is difficult to predict and will probably depend on a number of factors including the amount of rain, the volume of surface runoff, the time interval since the last rain event, and the location and concentration of E. coli sources such as animal waste on land surfaces. However, with the exception of 5/16/2012, each of the rain events elevated E. coli levels at or near the surface for at least one sampling location in the Lake.

The level of E. coli in Lake Laura is probably affected most strongly by rain. Interval sampling was conducted at regular time intervals during 2010, 2011, and 2013 and that sampling captured contaminant levels during both dry periods and during/after rain events. However, we were not able to analyze the impact of storm runoff quantitatively due to the lack of local rain fall data.[9] However, it appears that the long-term averages are themselves elevated in proportion to the number of rain events that were captured in the interval sampling.

[9] Localized rain events can have a large impact and there is no official rain gauge in close proximity to the lake that can be used to evaluate the impact of rain events in a quantitative manner.

Figure 4-3. Impact of Rain Events on E. coli Levels in Lake Laura

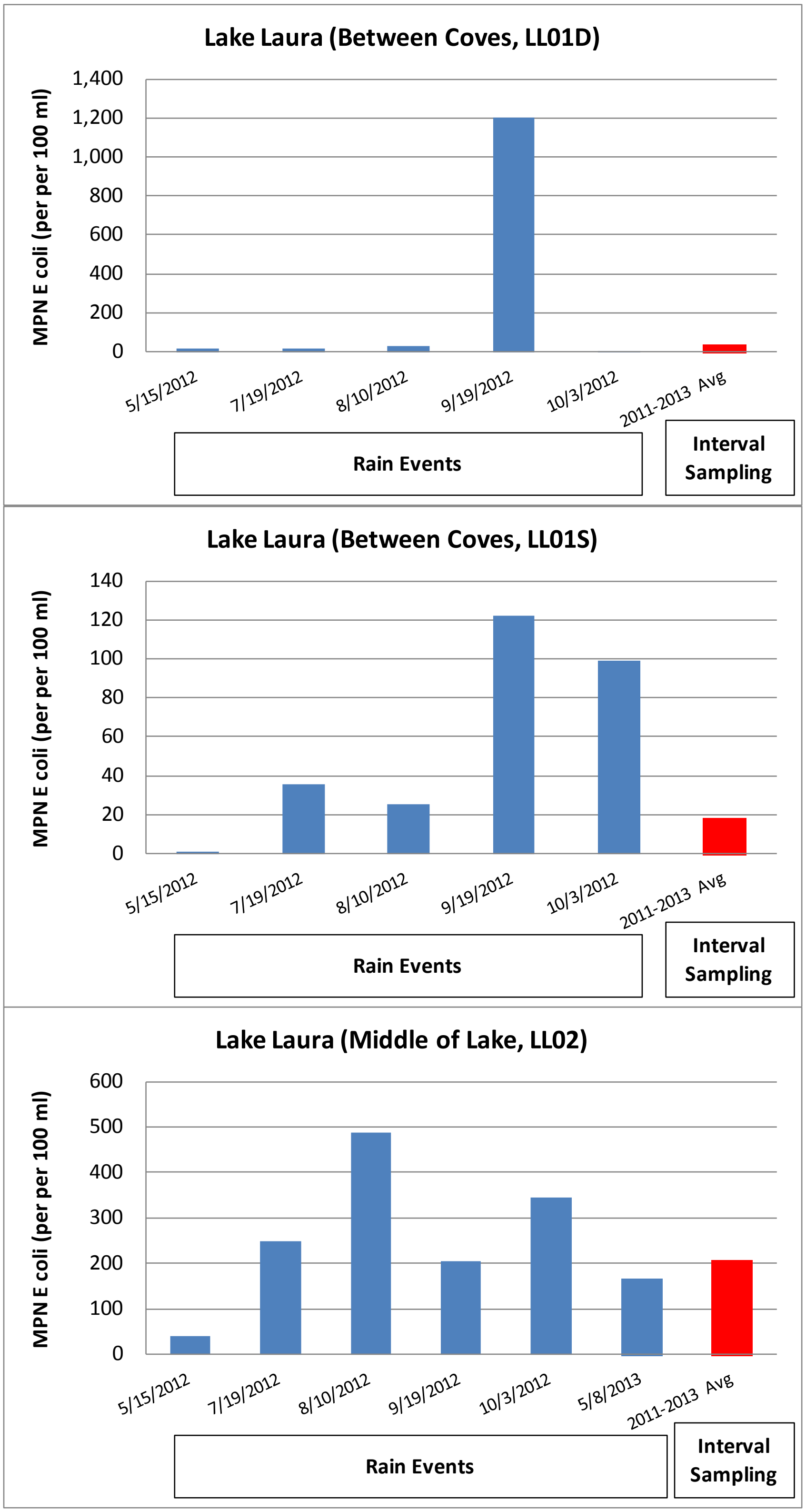
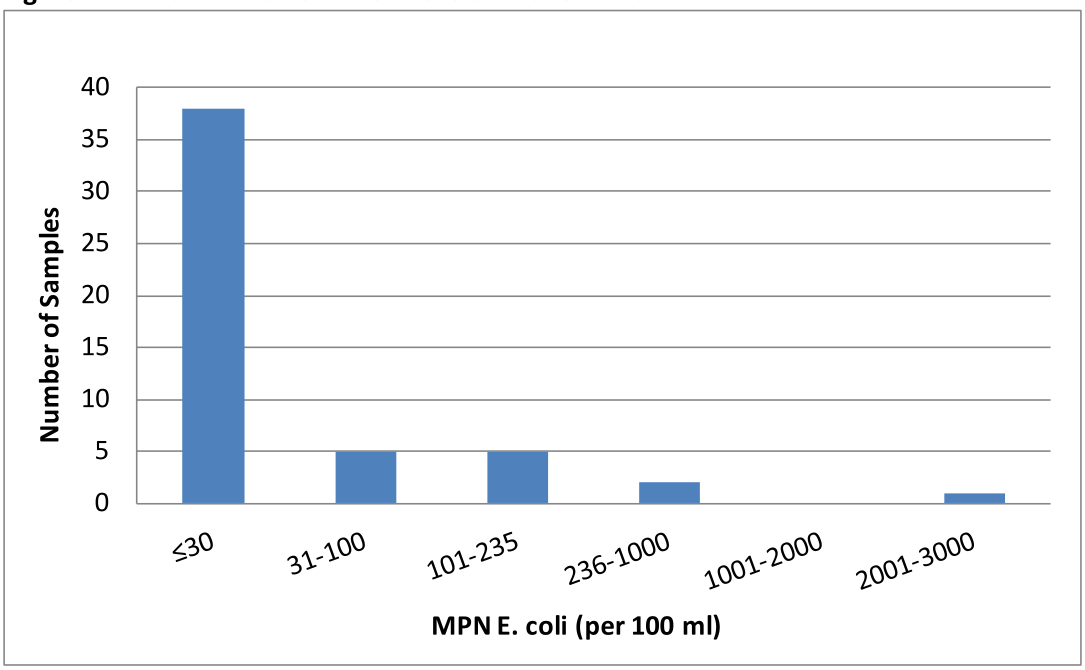


Figure 4-4 shows the distribution of E. coli levels recorded in the lake during the 2011-2013 interval sampling. For 75 percent of the samples, measured E. coli levels were less than or equal to 30 MPN[10] per 100 ml. For 10 percent of samples, E. coli levels were between 31 and 100 MPN per ml and levels were between 101 and 235 MPN per 100 ml for another 10 percent. For 6 percent of samples, E. coli levels were above the maximum standard of 235 MPN per 100 ml level for fresh water. Thus, E. coli levels in Lake Laura are low most of the time, but become elevated on an episodic basis. These episodes are most likely rain events in which runoff carries E. coli into the lake.

