Black Creek Assimilative Capacity Study

Draft Report

February 11, 2011

Regional Municipality of Halton

06-6413

Submitted by

Dillon Consulting Limited

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1. INTRODUCTION AND BACKGROUND

Dillon Consulting Limited (Dillon) is undertaking a Class Environmental Assessment (EA) for the Acton Wastewater Treatment Plant (WWTP) for the Regional Municipality of Halton. The Acton WWTP Class EA was initiated to identify the preferred alternative for addressing immediate and long-term wastewater treatment servicing for the community of Acton. Various alternative solutions are being considered including upgrading the existing Acton WWTP. The Acton WWTP discharges to Black Creek, which is a sensitive tributary of the Credit River, with a cold-water fishery. As part of the Class EA, a desktop assimilative capacity study of Black Creek was completed by Donald G. Weatherbe Associates Inc. in 2007. The desktop analysis of available data identified the need for additional information to be collected in the field during the summer of 2007 to address the potential impacts on Black Creek of the Acton WWTP expansion. Also, Dillon completed a spawning redd survey of Black Creek in 2006.

The 2007 field data were used by Donald G. Weatherbe Associates to finalize the assimilative capacity study by conducting mass balance calculations and modeling dissolved oxygen and temperature. In January 2011 Donald G. Weatherbe Associates provided an update to the draft assimilative capacity study originally completed in October 2007. This update incorporated additional flow data provided for years 2007 to 2009 and addressed specific comments received from the Ministry of Environment and Credit Valley Conservation Authority (CVC). Low flow analyses and assimilative capacity modelling calculations were updated to reflect recent data. Total phosphorous loading was also addressed.

The Regional Municipality of Halton has commenced a separate Class EA study for the Acton water supply to increase the permitted pumping capacity at the Prospect Park well field and expand the in-ground water storage volume to service future growth in the Acton urban area. Halton Region has also commenced a groundwater resource investigation to identify potential sites for a new municipal well field. If approvals are granted for these Acton water supply projects, the Acton WWTP will require an expansion. Although the EA is being completed for the ultimate plant expansion to 7,000 m^3/day, it is proposed that the expansion occurs in two phases. Most likely Phase 1 will increase the plant capacity to 5600m^3/d , and Phase 2 will increase the plant capacity to 7000m^3/day. Specific capacity to be constructed in each phase will be determined during preliminary design.

1.1 Spawning Redd Survey

The results of the spawning redd survey of Black Creek, which was completed in October 2006, is included as the **Part I appended** report. Based on the field survey, the presence of spawning redd as well as brook trout in Black Creek downstream of the Acton WWTP outfall was confirmed. Also, the presence of a spawning redd suggests that groundwater upwelling is occurring in Black Creek.

1.2 Assimilative Capacity Study Field Sampling

Field monitoring and sampling were completed from June to August 2007 to investigate the water quality and physical characteristics of Black Creek. The work consisted of the installation of temperature loggers, a bi-weekly water quality sampling program, intensive diurnal surveys in June and August, flow estimates, and benthic invertebrate sampling.

The Assimilative Capacity Field Study Report is included as the **Part II** appended report.

The monitoring stations for the field study are shown in **Figure 1.**

The following conclusions were made based on the field data collected:

- The background water quality shows evidence of elevated phosphorus, nitrite, and *E.Coli* in excess of the provincial and/or Canadian water quality objectives.
- Station B2 (immediately upstream of the WWTP) is significantly higher in both ammonia and TKN compared to all other sampling stations. The concentration of nitrate in the vicinity of the Acton WWTP outfall is elevated above the Canadian Water Quality Guideline (CWQG). This suggests that a backwater movement near the treatment plant outfall, potentially caused by beaver dam activity, may be contributing to the background water quality in this area. The marshy area upstream of the Acton WWTP may also be a potential source of ammonia and TKN. It is recommended that a new Station B2A be added (by CVC) upstream of Station B2 (i.e. between Station B2 and Station B1). The monitoring results for Station B2A could be compared to results for Station B2 to assess whether Station B2 has elevated concentrations due to a backwater movement.
- The dissolved oxygen concentration is generally above the Provincial Water Quality Objectives (PWQO) downstream of the WWTP. The dissolved oxygen concentration is generally below the PWQO at locations upstream of the Acton WWTP outfall, which may be due to a backwater movement near the treatment plant outfall. These data suggest that the receiver is assimilating the organic oxygen demand from the WWTP. The current Acton WWTP effluent DO concentration could be monitored to assess the need for aeration of the effluent, in the case of an expansion of the Acton WWTP. The need for mechanical mixing and/or aeration of the effluent would be considered in the design of the outfall, if required.
- Water temperature data collected upstream and downstream of the Acton WWTP outfall (Stations B2 and B3) suggested cold-water characteristics in this area of Black Creek. On

several days the maximum water temperature at almost all of the monitoring stations was above the CVC. Authority interim guideline of 20^{o}C for protection of the cold-water fishery. Monitoring Stations B2, B3, and B4 had the lowest water temperatures (at the 75th percentile) of those stations monitored indicating that the Acton WWTP effluent may not be causing an increase in the temperature of Black Creek.

- The monitoring station at the outlet from Fairy Lake (Station B1) had the highest water temperatures, reflecting its proximity to Fairy Lake.
- The North Branch of Black Creek at 6th Line (Station T1) exhibited warm-water conditions.
- Benthic invertebrate sampling at the monitoring station upstream of the Acton WWTP (Station B2) suggested that Black Creek water quality is slightly impaired in this reach.
- The estimated average flow rate increased significantly between the upstream monitoring Station B1 (Fairy Lake) and the downstream Station B6 (8th Line).
- The trend in water temperature decrease from the outlet from Fairy Lake (Station B1) to downstream locations and the net increase in system flow rates, in addition to WWTP effluent and other sources of surface water, suggests that the portion of Black Creek studied is affected by groundwater inputs.

1.3 Assimilative Capacity Modelling

Historical water quality data was collected and analyzed for Black Creek. Data collected as part of the summer 2007 field monitoring program was used to model the impact of wastewater discharge on dissolved oxygen (DO) and the temperature changes downstream. The water quality data and modelling results were used to further assess Black Creek water quality and determine the impact of a potential Acton WWTP expansion and increased discharge to the receiver. Flow data was updated with data collected between 2006 and 2009. The temperature and dissolved oxygen models considered a dilution effect based on the Black Creek cross-section flow measurements at each downstream sampling station.

The Acton Quarry (Dufferin Aggregates) discharges downstream of the Black Creek Sampling Station B2, which is located south of the intersection of Third Line and Glen Lawson Road. Low flow conditions and mass balance calculations for the assimilative capacity study were based on the impact of the Acton WWTP effluent at the point of discharge, and would not be affected by downstream dilution. Ellen Schmarje, Supervisor of the Environment-Water Resources Unit, Ontario Ministry of the Environment (MOE), indicated in a meeting with the Region of Halton on August 21, 2008 that the Acton WWTP would be reviewed under existing conditions, and that scenarios associated with reduced flows from the Acton Quarry will not be required as part of the Assimilative Capacity Study.

Historical data and assimilative capacity modelling results are included as the **Part III** appended report.

2. PROPOSED EFFLUENT QUALITY PARAMETERS

The current Acton WWTP Certificate of Approval (CofA) effluent objectives and limits are summarized in **Table 2.1** for an approved daily average flow of 4,545 m^3/d. Currently, for the parameters listed in Table 2.1, compliance is based on the average of annual or monthly samples, with the exception of un-ionized ammonia which is based on any single sample.

Table 2.1 Existing Acton WWTP CofA Effluent Objectives and Limits

Parameter	Effluent Objective	Effluent Limit
BOD_5	2 mg/L	5 mg/L
TSS	3 mg/L	5 mg/L
Total Phosphorus	0.2 mg/L	0.3 mg/L
(Ammonia + Ammonium) Nitrogen	1.0 mg/L	
Non-freezing period (May 1 – Nov. 31):		2.0 mg/L
Freezing period (Dec. 1 – April 30):		4.0 mg/L
Un-ionized Ammonia (any single sample)	--	0.1 mg/L
Escherichia Coli (monthly geometric mean density)	100 organisms/100mL	150 organisms/100mL

Effluent discharge guidelines are proposed for the expansion of the Acton WWTP to 7,000 m^3/d total flow based on the analysis of the assimilative capacity of Black Creek. Mass balance calculations were completed to derive effluent limits in the case of an upgrade and expansion. These calculations included low flow conditions in Black Creek and the 75th percentile of background water quality (1993-2006) upstream of the Acton WWTP outfall. Long-term background water quality is not anticipated to be impacted by backwater impacts and the Acton WWTP effluent. A further study to consider backwater impacts and background water quality characterization is not justified at this time. The proposed effluent objectives and limits for the facility expansion are shown in **Table 2.2;** a discussion follows. Effluent objectives and non-compliance limits would be compared to monthly average measured concentration.

Table 2.2 Proposed Acton WWTP Effluent Objectives and Limits for Expansion

Parameter	Effluent Objective	Effluent Limit
BOD_5	2 mg/L	5 mg/L
TSS	2 mg/L	5 mg/L
Total Phosphorus*		
Phase 1 (5,600 m^3/d)	0.1 mg/L (204 kg/yr)	0.2 mg/L (409 kg/yr)
Phase 2 (7,000 m^3/d)	0.1 mg/L (255 kg/yr)	0.2 mg/L (511 kg/yr)
(Ammonia + Ammonium) Nitrogen**		
Non-freezing period (May 1 – Nov. 31):	0.5 mg/L as N	2.0 mg/L as N
Freezing period (Dec. 1 – April 30):	1.0 mg/L as N	4.0 mg/L as N
Escherichia Coli (monthly geometric mean density)	100 organisms/100mL	150 organisms/100mL

* It is understood that the total phosphorus loading objective to the receiver will be maintained at its current loading of 156kg/yr. Refer to Section 2.3 for a description of the approach to total phosphorus management.

** The corresponding un-ionized ammonia values (based on effluent pH and temperature) are as follows:

- ammonia objective always meets the PWQO for unionized ammonia of 0.016 mg/L (or 0.02 mg/L as NH_3)
- ammonia limit always meets the acute target value for un-ionized ammonia of 0.08 mg/L as N (or the current single sample compliance limit of 0.1 mg/L as unionized NH_3).

2.1 Biochemical Oxygen Demand

The background water quality data indicates that the dissolved oxygen (DO) saturation in Black Creek downstream of the WWTP discharge is above the PWQO of 57% saturation and/or above the DO concentration objective of 5 mg/L. The five-day biological oxygen demand (BOD_5) effluent criteria in the case of an expansion can be maintained at the current concentration limits, as it is expected that the DO profile will not be affected. The proposed BOD_5 effluent objective and limit will remain at **2 mg/L** and **5 mg/L,** respectively. Compliance would be based on the monthly average concentration.

2.2 Total Suspended Solids

The historical total suspended solids (TSS) concentration in Black Creek, from 1993 to 2006, is 9 mg/L as measured at the 75th percentile observation (Donald G. Weatherbe Associates, 2011). There is currently no PWQO for TSS. The TSS effluent criteria in the case of an expansion can be maintained at the current concentration limits, as they are lower than the background water quality. The proposed TSS effluent objective and limit will remain at **2 mg/L** and **5 mg/L,** respectively. Compliance would be based on the monthly average concentration.

2.3 Phosphorus

Black Creek is considered a "Policy 2" type receiver with respect to total phosphorus (TP) since the background water quality in Black Creek exceeds the PWQO for TP of 0.030mg/L. Policy 2 of the MOE Water Management Policies Guidelines and PWQO states:

> "Water quality which presently does not meet the PWQOs shall not be further degraded and all practical measures shall be undertaken to upgrade the water quality to the objectives… Where new or expanded discharges are proposed, no further degradation will be permitted and all practical measures shall be undertaken to upgrade water quality." (MOE, 1994)

Based on comments provided by Ellen Schmarje and Ted Belayneh of the MOE, the WWTP effluent limits for expansion should be set to maintain the current measured loading of phosphorus. The average annual TP loading from Acton WWTP is 156.2 kg/yr (based on 2003-2009 data).

Effluent objectives for short and long term expansion flow rates will be set based on the expected performance of currently available technology. For both Phase 1 and Phase 2 expansion flow rate of 5,600 m^3/d and 7,000m^3/d, the proposed phosphorus objective is **0.1mg/L** and the phosphorus limit is **0.2 mg/L.** Compliance would be based on the monthly average concentration.

Based on the proposed effluent objective concentration for Phase 1 and Phase 2 expansion flow rates the corresponding loading would exceed current TP loads from Acton WWTP (i.e. 156kg/yr). The MOE has indicated that loadings in excess of current average values could be permitted, provided a total phosphorous offset program is undertaken. For the Phase 2 expansion flow rate of 7000 m^3/d, approximately 100 kg/yr of TP loading would have to be offset. If urban runoff controls are implemented, 200 kg/yr of TP loading would have to be controlled, at an offset ratio of 2 to 1. If rural runoff controls are implemented, 400 kg/yr of TP loading would have to be controlled, at an offset ratio of 4 to 1. The total offset requirement could be achieved through a combination of urban and rural controls. The TP loading requirement could also be met through technological improvements at the plant.

If the Region proposes to reduce the TP loading from the Acton WWTP expansion through TP offsets, a Policy 2 Deviation Request may need to be made to MOE by Halton Region.

2.4 Ammonia and Un-ionized Ammonia

The PWQO concentration of un-ionized ammonia nitrogen is 0.016 mg/L. The background water quality data in Black Creek is below this PWQO for un-ionized ammonia nitrogen. The WWTP effluent limits for expansion should be set to ensure that in-stream concentration of un-ionized ammonia in Black Creek is below the PWQO. Un-ionized ammonia exists in equilibrium with ammonia in water, depending on the temperature and pH; however, no provincial or Canadian water quality guidelines or objectives exist for ammonia. It is understood that the CofA in the case of an expansion of the Acton WWTP would be based on total ammonia nitrogen effluent criteria, as opposed to un-ionized ammonia effluent criteria.

The Acton WWTP effluent pH and temperature (monthly 75th percentile values) were found to yield more stringent and therefore more conservative ammonia concentration values, in comparison to the use of stream pH and temperature (for Black Creek). The proposed ammonia effluent objectives were set to ensure that the PWQO, or the un-ionized ammonia concentration value of 0.016 mg/L as N (or 0.02 mg/L as NH_3), was always met. The proposed ammonia effluent limits were set to always meet the unionized ammonia value of 0.08 mg/L as N (or the current single sample unionized ammonia compliance limit of 0.1 mg/L as NH_3), which is equivalent to the MOE target for acute toxicity. However, effluent at MOE compliance limits could exceed PWQO values for un-ionized ammonia at effluent temperature and pH.

The ammonia effluent criteria can be maintained at the current concentration limits in for an expansion. Ted Belayneh, Group Leader, Surface Water – Environment, Water Resources Unit, MOE, confirmed that the ammonia-nitrogen effluent criteria proposed for an expansion of the Acton WWTP would be acceptable to the MOE. Compliance would be based on the monthly average concentration data.

2.5 Nitrites and Nitrates

The CWQG provide a recommended maximum nitrite concentration of 0.018 mg/L as nitrogen. The observed nitrite concentration in Black Creek exceeds the CWQG at the 75th percentile observation at sampling points upstream and downstream of the Acton WWTP outfall. The concentration of nitrite in the Acton WWTP effluent is not significantly different from the other monitoring stations, and is therefore not the likely source of nitrite.

Background water quality in Black Creek exceeds the interim Canadian Water Quality Guideline (CWQG) for nitrate of 2.93 mg/L as nitrogen. This may be caused by a backwater effect near the outfall caused by a beaver dam or by a marshy upstream area. This concentration is intended as a screening value and the likelihood of direct effects of nitrate on aquatic life depends on the species present. The guideline derivation notes that amphibian egg and juvenile stages are among the most sensitive. The CWQG has not yet been adopted as a PWQO. Although specific amphibian studies were not carried out as part of the Assimilative Capacity Study, the habitat conditions observed during the fall 2006 spawning redd survey and the summer 2007 field work suggests that amphibian habitat is present in reaches located downstream of the Acton WWTP discharge area.

Although an effluent nitrite or nitrate concentration is not proposed in the case of an expansion of the Acton WWTP, a denitrification treatment process could be provided to reduce or at least maintain the current loading of nitrate-nitrogen to the receiver.

2.6 Escherichia Coli

Background water quality in Black Creek exceeds the PWQO for *E. coli*. The WWTP effluent will continue to use the existing concentration objective and limit of **100 organisms/100 mL** and **150 organisms/100 mL**, respectively. Compliance would be based on the monthly geometric mean density.

3. MITIGATION MEASURES AND MONITORING

It is technically feasible to upgrade the existing Acton WWTP based on the results of this Assimilative Capacity Study. An expansion of the existing treatment facility was identified as the preferred solution during the Class EA process. The following considerations should be addressed as part of detailed design for the preferred solution.

The 7Q20 (7-day average low flow that can be expected to occur once in 20 years which is the statistical flow applied in the evaluation of discharges to surface water) creek flow for Black Creek is equivalent to 1400 m^3/d. The minimum dilution ratio is equivalent to the ratio of the 7Q20 creek flow to the Acton WWTP effluent flow. The minimum dilution ratios for current flow and future expansion are provided in Table 3 below.

Table 3. Minimum Dilution Ratios for the Acton WWTP

	Minimum Dilution Ratio
Current (4,545 m^3/d)	0.31 to 1
Future – Short Term (5,600 m^3/d)	0.25 to 1
Future – Long Term (7,000 m^3/d)	0.20 to 1

There is no formal, written Ministry of the Environment Policy that requires maintaining a certain minimum dilution ratio for municipal wastewater discharges to watercourses. It has been a long established practice in Central Region, however, where feasible and practical, to encourage proponents to design their discharge such that a minimum dilution ratio of 10 to 1 is maintained even under low flow conditions such as the 7Q20. By doing so, it is expected that the risk for significant impact to the receiving stream is reduced if spills, bypasses and/or process upsets occur.

It is understood that expansion of the Acton WWTP must include appropriate mitigation and safety measures to account for the lack of additional buffering capacity in Black Creek.

The Acton WWTP Class EA considered appropriate mitigation and safety measures for peak flow management and these included:

- build additional offline equalization tank to accommodate peak instantaneous wet weather flow; and
- oversize certain plant process units to accommodate maximum hourly flows.

The EA recommended providing additional hydraulic capacity to handle peak wet weather flow in addition to monitoring the Acton WWTP effluent and Black Creek upstream and downstream of the WWTP outfall.

Concerns about high levels of chloride in the Acton WWTP effluent could be addressed by reducing salt use in water softeners. The Regional Municipality of Halton and the Town of Halton Hills could require new developments to install high efficiency water softeners. In addition, existing water softener users could be encouraged through incentives to replace their current models with more efficient ones.

It is understood that a monitoring program must be developed for Black Creek for the proposed expansion or upgrade of the Acton WWTP. The following is recommended as part of a monitoring program:

- quarterly monitoring of Acton WWTP effluent quality to establish background levels of metals;
- quarterly monitoring of Acton WWTP effluent toxicity to indicate acute toxicity;
- addition of chlorides to routine monitoring program;
- continuous monitoring of Black Creek quality downstream of Acton WWTP for in-stream dissolved oxygen, temperature, and conductivity;
- monitoring of nitrate concentration in the effluent, as well as upstream and downstream of the Acton WWTP outfall;
- annual monitoring of Black Creek for in-stream macroinvertebrates and fisheries; and
- investigation of Black Creek background water quality upstream of the Acton WWTP outfall. The marshy area between Fairy Lake and the Acton WWTP will be considered to determine if a natural source can explain the high levels of nitrogen compounds and the low dissolved oxygen observed immediately upstream of the Acton WWTP outfall. The impact of beaver activity on these parameters should also be considered, along with the potential impact of man-induced sources produced from the surrounding urban area.

A Spill Prevention Control and Countermeasures Plan could be prepared for the upgraded Acton WWTP to formalize plant operation to minimize the potential for spills, bypasses, or process upsets.

The Acton WWTP Class EA Environmental Study Report outlines the Region's various commitments related to the expansion of the Acton WWTP, such as:

- potential provision of denitrification treatment at the Acton WWTP;
- chloride management;
- an effluent and Black Creek monitoring program;
- beaver dam management, if backwater effects become evident; and
- implementation of mitigation measures.

PART I

SPAWNING REDD SURVEY

PART II

ASSIMILATIVE CAPACITY FIELD STUDY

DRAFT REPORT

PART III

ASSIMILATIVE CAPACITY MODELLING REPORT

TECHNICAL BRIEF

Acton WWTP Class Environmental Assessment, Halton Region

Black Creek Spawning Redd Survey

March 2007 (Revised January 2009)

06-6413

A spawning redd survey was conducted in Black Creek on October 27, 2006 by Dillon biologists (Mark Brobbel and Barry Myler) and a Credit Valley Conservation (CVC) aquatic biologist (Jon Clayton). The section of Black Creek surveyed began at the CVC station located downstream of Third Line and extended upstream to within the Black Creek Provincially Significant Wetland (PSW), located upstream of the Acton Wastewater Treatment Plant (WWTP) (**Figure 1**).

The survey was conducted by making systematic observations of streambed conditions, looking for disturbed/clean areas within fine or coarse substrates that may be used as spawning sites by salmonids, particularly the native brook trout (*Salvelinus fontinalis*). Site conditions at redd locations were documented, including visual descriptions of substrate and redd size, water depth, water temperature and general habitat characteristics.

As part of the survey, representative photographs were taken of Black Creek, working upstream to the Black Creek PSW. Survey findings were discussed as they pertain to the sensitivity of Black Creek for WWTP discharge.

Results

A description of general habitat attributes and spawning redd survey results is provided below (from downstream to upstream), with reference to photographs in **Attachment 1**. Photographs in **Attachment 1** show Black Creek conditions beginning at Third Line and progressing upstream beyond the WWTP discharge location. Photograph locations are also indicated on **Figure 1**. The field data sheet for the one confirmed spawning redd location is provided as **Attachment 2**.

Black Creek at Third Line was observed to have a wetted width of approximately 1.0 m, and an average depth of approximately 0.4 m within a mixture of riffle, run and pool habitat (**Plates 1, 2**). Cover was provided in the form of overhanging reed canary grass and undercut banks, and dense patches of watercress were observed at several locations in the streambed downstream of Third Line. The tree canopy was limited within this reach of the stream, which flowed through a beaver meadow. Although substrates in this area were noted to include coarse sands and fine gravels, no potential spawning redds were observed.

Brook trout have been captured by CVC in fish community sampling undertaken between 1999 and 2003 and from 2006 to 2008 at an established monitoring station downstream of Third Line (Bob Morris, CVC, Personal Communication). Eight additional native species were represented in the catches. Species presence by year at this sampling station has been summarized in **Table 1**.

Table 1. Summary of Fish Species Sampled by CVC at
"Black Creek Downstream of Third Line" Station, 1999-2003, 2006-2008

Common name	Scientific name	1999	2000	2001	2002	2003	2006	2007	2008
Eastern blacknose dace	*Rhinichthys atratulus*		✓	✓		✓	✓	✓	✓
Brook stickleback	*Culaea inconstans*	✓	✓	✓	✓	✓		✓	
Brook trout	*Salvelinus fontinalis*	✓	✓	✓	✓	✓	✓	✓	✓
Central mudminnow	*Umbra limi*	✓	✓	✓	✓	✓		✓	
Creek chub	*Semotilus atromaculatus*	✓	✓	✓	✓	✓	✓	✓	✓
Pumpkinseed	*Lepomis gibbosus*		✓						
Black crappie	*Pomoxis nigromaculatus*								✓
Northern redbelly dace	*Phoxinus eos*						✓		
White sucker	*Catostomus commersoni*	✓	✓	✓	✓	✓	✓	✓	✓
	Number of species:	5	7	6	5	6	5	6	5

*Compiled from CVC's electrofishing station summaries and Adrienne Ockenden, CVC Personal Communication, September 16, 2008

This station is considered a groundwater rich reach (Bob Morris, CVC, Personal Communication). CVC uses an Index of Biotic Integrity (IBI) scoring system, which is used to provide a measure of ecological health according to the biomass of a given species and its relative sensitivity or ecological importance. Based on calculated IBI scores, the Third Line station in Black Creek ranged between good and excellent ecological health in recent years.

Upstream of Third Line, several beaver dams were noted, including one approximately 100 m upstream of Third Line (**Plate 3**). Upstream of this beaver dam, Black Creek was noted to have a wetted width that averaged approximately 2.5 m within a mixture of riffle and run habitat (**Plate 4**). Substrates were dominated by fine gravels, and woody debris was noted to provide good cover opportunities for the fish community.

A steep cascade section of creek is located immediately downstream of the concrete arch railway crossing (**Plates 5-7**), with a perched concrete ledge causing an elevation drop of approximately 0.4 m downstream of the crossing (**Plate 7**). In the vicinity of this ledge and the cascading section of the watercourse, several large boulders were observed and extensive woody debris had accumulated (**Plates 6, 7**). A significant beaver dam was also observed at the upstream end of the railway crossing (**Plate 6**). The backwater effect of this beaver dam contributed to the slower moving flat located upstream of the railway crossing (**Plate 8**), where the creek was observed to have a wetted width approaching 3.0 m and pools that were greater than 1.0 m in depth. Within the flat, bottom substrates were dominated by sand, and submergent vegetation included curly-leaf pondweed and common waterweed.

Further upstream, Black Creek flows within a more densely wooded floodplain with additional evidence of beaver activity (**Plate 9**). Here, the valley was observed to be more defined compared to downstream reaches, with steep valley slopes encroaching to within a few metres of the creek in some areas (**Plates 10, 11**).

One confirmed brook trout spawning redd location was observed within Black Creek as a result of this survey (see **Attachment 2**). The redd location is shown on **Figure 1**, and was situated near the upper portion of the treed valley area, approximately 400 m downstream of the WWTP discharge location. The redd was located beneath a log (**Plates 12, 13**) in water depth of 0.6 – 0.7 m. The redd dimensions could not be determined due to its location beneath a log, but gravel substrates were observed. Creek morphology in the vicinity of the redd was comprised of run and pool habitat, although a riffle was observed downstream of the redd location. Two adult brook trout were observed at the redd; both were observed to have total estimated lengths in the 25-30 cm range. The tree canopy over Black Creek at the redd location was considered to be approximately 30%. An upstream groundwater seepage area was observed approximately 10-15 m upstream of the redd location. It is noteworthy that the water temperature of the seepage area (4 °C) was 3 °C colder than the Black Creek water temperature beside the redd (7 °C).

Upstream of the wooded valley, Black Creek was observed to flow as a more open reach through floating vegetated mats with dense overhanging reed canary grass (**Plate 14**). The average width of the channel ranged between approximately 1.0 and 2.0 m, and water depth ranged between 0.5-1.3 m. Dense instream cover for fish was observed in the form of undercut banks, overhanging reed canary grass, and some woody debris. In this reach, substrates were observed to include gravel and sand, and were considered suitable for spawning. While this reach was considered to provide potential spawning habitat, the dense cover, undercut banks, and shade from overhanging vegetation made visibility of the stream bottom difficult. Upstream of this reach, more beaver dams were noted in Black Creek (**Plate 15**) and the substrate size tended to be smaller (e.g., more sand, less gravel). The outfall of the WWTP is shown in **Plate 16**.

Upstream of the WWTP outfall, beaver activity was prevalent (**Plate 17**), and a series of dams were noted to result in slow-moving flooded conditions. Beyond the backwater effect of these beaver dams, substrates were observed to be coarser than the silts/sands observed immediately upstream of the beaver activity. Good pool and run habitat, with depths up to 1.2 m, was noted in an approximately 2 m wide channel through floating, vegetated mats (**Plate 18**). At the upstream end of the spawning survey area, a wide expanse of creek was created by a large beaver dam (**Plate 19**).

Discussion

Brook trout rely on groundwater upwellings to incubate their eggs over the winter and prevent their eggs from freezing. The presence of the confirmed spawning redd in Black Creek downstream of the WWTP, combined with the observations of brook trout, indicate that brook trout are using at least that portion of Black Creek as spawning habitat. To the knowledge of the investigators, brook trout were not previously documented in Black Creek upstream of CVC's Third Line sampling station. The presence of the spawning redd also suggests that groundwater upwelling is occurring in Black Creek. Groundwater seepage into Black Creek was also documented in an area immediately upstream of the redd location.

The findings of the spawning redd survey highlight the importance of considering the sensitivity of Black Creek to any potential change in discharge from the WWTP.

No spawning redds were documented upstream of the WWTP location, which is consistent with the findings of the 2004 fall spawning redd survey conducted by Dillon biologists as part of the Prospect Park Wellfield Impact Assessment. However, that study did indicate groundwater discharge conditions immediately upstream of the WWTP outfall location. It should be noted that spawning activity and resulting redds may not have been detected given the considerable cover afforded by overhanging vegetation, undercut banks and coarse woody debris.

Attachments:
Figure 1
Attachment 1 – Photographs
Attachment 2 – Spawning Redd Survey Field Data Sheet

Regional Municipality of Halton

PART II:

ASSIMILATIVE CAPACITY FIELD STUDY DRAFT REPORT

January 14, 2011 **06-6413**

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1. BACKGROUND

Field work was completed by Dillon Consulting Limited (Dillon) from June to August 2007 to investigate the water quality and physical characteristics of Black Creek as part of the Assimilative Capacity Study. The work consisted of the installation of temperature loggers, a bi-weekly water quality sampling program, intensive diurnal surveys in June and August, measurements of water depth and velocity to estimate flow, and benthic invertebrate sampling.

Figure 1.1 and **Table 1.1** outline the eight sampling locations.

Table 1.1 Sampling Program by Location

Sample Point	Location	Sampling Program
B1	Outlet from Fairy Lake	TC, DF, DS, BWS, FCG*
B2	Upstream of Acton WWTP	TC, DF, DS, FCG, BWS, BEN
B3	3rd Line/Glen Lawson	TC, DF, DS, FCG, BWS
B4	5th Line	DF, DS, FCG, BWS
B5	No. 17 Sideroad and 6th Line	TC, DF, DS, FCG, BWS
B6	8th Line (above confluence with Silver Cr.)	TC, DF, DS, FCG, BWS
S1	Acton WWTP effluent	DF, DS, Flow recorded, BWS
T1	North Branch Black Cr at 6th Line	TC, DF, DS, FCG, BWS

*to occur downstream of the outlet from Fairy Lake at the nearest appropriate location.

Table 1.2 presents the details of the sampling programs including the duration and frequency of sample collection.

Table 1.2 Sampling Program Description

Code	Description	Duration/Frequency
TC – Continuous Temperature	Continuously recording temperature (digitally recorded at time intervals of ten minutes)	June 1 to August 31
DF – Diurnal Field data	Dissolved oxygen, Temperature and pH	Over 24 hour period, either continuous or spot measurement each four hours. Diurnal Survey to occur once in June and once in August.

Code	Description	Duration/Frequency
DS – Diurnal Survey	24 hour composite (minimum four sub-samples) for eight parameters	During week of diurnal survey during base flow. Once per survey. Diurnal Survey to occur once in June and once in August.
FCG – Flow and channel geometry	Flow measurement including average width, velocity and depth	During week of diurnal survey (once per survey in June and August) and once in July, for a total of three measurements during base flow. Note that base flow measurements should be conducted when there has been no significant rainfall for the preceding four or more days.
BWS – bi-weekly samples	Grab samples taken every two weeks, preferably in dry weather, for eight parameters (also field pH, DO and Temperature)	From June 1 to August 30 – seven times. Can be coordinated with diurnal surveys.
BEN – Benthic Invertebrates	Sample and identification of benthic invertebrates	Once in late June

Historical Fish Community Data

A scoped review of historical fish community data was undertaken based on information received from Credit Valley Conservation (CVC) (Adrienne Ockenden, CVC Watershed Monitoring Specialist, Personal Communication, September 16, 2008) and by reviewing the Black Creek Subwatershed Study Background Report (CVC, 2009). This scoped review took place to provide additional information for consideration in the context of the Assimilative Capacity Study.

Brook trout have been captured by CVC in fish community sampling undertaken between 1999 and 2003 and from 2006 to 2008 at an established monitoring station downstream of Third Line (Bob Morris, CVC, Personal Communication). Species presence by year at this sampling station has been summarized in **Table 1.3**.

Table 1.3 Summary of Fish Species Sampled by CVC at "Black Creek Downstream of Third Line" Station, 1999-2003, 2006-2009

Common name	Scientific name	1999	2000	2001	2002	2003	2006	2007	2008	2009
Eastern blacknose dace	*Rhinichthys atratulus*		✓	✓		✓	✓	✓	✓	
Brook stickleback	*Culaea inconstans*	✓	✓	✓	✓	✓		✓		✓
Brook trout	*Salvelinus fontinalis*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Central mudminnow	*Umbra limi*	✓	✓	✓	✓	✓		✓		✓
Creek chub	*Semotilus atromaculatus*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Pumpkinseed	*Lepomis gibbosus*		✓							✓
Black crappie	*Pomoxis nigromaculatus*								✓	
Northern redbelly dace	*Phoxinus eos*						✓			
White sucker	*Catostomus commersoni*	✓	✓	✓	✓	✓	✓	✓	✓	✓
Brown bullhead	*Ameiurus nebulosus*									✓
Rock bass	*Ambloplites rupestris*									✓
Largemouth bass	*Micropterus salmoides*									✓
	Number of species:	5	7	6	5	6	5	6	5	

*Compiled from CVC's electrofishing station summaries and Adrienne Ockenden, CVC Personal Communication, September 16, 2008; and the Black Creek Subwatershed Study (February 2009).

The Black Creek at Acton Wetland Complex, which includes the reach of Black Creek downstream of the Acton WWTP, was evaluated by the Ontario Ministry of Natural Resources (MNR) in 1987. The evaluation was revisited in 2004 and the wetland was designated to be provincially significant (Emma Followes, MNR Aurora District, Personal Communication), based on the presence of redside dace (*Clinostomus elongatus*), which has a Species at Risk in Ontario (SARO) status of Endangered. However, based on a discussion with CVC, it is our understanding that the presence of redside dace may not be confirmed within this reach of Black Creek. Based on the results of further correspondence with MNR (Melinda Thompson-Black, MNR Species at Risk Biologist, Personal Communication, December 3, 2010), it is known that there are historical records of redside dace in Black Creek downstream of 5th Line, which is several kilometers downstream of the Acton WWTP.

2. BLACK CREEK WATER QUALITY

The following parameters were analyzed bi-weekly:

- Total Phosphorus
- Soluble Phosphorus
- Total Kjeldahl Nitrogen
- Total Ammonia Nitrogen
- Nitrate and Nitrite
- E. coli
- BOD (carbonaceous)
- Lab pH.

Field temperature, Dissolved Oxygen (DO), and pH were also recorded during the collection of bi-weekly grab samples. Diurnal surveys were completed twice (June 21/22 and August 28/29, 2007) to capture the daily pattern of DO, temperature, and field pH by measuring these parameters over a 24 hour period.

Water quality in Black Creek was evaluated for each parameter outlined above. The average and 75th percentile of observed values were calculated and reported. Each parameter was compared at the 75th percentile level to both the Provincial Water Quality Objective (PWQO) (MOE, 1994) and Environment Canada, Aquatic Water Quality Guidelines (CWQG) (Canadian Council of Ministers of the Environment (CCME), 2002). It should be noted that the 2007 data represent a single-point comparison and cannot be used alone to estimate water quality trends. **Table 2.1** through **Table 2.8** provides water quality summary data for each sampling location. Parameters reported as N/D were not detected since they were below the laboratory reportable detection limit. The laboratory reportable detection limit for BOD was 2 mg/L. **Figure 2.1** through **Figure 2.12** provide Tukey post-hoc comparisons of the average concentration of contaminants at each station, which are shown to illustrate the general trends in the concentration of parameters along the reach of Black Creek considered. These Tukey post-hoc comparisons were not considered when setting the Acton WWTP effluent quality limits and objectives, in the case of an expansion.

In the Tukey post-hoc figures, stations underlined in red are said to have average values not significantly different from each other. Where Tukey pairs overlap with one or more common stations but not all, then it is said that the un-paired stations are different from each other, but not significantly different from the common stations. In some figures, this can be interpreted as a gradual change in the water quality of the receiver (e.g., **Figure 2.5**). Some Tukey pairs are duplicated (i.e., include exactly the same stations). This duplication is not significant to reading the figures. Some figures (e.g., **Figure 2.1**) include a single underlined station, indicating that this station is significantly different from all others.

