Hamilton Conservation Authority
Healthy Streams...Healthy Communities!

Watershed Planning & Engineering
March 31, 2016

2015 TRIBUTARY MONITORING FOR COOTES PARADISE

To support the Hamilton Harbour Remedial Action Plan

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Background

In spring of 2014, the Hamilton Conservation Authority (HCA) and the Royal Botanical Gardens (RBG) began discussions for a plan to divide and expand a monitoring program aimed at understanding water quality contributions from creeks flowing into Cootes Paradise Marsh and ultimately, Hamilton Harbour. With the assistance of the Ministry Of Environment and Climate Change and the City of Hamilton, this program aims to explore water quality conditions in the sub-watersheds of Ancaster Creek, Sulphur Creek, Borers Creek, Lower Spencer Creek and Chedoke Creek; their drainage areas can be seen on Figure 1. It was determined that the HCA would assume sampling responsibilities for three existing creek sampling sites within the Cootes Paradise study area previously sampled by RBG staff. These sites are known as CP-7, CP-11 and CP-18.1 (See Figure 2) and their respective locations are on Spencer Creek, Chedoke Creek and Borers Creek upstream of the locations where they drain into the Cootes Paradise Marsh. The monitoring program was expanded to include four new sites to help characterize the water quality contributions coming from the Ancaster Creek sub-watershed (AC-1, AC-2, AC-3 and AC-4), which has relatively little water quality and flow data near the lower reaches of the sub-watershed boundaries.

The new expanded monitoring program began on May 6, 2014 and the annual sampling period ended on September 23, 2014. With the addition of the four sampling locations on Ancaster Creek there are now a total of seven surface water sampling locations.

Changes to Water Quality Monitoring Program in 2015

In 2015 the sampling period was lengthened to begin in April and end in November. In addition to the extended sampling period in 2015, storm event samples were taken at site AC-1 using an ISCO automated composite sampler. Once the targeted storm event was captured and sampled into the 24 bottle drum of the ISCO, a composite sample was made using a level weighted average to calculate volumes from each bottle. Thus giving a snapshot of the storm event, from beginning to end, in a single sample submission. At various points throughout the sample season, flows were measured at site AC-1 using a Marsh McBirney flow meter to establish a rating curve (See Figure 3), and estimate loadings coming from Ancaster Creek before the confluence with Spencer Creek.

It is beneficial to undertake an enhanced surface water monitoring program on lower Ancaster Creek to help identify important contributors and sources of nutrients and sediment as well as provide information to support where mitigation activities can be best applied to benefit the overall water quality within Cootes Paradise. Currently, there is a nutrient loadings model being developed for Cootes Paradise by the University of Toronto. This model could benefit greatly by utilizing the data from non-defined inputs being collected by this monitoring program and the HCA would welcome the opportunity to share this information to help better the understanding of the inputs into Cootes Paradise. Overall, several years of measurements will be required to establish trends and determine baseline and wet event conditions. This program covers the 2014 and 2015 sample seasons but is planned to continue for the next 3-5 years.

Figure 1: Sub-watersheds within the Hamilton Conservation Authority watershed

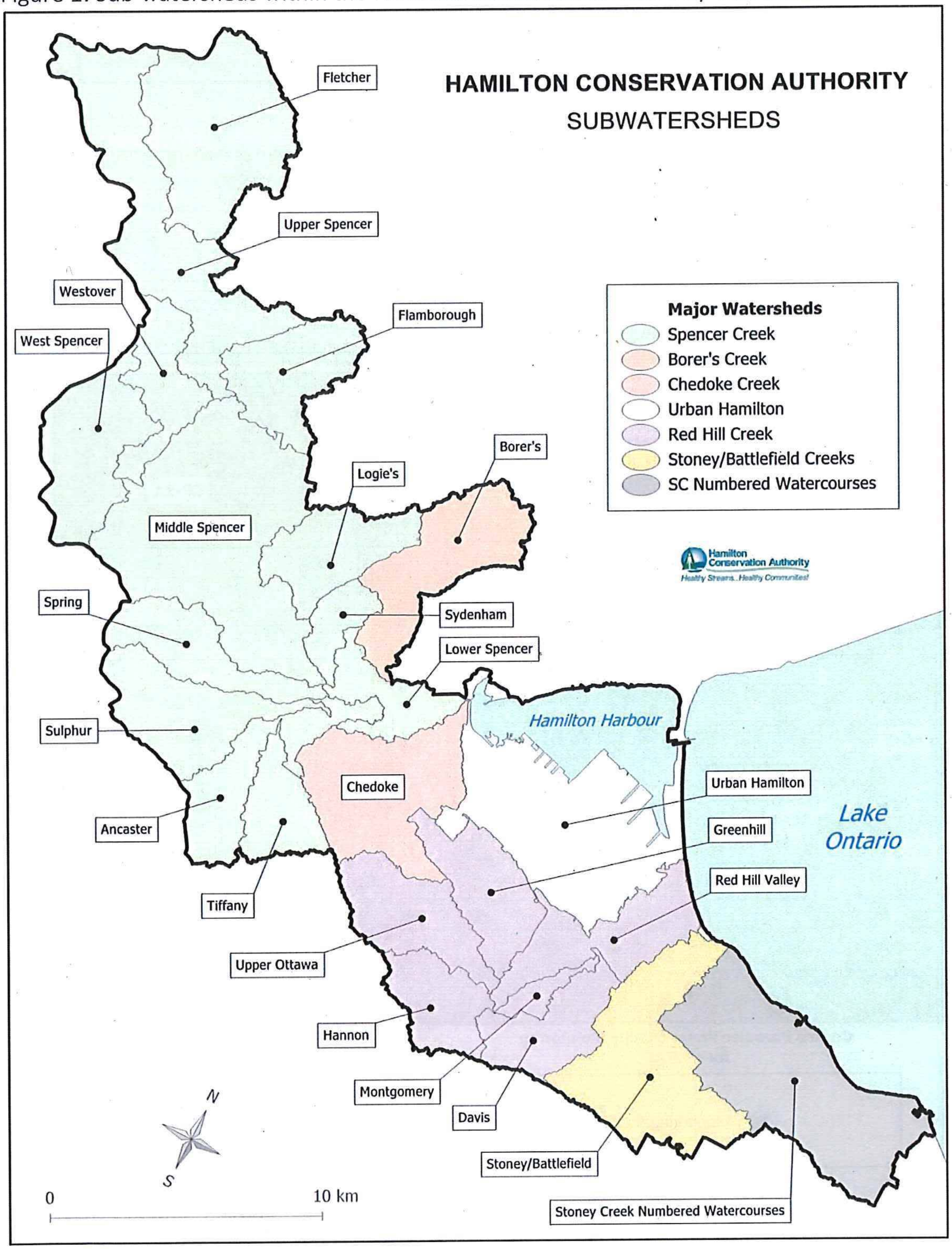


Figure 2: Study area and sample locations.

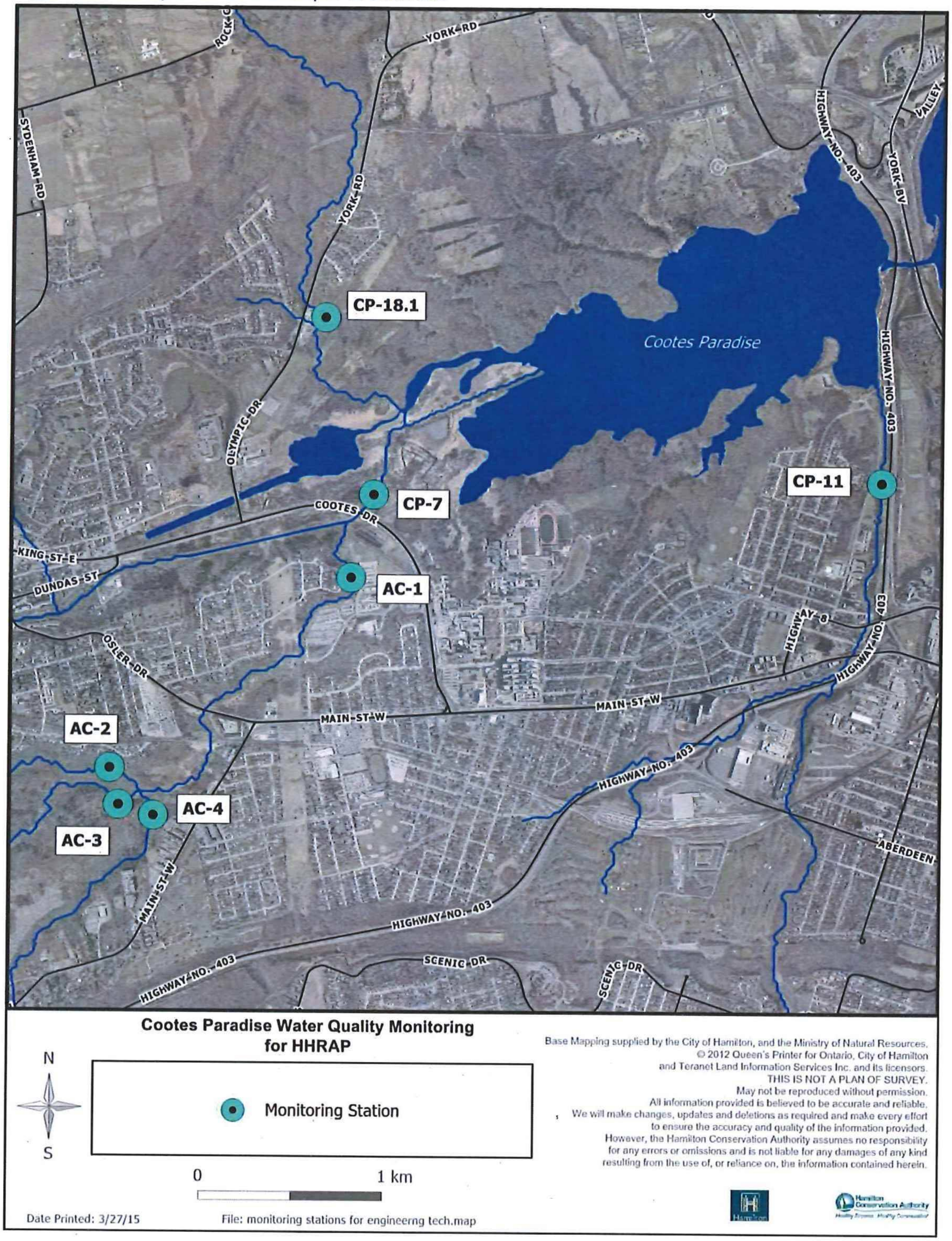


Table 1: Sampling Stations Identified by Location and Sub-watershed

Station	Location	Sub-watershed
CP-7	Downstream of Cootes Drive	Lower Spencer Creek
CP-11	Downstream of King Street	Chedoke Creek
CP-18.1	Downstream of York Road	Borers Creek
AC-1*	Upstream of Spencer Creek	Ancaster Creek
AC-2	Upstream of confluence with Ancaster Creek	Sulphur Creek
AC-3	Upstream of confluence with Sulphur Creek	Ancaster Creek
AC-4	Downstream of Wilson Street	Ancaster Creek

*Indicates location where storm event sampling is taking place

Methodology

Water quality grab samples were taken during daylight hours with same day drop off for analysis at the City of Hamilton Regional Environmental Lab. Sampling frequency was every other week to coincide with RBG sampling programs, see Table 2 for sampling dates. Each station was sampled 17 times throughout the 2015 sampling season. Measurements of temperature, pH, conductivity, turbidity, and dissolved oxygen were measured on site by HCA staff for each sample site using a YSI 6600. Chlorophyll-a is measured in an accredited laboratory once every three years (samples in 2013 were analyzed for Chlorophyll-a, next scheduled sampling is 2016). Sampling events were classified as wet or dry by viewing and confirming rain data recorded at Environment Canada precipitation monitoring station at Hamilton Airport Climate ID 6153193; if 4mm of rain occurred in the previous 24 hours it was considered a wet event. Wet and dry events are classified in Table 2. A visual inspection of storm water outfalls in the area was also completed if storm event conditions were suspected.

Table 2: Rainfall totals for corresponding sample dates

Sampling Date	Previous 24 Hour Rainfall (mm)	Classification
April 9, 2015	12	Wet
April 20, 2015	19.2	Wet
May 4, 2015	0	Dry
May 19, 2015	0	Dry
June 1, 2015	52.2	Wet
June 15, 2015	20.2	Wet
June 30, 2015	0	Dry
July 13, 2015	0	Dry
July 27, 2015	0	Dry
August 10, 2015	0	Dry
August 24, 2015	0	Dry
September 8, 2015	7.8	Wet
September 22, 2015	0	Dry
October 15, 2015	0.4	Dry
October 22, 2015	2.8	Dry
November 3, 2015	0	Dry
November 18, 2015	0	Dry

Storm event samples were targeted at sample site AC-1 in 2015. An ISCO automated sampler was put in place under a bridge that overpasses Ancaster Creek in fall of 2014 (at site AC-1). Level-weighted samples were made using water level data taken on-site. During spring melt, there were several attempts to capture storm events. However due to suction issues along the intake line, there was not a sufficient amount of surface water to make a composite sample. Repairs were made and the ISCO was brought back on-line. Overall, two storm events were sampled. The dates for these events are August 21 and October 28. Rainfall amounts for the storm events can be seen on Table 3. Flows were measured five times throughout the sampling period, these dates can be seen on Table 4 along with the total discharge amounts in cubic meters per second.