Based on these data, one can reasonably assume that E. coli levels will be elevated at one or more locations in the lake after rain events. The elevation is "temporary" but we have no time series data to show the rise and fall in E. coli over time that results from a rain event. However, we can note that when we first observed a high E. coli level in the lake in 2011, we re-sampled ten days later and found the E. coli levels to be much lower.

Figure 4-4. Distribution of E. coli Levels in Lake Laura



[10] As noted earlier, the laboratory method used in this study provides E. coli results as the Most Probably Number (MPN) of colony forming units in the sample. It is appropriate to compare MPN to the standard, which is expressed in colony forming units, because the MPN is the most probably count of colonies in the sample.

Table 4-7: Rain Event Dataset					
Site ID	Date	Date Collected	Time Collected	Stream T(C)	MPN E. coli per 100 ml
LL01D	5/16/2012	5/15/2012	10:20	17.0	16.9
LL01S	5/16/2012	5/15/2012	10:30	17.0	1.0
LL02	5/16/2012	5/15/2012	10:00	16.0	38.9
LL01D	7/20/2012	7/19/2012	09:20	24.0	16.0
LL01S	7/20/2012	7/19/2012	09:15	26.0	35.9
LL02	7/20/2012	7/19/2012	09:00	26.0	248.1
LL01D	8/11/2012	8/10/2012	09:15	25.0	27.5
LL01S	8/11/2012	8/10/2012	09:30	25.0	25.3
LL02	8/11/2012	8/10/2012	09:00	25.0	488.4
LL01D	9/20/2012	9/19/2012	09:10	18.0	1,203.3
LL01S	9/20/2012	9/19/2012	09:00	18.0	122.3
LL02	9/20/2012	9/19/2012	09:30	18.0	204.6
LL01D	10/4/2012	10/3/2012	09:50	17.0	6.3
LL01S	10/4/2012	10/3/2012	09:40	17.0	99.0
LL02	10/4/2012	10/3/2012	09:15	17.0	344.8
LL02	5/9/2013	5/8/2013	09:50	14.0	165.8

Appendix A

Supporting Tables: Water Quality Data for Periods Before (2010-2011) and After (2013) Shutdown of the Orkney Springs Wastewater Treatment Plant

Table A-1: Summary of Contaminant Levels on Orkney Springs Tributary (2010, 2011 Data)

Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

	OS01	OS02	OS03	OS04	OS05	Orkney Springs
E. coli						
Samples (N)	24	24	21	2	2	73
Maximum	440	1,733	1,733	33	488	1,733
Average	209	260	209	21	275	222
Minimum	2	1	2	11	62	1
Nitrates						
Samples (N)	33	34	32	2	2	103
Maximum	0.36	8.24	7.87	0.02	0.08	8.24
Average	0.17	2.35	1.74	0.015	0.065	1.38
Minimum	0.02	0.08	0.01	0.01	0.05	0.01
Orthophosphates						
Samples (N)	33	34	30	2	2	101
Maximum	0.01	1.91	0.56	0.01	0.01	1.91
Average	0.01	0.43	0.11	0.01	0.01	0.18
Minimum	0.00	0.01	0.01	0.01	0.01	0.00
Ammonia						
Samples (N)	33	34	32	2	2	103
Maximum	0.03	5.16	0.15	0.12	0.01	5.16
Average	0.012	0.64	0.02	0.07	0.01	0.22
Minimum	0.01	0.01	0.01	0.02	0.01	0.01
Turbidity						
Samples (N)	27	28	26	1	1	83
Maximum	18	17	15	39	4.5	39
Average	7	6	5.4	39	4.5	6
Minimum	2	1	<1	39	4.5	<1

Supporting Tables

Table A-2: Summary of Contaminant Levels on Stoney Creek (2010, 2011 Data)

Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

	STY03	STY01	Stoney Creek Above Lake	Stoney Creek Below Dam
E. coli				
Samples (N)	11	24	35	23
Maximum	387	613	613	613
Average	135	93	106	40
Minimum	20	10	10	1
Nitrates				
Samples (N)	16	34	50	34
Maximum	0.26	1.31	1.31	0.46
Average	0.15	0.22	0.194	0.08
Minimum	0.05	0.01	0.01	0.00
Orthophosphates				
Samples (N)	16	34	50	34
Maximum	0.02	0.18	0.18	0.02
Average	0.011	0.02	0.02	0.01
Minimum	0.01	0.00	0.00	0.00
Ammonia				
Samples (N)	16	34	50	34
Maximum	0.01	0.10	0.10	0.78
Average	0.01	0.016	0.014	0.16
Minimum	0.01	0.01	0.01	0.01
Turbidity				
Samples (N)	13	28	41	28
Maximum	10	13	13	35
Average	3	3	3	11
Minimum	1	<1	<1	1.4

Supporting Tables

Table A-3: Summary of Contaminant Levels in Lake Laura (2010, 2011 Data)

Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

	LL01D	LL01S	LL02	Lake Laura
E. coli				
Samples (N)	13	16	15	44
Maximum	201	201	145	201
Average	33	18	33	27
Minimum	1	1	2	1
Nitrates				
Samples (N)	24	23	23	70
Maximum	0.41	0.41	0.41	0.41
Average	0.11	0.08	0.10	0.09
Minimum	0.01	0.01	0.01	0.01
Orthophosphates				
Samples (N)	24	23	23	70
Maximum	0.02	0.01	0.01	0.02
Average	0.01	0.01	0.01	0.01
Minimum	0.00	0.00	0.00	0.00
Ammonia				
Samples (N)	24	23	23	70
Maximum	0.52	0.10	0.10	0.52
Average	0.05	0.02	0.03	0.04
Minimum	0.01	0.01	0.01	0.01
Turbidity				
Samples (N)	20	19	19	58
Maximum	115	22	34	115
Average	17	5	8	10
Minimum	2.4	<1	2	<1

Supporting Tables

Table A-4: Summary of Contaminant Levels on Orkney Springs Tributary (2013 Data)

Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

	OS01	OS02	OS03	OS04	OS05	Orkney Springs
E. coli						
Samples (N)	6	7				13
Maximum	1,203	2,420				2,420
Average	317	640				491
Minimum	66	18				18
Nitrates						
Samples (N)	12	12				24
Maximum	0.27	0.46				0.46
Average	0.17	0.21				0.19
Minimum	0.01	0.08				0.01
Orthophosphates						
Samples (N)	12	12				24
Maximum	0.20	0.07		NO DATA		0.20
Average	0.03	0.02				0.02
Minimum	0.01	0.01				0.01
Ammonia						
Samples (N)	12	12				24
Maximum	0.22	0.08				0.22
Average	0.04	0.02				0.03
Minimum	0.01	0.01				0.01
Turbidity						
Samples (N)	9	11				20
Maximum	19	200				200
Average	10	24				18
Minimum	3	<1				<1

Supporting Tables

Table A-5: Summary of Contaminant Levels on Stoney Creek (2013 Data)

Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

	STY03	STY01	Stoney Creek Above Lake	Stoney Creek Below Dam
E. coli				
Samples (N)	7	6	13	NO DATA
Maximum	2,420	2,420	2,420	
Average	501	857	666	
Minimum	30	24	24	
Nitrates				
Samples (N)	12	10	22	
Maximum	0.29	0.43	0.43	
Average	0.15	0.20	0.17	
Minimum	0.07	0.12	0.07	
Orthophosphates				
Samples (N)	12	10	22	
Maximum	0.07	0.08	0.08	
Average	0.02	0.02	0.02	
Minimum	0.01	0.01	0.01	
Ammonia				
Samples (N)	12	10	22	
Maximum	0.015	0.04	0.04	
Average	0.010	0.014	0.012	
Minimum	0.010	0.01	0.01	
Turbidity				
Samples (N)	10	9	19	
Maximum	17	205	205	
Average	6	28	16	
Minimum	<1	1	<1	