Table 2.1 Black Creek Water Quality, Sampling Station B1, Compared to Provincial and CCME Water Quality Objectives

Parameter	Summer 2007 Statistics				MOE PWQO, (Appendix A, 1999) mg/L except as noted	CCME CWQG, (1999 with Update 2, 2002) mg/L except as noted	Water Quality Comment (75th Percentile)
	Average	Min	Max	75th Percentile			
Total Ammonia-N, mg/L	0.117	0.060	0.200	0.14500	-	-	-
Total Kjeldahl Nitrogen (TKN), mg/L	0.714	0.600	0.800	0.75000	-	-	-
Un-ionized Ammonia, (Calculated, Ammonia) mg/L	0.006	0.001	0.013	0.00999	0.0164 as N	0.0156 as N	-
Bacteria, E. coli per 100 mL	237.1	20.0	410.0	295.0	100 E. coli per 100 mL	-	Exceeds PWQO
Biological Oxygen Demand (BOD), mg/L	2.0	N/D	2.0	2.0	-	-	-
Field Dissolved Oxygen*, mg/L	8	7	9	7	Derived from Saturation	9.5 mg/L, cold water early life biota	Below CWQG
Dissolved Oxygen*, (Calculated) % Sat.	90.1%	83.6%	109.9%	85.1%	57% Saturation, Cold Water Biota @ 20ºC	-	-
Nitrate-N, mg/L	0.271	0.200	0.400	0.30000	-	2.937 as N	-
Nitrite-N, mg/L	0.010	0.000	0.020	0.020	-	0.018 as N	Exceeds CWQG
Field pH	8.0	7.5	8.2	8.1	6.5 - 8.5	6.5 - 9.0	-
Dissolved Phosphorus, mg/L	0.006	0.003	0.009	0.00700	-	-	-
Total Phosphorus, mg/L	0.017	0.010	0.022	0.01950	0.03	-	-
Field Water Temperature, ºC	23.7	22.6	25.4	24.2	10ºC Increase, Max 30ºC	(Only marine limits specified)	-

* Note. Dissolved Oxygen evaluated at 25th percentile (and not 75th percentile)
N/D - Below Detection Limit

Table 2.2 Black Creek Water Quality, Sampling Station B2, Compared to Provincial and CCME Water Quality Objectives

Parameter	Summer 2007 Statistics				MOE PWQO, (Appendix A, 1999) mg/L except as noted	CCME CWQG, (1999 with Update 2, 2002) mg/L except as noted	Water Quality Comment (75th Percentile)
	Average	Min	Max	75th Percentile			
Total Ammonia-N, mg/L	1.59571	1.160	1.750	1.71000	-	-	-
Total Kjeldahl Nitrogen (TKN), mg/L	2.34286	1.900	2.500	2.50000	-	-	-
Un-ionized Ammonia, (Calculated, Ammonia) mg/L	0.01176	0.004	0.024	0.01360	0.0164 as N	0.0156 as N	-
Bacteria, E. coli per 100 mL	175.7	50.0	630.0	140.0	100 E. coli per 100 mL	-	Exceeds PWQO
Biological Oxygen Demand (BOD), mg/L	N/D	N/D	N/D	N/D	-	-	-
Field Dissolved Oxygen*, mg/L	5	3	10	4	Derived from Saturation	9.5 mg/L, cold water early life biota	Below CWQG
Dissolved Oxygen*, (Calculated) % Sat.	56.3%	38.0%	100.0%	41.5%	57% Saturation, Cold Water Biota @ 20ºC	-	Below PWQO
Nitrate-N, mg/L	2.54286	1.000	3.600	3.25000	-	2.937 as N	Exceeds CWQG
Nitrite-N, mg/L	0.289	0.200	0.390	0.325	-	0.018 as N	Exceeds CWQG
Field pH	7.3	6.8	7.6	7.4	6.5 - 8.5	6.5 - 9.0	-
Dissolved Phosphorus, mg/L	0.00857	0.005	0.016	0.00900	-	-	-
Total Phosphorus, mg/L	0.02529	0.012	0.038	0.02800	0.03	-	-
Field Water Temperature, ºC	17.8	17.0	19.2	18.1	10ºC Increase, Max 30ºC	(Only marine limits specified)	-

* Note. Dissolved Oxygen evaluated at 25th percentile (and not 75th percentile)
N/D - Below Detection Limit

Table 2.3 Black Creek Water Quality, Sampling Station B3, Compared to Provincial and CCME Water Quality Objectives

Parameter	Summer 2007 Statistics				MOE PWQO, (Appendix A, 1999) mg/L except as noted	CCME CWQG, (1999 with Update 2, 2002) mg/L except as noted	Water Quality Comment (75th Percentile)
	Average	Min	Max	75th Percentile			
Total Ammonia-N, mg/L	0.15143	0.090	0.300	0.18000	-	-	-
Total Kjeldahl Nitrogen (TKN), mg/L	0.94286	0.800	1.100	1.05000	-	-	-
Un-ionized Ammonia, (Calculated, Ammonia) mg/L	0.00229	0.001	0.004	0.00315	0.0164 as N	0.0156 as N	-
Bacteria, E. coli per 100 mL	144.3	70.0	230.0	175.0	100 E. coli per 100 mL	-	Exceeds PWQO
Biological Oxygen Demand (BOD), mg/L	N/D	N/D	N/D	N/D	-	-	-
Field Dissolved Oxygen*, mg/L	8	7	10	7	Derived from Saturation	9.5 mg/L, cold water early life biota	Below CWQG
Dissolved Oxygen*, (Calculated) % Sat.	87.3%	77.1%	105.8%	77.9%	57% Saturation, Cold Water Biota @ 20ºC	-	-
Nitrate-N, mg/L	6.75714	4.200	8.800	7.60000	-	2.937 as N	Exceeds CWQG
Nitrite-N, mg/L	0.136	0.110	0.200	0.150	-	0.018 as N	Exceeds CWQG
Field pH	7.6	7.3	7.8	7.8	6.5 - 8.5	6.5 - 9.0	-
Dissolved Phosphorus, mg/L	0.02057	0.018	0.028	0.02000	-	-	-
Total Phosphorus, mg/L	0.03914	0.031	0.053	0.04050	0.03	-	Exceeds PWQO
Field Water Temperature, ºC	18.0	17.0	20.0	18.1	10ºC Increase, Max 30ºC	(Only marine limits specified)	-

* Note. Dissolved Oxygen evaluated at 25th percentile (and not 75th percentile)
N/D - Below Detection Limit

Table 2.4 Black Creek Water Quality, Sampling Station B4, Compared to Provincial and CCME Water Quality Objectives

Parameter	Summer 2007 Statistics				MOE PWQO, (Appendix A, 1999) mg/L except as noted	CCME CWQG, (1999 with Update 2, 2002) mg/L except as noted	Water Quality Comment (75th Percentile)
	Average	Min	Max	75th Percentile			
Total Ammonia-N, mg/L	0.10667	0.050	0.210	0.13500	-	-	-
Total Kjeldahl Nitrogen (TKN), mg/L	0.65714	0.500	0.900	0.70000	-	-	-
Un-ionized Ammonia, (Calculated, Ammonia) mg/L	0.00309	0.002	0.006	0.00384	0.0164 as N	0.0156 as N	-
Bacteria, E. coli per 100 mL	168.6	70.0	480.0	155.0	100 E. coli per 100 mL	-	Exceeds PWQO
Biological Oxygen Demand (BOD), mg/L	N/D	N/D	N/D	N/D	-	-	-
Field Dissolved Oxygen*, mg/L	9	8	11	8	Derived from Saturation	9.5 mg/L, cold water early life biota	Below CWQG
Dissolved Oxygen*, (Calculated) % Sat.	94.5%	84.6%	115.9%	86.8%	57% Saturation, Cold Water Biota @ 20ºC	-	Equivalent to PWQO
Nitrate-N, mg/L	3.61429	2.400	4.500	4.00000	-	2.937 as N	Exceeds CWQG
Nitrite-N, mg/L	0.010	0.000	0.040	0.015	-	0.018 as N	-
Field pH	7.8	7.5	8.1	8.0	6.5 - 8.5	6.5 - 9.0	-
Dissolved Phosphorus, mg/L	0.01657	0.012	0.022	0.01700	-	-	-
Total Phosphorus, mg/L	0.02743	0.016	0.046	0.03100	0.03	-	Exceeds PWQO
Field Water Temperature, ºC	16.9	16.0	18.9	17.1	10ºC Increase, Max 30ºC	(Only marine limits specified)	-

* Note. Dissolved Oxygen evaluated at 25th percentile (and not 75th percentile)
N/D - Below Detection Limit

Table 2.5 Black Creek Water Quality, Sampling Station B5, Compared to Provincial and CCME Water Quality Objectives

Parameter	Summer 2007 Statistics				MOE PWQO, (Appendix A, 1999) mg/L except as noted	CCME CWQG, (1999 with Update 2, 2002) mg/L except as noted	Water Quality Comment (75th Percentile)
	Average	Min	Max	75th Percentile			
Total Ammonia-N, mg/L	0.12000	0.060	0.160	0.15000	-	-	-
Total Kjeldahl Nitrogen (TKN), mg/L	0.64286	0.500	0.700	0.70000	-	-	-
Un-ionized Ammonia, (Calculated, Ammonia) mg/L	0.01115	0.007	0.016	0.01342	0.0164 as N	0.0156 as N	-
Bacteria, E. coli per 100 mL	172.9	70.0	460.0	170.0	100 E. coli per 100 mL	-	Exceeds PWQO
Biological Oxygen Demand (BOD), mg/L	N/D	N/D	N/D	N/D	-	-	-
Field Dissolved Oxygen*, mg/L	10	9	12	9	Derived from Saturation	9.5 mg/L, cold water early life biota	Below CWQG
Dissolved Oxygen*, (Calculated) % Sat.	108.8%	95.2%	134.2%	99.4%	57% Saturation, Cold Water Biota @ 20ºC	-	-
Nitrate-N, mg/L	3.41429	2.800	4.000	3.65000	-	2.937 as N	Exceeds CWQG
Nitrite-N, mg/L	0.001	0.000	0.010	N/D	-	0.018 as N	-
Field pH	8.3	7.9	8.5	8.4	6.5 - 8.5	6.5 - 9.0	-
Dissolved Phosphorus, mg/L	0.01029	0.006	0.014	0.01100	-	-	-
Total Phosphorus, mg/L	0.02000	0.012	0.032	0.02200	0.03	-	-
Field Water Temperature, ºC	18.9	17.4	21.7	19.4	10ºC Increase, Max 30ºC	(Only marine limits specified)	-

* Note. Dissolved Oxygen evaluated at 25th percentile (and not 75th percentile)
N/D - Below Detection Limit

Table 2.6 Black Creek Water Quality, Sampling Station B6, Compared to Provincial and CCME Water Quality Objectives

Parameter	Summer 2007 Statistics				MOE PWQO, (Appendix A, 1999) mg/L except as noted	CCME CWQG, (1999 with Update 2, 2002) mg/L except as noted	Water Quality Comment (75th Percentile)
	Average	Min	Max	75th Percentile			
Total Ammonia-N, mg/L	0.09333	0.060	0.160	0.11000	-	-	-
Total Kjeldahl Nitrogen (TKN), mg/L	0.54286	0.400	0.700	0.60000	-	-	-
Un-ionized Ammonia, (Calculated, Ammonia) mg/L	0.00640	0.003	0.011	0.00813	0.0164 as N	0.0156 as N	-
Bacteria, E. coli per 100 mL	180.0	80.0	310.0	225.0	100 E. coli per 100 mL	-	Exceeds PWQO
Biological Oxygen Demand (BOD), mg/L	N/D	N/D	N/D	N/D	-	-	-
Field Dissolved Oxygen*, mg/L	10	9	13	10	Derived from Saturation	9.5 mg/L, cold water early life biota	-
Dissolved Oxygen*, (Calculated) % Sat.	112.1%	94.4%	136.9%	100.8%	57% Saturation, Cold Water Biota @ 20ºC	-	-
Nitrate-N, mg/L	3.00000	2.800	3.300	3.05000	-	2.937 as N	Exceeds CWQG
Nitrite-N, mg/L	0.006	0.000	0.020	0.010	-	0.018 as N	-
Field pH	8.2	7.9	8.4	8.4	6.5 - 8.5	6.5 - 9.0	-
Dissolved Phosphorus, mg/L	0.00714	0.004	0.010	0.00750	-	-	-
Total Phosphorus, mg/L	0.01329	0.007	0.019	0.01650	0.03	-	-
Field Water Temperature, ºC	18.8	17.0	21.8	19.2	10ºC Increase, Max 30ºC	(Only marine limits specified)	-

* Note. Dissolved Oxygen evaluated at 25th percentile (and not 75th percentile)
N/D - Below Detection Limit

Table 2.7 Black Creek Water Quality, Sampling Station S1, Compared to Provincial and CCME Water Quality Objectives

Parameter	Summer 2007 Statistics				MOE PWQO, (Appendix A, 1999) mg/L except as noted	CCME CWQG, (1999 with Update 2, 2002) mg/L except as noted	Water Quality Comment (75th Percentile)
	Average	Min	Max	75th Percentile			
Total Ammonia-N, mg/L	0.08400	0.070	0.090	0.09000	-	-	-
Total Kjeldahl Nitrogen (TKN), mg/L	1.02857	0.900	1.300	1.05000	-	-	-
Un-ionized Ammonia, (Calculated, Ammonia) mg/L	0.00034	0.000	0.000	0.00040	0.0164 as N	0.0156 as N	-
Bacteria, E. coli per 100 mL	13.3	10.0	20.0	15.0	100 E. coli per 100 mL	-	-
Biological Oxygen Demand (BOD), mg/L	N/D	N/D	N/D	N/D	-	-	-
Field Dissolved Oxygen*, mg/L	6	5	7	5	Derived from Saturation	9.5 mg/L, cold water early life biota	Below CWQG
Dissolved Oxygen*, (Calculated) % Sat.	60.9%	54.7%	73.4%	56.8%	57% Saturation, Cold Water Biota @ 20ºC	-	Below PWQO
Nitrate-N, mg/L	16.28571	12.000	21.000	18.50000	-	2.937 as N	Exceeds CWQG
Nitrite-N, mg/L	0.007	0.000	0.050	N/D	-	0.018 as N	-
Field pH	7.1	6.9	7.2	7.1	6.5 - 8.5	6.5 - 9.0	-
Dissolved Phosphorus, mg/L	0.06186	0.044	0.090	0.06600	-	-	-
Total Phosphorus, mg/L	0.08186	0.067	0.100	0.08850	0.03	-	Exceeds PWQO
Field Water Temperature, ºC	19.4	17.1	21.0	20.7	10ºC Increase, Max 30ºC	(Only marine limits specified)	-

* Note. Dissolved Oxygen evaluated at 25th percentile (and not 75th percentile)
N/D - Below Detection Limit

Table 2.8 Black Creek Water Quality, Sampling Station T1, Compared to Provincial and CCME Water Quality Objectives

Parameter	Summer 2007 Statistics				MOE PWQO, (Appendix A, 1999) mg/L except as noted	CCME CWQG, (1999 with Update 2, 2002) mg/L except as noted	Water Quality Comment (75th Percentile)
	Average	Min	Max	75th Percentile			
Total Ammonia-N, mg/L	0.15000	0.110	0.190	0.17000	-	-	-
Total Kjeldahl Nitrogen (TKN), mg/L	0.52857	0.400	0.800	0.55000	-	-	-
Un-ionized Ammonia, (Calculated, Ammonia) mg/L	0.01293	0.011	0.015	0.01377	0.0164 as N	0.0156 as N	-
Bacteria, E. coli per 100 mL	157.1	110.0	230.0	180.0	100 E. coli per 100 mL	-	Exceeds PWQO
Biological Oxygen Demand (BOD), mg/L	N/D	N/D	N/D	N/D	-	-	-
Field Dissolved Oxygen*, mg/L	9	8	11	9	Derived from Saturation	9.5 mg/L, cold water early life biota	Below CWQG
Dissolved Oxygen*, (Calculated) % Sat.	102.7%	89.2%	124.2%	95.8%	57% Saturation, Cold Water Biota @ 20ºC	-	Equivalent to PWQO
Nitrate-N, mg/L	0.91429	0.300	1.500	1.35000	-	2.937 as N	-
Nitrite-N, mg/L	N/D	0.000	0.000	N/D	-	0.018 as N	-
Field pH	8.2	7.8	8.5	8.4	6.5 - 8.5	6.5 - 9.0	-
Dissolved Phosphorus, mg/L	0.00857	0.005	0.010	0.00950	-	-	-
Total Phosphorus, mg/L	0.01514	0.011	0.018	0.01700	0.03	-	-
Field Water Temperature, ºC	20.3	18.8	22.9	20.7	10ºC Increase, Max 30ºC	(Only marine limits specified)	-

* Note. Dissolved Oxygen evaluated at 25th percentile (and not 75th percentile)
N/D - Below Detection Limit

Total Ammonia-N, mg/L

	S1	B6	B4	B1	B5	T1	B3	B2
Samples	5	3	3	6	3	2	7	7
Avg	0.084	0.093333	0.106667	0.116667	0.12	0.15	0.151429	1.595714

Tukey Stats

MSE : 0.012159	m : 8	v : 28	α : 0.05
$Q_{\alpha,m,v}$: 4.68			
w : 0.243267			

Figure 2.1 Total Ammonia-N Tukey Pairing of Average Values

Total Kjeldahl Nitrogen (TKN), mg/L

	T1	B6	B5	B4	B1	B3	S1	B2
Samples	7	7	7	7	7	7	7	7
Avg	0.528571	0.542857	0.642857	0.657143	0.714286	0.942857	1.028571	2.342857

Tukey Stats

MSE : 0.01756	m : 8	v : 48	α : 0.05
$Q_{\alpha,m,v}$: 4.52			
w : 0.226384			

Figure 2.2 TKN Tukey Pairing of Average Values

Unionozed Ammonia-N, (Calculated) mg/L

	S1	B3	B4	B1	B6	B5	B2	T1
Samples	5	7	3	6	3	3	7	2
Avg	0.000344	0.002286	0.003087	0.006041	0.006405	0.011146	0.011764	0.012925

Tukey Pairs

Tukey Stats

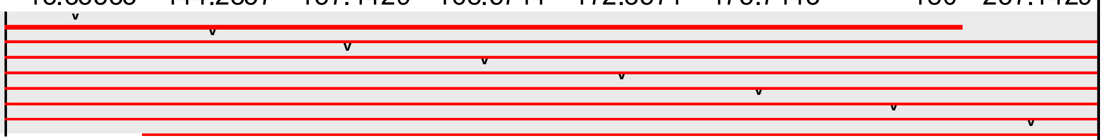
MSE :	1.77E-05	m : 8	v : 28	α : 0.05
$Q_{\alpha,m,v}$:	4.68			
w :	0.009274			

Figure 2.3 Unionized Ammonia-N Tukey Pairing of Average Values

Escherichia Coli, CFU/100mL

	S1	B3	T1	B4	B5	B2	B6	B1
Samples	3	7	7	7	7	7	7	7
Avg	13.33333	144.2857	157.1429	168.5714	172.8571	175.7143	180	237.1429

Tukey Pairs



Tukey Stats

MSE :	14561.9	m : 8	v : 44	α : 0.05
$Q_{\alpha,m,v}$:	4.52			
w :	213.9394			

Figure 2.4 E-Coli Tukey Pairing of Average Values

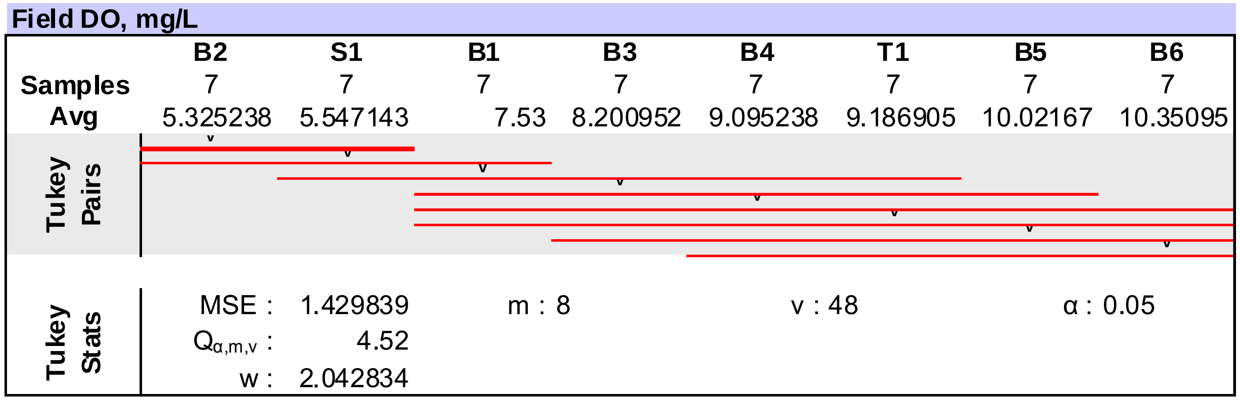


Figure 2.5 Field Dissolved Oxygen Tukey Pairing of Average Values

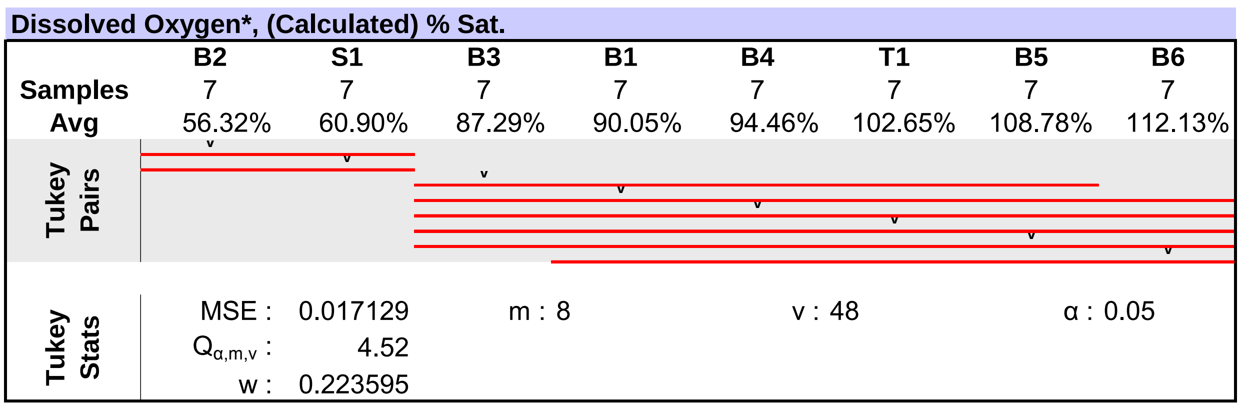


Figure 2.6 Dissolved Oxygen Saturation Tukey Pairing of Average Values

Nitrate (N), mg/L	B1	T1	B2	B6	B5	B4	B3	S1
Samples	7	7	7	7	7	7	7	7
Avg	0.271429	0.914286	2.542857	3	3.414286	3.614286	6.757143	16.28571

Tukey Pairs

Tukey Stats

MSE :	2.071726	m : 8	v : 48	α : 0.05
$Q_{\alpha,m,v}$:	4.52			
w :	2.458983			

Figure 2.7 Nitrate-N Tukey Pairing of Average Values

Nitrite (N), mg/L	T1	B5	B6	S1	B1	B4	B3	B2
Samples	7	7	7	7	7	7	7	7
Avg	0	0.001429	0.005714	0.007143	0.01	0.01	0.135714	0.288571

Tukey Pairs

Tukey Stats

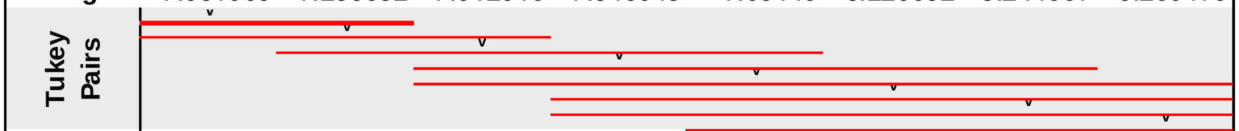
MSE :	0.00088	m : 8	v : 48	α : 0.05
$Q_{\alpha,m,v}$:	4.52			
w :	0.05069			

Figure 2.8 Nitrite-N Tukey Pairing of Average Values

Field pH,

	S1	B2	B3	B4	B1	T1	B6	B5
Samples	7	7	7	7	7	7	7	7
Avg	7.051905	7.285952	7.612619	7.849048	7.95119	8.220952	8.241667	8.290476

Tukey Pairs



Tukey Stats

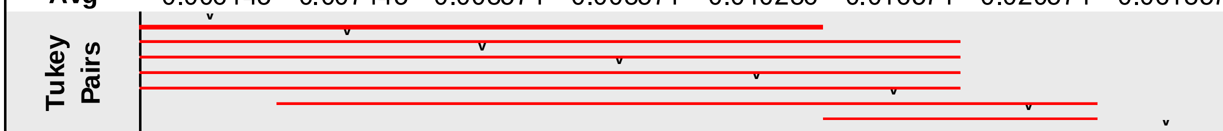
MSE : 0.054088   m : 8   v : 48   α : 0.05
$Q_{\alpha,m,v}$: 4.52
w : 0.397321

Figure 2.9 Field pH Tukey Pairing of Average Values

Dissolved Phosphorus, mg/L

	B1	B6	B2	T1	B5	B4	B3	S1
Samples	7	7	7	7	7	7	7	7
Avg	0.006143	0.007143	0.008571	0.008571	0.010286	0.016571	0.020571	0.061857

Tukey Pairs



Tukey Stats

MSE : 3.36E-05   m : 8   v : 48   α : 0.05
$Q_{\alpha,m,v}$: 4.52
w : 0.009903

Figure 2.10 Dissolved Phosphorus Tukey Pairing of Average Values

Total Phosphorus, mg/L

	B6	T1	B1	B5	B2	B4	B3	S1
Samples	7	7	7	7	7	7	7	7
Avg	0.013286	0.015143	0.016571	0.02	0.025286	0.027429	0.039143	0.081857

Tukey Pairs

Tukey Stats

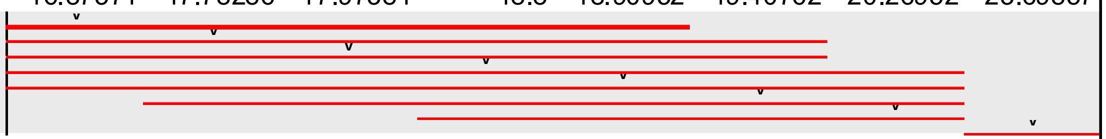
MSE : 5.32E-05   m : 8   v : 48   α : 0.05
$Q_{\alpha,m,v}$: 4.52
w : 0.012459

Figure 2.11 Total Phosphorus Tukey Pairing of Average Values

Field Water Temp, oC

	B4	B2	B3	B6	B5	S1	T1	B1
Samples	7	7	7	7	7	7	7	7
Avg	16.87571	17.78286	17.97381	18.8	18.90952	19.40762	20.26952	23.69857

Tukey Pairs



Tukey Stats

MSE : 1.533166   m : 8   v : 48   α : 0.05
$Q_{\alpha,m,v}$: 4.52
w : 2.115359

Figure 2.12 Field Water Temperature Tukey Pairing of Average Values

2.1 Phosphorus

The PWQO for phosphorus of 0.030 mg/L is recommended to avoid excessive plant growth. Black Creek data indicate that this limit is exceeded at sampling stations S1 (the WWTP effluent) and stations B3 and B4 located downstream of the WWTP outfall with 75th percentile observed concentrations of 0.089 mg/L, 0.041 mg/L, and 0.031 mg/L, respectively. Tukey pairing indicates that the Acton WWTP outfall (Station S1) is significantly higher in phosphorus from all other stations with downstream stations becoming progressively lower in phosphorus concentrations.

2.2 Un-Ionized Ammonia

The PWQO and CWQG recommend upper limits for un-ionized ammonia of 0.0164 mg/L and 0.0156 mg/L as nitrogen, respectively, in natural waters. Since the available water quality data do not provide a direct measure of un-ionized ammonia, the statistics shown in **Table 2.1** through **Table 2.8** were calculated from the measured aqueous ammonia concentration and field pH. Un-ionized ammonia is calculated from ammonia and pH, as shown in the following equation:

Calculation of Un-ionized Ammonia

$$\text{un-ionized ammonia} = \text{ammonia} \cdot f$$

$$f = \frac{1}{1 + 10^{(pKa - pH)}}$$

$$pKa = 0.0901821 + \frac{2729.92}{T} \quad \textit{for T in Kelvin}$$

Calculated on this basis, the un-ionized ammonia concentration in Black Creek is below the CWQG at all sampling stations with the lowest recorded 75th percentile value of 0.0004 mg/L at station S1. Station B2 appears to be significantly higher in both ammonia and TKN concentrations according to the Tukey pairing; however, the impact of varying pH at each station appears to mitigate the unionized ammonia concentration at B2. Furthermore, Station B2 (upstream of the Acton WWTP outfall) is significantly higher in concentration than Station S1 (Acton WWTP effluent). This suggests that a backwater movement near the treatment plant outfall, potentially caused by beaver dam activity, may be contributing to the background water quality in this area. The marshy area upstream of the Acton WWTP may also be a potential source of ammonia and TKN.

2.3 Nitrites and Nitrates

The CWQG provide a recommended maximum nitrite concentration of 0.018 mg/L as nitrogen. The observed nitrite concentration in Black Creek exceeds the CWQG at the 75th percentile at sampling points B1, B2, and B3, with values of 0.020 mg/L, 0.325 mg/L, and 0.150 mg/L respectively. Monitoring stations B2 and B3, which are located upstream and downstream of the Acton WWTP outfall respectively, are significantly higher in nitrite concentration from the other stations suggesting a nitrite source near B2; however, Station S1 (Acton WWTP effluent) is not significantly different from the other Stations and is not the likely source of nitrite.

The CWQG provide a recommended maximum nitrate concentration of 2.937 mg/L as nitrogen. The observed nitrate concentrations in Black Creek exceed the CWQG at the 75th percentile observed level for all but sampling stations B1 (outlet from Fairy Lake) and T1 (north branch of Black Creek at 6th Line). The nitrate level rises from 0.300 mg/L at Station B1 to 3.250 mg/L at Station B2, again suggesting a nitrate source upstream of the WWTP, potentially due to a backwater movement near the treatment plant outfall. The Tukey pairing indicates that Station S1 (the WWTP effluent) is significantly higher than other stations, suggesting that the WWTP may be the source of nitrates. Nitrate concentrations downstream of Station B3 (3rd Line/Glen Lawson) are not significantly different from stations upstream of the Acton WWTP outfall.

2.4 Dissolved Oxygen and Biochemical Oxygen Demand

The PWQO and CWQG do not provide specific limits for biochemical oxygen demand (BOD). All stations had BOD readings below the detection limit (N/D), with the exception of a single sample at Station B1 (Fairy Lake outlet) with a concentration of 2 mg/L, which is equivalent to the laboratory reportable detection limit. DO concentration and saturation values were evaluated at the 25th percentile, as opposed to the 75th percentile, since lower values of these parameters indicate poorer water quality. DO saturation values were calculated in some instances to be above 100% which is generally observed in flowing waters that have some algae. It is noted that the dissolved oxygen concentration in the background water quality data is below the recommended PWQO saturation level at the 25th percentile level at Station B2 (upstream of the Acton WWTP outfall) and steadily increases downstream of the Acton WWTP outfall at Stations B4, B5, and B6 where the DO saturation is above the PWQO of 57% for cold water biota. Tukey pairing suggests that the DO saturation is not significantly different at any location downstream of the WWTP. This suggests that the current BOD load from the Acton WWTP is assimilated by the receiver.

DO measurements were collected in the field during the diurnal surveys (June 21/22 and August 28/29, 2007) to determine the daily pattern of these readings. **Figures 2.4.1 and 2.4.2** illustrate the field DO measurements collected in intervals of about four hour intervals over duration of about 20 hours at each monitoring station, for both the June and August diurnal surveys, respectively. As a rule of thumb, diurnal maximum and minimum DO concentrations that differ by 4 mg/L or more tend to be indicative of conditions of high algal growth and plant productivity. None of the stations considered had diurnal maximum and minimum DO concentrations that varied by more than about 2.4 mg/L during each of the diurnal surveys.

Figure 2.4.1 Diurnal Field Dissolved Oxygen Concentration June 21/22, 2007

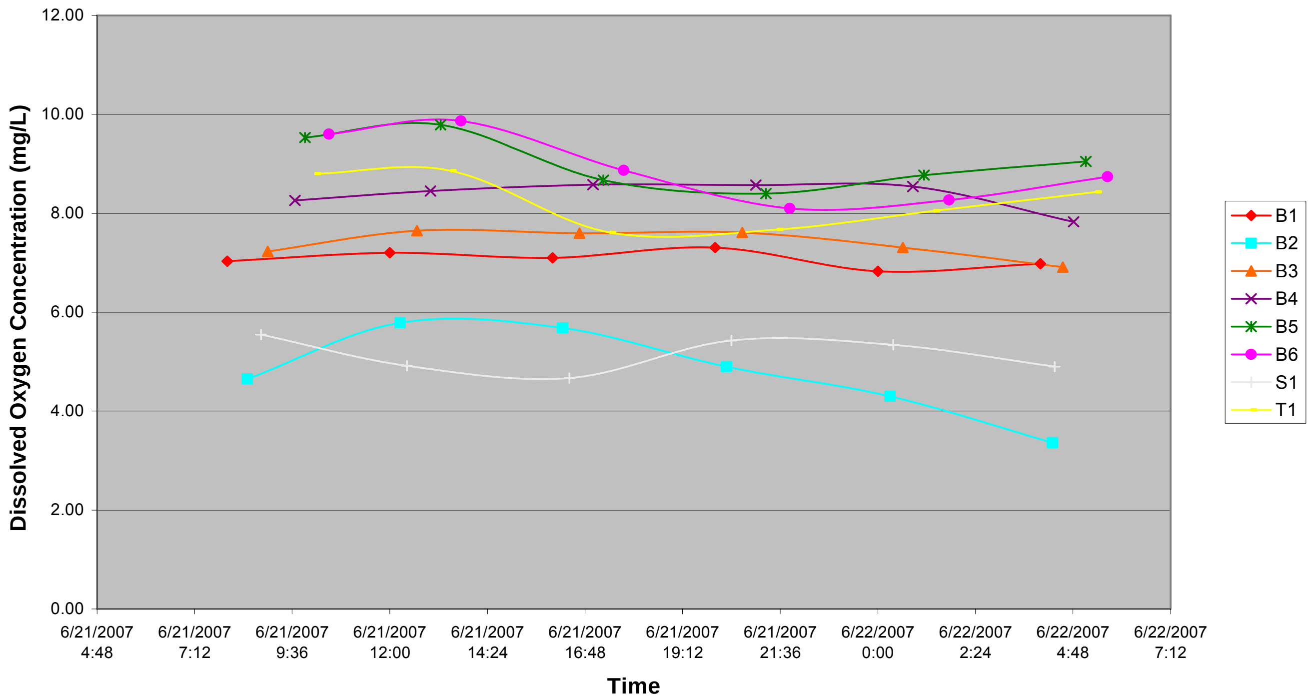
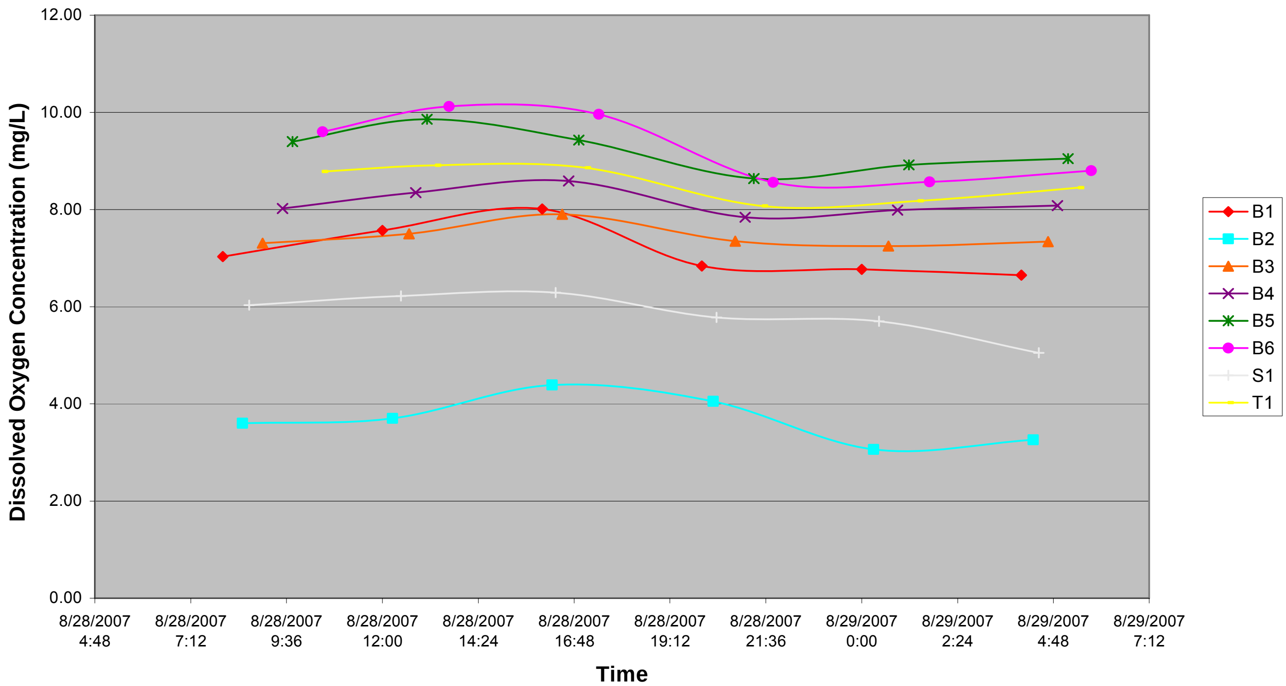


Figure 2.4.2 Diurnal Field Dissolved Oxygen Concentration
August 28/29, 2007



Figures 2.4.3 and 2.4.4 illustrate the calculated DO saturation values, based on the water temperature and DO concentration data, which was collected in the field at about four hour intervals over a duration of about 20 hours, at each monitoring station, for both the June and August diurnal surveys, respectively.

Figure 2.4.3 Diurnal Dissolved Oxygen Saturation (Calculated)
July 21/22, 2007

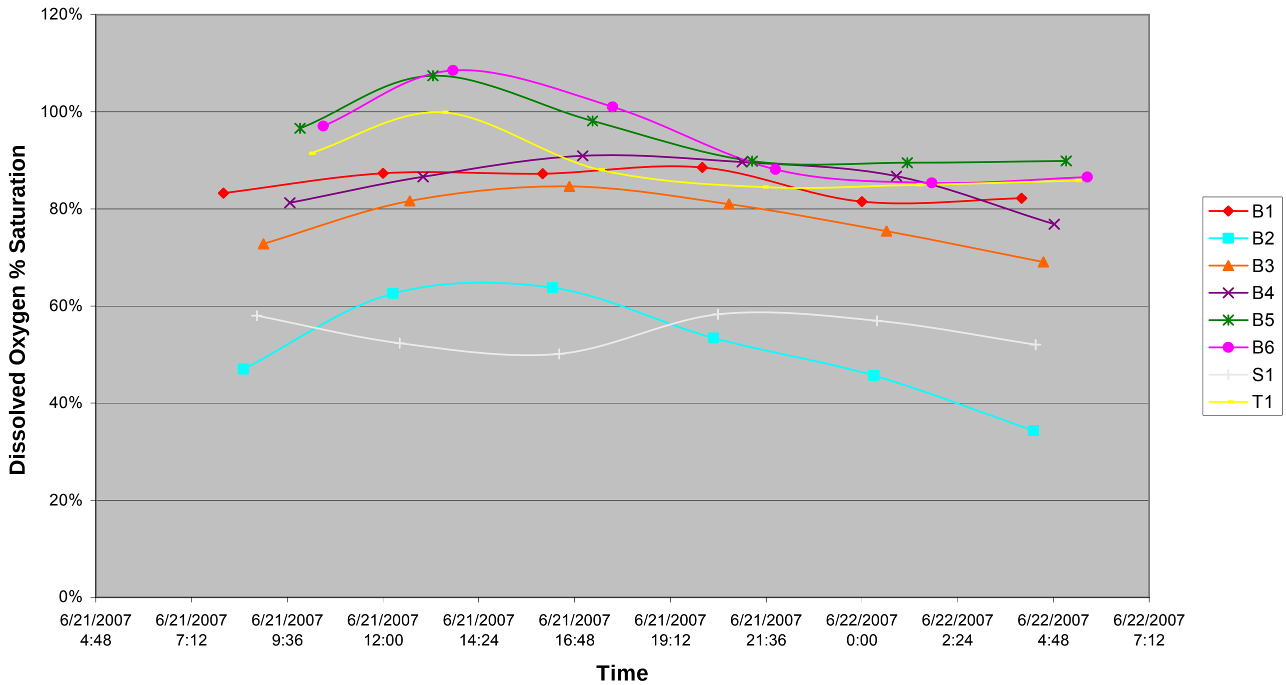
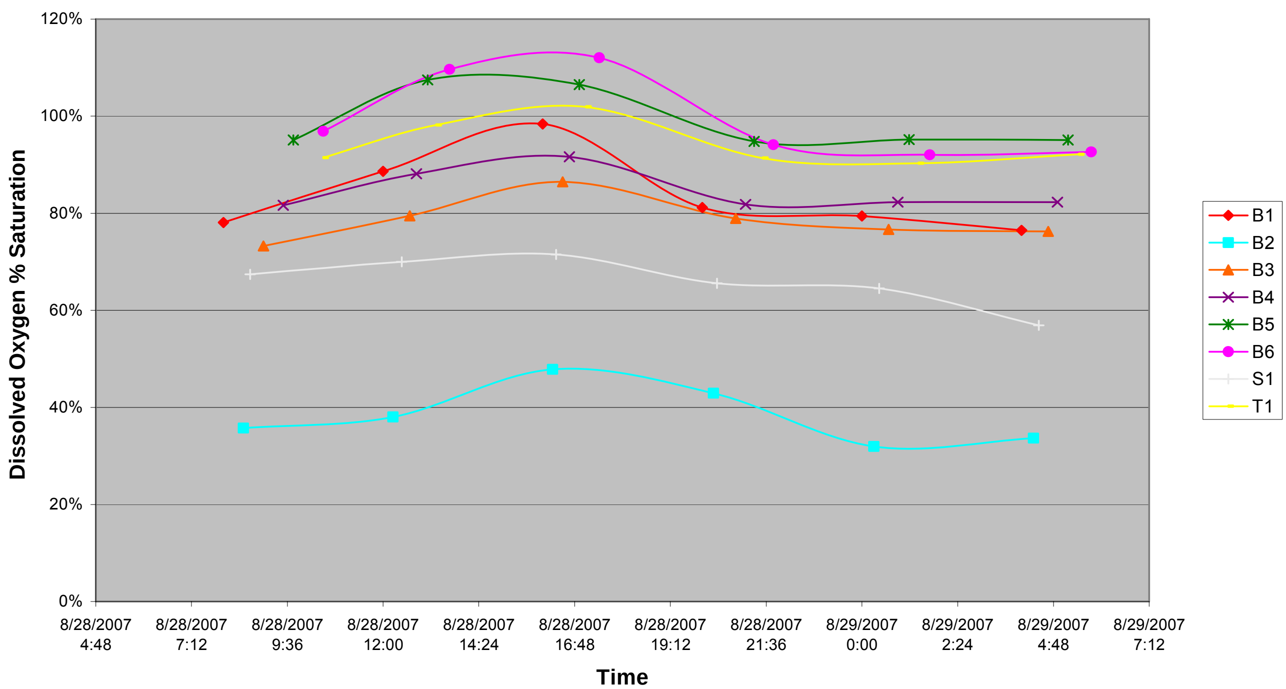


Figure 2.4.4 Diurnal Dissolved Oxygen Saturation (Calculated)
August 28/29, 2007



2.5 Escherichia Coli

The PWQO suggests a limit of 100 *E.Coli* per 100 mL. Most stations along Black Creek exceed these objectives with 75th percentile values ranging from 140 *E.Coli*/100mL to 295 *E.Coli*/100mL. Only the Acton WWP effluent (Station S1) is significantly different among the sampling locations with a 75th percentile value of 15.0 *E.Coli*/100mL.

3. BLACK CREEK WATER TEMPERATURE

3.1 Methods

Water temperature was continuously monitored in Black Creek (Stations B1, B5, B6) and in the North Branch of Black Creek (Station T1) from June 1 – August 31, 2007 using water temperature loggers (HOBO™ Water Temp Pro). Measurements were taken every ten minutes in an effort to better understand the thermal status of the stream and to examine diurnal water temperature fluctuations. In addition, CVC recorded water temperature in 2007 using the same equipment and measurement frequency within Black Creek at Stations B2 and B3.

Downloaded water temperature data from Dillon and CVC were summarized into daily average, daily minimum, and daily maximum temperatures for each station. These data were subsequently graphed with historical air temperature data provided for nearby Guelph, Ontario from the Environment Canada website (Guelph Turfgrass station). In addition, general comparisons were made with water temperature data collected by CVC at Stations B2 and B3 prior to 2007, based on a review of the Black Creek Subwatershed Study, Draft Background Report (CVC, September 2008).

3.2 Results and Discussion

Water temperature data (daily minimum, daily average, and daily maximum) are shown in **Figures 3.1 – 3.3**, with a comparison to daily air temperatures.