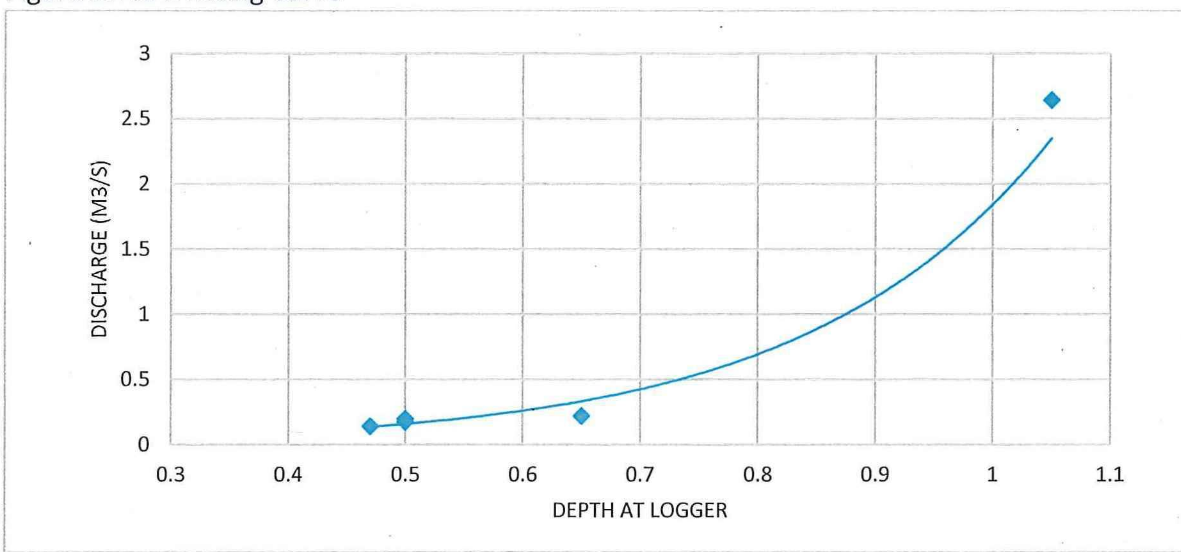
Table 3: Rainfall totals for storm event sample dates

Date	Previous 24 Hour Rainfall (mm)
August 21, 2015	9.2
October 28, 2015	40.4

Table 4: Flow measuring dates

Date	Discharge (m^3/s)
June 9, 2015	2.64
July 8, 2015	0.218
July 22, 2015	0.173
August 11, 2015	0.198
August 18, 2015	0.142

Figure 3: AC-1 Rating Curve



Water Quality Targets/Objectives

Samples were analyzed for the parameters listed in Table 5. Objectives to ensure that water quality is satisfactory for aquatic life were based on Provincial Water Quality Objectives (MOE 1999), federal guidelines outlined by the Canadian Council of Ministers of the Environment (2001) and Cootes – Grindstone Water Quality Targets (RAP office 2012). The target objective is to apply to 14 out of the 17 samples taken in 2014. A description of each parameter is provided below.

Table 5: Water Quality Parameters and their Desired Target/Objective

Parameter	Units	Target/Objective	Reference
Unionized Ammonia	mg/L	0.02 mg/L	HHRAP
Nitrate as N	mg/L	3 mg/L	HHRAP
Nitrite as N	mg/L	0.06 mg/L	CWQG
o-Phosphate as P	mg/L	n/a	
Total Phosphorous	mg/L	0.03 mg/L	PWQO
Total Suspended Solids	mg/L	25 mg/L	HHRAP
Volatile Suspended Solids	mg/L	n/a	
Escherichia coli	CFU/100mL	100 CFU/100mL	PWQO

Total Phosphorous

Total Phosphorous (TP) is commonly found in fertilizers, manure and organic wastes in sewage and industrial effluent. It is an essential nutrient to aquatic life, but in excess can cause eutrophication and algae blooms. Soil erosion is a main contributor of TP in surface waters, as phosphorous particles tend to attach to soil particles.

Unionized Ammonia

Ammonia is the preferred nitrogen containing nutrient for plant growth, yet it can also cause algal blooms and stress to fish in high concentrations. In water, ammonia occurs in two forms; ionized and unionized ammonia. This difference is important to know because NH_3, un-ionized ammonia, is the form more toxic to fish. Both water temperature and pH affect which form of ammonia is predominant at any given time in an aquatic system.

Nitrate

Nitrates are an essential nutrient for regulating plant life but can cause degraded water quality in excess concentrations. The target concentration for nitrates in this study is based on the Canadian Water Quality Guideline (CWQG) of 3.0mg/L. Typically nitrate concentrations tend to be low during base-flow conditions; however runoff from fertilizer, waste water treatment plants and storm sewer outfalls can bring the concentration of nitrates up to and beyond the target for water quality.

Nitrite

For this study, we've adopted the Canadian Water Quality Guideline (CWQG) target of 0.06mg/L as N.

Total Suspended Solids

Targeted concentrations of Total Suspended Solids (TSS) vary depending on the system being monitored. TSS thresholds are established by understanding the underlying background levels of a site which may or may not have clear flow during base-flow conditions. Storm events move sediment downstream and therefore TSS values are expected to be much higher during these events. Since background levels of TSS is unavailable for the majority of the sites sampled, the Hamilton Harbour Remedial Action Plan interim target of 25 mg/L was used as the target for TSS (RAP office 2012). This target is derived from the Canadian Water Quality Guideline (CWQG) for total suspended sediment.

Volatile Suspended Solids

Volatile Suspended Solids represent the organic portion of Total Suspended Solids. There is no current target set for Volatile Suspended Solids for the HHRAP or PWQO's.

Escherichia coli

E.coli is well known to have harmful effects on human health when found in the environment at certain concentrations. There are strict guidelines for E.*coli* targets for drinking and recreational purposes. Since there is little to no background data for the majority of the sites, we will be comparing the geometric mean concentrations from each site to the PWQO of 100CFU/100mL (MOE 1999), the target for recreational purposes.

Results and Discussion

Total Phosphorous

As seen in Table 6, the majority of Total Phosphorous (TP) samples taken in 2015 exceeded the Provincial Water Quality Objective (PWQO) of 0.03 mg/L. Elevated TP values were observed at all sites, indicating TP impairment throughout the watershed. Site CP-11 exceeded the target objective on every sample event, while sites CP-7, CP-18.1 & AC-4 exceeded 53% – 65% of the sample events. Sites AC-2 and AC-3 exceeded only 35% and AC-1 exceeded 47% of the time. As seen on Figure 4, exceedances were strongly related to wet sample events, with only one sample taken during a wet event that tested below the objective. The wet sample events in the spring (April 9th and April 20th) saw the highest TP values at every site. As seen on Figure 5, seasonal average TP values at all locations declined as the seasons advanced.

Site CP-11 at the mouth of Chedoke Creek had the greatest TP impairment throughout the sample period. Sites CP-7 & CP-18.1 exceeded the target in most sample events, yet the mean values throughout the entire period are the lowest. This indicates that although TP impairment is common at these locations, they are less susceptible to higher TP spikes in storm runoff events. Although the AC sample sites had the fewest exceedances (with the exception of AC-4), the mean values for the sampling period were among the highest. This indicates that these locations are susceptible to high increases of TP during storm runoff events. Site AC-4 exceeded the target 65% of sample events, with some of the exceedances coming on dry events. AC-4 has a relatively small drainage area compared to AC-2 and AC-3 that originates about 2.5 kilometers upstream of the sample location and the land use is mostly urban residential.

Observation of 2014 total phosphorous results for sites CP-7, CP-11 & CP-18.1 are relatively consistent with results obtained in 2015 as seen on Table 7, however sites AC-1, AC-2, AC-3 & AC-4 all had noticeable increases in the past year. This may be explained by the extended sampling period. Most of the greatest exceedances came within the early extension of the sample period in April. Also, a greater number of wet sample events were captured in 2015 (5 in 2015 vs. 1 in 2014). Further years of consistent sampling protocol should give a better indication TP levels and concerns at these locations.

Historical records for sites CP-7, CP-11 & CP-18.1 obtained from the Royal Botanical Gardens (RBG) can be seen on Figure 6. Site CP-7 has an overall downward trend, while CP-11 is stable and CP-18.1 seems to be experiencing an upward trend. Site CP-11 is badly impacted by TP since the historical records began in 1999. The last 2 years of sampling has seen a sharp increase in TP values at both CP-7 & CP-18.1, this could be due to the extended sampling period beginning in 2015. Site CP-18.1 has a fairly short historical record, beginning in 2012. More samples taken on a consistent protocol will give better indication of seasonal distribution and annual averages of TP at these locations.

Figure 4: Total phosphorous in 2015

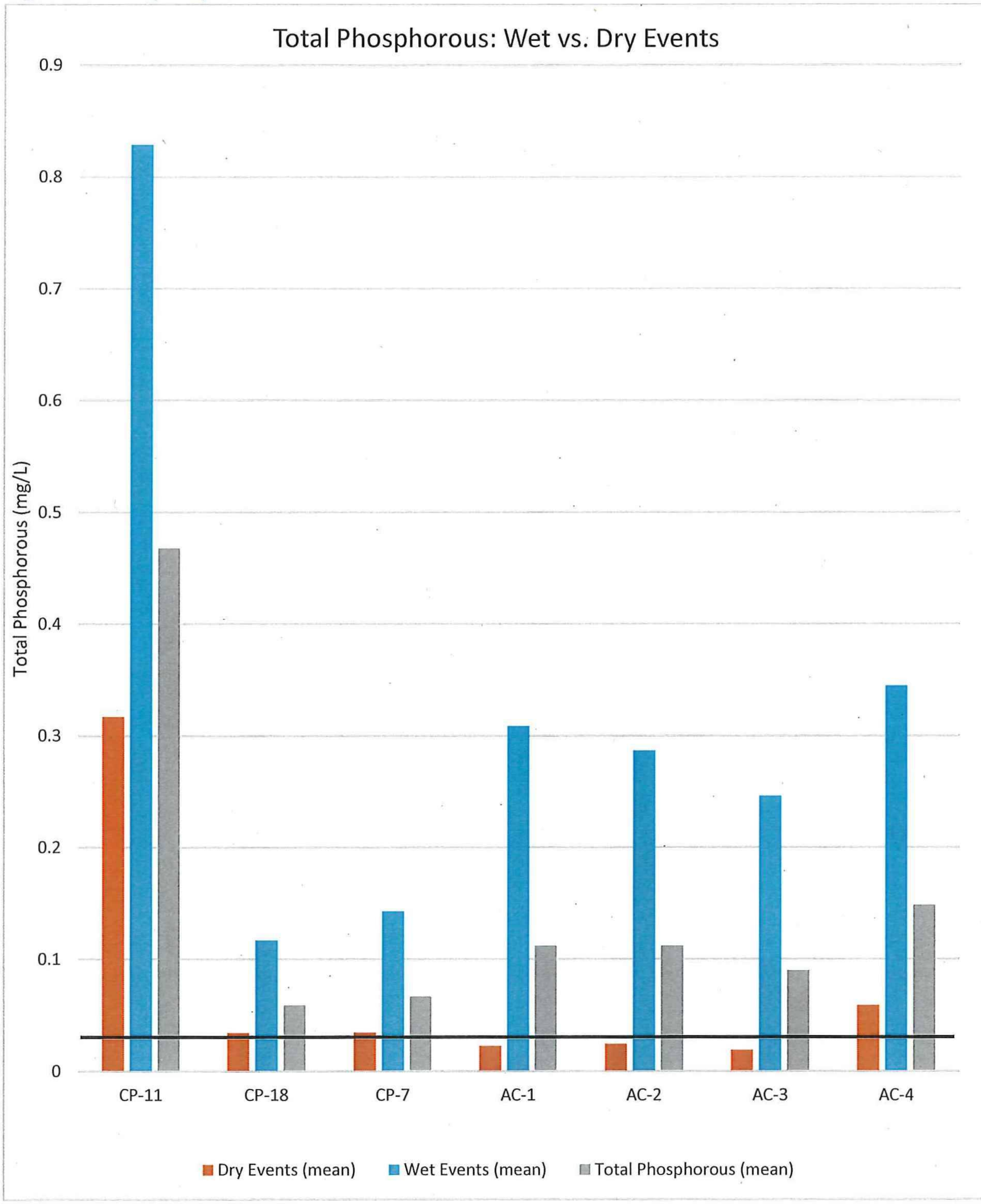


Figure 5: seasonal distribution of TP in 2015 for all stations

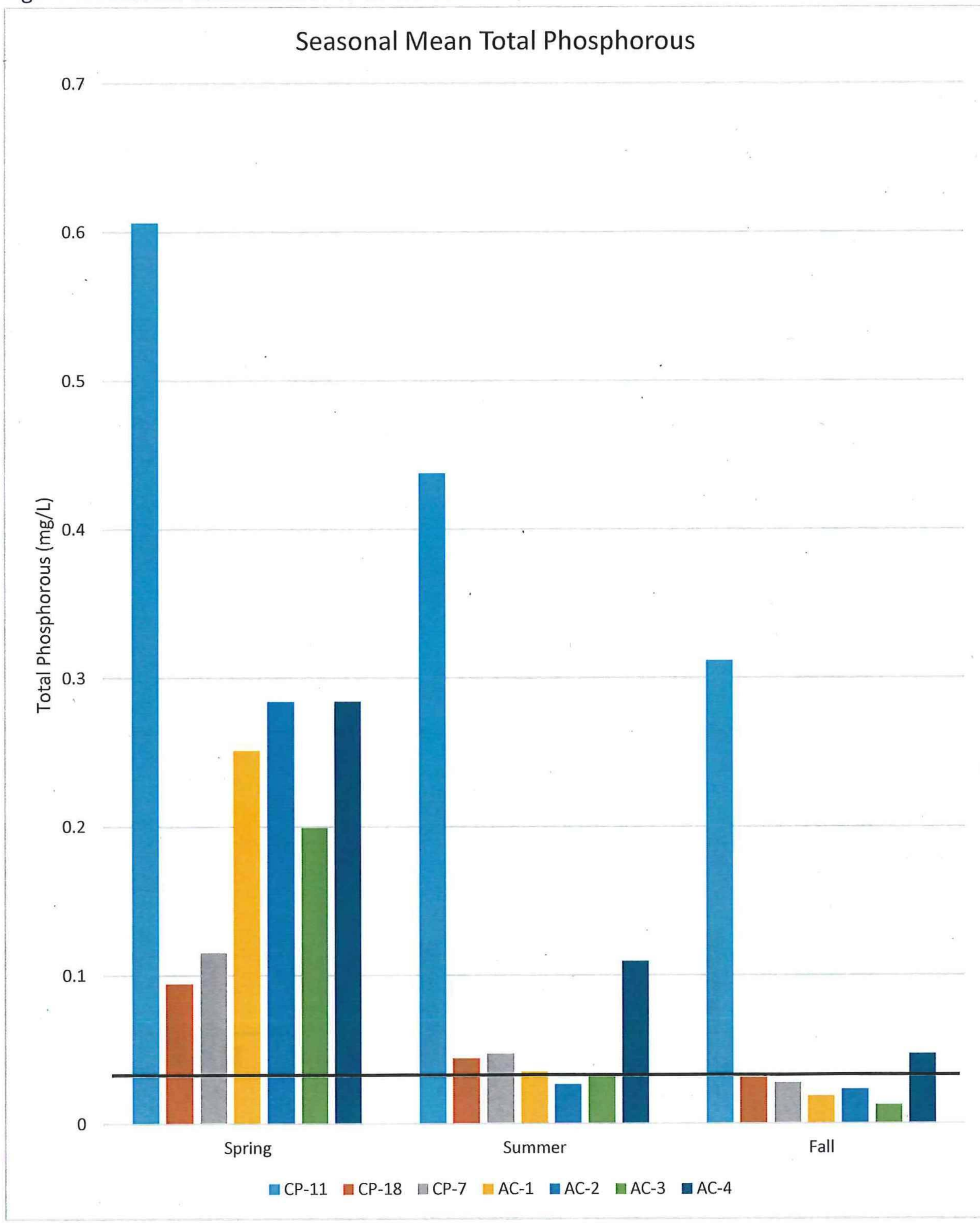
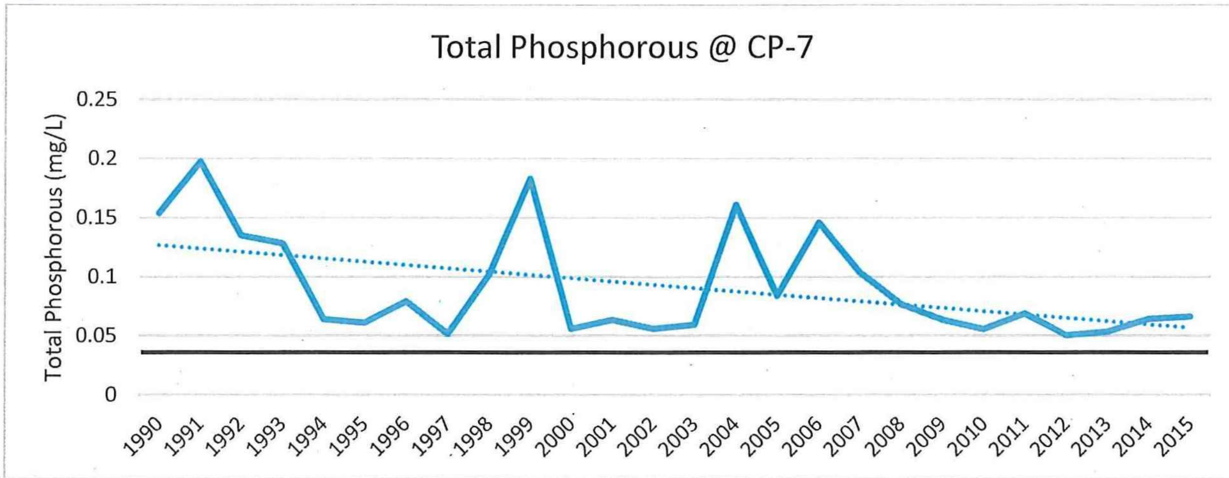
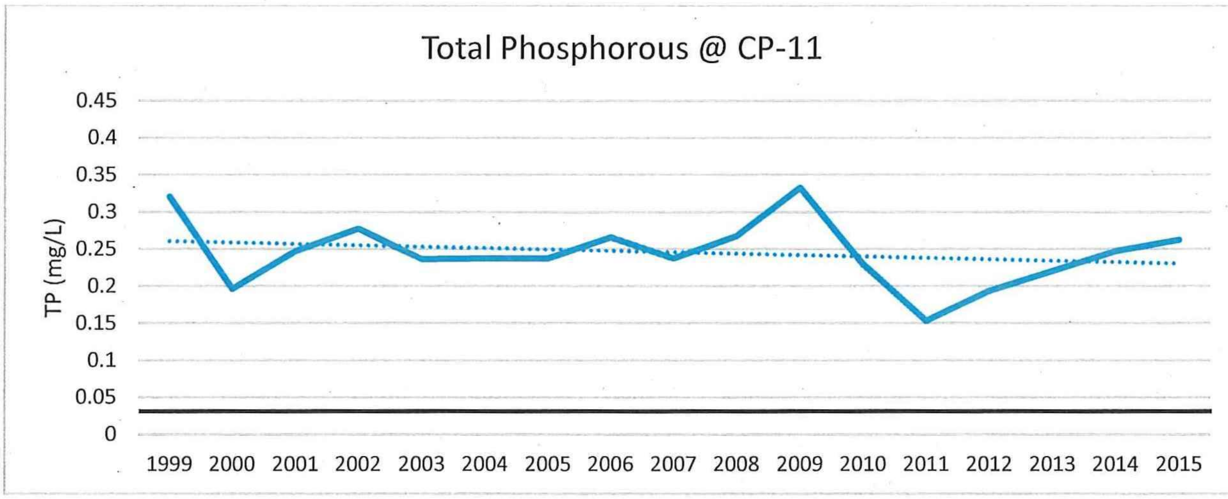