Supporting Tables

Table A-6: Summary of Contaminant Levels in Lake Laura (2013 Data)

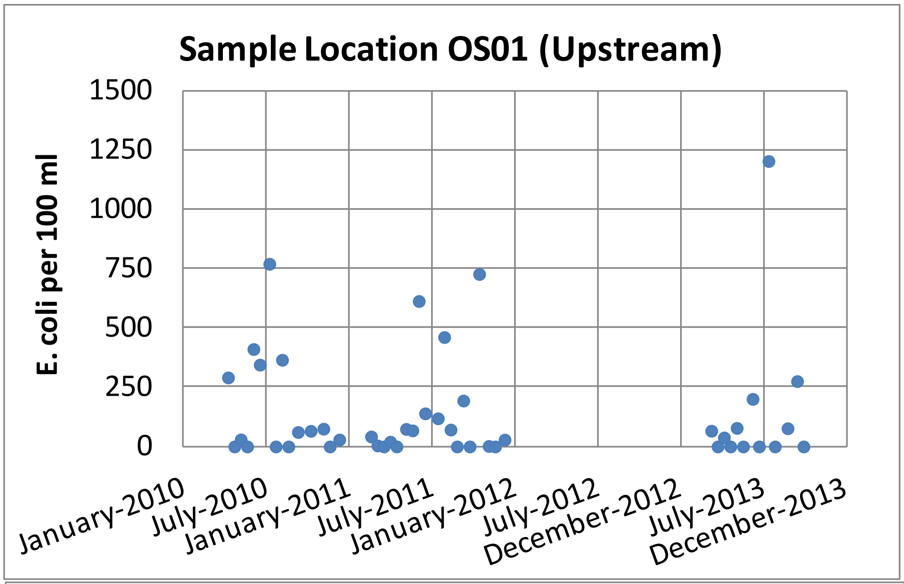
Yellow codes Highest Average Concentration; Rose codes Highest Maximum Concentration.

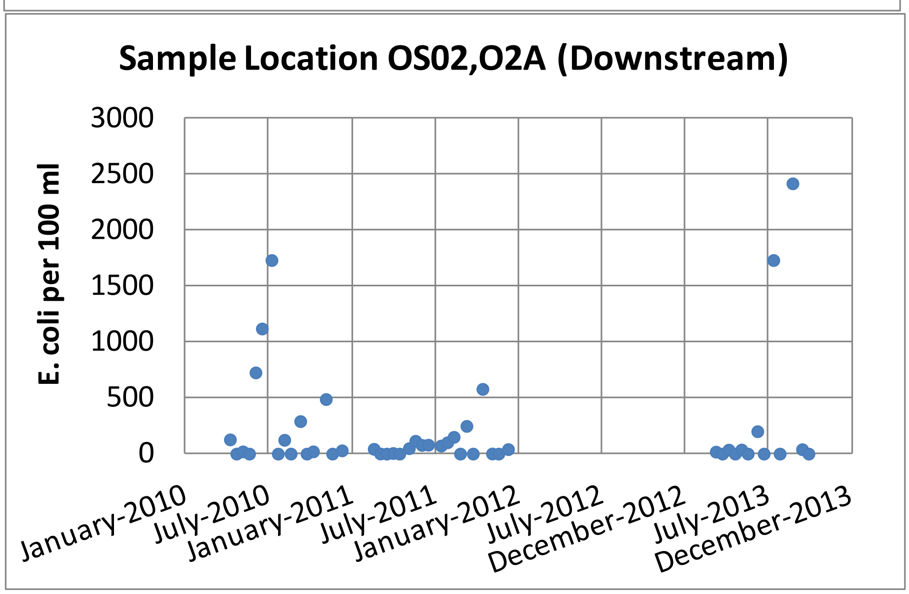
	LL01D	LL01S	LL02	Lake Laura
E. coli				
Samples (N)	NO DATA		7	7
Maximum			2,420	2,420
Average			580	580
Minimum			2	2
Nitrates				
Samples (N)			12	12
Maximum			0.36	0.36
Average			0.10	0.10
Minimum			0.01	0.01
Orthophosphates				
Samples (N)			12	12
Maximum			0.21	0.21
Average			0.03	0.03
Minimum			0.01	0.01
Ammonia				
Samples (N)			12	12
Maximum			0.12	0.12
Average			0.03	0.03
Minimum			0.01	0.01
Turbidity				
Samples (N)			4	4
Maximum			116	116
Average			32	32
Minimum			3	3