Figure 3.1 Black Creek Daily Minimum Water Temperature

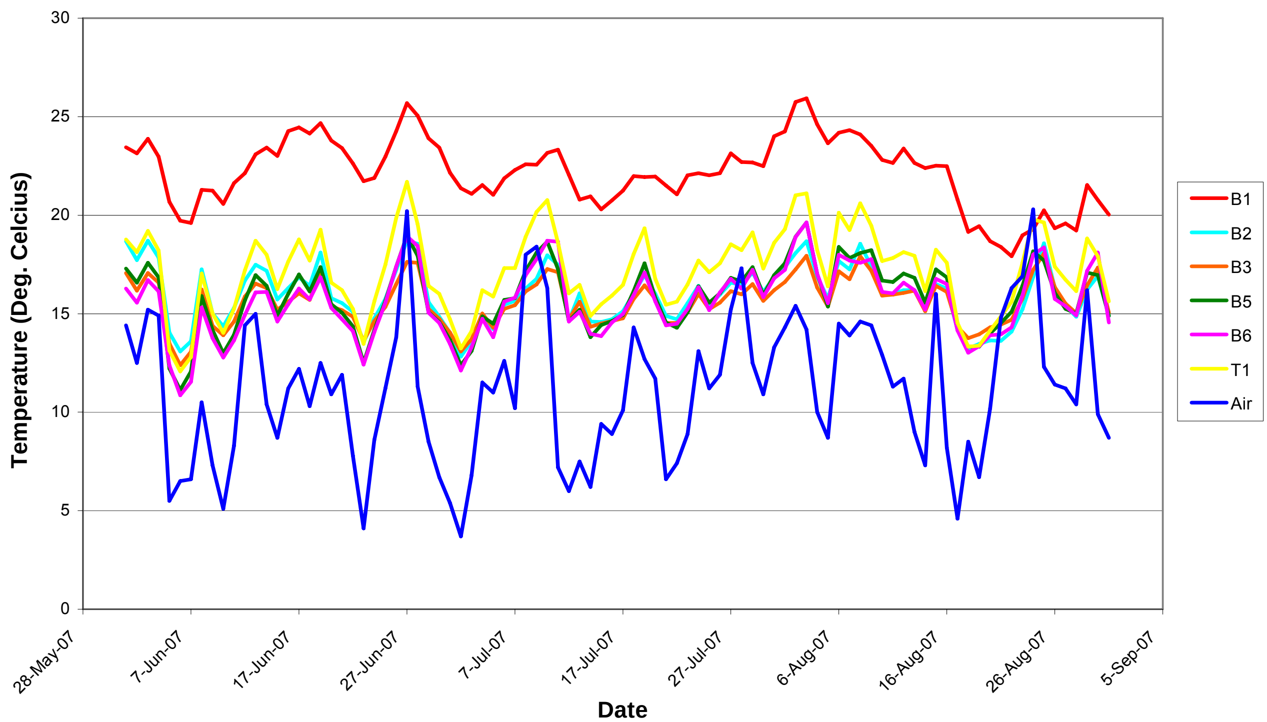


Figure 3.2 Black Creek Daily Average Water Temperature

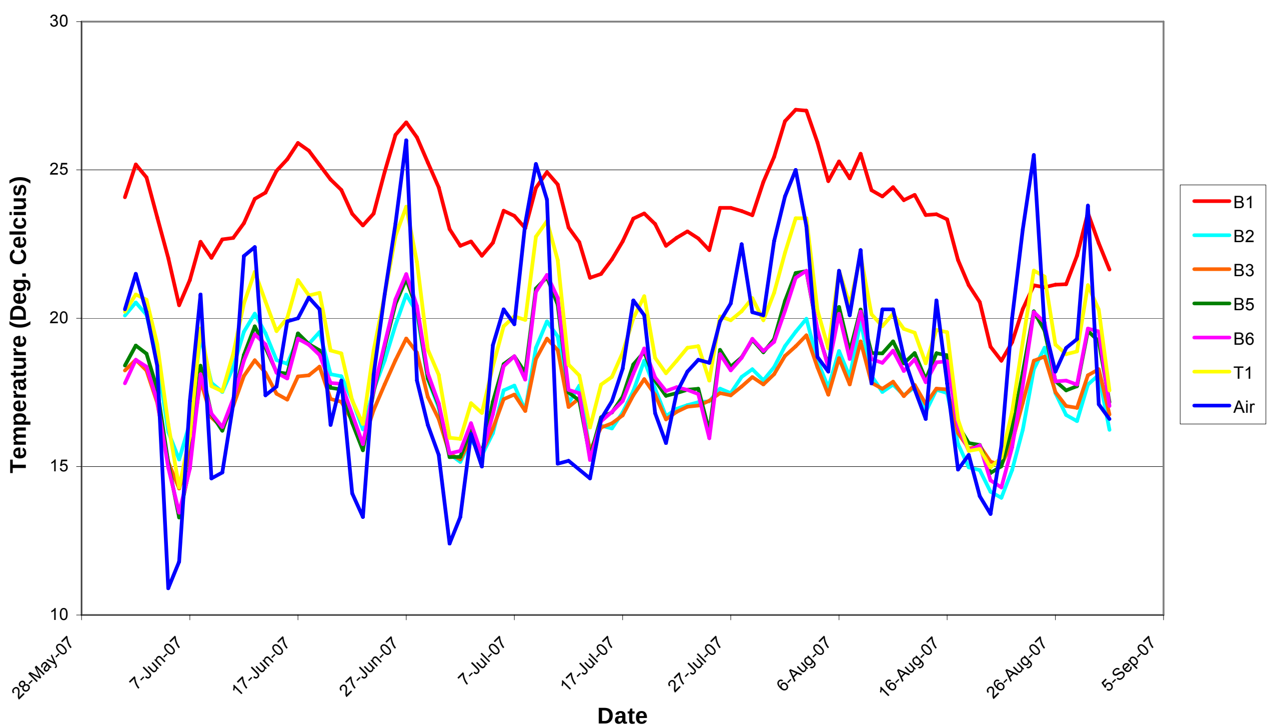
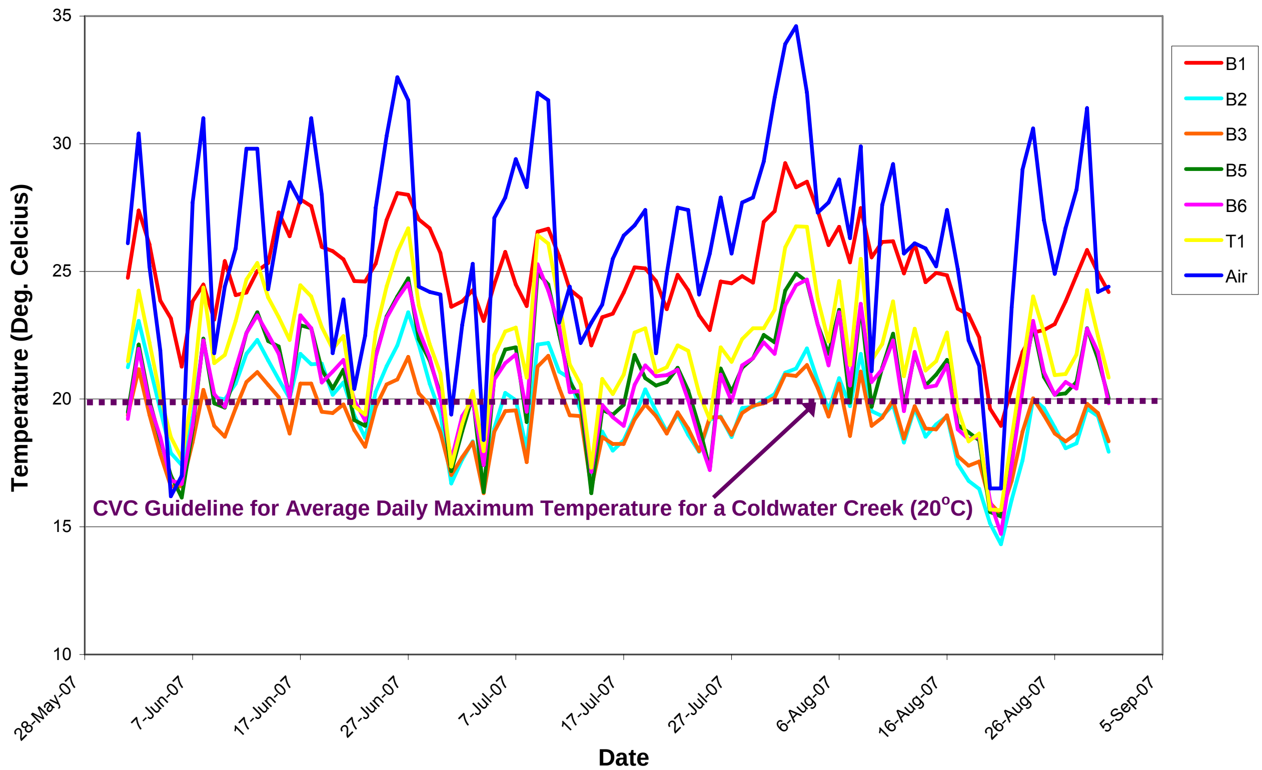


Figure 3.3 Black Creek Daily Maximum Water Temperature



A comparison of daily maximum and average water temperatures for the period of June 1 to August 31, 2007 indicated the following general trends:

- Stations B2 (upstream of Acton WWTP) and B3 (3rd Line/Glen Lawson) in Black Creek exhibited the coolest water temperatures compared to other stations monitored, with Station B3 tending to be slightly cooler than Station B2. This indicates that the Acton WWTP effluent does not appear to be increasing the temperature in Black Creek based on summer 2007 data;
- Station B1 (Fairy Lake outlet) exhibited the warmest water temperatures over the summer monitoring period;
- Stations B5 (No. 17 Sideroad/6th Line) and B6 (8th Line) exhibited similar thermal characteristics, being generally warmer than Stations B2 and B3; and
- Station T1 (North Branch Black Creek at 6th Line) was warmer than all Black Creek stations, with the exception of Station B1.

Overall, the temperatures observed suggest that Black Creek at the outlet from Fairy Lake (Station B1) exhibits warmwater conditions, with the creek getting cooler downstream near the WWTP (Station B2) and just downstream of the WWTP at Black Creek's 3rd Line crossing (Station B3). The warmest water temperature observed at Station B3 was 21.7 °C, on a day that had a maximum air temperature of 31.7 °C (July 10, 2007). In comparison, Station B1 exhibited a maximum water temperature of 26.7 °C that same day. There were several days during the summer when the Station B2 and B3 daily maximum water temperatures were above the CVC guideline for average daily maximum temperature of 20°C for protection of the coldwater fishery (*Credit River Fisheries Management Plan*; MNR and CVC, 2002). The recommended target for overall summer maximum temperature in coldwater habitat is 26 °C (CVC, 2008).

Select metrics from water temperature data collected at Stations B2 and B3 for the year 2007, as well as earlier years are shown below in Table 3.1 (CVC, 2008). As indicated in the table below, Stations B2 and B3 tended to be cooler in 2007 compared to previous years.

Table 3.1 Select Water Temperature Results for Stations B2 and B3, 2004-2007
(Source: Table 4.6.9 of CVC Black Creek Subwatershed Study Draft Background Report, 2008)

Year	Station B2 Black Creek Upstream of Acton WWTP		Station B3 Black Creek Upstream of 3rd Line	
	Overall Maximum Temperature (°C)	Average Daily Maximum Temperature (°C)	Overall Maximum Temperature (°C)	Average Daily Maximum Temperature (°C)
2004	23.95	18.80	22.90	18.70
2005	26.56	20.16	25.03	19.99
2006	n/a	n/a	25.60	19.23
2007	23.40	18.73	21.70	18.57

Using the nomogram provided by Stoneman and Jones (1996) as a guide, the data collected in the summer of 2007 suggest that Stations B2 and B3 lie within cool-water reaches of Black Creek, whereas Stations B5 and B6 exhibited borderline cool-water/warm-water characteristics. In contrast, the north branch of Black Creek at 6th Line (Station T1) exhibited warm-water characteristics. The warm-water conditions observed at the upper end of Black Creek, at Station B1, were not surprising given the warming effect of Fairy Lake on Black Creek water temperatures; however, cooler water temperatures downstream, at and downstream of the WWTP, are expected to be a result of potential groundwater input within Black Creek. It is noteworthy that brook trout spawning activity observed between Stations B2 and B3 by Dillon and CVC in the Fall of 2006 provided evidence that Black Creek, in the vicinity of the WWTP, provides habitat for a coldwater fishery. In addition, brook trout have been captured by CVC in fish community sampling undertaken between 1999 and 2003 at CVC's Third Line station.

4. BLACK CREEK BENTHIC INVERTEBRATE COMMUNITY

4.1 Methods

A travelling kick survey was conducted on June 26, 2007 at a station chosen in consultation with CVC (Adrienne Duff and Jennifer Dougherty, CVC, *Personal Communication*, May 31, 2007). The selected station was located upstream of the Acton WWTP outfall (at Station B2). The travelling kick survey is a method employed by CVC, and involved positioning the net along the bottom of the stream and disturbing substrate by kicking along five equally spaced transects within the sampling station. The sample was preserved in Kahle's solution (formalin, glacial acetic acid, ethanol, water) and subsequently delivered to an independent taxonomist for identification of macroinvertebrates to the lowest level possible. Invertebrate identifications were conducted showing actual or calculated numbers of individuals from a sub-sample of the homogenized sample.

Following taxonomic analysis of the benthic sample, the following parameters were calculated:

- Total number of organisms
- Species richness (total number of taxa in sample)
- Hilsenhoff biotic index (HBI)
- Shannon-Weaver diversity index
- EPT (Ephemeroptera, Plecoptera, Trichoptera) as % Taxa.

These parameters provided a measure of relative diversity of the benthic community and were used to give an indication of the water quality in Black Creek upstream of the Acton WWTP.

The HBI was calculated by assigning pollution tolerance values from Hilsenhoff (1988). These values were assigned at the family taxonomic value for selected arthropods (insects, isopods and amphipods) that represent a diverse, non-mobile community with life cycles of one year or more, are easily collected and generally abundant. Because the sample was collected from five equally spaced transects, a mix of riffle, run, and pool habitats were sampled. Accordingly, HBI ranges derived by Barton (1996) were utilized as a measure of impairment:

- HBI value >8: impaired;
- HBI value of 6 to 8: possibly impaired; and
- HBI value <6: unimpaired.

The diversity of the benthic community within each sample was calculated using the Shannon-Weaver Diversity Index (Shannon and Weaver, 1949), which reflects both the number of different types of organisms and their frequency within the sample. Thus, the diversity index measures both community richness and distribution among taxonomic groups. Diversity values are low when only a few organism types are represented in the sample and when there is a predominance of one type. Diversity values are high when there are many different types of organisms within the sample and when their distribution is relatively even. When only one or zero species are represented, the diversity index will be zero. The Diversity Index (DI) is calculated using the following formula:

$$DI = \sum i/j * Ln\ i/j$$

where: i = number of individuals in one taxon
j = total number of individuals in all taxa.

Shannon-Weaver Diversity Index value ranges indicate the following conditions (Griffiths, 1999):

- 3-5: implies unpolluted conditions
- 1-3: implies moderate pollution
- <1: implies substantial pollution.

The EPT index is the total number of distinct taxa within the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). The EPT value generally increases with increasing water quality, as the taxa within these three orders are considered to be pollution sensitive. The EPT index, when expressed as percent taxa, allows for easier comparison between sample years, as this value takes into account changes in the number of taxa.

In addition to the above analysis, general comparisons of select metrics were made with historical benthic information provided by CVC (Adrienne Ockenden, CVC Watershed Monitoring Specialist, Personal Communication, September 16, 2008) for their "Black Creek Upstream of Eighth Line" station" and their "Black Creek at Third Line" station.

4.2 Results and Discussion

Results from the benthic invertebrate analysis are summarized below in **Table 4.1**, with raw data presented in **Table 4.2**.

Table 4.1 Summary of Black Creek Benthic Invertebrate Analysis Results, June 26, 2007

Parameter	Sample 1
Total Number of Individuals	1300
Total Number of Taxa	26
Shannon-Weaver Diversity Index	1.85
Hilsenhoff Biotic Index (HBI)	7.77
EPT as % Taxa	3.8%

Table 4.2 Black Creek Benthic Invertebrate Analysis Raw Data for Black Creek, June 26, 2007

Fraction subsampled	**combined samples 1/128**
TAXA LIST	
TURBELLARIA	76
NEMATODA	28
OLIGOCHAETA:	
NAIDIDAE	4
TUBIFICIDAE:	
with hair chaetae	228
no hair chaetae	20
TUBIFICIDAE or NAIDIDAE	56
HIRUDINEA:	
Erpobdellidae:	
Erpobdella or near it	8
BIVALVIA:	
SPHAERIIDAE	8
CRUSTACEA:	
AMPHIPODA:	
Crangonyctidae:	
Crangonyx sp.	8
Talitridae:	
Hyalella sp.	8
CLADOCERA	8
ISOPODA:	
ASELLIDAE:	
Caecidotea sp.	656
INSECTA:	
TRICHOPTERA:	
HYDROPSYCHIDAE:	
Cheumatopsyche sp.	16
DIPTERA:	
CHIRONOMIDAE:	
Chironominae:	
Chironomini:	
Microtendipes sp.	60
Phaenopsectra or near it	4
Polypedilum sp.	52
Tanytarsini:	
Rheotanytarsus sp.	8
Orthocladinae:	
Cricotopus /Orthocladius	4
Thienemaniella sp.	8
Tanypodinae:	
Thienemannimyia complex	8
SIMULIDAE	1

Fraction subsampled	combined samples 1/128
COLEOPTERA:	
DYTISCIDAE:	
Colymbetinae:	
Agabus sp.	1
Hydroporinae	1
ELMIDAE:	
Dubiraphia sp.	20
HALIPLIDAE:	
Peltodytes sp.	1
ODONATA:	
LIBELLULIDAE	8

The Shannon-Weaver Diversity Index value of 1.85 implies a moderate level of pollution in Black Creek at the station sampled. Using the Barton derived criteria, the HBI score of 7.77 indicates a "possibly impaired" benthic community.

There was a low percentage of Ephemeroptera, Plecoptera and Trichoptera (EPT) within the sample, which also suggests that there is some impairment of water quality. Only one Trichoptera (Hydropsychidae Family) of the three aquatic insect EPT indicator orders was represented in the sample.

The large number of worms, asellid isopods, and other invertebrates other than insects in the sample suggests that Black Creek at the station sampled is somewhat degraded, and that the sample included transects in areas of slow moving stream with organic detritus on the bottom (H. Frania, *Personal Communication*, September 2007). This matches Dillon's observations at the station during sample collection activities.

A review of historical benthic data collected by CVC from 1999 to 2007 at their "Black Creek Upstream of Eighth Line" station and their "Black Creek at Third Line" station was undertaken.

At the "Black Creek Upstream of Eighth Line" station, EPT as % taxa ranged between 10-32%, and calculated HBI scores were in the range of 4.63-5.72, implying an "unimpaired" benthic community. By comparison, the "Black Creek at Third Line" station exhibited EPT as % taxa ranging between 19-50%. The HBI scores at this station ranged between 4.88-6.06 between 1999 and 2007, which also generally implies an unimpaired benthic invertebrate community (all annual values were less than 6 except for one).

The impairment of the benthic community at Station B2 may be a reflection of relatively slow moving conditions in Black Creek upstream of the WWTP outfall, in addition to upstream urban encroachment. Overall, the benthic invertebrate community at this Black Creek station is considered to be slightly impaired and suggests some pollution within Black Creek in the area sampled. By comparison, historical downstream benthic sampling undertaken by CVC indicated less impaired conditions than at Station B2.

5. BLACK CREEK FLOW AND CHANNEL GEOMETRY

5.1 Methods

Flow conditions were estimated at the locations outlined in Table 1.1, using a Flow-Mate™ Model 2000 Portable Flowmeter by measuring water depth and velocity across multiple panels. Measurements took place during periods with no significant rainfall, on the following dates:

- June 14, 2007;
- July 25, 2007; and
- August 31, 2007.

The June and August dates were chosen to match the week of 24-hour water quality sampling, and the July date was chosen to get a third period for calculation of average base flow conditions.

It is noteworthy that due to beaver activity in the vicinity of Station B2, flow estimates would have been affected due to backwater effects. On August 31, 2007, a flow estimate at Station B2 was not possible due to a backwater movement caused by a higher level of beaver activity compared to previous site visits. The site of the Fairy Creek Outlet flow monitoring (for Station B1) was located at the Black Creek crossing of Regional Road 25, as this culvert was considered a more suitable location to monitor flow than the Station B1 location.

Collected data were used to draw a channel cross-section for each station. Flow estimates were calculated for each station using the measured water depth and velocity data, and average flow was calculated for each station from the measurements obtained during the three monitoring periods.

5.2 Results and Discussion

A summary of system flow by station from upstream to downstream is provided in **Table 5.1** below.

Table 5.1 Black Creek Flow Summary Data – Summer 2007

Date	Monitoring Station Estimated Flow Rate (L/s)							
	Black Creek							North Branch of Black Creek
	B1	B2	S1*	B3	B4	B5	B6	T1
14-Jun-07	28	53	48	164	234	244	342	34
25-Jul-07	10	22	39	117	170	165	245	14
31-Aug-07	2	n/a	38	78	198	173	234	3
Average	**13.3**	**37.5**	**41.7**	**119.7**	**200.7**	**194.0**	**273.7**	**17.0**

* Acton WWTP effluent flow data provided by the Regional Municipality of Halton

In addition, flow cross-sections and representative photographs are provided in the following figures (**Figure 5.1** through **Figure 5.7**).

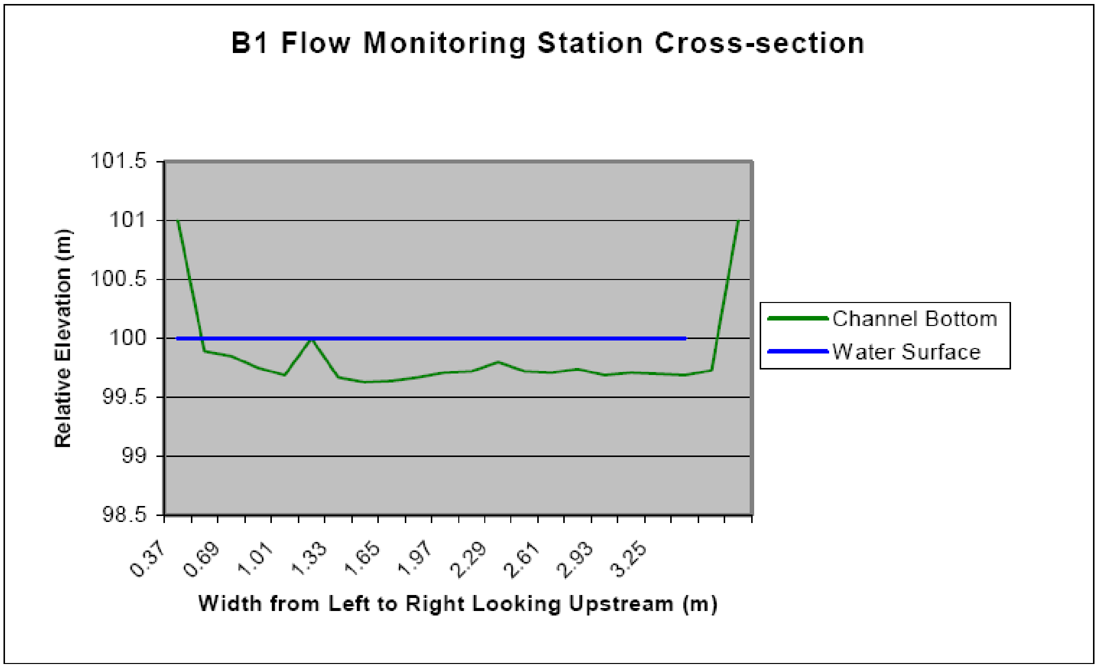


Figure 5.1 Monitoring Station B1 (at Regional Road 25) Channel Cross-Section

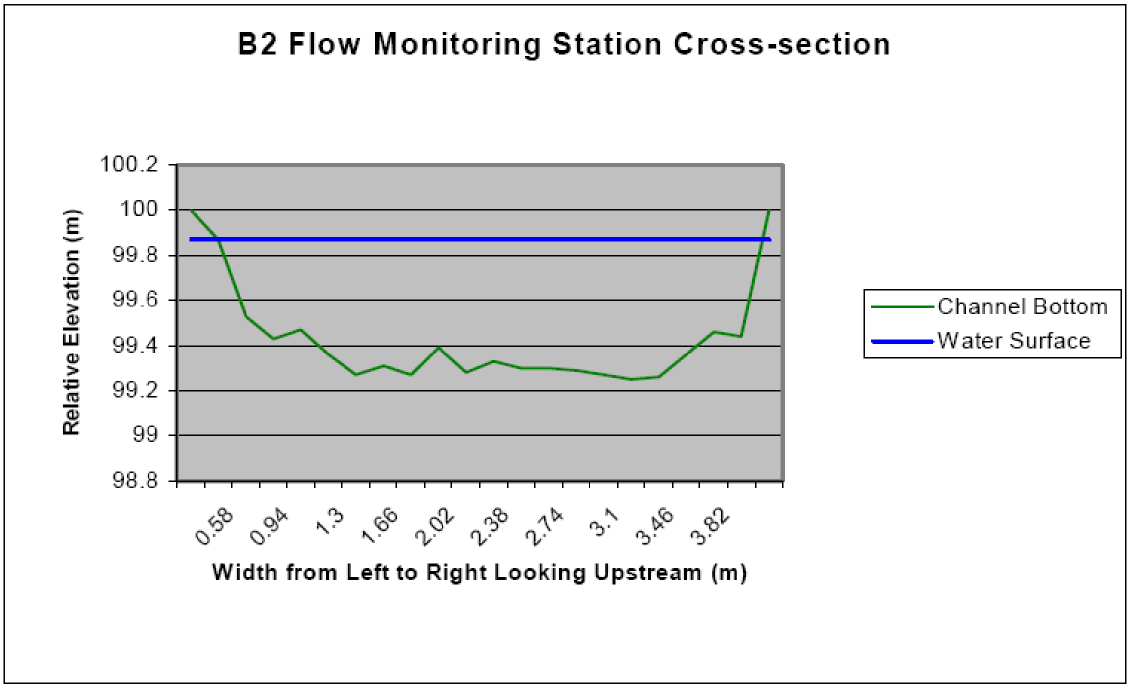


Figure 5.2 Monitoring Station B2 (Upstream of Acton WWTP) Channel Cross-Section

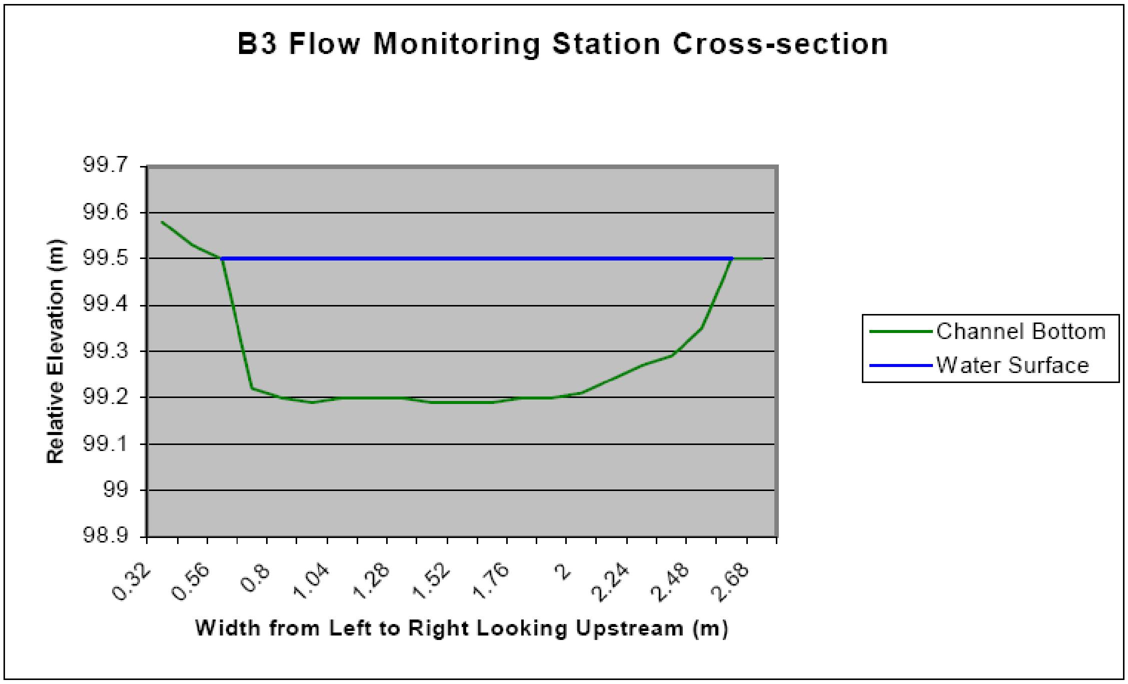


Figure 5.3 Monitoring Station B3 (3rd Line/Glen Lawson) Channel Cross-Section

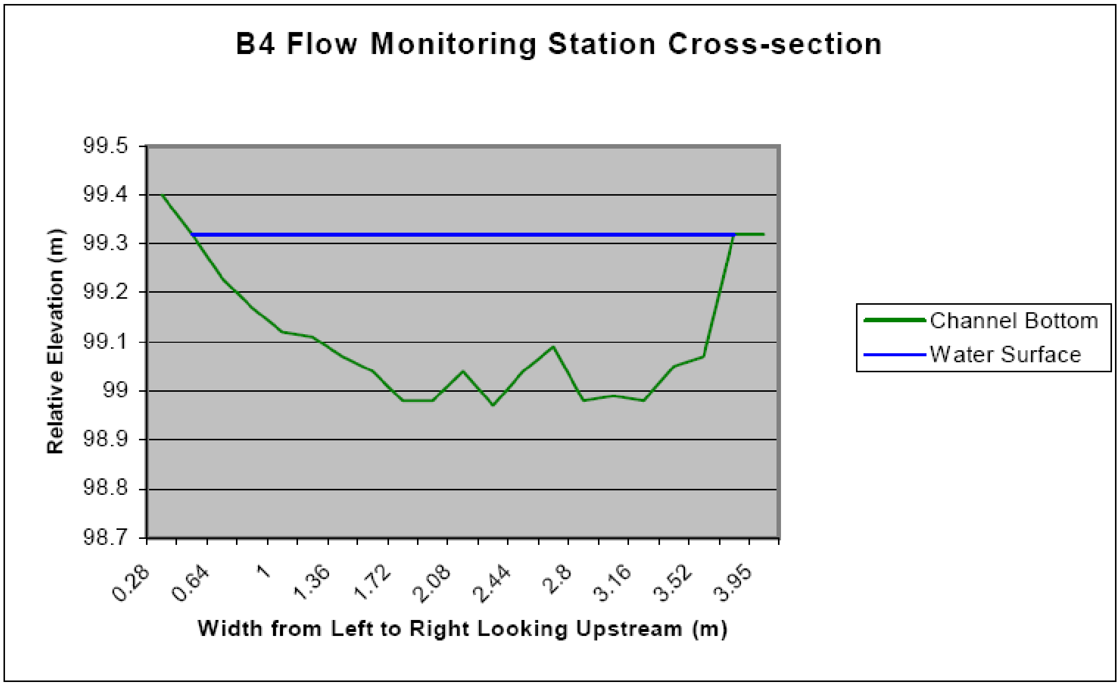


Figure 5.4 Monitoring Station B4 (5th Line) Channel Cross-Section

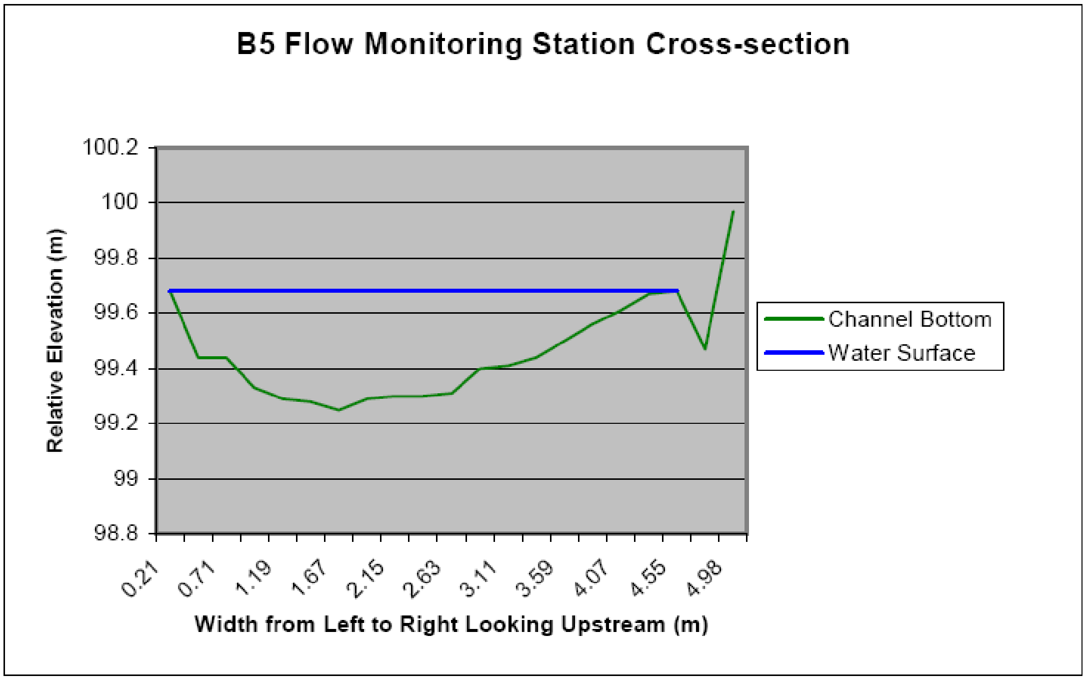


Figure 5.5 Monitoring Station B5 (No. 17 Sideroad and 6th Line) Channel Cross-Section

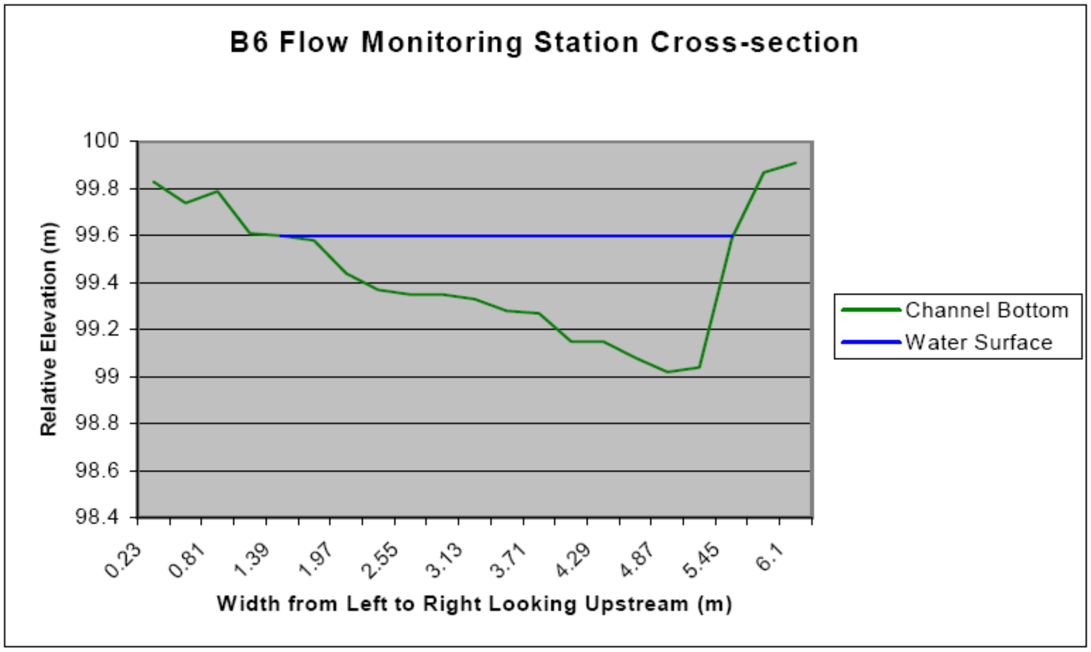


Figure 5.6 Monitoring Station B6 (8th Line above confluence with Silver Cr.) Channel Cross-Section

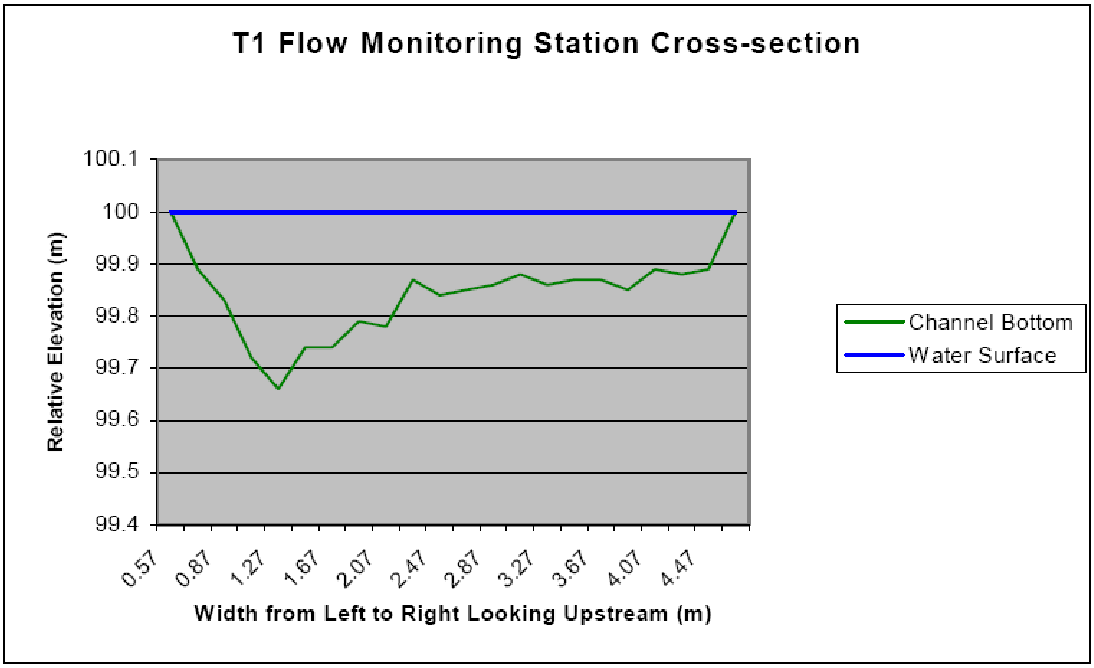


Figure 5.7 Monitoring Station T1 (North Branch of Black Cr. at 6th Line) Channel Cross- Section

General trends regarding system flow are provided below:

- The average flow rate along Black Creek, from upstream (Station B1) to downstream (Station B6) stations increased significantly.
- Wastewater treatment plant effluent discharge averaged approximately 42 L/s during the three flow monitoring dates. Measured flow rates at the next downstream monitoring Station B3 reflected the addition of WWTP effluent on system flow rate.
- Surface water input from the tributary of the north branch of Black Creek at 6th Line (Station T1) averaged 17 L/s during the three flow monitoring dates. Measured flow rates at the next downstream station (Station B5) did not accurately reflect the addition of surface water at this location.
- The measured loss in system flow between Station B4 (5th Line) and Station B5 (No. 17 Sideroad and 6th Line) could potentially be attributed to loss of surface flow to groundwater in this reach or to inaccuracies in flow measurement.
- Average system flow rates where significantly lower than the values measured at all monitoring locations on June 14, 2007. Precipitation in the week prior to the field measurements likely explains the fluctuation in measured surface water flow rates; however, there was no significant precipitation for several days prior to the June 14th, 2007 measurements.
- The noted trend in temperature decrease from Station B1 (outlet from Fairy Lake) to downstream stations and the net increase in system flow rates, in addition to WWTP effluent and other sources of surface water, suggests that the portion of Black Creek studied is affected by the presence of groundwater inputs.

6. CONCLUSIONS

The following conclusions can be made based on the field data collected for Black Creek during the summer of 2007:

- The background water quality shows evidence of elevated phosphorus, nitrite, and E.Coli in excess of the Provincial and/or Canadian water quality objectives.
- Station B2, which is located upstream of the Acton WWTP outfall, is significantly higher in both ammonia and TKN in comparison to the other sampling stations. This suggests that a backwater movement near the treatment plant outfall, potentially caused by beaver dam activity, may be contributing to the background water quality in this area. The

marshy area upstream of the Acton WWTP may also be a potential source of ammonia and TKN.

- The concentration of nitrate in the vicinity of the WWTP effluent is elevated above the CWQG. The data suggests either the WWTP, the backwater effect or the upstream marshy area as a possible cause.
- The dissolved oxygen saturation generally above the PWQO downstream of the WWTP. The oxygen saturation is below the PWQO at locations upstream of the WWTP. These data suggest that the receiver is assimilating the organic oxygen demand from the WWTP.
- Water temperature data collected upstream and downstream of the Acton WWTP outfall (Stations B2 and B3) suggested cold-water characteristics in this area of Black Creek. On several days the maximum water temperature at almost all of the monitoring stations was above the CVC guideline of 20^{o}C for protection of the cold-water fishery. Monitoring Stations B2, B3, and B4 had the lowest water temperatures (at the 75th percentile) of those stations monitored. This indicates that the Acton WWTP effluent does not appear to be causing an increase in the temperature of Black Creek based on summer 2007 data.
- The monitoring station at the outlet from Fairy Lake (Station B1) had the highest water temperatures, reflecting its proximity to Fairy Lake.
- The North Branch of Black Creek at 6th Line (Station T1) exhibited warm-water conditions.
- Benthic invertebrate sampling at the monitoring station upstream of the Acton WWTP (Station B2) suggested that Black Creek water quality is slightly impaired in this reach.
- Flow estimates indicated that the average flow rate along Black Creek from the upstream monitoring station at the outlet from Fairy Lake (Station B1) to the downstream station near 8th Line (above the confluence with Silver Creek) (Station B6) increased significantly.
- The noted trend in water temperature decrease from the outlet from Fairy Lake (Station B1) to downstream locations and the net increase in system flow rates, in addition to WWTP effluent and other sources of surface water, suggests that the portion of Black Creek studied is affected by the presence of groundwater inputs.

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Black Creek Assimilative Capacity Study

PART III:
ASSIMILATIVE CAPACTIY MODELLING

for
The Regional Municipality of Halton

Donald G. Weatherbe Associates Inc

January 14, 2011 **06-6413**

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1.0 BACKGROUND

As part of the Class EA for the Acton WWTP, owned by the Regional Municipality of Halton, an Assimilative Capacity Study of Black Creek was required. The Class EA is being carried out by Dillon Consulting.

This Assimilative Capacity Study reviews potential expanded discharge flows at the existing discharge location on Black Creek. Consequently, consideration is given to the potential impacts of an expanded discharge flow to Black Creek and measures to alleviate or offset impacts.

This report is a revision of an earlier draft (dated October 31, 2007) based on comments received from the CVC and the MOE. Three more years of data were added to the analysis of low flows on Black Creek, and a more detailed monthly analysis of total phosphorus loadings was carried out. Modelling of mass balances, dissolved oxygen and temperature was updated with the new low flow estimates.

1.1 Terms of Reference

The terms of reference issued by Dillon Consulting Limited (Dillon) on November 6, 2006 for this study called for:

1. A background data review;
2. A spawning redd survey (by Dillon);
3. Development of terms of reference for the field component of the study;
4. The field study (by Dillon); and
5. Preparation of a report on assimilative capacity based on the background data review and additional field study results.

This report includes the results of the background review and the assimilative capacity assessment. The terms of reference for the field work were produced and Dillon was retained by the Regional Municipality of Halton to carry out this work (Part II Report). The scope of the assessment is to include:

- Policy of various government agencies;
- Review of planning documents;
- Consideration of water uses;
- Background water quality;

- Low flows;
- Feasibility of potential improvements to increase assimilative capacity; and
- Receiving water assessment including comparison of effluent impacts with provincial water quality objectives, dissolved oxygen modelling, ammonia and nitrate toxicity, and thermal impacts.

1.2 Certificate of Approval and Potential Expanded Discharge Flows

The existing Acton WWTP Certificate of Approval (CofA) issued under the Ontario Water Resources Act stipulates the operating conditions for the plant, including flow rate and effluent objectives, as well as effluent compliance limits as given in **Table 1**.

Table 1 Acton WWTP Certificate of Approval Effluent Concentrations

	BOD5*	Ammonia-N	Unionized Ammonia	Total Phosphorus	Total Suspended Solids
	mg/L	mg/L		mg/L	mg/L
Objective	2	1.0		0.2	3
Compliance Limit	5	2.0	0.1	0.3	5
Winter**		4.0			

*Interpreted as carbonaceous biological oxygen demand
**Dec. 1 to April 30

Table 2 provides the flow stipulated in the CofA with different reporting units for convenience. The two growth scenarios and the design flows associated with them are also shown.