Figure 6: Historical Total Phosphorous at sites CP-7, CP-11 & CP-18.1





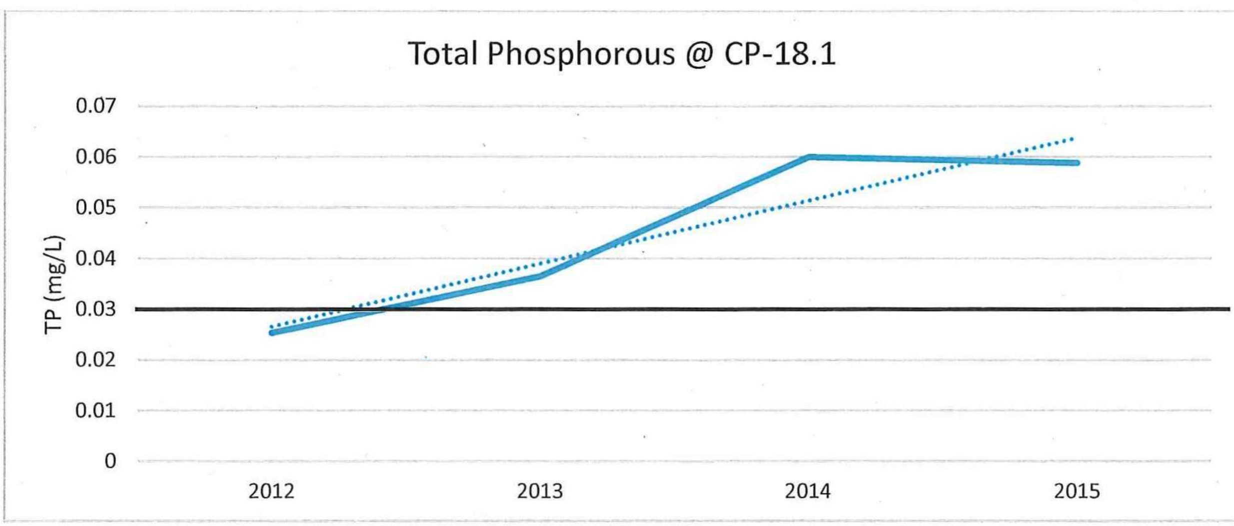


Table 6: Total Phosphorous Values for Stations Sampled in 2015

Date	CP-11	CP-18	CP-7	AC-1	AC-2	AC-3	AC-4	Wet/Dry
4/09/15	1.25	0.108	0.114	0.226	0.325	0.126	0.168	**Wet**
4/20/15	1.06	0.287	0.41	1.1	0.95	0.901	1.1	**Wet**
5/04/15	0.113	0.014	0.017	0.015	0.012	0.024	<0.01	**Dry**
5/19/15	0.207	0.021	0.024	0.017	<0.01	0.013	0.022	**Dry**
6/01/15	0.508	0.057	0.039	0.053	0.059	0.053	0.05	**Wet**
6/15/15	0.501	0.08	0.088	0.097	0.076	0.08	0.082	**Wet**
6/30/15	0.465	0.07	0.094	0.061	0.066	0.045	0.143	**Dry**
7/13/15	0.324	0.039	0.029	0.015	0.018	0.02	0.029	**Dry**
7/27/15	0.475	0.057	0.043	0.019	0.024	0.023	0.174	**Dry**
8/10/15	0.369	0.025	0.021	<0.01	0.025	<0.01	0.027	**Dry**
8/24/15	0.3	0.033	0.056	0.037	0.02	0.015	0.044	**Dry**
9/08/15	0.826	0.054	0.064	0.068	0.024	0.072	0.325	**Wet**
9/22/15	0.306	0.031	0.023	0.011	0.01	0.019	0.024	**Dry**
10/15/15	0.34	0.029	0.025	0.012	0.01	0.011	0.049	**Dry**
10/22/15	0.379	0.04	0.036	0.02	<0.01	0.013	0.082	**Dry**
11/03/15	0.299	0.029	0.029	0.031	0.029	0.016	0.03	**Dry**
11/18/15	0.229	0.027	0.02	0.012	0.031	0.011	0.027	**Dry**
Mean	**0.4677058**	**0.058882**	**0.06658**	**0.11212**	**0.11193**	**0.09012**	**0.1485**	

Table 7: 2014 total phosphorous results (mean)

CP-11	**CP-18**	**CP-7**	**AC-1**	**AC-2**	**AC-3**	**AC-4**
0.475	0.060	0.068	0.085	0.092	0.097	0.041

Unionized Ammonia

As seen in Table 8, the only site to exceed unionized ammonia target level of 0.02 mg/L is site CP-11, which exceeded the target 6 out of 17 sample events. Four of those six exceedances occurred on wet events. Every other sample location tested well below the target objective in every sampling event. On the October 22 sample event, the pH probe on the YSI multi-meter malfunctioned in the field and would not give a dependable result, therefore unionized ammonia was not able to be calculated for this day. When comparing 2015 results to 2014 averages in Table 9, annual averages for unionized ammonia are on the decline at all locations.

Figure 7 displays the up and down nature of unionized ammonia at site CP-11 in 2015, while all other sites are well below the target marked on the graph.

Figure 7: Unionized ammonia at all sites in 2015

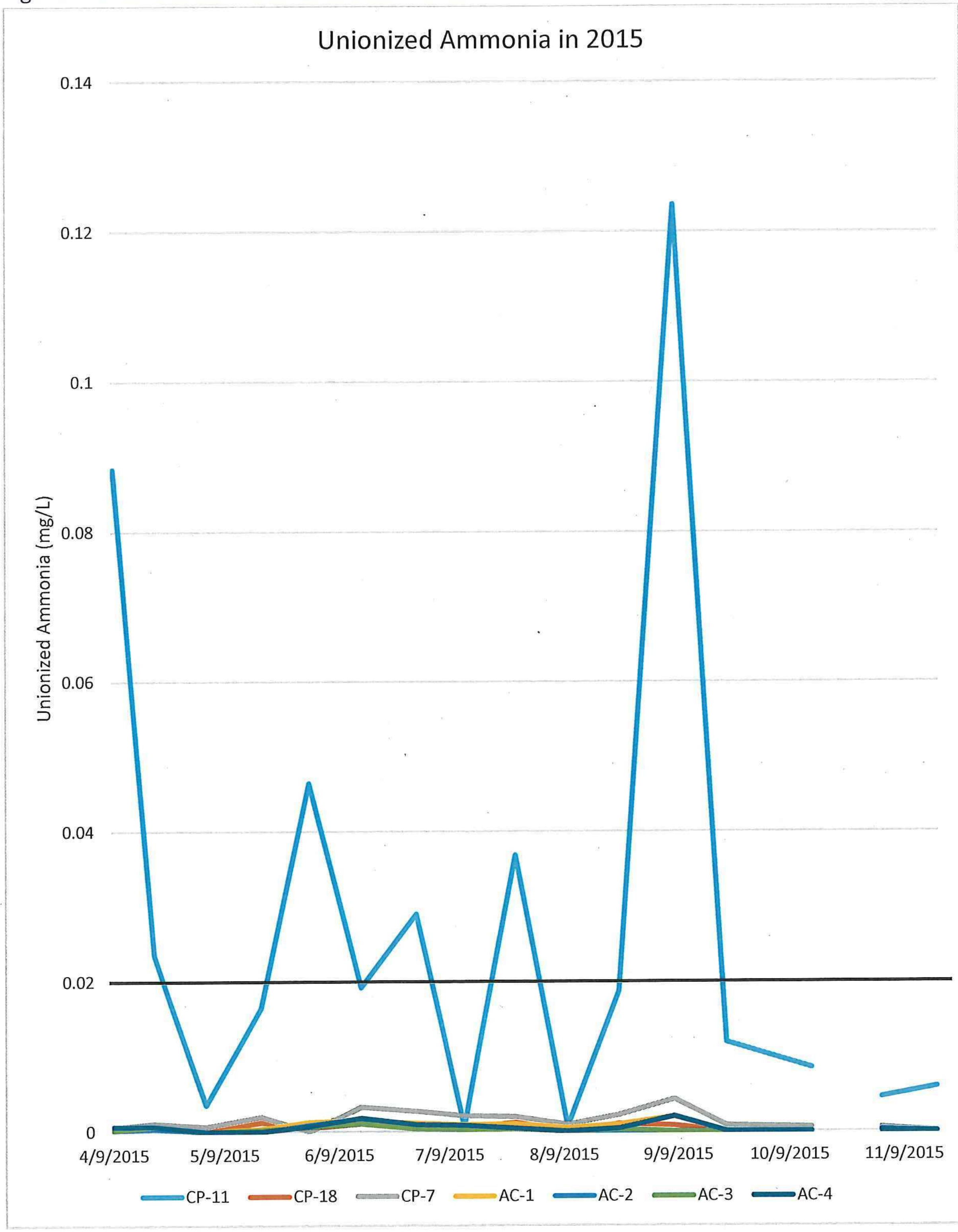


Table 8: Unionized Ammonia Values for Stations Sampled in 2015

Date	CP-11	CP-18	CP-7	AC-1	AC-2	AC-3	AC-4	Wet/Dry
4/09/15	0.088351	0.000452	0.00058	0.00049	0.000264	0.000215	0.000671	**Wet**
4/20/15	0.023528	0.000858	0.001095	0.000651	0.000421	0.000728	0.000734	**Wet**
5/04/15	0.003546	---	0.000665	---	---	---	---	**Dry**
5/19/15	0.016484	0.001269	0.001989	0.000403	---	0.000236	---	**Dry**
6/01/15	0.046451	0.000529	---	0.001309	0.000891	0.000641	0.000712	**Wet**
6/15/15	0.019203	0.001088	0.00327	0.001466	0.001761	0.001056	0.001836	**Wet**
6/30/15	0.028982	0.000508	0.002717	0.001158	0.000733	0.000403	0.000934	**Dry**
7/13/15	0.000652	0.000479	0.002075	0.000899	0.000291	0.000309	0.000831	**Dry**
7/27/15	0.036848	0.001206	0.001973	0.001031	0.000394	0.000359	0.000436	**Dry**
8/10/15	0.000653	---	0.000922	0.000455	---	---	---	**Dry**
8/24/15	0.018702	0.001042	0.0022	0.000969	---	0.000301	0.000389	**Dry**
9/08/15	0.123604	0.000796	0.004292	0.00199	---	---	0.002029	**Wet**
9/22/15	0.011916	---	0.000739	---	---	---	---	**Dry**
10/15/15	0.008527	---	0.000559	---	---	---	---	**Dry**
10/22/15								**Dry**
11/03/15	0.004598	---	0.000487	---	0.000249	---	0.000106	**Dry**
11/18/15	0.005977	---	---	---	---	---	---	**Dry**
Mean	**0.02737**	**0.00082**	**0.00168**	**0.00098**	**0.00062**	**0.00047**	**0.00086**	