Appendix B

Supporting Graphs: Water Quality Data for Sampling Points Above and Below the Discharge Point for the Orkney Springs Wastewater Treatment Plant.

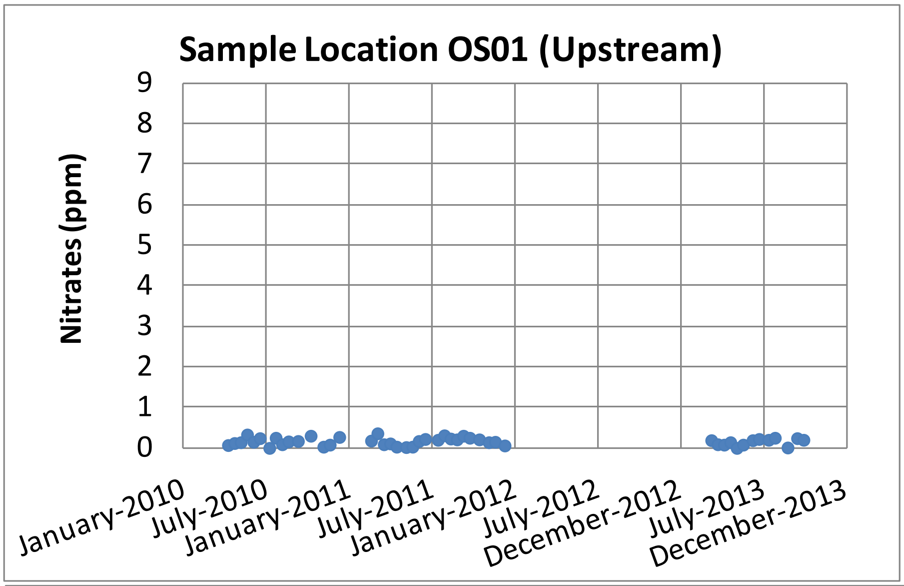
E. coli