Table 2 Acton WWTP Effluent Flow Rate

	m^3/day	m^3/s	L/s
Current CofA	4545	0.0526	52.60
Scenario 1	5600	0.0648	64.81
Scenario 2	7000	0.0810	81.02

1.3 Assimilative Capacity Approach

The approach in this study follows the procedures outlined in "Deriving Receiving-Water Based, Point-Source Effluent Requirements for Ontario Waters" (Guideline B-1-5, MOE, 1994). In particular, this document outlines the conditions under which discharge effects are to be considered, defining the "design case" as being a combination of background conditions (75th percentile of background data) and low flows (seven day average flow with a 20 year occurrence - 7Q20).

In reviewing background conditions in the stream, Water Management (MOE, 1994) states that at a potential discharge location, one of the following two cases would apply:

- Policy 1: In areas which have water quality better than the PWQO, water quality shall be maintained at or above the objective.
- Policy 2: Water Quality which presently does not meet the PWQOs shall not be further degraded and all practical measures shall be undertaken to upgrade the water quality to the objectives.

"Where new or expanded discharges are proposed, no further degradation will be permitted and all practical measures shall be undertaken to upgrade water quality. However, it is recognized that, in some circumstances, it may not be technically feasible, physically possible or socially desirable to improve water quality toward Provincial Water Quality Objective (PWQO)."

"PWQOs are numerical and narrative ambient surface water quality criteria. They are applicable to all waters of the Province (e.g. lakes, rivers and streams)…PWQOs represent a desirable level of water quality that the MOE strives to maintain in the surface waters of the Province. In accordance with the goals and policies in Water Management (MOE, 1994), PWQOs are set at a level of water quality which is protective of all forms of aquatic life and all aspects of the aquatic life cycle during indefinite exposure to the water."

Parameters of concern (POCs) are based on analysis of existing effluent and existing water quality. The typical POCs for treatment plants with secondary treatment or better are the parameters currently limited by the CofA (BOD, total suspended solids, total phosphorus, and ammonia). In addition to this list, we are considering dissolved oxygen (to assist in evaluation of oxygen demand effects), total kjeldahl nitrogen (TKN-to account for the oxygen demand component), pH and temperature (to allow calculation of the ammonia toxicity dependent on pH and T). This study also considers that nitrates may be a potential future control parameter with the adoption of a nitrate water quality guideline limit by the Canadian Council of Environment Ministers. In addition, chlorides in the discharge and receiving streams are compared to the CVC guideline.

1.4 Policy Considerations

- **Mixing zone**: A mixing zone is defined as an area of water contiguous to a point source where the water quality does not comply with one or more of the Provincial Water Quality Objectives. In a shore based discharge to a watercourse, the effluent mixes laterally with the natural flow while the flow continues downstream in a longitudinal direction. This may produce a zone on the near shore in which the water exceeds the PWQO for one or more effluent parameters. Water Management (MOE 1994) includes Policy 5 "Mixing Zones should be as small as possible and not interfere with beneficial uses." The concerns for a river based discharge include potential damage to beneficial uses such as fish spawning areas or water intakes on the same shoreline as the discharge.

- **Non-acutely lethal effluent:** The MOE has requested that effluents be non-acutely lethal at the point of discharge prior to dilution with receiving water. This requirement can be addressed by using alternatives to chlorine for disinfection and by setting limits for ammonia levels. In the case of the Acton WWTP, ultraviolet irradiation is the current disinfection method and will continue to be applied with any expansion. The current limit on ammonia levels in the discharge is 0.1 mg/L un-ionized ammonia. This target is set by the MOE to prevent acutely toxic effluent. To ensure that the effluent remains non-acutely lethal from other parameters, a monitoring program for this should be included. It is recommended that quarterly samples be taken for testing with rainbow trout fingerlings and *daphnia magna.*

- **Dilution ratio:** Ellen Schmarje's email memo (Ellen Schmarje, MOE, Personal Communication, July 16, 2007) states that: "This is to clarify the ministry's position regarding the minimum dilution ratio requirement that was identified as a concern during our meeting, held on June 15th, 2007 to discuss the progress of the assimilative capacity study for an increased capacity for the Acton WWTP. Based on the information presented, at present, the minimum dilution ratio between flow in Black Creek under 7Q20 condition and the Acton WWTP discharge is 0.8 to 1. Under the proposed expansion scenario, the minimum dilution ratio would be 0.53 to 1. As indicated at the meeting, there is no formal, written Ministry Policy that requires maintaining a certain minimum dilution ratio for municipal wastewater discharges to watercourses. However, it has been a long established practice in Central Region, where feasible and practical, to encourage proponents to design their discharge such that minimum dilution ratio of 10 to 1 is maintained even under low flow conditions such as the 7Q20. By doing so, it is expected that the risk for significant impact to the receiving stream is reduced if spills, bypasses and/or process upsets occur. In addition, this provision allows to implicitly account for other considerations such as: other sources of pollution; uncertainty in data used in analysis as well as the inherent limitation in the impact analysis which typically is focused on a few conventional parameters only. However, it is also recognized that achieving this level of minimum dilution is not always possible, and approvals have been granted in the past that allow lower minimum dilution ratios. Under these scenarios, the impact analysis is expected to include more detailed information on items such as: effluent characterization; detailed hydrological analysis to show how flows change along the watercourse; potential changes in hydrology and thermal regime as a result of the discharge etc. Often, dischargers are also asked to design and implement appropriate mitigation/ safety measures to compensate for the lack of the additional dilution buffering capacity. As you may recall, some examples of the mitigation measures that can be implemented were also discussed at our June 15th meeting (e.g., diverting some of the wastewater to another receptor; providing for system redundancies and excess holding capacity to eliminate bypasses/ spills). An enhanced monitoring program that includes water quality and biological monitoring is also imposed as condition of approval. Understandably, the need for such measures becomes even greater where the receiving watercourse is known to provide good quality habitat, such as found in Black Creek. Based on the above, MOE, Central Region will NOT oppose the proposed expansion solely on the basis of the lack of the desired minimum dilution ratio. However, we will support the proposed expansion only if the study in support of the expansion addresses all of our concerns and if Halton agrees to implement an acceptable mitigation plan along with a suitable enhanced monitoring program." (Note that the dilution ratios quoted above were preliminary estimates – revised values are presented later in this report.)

- **Diversions:** The Safeguarding and Sustaining Ontario's Water Act implements the Great Lakes-St. Lawrence River Basin Sustainable Water Resources Agreement, signed by Ontario, Quebec and the eight Great Lakes U.S. states on December 13, 2005. The Act, passed June 1, 2007, bans new and increased transfers of water from one Great Lakes watershed to another, with strictly regulated exceptions (known as intra-basin transfers). The act prohibits the diversion of water for new or increased intra-basin transfers of 379,000 litres per day or greater from one Great Lake watershed to another Great Lake watershed, subject to strictly regulated exceptions. Consequently, diversions of water (sewage) to a different Great Lake watershed are restricted (e.g., Acton to Grand R.); however, diversion within the same watershed is acceptable on a policy basis, subject to approval on technical grounds (e.g. Acton to Silver Creek or Sixteen Mile Creek).

2.0 BACKGROUND DATA REVIEW

2.1 Surface Water Quality

A statistical analysis to determine the background water quality above and below the WWTP discharge was carried out. The statistic of interest is the 75th percentile value since this forms the basis of establishing the background water quality in the subsequent analysis ("Deriving Receiving-Water Based, Point-Source Effluent Requirements for Ontario Waters" - MOE, Guideline B-1-5, 1994). The analysis was carried out for three locations (shown on **Figure 1**) where Provincial Water Quality Monitoring Network stations have been in place for several years, with results described below.

The statistical values for the POCs are compared to the PWQO set out in the MOE's publication, "Water Management Policies, Guidelines and Provincial Water Quality Objectives" (July, 1994). Comparisons against the PWQO and CWQG are made where appropriate. Any temporal or spatial trends are noted.

Table 3 lists the water quality parameters analyzed in this review and their significance. It includes all of the parameters that are currently listed in the CofA for Acton, and as well as other parameters that might be affected by sewage discharges. Some of the parameters have PWQOs while other guideline levels are noted, notably for chloride and nitrate.

Table 4a presents the data for Black Creek Upstream of Acton giving the full dataset available from 1964 to 2006. Note that no samples were collected here between 1972 to 1992, which created a gap in data. **Table 4b** presents data after1993 to compare to more recent data from the downstream station.
The full record has a gap in data from 1971 to 1993, during which major changes in land use upstream were made. For example, there is a decrease in both chloride and total phosphorus levels for the later period compared to the whole dataset. For some metals, the minimum value reported is negative. This is because the reporting method for trace amounts includes negative values. In addition, sampling procedures and analytical methods (particularly for metals) changed over this period. Consequently, for background conditions for establishing Policy 2 and for calculations of impact, the data after 1993 only will be considered.

Tables 5a and 5b give data for the PWQMN station downstream of Acton WWTP (Black Creek at 3rd Line). There is no gap in the full dataset in **Table 5a**. **Table 5b** presents data after 1993.

Tables 6a and 6b give data for the PWQMN station (Silver Creek at Mountainview Road) on Silver

Creek downstream of the confluence with Black Creek, and above the Georgetown WWTP. This station is presented to indicate if there are impacts from Acton carried over to Silver Creek.

Table 3 Significance of Water Quality Parameters

Parameter	Units	PWQO/ Guideline	Note
BOD, 5 Day	mg/L		No guideline - related to dissolved oxygen - WWTP control parameter.
Chloride	mg/L	250	Credit Valley Conservation guideline - protects aquatic biota – guideline value supported by information presented in Road Salt notice under Canadian Environmental Protection Act.
Copper	µg/L	5.0	PWQO to protect fish
Dissolved Oxygen	mg/L	5	PWQO for cold water fish above 20 C
Dissolved Oxygen	% Saturation	57%	PWQO for cold water fish above 20 C
Dissolved Oxygen	mg/L	4	PWQO for warm water fish above 20 C
Dissolved Oxygen	% Saturation	47%	PWQO for warm water fish above 20 C
E. Coli	counts/ 100 ml	100	Bathing beach PWQO for geometric mean
Hardness	mg/L		No guideline - Some metals PWQO related to hardness
Iron	µg/L	300	PWQO to protect fish
pH		6.5-8.5	PWQO - also affects Unionized ammonia
Temperature	Deg C	20	CVC guideline to protect cold water fishery
Nickel	µg/L	25	PWQO to protect fish
Nitrite	mg/L as N		No PWQO
Nitrates	mg/L as N	2.93	CWQ Guideline
Ammonia	mg/L as N		No Guideline - Adds to BOD effect and unionized ammonia - WWTP control parameter
Un-ionized Ammonia	mg/L as N	0.0165	PWQO to protect fish - Concentration varies with ammonia ,T, pH - WWTP control parameter
Total Kjeldahl Nitrogen	mg/L as N		Sum of organic nitrogen and ammonia. No Guideline - Adds to BOD effect and ammonia
Phenolics	ug/l	1	PWQO to protect fish
Dissolved Phosphorus	mg/L	0.030	Most available form of phosphorus - related to nuisance aquatic growths and DO - PWQO is for Total P which includes dissolved form.
Total Phosphorus	mg/L	0.030	PWQO - related to nuisance aquatic growths and DO - WWTP control parameter
Suspended Solids	mg/L		No PWQO - WWTP control parameter
Vanadium	µg/L	7	PWQO to protect fish
Zinc	µg/L	20	PWQO to protect fish

Table 4a Black Creek Upstream of Acton - Full Dataset

Parameter	Units	Average	75th** Percentile	Min	Max	PWQO/ Guideline	% Violation	# of Data Points
BOD, 5 DAY	mg/L	6.2	7.7	0.8	154.0			235
Chloride	mg/L	174.5	228.0	5.0	498.0	250	19%	235
Copper	µg/L	1.887	2.29	0.071	10.100	5.0	3%	116
Dissolved Oxygen **	mg/L	7.7	6.0	2.0	14.8	5	8%	169
Dissolved Oxygen **	% Saturation	71.9	54.8	14.3	137.2	57%	27%	168
E. Coli *	counts/100 ml	86	100	4	1020	100	25%	110
Hardness	mg/L	287	321	172	460			124
Iron	µg/L	535	709	75	1600	300	73%	126
pH		7.51	7.69	6.37	8.49	6.5-8.5	1.90%	54
Temperature	Deg C	10.03	15.85	0.10	26.10	20	8.2%	170
Nickel	µg/L	0.977	1.60	-0.651	4.110	25	0%	106
Nitrite	mg/L as N	0.201	0.20	0.002	3.000			236
Nitrates	mg/L as N	1.797	2.41	0.030	12.400	2.93	16%	232
Ammonia	mg/L as N	1.53	2.24	0.00	10.00			242
Un-ionized Ammonia	mg/L as N	0.005	0.0059	0.0000	0.0481	0.0165	5.56%	54
Total Kjeldahl Nitrogen	mg/L as N	2.98	3.53	0.24	23.00			232
Phenolics	ug/l	0.31	0.40	0.20	2.00	1	3%	114
Dissolved Phosphorus	mg/L	0.32	0.526	0.001	2.092	0.030	52%	233
Total Phosphorus	mg/L	0.477	0.760	0.014	4.500	0.030	84%	229
Suspended Solids	mg/L	15	15	1	286			183
Vanadium	µg/L	0.420	0.72	-0.898	1.880	7	0%	87
Zinc	µg/L	7.124	7.48	-0.614	67.400	20	7%	87

Period of Record 1964 -1971; 1993 - 2006

Highlighted/shaded values exceed the PWQO or Guideline

* Geometric mean for E. Coli

** 25th percentile for dissolved oxygen

Table 4b Black Creek Upstream of Acton - Since 1993

Parameter	Units	Average	75th Percentile	Min	Max	PWQO/ Guideline	% Violation	# of Data Points
BOD, 5 DAY	mg/L	4.1	5.5	0.8	11.4			116
Chloride	mg/L	130.0	160.5	52.0	298.0	250	3%	120
Copper	µg/L	1.891	2.29	0.071	10.100	5.0	3%	116
Dissolved Oxygen **	mg/L	8.7	6.39	2.800	14.780	5	7%	74
Dissolved Oxygen **	% Saturation	66.6	52.9	14.3	123.5	57%	32%	168
E. Coli *	counts/100 ml	86	100	4	1020	100	25%	110
Hardness	mg/L	275	306.00	172.00	432.00			105
Iron	µg/L	506	660.00	75.30	1470.00	300	71%	106
pH		7.51	7.69	6.37	8.49	6.5-8.5	1.85%	54
Temperature	Deg C	10.79	16.45	0.30	26.10	20	10.7%	75
Nickel	µg/L	0.978	1.60	-0.651	4.110	25	0%	106
Nitrite	mg/L as N	0.202	0.18	0.002	2.860			120
Nitrates	mg/L as N	2.180	2.69	0.360	12.400	2.93	19%	118
Ammonia	mg/L as N	0.81	0.96	0.00	10.00			118
Un-ionized Ammonia	mg/L as N	0.005	0.0059	0.0000	0.0481	0.0165	5.56%	54
Total Kjeldahl Nitrogen	mg/L as N	1.76	1.84	0.24	18.00			118
Phenolics	µg/l	0.31	0.40	0.20	2.00	1	3%	114
Dissolved Phosphorus	mg/L	0.027	0.017	0.001	0.800	2.930	6%	119
Total Phosphorus	mg/L	0.070	0.057	0.014	1.300	2.930	69%	119
Suspended Solids	mg/L	9	9	1	79			92
Vanadium	µg/L	0.421	0.72	-0.898	1.880	7	0%	87
Zinc	µg/L	7.165	7.48	-0.614	67.400	20	7%	87
Period of Record	1993 - 2006							

Highlighted/shaded values exceed the PWQO or Guideline
* Geometric mean for E. Coli
** 25th percentile for dissolved oxygen

Table 5a Black Creek downstream of Acton - Full Record

Parameter	Units	Average	75th Percentile	Min	Max	PWQO/ Guideline	% Violation	# of Data Points
BOD, 5 DAY	mg/L	3.2	4.2	0.1	30.0			378
Chloride	mg/L	208.2	260.0	10.0	445.0	250	29%	373
Copper	µg/L	4.4	4.2	0.4	130.00	5.0	15%	268
Dissolved Oxygen **	mg/L	9.0	7.50	3.800	17.0	5	3%	317
Dissolved Oxygen **	% Saturation	77.8	67.2	28.3	144.4	57%	10%	307
E. Coli *	counts/100 ml	36	100	4	820	100	23%	130
Hardness	mg/L	300	333.25	185.00	441.00			128
Iron	µg/L	354	460	0	2240	300	60%	132
pH		7.37	7.72	5.40	8.80	6.5-8.5	11.85%	135
Temperature	Deg C	9.73	15.48	0.50	21.50	20	1.9%	314
Nickel	µg/L	1.674	2.46	-0.825	5.010	25	0%	128
Nitrite	mg/L as N	0.152	0.19	0.003	1.870			388
Nitrates	mg/L as N	4.567	6.13	0.365	11.5	2.93	71%	388
Ammonium	mg/L as N	1.05	1.04	0.00	19.30			390
Un-ionized Ammonia	mg/L as N	0.004	0.0013	0.0000	0.0738	0.0165	5.97%	134
Total Kjeldahl Nitrogen	mg/L as N	1.81	1.81	0.11	27.50			383
Phenolics	ug/l	0.45	0.50	0.20	0.80	1	0%	4
Dissolved Phosphorus	mg/L	0.116	0.115	0.001	1.400	0.030	57%	387
Total Phosphorus	mg/L	0.198	0.202	0.013	2.390	0.030	97%	381
Suspended Solids	mg/L	8	10	0	91			232
Vanadium	µg/L	0.356	0.63	-1.570	2.2	7	0%	103
Zinc	µg/L	8.248	9.89	3.120	20.4	20	1%	103

Period of Record 1972 - 2006
* Geometric mean for E. Coli
** 25th percentile for dissolved oxygen

Table 5b Black Creek downstream of Acton - Since 1993

Parameter	Units	Average	75th Percentile	Min	Max	PWQO/ Guideline	% Violation	# of Data Points
BOD, 5 DAY	mg/L	2.3	3.0	0.2	12.0			143
Chloride	mg/L	183.6	223.0	51.2	374.0	250	13%	147
Copper	µg/L	2.8	3.2	0.4	7.31	5.0	3%	144
Dissolved Oxygen **	mg/L	9.6	11.20	5.300	17.0	5	0%	81
Dissolved Oxygen **	% Saturation	89.4	67.2	28.3	144.4	47%	1%	307
E. Coli *	counts/100 ml	71	88	4	820	100		113
Hardness	mg/L	301	332	185	441			124
Iron	µg/L	369	466	0	2240	300	62%	127
pH		7.61	7.72	6.45	8.40	6.5-8.5	1.85%	54
Temperature	Deg C	10.66	16.00	1.00	21.10	20	3.6%	84
Nickel	µg/L	1.687	2.46	-0.825	5.010	25	0%	127
Nitrite	mg/L as N	0.133	0.17	0.003	1.110			147
Nitrates	mg/L as N	4.694	6.12	1.270	9.3	2.93	78%	147
Ammonium	mg/L as N	0.44	0.34	0.00	7.10			147
Un-ionized Ammonia	mg/L as N	0.001	0.0012	0.0000	0.0058	0.0165	0.00%	53
Total Kjeldahl Nitrogen	mg/L as N	1.10	1.02	0.36	8.80			146
Phenolics	ug/l	0.45	0.50	0.20	0.80	1	0%	4
Dissolved Phosphorus	mg/L	0.023	0.031	0.001	0.080	0.030	25%	147
Total Phosphorus	mg/L	0.061	0.070	0.016	0.254	0.030	95%	146
Suspended Solids	mg/L	8	8	2	87			127
Vanadium	µg/L	0.350	0.63	-1.570	2.2	7	0%	103
Zinc	µg/L	8.218	9.89	3.120	20.4	20	1%	103

Period of Record 1993 - 2006
* Geometric mean for E. Coli
** 25th percentile for dissolved oxygen

Table 6a Silver Creek Upstream of Georgetown - Full Record

Parameter	Units	Average	75th Percentile	Min	Max	PWQO/ Guideline	% Violation	# of Data Points
BOD, 5 DAY	mg/L	1.2	1.4	0.0	14.0			272
Chloride	mg/L	88.3	106.0	18.5	306.0	250	1%	283
Copper	µg/L	2.82	3.00	0.20	18.00	5.0	11%	251
Dissolved Oxygen **	mg/L	10.8	9.2	5.8	16.0	5	0%	230
Dissolved Oxygen **	% Saturation	93.9	85.4	41.1	179.6	57%	1%	212
E. Coli *	counts/100 ml	95	253	4	7400	100	53%	112
Hardness	mg/L	298	329	180	366			105
Iron	µg/L	225	245	0	1550	300	17%	109
pH		7.69	8.07	5.50	13.20	6.5-8.5	9.09%	132
Temperature	Deg C	10.48	16.43	0.10	23.20	20	8.6%	222
Nickel	µg/L	0.665	1.06	-1.520	2.660	25	0%	109
Nitrite	mg/L as N	0.019	0.02	0.001	0.480			283
Nitrates	mg/L as N	1.920	2.36	0.005	4.500	2.93	8%	283
Ammonia	mg/L as N	0.10	0.04	0.00	2.05			285
Un-ionized Ammonia	mg/L as N	0.001	0.0006	0.0000	0.0086	0.0165	0.00%	128
Total Kjeldahl Nitrogen	mg/L as N	0.57	0.57	0.14	5.25			282
Phenolics	ug/l	0.37	0.40	0.20	0.80	1	0%	13
Dissolved Phosphorus	mg/L	0.01	0.010	0.001	0.150	0.030	6%	282
Total Phosphorus	mg/L	0.040	0.041	0.004	0.485	0.030	35%	283
Suspended Solids	mg/L	12	12	1	139			130
Vanadium	µg/L	0.294	0.61	-1.090	2.250	7	0%	93
Zinc	µg/L	3.79	3.97	-0.86	28.30	20	2%	94

Period of Record 1964 -1971; 1993 - 2006
* Geometric mean for E. Coli
** 25th percentile for dissolved oxygen
Shaded cells are above the PWQO/Guideline

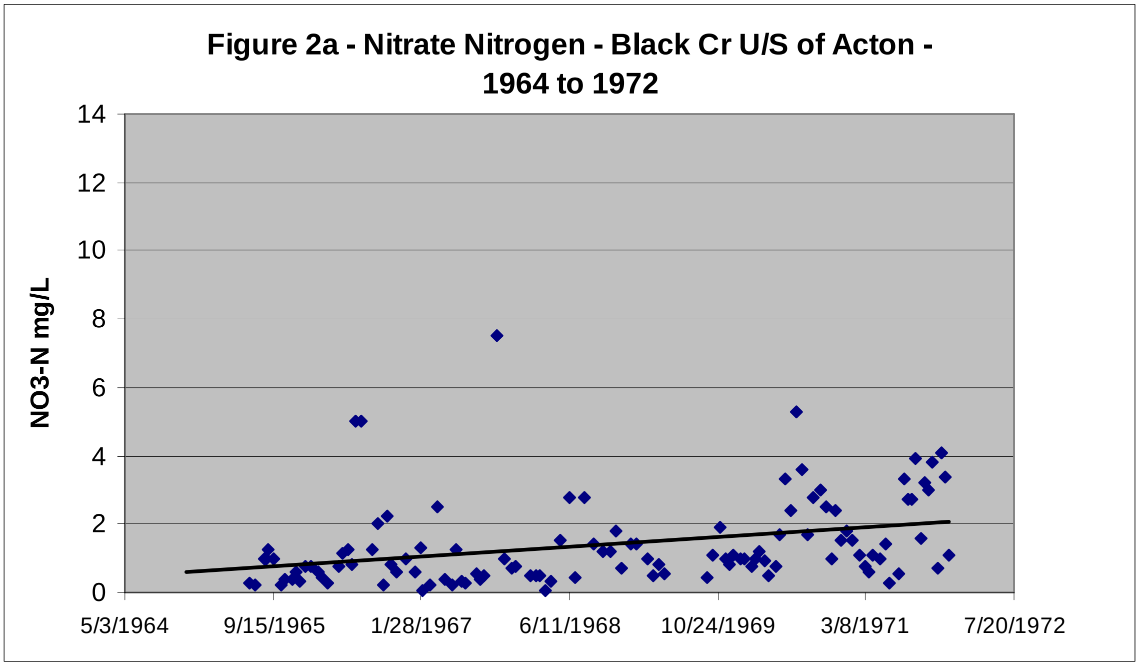
Table 6b Silver Creek Upstream of Georgetown - Since 1993

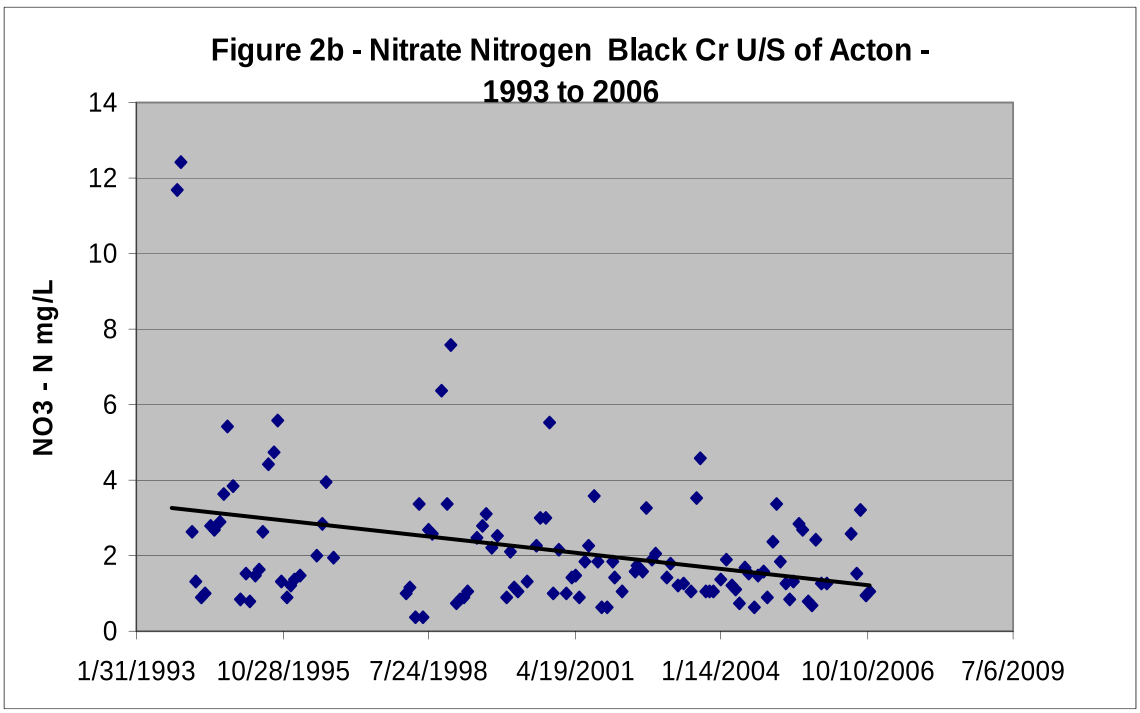
Parameter	Units	Average	75th Percentile	Min	Max	PWQO/ Guideline	% Violation	# of Data Points
BOD, 5 DAY	mg/L	1.2	1.4	0.2	6.8			124
Chloride	mg/L	97.6	110.3	40.4	306.0	250	1%	128
Copper	µg/L	1.72	1.93	0.20	7.59	5.0	1%	126
Dissolved Oxygen **	mg/L	10.5	12.375	6.4	15.6	5	0%	72
Dissolved Oxygen **	% Saturation	92.2	99.1	52.2	117.4	57%	1%	71
E. Coli *	counts/100 ml	257	253	4	7400	100	50%	112
Hardness	mg/L	298	329	180	366			105
Iron	µg/L	225	245	0	1550	300	16%	109
pH		7.94	8.09	7.00	8.43	6.5-8.5	0.00%	53
Temperature	Deg C	10.87	16.20	0.10	23.20	20	3.3%	78
Nickel	µg/L	0.665	1.06	-1.520	2.660	25	0%	109
Nitrite	mg/L as N	0.021	0.01	0.001	0.310			128
Nitrates	mg/L as N	1.884	2.37	0.005	4.100	2.93	3%	128
Ammonia	mg/L as N	0.11	0.03	0.00	1.80			128
Un-ionized Ammonia	mg/L as N	0.000	0.0004	0.0000	0.0019	0.0165	0.00%	53
Total Kjeldahl Nitrogen	mg/L as N	0.57	0.59	0.28	2.30			128
Phenolics	ug/l	0.33	0.40	0.20	0.60	1	0%	12
Dissolved Phosphorus	mg/L	0.00	0.006	0.001	0.029	0.030	0%	128
Total Phosphorus	mg/L	0.034	0.039	0.004	0.296	0.030	14%	128
Suspended Solids	mg/L	13	13	1	139			109
Vanadium	µg/L	0.294	0.61	-1.090	2.250	7	0%	93
Zinc	µg/L	3.79	3.97	-0.86	28.30	20	2%	94

Period of Record 1993 - 2006
* Geometric mean for E. Coli
** 25th percentile for dissolved oxygen
Shaded cells are above the PWQO/Guideline

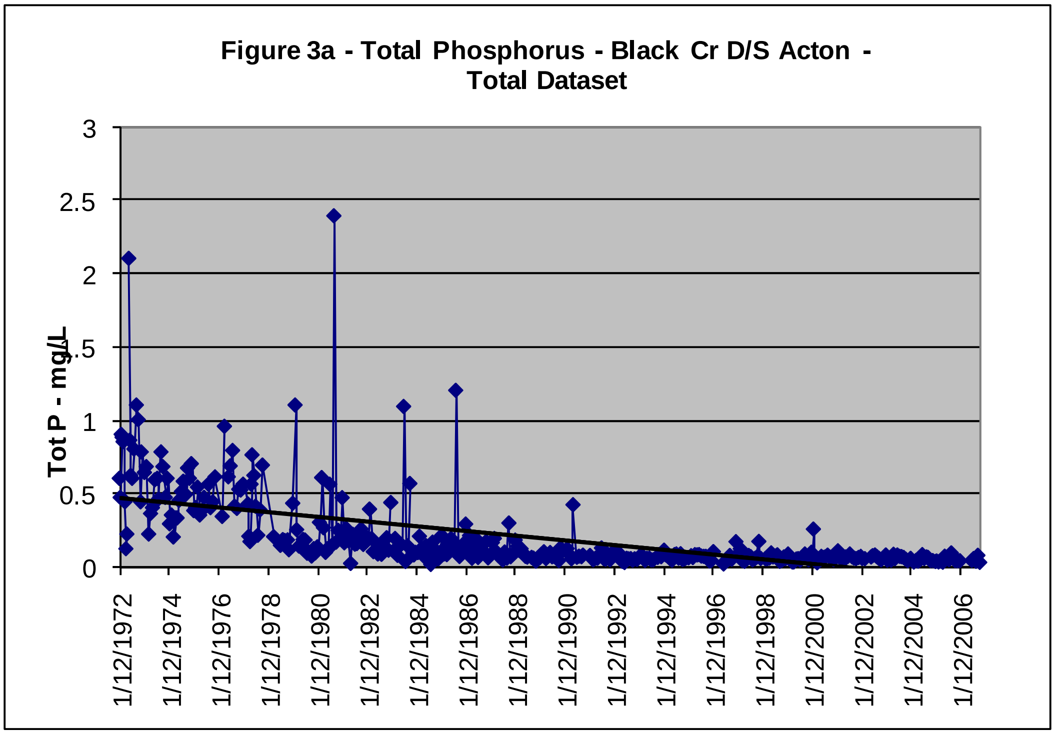
In this analysis, consideration of the 75th percentile column only is pertinent. Values that exceed the PWQO or guideline are shaded (or highlighted in yellow). Temperature data are available in the data as well and are discussed separately below (monthly temperature analysis).

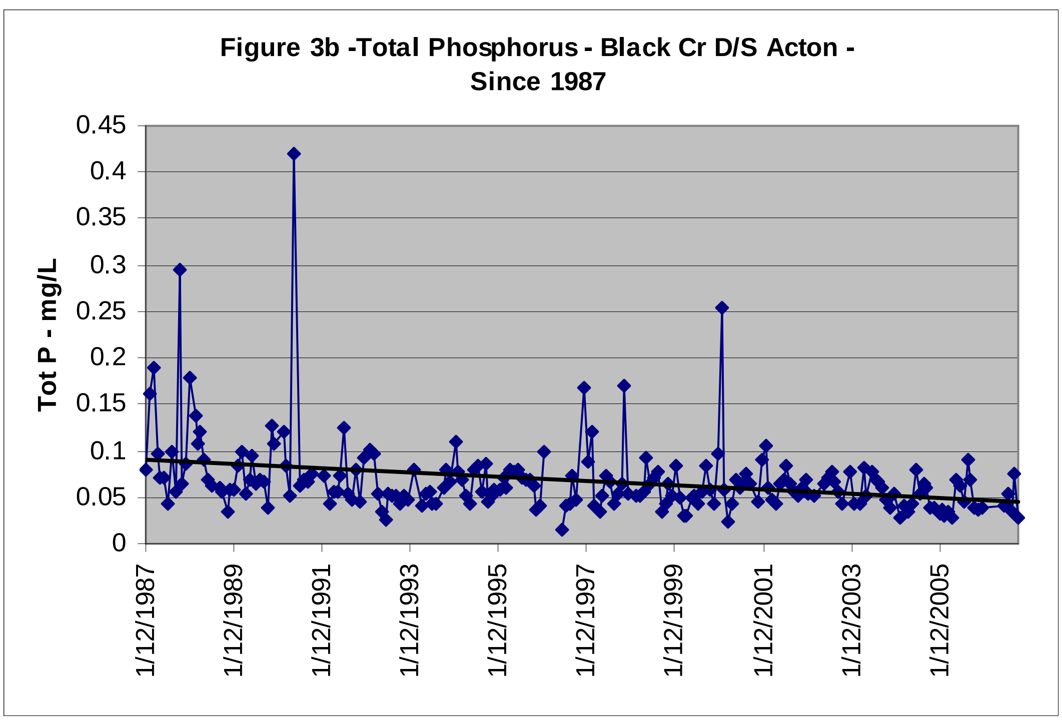
The only parameters that exceed the PWQO or Guideline levels at the 75th percentile for the background are iron, E. coli and total phosphorus.





In **Figure 2a and 2b,** data on nitrates are presented for the location upstream of the Acton WWTP. The break in the data and the trend lines are opposite; there is an increasing trend from 1964 to 1972 and a decreasing trend from 1993 to 2006.





Figures 3a and 3b for Black Creek downstream of the Acton WWTP show total phosphorus data at two different concentration (vertical) and time scales. This shows the impact of improved sewage treatment levels for phosphorus removal over the years.

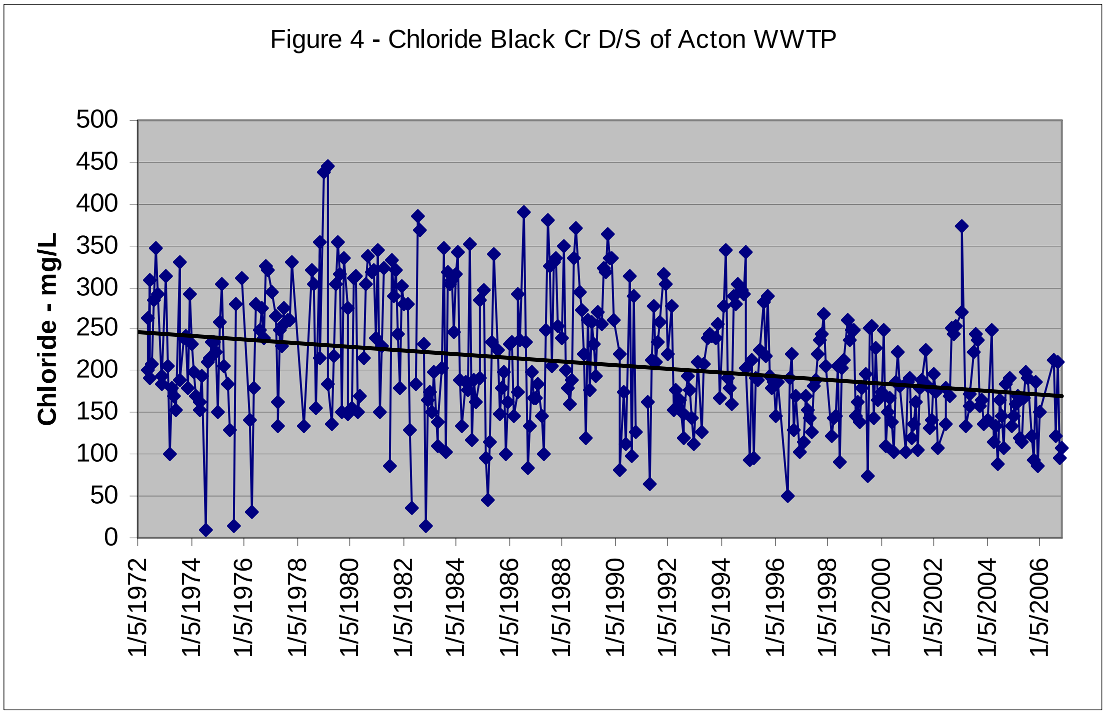


Figure 4 shows chloride data from 1972 to 2006 including a trend line. Wide fluctuations are likely due to road salting practices and snowmelt runoff events. There is an un-anticipated trend showing reduced values over time, possibly due to improved road salt management practices.

Additional background characterization is presented in **Section 3.2 Monthly Ammonia Impacts** and **Section 3.3 Temperature Impacts.**

Based on comments received from the MOE, additional data on total phosphorus was analysed. The additional analysis included adding three years to the data-set (2006 to 2009) and presenting the data monthly. This data is presented in **Table B5** in **Appendix B** and discussed in **Section 3.2.**

2.2 Effluent Characterization

Table 7a- Acton WWTP Effluent Characteristics - 2000- 2006

		Average	Max	Min	75th percentile	# data
Ammonia – Nitrogen *	mg/L	1.31	16.4	0.02	0.85	352
Carbonaceous BOD*	mg/L	1.20	4.2	1	1.2	365
Nitrate Nitrogen	mg/L	16.31	25	3.7	19.1	366
Nitrite Nitrogen	mg/L	0.20	2.18	0.01	0.32	313
pH		7.62	8.38	6.95	7.83	365
Suspended Solids*	mg/L	1.91	7.6	1	2.4	366
Total Kjeldahl Nitrogen	mg/L	2.30	19.5	0.3	2.1	363
Total Phosphorus*	mg/L	0.14	0.55	0.02	0.19	366

* Parameters with Effluent Limits and Objectives.
Annual values

Table 7a gives the annual statistics of the effluent quality for the Acton WWTP. All of the values meet the effluent objectives and compliance limits in the CofA (**Table 1**) except the maximum value for TSS. However, a single occurrence of TSS above the compliance limit is not in non-compliance, since the compliance requirement is based on the annual average. Note that the biochemical oxygen demand is carbonaceous (nitrifiers suppressed). The ammonia nitrogen levels are low (below the CofA limit and objective. The high values of nitrate, from16 to 20 mg/L, consistently, along with the low ammonia nitrogen show almost complete nitrification. Also the total phosphorus levels consistently meet objectives.

Additional analysis of the total phosphorus effluent quality was carried out after comments received from reviewers. Reviewers agreed that only data collected after 2003 could indicate current effluent quality, since new final effluent filters were operational in 2002. **Table 7b** gives the results of comparison of different time periods for calculation of effluent quality. The annual loading rate of 156.2 Kg/year of total phosphorus is considered as the basis for Policy 2 consideration. The MOE indicated that the TP loading for an expanded WWTP for Acton could not exceed this value. This could be achieved by treatment plant upgrades or a combination of upgrades and offsets (to be discussed below in Section 5.0).

Table 7b Acton WWTP Effluent Total Phosphorus Characteristics			
Total Phosphorus Multi-Year Average Data			
	Yearly averages	75th Percentile concentration	Total loading
Years	TP (mg/L)	TP (mg/L)	TP (kg/yr)
2000-2009	0.131	0.16	NA
2003-2005	0.106	0.12	149.0
2005-2008	0.094	0.1125	149.4
2005-2009	0.099	0.12	156.0
2003-2009	0.103	0.12	156.2
2004-2007	0.090	0.11	131.5
2007-2009	0.109	0.13	176.8
2008-2009	0.119	0.14	199.0

For assessment of parameters requiring monthly effluent flows (ammonia, temperature and total phosphorus), three years of data were characterized to develop a monthly fraction of the annual flow rate. **Table 8** shows the result, with higher flow rates in winter and spring likely due to infiltration. The values for each for the full CofA capacity and the two expansion scenarios are given.

Table 8 Monthly Effluent Flow for Scenarios

	Fraction*	**Current Cof A**	**Scenario 1**	**Scenario 2**
Month		**m^3/s**	**m^3/s**	**m^3/s**
Jan	1.080	0.0568	0.0700	0.0875
Feb	1.047	0.0551	0.0679	0.0849
Mar	1.101	0.0579	0.0714	0.0892
Apr	1.138	0.0599	0.0738	0.0922
May	1.097	0.0577	0.0711	0.0888
June	1.006	0.0529	0.0652	0.0815
July	0.883	0.0464	0.0572	0.0715
Aug	0.852	0.0448	0.0552	0.0690
Sept	0.907	0.0477	0.0588	0.0735
Oct	0.909	0.0478	0.0589	0.0736
Nov	0.987	0.0519	0.0640	0.0800
Dec	0.994	0.0523	0.0644	0.0805
Annual	1.000	0.0526	0.0648	0.0810

*Fraction based on 75th percentile of average monthly flow
Flow statistics from 2004 to 2006.

2.3 Discussion of Water Quality Issues and Parameters of Concern

Chloride: levels increase at the downstream station compared to the upstream. Some exceedances of the CVC guideline level are noted, with more occurring at the downstream station. These could be associated with winter runoff and salting practices. In addition, the increase in average levels could also be due to the WWTP discharge of high levels of chloride from the use of water softeners in the residential areas of Acton. The concentration of chloride drops significantly at the Silver Creek station that receives the Black Creek flow.