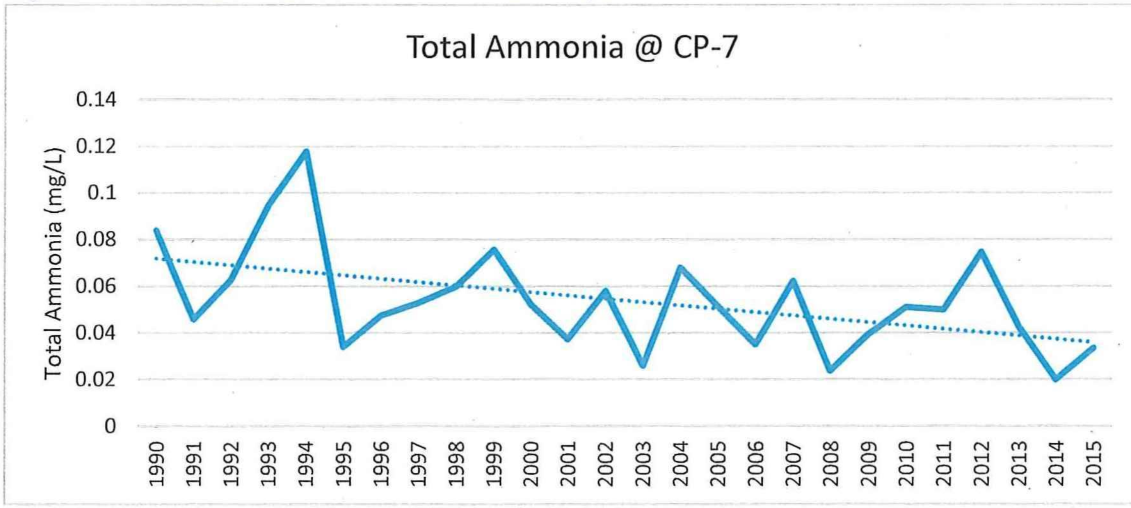
Table 9: 2014 unionized ammonia results (mean)

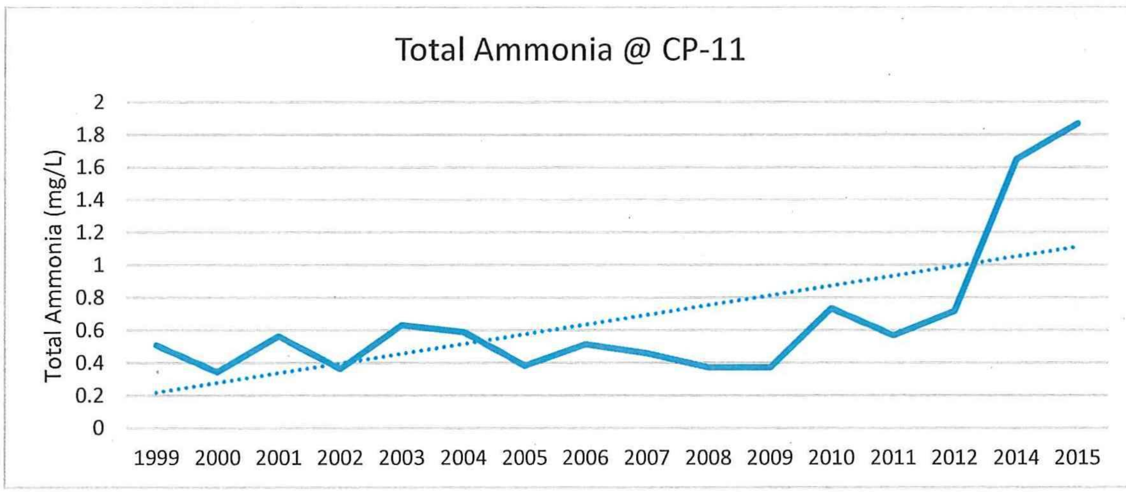
CP-11	CP-18.1	CP-7	AC-1	AC-2	AC-3	AC-4
0.043	0.001	0.002	0.001	0.001	0.001	0.001

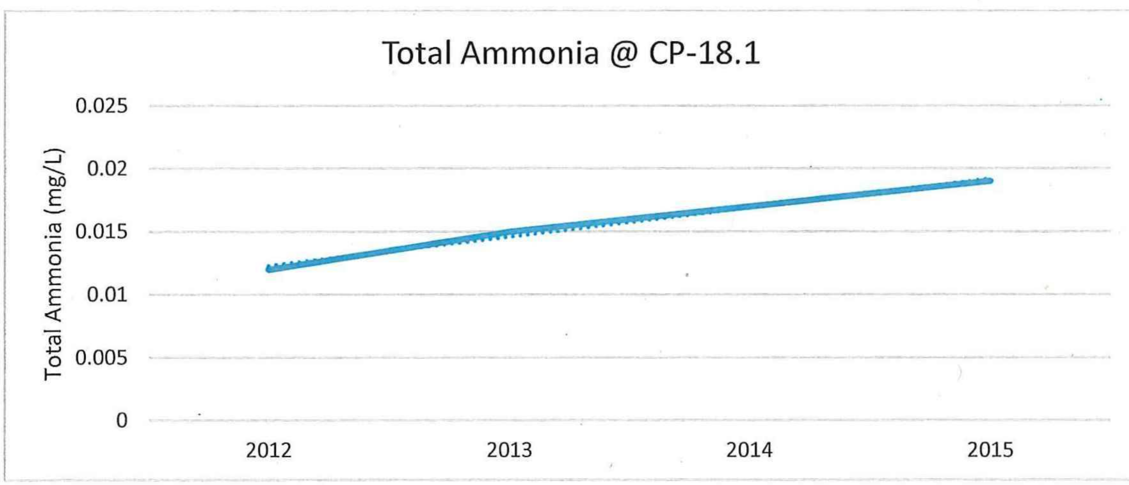
Total Ammonia

When compared to historical total ammonia results for sites CP-7, CP-11 & CP-18.1, site CP-7 has an overall downward trend while CP-11 and CP-18.1 are experiencing an overall increase in total ammonia concentration. CP-7 located in Lower Spencer Creek is downstream of 4 out of other 6 sample locations AC-1, AC-1, AC-3 & AC-4), and accounts for the most discharge of all the other sub-watersheds draining into Cootes Paradise. Site CP-11 in Chedoke Creek has risen in total ammonia concentration in the past three years. This may be due to the increase of sampling on heavy rain events, as a majority of the exceedances occur during wet sampling days. More sampling will have to be done in future years to determine the overall trend of total ammonia for the sample sites.

Figure 8: Historical Total Ammonia at sites CP-7, CP-11 & CP-18.1.







Nitrate

As seen in Figure 9, nitrate concentrations did not exceed the target objective of 3 mg/L at any location during the sampling season. Site CP-11 had the highest average concentration at 1.36 mg/L. Water quality impairment from nitrate does not seem to be a concern at this time. Nitrate concentration results can be seen in Table 10.

The historical trends for nitrate concentrations in CP-7 and CP-11 are decreasing. CP-18.1 has four years of historical data that suggest nitrite is on the rise, however still far below the target objective. When comparing 2014 data in Table 11 to the 2015 results, some locations (particularly the CP sample locations) are experiencing a rise in average concentrations while others (AC sample locations) are experiencing a slight decrease. More data will have to be collected to gain a clearer understanding of which direction nitrate concentrations are actually trending.

Figure 9: Nitrate concentrations in 2015

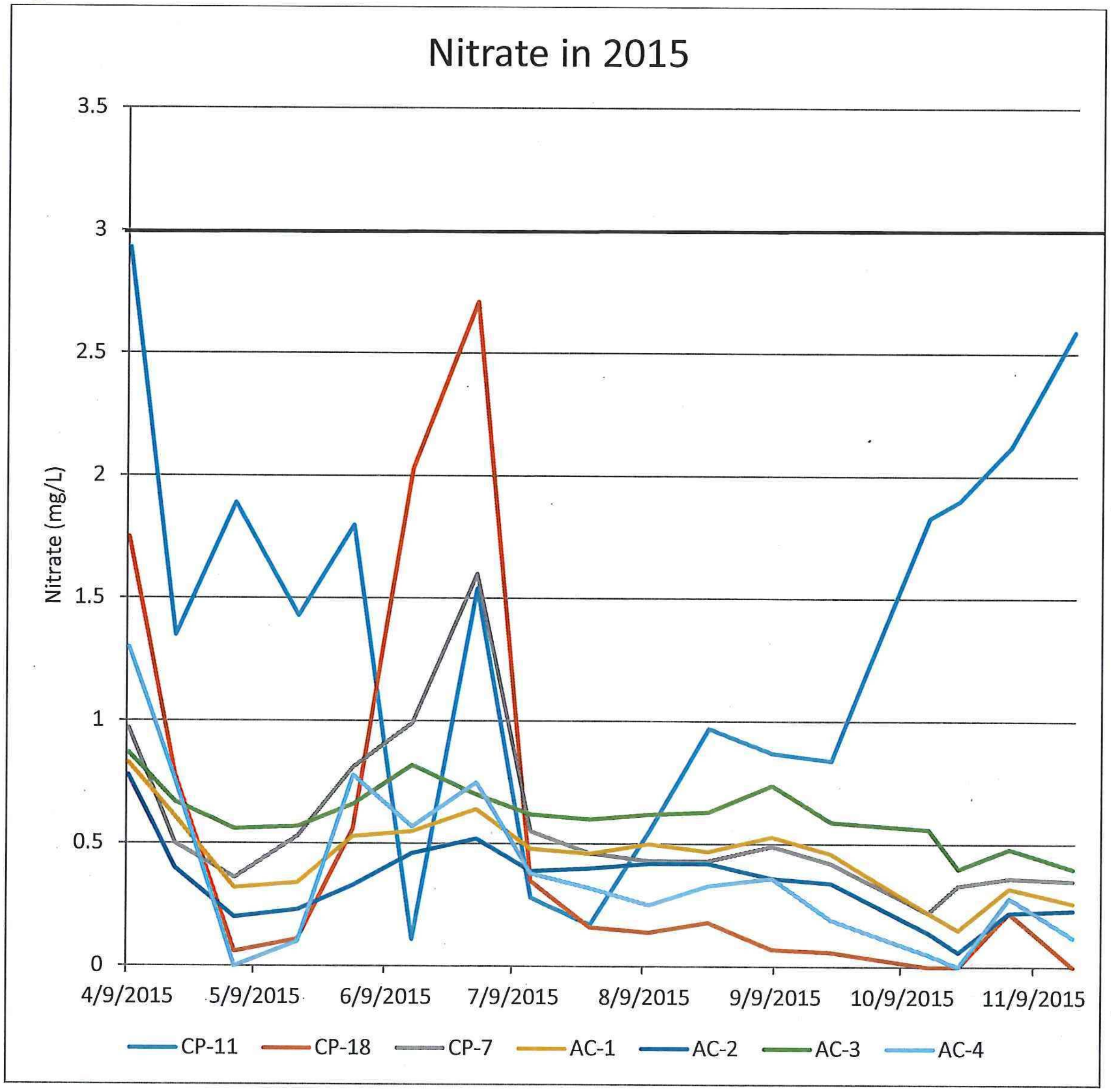
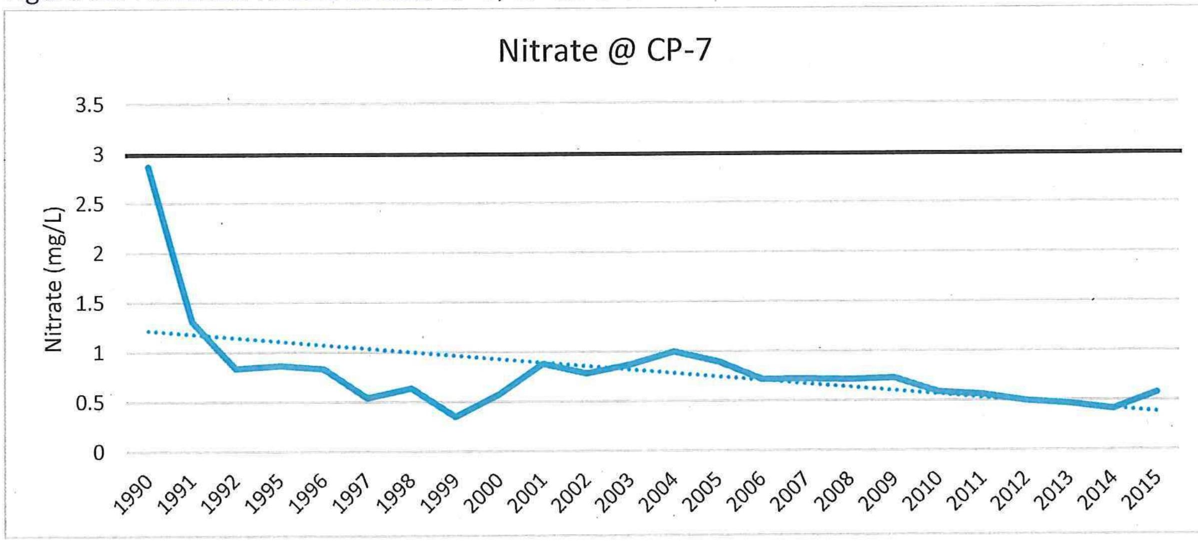
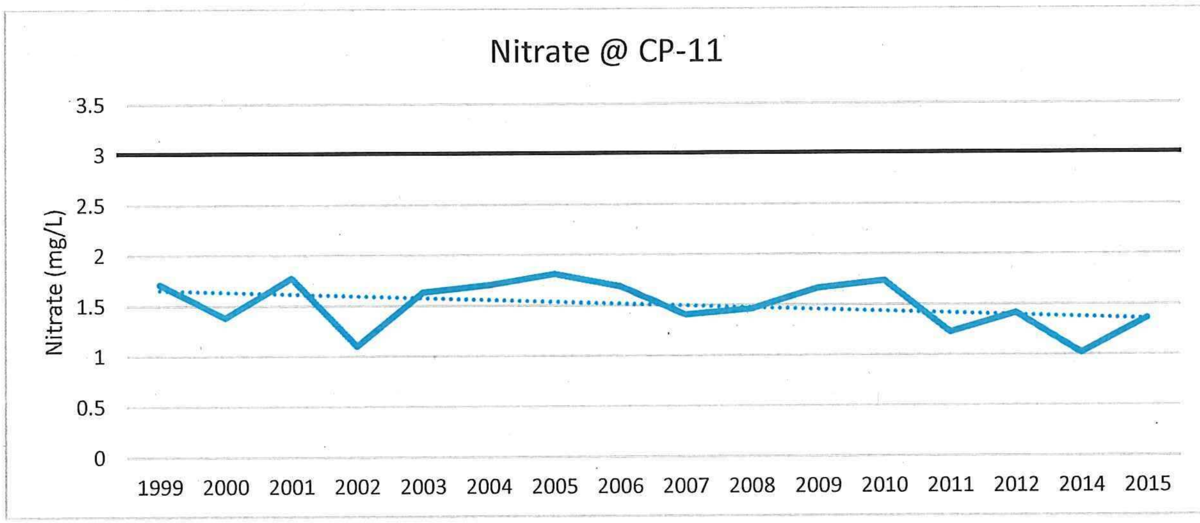