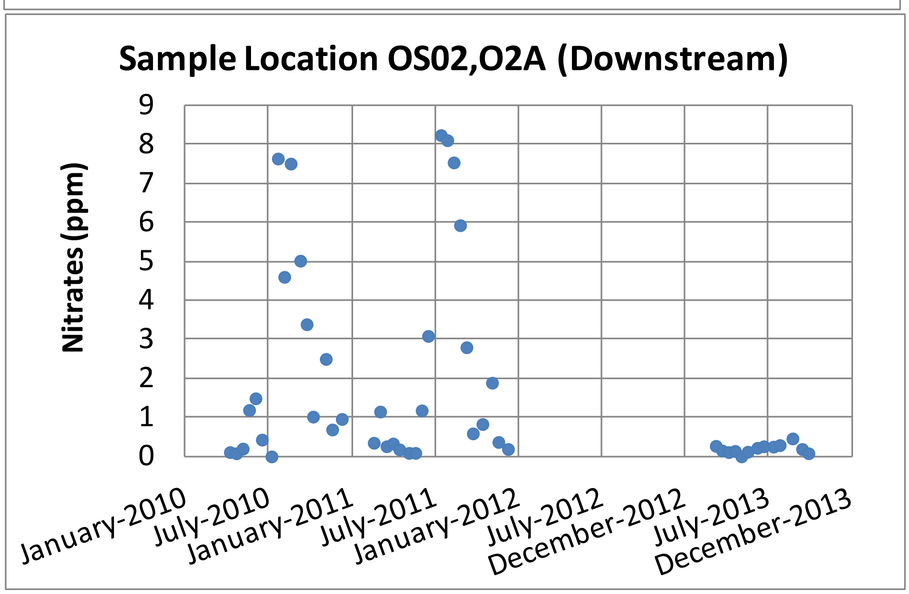




Supporting Graphs

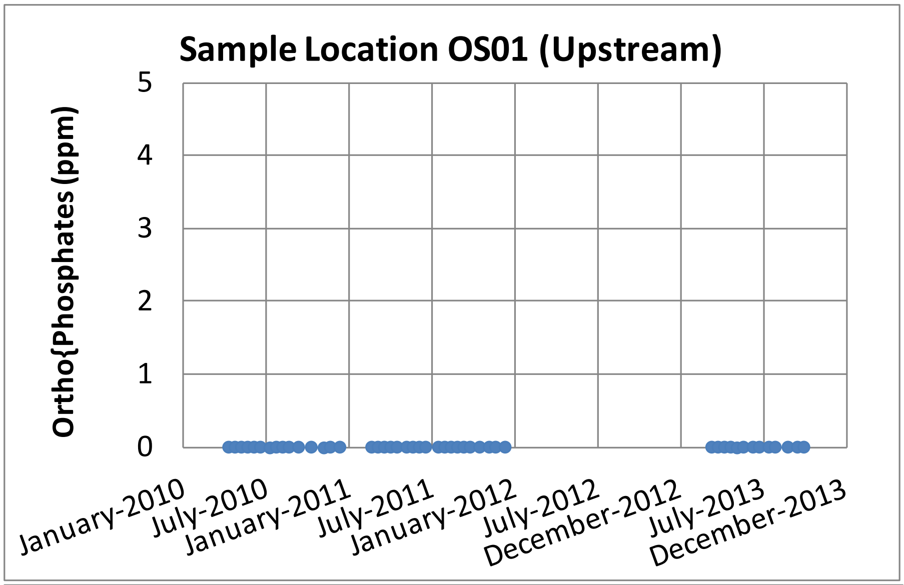
Nitrates

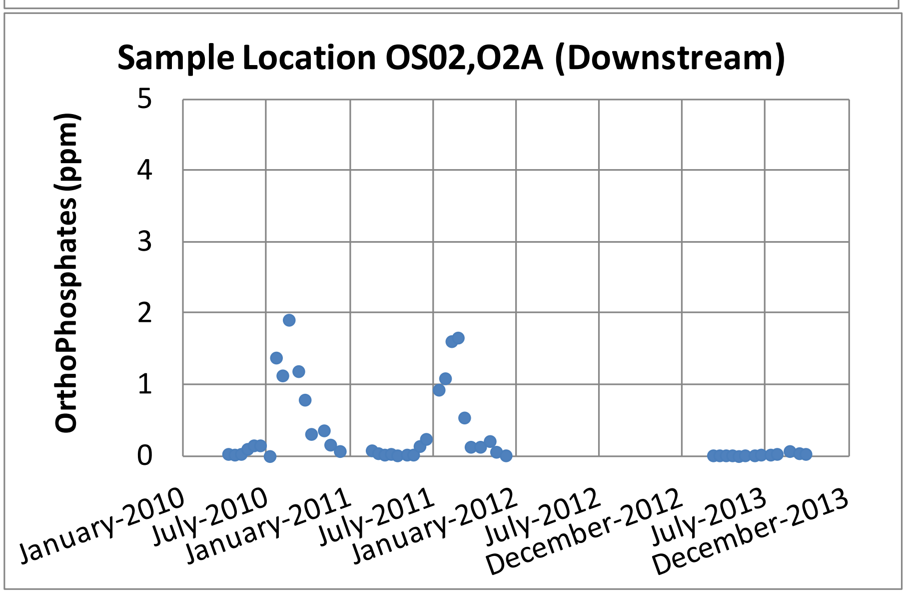




Supporting Graphs

Ortho-Phosphates





Supporting Graphs

Ammonia