Dissolved Oxygen and BOD: the data collected in the PWQMN are insufficient to assess dissolved oxygen, since the samples are typically collected during the day. Minimum DO usually occurs early in the morning before sunrise. The assimilative capacity field work is addressing this issue and it is assessed later in this report with dissolved oxygen modelling. DO and oxygen demanding parameters (including total Kjeldahl nitrogen) are included in this analysis.

E. coli: levels are fairly stable from upstream (u/s) to downstream (d/s). High levels that occur occasionally both upstream and downstream of the WWTP are likely due to runoff events. The Acton WWTP continues to practice disinfection year round using ultra-violet irradiation.

Metals: *Iron* levels are higher upstream than downstream below WWTP, with both parameters above the PWQO. This is likely due to natural groundwater sources. While no data was collected on this parameter from the WWTP effluent, it is not expected to be a source. *Nickel* values show an increase from upstream to downstream, but are still well below the PWQO. *Vanadium* levels show a minor decrease from upstream to downstream, and are still well below the PWQO. *Zinc* shows a minor increase from upstream to downstream, but still well below the PWQO.

Un-ionized ammonia nitrogen: results are limited since both field pH and temperature as well as ammonia data must be available to calculate this. No exceedances of the PWQO were noted in the more recent record. This remains a parameter of concern.

Nitrate nitrogen: levels show an increase below the WWTP. A fairly high background level was observed from unknown upstream sources. At 2.7 mg/L nitrate-N is just below the CWQ guideline value of 2.93 mg/L. The downstream station shows a significant increase to levels above the CWQG for both the average and 75th percentile statistic. The level of nitrate nitrogen in the Acton WWTP (16.3 mg/L average) confirm that the source is the Acton WWTP.

Total P (also soluble P): this parameter is above the PWQO at the 75th percentile both upstream and downstream of the Acton WWTP outfall and consequently is considered a Policy 2 parameter.

2.4 Low Flow Analysis

The low flow estimates were prepared for Silver Creek and Black Creek together and are reported on in **Appendix A1** and in an update **Appendix A2**. The gauge for Black Creek is below the WWTP so the sewage flow must be accounted for (removed). In addition, historically Beardmore Tannery removed flow from Black Creek and used it in their process with the wastewater discharged to spray irrigation. Consequently, this flow was added back into the record. The results of these adjustments are shown in **Table 9a** and **Table 9b.**

Annual 7Q20 is 0.0162 m^3/s, while annual sewage flow rated capacity is 0.0526 m^3/s. The ratio of creek flow to sewage flow (the dilution ratio) is 0.31 to 1 for the low flow condition at the current plant capacity.

Table 9a - Estimated 7-day low flows for Black Creek below Acton gauge

Return Period (Years)	Raw Data For WSC gauge#	Missing Values Filled-in for 1960 to 1987#	Adjusted For irrigation Amounts (1960 to 1987)#	Acton STP Outflows Removed*	Revised Acton STP Outflows Removed	Percent Difference
[1]	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**	**[7]**
1.25	0.1000	0.0859	0.0911	0.0652	0.0634	-2.8%
1.5	0.0883	0.0726	0.0797	0.0555	0.0529	-4.7%
2	0.0787	0.0628	0.0707	0.0472	0.0446	-5.5%
5	0.0600	0.0467	0.0544	0.0305	0.0290	-4.9%
10	0.0509	0.0402	0.0470	0.0216	0.0217	0%
20	0.0439	0.0360	0.0416	0.0144	0.0162	+12.5%
25	0.0420	0.0350	0.0402	0.0124	0.0148	+19.4%
50	0.0369	0.0324	0.0366	0.0068	0.0110	+61.8%
Number of Years in record	**18**	**46**	**46**	**46**	**50**	

Note: all flows in m^3/s. * Results reported in Appendix A1 (Table 1 in Appendix A2)

Table 9b - Monthly 7-day low flow with 20 year return period for Black Creek below Acton gauge.

month	m^3/s
Jan	0.0304
Feb	0.0328
Mar	0.0314
Apr	0.0714
May	0.0715
Jun	0.0414
Jul	0.0313
Aug	0.0213
Sep	0.011
Oct	0.013
Nov	0.0321
Dec	0.0334
Annual	0.0162

(taken from Table 3 in Appendix A2)

2.5 Water Uses

The CVC considers Black Creek to be a coldwater fishery (Credit River Water Management Strategy – Phase II, (Beak Consultants, Aquafor Engineering, Donald G Weatherbe Associates, for CVC, 1992). Targets adopted for the coldwater fishery include:

- Dissolved oxygen better than 5 mg/L (this is the PWQO at 20^{o}C for coldwater fishery)
- Temperature less than 20^{o}C.
- Riparian canopy better than 80%

Passive recreation occurs at the many locations where the Creek crosses roadways, and in the Limehouse Conservation Area.

Fairy Lake upstream of the Acton WWTP has public boating and a warmwater sport fishery.
One Permit to Take Water has been issued to Dufferin Aggregates (south of the Creek on Third Line).

The water is taken from groundwater to dewater the quarry operations, with water released back to Sixteen Mile Creek and Black Creek in a 45/55% split. The maximum taking and release to Black Creek could be 0.14 m^3/s, which is almost nine times higher than the natural seven day low flow of 0.0162 m^3/s.

3.0 IMPACT OF ACTON WWTP DISCHARGE ON BLACK CREEK

3.1 Annual Impact

The purpose of this analysis is to evaluate effect of effluent at the point of discharge, assuming complete mixing. The mass balance assumptions are shown in **Table 10.**

Appendix B contains the inputs, assumptions and results of the analysis **Table B1** gives the calculation basis and conversion factors. **Table B2** shows the effluent characteristics. The effluent concentrations used are based on CofA objectives and limits. Some values are not actually in the CofA but are derived (TOD and TKN) or observed (nitrate nitrogen and chloride). **Table B2** also gives results of the calculation of annual loading rate (kg/day) of CBOD, TKN, Total Oxygen Demand (TOD = sum of ultimate carbonaceous and nitrogenous oxygen demand), ammonia nitrogen, nitrate nitrogen, chlorides and TSS.

Table 10 - Mass Balance Assumptions	
Mass balance equation	
C1xQ1 + CsxQs = C3xQ3	
Where:	
C1 = upstream concentration - typically 75th percentile of the background data	
Cs = sewage conc. - based on Certificate of Approval	
C3 = mixed, downstream concentration	
Q1 = upstream flow - typically 7Q20	
Qs = sewage flow	
Q3 = Q1 + Q2 = mixed flow	
Solved for C3	C3 = (C1xQ1+CsxQs)/Q3 to show in-stream result
Solved for Cs	Cs = (Q3xC3 -Q1xC1)/Qs to derive effluent limit
C - units mg/L	Q - units m^3/s
Q x C = load, or mass units/time, e.g. kg/day	

All calculations assume the background flow is the 7Q20 low flow derived in section 2.4 above. The background in-stream concentration is the 75th percentile for each parameter. Background conditions are given in **Table B3**.

The mass balance calculation is used to derive the resulting mixed in-stream values from the different growth scenarios assuming existing effluent limits and objectives. **Table B4** gives the results.

- Nitrate nitrogen is very high, up to 4 times higher than the CWQ guideline of 2.93 nitrate nitrogen. The status of nitrate as a control parameter in Ontario is not clear, since it is not a PWQO. Until the status as a PWQO is resolved, no effluent limit is recommended.
- Total P decreases compared to the currently permitted discharges in the CofA..
- Chloride levels are predicted to be higher than the CVC guideline. Chlorides cannot be treated in the treatment plant and reductions could only be achieved by reducing the source (discussed in Section 5.2).

3.2 Monthly Total Phosphorus Impact

After discussions with MOE following issuance of the first draft of this report, the Region of Halton proposed effluent objectives and limits for TP as follows:

- Proposed effluent objective: 0.1 mg/L
- Proposed effluent limit: 0.2 mg/L.

These values are used in the analysis presented in **Appendix B**. **Table B5** includes the monthly background for the PWQM station just upstream of the Acton WWTP for the years 2003 to 2009 inclusive. The 75th percentile values were used to calculate the increased TP concentrations expected at low-flow (using monthly 7-day low flows with a 20 year return period). The predicted in-stream values for the expansion Scenario 1 are shown in **Table B6**, while the in-stream values for expansion Scenario 2 are shown in **Table B7**.

3.3 Monthly Ammonia Impact

Based on preliminary analysis, the effluent objectives for ammonia are proposed to be more stringent than currently in the CofA, with effluent compliance limits left as currently.

- Proposed ammonia objective (May 1 to Nov. 30) - 0.5 mg/L as N
- Proposed ammonia objective (Dec. 1 to April 30) - 1.0 mg/L as N

These values as well as the current limits were analysed in Appendix B (Tables B8 to B13)

Table B8 gives data on Black Creek Upstream of Acton: monthly un-ionized ammonia nitrogen, pH, and Temperature. The full dataset was used. It is noted that the high ammonia values were recent (since 1993) in this background station. Note that the 75th percentile value of un-ionized ammonia nitrogen exceeds the PWQO in June only.

Table B9 shows results of calculation of the un-ionized ammonia in the effluent, based on in-stream temperature and pH and with effluent at the compliance limits for ammonia. None of the values exceed the current un-ionized ammonia nitrogen limit of 0.0824 mg/L (0.1 as NH_3) considered by MOE to be the limit for acute lethality.

Table B10 shows the results in-stream using the effluent ammonia concentrations from **Table B9**. Existing and future effluent flow rates show exceedances of the un-ionized ammonia PWQO when mixed with the background for the low flow condition. One contributing factor is the high background condition. To achieve levels of un-ionized ammonia that meet the instream PWQO, the effluent must also meet the PWQO. It must be recognized that the occurrence of the effluent at the ammonia limit is unlikely, based on past operational experience at the Acton WWTP.

The proposed effluent objectives of 1 mg/L ammonia in winter and 0.5 mg/L ammonia in summer will meet the PWQO at stream temperature and pH. As shown in **Table 11** (also **B11**), the mixed in-stream concentration is below the PWQO, even for the June case where the background concentration was above the PWQO.

As a check on the proposed effluent objectives, the effluent level of un-ionized ammonia was calculated for two conditions - stream temperature and pH (**Table B12**) and effluent pH and temperature (**Table B13**) - all at their respective 75th percentile levels. For the Table B12 case at stream temperature and pH, the effluent concentration is below the PWQO for 11 months of the year. However, for the case shown in Table B13, the effluent could be above the PWQO for unionized ammonia at effluent temperature and pH.

Table 11 - Black Creek d/s Acton - Unionized Ammonia Downstream with Effluent Mixed in at effluent objective- Predicted by Mass Balance

Month	Proposed ammonia Objective	Existing STP Flow	Scenario 1	Scenario 2
	mg/L	mg/L	mg/L	mg/L
Jan	1	0.0071	0.0070	0.0069
Feb	1	0.0046	0.0045	0.0044
Mar	1	0.0049	0.0050	0.0051
Apr	1	0.0093	0.0093	0.0093
May	0.5	0.0043	0.0044	0.0045
Jun	0.5	0.0124	0.0118	0.0112
Jul	0.5	0.0053	0.0053	0.0054
Aug	0.5	0.0051	0.0050	0.0049
Sep	0.5	0.0059	0.0059	0.0059
Oct	0.5	0.0051	0.0048	0.0046
Nov	0.5	0.0027	0.0028	0.0028
Dec	1	0.0039	0.0038	0.0038

PWQO 0.02 mg/L NH3 or 0.01647 as NH3-N mg/L as N
Shaded exceeds PWQO
*at stream temperature and pH
Based on concentration upstream Table B7 and effluent at proposed objective
Using monthly effluent flows from Table 8 and monthly 7Q20 from Table 9

3.4 Temperature Impacts

3.4.1 Monthly Temperature Balance

A monthly temperature analysis is presented in a series of Tables in **Appendix B.**

Table B14 to Table B19 give the steps in the temperature balance at the point of discharge. The temperature variation of the Acton WWTP effluent are shown in **Table B14.** The existing background condition in **Table B15** has maximum values in the order of 26°C in July and August, but that the 75th percentile is close to the target of 20°C. Also note that the downstream station below the Acton WWTP has lower temperatures than the upstream station for many months. **Table B17** gives the change from upstream to downstream in the historical data statistics. This shows little effect from the WWTP discharge plant, or even a tempering (temperature reducing) effect.

Temperature balance calculations **Table B18** predict that the in-stream temperature no higher than 20.4^{o}C in low flow conditions for the growth scenarios, assuming 75th percentile temperatures upstream and in the effluent with the increases predicted in **Table B19.**

A temperature target was developed in discussion with CVC staff based on the designation of the stream fisheries as cold/cool mixture. The temperature target for Black Creek is 20^{o}C based on the background review. The dominant cold water species is brook trout and this species needs protection from high temperature fluctuations above the target.

3.4.2 Temperature Survey

The temperature survey data is presented in the Part II Field Study Report, Section 3.

3.4.3 Temperature Model

A temperature model was set up for the reaches below the Acton WWTP outfall along Black Creek from the Fairy Lake outflow to the confluence of Black Creek and Silver Creek. The inputs include initial mixing at the point of discharge of the WWTP, groundwater, and one tributary as well as meteorological factors such as solar radiation, dew-point temperature and wind speed. The stream geometry (depth, width, reach-length and flow velocity) along with the location of inputs defines the system modelled. The reach setup is the same as for the dissolved oxygen model discussed below and shown in **Figure 1** and documented in **Appendix D.** The model is described in detail in **Appendix E,** with inputs and results given in **Appendix F**. Once set up, the model can be used to assess the impact of changes in the flow regime, channel geometry, channel shade from bank canopy and location of discharges.

The model was set up initially for the conditions present during the August 31, 2007 flow survey. The results can be seen in **Figure 5.** In calibrating the model, the only changes made were in the estimate of the amount of canopy present in each reach. To verify that the model is reasonable, a separate case was set up for the June survey. Only changes to parameters for known inputs were made such as meteorological data, flows and upstream temperatures. The verification case in **Figure 6** shows reasonable agreement with the observed data.

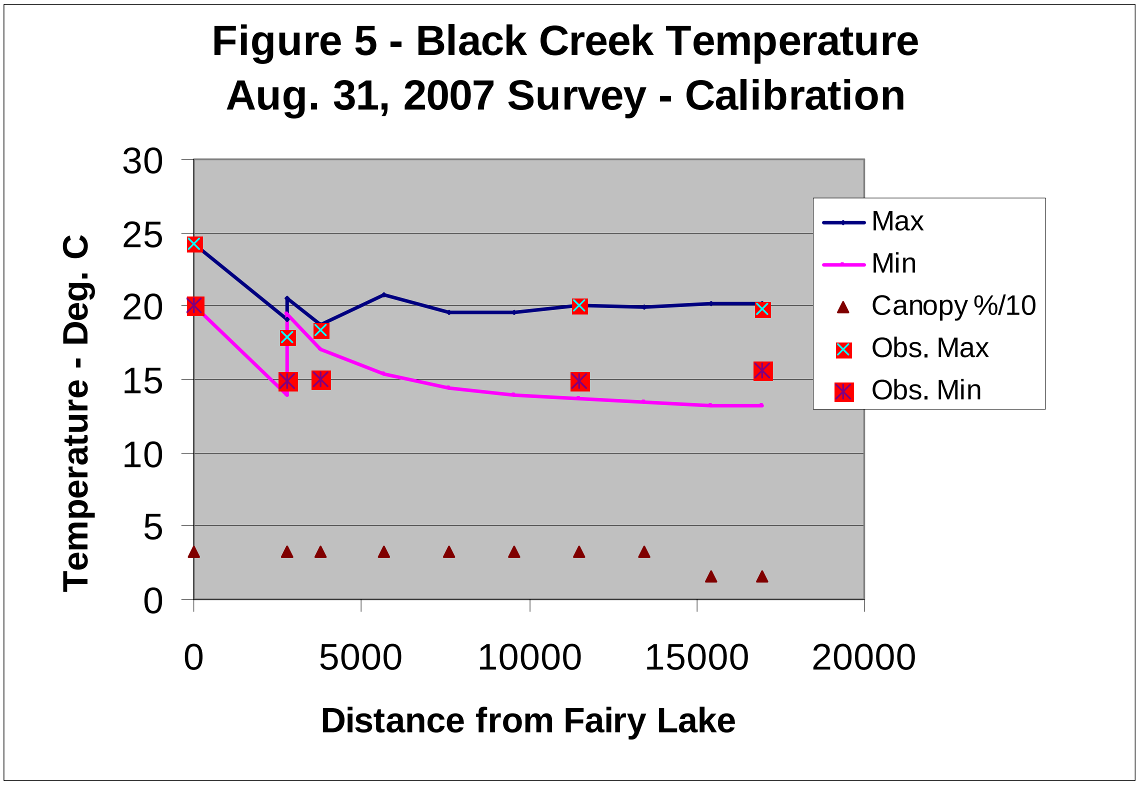


Figure 5 - Black Creek Temperature
Aug. 31, 2007 Survey - Calibration
Temperature - Deg. C
0
5
10
15
20
25
30
0
5000
10000
15000
20000
Distance from Fairy Lake
Max
Min
Canopy %/10
Obs. Max
Obs. Min

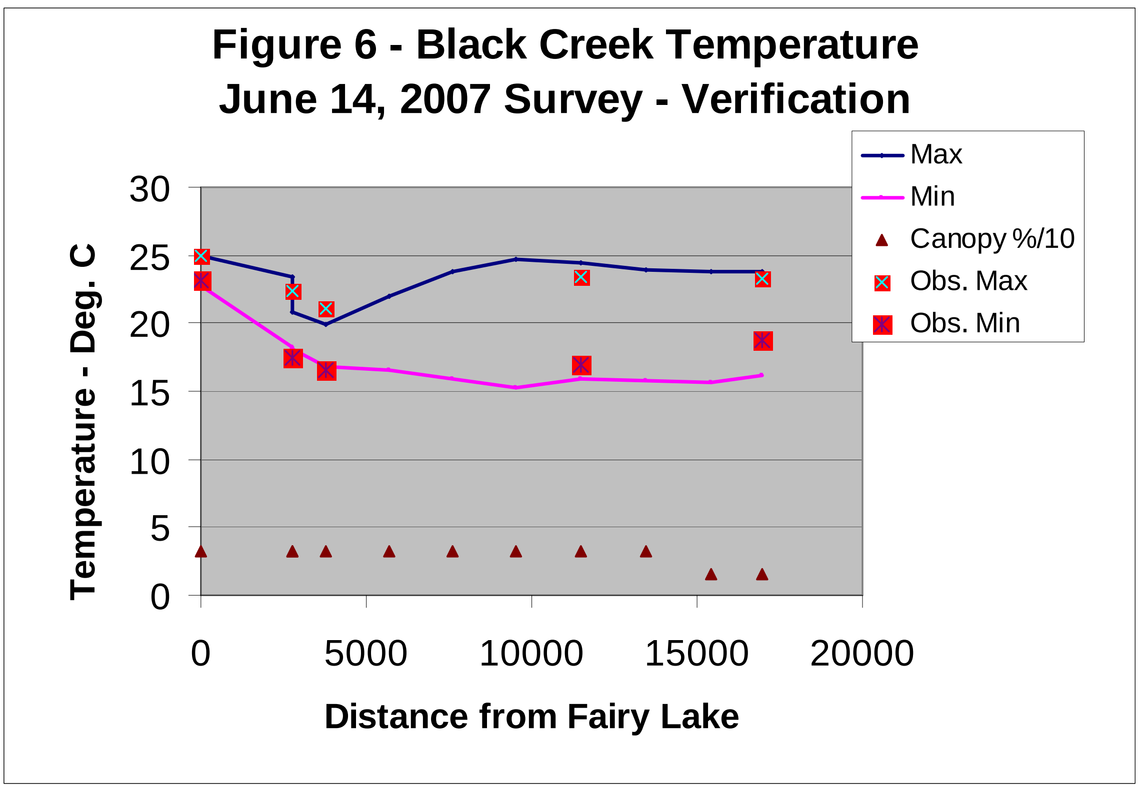
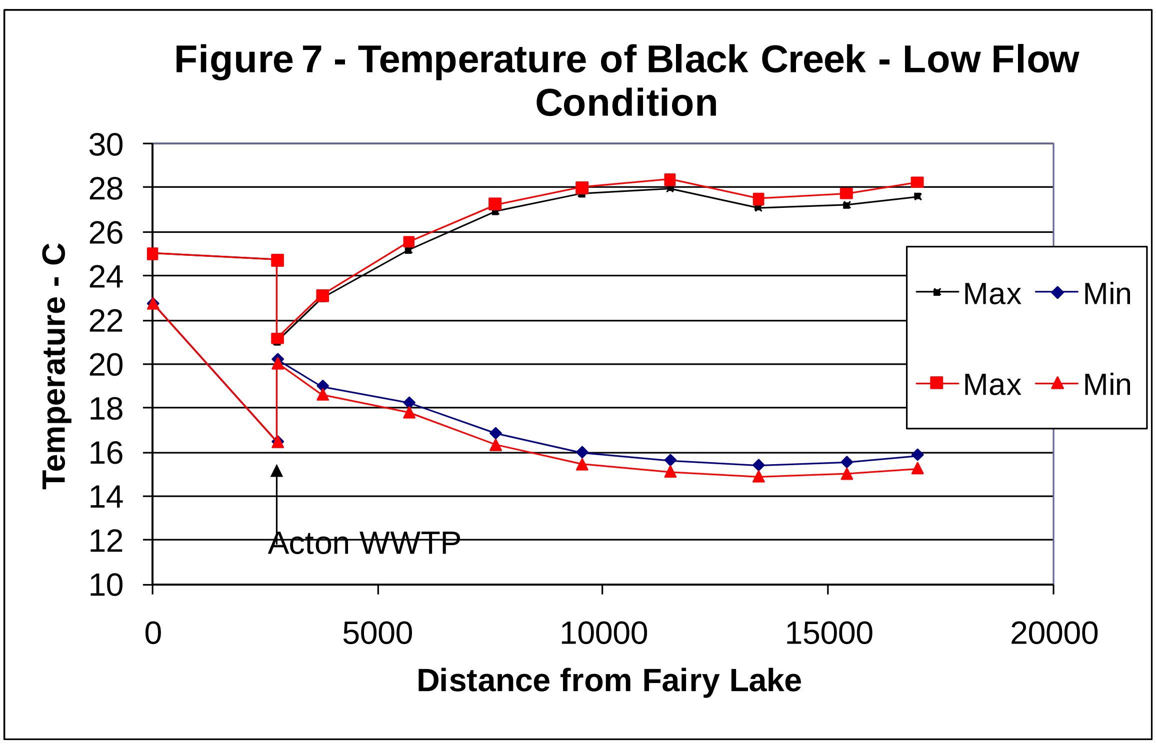


Figure 6 - Black Creek Temperature
June 14, 2007 Survey - Verification
Temperature - Deg. C
0
5
10
15
20
25
30
0
5000
10000
15000
20000
Distance from Fairy Lake
Max
Min
Canopy %/10
Obs. Max
Obs. Min

The model was then run for low flow conditions with the following assumptions made:

- Black Creek Upstream flow 7Q20 annual flow: 0162 m^3/s
- Temperature upstream at Fairy Lake – as for the June survey
- Ground water temperature and flow – as calibrated – 15°C
- Tributary – Black Creek North Branch – as for June Survey
- Canopy – as calibrated – varies from 16 to 32 %
- Meteorological conditions. The hottest day in the three month record of temperatures was chosen as it represents a worst case – Aug. 3, 2007
- WWTP flow – three scenarios
- Existing condition of plant at CofA capacity 4545 m3/day
- Fully expanded WWTP at 7000 m3/day
- All WWTP temperatures assumed 75th percentile for August – 20.6 C.

Figure 7 shows the result of the low flow case for the existing WWTP at full flow capacity and the fully expanded WWTP after the second expansion (to 7000 m^3/day). The expanded WWTP effect is to reduce maximum temperature by up to 0.5°C, due to the increased flow at a cooler temperature than the receiving water.



3.5 Dissolved Oxygen Impacts

3.5.1 Dissolved Oxygen Survey

Two surveys were carried out (June 2007 and August 2007) as described in the Part II Field Study Report. It is noted that the station immediately upstream of the Acton WWTP has high levels of several parameters (and low dissolved oxygen) due to marshy conditions, beaver activity, some unidentified source, or backwater effects near the outfall. The August 31 2007 survey in **Table 12** was used in calibrating the dissolved oxygen model.

Table 12 - August 31, 2007 Field Survey Data

Location	DO mg/L Max	DO mg/L Min	DO mg/L Avg	NO_3-N mg/L	TKN mg/L
B1	6.65	8.01	7.15	0.2	0.6
B2	4.39	3.06	3.68	3.6	2.3
S1	5.05	6.29	5.85	17	0.9
B3	7.25	7.9	7.44	8.2	0.8
B4	7.84	8.59	8.15	3.8	0.7
B5	8.64	9.86	9.22	2.9	0.6
B6	8.56	10.12	9.27	3	0.4
T1	8.07	8.91	8.54	0.3	0.4

3.5.2 Dissolved Oxygen Model

A dissolved oxygen model (DOMOD) was set up for Black Creek from the point of discharge to the confluence with Silver Creek. The model is steady-state and accounts for the impact of oxygen consuming substances from the sewage, sediment oxygen demand, and reaeration from the atmosphere. The oxygen demanding substances are from carbonaceous sources (often measured as BOD_5) and nitrogenous sources (calculated from the total Kjeldahl nitrogen levels). The model is described in detail in **Appendix C**.

The model was set up for the low flow and loading conditions as described in the mass balance discussion above. A full description of input values and assumptions is given in **Appendix D**.

The model building proceeds with the following steps:

1) The geometry of reaches and flow inputs was set up along with hydraulic coefficients describing the change in width, depth and flow velocity with flow rate.
2) The hydraulic coefficients were adjusted to reflect measurements during the three flow surveys detailed in the Part II Field Study Report.

3) The model was calibrated for the August 2007 field survey. **Figure 8** shows the predicted carbonaceous (CarBOD) and nitrogenous oxygen demand (NOD) along with the observed NOD (based on the total Kjeldahl nitrogen). The BOD data collected all showed below detection limit values. The reportable detection limit of 2 mg/L BOD would convert to approximately 3mg/L CarBOD ultimate (as plotted), which is consistent with the predicted values. This correctly reproduces the reduction in concentration of the NOD parameter largely due to the dilution effect of groundwater inputs. **Figure 9** shows the calibrated model prediction as well as the observed data. Note that the curve showing the dissolved oxygen prediction (DO Pred) tends to plot over the minimum DO observed levels. For the downstream reaches, after the initial mixing of the effluent, the DO is very close to the saturation level. The only change to input parameters was to reduce the reaeration term to give a better match between the predicted and observed DO concentrations.
4) The model was then set up for the design conditions, with background levels of BOD, DO, TKN and temperature set at 75th percentile levels. Flows based on 7Q20 flows natural flow upstream of the WWTP with estimates of tributary and groundwater inputs made in proportion to the average of the three flow surveys. The calibrated hydraulic coefficients and reaeration rates were adopted as well. This was run with the existing CofA flow and concentration compliance limits to show the impact and provide a basis to compare other flow scenarios. The results are shown in **Figures 10** and **11**.

Figure 8 – Oxygen Demanding Substances – Black Creek Downstream of Acton – Calibration to August 2007 Survey

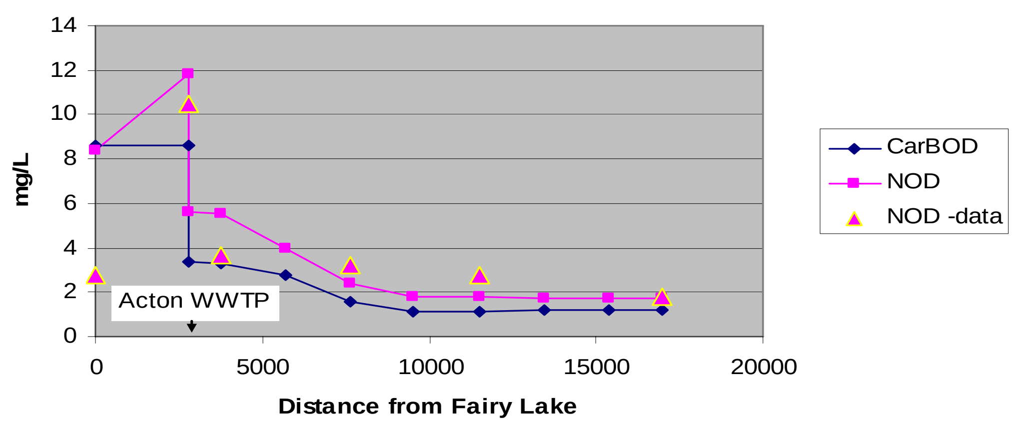


Figure 9 – Dissolved Oxygen – Black Creek Downstream of Acton – Calibration to Aug. 2007 Survey

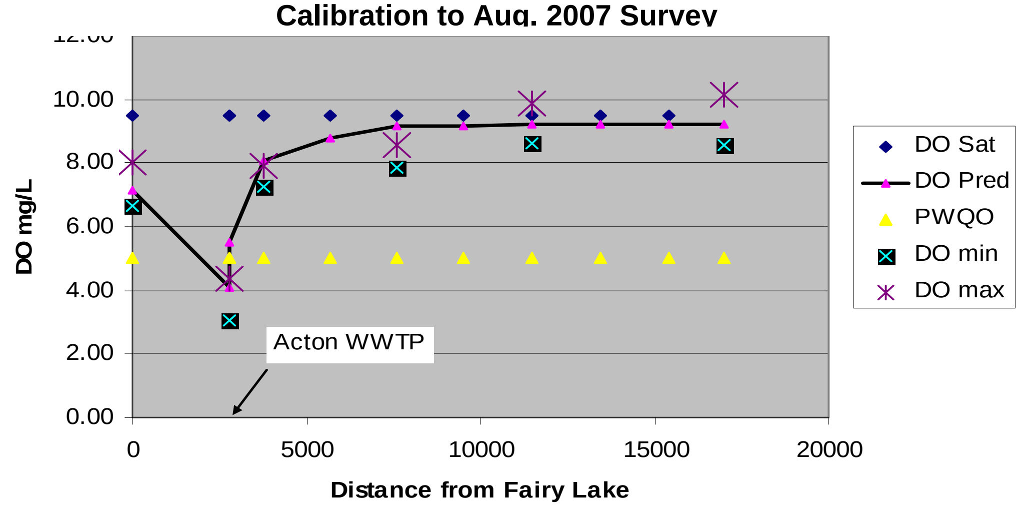
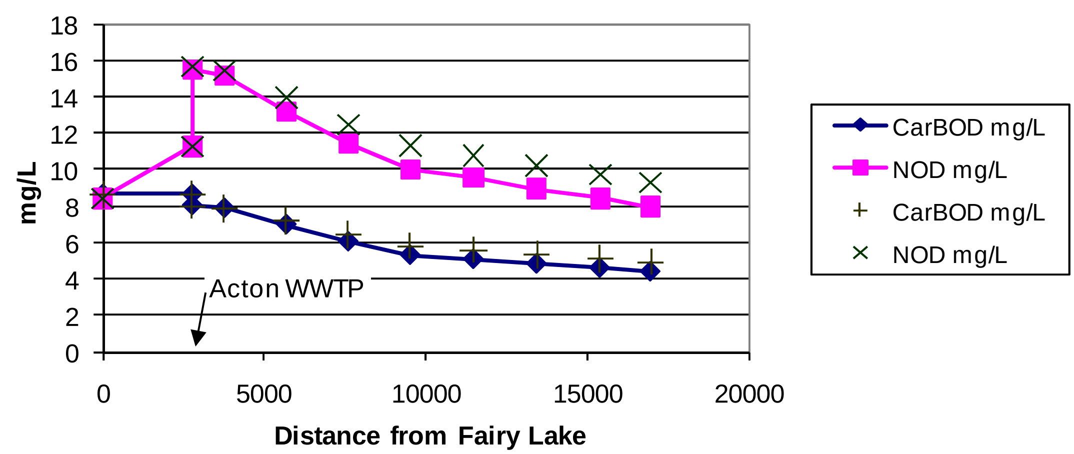
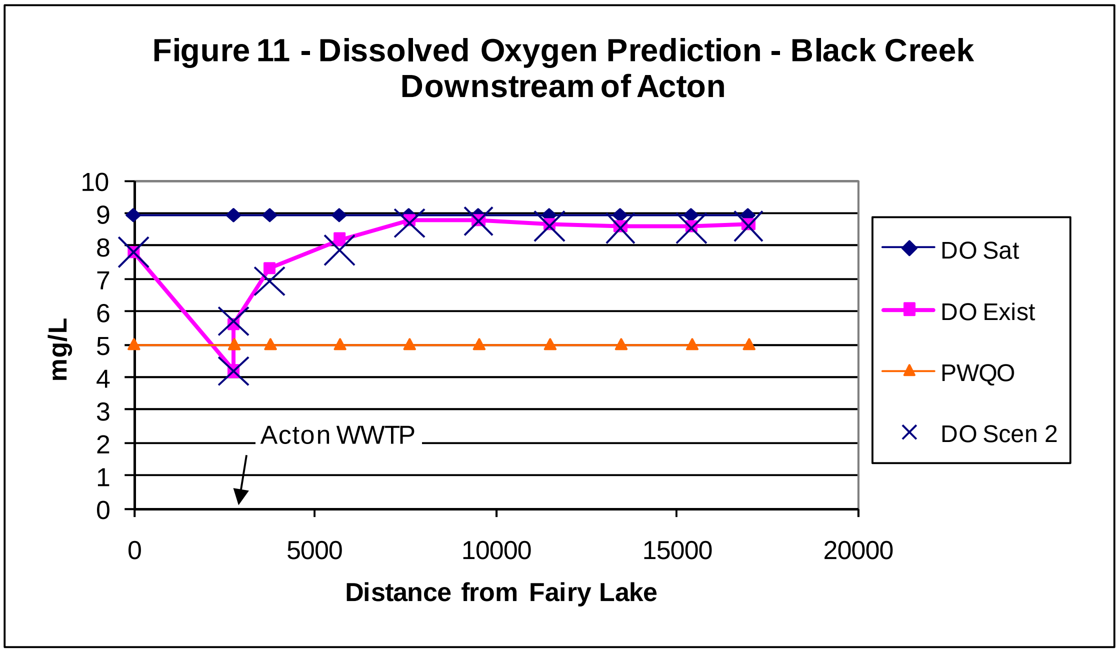


Figure10 - Oxygen Demanding Parameters - Black Creek Downstream of Acton WWTP



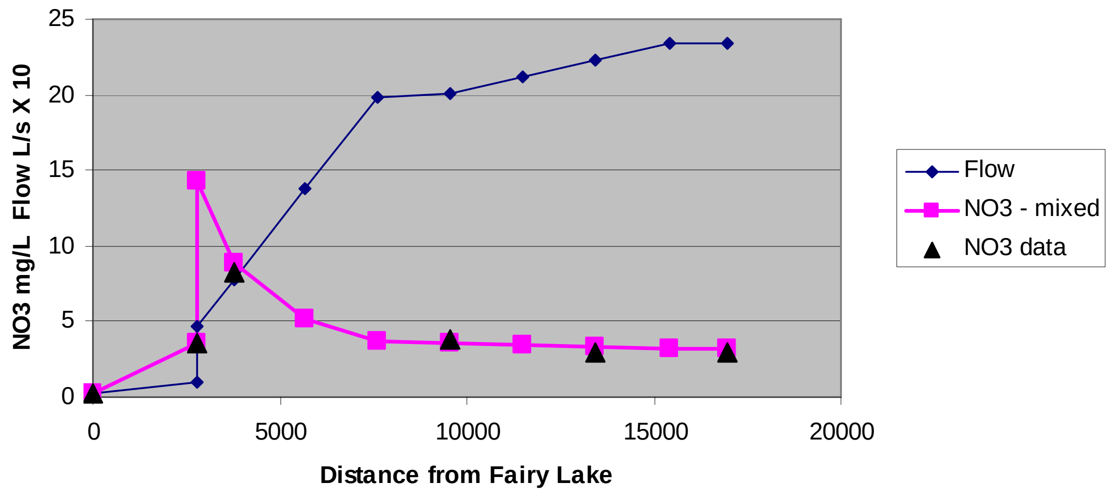


5) The model was run for growth scenarios. Summary results showing minimum dissolved oxygen predicted for each scenario is given in **Appendix D.** The lowest DO for each case is at the point of discharge, due to the low background level as observed in the field surveys. Since the effluent is well aerated (also observed) it actually raises the DO. In addition to the CofA case, Scenario 2 with the ultimate flow of 7000 m^3/d is shown on **Figure 10** and **Figure 11**. In Figure 11, the DO predicted for the existing rated capacity is shown as "DO Exist" and for Scenario 2 as "DO Scen 2".

The impact of the discharges other than the initial mixing is minimal. This is because the loadings and resulting concentrations of oxygen demanding substances are low relative to the capacity of the stream to assimilate the load. The assimilation of these substances is high due to the relatively fast moving stream which transports the wastewater to Silver Creek in only a few hours and because of dilution from groundwater inputs and tributaries. The oxygen demand by contaminants is low relative to this transport. In addition, a high degree of dilution by groundwater with low levels of contaminants reduces the concentration of effluent parameters. Also, the shallow, relatively fast moving stream has a high reaeration rate. The result is that after the initial mixing, the DO recovers close to the DO saturation level as can be seen in **Figure 11**.

The impact of the flow dilution effect can be seen in **Figure 12** based on the August 31, 2007 field survey. The graph shows both the nitrate nitrogen predicted levels and the observed from the survey. The increase in flow downstream below the WWTP exactly mirrors the decrease of both the observed and predicted nitrate nitrogen concentrations. In this analysis the nitrate was considered conservative, so the only process involved in reducing the concentration is dilution.

Figure 12 – Nitrate Nitrogen and Flow for Black Creek Downstream of Acton WWTP – Aug. 2007 Field Survey



3.6 Mixing Zone Consideration

No mixing zone calculations are presented. An important condition for calculating a mixing zone is that the watercourse flow be substantially greater than the discharge it is being mixed with. In the case of Acton, for the low flow case, the WWTP discharge flows are greater than the stream flow. In this case the mixing zone or mixing length is considered to be negligible. In other words, the effluent can be considered to be completely mixed at the point of discharge. The parameter of concern for mixing zones is typically un-ionized ammonia with consideration of effluent and instream pH values. The evaluation of ammonia impacts above considered both cases and concluded that the proposed effluent objectives were sufficiently conservative that the PWQO would always be met in Black Creek.

4.0 EFFLUENT REQUIREMENTS

The effluent requirements for the following parameters are proposed:

- **Ammonia**: the ammonia nitrogen objective to be set at a level that meets the PWQO for unionized ammonia. The above analysis indicates that meeting 1.0 mg/L ammonia nitrogen in winter (December to April) and 0.5 mg/L in summer (May to November) satisfies this requirement.

- **Un-ionized ammonia:** A limit of 0.1 mg/L for any single sample. This requires effluent monitoring for ammonia, temperature and pH in order to calculate un-ionized ammonia.
- **Biochemical Oxygen Demand:** limit of 5 mg/L and a treatment objective of 2 mg/L (same as the current CofA).
- **Total suspended solids**: limit of 5 mg/L and a treatment objective of 2 mg/L (same as the current CofA).
- **Total phosphorus**: a compliance limit of 0.2 mg/L and a treatment objective of 0.1 mg/L. These effluent targets for TP are considered by the study team and Halton Region operations staff to be the limit of technology. MOE has advised that these effluent targets do not meet Policy 2 interpretation that allows no increase of TP loads over existing observed levels. The impact of this is discussed below in Section 5.1 - Alternative Measures - Total Phosphorus Control.
- **Nitrate nitrogen**: since there is no PWQO for nitrate, the requirement to meet the CWQ objective should be considered in discussion with MOE.
- **Toxicity**: the effluent should be non-acutely lethal. This will be attained through the un-ionzed ammonia objective.

No effluent limits or objectives are proposed for the following parameters:

- **Chlorides**: no limit or objective is proposed. It is recommended that chloride be monitored and that a source control program be carried out (see **Section 5.2** below).
- **Metals**: no limits are proposed. The effluent should be monitored to establish metal concentration characteristics.
- **Dissolved oxygen:** monitoring of the effluent and downstream as part of the monitoring and contingency plan.
- **Chlorine residual:** the current method of effluent disinfection - ultraviolet irradiation - will continue and chlorination will not be used.

A monitoring and contingency plan of action should be adopted as discussed in Section 6.

5.0 ALTERNATIVE MEASURES

5.1 Total Phosphorus Controls

One option considered for phosphorus control is to offset the increased discharge of TP above the current CofA by reducing loads from another source that discharges to the same watercourse. There are a number of precedents in Ontario where this has been allowed, such as the South Nation River watershed, and the Lake Simcoe watershed. In some of the cases, a multiplier is applied to account for uncertainty of the measures. For example in the South Nation, an increase of 1 kg of annual load from a point source must be offset by a 4 kg reduction from agricultural sources. This ratio of 4 to 1 reductions is often called the trading ratio.

For the Uxbridge urban area, the WWTP discharges to Uxbridge Brook, this is a Policy 2 watercourse for phosphorus. It was considered by the Region of Durham (the WWTP owner) that the limit of cost effective control technology had been reached and higher level of control would be prohibitively expensive. The proposed expansion along with increased TP loading was allowed on the condition that equivalent reductions were to be made by retrofitting stormwater management controls in the existing urban area drainage system. In this case, the trading ratio was 1 to 1. In discussion with MOE staff, another example (Nobleton, Ontario) was cited with a trading ratio of 2 to 1.

The MOE has indicated the basis for offset calculations in accord with its Policy 2 interpretation. **Table 13** below indicates the calculation. For the full expansion to Scenario 2, approximately 100 kg/yr of total phosphorus loading would have to be offset. If urban runoff controls are to be implemented, then about 200 kg/yr of TP loading would have to be controlled at an offset ratio of 2 to 1. If rural measures were to be implemented, then 400 kg/yr would have to be offset. Combinations of rural and urban measures would be between these two loads.

The Region of Halton has carried out a separate analysis of urban and rural controls (Acton Total Phosphorus Management Study, 2009 and Acton Total Phosphorus Management Study- Rural Offsets, 2010).