Figure 10: Historical nitrate at sites CP-7, CP-11 & CP-18.1





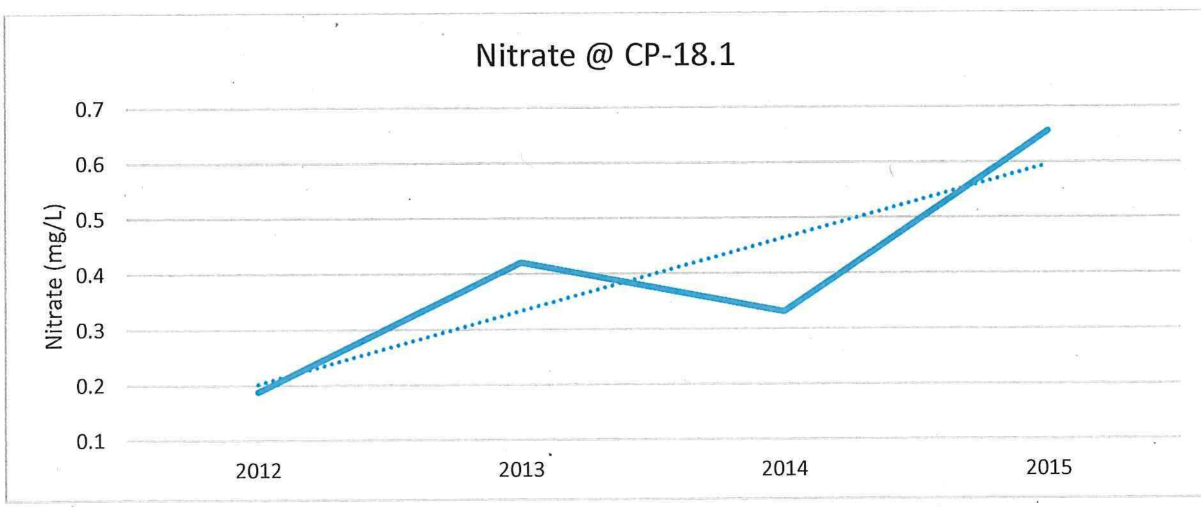


Table 10: Nitrate values for stations sampled in 2015

Dates	CP-11	CP-18	CP-7	AC-1	AC-2	AC-3	AC-4	Wet/Dry
4/09/15	2.93	1.75	0.97	0.83	0.78	0.87	1.3	**Wet**
4/20/15	1.35	0.78	0.5	0.61	0.4	0.67	0.76	**Wet**
5/04/15	1.89	0.06	0.36	0.32	0.2	0.56	<0.05	**Dry**
5/19/15	1.43	0.11	0.53	0.34	0.23	0.57	0.1	**Dry**
6/01/15	1.8	0.56	0.81	0.53	0.33	0.66	0.78	**Wet**
6/15/15	0.11	2.03	0.99	0.55	0.46	0.82	0.57	**Wet**
6/30/15	1.54	2.71	1.6	0.64	0.52	0.7	0.75	**Dry**
7/13/15	0.28	0.35	0.55	0.48	0.39	0.62	0.38	**Dry**
7/27/15	0.17	0.16	0.46	0.46	0.4	0.6	0.32	**Dry**
8/10/15	0.55	0.14	0.43	0.5	0.42	0.62	0.25	**Dry**
8/24/15	0.97	0.18	0.43	0.47	0.42	0.63	0.33	**Dry**
9/08/15	0.87	0.07	0.49	0.53	0.36	0.74	0.36	**Wet**
9/22/15	0.84	0.06	0.42	0.46	0.34	0.59	0.19	**Dry**
10/15/15	1.83	<0.05	0.22	0.22	0.14	0.56	0.05	**Dry**
10/22/15	1.9	<0.05	0.33	0.15	0.06	0.4	<0.05	**Dry**
11/03/15	2.12	0.22	0.36	0.32	0.22	0.48	0.28	**Dry**
11/18/15	2.59	<0.05	0.35	0.26	0.23	0.4	0.12	**Dry**
Mean	**1.36294**	**0.65571**	**0.57647**	**0.45117**	**0.34705**	**0.61705**	**0.436**	

Table 11: 2014 nitrate results (mean)

CP-11	**CP-18.1**	**CP-7**	**AC-1**	**AC-2**	**AC-3**	**AC-4**
1.0218	0.3309	0.4209	0.6018	0.4455	0.7845	0.4291

Nitrite

The target objective for nitrite for the purpose of this report is based on the Canadian Water Quality Guideline of 0.06 mg/L. As seen in Table 12 and Figure 11, the majority of samples taken tested below the detection limits of the laboratory instrumentation. Site CP-11 exceeded the target for 12 of the 17 sampling events. Every other site was regularly below the target on both wet and dry sampling events. The sampling event on August 24 was peculiar because all sites tested above the target and it was not classified as a wet event.

Historical data seen in Figure 12 suggests that sites CP-7 and CP-11 are experiencing an increase in annual nitrite concentrations. CP-18.1 in Borers Creek regularly tests below detection limits for nitrite throughout the sampling season therefore a graph was not constructed. Site CP-11 is the only site being routinely impaired by excess nitrite at this time. Concentrations are slightly up this year at CP-11 compared to 2014 (Table 13).

Figure 11: Nitrite concentrations in 2015

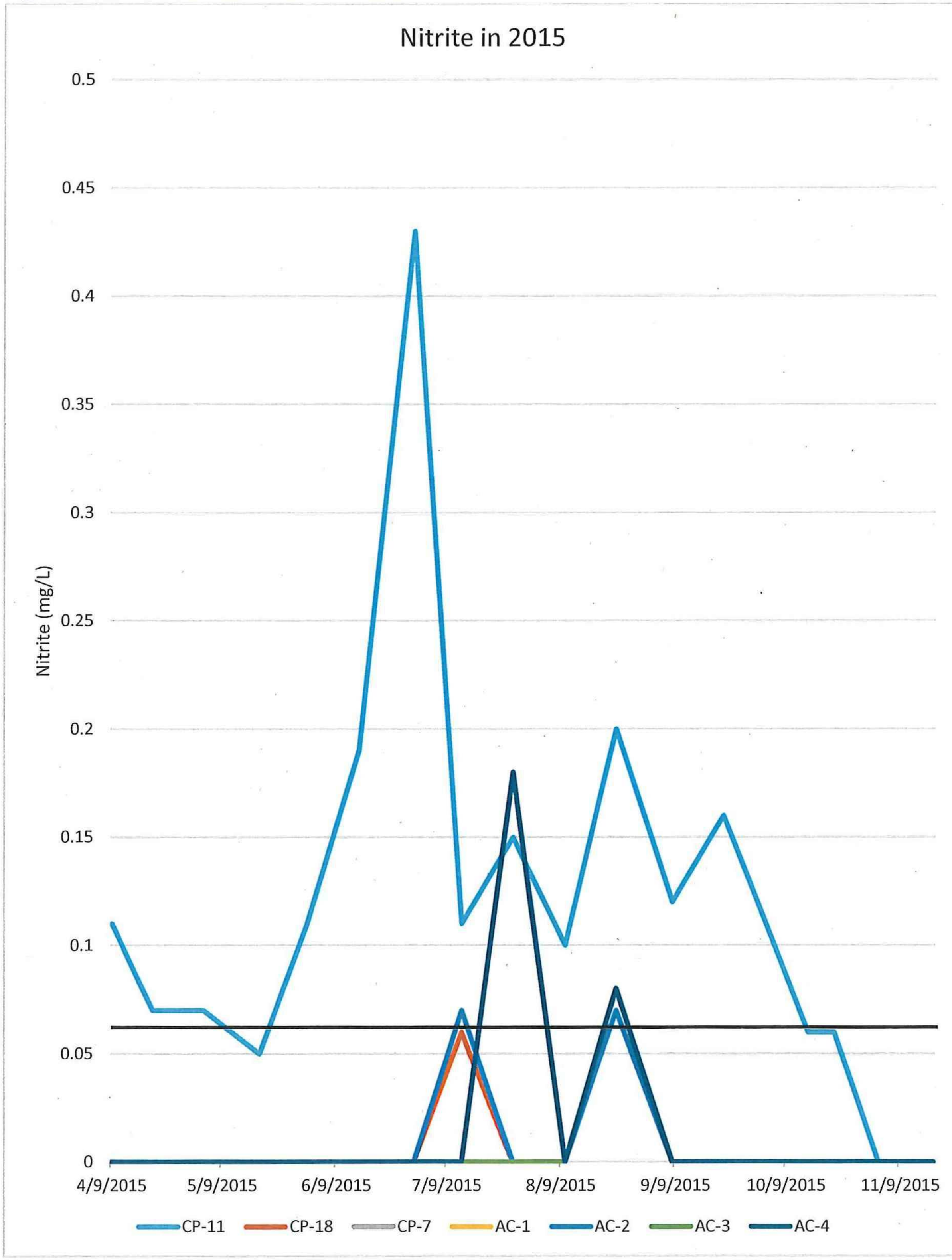
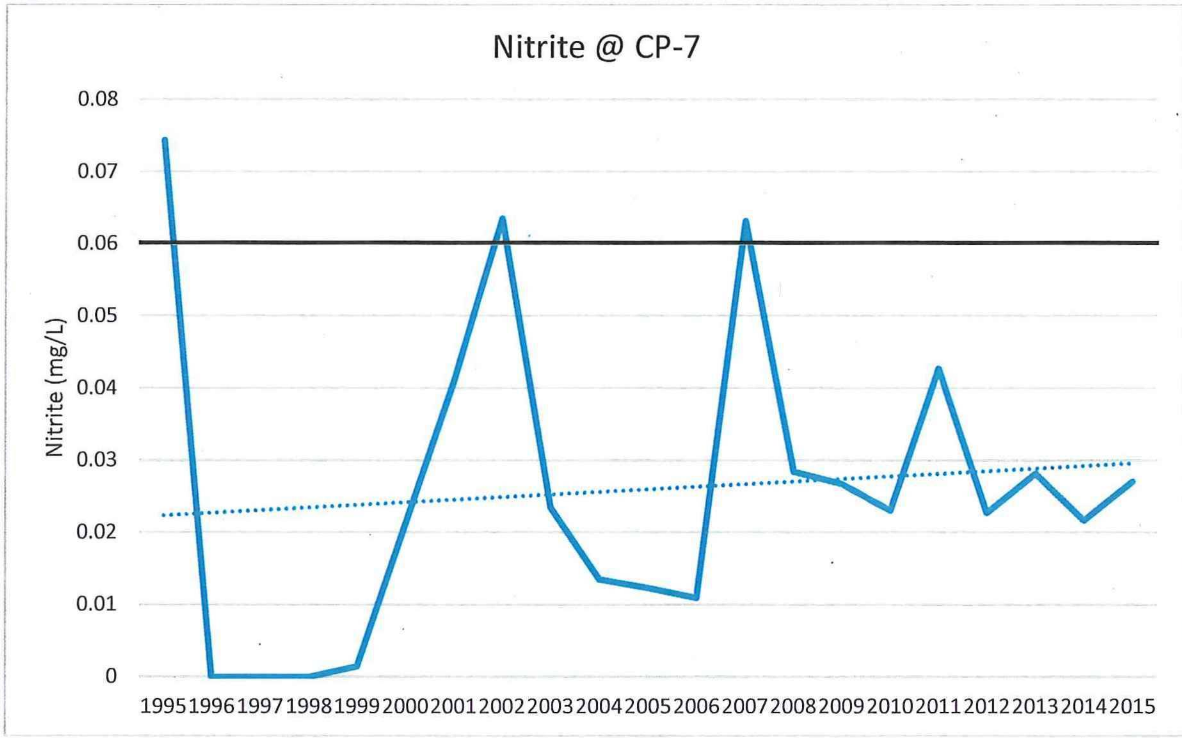


Figure 12: Historical Nitrate at sites CP-7 & CP-11



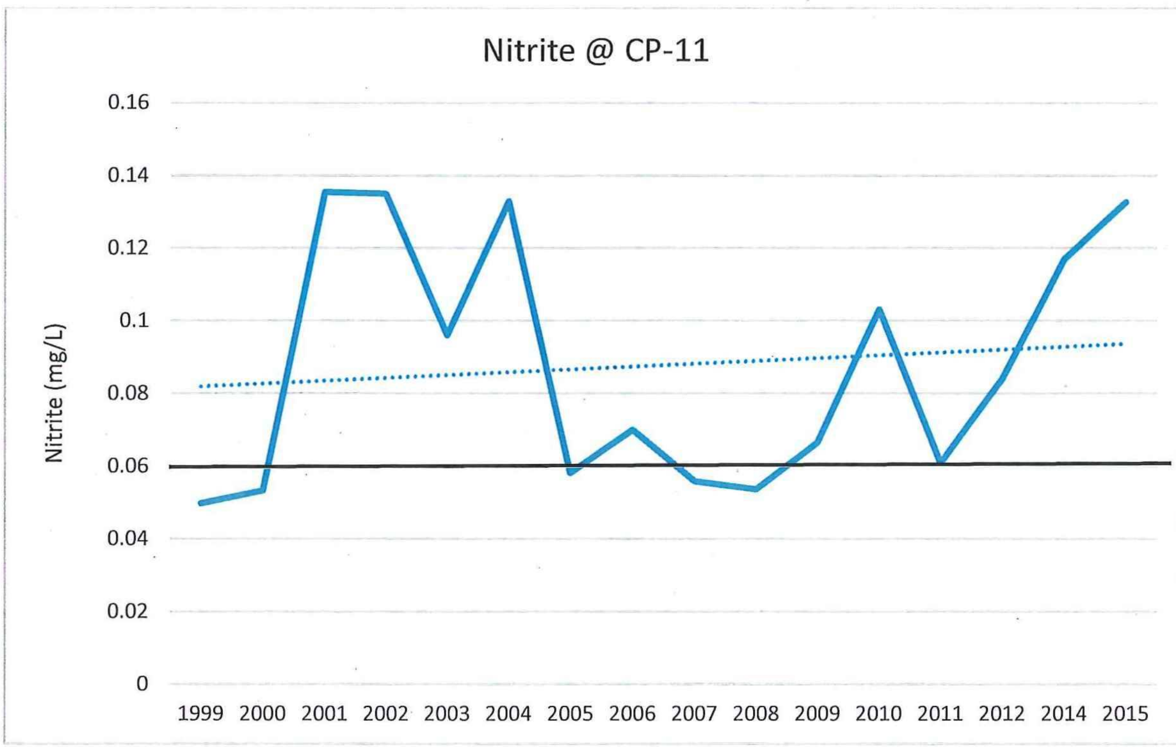


Table 12: Nitrite values for stations sampled in 2015

Dates	CP-11	CP-18	CP-7	AC-1	AC-2	AC-3	AC-4	Wet/Dry
4/09/15	0.11	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**Wet**
4/20/15	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Wet**
5/04/15	0.07	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Dry**
5/19/15	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Dry**
6/01/15	0.11	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Wet**
6/15/15	0.19	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Wet**
6/30/15	0.43	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Dry**
7/13/15	0.11	0.06	<0.05	0.07	0.07	<0.05	<0.05	**Dry**
7/27/15	0.15	<0.05	<0.05	<0.05	<0.05	<0.05	0.18	**Dry**
8/10/15	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Dry**
8/24/15	0.2	0.07	0.08	0.07	0.07	0.08	0.08	**Dry**
9/08/15	0.12	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Wet**
9/22/15	0.16	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Dry**
10/15/15	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Dry**
10/22/15	0.06	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Dry**
11/03/15	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Dry**
11/18/15	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	**Dry**
Mean	0.13267	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	

Table 13: 2014 nitrite results (mean)

CP-11	CP-18.1	CP-7	AC-1	AC-2	AC-3	AC-4
0.117	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05

Total Suspended Solids

As Table 14 shows, the majority of samples taken in 2015 tested below the target objective of 25 mg/L. The Ancaster Creek locations had some of the highest exceedances in 2015. The lowest values were seen in site CP sample locations. The highest exceedances occurred during wet sampling events and in the spring. The Ancaster Creek sites seem to be more susceptible to increased sediment loading during storm events. Figure 13 illustrates how much higher TSS values are during wet events, particularly in the Ancaster Creek sub-watershed.

Historical data for the CP sites suggest that TSS is in an overall decreasing trend for sites CP-7 in Spencer Creek and CP-11 in Chedoke Creek. Annual averages for AC sites from 2015 is much higher than 2014 as seen in Table 15, however very high TSS values in the spring and the fact that more wet events were captured in 2015 might account for the change in results. The AC site locations seem to be easily impacted by wet events and sediment loads increase greatly during these times. The CP sites do not experience much in the way of change between 2014 and 2015.

Figure 13: Average TSS for wet events, dry events and the entire sample period.

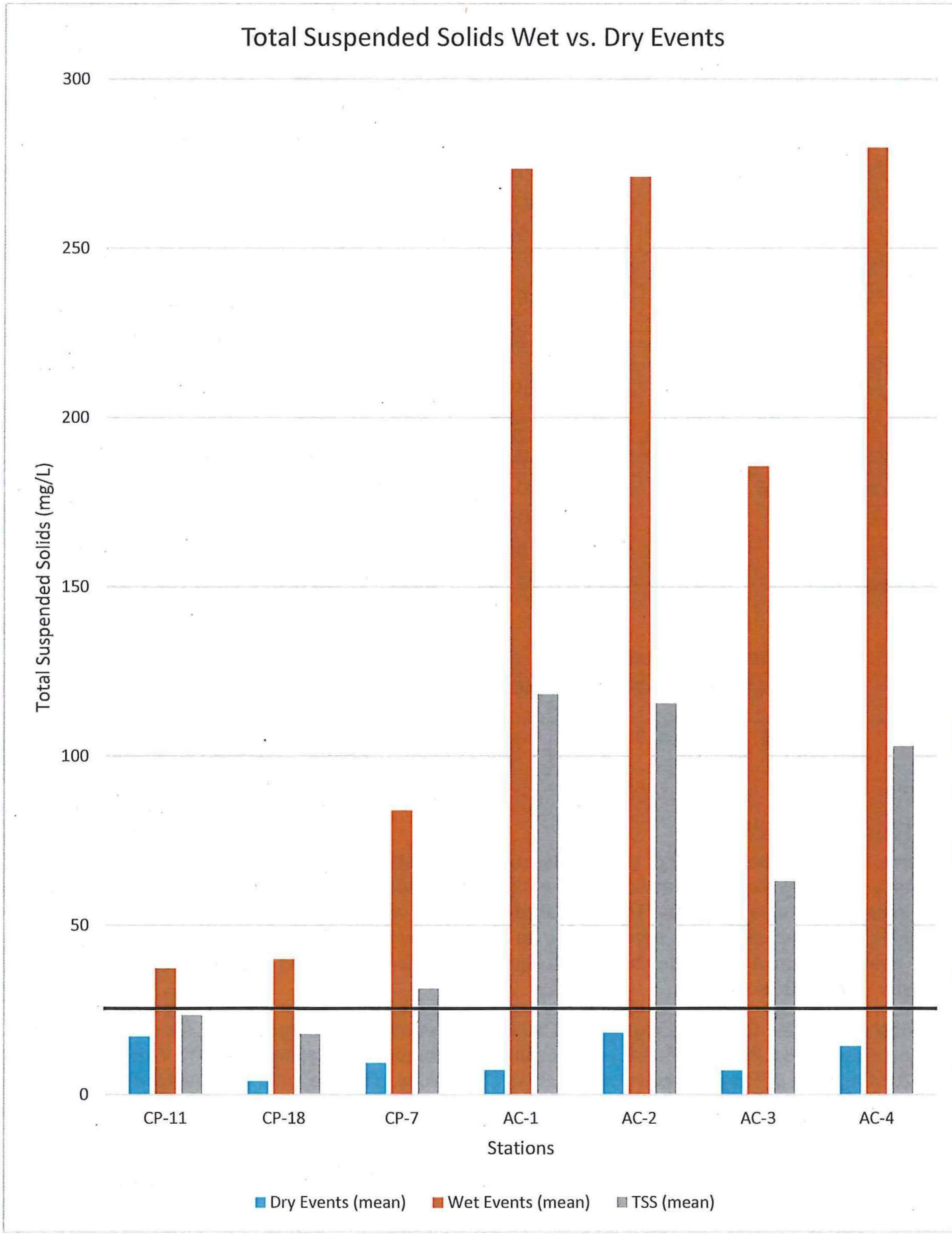
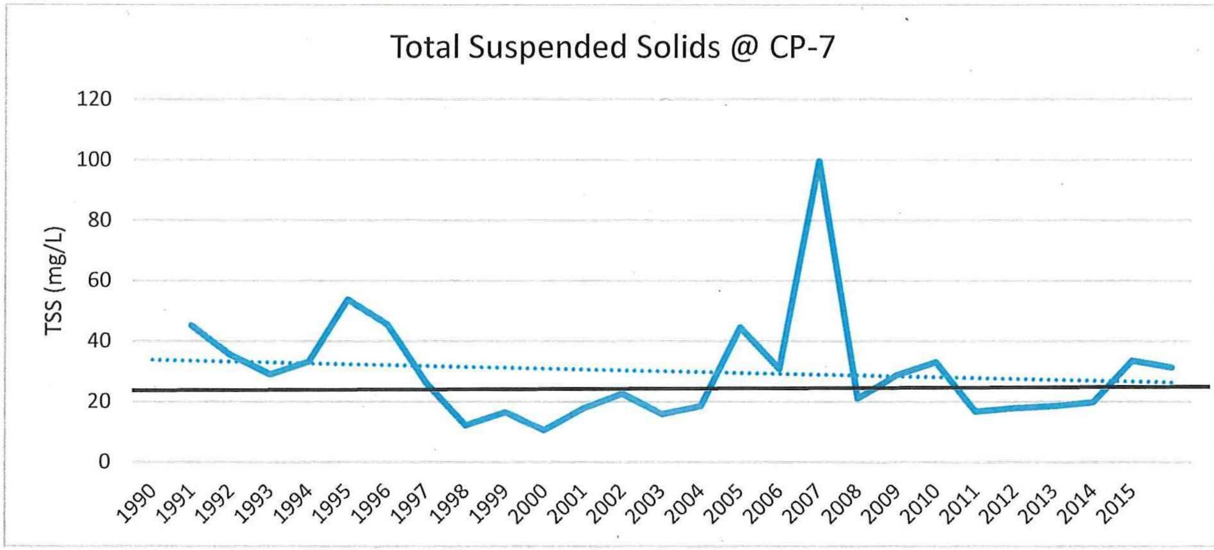
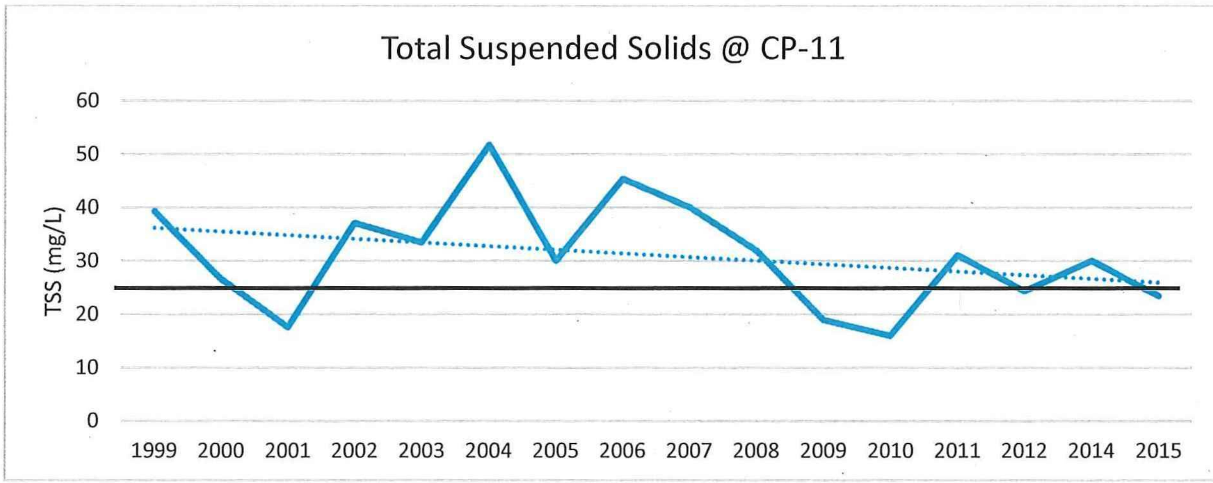


Figure 14: Historical TSS at sites CP-7, CP-11 and CP-18.1





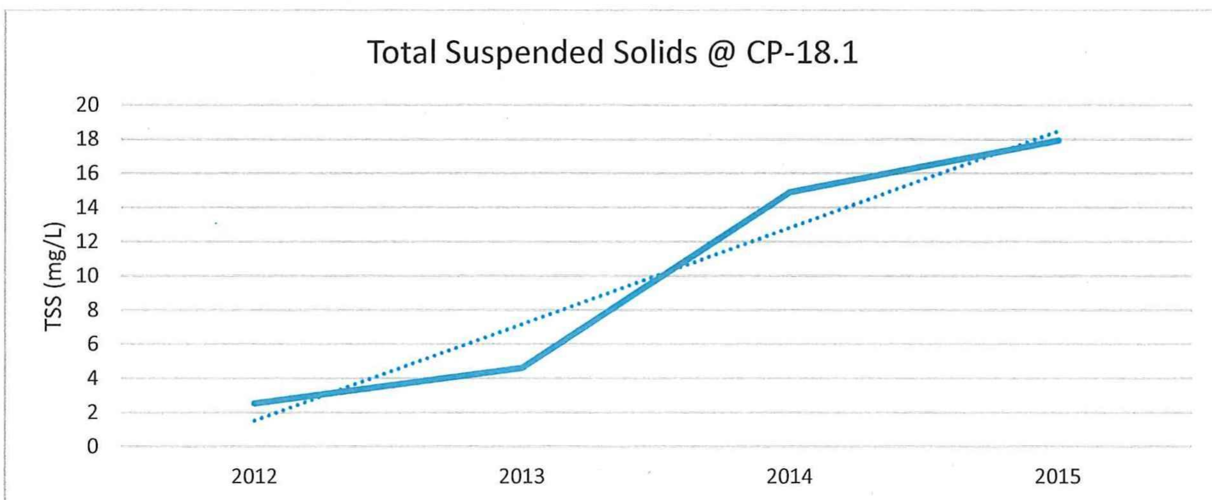


Table 14: Total Suspended Solids values for stations sampled in 2015

Dates	CP-11	CP-18.1	CP-7	AC-1	AC-2	AC-3	AC-4	Wet/Dry
4/09/15	48.5	28.1	55.2	207	315	111	152	Wet
4/20/15	58	132	296	1050	927	739	1060	Wet
5/04/15	<3	<3	3.6	<3	<3	22.8	<3	Dry
5/19/15	10.4	5.4	10.2	3.6	4.8	10.6	10.2	Dry
6/01/15	22.7	11.5	6.7	29	50	19.2	22.8	Wet
6/15/15	28.7	24.2	43.7	57	58	32	28.7	Wet
6/30/15	5	7.9	29.8	31.7	55.3	13.9	38.8	Dry
7/13/15	34	4	6	4.4	13.6	9.6	9.6	Dry
7/27/15	27.6	6.4	6.9	3.4	12.4	4	40.6	Dry
8/10/15	24.8	2.4	8.6	3.8	38.4	5	18.8	Dry
8/24/15	38.8	<3	22.4	3.2	17.2	4.8	11.2	Dry
9/08/15	28.8	4.8	18.4	25	6.2	27.6	136	Wet
9/22/15	14.4	2.2	1.8	<2	1.6	3.2	4.2	Dry
10/15/15	5.8	2.4	5.4	<2	<2	1.6	1.6	Dry
10/22/15	10.9	1.8	9.4	1.6	<2	<2	7.8	Dry
11/03/15	15.2	<2	5	<2	3.4	2.2	1.6	Dry
11/18/15	2.2	<2	4.4	<2	<2	2	<2	Dry
Mean	**23.4875**	**17.93077**	**31.38235**	**118.3083**	**115.6077**	**63.03125**	**102.9267**	
Dry Events (mean)	**17.19091**	**4.0625**	**9.458333**	**7.385714**	**18.3375**	**7.245455**	**14.44**	
Wet Events (mean)	**37.34**	**40.12**	**84**	**273.6**	**271.24**	**185.76**	**279.9**	

Table 15: 2014 TSS results (mg/L) (mean)

CP-11	CP-18.1	CP-7	AC-1	AC-2	AC-3	AC-4
30.1	14.9	36.1	42	71.5	56.9	8.02

Volatile Suspended Solids

Volatile suspended solids do not have a target objective outlined for this report. Figure 15 displays the make-up of the suspended solids at each location. All locations except CP-11 consist of mostly fixed suspended solids, which are inorganic materials. Site CP-11 is made up of mostly volatile suspended solids, meaning that the majority of suspended material is organic. This is consistent with the high nutrient values we are seeing in site CP-11.