Table 13 - Total Phosphorus Loading Rates for Acton WWTP				
	Flow	**Effluent Conc**	**Loading Rates**	**Case**
	m3/day	mg/L	kg/yr	
Existing CofA	4545	0.2	331.8	CofA objective
	4545	0.3	497.7	CofA limit
Current Effluent Load.	4545		156.2	Average loading 2003 -2009*
Scenario 1	5600	0.1	204.4	Proposed objective
	5600	0.2	408.8	Proposed limit
			48.2	Load to be offset**
Scenario 2	7000	0.1	255.5	Proposed objective
	7000	0.2	511.0	Proposed limit
			99.3	Load to be offset**
* MOE determined base case for load cap to calculate effluent ojective				
** Based on effluent objectiv				

This option is considered reasonable as an alternative to increased levels of treatment as the treatment level needed becomes higher (and more costly) in order to satisfy MOE policy requirements.

"Policy 2: Water Quality which presently does not meet the PWQOs shall not be further degraded and all practical measures shall be undertaken to upgrade the water quality to the objectives.

"Where new or expanded discharges are proposed, no further degradation will be permitted and all practical measures shall be undertaken to upgrade water quality. However, it is recognized that, in some circumstances, it may not be technically feasible, physically possible or socially desirable to improve water quality toward Provincial Water Quality Objectives (PWQO).

Accordingly, where it is clearly demonstrated that all reasonable and practical measures to attain Provincial Water Quality Objectives have been undertaken but where:

1) the Provincial Water Quality Objectives are not attainable because of natural background water quality; or
2) the Provincial Water Quality Objectives are not attainable because of irreversible human induced conditions; or
3) to attain or maintain the Provincial Water Quality Objectives would result in substantial and widespread adverse economic and social impact; or

4) suitable pollution prevention techniques are not available; then deviations from this policy may be allowed, subject to the approval of the Ministry of the Environment." (Water Management, MOE, 1994)

If the application for use of offsets in lieu of treatment would seen as a deviation from Policy 2, then a deviation would be required. There is a "request for deviation" procedure to apply for this consideration of offsets. Implementation of an offset plan would be required as a condition as part of the Certificate of Approval for the WWTP.

5.2 Chloride and Water Softeners

Chloride levels in the effluent were sampled only recently (September 2007). The levels are higher in the effluent (308 mg/L) than the background in-stream levels (75^{th} percentile of 238 mg/L). A likely source is the extensive use of water softeners. The water supply is taken from groundwater sources with a high hardness level, with the result that water softeners in the residential areas are used extensively. Water softeners remove hardness (calcium carbonate equivalent) through ion exchange, and frequently must be recharged. The recharging or regeneration process involves flooding the ion exchange column with a brine solution of high concentrations of sodium chloride with the excess amounts wasted to the sewage system. The water supply of Acton has a level of hardness at 318 mg/L (as $CaCO_3$) or 22.3 grains/gallon (gpg). Canada Mortgage and Housing Corp. classify water over 180 mg/L of hardness or 10.5 gpg as "very hard".

The only available measure to reduce salt levels in the wastewater flow is to reduce salt use in water softeners. This is related to softener efficiency. Most softeners used by residents are of the type that is classed as "fully automatic" with regeneration cycles preset on a time basis. The regeneration cycle is calculated from the water hardness and the number of residents in the household and represents an average hot water use. More efficient softeners use "demand initiated regeneration" (DIR) that includes a flow meter or harness sensor which automatically initiates the regeneration process based on need identified by processing a preset volume of water or an increase in hardness in the processed water. According to various manufacturers' claims, DIR equipped softeners use between 40 and 50% less salt and also less water for regeneration. Softened water use is directly related to hot water use, so water and energy efficiency measures related to hot water use will reduce salt load to the sewage system as well.

Consumers on well systems with water quantity problems would buy the more efficient units for the water efficiency benefit alone. Environmentally conscious homeowners would buy them for environmental and energy benefits. There is a limited cost advantage – reduced salt use may only save in the order of $10 per year.

CMHC recommends that all products that come into contact with drinking water be certified to the appropriate health-based performance standard developed by NSF International. In the case of water softener units, it is recommended that they be certified as meeting standard NSF/ANSI 44.

The Water Quality Association certifies the efficiency of water softeners according to NSF/ANSI 44 and lists the efficiency of all tested softeners according to two levels.

- Efficiency Rated – an efficiency rated softener was tested and found to have met the standards for salt efficiency rating (at least 3350 grains of total hardness removal per pound of salt utilized) hardness removal and reduction of specific contaminants.
- CA Efficiency Rated – a California efficiency rated water softener was tested and found to have met the standards for salt efficiency rating (at least 4000 grains of total hardness removal per pound of salt utilized) hardness removal and reduction of specific contaminants.

Two suppliers of softener units (Culligan International and Kinetico Inc.) were contacted to see if Efficiency Rated and CA Efficiency Rated softeners were available in Ontario. Both suppliers market locally, and carry softener models that meet the higher CA Efficiency rated standard in their inventory.

A calculation was made of the impact of use of more efficient softeners in the Acton urban area. Assuming new residents use water softeners that are 40% more efficient (use 40% less salt), and then the concentration of chloride should fall by 6% to 11% in the effluent on average for the two increased serviced population scenarios. If all softeners in Acton are replaced with more efficient softeners, then the average concentration should fall by 33%. Details of the calculations are given in **Appendix H.**

It is recommended that Halton Region and the Town of Halton Hills require all residential units to be equipped with water softeners meeting the CA Efficiency Rating for salt use. This requirement can be part of the development agreement with land developers and builders. In addition, an education program should recommend current residential users replace existing water softeners with more efficient units. The Town of Halton Hills should consider developing a by-law requiring more efficient (CA Efficiency Rated) softeners be used when replacing existing units in Acton. This will also result in some water and energy efficiencies, and these benefits should be recognized in the education program.

Environment Canada issued a report on road salts under the Canadian Environmental Protection Act, 1999, (Priority Substances List Assessment Report, Road Salts Environment Canada, Health Canada, 2001). This was followed by a "Notice with Respect to the Code of Practice for the Environmental Management of Road Salts" (Canada Gazette Government Notices, April 2004). The main focus of the notice is the requirement that road authorities develop salt management plans. Included in the notice are Annex A: "Environmental Impact Indicators for Road Salts" and "Annex B: Guidance for Identifying Areas that are Vulnerable to Road Salts". The references identify that chlorides are a potential problem for aquatic biota in the Credit River. For example, the No Observed Effect Concentration for fathead minnows of 252 mg/L chloride has been cited by the CVC in adopting the guideline level of 250 mg/L chloride.

In addition, if Black Creek is considered to be an area vulnerable to salt, then the road authorities (Halton Region and Town of Halton Hills) should review and update their Salt Management Plans to account for this concern. In doing this, additional best management practices for roads draining to Black Creek.

5.3 Flow Augmentation

There are two possible sources of additional water that could possibly be used for flow augmentation - Fairy Lake and Dufferin Aggregates. An arbitrary set of target flows were identified in **Table 14** that relate to the estimated 7Q20 low flow and the current dilution ratio.

Table 14 - Flow Augmentation Targets

Target	Augmentation Flow	Target Assumption
	m^3/s	
Target 1	0.0162	Double 7Q20 flow
Target 2	0.0122	Add amount of increased WWTP flow Scenario 1
Target 3	0.0284	Add amount of increased WWTP flow Scenario 2
Target 4	0.0033	Maintain current dilution ratio for scenario 1
Target 5	0.0088	Maintain current dilution ratio for scenario 2

5.3.1 Fairy Lake Augmentation

Fairy Lake is a 26.6 ha lake upstream of the Acton WWTP on Black Creek. The lake was created by a dam to provide a water supply source for Beardmore Tannery in Acton. The water taking was discontinued in 1987. The lake is maintained at a relatively constant level with flow routed through the lake fairly rapidly following storm events. Land use around the lake includes residents, parkland, and a trailer park. The upper end of the lake is a wetland. Water uses include some boating, warm water fishing and passive recreation. The dam overflow weir is maintained with stop logs.

If the water level were allowed to rise 0.3 m (approximately 1 foot) and/or drop 0.3 m, then 0.3 to 0.6 m of water could be stored and released slowly to the Black Creek. This would be an addition to the current flow rate over the outlet weir. **Table 15** indicates the amount of time that the various target flows could be maintained by drawing down the lake by 0.3 m or 0.6 m.

Table 15 - Augmentation Option 1 - Fairy Lake Draw-down

		Duration of Augmented Flow				
Storage elevation change	vol	target 1	target 2	target 3	target 4	Target 5
m	ha.m	days	days	days	days	days
0.3	7.98	57.01	75.64	32.51	246.30	104.96
0.6	15.96	114.03	151.28	65.01	492.59	209.91

It can be seen that even with the lower level of drawdown of 0.3 m, augmentation targets can be sustained for substantial periods of time. The actual duration of a drought has not been analyzed here, but two to three months is a reasonable estimate.

In order to implement this option, the following actions would need to be taken:

1) Assess the impact on the wetland and fishery;
2) Assess the impact on shore land uses;
3) Consider the acceptability of a change in operation of the lake. Note that the historical operation of removing 0.026 m^3/s for the tannery use is larger than all but one of the suggested targets, suggesting that the magnitude of water level fluctuations was experienced previously;
4) An analysis of continuous operation of the lake levels to meet various targets with predictions of water level fluctuations; or

5) If acceptable, a low flow outlet would have to be constructed at the location of the dam with a manually controlled valve.

5.3.2 Dufferin Aggregates Augmentation

Dufferin Aggregates operates a quarry located near the bank of Black Creek near Third Line (Station B3 on **Figure 1**). The quarry is dewatered to allow the workings of the site. The Permit to Take Water provides for the pumped water to be released to Sixteen Mile Creek and Black Creek. The PTTW issued under the Ontario Water Resources Act expires in October 2007 and is presumably been reissued, possibly with different conditions. The daily maximum allowable release to Black Creek is 0.14 m^3/s. The release point is approximately 2 km from the Acton WWTP. Conceptually, part of the flow could be pumped upstream and added into Black Creek at the location of the Acton WWTP outfall. **Table 16** gives an indication of the percentage of the Dufferin Aggregates flow that would be needed to meet the augmentation targets.

Table 16 - Augmentation Option 2 - Diversion from Dufferin Aggregates

Case	sewage flow	upstream flow	dilution ratio	Augmented	total	dilution ratio	% of Duf. Ag. flow
	m3/s	m3/s		m3/s	m3/s		%
Current CofA	0.0526	0.0162	0.3080	0	0.0162	0.3080	0
Target 1		0.0162		0.0162	0.0324		11.6
Target 2	0.0648	0.0162	0.2499	0.0122	0.0284	0.4383	8.8
Target 3	0.0810	0.0162	0.2000	0.0284	0.0446	0.5507	20.4
Target 4	0.0648	0.0162	0.2499	0.0038	0.0200	0.3078	2.7
Target 5	0.0810	0.0162	0.2000	0.0088	0.0250	0.3086	6.3

In order to implement this option, the following actions would need to be taken:

1) Assess the availability of the water on a continuous basis by examining records of the water taking. Identify if the water would be available long term, even after Dufferin Aggregates the quarry operation was worked-out;
2) Approach Dufferin Aggregates to find out if an agreement can be reached for the diversion of the water; or
3) Determine costs for pumping, location of the pump operation, and potential routes of a diversion pipe.

6.0 MONITORING AND CONTINGENCY MEASURES

In order to protect the water quality of Black Creek from potential negative impacts of the Acton WWTP discharge during low flow conditions, a series of monitoring and contingency action items is suggested. The MOE is concerned that the low dilution ratio provides little capability for the stream to absorb plant upsets or other conditions that might be harmful. Monitoring is suggested to obtain more background information and to provide a basis for making decisions about remedial actions. The remedial actions should be planned for and ready to implement when warranted. Key to the monitoring program is to establish various triggers that will initiate levels of preparedness or action. The actions are outlined in **Table 17.**

Table 17 - Monitoring and Contingency Actions

Measure	Purpose	Comment/timing
Upstream and downstream flow monitoring	Indicate drought condition	Install new gauge upstream and remotely acquire flow information from this gauge and the gauge at Third Line. Use indication of low flows to initiate other measures
Operate Fairy Lake (install manual valve for more accurate flow control). Consider diversion of Dufferin Aggregates dewatering flow	Augment flows	When drought condition and problems downstream. Evaluate augmentation options to assess acceptability
Effluent DO monitoring	Indicate occurrence of low DO in effluent	Establish if need for aeration contingency
Effluent aeration (if need established)	Raise DO to 5 mg/L	When DO in effluent low and drought condition
Instream DO, T, and Conductivity	Measure impact downstream. Indicate success of treatment.	Continuous station – at Third Line (same location as flow gauge), Also indicates need for augmentation or other measures. Conductivity can be a surrogate for chorides
Instream macroinvertebrates/fishery	Establish health of stream habitat and biota	Annual. Report to CVC and MOE
Effluent toxicity monitoring	Indicate acute toxicity	Quarterly initially. Consider reducing to annually after 2 years.
Effluent parameters (metals – others?) Chloride	Collect background characterization Measure effectiveness of softener efficiency program,	Use to modify source control (sewer use by-law) if problem. Add to routine effluent monitoring program

7.0 CONCLUSIONS

The findings of the Assimilative Capacity study are outlined below:

- Black Creek at the point of discharge of the Acton Wastewater Treatment Plant is considered to be a Water Management Policy 2 for total phosphorus as the background concentration exceeds the Provincial Water Quality Objectives (PWQO). To stay within Policy 2, increased treatment requirements are outlined in this report.
- The high levels of nitrate nitrogen in the effluent cause exceedances of the CWQG. To meet the guideline, an additional treatment process called de-nitrification would be required to remove nitrate nitrogen. As there is no PWQO for nitrate, the need to remove nitrate and the effluent concentration objective should be reviewed with the MOE.
- The current effluent requirement for ammonia nitrogen should be modified such that the effluent limit for ammonia meets the PWQO for un-ionized ammonia.
- Dissolved oxygen modeling based on extensive field work indicates that the current levels of treatment protect the water quality from degradation. There is no justification for changing the current effluent objectives for biological oxygen demand (BOD) or suspended solids.
- Concerns about high levels of chloride in the effluent should be addressed by reducing salt use in water softeners. The Region of Halton and Town of Halton Hills should require new developments to install high efficiency softeners that meet the California standard. In addition, existing users of softeners should be encouraged to replace the current models with more efficient softeners.
- Total phosphorus offsets could be considered as an alternative to additional treatment for this parameter. Either retrofitted urban stormwater management or rural runoff controls in the watershed could provide these offsets. Temperature impacts from the discharge of Acton WWTP are minimal. Additional riparian plantings of shade trees and bushes should be encouraged.
- The possibility of flow augmentation from changing operation of Fairy Lake should be further investigated.
- A monitoring and contingency plan should be implemented to identify problem situations and provide appropriate responses to protect the water quality of Black Creek.

APPENDIX A1
Low Flow Analysis

Schroeter & Associates

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MEMORANDUM

TO: Don Weatherbe, P.Eng., Weatherbe Associates, Mississauga, Ontario

FROM: Dr. Harold Schroeter, P.Eng.
Signature:_____________________________

DATE: Wednesday July 18, 2007

PROJECT: 06-13

SUBJECT: Acton and Georgetown STP low flow analyses - results **Pages: 12**

As requested last week, this memo summarizes the low flow analyses for the receiving streams at the approximate locations of the Acton and Georgetown STP (Sewage Treatment Plant) outfalls. The description of the various analyses is presented below in point form with some commentary. All the figures and tables that are referenced in the text have been located at the end of this memo.

1. The Acton STP discharges to Black Creek. The closest available Water Survey of Canada (WSC) stream gauge to this location is called the *Black Creek below Acton* (02HB024), which has an effective drainage area of 24.5 km^2 (as measured in the Subwatershed 11 Study). This gauge began monitoring daily flows in 1987. For the purposes of this memo, this gauge will be referred to as the Black Creek gauge.

2. The Georgetown STP discharges to Silver Creek, also known as the Credit River West Branch. The closet available WSC gauge to this location is called the *Credit River West Branch at Norval* (02HB008), and it has an effective drainage area of 128 km^2 (also measured in the Subwatershed 11 Study). It has been in operation since 1963. For this memo, this gauge will be referred to as the Silver Creek gauge.

   Daily flow data to the end of 2005 were available for both WSC gauges directly from the WSC website, or from the most recent HYDAT CD-ROM. Some processing of the available data for both gauges was required to obtain a suitable length of record. Here, it was decided to consider flows for the 1960 to 2005 period. Because there is a strong correlation between the flows measured at both gauges, it was decided to develop time-series relationships in order to fill-in missing values in each record.

The flows at the Silver Creek gauge can be used to estimate for missing values at the Black Creek gauge. The following time-series relationships were developed:

[1] $QB(t) = 0.7266\ QB(t-1) + 0.1566\ QS(t) – 0.114\ QS(t-1)$

[2] $QB(t) = 0.1587\ QS(t)$

where QB represents the flows at the Black Creek gauge, QS the flows at the Silver Creek gauge, and t is the time in days. The correlation coefficient (R^2) for Eq. [1] was found to be 93%, whereas the corresponding value for Eq. [2] was 81%. Eq. [2] was used to start the missing value fill-in procedures, and Eq. [1] was applied for the bulk of the work.

For the Silver Creek gauge, missing values for 1960 to 1963 were estimated using the following relationships:

[3] $QS(t) = 0.8013\ QS(t-1) + 0.5727\ QC(t) – 0.4306\ QC(t-1)$

[4] $QS(t) = 0.7261\ QC(t)$

where QS represents the flows at the Silver Creek gauge, QC the flows at the Credit River near Cataract gauge (02HB001), a gauge that has been monitoring flows since 1913. Flows for the Cataract gauge were obtained also from the WSC website. The correlation coefficient (R^2) for Eq. [3] was found to be 89%, whereas the corresponding value for Eq. [4] was 71%. Eq. [4] was used to start the missing value fill-in procedures for the Silver Creek gauge.

3. The single station frequency analyses (SSFA) were carried out using procedures in a program called FAPLOT (for **F**requency **A**nalysis **Plot**ting), a program developed in-house by Schroeter & Associates. The procedures fitting the normal (N), lognormal (LN), the three-parameter lognormal (LN3P), and the Gumbel (also called the Extreme Value Type I, or EV1) distributions for both high and low flows by moments are identical to those utilized in the Consolidated Frequency Analysis (CFA) program (Pilon et al., 1985; 1993) provided by Environment Canada, and also described in Kite (1978) and Watt et al. (1989). The FAPLOT program was updated in 2005 to fit the Extreme Value Type III (EV3 or Weibull) distribution that is typically applied for low flow analyses. The procedures for fitting this distribution by the method of moments (MM), and by the method of lowest observable drought (LOD) are identical to those given in Kite (1978). The requisite tests for independence, trend, homogeneity and randomness (see Watt et al., 1989; Kite 1978) indicated that the annual minimum 7-day low flow series for each gauge were acceptable for a SSFA. The procedures given in FAPLOT were modified slightly to allow automatic processing of the records for monthly 7-day low flow estimates as well.

4. Before 1987, irrigation water was removed during the summer months (May to September) from Fairy Lake in Acton. The maximum rate at which this water was removed from Fairy Lake has been estimated to be 0.026 m^3/s. The flow records for both gauges were adjusted to account for the irrigation water taking, that is the estimated amounts were added back into the records.

5. Using information obtained from Peel Region, the average annual discharge for each STP was estimated for the entire period of record (1960 to 2005) considered in the present analysis. **Figure 1** illustrates the annual time-series of the flows noted above, showing the actual measured and filled-in 7-day low flows, for the Black Creek gauge, whereas Figure 2 shows the annual 7-day low flow series adjusted for the irrigation amounts, and the removal of the Acton STP flows. Figure 3 and 4 are similar plots for Silver Creek at the Georgetown STP outfall. Figures 5 and 6 are the annual frequency distribution plots for both the Black and Silver Creek gauges before the STP flows are removed from the analyses. As you can see, the fitted EV3 distribution agrees well with the observed values.

6. Tables 1 and 2 give return period 7-day low flow estimates for the annual series at each gauge following the adjustments noted above. For example, the 7Q20 (7-day low flow with 20 year return interval) at the Black Creek gauge is 0.0439 m^3/s when estimated using the as measured WSC data for 18 years of record, but is 0.0416 m^3/s when the data set has been extended to 46 years and the irrigation flows for 1960 to 1987 have added back in. When the Acton STP outflows are removed from the analysis, the 7Q20 flow has been estimated to be 0.0144 m^3/s. The 7Q20 flow just upstream of the Georgetown STP outfall when all the factors noted above have been considered has been computed as 0.094 m^3/s.

7. The final fully-processed monthly 7-day low flow estimates for locations just upstream of the Acton and Georgetown STP outfalls are noted in Tables 3, 4, 5 and 6.

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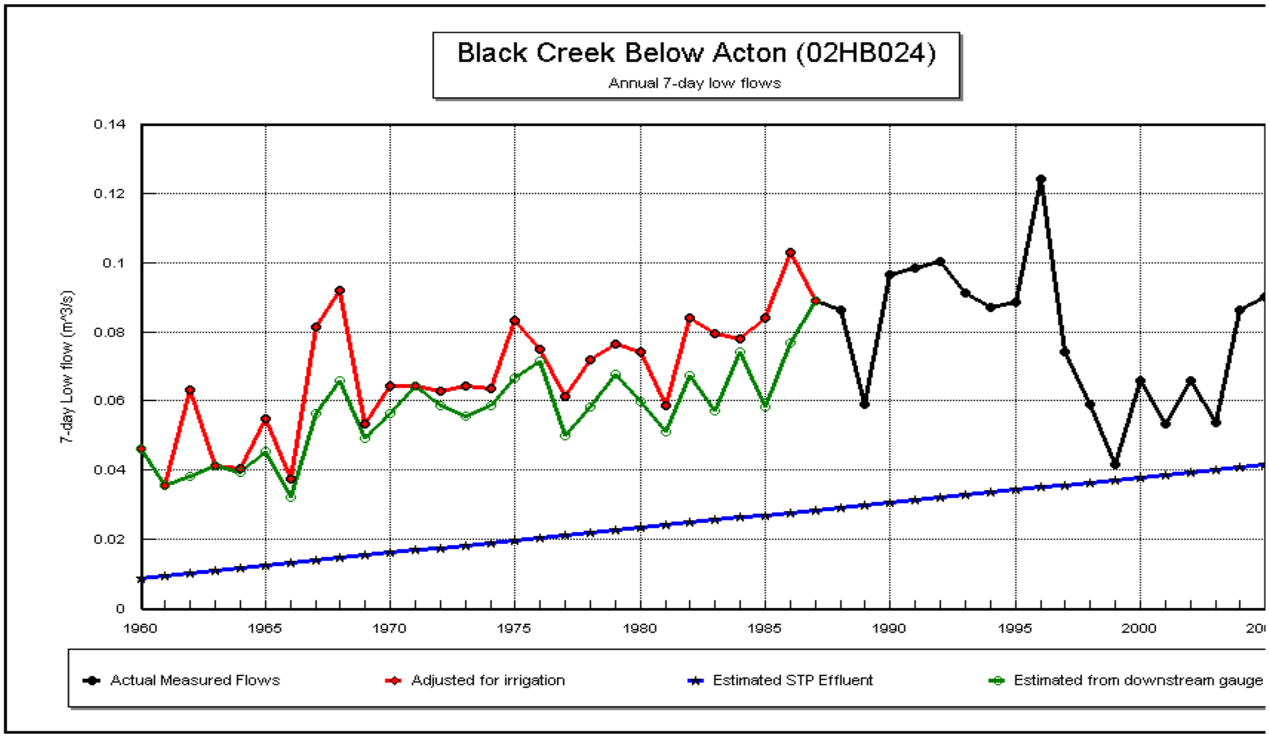

Figure 1 Time-series of 7-day low flows for Black Creek below Acton gauge (02HB024)

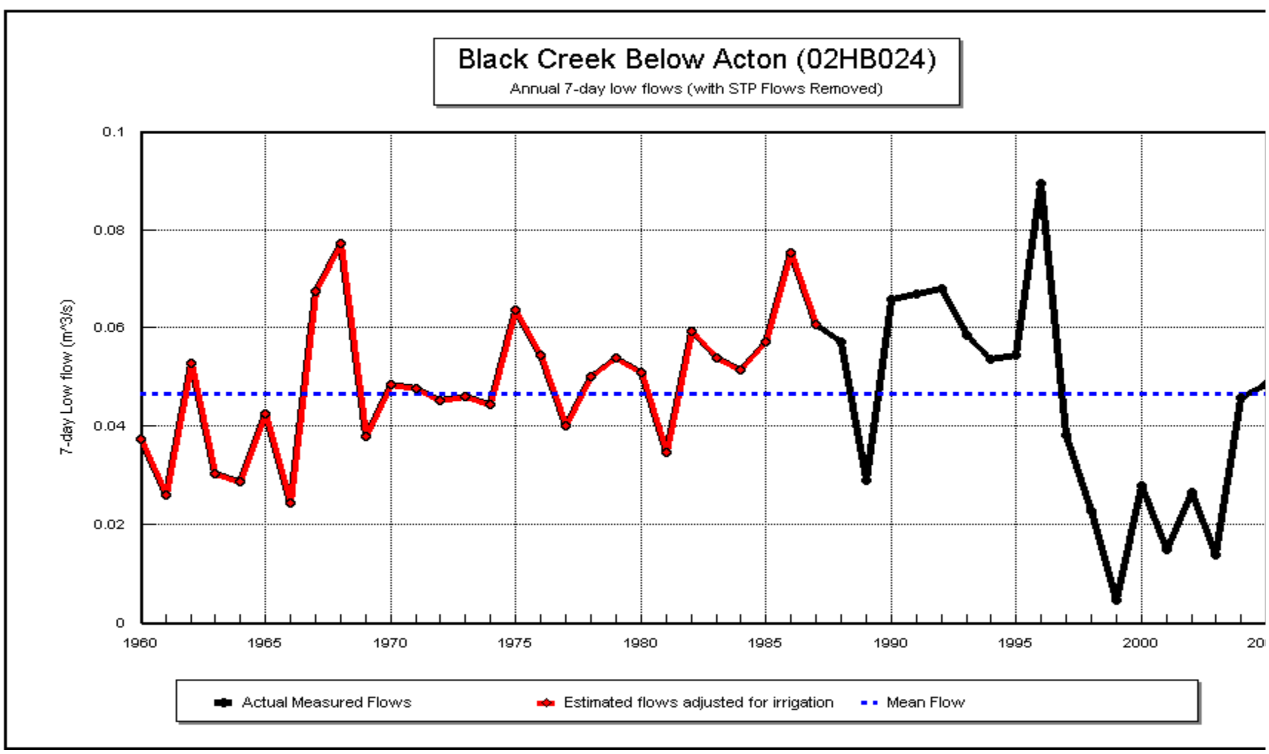

Figure 2 Time-series of 7-day low flows for Black Creek below Acton gauge (02HB024) with Acton STP outflows removed

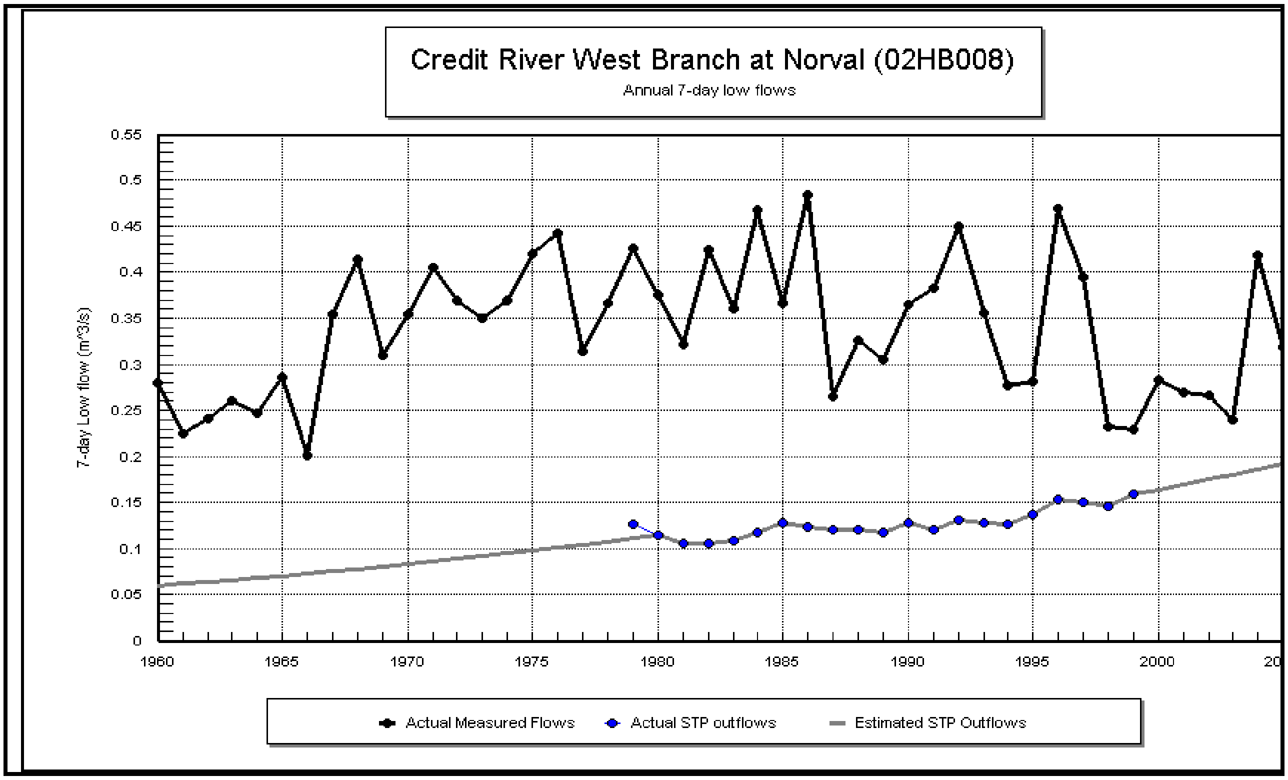

Figure 3 Time-series of 7-day low flows for Credit River West Branch at Norval gauge (02HB008)

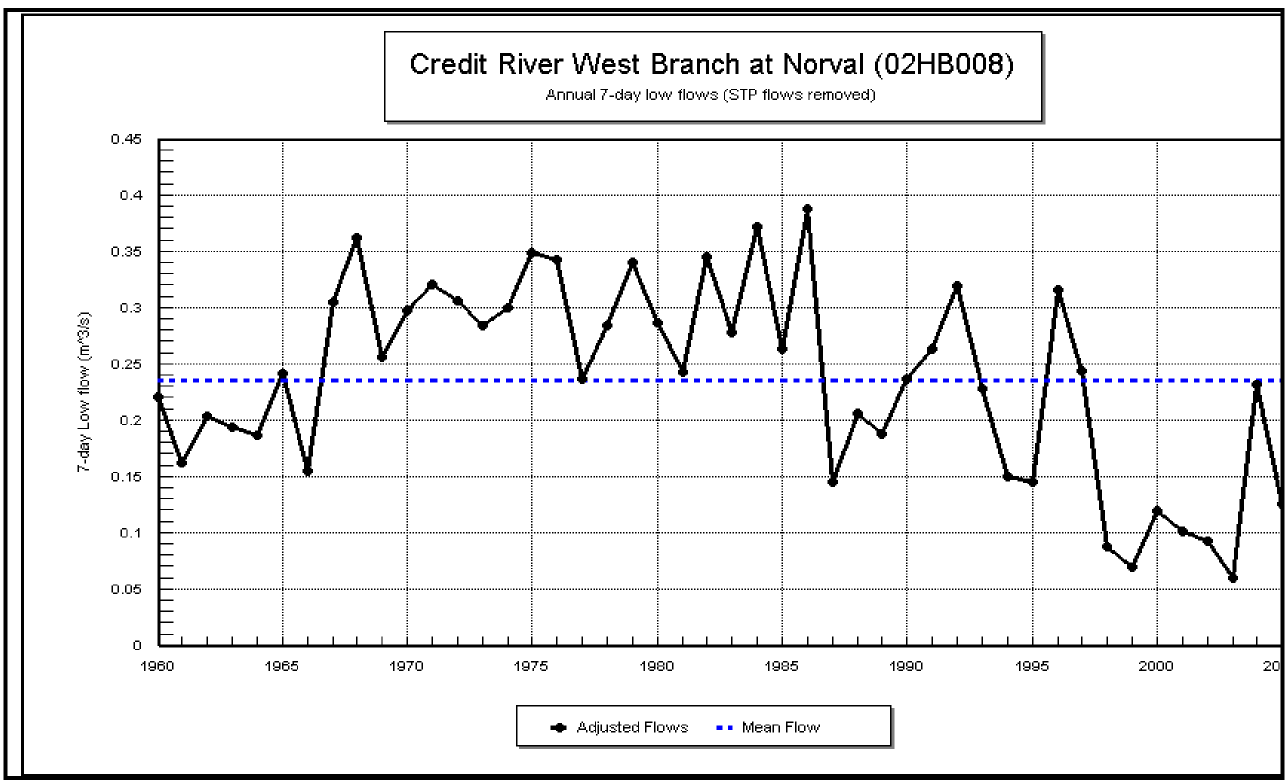

Figure 4 Time-series of 7-day low flows for Credit River West Branch at Norval gauge (02HB008)

With Georgetown STP outflows removed

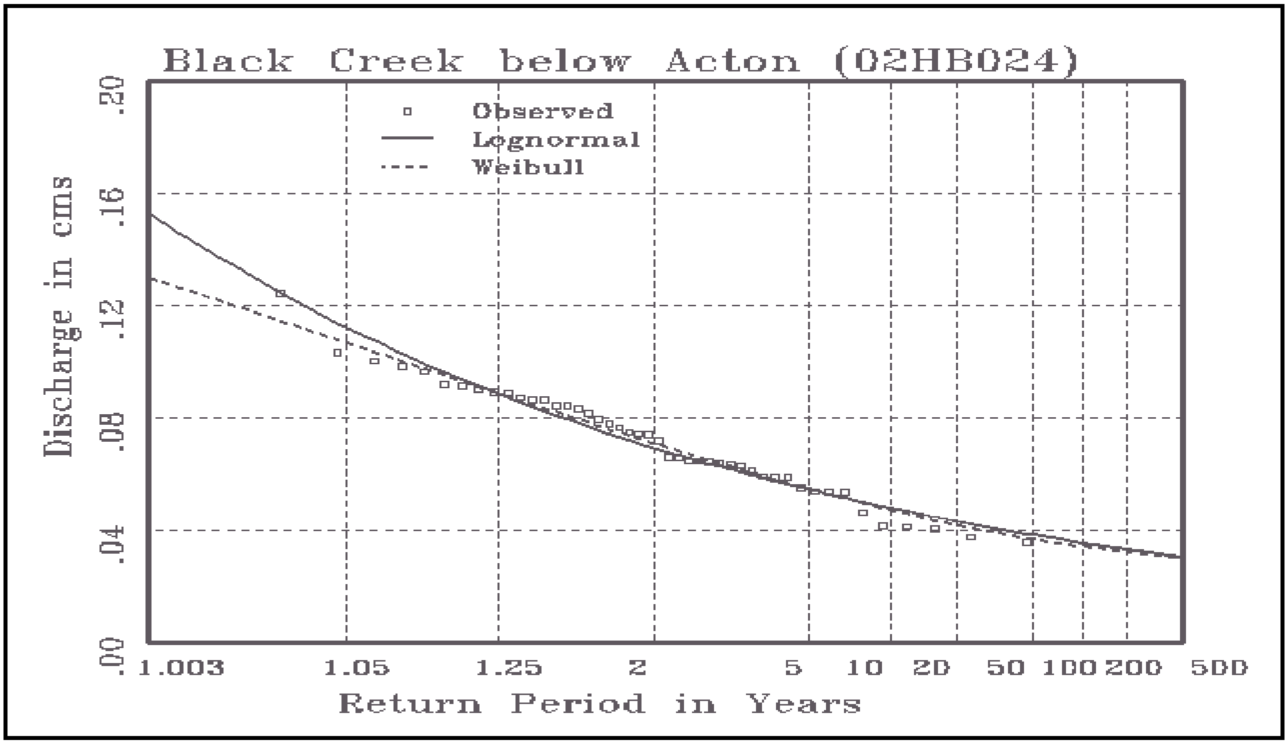

Figure 5 Frequency plot for 7-day low flows at Black Creek below Acton gauge
(time-series adjusted for missing values and irrigation amounts)

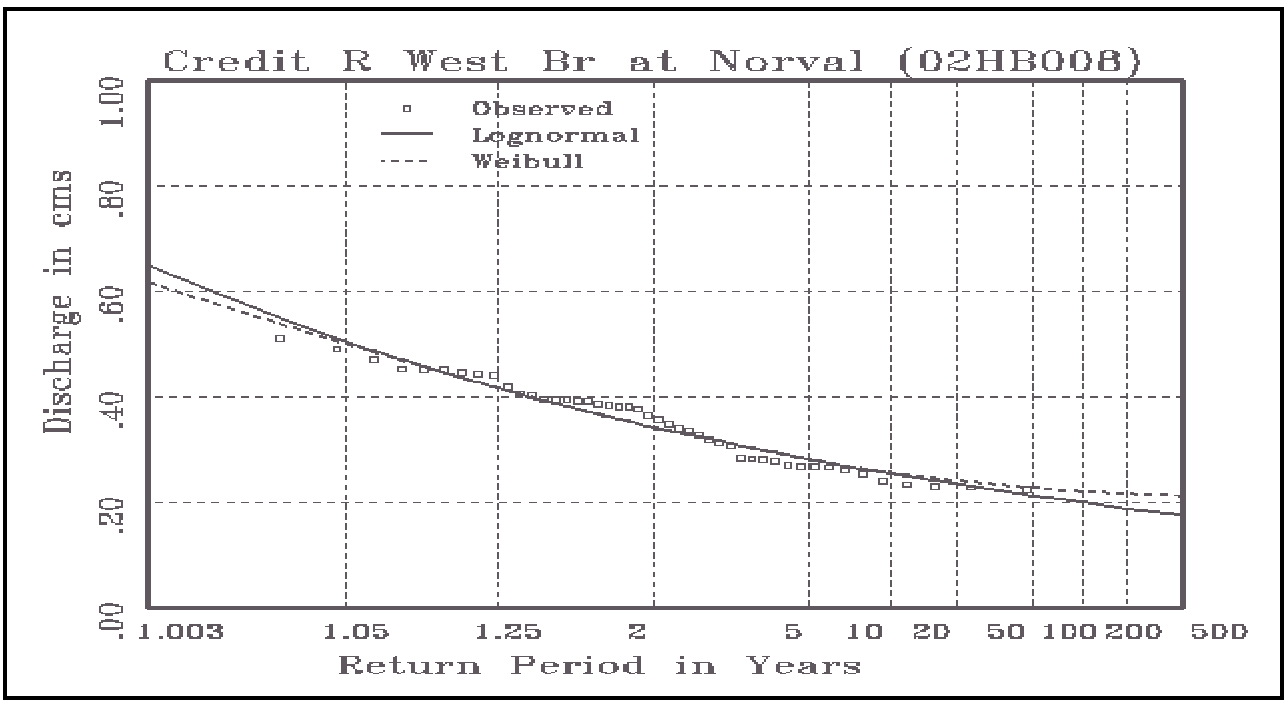

Figure 6 Frequency plot for 7-day low flows at Credit River West Branch at Norval gauge
(time-series adjusted for missing values and irrigation amounts)

Table 1 Estimated 7-day low flows for Black Creek below Acton gauge

Return Period (Years)	*Raw Data For WSC gauge*	*Missing Values Filled-in for 1960 to 1987*	*Adjusted For irrigation Amounts (1960 to 1987)*	*Acton STP Outflows Removed*
1.25	0.1000	0.0859	0.0911	0.0652
1.5	0.0883	0.0726	0.0797	0.0555
2	0.0787	0.0628	0.0707	0.0472
5	0.0600	0.0467	0.0544	0.0305
10	0.0509	0.0402	0.0470	0.0216
20	0.0439	0.0360	0.0416	0.0144
25	0.0420	0.0350	0.0402	0.0124
50	0.0369	0.0324	0.0366	0.0068
Number of Years in record	**18**	**46**	**46**	**46**

Note: all flows in m^3/s.

Table 2 Estimated 7-day low flows for Credit River West Branch gauge at Norval

Return Period (Years)	*Raw Data For WSC gauge*	*Missing Values Filled-in for 1960 to 1962*	*Adjusted For irrigation Amounts (1960 to 1987)*	*Georgetown STP Outflows Removed*
1.25	0.417	0.412	0.427	0.322
1.5	0.375	0.368	0.377	0.274
2	0.342	0.334	0.340	0.234
5	0.279	0.272	0.280	0.159
10	0.249	0.244	0.255	0.122
20	0.227	0.224	0.239	0.094
25	0.221	0.218	0.236	0.086
50	0.205	0.205	0.226	0.066
Number of Years in record	**43**	**46**	**46**	**46**

Note: all flows in m^3/s.