Figure 15: Suspended Solids breakdown of Volatile vs. Fixed substances

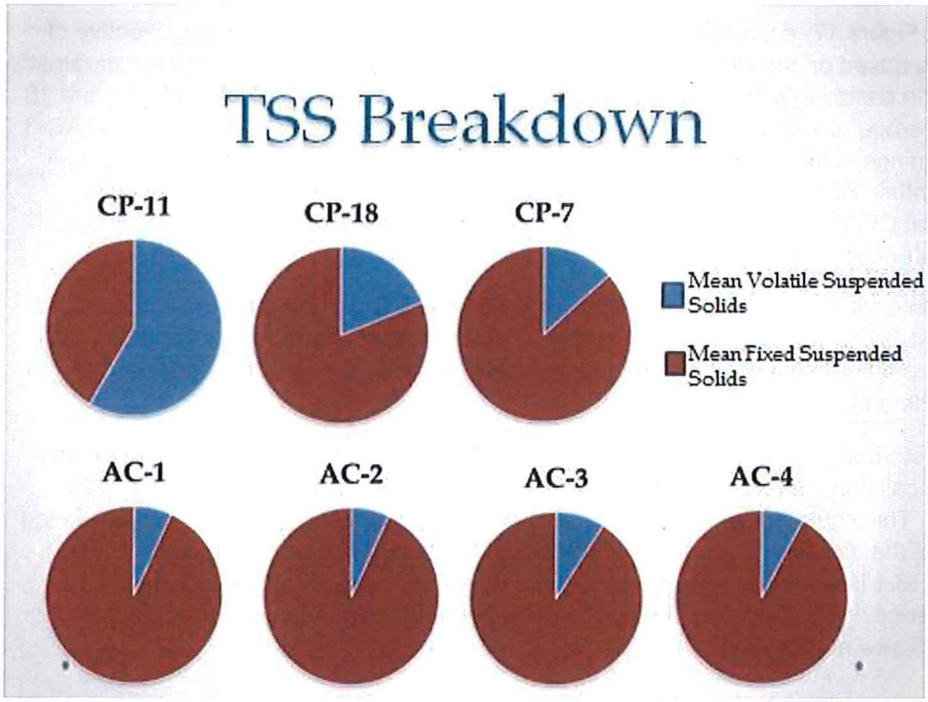


Table 16: Volatile Suspended Solids for stations sampled in 2015 (mg/L)

Date	CP-11	CP-18	CP-7	AC-1	AC-2	AC-3	AC-4	Wet/Dry
4/09/15	25.3	3.9	6.2	12.1	17.7	6.6	11	Wet
4/20/15	34.4	18	22.2	61.2	52.3	52.1	68.3	Wet
5/04/15	<3	<3	2.8	<3	<3	3.2	<3	Dry
5/19/15	6.2	3	2.6	<0.8	2.2	3	3.6	Dry
6/01/15	17.3	2.5	2	3.1	4.5	4.8	3.3	Wet
6/15/15	10.6	5	8.2	7.3	6.2	4.8	4.6	Wet
6/30/15	5	1.7	5.1	3.4	4.3	1.4	3.8	Dry
7/13/15	21.2	1.6	2.4	1.2	2.8	2	0.8	Dry
7/27/15	20.4	1.6	2	1	1.8	1	3.6	Dry
8/10/15	20	1.6	2.8	1.8	4.4	1.6	3	Dry
8/24/15	18.9	<3	4.8	2.4	5.2	3.6	2.8	Dry
9/08/15	14.4	1.2	3.2	2.8	1.2	2.8	10.8	Wet
9/22/15	10.4	1	<0.8	<2	1.2	1.6	1.2	Dry
10/15/15	3.8	1.6	2.2	<2	<2	1.2	1	Dry
10/22/15	7	1.4	2	1.4	<2	<2	1.8	Dry
11/03/15	2.6	<2	1	<2	0.8	<0.8	1.4	Dry
11/18/15	1.6	<2	1	<2	<2	1.2	<2	Dry
Mean	13.69375	3.392308	4.40625	8.881818	8.046154	6.06	8.066667	

Escherichia coli

As seen in Table 17 and Figure 17, e.coli levels at every site regularly exceeded the target objective of 100CFU/100mL, which is based on the Provincial Water Quality Objective. Site CP-11 saw the greatest impairment throughout the sampling season, with a geometric mean of 15,734.8 CFU/100mL. Figure 16 displays the seasonal average distribution of e.coli at each sample site. Sites CP-11, CP-18.1 and AC-3 have very high e.coli readings in the spring. Sites CP-7, AC-1, AC-2 and AC-4 saw most of their e.coli occur in the summer months. As with most other parameters, e.coli levels increase on wet sample events. The high levels at CP-11 in Chedoke Creek will have to be explored by continual sampling and investigation of storm water conditions in the area.

When comparing 2015 data to 2014 data we find that most sites have a lower geometric mean result, while only CP-7 and AC-4 have only slightly higher values. This is perhaps explained by the extended sampling period. E.coli concentrations tapered off in the fall season at all locations, this reduces the overall geometric mean data for all sites.

Figure 17 displays the historical data for sites CP-7, CP-11 and CP-18.1. At site CP-7 there has been a consistent decrease in e.coli concentrations, while CP-11 has had a fairly drastic increase in the past couple sample seasons. This could be due to the extended sampling protocol or perhaps samples being taken at different times of the day, keeping an eye in this recent upward trend will be a focus in future sampling seasons. Site 18.1 indicates an overall upward trend in e.coli concentrations in the past 4 years. However more sampling seasons are required to get a better idea of which way the trend is actually heading, as 2015 saw a decrease from 2014.

Figure 16: Seasonal distribution of e.coli

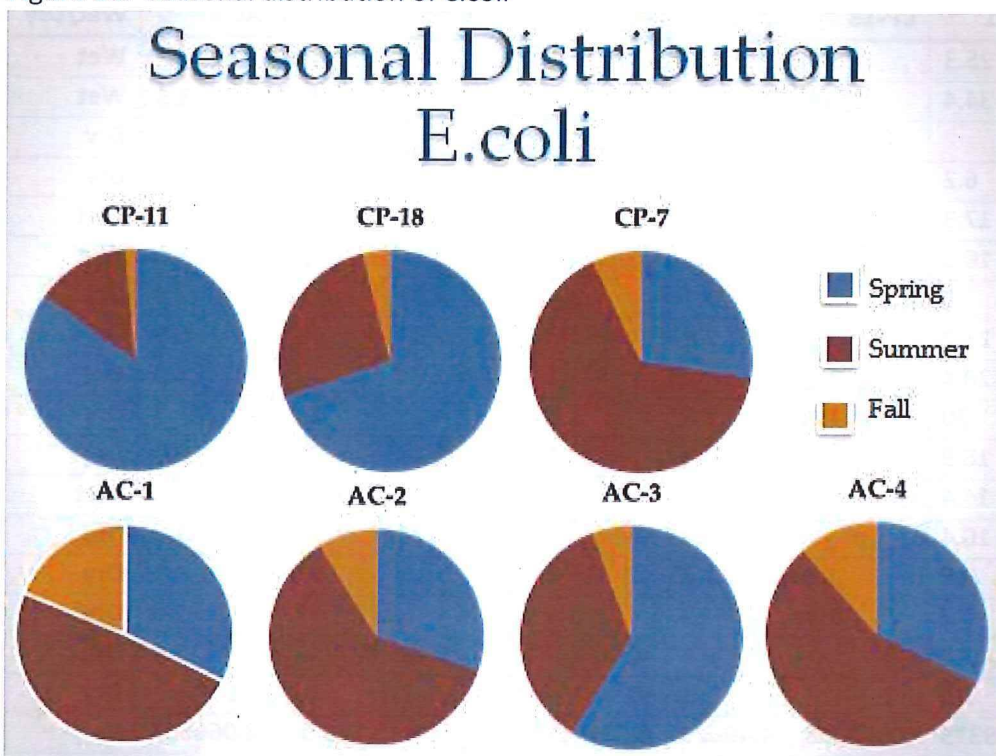


Figure 17: Geometric mean e.coli concentrations for wet and dry events

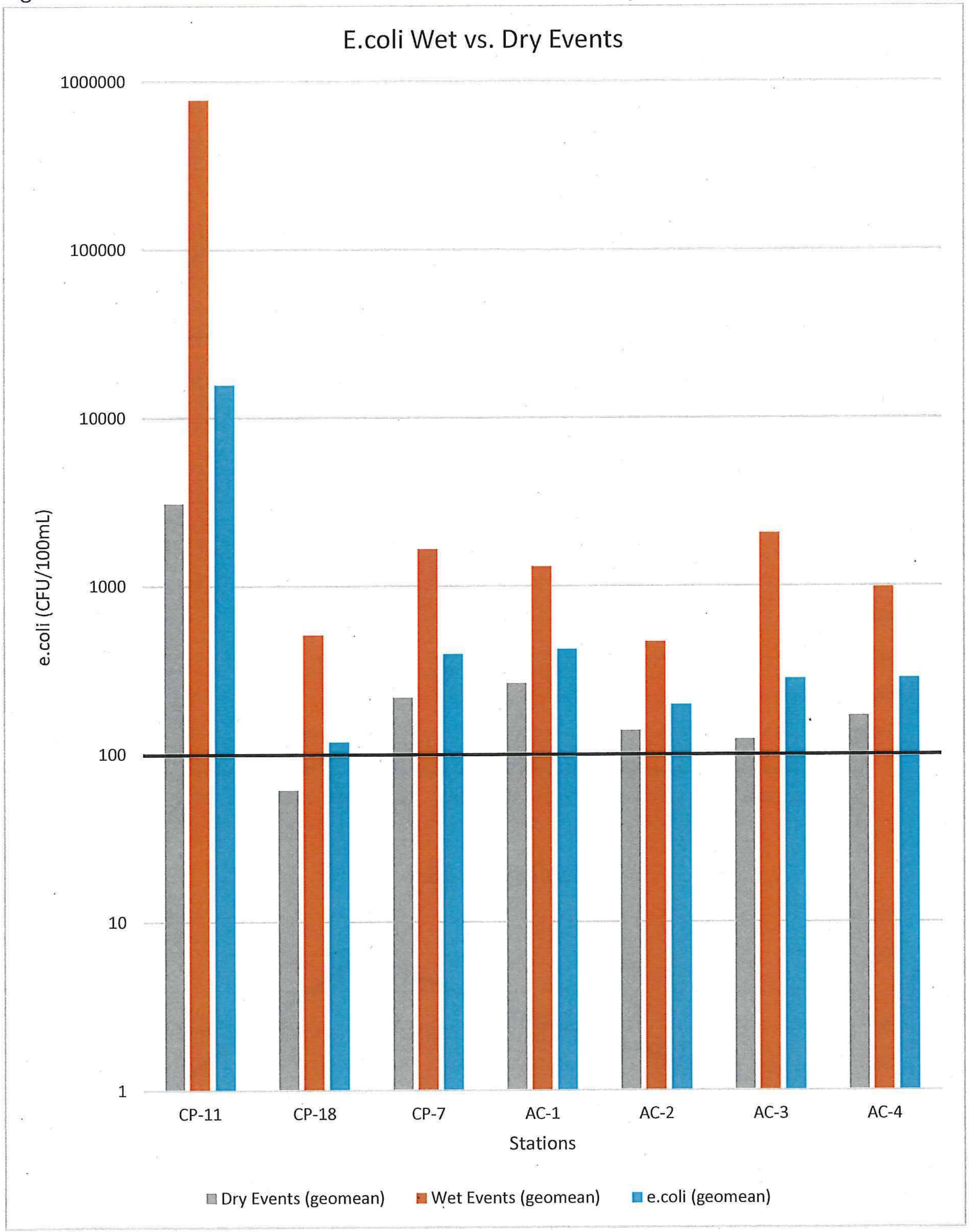


Figure 18: Historical e.coli at sites CP-7, CP-11 and CP-18.1

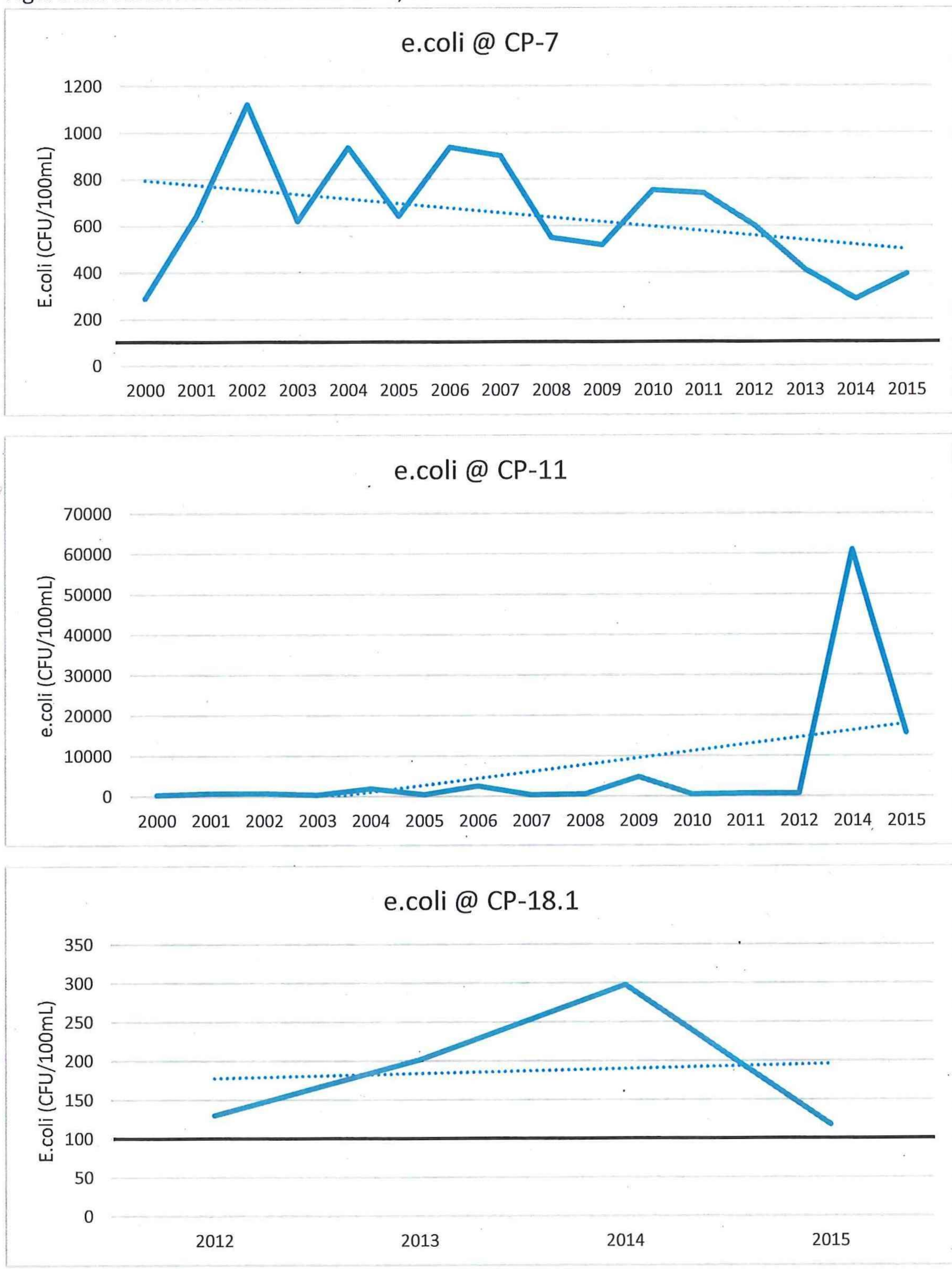


Table 17: E.coli for stations sampled in 2015 (CFU/100mL)

Dates	CP-11	CP-18	CP-7	AC-1	AC-2	AC-3	AC-4	Wet/Dry
4/09/15	900000	150	210	240	80	380	500	Wet
4/20/15	900000	1800	970	1000	410	3700	1280	Wet
5/04/15	5900	60	20	20	90	60	40	Dry
5/19/15	420	<10	210	180	40	100	70	Dry
6/01/15	620000	1900	10100	3700	1380	5100	650	Wet
6/15/15	650000	400	710	1800	680	2000	810	Wet
6/30/15	490000	430	450	760	460	540	640	Dry
7/13/15	220	130	370	520	490	190	140	Dry
7/27/15	110000	190	290	360	280	220	320	Dry
8/10/15	280	100	300	450	230	200	500	Dry
8/24/15	4700	80	9500	480	760	360	680	Dry
9/08/15	889000	170	8700	2400	710	2600	2700	Wet
9/22/15	1790	100	440	230	210	130	150	Dry
10/15/15	640	10	240	570	40	90	240	Dry
10/22/15	4800	20	210	370	70	10	80	Dry
11/03/15	4800	40	40	110	40	120	80	Dry
11/18/15	750	10	20	180	50	80	80	Dry
Geomean	15734.8	118.051	393.548	420.854	197.078	280.356	282.243	

Table 18: 2014 e.coli results (CFU/100mL) (geometric mean)

CP-11	CP-18.1	CP-7	AC-1	AC-2	AC-3	AC-4
61077.809	298.179	352.004	530.384	340.644	416.392	280.397

Storm Sample Events

In 2015, the HCA began targeting storm events to get an idea of the impairment to water quality during these events. Storm events were only captured at site AC-1. Due to technical difficulties with the equipment early in the sample season, and a lack of rain events, only two storm events were successfully captured during the sampling period. The laboratory results from the storm events can be seen in Table 19.

When comparing the initial results from the storm event samples in 2015 to the yearly averages from AC-1, there does not seem to be much of a difference in most parameters. All parameters saw a general increase in concentration during storm events, which is expected. However Figure 18, 19 and 20 illustrate the significant differences in concentrations during storm events for TP and e.coli and TSS. More storm events captured in 2016 will provide additional data to provide a better indication of water quality impairment during these storm events.

Table 19: Results from storm event sampling at AC-1.

Parameter	21-Aug-15	28-Oct-15	Storm Event Average	Grab Event Average
Ammonia + Ammonium as N mg/L	0.03	0.02	0.025	0.0188
Nitrate as N mg/L	0.54	0.42	0.48	0.4512
Nitrite as N mg/L	<0.05	<0.05	<0.05	<0.05
o-Phosphate as P mg/L	<0.2	<0.2	<0.2	<0.2
Phosphorus Total mg/L	0.26	0.322	0.291	0.1121
Total Suspended Solids mg/L	176	209	192.5	118.308
Volatile Suspended Solids mg/L	15.2	19	17.1	8.8818
Escherichia coli CFU/100mL	11200	800	2993.326	420.85

Figure 19: TP in AC-1 storm events mean vs. annual mean

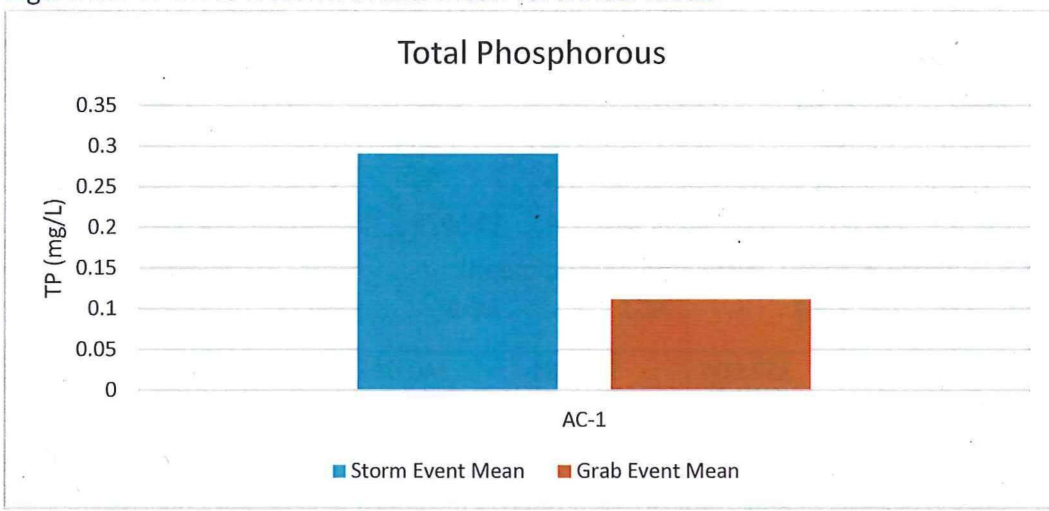


Figure 20: e.coli in AC-1 storm events mean vs. annual mean

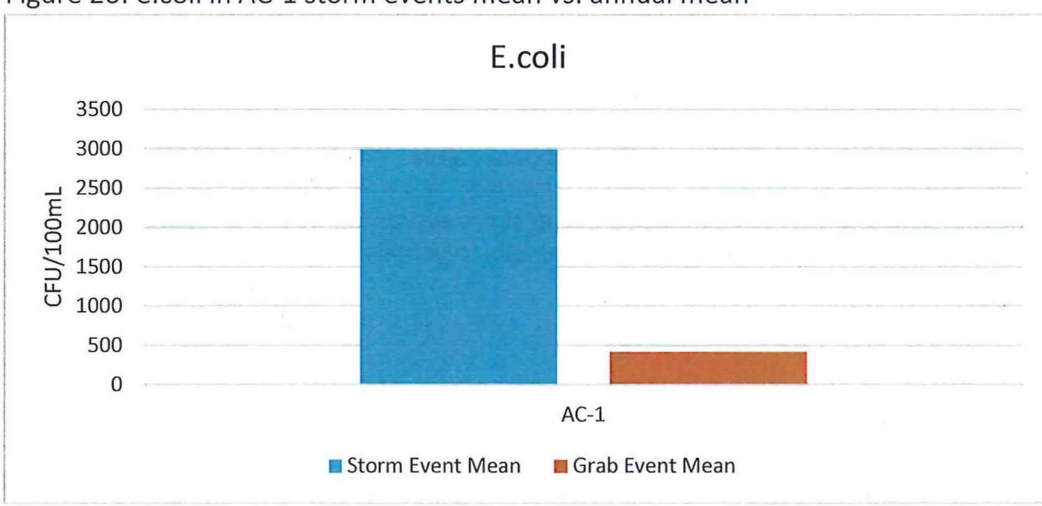
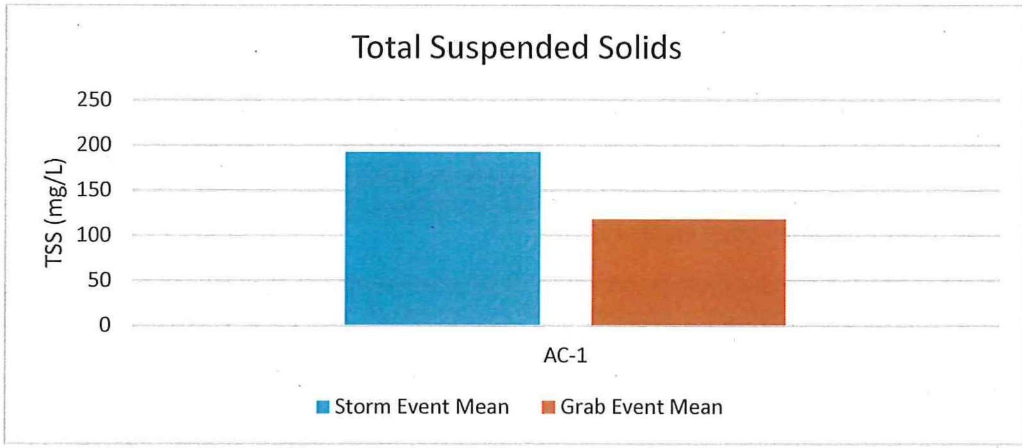


Figure 21: TSS in AC-1 storm events vs. annual mean



Discussion Summary

Water quality data collected over the past two years has provided valuable insight into the overall water quality contributions from tributaries entering Cootes Paradise. Expanding the sampling season in 2015 to include April gave further evidence that sediment, e.coli and nutrient loading during wet events are typically significantly higher than for dry events. Of all the stations sampled, site CP-11 at the mouth of Chedoke Creek was the most impaired by far, with the highest mean concentrations for all parameters except TSS. Also, CP-11 concentrations exceeded targets, often substantially, for TP (wet & dry events), unionized ammonia (most wet events), nitrite (all wet & ½ dry events), TSS (wet events only) and e.coli (wet & dry events). AC sites in the Ancaster Creek watershed had substantially higher TSS mean concentrations than the other sites. The AC sample sites experience a lot of sediment displacement during spring runoff and heavy wet events, which brings with it elevated phosphorous and bacteria. AC sites also had concentrations that exceeded targets for TP (wet events), nitrite (2x dry events only) and e.coli (most wet events & majority of dry events). For CP-7 in Spencer Creek, mean concentrations of TP exceeded targets, with concentrations well above targets for wet events. TSS (mean) concentrations exceeded targets for wet events and for overall mean concentration values. The majority of e.coli concentrations exceeded targets, including for all wet events. For CP-18.1 in Borers Creek, similar findings to CP-7 were found, except that TSS (mean) concentrations were exceeded only for wet events. Ortho-phosphate and nitrate were found to be negligible in terms of water quality. This is similar to results from 2014, therefore nitrate and ortho-phosphate discussion will not take place in this summary.

An important change in the sampling protocol made in 2015 was to expand the sampling season from May – September (as it was in 2014) to April – November. This allowed for the capture of more samples while water levels were still elevated from spring runoff and also resulted in more "wet" sample days throughout the whole season. The samples taken in April had very high levels of total phosphorous, total suspended solids and e.coli at every sample location. Wet sample days throughout the year had the same effect on water impairment on these key parameters. For dry events, 9/67 samples submitted for all locations tested above target for total suspended solids, compared to 25/35 exceedances for wet sample events. As the sampling season progressed into summer and fall, nearly all parameters experienced a drop-off in overall concentration. Also for summer and fall, dry event samples were predominant. The fall season experienced the best overall water quality at every sample location.

Exceedances of total phosphorous, total suspended solids and even e.coli were not common in the fall at all sample sites, with the exception of CP-11 for total phosphorous and e.coli which is an issue during the entire sample season at this location.

Site CP-11 in Chedoke Creek is by far the most impaired of the sample locations. The downstream proximity to a combined sewer overflow location, which discharges raw sewage into the creek during some high flow events, as well as the concrete and culverted nature of the creek are likely reasons that this location is experiencing poor water quality. E.coli, total phosphorous, unionized ammonia and nitrite were much higher at CP-11 than at all other locations.

Total phosphorous exceeded the target objective on >50% of sample events for all locations except AC-1, AC-2 and AC-3. These three locations saw a drop-off in TP exceedances beginning in July, after which most sample events were dry. 2015 TP (mean) concentrations were similar to 2014 for Cp-11, CP-18.1 and CP-7, while 2015 concentrations were increased for AC-1, AC-2 and AC-4.

The sites experiencing the most issues with TSS are AC-1, AC-2, AC-3 and AC-4. When analyzing the data results from the different seasons, it becomes clear that a disproportional amount of high TSS concentrations is taking place in spring which has a large amount of rain and spring runoff sample events. On the April 20th sample event, the AC sites experienced severely high TSS concentrations (highest of 1060 mg/L @ AC-4 and lowest of 739 mg/L at AC-3). These concentrations are much higher when compared to any other TSS result taken in 2015. It would seem a large portion of the sediment being moved downstream and deposited in the marsh from Ancaster Creek is happening early in the year, and during wet events.

Although site CP-18.1 in Borers Creek had TP exceedances 11/17 sample events, it still had the lowest average concentration at the end of the sample season. It also had the fewest amount of e.coli exceedances (8/17) as well as the lowest annual mean concentration.

Site CP-7 in Spencer Creek just downstream of Cootes Drive had 9 exceedances for TP in the 17 sample events, the highest concentrations taking place in April. Site AC-1 has a higher average TP and TSS concentrations than CP-7, and is about 500 meters upstream. This may imply that the TP concentration coming from Ancaster Creek is being diluted once it merges with Spencer Creek. Data from 2014 supports this finding as well. CP-7 also seems to be contributing high concentrations of e.coli in the summer months on dry sampling events.

2015 was the first year storm event sampling was added to the protocol. In fall of 2014 an automated sampler was installed at the AC-1 sample location for the purpose of collecting 24 surface water samples throughout the duration of the storm event. Once all the bottles have been filed with sample water, a water level logger attached to the intake pipe is used to determine water levels during the storm event. Using this data, a level-weighted sample is prepared and submitted for analysis. Due to technical difficulties with the equipment and early in the season, two storm events were captured in 2015. The data collected infers that water quality impairment during storm events is more severe than in baseflow conditions. Due to the lack of storm events captured, more data is required to begin analysis the magnitude to which Ancaster Creek is being impaired and the amount of sediments and nutrients that are being displaced during storm events.

Changes in sampling protocol from 2014 to 2015 could account for some of the changes we are seeing in water quality. It is clear that samples captured in the spring are higher in concentration for most parameters, but on the other hand water quality improved for the fall sampling season in most cases. However the concentrations were so high in the spring that the overall annual mean concentrations were still generally higher. In 2014 there was only one sample event classified at 'wet', whereas in 2015 we managed to capture 5 wet events (not including storm event samples). As pointed out earlier in this report, wet sample events resulted in much higher TSS and TP concentrations. Subsequently, it is important to note that there were 5 times as many wet sampling events this year compared to 2014.

Future Planned Monitoring Activities

For the 2016 sampling period, the HCA is looking to expand the sampling season to the full year (26 bi-weekly samples) as well as install two additional automated samplers in Spencer Creek. Interest in full-year sampling arose out of the large discrepancies in seasonal data gathered in 2015. It is in the best interest of the HCA and its partners to collect water quality data throughout the entire year to gain a better understanding of nutrient and sediment inputs during different climate conditions. All locations are proposed to be upgraded to a year-round grab sample protocol.

The addition of two automated samplers in Spencer Creek, one at the intersection with Market Street and one at the intersection of Highway 5, will provide us with a better understanding of storm water conditions in Spencer Creek as it passed from agricultural land use (Highway 5) to urban residential land use (Market Street). It will be interesting to discover what water chemistry characteristics are exhibited between the two sites. The data would be beneficial to local stewardship activities and would help to identify what sort of initiatives can be taken to improve water quality in the area.