Table 3 7-d Low Flows for BLACK CREEK BELOW ACTON WSCID: 02HB024

Drainage Area= 24.0000 km^2

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1960	0.0373	0.1150	0.0961	0.2573	0.2708	0.1978	0.1371	0.1212	0.1095	0.0438	0.0588	0.0452	0.0373
1961	0.0261	0.0261	0.2241	0.3107	0.1623	0.0866	0.0827	0.0809	0.0843	0.0495	0.0538	0.0628	0.0261
1962	0.1034	0.0530	0.0527	0.1074	0.0887	0.0629	0.0611	0.0540	0.0579	0.0546	0.0818	0.0747	0.0527
1963	0.0749	0.0652	0.0584	0.0425	0.1211	0.0774	0.0653	0.0583	0.0644	0.0330	0.0348	0.0303	0.0303
1964	0.0300	0.0296	0.0327	0.1346	0.1288	0.0828	0.0542	0.0535	0.0544	0.0287	0.0355	0.0461	0.0287
1965	0.0963	0.1003	0.1228	0.1175	0.1059	0.0746	0.0612	0.0590	0.0610	0.0425	0.0731	0.1237	0.0425
1966	0.1065	0.1002	0.1709	0.1970	0.1341	0.0774	0.0538	0.0495	0.0448	0.0242	0.0306	0.0700	0.0242
1967	0.0715	0.0916	0.0916	0.2208	0.1198	0.0901	0.0949	0.0838	0.0683	0.0675	0.1315	0.0854	0.0675
1968	0.0879	0.0974	0.0913	0.1637	0.1525	0.0983	0.0772	0.0785	0.1078	0.0834	0.0918	0.1104	0.0772
1969	0.1040	0.1312	0.1058	0.3621	0.1692	0.1003	0.0651	0.0649	0.0599	0.0380	0.0582	0.0575	0.0380
1970	0.0483	0.0703	0.0780	0.2964	0.1709	0.0938	0.0904	0.0661	0.0847	0.0687	0.1179	0.1361	0.0483
1971	0.0961	0.0952	0.1658	0.2814	0.1228	0.1126	0.0874	0.0763	0.0813	0.0476	0.0592	0.0712	0.0476
1972	0.1046	0.0816	0.0841	0.2660	0.1350	0.0963	0.0802	0.0711	0.0670	0.0453	0.1217	0.1061	0.0453
1973	0.0910	0.1173	0.1166	0.2105	0.1791	0.1245	0.0764	0.0667	0.0633	0.0459	0.0667	0.0543	0.0459
1974	0.1980	0.1261	0.1384	0.1570	0.1313	0.1551	0.0843	0.0689	0.0655	0.0445	0.0481	0.0656	0.0445
1975	0.0664	0.0871	0.2078	0.2853	0.1383	0.1047	0.0755	0.0730	0.0941	0.0635	0.0778	0.1016	0.0635
1976	0.0900	0.1170	0.5225	0.2724	0.1902	0.1179	0.1018	0.0789	0.0770	0.0794	0.0792	0.0544	0.0544
1977	0.0414	0.0400	0.1053	0.1575	0.0878	0.0712	0.0547	0.0697	0.0697	0.1146	0.1026	0.1505	0.0400
1978	0.1287	0.1253	0.1210	0.3271	0.2043	0.0975	0.0622	0.0658	0.0647	0.0507	0.0500	0.0654	0.0500
1979	0.0666	0.0541	0.1180	0.4176	0.2764	0.1172	0.0726	0.0746	0.0710	0.0538	0.0654	0.0804	0.0538
1980	0.0915	0.0509	0.0531	0.2382	0.1292	0.1159	0.0921	0.0623	0.0630	0.0556	0.0583	0.0581	0.0509
1981	0.0346	0.0353	0.0922	0.1129	0.0922	0.0765	0.0529	0.0588	0.0772	0.0798	0.1238	0.0730	0.0346
1982	0.0684	0.0593	0.0750	0.2859	0.1352	0.1506	0.0890	0.0722	0.0686	0.0702	0.0741	0.1918	0.0593
1983	0.1505	0.1410	0.2081	0.2113	0.2817	0.1357	0.0577	0.0756	0.0588	0.0539	0.0752	0.0997	0.0539
1984	0.0679	0.0777	0.1493	0.3004	0.1903	0.1204	0.0740	0.0744	0.0928	0.0516	0.0715	0.0897	0.0516
1985	0.1063	0.0891	0.4930	0.2810	0.1698	0.1088	0.0571	0.0623	0.0895	0.0664	0.0980	0.1454	0.0571
1986	0.1202	0.1163	0.0945	0.1837	0.1146	0.1119	0.0752	0.1060	0.2779	0.2678	0.1723	0.2097	0.0752
1987	0.1163	0.1269	0.1841	0.2322	0.1319	0.0787	0.0959	0.0606	0.0620	0.0662	0.0987	0.1916	0.0606
1988	0.0915	0.1537	0.1479	0.2279	0.1779	0.0571	0.0587	0.0631	0.0621	0.0599	0.0579	0.1051	0.0571
1989	0.0400	0.0680	0.0634	0.1587	0.0928	0.1415	0.0521	0.0485	0.0512	0.0542	0.0578	0.0290	0.0290
1990	0.1023	0.1780	0.1451	0.1665	0.1194	0.0980	0.0684	0.0657	0.0780	0.1080	0.1265	0.2223	0.0657
1991	0.1687	0.1630	0.2501	0.4087	0.1830	0.1130	0.0930	0.1016	0.1030	0.0787	0.0670	0.0830	0.0670
1992	0.0879	0.0793	0.1522	0.1708	0.1008	0.0836	0.0680	0.1150	0.1808	0.1250	0.1865	0.2665	0.0680
1993	0.0602	0.1586	0.1486	0.3672	0.1586	0.1258	0.0722	0.0658	0.0585	0.0653	0.0829	0.0701	0.0585
1994	0.0595	0.0652	0.1179	0.2136	0.1694	0.0715	0.0779	0.0536	0.0571	0.0604	0.0951	0.1051	0.0536

1995	0.0858	0.1101	0.1144	0.1287	0.1258	0.0958	0.0675	0.0577	0.0544	0.0729	0.1758	0.1129	0.0544
1996	0.0893	0.1164	0.1264	0.2679	0.2421	0.1921	0.1279	0.1521	0.1607	0.1521	0.1236	0.1464	0.0893
1997	0.0800	0.1572	0.2872	0.2772	0.1972	0.0710	0.0563	0.0512	0.0390	0.0383	0.0500	0.0727	0.0383
1998	0.0275	0.0750	0.1836	0.1465	0.0836	0.0617	0.0490	0.0310	0.0227	0.0369	0.0316	0.0276	0.0227
1999	0.0220	0.0633	0.0676	0.1158	0.0579	0.0536	0.0325	0.0095	0.0045	0.0569	0.0659	0.0629	0.0045
2000	0.0348	0.0277	0.0827	0.1178	0.1235	0.0992	0.0950	0.0424	0.0428	0.0520	0.0692	0.0664	0.0277
2001	0.0493	0.0843	0.1428	0.1214	0.1085	0.0673	0.0368	0.0218	0.0148	0.0410	0.0714	0.1328	0.0148
2002	0.0693	0.0878	0.1436	0.1678	0.1536	0.1007	0.0264	0.0300	0.0293	0.0413	0.0477	0.0516	0.0264
2003	0.0373	0.0345	0.0336	0.1213	0.1228	0.0419	0.0279	0.0192	0.0136	0.0169	0.0956	0.1256	0.0136
2004	0.0692	0.0576	0.0735	0.2049	0.2592	0.0878	0.0715	0.0735	0.0505	0.0496	0.0456	0.0849	0.0456
2005	0.0799	0.0785	0.1171	0.2414	0.1028	0.0558	0.0486	0.0628	0.0651	0.0685	0.0685	0.0742	0.0486
Mean	0.0800	0.0908	0.1402	0.2186	0.1503	0.0990	0.0709	0.0663	0.0724	0.0645	0.0811	0.0976	0.0466
N	46	46	46	46	46	46	46	46	46	46	46	46	46
Std	0.0378	0.0395	0.0975	0.0866	0.0535	0.0334	0.0228	0.0257	0.0449	0.0403	0.0373	0.0535	0.0179
High	0.1980	0.1780	0.5225	0.4176	0.2817	0.1978	0.1371	0.1521	0.2779	0.2678	0.1865	0.2665	0.0893
Low	0.0220	0.0261	0.0327	0.0425	0.0579	0.0419	0.0264	0.0095	0.0045	0.0169	0.0306	0.0276	0.0045

Table 4 7-d Low Flows for BLACK CREEK BELOW ACTON WSCID: 02HB024
Drainage Area= 24.0000 km^2

Raw Statistical Characteristics:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	0.1980	0.1780	0.5225	0.4176	0.2817	0.1978	0.1371	0.1521	0.2779	0.2678	0.1865	0.2665	0.0893
Min	0.0220	0.0261	0.0327	0.0425	0.0579	0.0419	0.0264	0.0095	0.0045	0.0169	0.0306	0.0276	0.0045
Med	0.0800	0.0875	0.1180	0.2125	0.1346	0.0969	0.0699	0.0658	0.0645	0.0544	0.0715	0.0817	0.0485
Mean	0.0800	0.0908	0.1402	0.2186	0.1503	0.0990	0.0709	0.0663	0.0724	0.0645	0.0811	0.0976	0.0466
Std	0.0374	0.0391	0.0964	0.0857	0.0529	0.0331	0.0226	0.0254	0.0444	0.0399	0.0369	0.0529	0.0177
Skew	0.8218	0.2932	2.5553	0.3644	0.9440	1.0191	0.5404	0.7475	2.5857	3.3425	1.1912	1.3181	-0.1358
Kurt	4.5132	2.6342	11.1991	2.8900	3.7847	4.7448	4.3648	5.8499	13.3415	18.1269	4.4662	4.8600	3.2319
N	46	46	46	46	46	46	46	46	46	46	46	46	46

Log Transformed Statistics

Mean	-2.6418	-2.5041	-2.1317	-1.6061	-1.9526	-2.3643	-2.6996	-2.8016	-2.7982	-2.8599	-2.6052	-2.4580	-3.1676
Std	0.5082	0.4905	0.5684	0.4423	0.3418	0.3256	0.3419	0.4733	0.6587	0.4657	0.4330	0.5189	0.5279
Skew	-0.4978	-0.6650	0.2242	-0.8965	0.0391	-0.0125	-0.7254	-1.7259	-1.5311	0.5796	0.1137	0.0037	-2.0519
Kurt	2.9734	3.0995	4.1779	5.0291	3.3506	3.4140	4.3844	8.3415	8.6984	5.7361	3.0552	3.1926	9.5187

LN3P Statistics ML Fit

AX	-0.0599	-0.1327	0.0072	-0.2694	0.0000	-0.0015	-0.0919	-0.1343	0.0000	0.0000	0.0000	0.0000	0.0000
Mean	-2.0015	-1.5140	-2.2282	-0.7350	-1.9526	-2.3477	-1.8311	-1.6159	-2.7982	-2.8599	-2.6052	-2.4580	-3.1676
Std	0.2630	0.0301	0.6498	0.0303	0.3418	0.1004	0.0187	0.0153	0.6587	0.4657	0.4330	0.5189	0.5279

Skew	0.0353	-0.0448	0.0551	-0.0293	0.0391	0.0040	0.0152	0.0618	-1.5311	0.5796	0.1137	0.0037	-2.0519

EV3 Statistics MM Fit

Beta	0.0878	0.1029	0.1369	0.2440	0.1600	0.1046	0.0769	0.0720	0.0708	0.0663	0.0860	0.1034	0.0533
Std	0.0374	0.0391	0.0964	0.0857	0.0529	0.0331	0.0226	0.0254	0.0444	0.0399	0.0369	0.0529	0.0177
Skew	0.8218	0.2932	2.5553	0.3644	0.9440	1.0191	0.5404	0.7475	2.5857	3.3425	1.1912	1.3181	-0.1358
Kurt	4.5132	2.6342	11.1991	2.8900	3.7847	4.7448	4.3648	5.8499	13.3415	18.1269	4.4662	4.8600	3.2319
Alfa	1.7554	2.6704	0.9218	2.5039	1.6202	1.5465	2.1599	1.8484	0.9211	1.1089	1.4006	1.3104	4.2317
GY	0.0163	-0.0060	0.0514	0.0181	0.0667	0.0489	0.0247	0.0210	0.0315	0.0204	0.0301	0.0289	-0.0198

EV3 Statistics MLOD Fit

Beta	0.0880	0.1007	0.1361	0.2471	0.1622	0.1060	0.0778	0.0745	0.0698	0.0665	0.0863	0.1039	0.0537
Std	0.0374	0.0391	0.0964	0.0857	0.0529	0.0331	0.0226	0.0254	0.0444	0.0399	0.0369	0.0529	0.0177
Skew	0.8218	0.2932	2.5553	0.3644	0.9440	1.0191	0.5404	0.7475	2.5857	3.3425	1.1912	1.3181	-0.1358
Kurt	4.5132	2.6342	11.1991	2.8900	3.7847	4.7448	4.3648	5.8499	13.3415	18.1269	4.4662	4.8600	3.2319
Alfa	1.7554	2.0582	0.9218	2.5039	1.6202	1.5465	2.1599	1.8484	0.9211	1.1089	1.4006	1.3104	4.2317
GY	0.0146	0.0142	0.0310	-0.0062	0.0483	0.0367	0.0173	0.0013	0.0034	0.0153	0.0271	0.0236	-0.0241

Return Period (in years) Quantiles Estimates Weibull EV3 LOD Distribution fitted

1.2	0.1170	0.1290	0.2290	0.3140	0.2120	0.1380	0.0966	0.1020	0.1280	0.1020	0.1170	0.1490	0.0652
1.5	0.0921	0.1050	0.1470	0.2570	0.1690	0.1100	0.0805	0.0783	0.0769	0.0710	0.0904	0.1100	0.0555
2.0	0.0742	0.0866	0.1020	0.2130	0.1390	0.0914	0.0684	0.0613	0.0480	0.0521	0.0727	0.0843	0.0472
5.0	0.0459	0.0559	0.0516	0.1330	0.0934	0.0629	0.0475	0.0338	0.0164	0.0286	0.0474	0.0492	0.0305
10.0	0.0350	0.0432	0.0401	0.0969	0.0767	0.0528	0.0386	0.0230	0.0092	0.0221	0.0390	0.0380	0.0216
20.0	0.0281	0.0346	0.0352	0.0711	0.0665	0.0468	0.0326	0.0160	0.0061	0.0189	0.0342	0.0319	0.0144
25.0	0.0265	0.0325	0.0343	0.0644	0.0641	0.0454	0.0311	0.0143	0.0055	0.0182	0.0331	0.0306	0.0124
50.0	0.0226	0.0272	0.0325	0.0471	0.0585	0.0422	0.0272	0.0102	0.0044	0.0169	0.0307	0.0277	0.0068
100.0	0.0200	0.0234	0.0317	0.0341	0.0550	0.0402	0.0245	0.0074	0.0039	0.0161	0.0293	0.0260	0.0021
200.0	0.0182	0.0208	0.0313	0.0243	0.0526	0.0389	0.0225	0.0055	0.0036	0.0158	0.0284	0.0250	0.0000

Table 5 7-d Low Flows for CREDIT RIVER WEST BR AT NORVAL WSCID: 02HB008
Drainage Area= 127.0000 km^2

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1960	0.2200	0.7201	0.6010	1.6160	1.5636	1.1038	0.7216	0.6212	0.5475	0.2714	0.3657	0.2800	0.2200
1961	0.1623	0.1623	1.4094	1.9551	0.8826	0.4054	0.3811	0.3697	0.3911	0.3094	0.3366	0.3937	0.1623
1962	0.4874	0.3346	0.3331	0.6774	0.4220	0.2591	0.2477	0.2034	0.2277	0.3449	0.5164	0.4717	0.2034
1963	0.2053	0.4139	0.3710	0.2710	0.6285	0.3528	0.2770	0.2328	0.2713	0.2110	0.2225	0.1939	0.1939
1964	0.2374	0.1917	0.2117	0.8531	0.6791	0.3891	0.2091	0.2048	0.2106	0.1860	0.2288	0.2960	0.1860
1965	0.7294	0.6394	0.7808	0.7480	0.5368	0.3397	0.2554	0.2411	0.2540	0.2751	0.4680	0.7865	0.2411
1966	0.4657	0.6414	1.0871	1.2514	0.7174	0.3602	0.2117	0.1845	0.1545	0.1628	0.2028	0.4514	0.1545
1967	0.4676	0.5890	0.5890	1.4033	0.6293	0.4421	0.4721	0.4021	0.3050	0.4376	0.8404	0.5504	0.3050
1968	0.5679	0.6279	0.5893	1.0451	0.8368	0.4953	0.3625	0.3711	0.5553	0.5393	0.5922	0.7093	0.3625
1969	0.3482	0.8425	0.6825	2.2967	0.9442	0.5099	0.2885	0.2870	0.2556	0.2553	0.3825	0.3782	0.2553
1970	0.3199	0.4613	0.5099	1.8856	0.9573	0.4716	0.4501	0.2973	0.4144	0.4513	0.7613	0.8756	0.2973
1971	0.6256	0.6199	1.0642	1.7928	0.6559	0.5916	0.4331	0.3631	0.3945	0.3199	0.3928	0.4685	0.3199
1972	0.7100	0.5357	0.5514	1.6971	0.7345	0.4903	0.3888	0.3317	0.3060	0.3071	0.7885	0.6900	0.3060
1973	0.5828	0.7628	0.7585	1.3499	1.0145	0.6702	0.3674	0.3059	0.2845	0.3128	0.4442	0.3656	0.2845
1974	0.4812	0.8198	0.8969	1.0141	0.7144	0.8644	0.4186	0.3215	0.3001	0.3055	0.3284	0.4384	0.3001
1975	0.5395	0.5753	1.3353	1.8238	0.7598	0.5484	0.3641	0.3484	0.4813	0.4267	0.5167	0.6667	0.3484
1976	0.3420	0.7648	3.3191	1.7434	1.0880	0.6322	0.5308	0.3865	0.3751	0.5277	0.5262	0.3705	0.3420
1977	0.2901	0.2815	0.6929	1.0215	0.4447	0.3404	0.2361	0.3304	0.3304	0.7515	0.6758	0.9772	0.2361
1978	0.4624	0.8195	0.7924	2.0910	1.1798	0.5070	0.2841	0.3070	0.2998	0.3495	0.3453	0.4424	0.2841
1979	0.4302	0.3717	0.7745	2.6617	1.6348	0.6319	0.3505	0.3634	0.3405	0.3702	0.4431	0.5374	0.3405
1980	0.3450	0.3521	0.3664	1.5321	0.7081	0.6239	0.4739	0.2867	0.2910	0.3821	0.3993	0.3979	0.2867
1981	0.2650	0.2693	0.6279	0.7579	0.4896	0.3910	0.2424	0.2796	0.3953	0.5493	0.8264	0.5064	0.2424
1982	0.4811	0.4240	0.5226	1.8511	0.7643	0.8614	0.4729	0.3671	0.3443	0.4926	0.5169	1.2583	0.3443
1983	0.5449	0.9406	1.3634	1.3834	1.6894	0.7694	0.2780	0.3909	0.2851	0.3920	0.5263	0.6806	0.2780
1984	0.4734	0.5363	0.9877	1.9391	1.1080	0.6680	0.3751	0.3780	0.4937	0.3720	0.4977	0.6120	0.3720
1985	0.7120	0.6034	3.1477	1.8120	0.9737	0.5894	0.2637	0.2966	0.4680	0.4606	0.6591	0.9577	0.2637
1986	0.8070	0.7841	0.6470	1.2084	0.6359	0.6187	0.3873	0.5816	1.6644	1.7384	1.1370	1.3727	0.3873
1987	0.3590	0.8576	1.2176	1.5204	0.7676	0.3533	0.4261	0.1447	0.2147	0.3176	0.4276	0.8804	0.1447
1988	0.5486	0.5614	0.6471	1.2043	0.5286	0.2386	0.2057	0.2643	0.2343	0.3143	0.4014	0.2814	0.2057
1989	0.2177	0.2820	0.2377	0.8320	0.7306	0.7149	0.3049	0.1934	0.1963	0.2120	0.2920	0.1877	0.1877
1990	0.4249	0.9049	0.8334	0.8134	0.6320	0.3734	0.3034	0.2363	0.2377	0.3734	0.4806	0.9934	0.2363
1991	0.8771	0.8329	1.4229	2.3286	0.8457	0.3229	0.2971	0.2914	0.2657	0.2757	0.2629	0.4814	0.2629
1992	0.4561	0.3190	0.7347	0.9047	0.6904	0.4119	0.3747	0.5119	0.8947	0.6133	0.9661	1.1647	0.3190
1993	0.3006	0.7191	0.7349	2.1277	0.9949	0.8163	0.4563	0.2634	0.2277	0.2820	0.4077	0.3149	0.2277
1994	0.2059	0.2287	0.5587	1.3944	1.0916	0.3359	0.2616	0.1730	0.1501	0.1601	0.2201	0.3330	0.1501

1995	0.2644	0.4287	0.3773	0.7316	0.8973	0.2559	0.2230	0.1544	0.1444	0.1559	0.5673	0.5344	0.1444
1996	0.3470	0.7713	0.9056	2.2727	1.5627	1.1927	0.5227	0.3156	0.3384	0.7399	0.7141	1.0270	0.3156
1997	0.4543	1.0229	1.5171	1.4657	1.3229	0.5757	0.3329	0.2443	0.3014	0.2657	0.4400	0.4443	0.2443
1998	0.0879	0.5221	1.3707	1.0450	0.5550	0.3964	0.2436	0.1279	0.1179	0.1679	0.1864	0.0879	0.0879
1999	0.0753	0.3624	0.3696	0.7453	0.3196	0.1624	0.1324	0.0924	0.0696	0.1910	0.1881	0.2267	0.0696
2000	0.1701	0.1187	0.9158	0.7872	0.6144	0.6472	0.4772	0.3087	0.2829	0.2329	0.2287	0.3087	0.1187
2001	0.3305	0.5534	1.0762	1.1334	0.6305	0.4162	0.2491	0.1319	0.1005	0.1519	0.3405	0.5448	0.1005
2002	0.1507	0.6507	1.0664	1.5107	1.1779	0.6393	0.2336	0.1707	0.1321	0.2079	0.2036	0.0921	0.0921
2003	0.0593	0.0707	0.2064	0.8350	0.8636	0.3736	0.1907	0.1579	0.1322	0.2836	0.4636	0.8736	0.0593
2004	0.6420	0.6463	0.8120	1.5377	1.3234	0.6505	0.5234	0.3705	0.2377	0.2320	0.3020	0.3920	0.2320
2005	0.6960	0.6845	0.9031	1.5931	0.7088	0.2960	0.2088	0.1260	0.1988	0.2517	0.2703	0.4903	0.1260
Mean	0.4124	0.5570	0.8896	1.4014	0.8620	0.5239	0.3415	0.2898	0.3287	0.3681	0.4631	0.5606	0.2357
N	46	46	46	46	46	46	46	46	46	46	46	46	46
Std	0.2021	0.2389	0.6166	0.5446	0.3310	0.2194	0.1189	0.1147	0.2508	0.2542	0.2191	0.3078	0.0883
High	0.8771	1.0229	3.3191	2.6617	1.6894	1.1927	0.7216	0.6212	1.6644	1.7384	1.1370	1.3727	0.3873
Low	0.0593	0.0707	0.2064	0.2710	0.3196	0.1624	0.1324	0.0924	0.0696	0.1519	0.1864	0.0879	0.0593

Table 6 7-d Low Flows for CREDIT RIVER WEST BR AT NORVAL WSCID: 02HB008
Drainage Area= 127.0000 km^2

Raw Statistical Characteristics:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	0.8771	1.0229	3.3191	2.6617	1.6894	1.1927	0.7216	0.6212	1.6644	1.7384	1.1370	1.3727	0.3873
Min	0.0593	0.0707	0.2064	0.2710	0.3196	0.1624	0.1324	0.0924	0.0696	0.1519	0.1864	0.0879	0.0593
Med	0.4276	0.5822	0.7665	1.3988	0.7621	0.4928	0.3189	0.2940	0.2848	0.3111	0.4338	0.4766	0.2418
Mean	0.4124	0.5570	0.8896	1.4014	0.8620	0.5239	0.3415	0.2898	0.3287	0.3681	0.4631	0.5606	0.2357
Std	0.1999	0.2363	0.6099	0.5387	0.3274	0.2170	0.1176	0.1134	0.2481	0.2514	0.2167	0.3045	0.0874
Skew	0.2758	-0.1846	2.5389	0.2128	0.9519	1.0346	0.7959	0.7031	3.8257	3.8471	1.0667	0.8501	-0.3000
Kurt	2.7247	2.4426	11.4550	2.6306	3.6683	4.5864	4.0776	4.2615	22.1860	22.8029	4.3119	3.4232	2.3958
N	46	46	46	46	46	46	46	46	46	46	46	46	46

Log Transformed Statistics

Mean	-1.0355	-0.7108	-0.2904	0.2530	-0.2153	-0.7273	-1.1312	-1.3176	-1.2784	-1.1315	-0.8714	-0.7364	-1.5335
Std	0.6115	0.5706	0.5880	0.4420	0.3688	0.4104	0.3432	0.4152	0.5521	0.4778	0.4572	0.6038	0.4611
Skew	-1.0840	-1.4129	0.0429	-0.9642	0.0473	-0.1325	-0.0849	-0.4708	0.3612	0.9454	0.0348	-0.7099	-1.1045
Kurt	4.3477	5.3864	3.9852	5.0253	3.2016	3.3320	3.0122	3.2285	5.2725	5.3804	2.6387	4.2202	3.8494

LN3P Statistics ML Fit

AX	-1.7673	0.0000	0.0000	-3.2131	0.0000	-0.0475	-0.0176	-0.2026	0.0000	0.1100	0.0000	-0.2123	0.0000
Mean	0.7750	-0.7108	-0.2904	1.5488	-0.2153	-0.6267	-1.0751	-0.7342	-1.2784	-1.6881	-0.8714	-0.3309	-1.5335
Std	0.0915	0.5706	0.5880	0.0127	0.3688	0.1344	0.1030	0.2273	0.5521	0.8169	0.4572	0.1482	0.4611

Skew	0.0878	-1.4129	0.0429	-0.0214	0.0473	-0.0124	-0.0354	0.0014	0.3612	0.0549	0.0348	-0.0346	-1.1045

EV3 Statistics MM Fit

Beta	0.4749	0.6468	0.8687	1.5755	0.9218	0.5599	0.3668	0.3163	0.3897	0.4331	0.4977	0.6225	0.2701
Std	0.1999	0.2363	0.6099	0.5387	0.3274	0.2170	0.1176	0.1134	0.2481	0.2514	0.2167	0.3045	0.0874
Skew	0.2758	-0.1846	2.5389	0.2128	0.9519	1.0346	0.7959	0.7031	3.8257	3.8471	1.0667	0.8501	-0.3000
Kurt	2.7247	2.4426	11.4550	2.6306	3.6683	4.5864	4.0776	4.2615	22.1860	22.8029	4.3119	3.4232	2.3958
Alfa	2.7138	4.5061	0.9224	2.8817	1.6121	1.5320	1.7868	1.9083	2.0023	2.1056	1.5031	1.7222	5.2927
GY	-0.0902	-0.3814	0.3276	-0.0282	0.3467	0.1981	0.1383	0.0819	-0.1464	-0.1357	0.1434	0.0517	-0.1662

EV3 Statistics MLOD Fit

Beta	0.4686	0.6383	0.8638	1.5886	0.9314	0.5674	0.3709	0.3188	0.3363	0.3726	0.4910	0.6251	0.2651
Std	0.1999	0.2363	0.6099	0.5387	0.3274	0.2170	0.1176	0.1134	0.2481	0.2514	0.2167	0.3045	0.0874
Skew	0.2758	-0.1846	2.5389	0.2128	0.9519	1.0346	0.7959	0.7031	3.8257	3.8471	1.0667	0.8501	-0.3000
Kurt	2.7247	2.4426	11.4550	2.6306	3.6683	4.5864	4.0776	4.2615	22.1860	22.8029	4.3119	3.4232	2.3958
Alfa	2.3220	3.3011	0.9224	2.8817	1.6121	1.5320	1.7868	1.9083	1.0756	1.0528	1.3784	1.7222	3.1367
GY	-0.0247	-0.1514	0.1955	-0.1362	0.2640	0.1300	0.1046	0.0617	0.0620	0.1461	0.1680	0.0305	-0.0145

Return Period (in years) Quantiles Estimates Weibull EV3 LOD Distribution fitted

1.2	0.6100	0.7910	1.4500	1.9800	1.2200	0.7700	0.4740	0.4110	0.5340	0.5400	0.6610	0.8650	0.3220
1.5	0.4890	0.6610	0.9360	1.6500	0.9720	0.5950	0.3850	0.3320	0.3610	0.3940	0.5140	0.6590	0.2740
2.0	0.3970	0.5550	0.6450	1.3800	0.7960	0.4740	0.3220	0.2740	0.2570	0.3060	0.4160	0.5110	0.2340
5.0	0.2340	0.3500	0.3270	0.8890	0.5270	0.2940	0.2200	0.1790	0.1300	0.2010	0.2770	0.2790	0.1590
10.0	0.1620	0.2480	0.2540	0.6540	0.4290	0.2310	0.1800	0.1410	0.0959	0.1730	0.2310	0.1910	0.1220
20.0	0.1130	0.1700	0.2220	0.4790	0.3700	0.1930	0.1550	0.1160	0.0793	0.1600	0.2050	0.1360	0.0940
25.0	0.0997	0.1480	0.2160	0.4320	0.3560	0.1840	0.1490	0.1100	0.0760	0.1570	0.2000	0.1230	0.0863
50.0	0.0672	0.0908	0.2050	0.3090	0.3230	0.1640	0.1350	0.0950	0.0693	0.1520	0.1870	0.0922	0.0661
100.0	0.0433	0.0446	0.2000	0.2130	0.3020	0.1520	0.1250	0.0848	0.0658	0.1490	0.1800	0.0716	0.0500
200.0	0.0257	0.0073	0.1980	0.1380	0.2890	0.1440	0.1180	0.0778	0.0640	0.1480	0.1750	0.0580	0.0372

APPENDIX A2
Low Flow Analysis Update

Schroeter & Associates

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MEMORANDUM

TO: Don Weatherbe, P.Eng., Weatherbe Associates, Mississauga, Ontario

FROM: Dr. Harold Schroeter, P.Eng.,
Signature:______________________________

DATE: Thursday October 28, 2010

PROJECT: 06-13

SUBJECT: Acton STP low flow analyses - Revised results **Pages: 5**

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As requested last week, this memo summarizes the low flow analysis for the receiving stream at the approximate location of the Acton STP (Sewage Treatment Plant) outfall.

The description of the data processing procedures and the various frequency analyses conducted are identical to those outlined in the July 18, 2007 memo. Those analyses utilized flow data for the period 1960 to 2005. The present analysis is considered an update to the 2007 work as it employs flow data collected for 2006 to 2009. A few remarks about the various analyses are presented below in point form with some commentary. All the figures and tables that are referenced in the text have been located at the end of this memo.

1. The Acton STP discharges to Black Creek. The closest available Water Survey of Canada (WSC) stream gauge to this location is called *Black Creek below Acton* (02HB024), which has an effective drainage area of 24.5 km^2 (as measured in the Subwatershed 11 Study), and has been in operation since 1987. For the purposes of this memo, this gauge is referred to as the Black Creek gauge.

   As noted in the 2007 report, daily flow data to the end of 2005 were obtained directly from the WSC website. Some processing of the available flow data produced a record length utilizing flows for the 1960 to 2005 period. This dataset was lengthened to include 2006 to 2009 daily flow data that were also extracted from the WSC website.

2. Before 1987, irrigation water was removed during the summer months (May to September) from Fairly Lake in Acton. The maximum rate at which this water was removed from Fairly Lake has been estimated to be 0.026 m^3/s. The flow records for the Black Creek gauge were adjusted so that the estimated irrigation water taking amounts were added back into the records.

3. Using information obtained from Halton Region, the average annual discharge for the Acton STP was estimated for the period 1960 to 1983. Actual measured monthly flows were available for 1984 to 2009 period. The mean monthly effluent discharge for the 1984 to 2009 period, as noted in Figure 1 below, was utilized to estimate the monthly discharges for the 1960 to 1983 period. This procedure is an enhancement over the July 2007 work. Recall, that in the previous (2007) work, the average annual STP outflows fore the entire 1960 to 2005 dataset were used in the analysis. As indicated in Figure 1, the new procedure causes more STP outflows to be subtracted from the stream gauge flows for the late winter early spring period (March to May), whereas less STP outflows are subtracted from the gauge flows during the summer and early autumn period (July to October). The impact of these revisions on the annual 7-day low flows are noted in the next point.

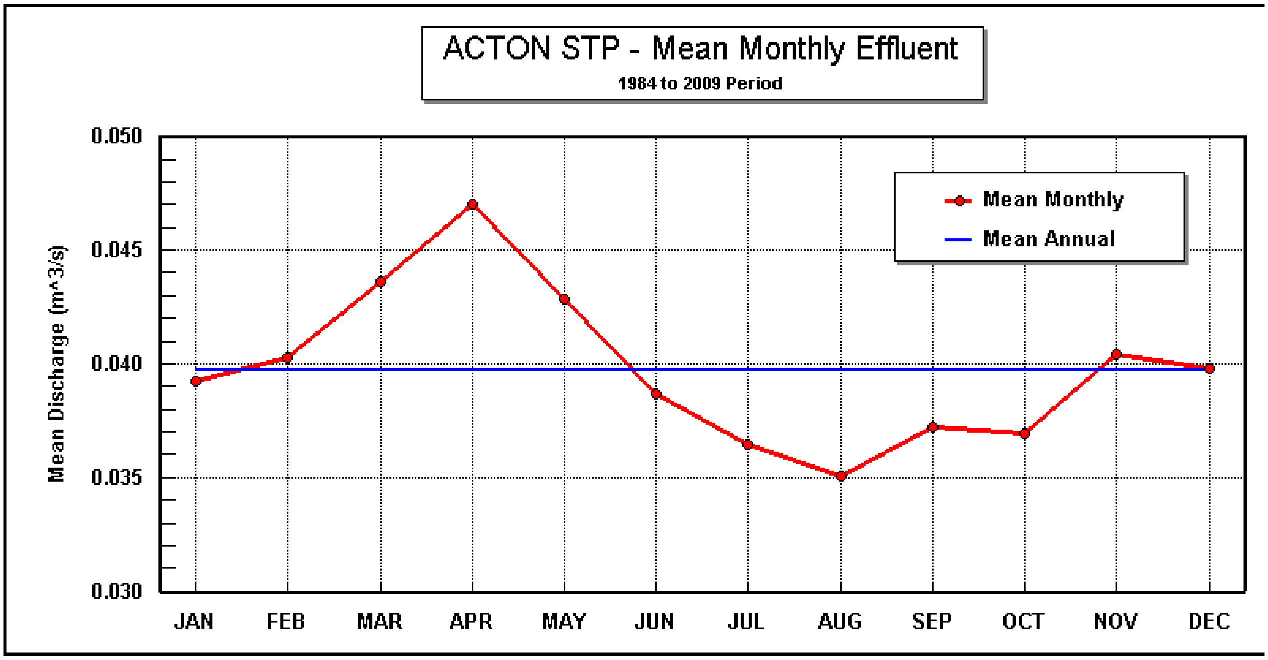


Figure 1 Mean monthly discharge for the ACTON STP for 1984 to 2009

4. As was done in the July 2007 work, the time-series of moving 7-day average flows were adjusted for the irrigation amounts (before 1987), and then the STP flows were removed. The resulting frequency analyses utilized the adjusted series of 7-day low flows. Table 1 provides a comparison of the annual 7-day return period low flows computed in the previous (2007) work (Column [5]), with those from the present analysis (Column [6]). For the return periods less than 10 years, the revised flows are about 3 to 6% lower than the previous work. However, for the less frequent flows (say, 20 to 50 year), the revisions noted here resulted in a 13% increase in the 7-day 20 year low flow (or 7Q20), an increase of 19% in the 7Q25, and a 62% increase in the 7Q50.

5. The revised final fully-processed monthly 7-day low flow estimates a location just upstream of the Acton STP outfalls are noted in Tables 2 and 3.

Table 1 Estimated 7-day low flows for Black Creek below Acton gauge (computed from annual minimum flow time-series)

Return Period (Years)	*Raw Data For WSC gauge#*	*Missing Values Filled-in for 1960 to 1987#*	*Adjusted For irrigation Amounts (1960 to 1987)#*	*Acton STP Outflows Removed#*	*Revised Acton STP Outflows Removed*	*Percent Difference*
[1]	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**	**[7]**
1.25	0.1000	0.0859	0.0911	0.0652	0.0634	-2.8%
1.5	0.0883	0.0726	0.0797	0.0555	0.0529	-4.7%
2	0.0787	0.0628	0.0707	0.0472	0.0446	-5.5%
5	0.0600	0.0467	0.0544	0.0305	0.0290	-4.9%
10	0.0509	0.0402	0.0470	0.0216	0.0217	0%
20	0.0439	0.0360	0.0416	0.0144	0.0162	+12.5%
25	0.0420	0.0350	0.0402	0.0124	0.0148	+19.4%
50	0.0369	0.0324	0.0366	0.0068	0.0110	+61.8%
Number of Years in record	**18**	**46**	**46**	**46**	**50**	

Note: all flows in m^3/s. # Results reported in previous July 2007 memo

Table 2   7-d Low Flows   for BLACK CREEK BELOW ACTON   WSCID: 02HB024

Drainage Area=   24.5000 km^2

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1960	0.0374	0.1149	0.0953	0.2557	0.2701	0.1980	0.1378	0.1222	0.1101	0.0444	0.0587	0.0452	0.0374
1961	0.0259	0.0256	0.2228	0.3086	0.1612	0.0865	0.0832	0.0817	0.0846	0.0498	0.0533	0.0624	0.0256
1962	0.1029	0.0522	0.0510	0.1048	0.0872	0.0626	0.0614	0.0547	0.0580	0.0548	0.0810	0.0741	0.0510
1963	0.0741	0.0641	0.0563	0.0393	0.1192	0.0767	0.0653	0.0587	0.0642	0.0329	0.0336	0.0293	0.0293
1964	0.0288	0.0281	0.0301	0.1309	0.1264	0.0818	0.0539	0.0537	0.0539	0.0283	0.0339	0.0447	0.0281
1965	0.0948	0.0984	0.1197	0.1132	0.1031	0.0733	0.0607	0.0589	0.0602	0.0418	0.0711	0.1220	0.0418
1966	0.1047	0.0980	0.1674	0.1923	0.1309	0.0758	0.0531	0.0493	0.0438	0.0233	0.0284	0.0680	0.0233
1967	0.0694	0.0891	0.0877	0.2155	0.1162	0.0882	0.0939	0.0834	0.0670	0.0663	0.1289	0.0830	0.0663
1968	0.0854	0.0945	0.0869	0.1578	0.1484	0.0961	0.0759	0.0778	0.1062	0.0819	0.0888	0.1077	0.0759
1969	0.1012	0.1279	0.1009	0.3557	0.1647	0.0977	0.0636	0.0640	0.0580	0.0362	0.0548	0.0544	0.0362
1970	0.0452	0.0667	0.0728	0.2895	0.1660	0.0910	0.0887	0.0651	0.0826	0.0667	0.1142	0.1327	0.0452
1971	0.0927	0.0912	0.1601	0.2740	0.1175	0.1094	0.0854	0.0750	0.0789	0.0453	0.0551	0.0675	0.0453
1972	0.1008	0.0773	0.0779	0.2580	0.1292	0.0928	0.0779	0.0696	0.0643	0.0428	0.1173	0.1020	0.0428
1973	0.0870	0.1127	0.1101	0.2020	0.1730	0.1208	0.0740	0.0650	0.0604	0.0432	0.0620	0.0499	0.0432
1974	0.1936	0.1211	0.1314	0.1480	0.1247	0.1510	0.0816	0.0670	0.0623	0.0415	0.0430	0.0609	0.0415
1975	0.0617	0.0817	0.2003	0.2757	0.1313	0.1003	0.0725	0.0709	0.0906	0.0602	0.0723	0.0965	0.0602
1976	0.0849	0.1112	0.5146	0.2623	0.1827	0.1132	0.0985	0.0765	0.0732	0.0758	0.0733	0.0489	0.0489
1977	0.0361	0.0340	0.0970	0.1469	0.0800	0.0662	0.0513	0.0672	0.0657	0.1108	0.0964	0.1448	0.0340
1978	0.1230	0.1189	0.1122	0.3159	0.1960	0.0922	0.0585	0.0630	0.0604	0.0466	0.0435	0.0593	0.0435
1979	0.0606	0.0473	0.1088	0.4059	0.2677	0.1116	0.0686	0.0716	0.0664	0.0494	0.0585	0.0739	0.0473
1980	0.0851	0.0437	0.0434	0.2259	0.1201	0.1099	0.0878	0.0591	0.0581	0.0509	0.0510	0.0513	0.0434
1981	0.0280	0.0279	0.0821	0.1002	0.0827	0.0703	0.0485	0.0554	0.0721	0.0749	0.1162	0.0659	0.0279
1982	0.0614	0.0515	0.0645	0.2726	0.1253	0.1440	0.0843	0.0686	0.0633	0.0650	0.0661	0.1843	0.0515
1983	0.1432	0.1328	0.1971	0.1974	0.2713	0.1288	0.0527	0.0717	0.0532	0.0485	0.0668	0.0919	0.0485
1984	0.0623	0.0648	0.1345	0.2724	0.1712	0.1017	0.0600	0.0716	0.0837	0.0483	0.0589	0.0737	0.0483
1985	0.0926	0.0693	0.4616	0.2441	0.1505	0.0964	0.0463	0.0546	0.0785	0.0569	0.0764	0.1330	0.0463
1986	0.1120	0.1073	0.0780	0.1687	0.0991	0.0933	0.0531	0.0862	0.2477	0.2343	0.1402	0.1934	0.0531
1987	0.1098	0.1194	0.1750	0.2177	0.1488	0.1059	0.1208	0.0828	0.0815	0.0624	0.0901	0.1851	0.0624
1988	0.0906	0.1519	0.1447	0.2201	0.1747	0.0628	0.0624	0.0645	0.0612	0.0613	0.0552	0.1042	0.0552
1989	0.0399	0.0670	0.0610	0.1517	0.0904	0.1480	0.0566	0.0507	0.0511	0.0564	0.0559	0.0289	0.0289
1990	0.0957	0.1703	0.1356	0.1513	0.1099	0.0996	0.0675	0.0620	0.0714	0.1043	0.1176	0.2157	0.0620
1991	0.1580	0.1534	0.2331	0.3854	0.1707	0.1072	0.0878	0.0995	0.1004	0.0763	0.0638	0.0763	0.0638
1992	0.0837	0.0749	0.1439	0.1553	0.0888	0.0781	0.0629	0.1062	0.1693	0.1154	0.1682	0.2526	0.0629
1993	0.0443	0.1527	0.1406	0.3519	0.1513	0.1175	0.0672	0.0644	0.0562	0.0628	0.0782	0.0676	0.0443
1994	0.0590	0.0608	0.1103	0.2128	0.1567	0.0661	0.0771	0.0520	0.0572	0.0644	0.0960	0.1057	0.0520

1995	0.0778	0.1108	0.1116	0.1267	0.1232	0.0948	0.0700	0.0586	0.0571	0.0726	0.1701	0.1117	0.0571
1996	0.0893	0.1143	0.1250	0.2571	0.2345	0.1889	0.1282	0.1557	0.1564	0.1524	0.1243	0.1426	0.0893
1997	0.0789	0.1514	0.2770	0.2699	0.1919	0.0719	0.0605	0.0564	0.0439	0.0444	0.0549	0.0764	0.0439
1998	0.0257	0.0746	0.1776	0.1431	0.0840	0.0628	0.0533	0.0378	0.0308	0.0444	0.0379	0.0340	0.0257
1999	0.0269	0.0643	0.0681	0.1168	0.0615	0.0574	0.0377	0.0178	0.0125	0.0626	0.0687	0.0649	0.0125
2000	0.0401	0.0332	0.0862	0.1184	0.1228	0.0960	0.0991	0.0494	0.0481	0.0574	0.0745	0.0725	0.0332
2001	0.0570	0.0821	0.1416	0.1191	0.1114	0.0726	0.0443	0.0315	0.0234	0.0451	0.0686	0.1346	0.0234
2002	0.0764	0.0898	0.1426	0.1627	0.1511	0.1040	0.0371	0.0463	0.0387	0.0514	0.0508	0.0485	0.0371
2003	0.0401	0.0348	0.0282	0.1132	0.1143	0.0365	0.0272	0.0195	0.0095	0.0117	0.0872	0.1247	0.0095
2004	0.0736	0.0618	0.0667	0.1980	0.2486	0.0836	0.0707	0.0739	0.0503	0.0509	0.0445	0.0797	0.0445
2005	0.0696	0.0739	0.1099	0.2259	0.0945	0.0533	0.0490	0.0634	0.0632	0.0654	0.0620	0.0682	0.0490
2006	0.1437	0.2076	0.1446	0.2464	0.1667	0.0675	0.0636	0.0461	0.0427	0.1472	0.1977	0.2681	0.0427
2007	0.1748	0.1114	0.1263	0.2208	0.2170	0.0727	0.0439	0.0418	0.0354	0.0356	0.0496	0.0626	0.0354
2008	0.1846	0.2240	0.3091	0.3431	0.1760	0.1204	0.0709	0.1349	0.0988	0.1206	0.1259	0.1637	0.0709
2009	0.2085	0.1912	0.2957	0.2921	0.2369	0.1365	0.0871	0.0875	0.0716	0.0823	0.1045	0.1115	0.0716
Mean	0.0849	0.0946	0.1404	0.2147	0.1488	0.0967	0.0697	0.0673	0.0700	0.0654	0.0798	0.0984	0.0453
N	50	50	50	50	50	50	50	50	50	50	50	50	50
Std	0.0449	0.0471	0.0966	0.0832	0.0528	0.0323	0.0225	0.0252	0.0390	0.0377	0.0378	0.0560	0.0161
High	0.2085	0.2240	0.5146	0.4059	0.2713	0.1980	0.1378	0.1557	0.2477	0.2343	0.1977	0.2681	0.0893
Low	0.0257	0.0256	0.0282	0.0393	0.0615	0.0365	0.0272	0.0178	0.0095	0.0117	0.0284	0.0289	0.0095

Table 3 7-d Low Flows for BLACK CREEK BELOW ACTON WSCID: 02HB024

Drainage Area= 24.5000 km^2

Raw Statistical Characteristics:

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Max	0.2085	0.2240	0.5146	0.4059	0.2713	0.1980	0.1378	0.1557	0.2477	0.2343	0.1977	0.2681	0.0893
Min	0.0257	0.0256	0.0282	0.0393	0.0615	0.0365	0.0272	0.0178	0.0095	0.0117	0.0284	0.0289	0.0095
Med	0.0813	0.0895	0.1160	0.2166	0.1398	0.0941	0.0663	0.0645	0.0628	0.0567	0.0686	0.0764	0.0444
Mean	0.0849	0.0946	0.1404	0.2147	0.1488	0.0967	0.0697	0.0673	0.0700	0.0654	0.0798	0.0984	0.0453
Std	0.0445	0.0467	0.0957	0.0824	0.0523	0.0319	0.0223	0.0250	0.0386	0.0374	0.0374	0.0554	0.0159
Skew	0.9952	0.7693	2.1841	0.2742	0.7875	1.1157	0.9684	1.2528	2.4597	2.4441	1.2333	1.3317	0.2406
Kurt	4.0109	3.6090	9.0541	2.7601	3.3171	5.1197	4.6548	6.5250	12.3499	11.3422	4.5287	4.7179	3.6370
N	50	50	50	50	50	50	50	50	50	50	50	50	50

Log Transformed Statistics

Mean	-2.6032	-2.4867	-2.1422	-1.6225	-1.9635	-2.3867	-2.7124	-2.7665	-2.7892	-2.8495	-2.6251	-2.4574	-3.1687
Std	0.5423	0.5325	0.5972	0.4402	0.3463	0.3207	0.3160	0.3878	0.5388	0.4901	0.4393	0.5280	0.4184
Skew	-0.2595	-0.4334	0.0645	-0.9986	0.0125	-0.0487	-0.1364	-0.8653	-0.9310	-0.0041	0.2265	0.1612	-1.3272
Kurt	2.7752	2.9303	3.8181	5.3347	2.8526	3.9490	3.8452	6.2693	7.0768	5.6309	2.9019	2.8751	6.2558

LN3P Statistics ML Fit

AX	-0.0110	-0.0337	0.0000	-0.3855	0.0000	0.0000	-0.0106	0.0000	0.0000	0.0000	0.0000	0.0000	-0.1537
Mean	-2.4470	-2.1176	-2.1422	-0.5112	-1.9635	-2.3867	-2.5588	-2.7665	-2.7892	-2.8495	-2.6251	-2.4574	-1.6178
Std	0.2098	0.1296	0.5972	0.0182	0.3463	0.3207	0.0717	0.3878	0.5388	0.4901	0.4393	0.5280	0.0799
Skew	-0.0952	-0.0723	0.0645	-0.0255	0.0125	-0.0487	0.0338	-0.8653	-0.9310	-0.0041	0.2265	0.1612	-0.0290

EV3 Statistics MM Fit

Beta	0.0926	0.1048	0.1389	0.2404	0.1601	0.1014	0.0737	0.0704	0.0687	0.0642	0.0845	0.1043	0.0503
Std	0.0445	0.0467	0.0957	0.0824	0.0523	0.0319	0.0223	0.0250	0.0386	0.0374	0.0374	0.0554	0.0159
Skew	0.9952	0.7693	2.1841	0.2742	0.7875	1.1157	0.9684	1.2528	2.4597	2.4441	1.2333	1.3317	0.2406
Kurt	4.0109	3.6090	9.0541	2.7601	3.3171	5.1197	4.6548	6.5250	12.3499	11.3422	4.5287	4.7179	3.6370
Alfa	1.5692	1.8201	0.9639	2.7178	1.7972	1.4610	1.5955	1.3552	0.9270	0.9282	1.3691	1.3015	2.8055
GY	0.0166	0.0126	0.0482	0.0072	0.0580	0.0508	0.0349	0.0338	0.0342	0.0307	0.0291	0.0269	0.0040

EV3 Statistics MLOD Fit

Beta	0.0914	0.1037	0.1385	0.2432	0.1611	0.1034	0.0750	0.0721	0.0678	0.0635	0.0849	0.1045	0.0511
Std	0.0445	0.0467	0.0957	0.0824	0.0523	0.0319	0.0223	0.0250	0.0386	0.0374	0.0374	0.0554	0.0159
Skew	0.9952	0.7693	2.1841	0.2742	0.7875	1.1157	0.9684	1.2528	2.4597	2.4441	1.2333	1.3317	0.2406
Kurt	4.0109	3.6090	9.0541	2.7601	3.3171	5.1197	4.6548	6.5250	12.3499	11.3422	4.5287	4.7179	3.6370
Alfa	1.4484	1.6852	0.9639	2.7178	1.7972	1.4610	1.5955	1.3552	0.9270	0.9282	1.3691	1.3015	2.8055
GY	0.0214	0.0181	0.0262	-0.0152	0.0503	0.0321	0.0232	0.0149	0.0086	0.0109	0.0253	0.0253	-0.0023

Return Period (in years) Quantiles Estimates Weibull EV3 LOD Distribution fitted

1.2	0.1260	0.1390	0.2320	0.3050	0.2040	0.1380	0.0979	0.1030	0.1200	0.1100	0.1170	0.1490	0.0634
1.5	0.0961	0.1090	0.1500	0.2520	0.1670	0.1080	0.0782	0.0762	0.0742	0.0691	0.0891	0.1100	0.0529
2.0	0.0757	0.0870	0.1030	0.2110	0.1410	0.0876	0.0644	0.0585	0.0485	0.0463	0.0709	0.0850	0.0446
5.0	0.0463	0.0533	0.0499	0.1340	0.0984	0.0576	0.0434	0.0338	0.0203	0.0213	0.0452	0.0503	0.0290
10.0	0.0362	0.0406	0.0371	0.0977	0.0820	0.0473	0.0358	0.0257	0.0138	0.0156	0.0368	0.0393	0.0217
20.0	0.0304	0.0328	0.0314	0.0714	0.0715	0.0414	0.0313	0.0213	0.0110	0.0130	0.0321	0.0334	0.0162
25.0	0.0291	0.0309	0.0303	0.0645	0.0690	0.0400	0.0302	0.0203	0.0105	0.0126	0.0310	0.0321	0.0148
50.0	0.0262	0.0266	0.0282	0.0463	0.0630	0.0370	0.0277	0.0181	0.0095	0.0117	0.0287	0.0292	0.0110
100.0	0.0244	0.0237	0.0272	0.0324	0.0589	0.0351	0.0261	0.0168	0.0090	0.0113	0.0273	0.0276	0.0081
200.0	0.0232	0.0218	0.0267	0.0216	0.0561	0.0340	0.0251	0.0160	0.0088	0.0111	0.0265	0.0266	0.0058

APPENDIX B
Mass and Temperature Balance Calculations

Appendix B Mass and Temperature Balance Calculations

Halton Region - Acton WWTP discharging to Black Creek

Table B1 - Mass Balance Assumptions							
	Mass balance equation						
	C1xQ1 + CsxQs = C3xQ3						
	C1 = upstream concentration - typically 75th percentile of the background data						
	Cs = sewage conc. - based on Certificate of Approval						
	C3 = mixed, downstream concentration						
	Q1 = upstream flow - typically 7Q20						
	Qs = sewage flow						
	Q3 = Q1 + Q2 = mixed flow						
	Solve for C3		C3 = (C1xQ1+CsxQs)/Q3			to show in-stream result	
	Solve for Cs		Cs = (Q3xC3 -Q1xC1)/Qs			to derive effluent limit	
	Q units m3/s						
	C units mg/L						
	Q x C = load or mass units/time, kg/day						
	Conversions						
	seconds per day	86400					
	Ratio TKN/NH3	1.763	Observed				
	CBODu/CBOD5	1.58	based on decay rate of 0.2/day				
	NOD/TKN	4.57	stoichiometric ratio				
	NH3-N to NH3	0.8235			NH3/NH3-N	1.214285714	
	Conversion	As ammonia	as ammonia- N				
	PWQO	0.02	0.0165	mg/L			
	Effluent Complia	0.1	0.0824	mg/L			

Table B2 - Effluent Characteristics							
	Effluent Concentrations - mg/L						
	CBOD5	TKN*	TOD*	Ammonia-N	Nitrates*	Total P	TSS	Cl*
Objective	2	1.763	11.215	1.0	12.9	0.2	3	307.7
Comp. Limit	5	3.525	24.009	2.0	12.9	0.3	5	307.7
Winter				4.0				
Proposed Objective						0.1		
Proposed Limit						0.2		

Total phosphorus based on proposed effluent quality objective and limit

* Not a Limit or Objective

* TKN calculated from ratio observed from annual effluent data .TOD calculated from summation of CBODu and NOD

* Nitrates based on estimate with proposed improved denitrification

	Effluent Flow Rate at different units							**dilution ratio**
Current CofA	4545	m^3/day	0.0526	m^3/s	52.60	L/s		0.31
Scenario 1	5600	m^3/day	0.0648	m^3/s	64.81	L/s		0.25
Scenario 2	7000	m^3/day	0.0810	m^3/s	81.02	L/s		0.20

	Effluent Load Rate - kg/day							
	CBOD5	TKN*	TOD*	Ammonia-N	Nitrates*	Total P**	TSS	Cl
Objective based								
Current CofA	9.09	8.01	50.97	4.55	58.63	0.909	13.64	1398
Scenario 1**	11.2	9.87	62.80	5.60	72.24	0.560	16.80	1723
Scenario 2**	14	12.34	78.50	7.00	90.30	0.700	21.00	2154
Limit Based								
Current CofA	22.73	16.02	109.12	9.09	58.63	1.36	22.73	1398
Scenario 1**	28.00	19.74	134.45	11.20	72.24	1.12	28.00	1723
Scenario 2**	35.00	24.68	168.07	14.00	90.30	1.40	35.00	2154
Winter Ammonia-N								
Current CofA				18.18				
Scenario 1				22.40				
Scenario 2				28.00				

**All TP loadings for scenarios at proposed objective and limits

Table B3 - Input to Mass Balance Calculation								
	Upstream Concentration C1 based on 75th percentile Since 1993							
	Annual values - mg/L							
	BOD5	TKN	TOD	Ammonia-N	Nitrates	Total P	TSS	Cl
	5.45	1.84	17.020	0.95	2.69	0.048	15	160.50
	Upstream Flow - Annual 7Q20 -							
	1399.68	m^3/day	0.0162	m^3/s	16.20	L/s		

Table B4 - Mass Balance Calculation - Mixed in Stream Concentration								
	BOD5	TKN	TOD	Ammonia-N	Nitrates	Total P**	TSS	Cl
Objective based								
Current CofA	2.81	1.78	12.58	0.988	10.49	0.164	5.8	273.0
Scenario 1**	2.69	1.78	12.38	0.990	10.86	0.090	5.4	278.3
Scenario 2**	2.57	1.78	12.18	0.991	11.20	0.091	5.0	283.2
Limit Based								
Current CofA	5.11	3.13	22.36	1.75	10.49	0.241	7.4	273.0
Scenario 1**	5.09	3.19	22.61	1.79	10.86	0.170	7.0	278.3
Scenario 2**	5.07	3.24	22.84	1.82	11.20	0.175	6.7	283.2
Winter Ammonia-N								
Current CofA				0.99				
Scenario 1**				0.99				
Scenario 2**				0.99				
** TP concentrations for scenarios at proposed objective and limits								
All calculated values assuming existing treatment levels as shown in Table B2								
C3 = (C1xQ1+CsxQs)/Q3								

Table B5 Montlhy total phosphorus concentration upstream of Acton WWTP

	Mean	Median	75th Percentile	Min	Max	PWQO/ Guideline	% Violation	# of Data Points
Jan	0.038	0.028	0.034	0.015	0.124	0.030	38%	16
Feb	0.037	0.029	0.051	0.013	0.064	0.030	44%	9
Mar	0.030	0.032	0.036	0.014	0.056	0.030	56%	9
Apr	0.020	0.019	0.022	0.017	0.024	0.030	0%	6
May	0.045	0.032	0.046	0.024	0.127	0.030	63%	8
Jun	0.038	0.037	0.045	0.026	0.050	0.030	70%	10
Jul	0.051	0.052	0.061	0.023	0.068	0.030	90%	10
Aug	0.064	0.040	0.051	0.015	0.303	0.030	70%	10
Sep	0.042	0.042	0.045	0.029	0.072	0.030	90%	10
Oct	0.040	0.033	0.054	0.020	0.069	0.030	70%	10
Nov	0.057	0.038	0.044	0.020	0.164	0.030	67%	9
Dec	0.094	0.066	0.078	0.035	0.288	0.060	1.042	
Annual	0.042	0.034	0.048	0.013	0.303	0.030	61%	107
Note	December estimate = avg Nov and jan				No December data			
	Data from	4-Jan-00	to	24-Feb-10				
	All values mg/L							

Table B6 Mixed in-stream total phosphorus downstream of Acton with effluent flow Scenario 1

	WWTP			Upstream		Downstream Mixed	
Month	Scen 1 flow	Objective	Limit	Low flow	TP	at Objective	at Limit
	m3/s	mg/L	mg/L	m3/s	mg/L	mg/L	mg/L
Jan	0.0700	0.1	0.2	0.0304	0.034	0.080	0.150
Feb	0.0679	0.1	0.2	0.0328	0.051	0.084	0.151
Mar	0.0714	0.1	0.2	0.0314	0.036	0.080	0.150
Apr	0.0738	0.1	0.2	0.0714	0.022	0.062	0.112
May	0.0711	0.1	0.2	0.0715	0.046	0.073	0.123
June	0.0652	0.1	0.2	0.0414	0.045	0.079	0.140
July	0.0572	0.1	0.2	0.0313	0.061	0.086	0.151
Aug	0.0552	0.1	0.2	0.0213	0.051	0.086	0.159
Sept	0.0588	0.1	0.2	0.011	0.045	0.091	0.176
Oct	0.0589	0.1	0.2	0.013	0.054	0.092	0.174
Nov	0.0640	0.1	0.2	0.0321	0.044	0.081	0.148
Dec	0.0644	0.1	0.2	0.0334	0.078	0.093	0.158
Annual	0.0648	0.1	0.2	0.0162	0.048	0.090	0.170

Table B7 Mixed in-stream total phosphorus downstream of Acton with effluent flow Scenario 2

	WWTP			Upstream		Downstream Mixed	
Month	Scen 1 flow	Objective	Limit	Low flow	TP	Effluent at Objective	Effluent at Limit
	m3/s	mg/L	mg/L	m3/s	mg/L	mg/L	mg/L
Jan	0.0875	0.1	0.2	0.0304	0.034	0.083	0.157
Feb	0.0849	0.1	0.2	0.0328	0.051	0.086	0.158
Mar	0.0892	0.1	0.2	0.0314	0.036	0.083	0.157
Apr	0.0922	0.1	0.2	0.0714	0.022	0.066	0.122
May	0.0888	0.1	0.2	0.0715	0.046	0.076	0.131
June	0.0815	0.1	0.2	0.0414	0.045	0.081	0.148
July	0.0715	0.1	0.2	0.0313	0.061	0.088	0.158
Aug	0.0690	0.1	0.2	0.0213	0.051	0.088	0.165
Sept	0.0735	0.1	0.2	0.011	0.045	0.093	0.180
Oct	0.0736	0.1	0.2	0.013	0.054	0.093	0.178
Nov	0.0800	0.1	0.2	0.0321	0.044	0.084	0.155
Dec	0.0805	0.1	0.2	0.0334	0.078	0.094	0.164
Annual	0.0810	0.1	0.2	0.0162	0.048	0.091	0.175

Table B 8 - Black Creek Upstream of Acton - Monthly Unionized Ammonia, pH, Temperature

Jan	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0093	0.0092	0.0005	0.0481	14	mg/L
pH	7.6	7.8	7.1	8.5	18	
Temperature	2.4	3.0	0.1	7.0	19	C
Feb	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0045	0.0063	0.0000	0.0119	5	mg/L
pH	7.5	7.5	7.4	7.7	9	
Temperature	2.5	3.5	0.3	5.0	9	C
Mar	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0032	0.0033	0.0000	0.0106	8	mg/L
pH	7.6	7.7	7.4	7.9	12	
Temperature	3.9	5.0	1.0	11.5	17	C
Apr	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0064	0.0095	0.0020	0.0136	8	mg/L
pH	7.5	7.7	7.2	7.9	12	
Temperature	8.9	11.3	4.0	13.0	10	C
May	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0024	0.0033	0.0000	0.0054	6	mg/L
pH	7.5	7.6	7.3	7.8	8	
Temperature	13.3	15.0	7.0	21.0	13	C
Jun	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0115	0.0192	0.0000	0.0332	9	mg/L
pH	7.4	7.5	7.1	7.9	12	
Temperature	19.5	20.7	15.1	23.6	15	C
Jul	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0022	0.0049	0.0000	0.0052	9	mg/L
pH	7.3	7.5	6.4	7.6	14	
Temperature	18.8	20.3	12.0	26.0	14	C
Aug	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0039	0.0066	0.0001	0.0088	8	mg/L
pH	7.3	7.4	6.9	7.6	12	
Temperature	16.1	18.0	1.3	26.1	16	C
Sep	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0034	0.0057	0.0000	0.0084	6	mg/L
pH	7.4	7.6	7.0	7.7	9	
Temperature	15.7	18.0	10.3	21.0	11	C
Oct	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0076	0.0106	0.0000	0.0298	13	mg/L
pH	7.4	7.5	7.2	7.7	16	
Temperature	10.3	12.2	3.9	15.0	17	C
Nov	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0013	0.0019	0.0002	0.0025	7	mg/L
pH	7.5	7.6	7.2	7.7	10	
Temperature	6.1	9.0	1.0	10.0	18	C
Dec	Average	75th %ile	Min	Max	# of Data	Units
Unionized Ammonia	0.0037	0.0046	0.0021	0.0051	3	mg/L
pH	7.3	7.5	6.9	7.7	4	
Temperature	3.6	4.5	1.0	9.0	11	C

Based on data from 1965 - 2006

Some field pH estimated from lab pH

Shaded exceeds PWQO

Table B9 - Acton WWTP - Monthly CofA Limit Ammonia in Effluent

Month	Ammonia Limit mg/L	Temp oC	pH	pKa	f	Unionized Ammonia* mg/L
Jan	4	3.0	7.8	10.0	0.0060	0.0242
Feb	4	3.5	7.5	10.0	0.0036	0.0144
Mar	4	5.0	7.7	9.9	0.0057	0.0230
Apr	4	11.3	7.7	9.7	0.0091	0.0363
May	2	15.0	7.6	9.6	0.0108	0.0216
Jun	2	20.7	7.5	9.4	0.0142	0.0284
Jul	2	20.3	7.5	9.4	0.0112	0.0223
Aug	2	18.0	7.4	9.5	0.0088	0.0175
Sep	2	18.0	7.6	9.5	0.0118	0.0237
Oct	2	12.2	7.5	9.7	0.0072	0.0143
Nov	2	9.0	7.6	9.8	0.0064	0.0128
Dec	4	4.5	7.5	9.9	0.0035	0.0139
CofA compliance limit	0.1 mg/L	as nH3	or	0.0824	mg/L as NH3-N	
*at stream temperature and pH						
All values assume ammonia-N			Shaded exceeds compliance limit			

Table B10 - Black Creek d/s Acton - Unionized Ammonia Downstream with Effluent Mixed in - Predicted by Mass Balance

Month	CofA Ammonia Limit mg/L	Existing STP Flow mg/L	Scenario 1 mg/L	Scenario 2 mg/L
Jan	4	0.0190	0.0197	0.0203
Feb	4	0.0114	0.0118	0.0121
Mar	4	0.0161	0.0170	0.0179
Apr	4	0.0217	0.0231	0.0246
May	2	0.0115	0.0124	0.0135
Jun	2	0.0244	0.0249	0.0253
Jul	2	0.0153	0.0161	0.0170
Aug	2	0.0140	0.0145	0.0150
Sep	2	0.0203	0.0209	0.0213
Oct	2	0.0135	0.0136	0.0138
Nov	2	0.0087	0.0092	0.0097
Dec	4	0.0103	0.0107	0.0112
PWQO 0.02 mg/L NH3 or		0.01647	as NH3-N	mg/L as N

Shaded exceeds PWQO

*at stream temperature and pH

Based on concentration upstream Table B7 and effluent at CofA Limit

Using monthly effluent flows from Table 8 and monthly 7Q20 from Table 9

Table B11 - Black Creek d/s Acton - Unionized Ammonia Downstream with Effluent Mixed in - Predicted by Mass Balance

Month	Proposed ammonia Objective mg/L	Existing STP Flow mg/L	Scenario 1 mg/L	Scenario 2 mg/L		
Jan	1	0.0071	0.0070	0.0069		
Feb	1	0.0046	0.0045	0.0044		
Mar	1	0.0049	0.0050	0.0051		
Apr	1	0.0093	0.0093	0.0093		
May	0.5	0.0043	0.0044	0.0045		
Jun	0.5	0.0124	0.0118	0.0112		
Jul	0.5	0.0053	0.0053	0.0054		
Aug	0.5	0.0051	0.0050	0.0049		
Sep	0.5	0.0059	0.0059	0.0059		
Oct	0.5	0.0051	0.0048	0.0046		
Nov	0.5	0.0027	0.0028	0.0028		
Dec	1	0.0039	0.0038	0.0038		
PWQO 0.02 mg/L NH3 or		0.01647	as NH3-N	mg/L as N		
Shaded exceeds PWQO						
*at stream temperature and pH						
Based on concentration upstream Table B7 and effluent at proposed objective						
Using monthly effluent flows from Table 8 and monthly 7Q20 from Table 9						

Table B12 - Acton WWTP - Monthly proposed objective Ammonia in Effluent

Month	Ammonia Limit mg/L	Temp oC	pH	pKa	f	Unionized Ammonia* mg/L
Jan	1	3.0	7.8	10.0	0.0060488	0.0060
Feb	1	3.5	7.5	10.0	0.0035977	0.0036
Mar	1	5.0	7.7	9.9	0.0057478	0.0057
Apr	1	11.3	7.7	9.7	0.0090854	0.0091
May	0.5	15.0	7.6	9.6	0.0108022	0.0054
Jun	0.5	20.7	7.5	9.4	0.0142133	0.0071
Jul	0.5	20.3	7.5	9.4	0.0111507	0.0056
Aug	0.5	18.0	7.4	9.5	0.0087685	0.0044
Sep	0.5	18.0	7.6	9.5	0.0118434	0.0059
Oct	0.5	12.2	7.5	9.7	0.0071573	0.0036
Nov	0.5	9.0	7.6	9.8	0.0064042	0.0032
Dec	1	4.5	7.5	9.9	0.0034735	0.0035
CofA compliance limit	0.1 mg/L	as nH3	or	0.0824	mg/L as NH3-N	
PWQO 0.02 mg/L NH3 or		0.01647	as NH3-N	mg/L as N		
*at stream temperature and pH						
All values assume ammonia-N			Shaded exceeds PWQO			

Table B13 - Acton WWTP - Monthly proposed objective Ammonia in Effluent

Month	Ammonia Limit mg/L	Temp oC	pH	pKa	f	Unionized Ammonia* mg/L
Jan	1	11.7	7.85	9.7	0.0145279	0.0145
Feb	1	10.4	7.80	9.7	0.0116675	0.0117
Mar	1	10.4	7.89	9.7	0.0144791	0.0145
Apr	1	11.8	7.88	9.7	0.0157590	0.0158
May	0.5	14.3	7.87	9.6	0.0186071	0.0093
Jun	0.5	18.0	7.81	9.5	0.0213443	0.0107
Jul	0.5	20.5	7.90	9.4	0.0310707	0.0155
Aug	0.5	20.6	7.78	9.4	0.0237834	0.0119
Sep	0.5	20.3	7.76	9.4	0.0224274	0.0112
Oct	0.5	18.0	7.79	9.5	0.0205186	0.0103
Nov	0.5	15.3	7.79	9.6	0.0167289	0.0084
Dec	1	12.7	7.75	9.6	0.0125166	0.0125
CofA compliance limit	0.1 mg/L	as nH3	or	0.0824	mg/L as NH3-N	
PWQO 0.02 mg/L NH3 or		0.01647	as NH3-N	mg/L as N		
*at effluent temperature and pH (75th percentile						
All values assume ammonia-N			Shaded exceeds PWQO			

Table B14 - Monthly Temperature - Acton WWTP Effluent - C

Month	Average	75th Percentile	Min	Max	# of Data Points
Jan	10.6	11.7	5.7	15.1	161
Feb	9.4	10.4	5.0	12.1	130
Mar	9.6	10.4	5.6	11.6	147
Apr	10.9	11.8	6.6	14.8	146
May	13.1	14.3	7.4	18.4	152
June	16.5	18.0	9.6	20.1	143
July	19.7	20.5	16.6	23.0	151
Aug	20.3	20.6	16.7	24.0	152
Sept	19.8	20.3	17.5	24.0	147
Oct	16.9	18.0	11.7	20.4	152
Nov	14.5	15.3	10.3	16.9	141
Dec	12.4	12.7	11.2	14.9	136

Data from 2002 to 2006
All values degrees C.

Table B15 - Black Creek Upstream of Acton - Monthly Temperature - C

Month	Average	75th Percentile	Min	Max	# of Data Points
Jan	2.4	3.0	0.1	7.0	19
Feb	2.5	3.5	0.3	5.0	9
Mar	3.9	5.0	1.0	11.5	17
Apr	8.9	11.3	4.0	13.0	10
May	13.3	15.0	7.0	21.0	13
Jun	19.5	20.7	15.1	23.6	15
Jul	18.8	20.3	12.0	26.0	14
Aug	17.1	18.0	14.0	26.1	15
Sep	15.7	18.0	10.3	21.0	11
Oct	10.3	12.2	3.9	15.0	17
Nov	6.1	9.0	1.0	10.0	18
Dec	3.6	4.5	1.0	9.0	11

Data from 1965 to 2006 as spot measurements
All values degrees C.

Table B16 - Black Creek Dowstream of Acton - Monthly Temperature - C

Month	Average	75th Percentile	Min	Max	# of Data Points
Jan	1.8	2.5	0.5	6.0	26
Feb	1.6	2.0	1.0	3.5	20
Mar	3.7	5.8	1.0	9.0	25
Apr	6.9	8.0	1.0	16.0	26
May	13.2	14.7	6.0	17.5	28
Jun	17.0	18.7	13.0	21.5	31
Jul	18.0	19.8	14.6	21.0	29
Aug	16.6	18.5	12.0	20.0	29
Sep	14.1	15.4	9.0	21.0	27
Oct	9.3	11.1	2.0	13.8	28
Nov	5.1	6.0	0.5	12.0	27
Dec	2.3	2.9	0.5	6.0	18

Data from 1965 to 2006 as spot measurements
All values degrees C.

Table B17- Black Creek Dowstream of Acton - Monthly Temperature Difference - C				
Month	**Average**	**75th**	**Min**	**Max**
Jan	-0.5	-0.6	0.4	-1.0
Feb	-0.9	-1.5	0.7	-1.5
Mar	-0.1	0.8	0.0	-2.5
Apr	-2.0	-3.3	-3.0	3.0
May	-0.1	-0.3	-1.0	-3.5
Jun	-2.4	-2.0	-2.1	-2.1
Jul	-0.7	-0.4	2.6	-5.0
Aug	-0.5	0.5	-2.0	-6.1
Sep	-1.6	-2.6	-1.3	0.0
Oct	-1.0	-1.2	-1.9	-1.2
Nov	-1.0	-3.0	-0.5	2.0
Dec	-1.4	-1.6	-0.5	-3.0
Data from 1972 to 2006				

Table B18 - Temperature Downstream with Effluent Mixed in - Predicted by Temperature Balance

		STP Flow CofA	**Scenario1**	**Scenario 2**
Month		Deg C	Deg C	Deg C
Jan		8.7	9.1	9.5
Feb		7.8	8.2	8.5
Mar		8.5	8.8	9.0
Apr		11.5	11.5	11.6
May		14.7	14.7	14.6
Jun		19.2	19.0	18.9
Jul		20.4	20.4	20.4
Aug		19.8	19.9	20.0
Sep		19.8	19.9	20.0
Oct		16.8	17.0	17.1
Nov		12.9	13.2	13.5
Dec		9.5	9.9	10.3

Based on 75th percentile background and effluent temperatures
All values degrees C.

Table B19 - Black Creek Dowstream of Acton - Monthly Temperature Difference - C - Predicted by Temperature Balance

		STP Flow CofA	**Scenario1**	**Scenario 2**
Month		Deg C	Deg C	Deg C
Jan		5.7	6.1	6.5
Feb		4.3	4.7	5.0
Mar		3.5	3.8	4.0
Apr		0.3	0.3	0.3
May		-0.3	-0.3	-0.4
Jun		-1.5	-1.7	-1.8
Jul		0.1	0.2	0.2
Aug		1.8	1.9	2.0
Sep		1.8	1.9	2.0
Oct		4.6	4.8	4.9
Nov		3.9	4.2	4.5
Dec		5.0	5.4	5.8

All values degrees C.

APPENDIX C
Dissolved Oxygen Model Description

For modelling purposes, the river system is divided into sections termed "reaches". The junction points of these reaches are called "nodes". The model has the ability to handle point sources discharges to each reach. These point sources generally take the form of sewage treatment plants and/or tributary streams.

The water quality parameters for each of the inputs along with the upstream river flow are input at the head of each reach and mixed according to the mass balance equation:

$$Q_1C_1 + Q_2C_2 = (Q_1 + Q_2)C_3 \qquad (1)$$

Solving for the new, instream mixed concentration, C_3, this becomes:

$$C_3 = \frac{(Q_1 C_1 + Q_2 C_2)}{Q_1 + Q_2} \qquad (2)$$

where: Q_1 = upstream flow (m^3/s)
Q_2 = waste input flow (m^3/s)
C_1 = upstream concentration (mg/L)
C_2 = waste input concentration (mg/L)
C_3 = instream mixed concentration (mg/L)

The combined flow with its pollutant load is then routed through the reaches. Reactive constituents such as BOD and NOD are allowed to decay during routing according to the following equations.

$$\text{BOD:} \qquad L_t = L_o\, e^{-Krt} \qquad (3)$$

where: L_t = Carbonaceous BOD (or CARBOD) concentration at time t - mg/L
L_o = ultimate BOD (or CARBOD) concentration at time t = 0 - mg/L
K_r = BOD removal rate - day^{-1}
t = Time

$$\text{NOD:} \qquad N_t = N_o\, e^{-Knt} \qquad (4)$$

where: N = NOD concentration- mg/L
K_n = NOD removal rate- day^{-1}
t = time

The N_o value is calculated as 4.57 times the TKN value in mg/L. The L_o value is calculated from the BOD5 value and the Kd reaction rate:

$$L_o = BOD5/(1-e^{-Kd*5})$$

Where: K_d = Deoxygenation rate constant for CARBOD - day^{-1}

More complex equations describing variations in downstream constituents can be simplified to a more mathematically convenient form using some basic assumptions. If we assume that:

a) convection (flow in the river) is unidirectional, that is significant only in the X direction;
b) diffusion effects are negligible; and
c) there is no change in streamflow, temperature, waste loads and stream processes (i.e. steady state prevails)

then the following simplified model applies:

$$V\frac{dc}{dx} = \sum Sources + Sinks \qquad (5)$$

where:
c = concentration of a substance, eg. dissolved oxygen - mg/L
x = direction downstream – m
V = Velocity in the x direction – m/s

Equation (5) was developed by Streeter and Phelps in 1925 and its solution known as the Streeter-Phelps model or the oxygen-sag model. The Streeter-Phelps model accounts for only one sink of oxygen - decomposition of organic matter (BOD) and one source - reaeration- and is applicable to rivers where these are the predominant processes. O'Connor and DiToro (1970) added terms to the model to account for increases in dissolved oxygen through the process of photosynthesis and decreases in dissolved oxygen through aquatic plant respiration, sludge respiration and carbonaceous and nitrogenous biochemical oxygen demand. The following processes are considered:

a) decomposition of carbonaceous oxygen demand - CARBOD and nitrogenous oxygen demand - NOD
b) sediment oxygen demand, SOD
c) algal and plant respiration, R
d) photosynthetic oxygen production by plants and algae, P
e) atmospheric reaeration, Ka

These processes are expressed in the following equation, which routes dissolved oxygen through the reach (and therefore through time):

$$\frac{dD(x,t)}{dt} + \frac{VdD(x,t)}{dx} = K_r L(x) + K_n N(x) + S(x) + R(x) - P(x,t) - K_a D(x,t) \qquad (6)$$

where
K_r = first order rate constant of CARBOD - day^{-1}
L = concentration of CARBOD according to equation (3) mg/L
K_n = first order decay rate constant of NOD - day^{-1}
N = concentration of NOD according to equation (4) - mg/L
S = average rate of sediment oxygen demand - mg/L
R = average rate of algal and plant respiration
P = photosynthetic oxygen production rate- mg/L
K_a = first order atmospheric reaeration rate constant - day^{-1}
$D(x,t)$ = dissolved oxygen deficit = $(C_s - C)$ - mg/L
C_s = oxygen saturation - mg/L
C = oxygen concentration - mg/L

O'Connor and DiToro (1970) solved equation (6) using a Fourier series expansion for the P and R terms. The photosynthesis and respiration terms (P and R) have been ignored in the equation below which can be applied to any waterway where the P and R terms are negligible.

$$\begin{aligned} D(x) = {} & D_0\, e^{-K_a(x/V)} + \frac{K_d\, L_0}{K_a - K_r}\left(e^{-K_r(x/V)} - e^{-K_a(x/V)} \right) \\ & + \frac{K_n\, N_0}{K_a - K_n}\left(e^{-K_n(x/V)} - e^{-K_a(x/V)} \right) \\ & + \frac{S}{K_a}\left(1 - e^{-K_a(x/V)} \right) \end{aligned} \tag{7}$$

where:	x/V	=	distance over velocity, or time of travel to location x
	V	=	Velocity - m/s

Note that the equation does not vary with time only x (or x/V or travel time)

Temperature corrections for the deoxygenation terms, reaeration term and SOD will be calculated by the following general equation:

$$K_T = K_{20}\, \theta^{(T-20)} \tag{8}$$

where:

K_T	=	generic reaction rate (1/day) for temperature T
K_{20}	=	specific reaction rate at 20ºC (1/day)
θ	=	Arrhenius equation temperature constant for each parameter.
T	=	temperature (C)

Values used for the θ term are as follows:

Coefficient	θ
Kd:	1.075
Ka:	1.024
Kr:	1.075
Kn:	1.097
S:	1.047

Oxygen saturation is a function of temperature as well as follows:

$$C_s = 14.48 - 0.36T + 0.0043T^2$$

The hydraulic relationships (Leopold, L.B., and Maddock, T., The Hydraulic Geometry of Stream Channels and some Physiographic Implications, Geological Survey Paper 252. USGS 1953) are used in the model:

$$V = aQ^b \qquad (9)$$

$$D = cQ^d \qquad (10)$$

$$W = eQ^f \qquad (11)$$

where:

V = velocity, m/s

Q = streamflow, m^3/s

D = river depth, m

W = Width, m

a, b, c, d, e, f = Leopold-Maddock coefficients

with: a x c x e = 1 and b + d + f =1

The reaeration term, Ka, is calculated using alternate relationships depending on the depth. For channel sections less than 0.61 m (2 ft) deep, use the relationship of Owens *et al*.

$$Ka = 5.32V^{0.67}/D^{1.85} \qquad (12)$$

For channel sections greater than than 0.61 m (2 ft) deep, use the relationship of O'Connor Dobbins

$$Ka = 3.9V^{0.5}/1.5 \qquad (13)$$

The units for areal rate terms need some clarification. The S, P and R terms by definition are channel bottom processes conventionally presented in units of $gm/m^2/day$. The relationship to the volumetric term used in the model is as follows for the SOD term, with units shown.

$$S\ (mg/L/day) = s\ (gm/m^2/day) / Depth\ (m)$$

The implication of this is that while the SOD rate would remain constant as flow varies, the volumetric S rate varies with depth and must be adjusted for predicting the impact of lower flows as follows:

$$S_2 = S_1 * D_1/D_2$$

With subscript 1 referring to the base example and 2 referring to the prediction scenario and D referring to depth (m). From this calculation it can be seen that lowering the flow rate (and thus the depth) magnifies the impact of SOD by the ratio of the depth. The same unit conversions apply to the P and R terms.

APPENDIX D

Dissolved Oxygen Model Inputs and Results

Appendix D - Dissolved Oxygen Model Inputs and Results

Table D1 - Black Creek Reach Geometry and Hydraulic Coefficients

Reach	Start Point	Finish Point	Length (m)	Velocity Cons. a	Velocity Exp. b	Depth Cons. c	Depth Exp. d	Width Cons. e	Width exp. f
1	Fairy L outlet	Acton WWTP	2770	0.100	0.504	1.700	0.322	7.075	0.195
2	Acton WWTP	3rd Line	1000	0.500	0.500	0.804	0.442	2.517	0.100
3	3rd Line	midpoint	1920	0.500	0.500	0.804	0.442	2.517	0.100
4	midpoint	Limehouse	1920	0.372	0.260	0.460	0.442	5.000	0.328
5	Limehouse	Confluence North Br.	1920	0.372	0.260	0.460	0.442	5.000	0.328
6	Confluence North Br.	midpoint	1960	0.370	0.260	0.612	0.342	5.500	0.328
7	midpoint	midpoint	1960	0.370	0.260	0.612	0.342	5.500	0.328
8	midpoint	Stewartown	1960	0.370	0.260	0.612	0.342	5.500	0.328
9	Stewartown	Confluence Silver Cr.	1570	0.317	0.260	0.604	0.442	5.147	0.328
		Total	16980						

Regime Equation Velocity = a*Q^b, Depth =c*Q^d, Width = e*Q^f
also a*c*e = 1
b+d+f = 1

Table D2 - Flow and Geometry Data and Variables - Calibration Case

Reach	Length (m)	Upst. Flow m3/s	WWTP Flow m3/s	Tributary/groundwater flow m3/s	Mixed Flow - m3/s	Travel time hours	Cumulative Travel time hrs	Velocity* m/s	Depth* m	Width* m
1	2770	0.0020		0.0074	0.0094	80.9	80.9	0.0095	0.378	2.847
2	1000	0.0094	0.038		0.0474	2.6	83.5	0.11	0.209	1.855
3	1920	0.0474		0.031	0.0780	3.8	87.3	0.14	0.260	1.950
4	1920	0.0780		0.060	0.1380	2.4	89.7	0.22	0.192	2.611
5	1920	0.1380		0.060	0.1980	2.2	91.9	0.24	0.225	2.940
6	1960	0.1980		0.003	0.2010	2.2	94.1	0.24	0.354	3.249
7	1960	0.2010		0.011	0.2120	2.2	96.3	0.25	0.360	3.307
8	1960	0.2120		0.011	0.2230	2.2	98.5	0.25	0.366	3.362
9	1570	0.2230		0.011	0.2340	2.0	100.5	0.22	0.318	3.196
total	16980									

Calibration - based on Aug. 21, 2007 field survey
* Calculated using regime equation and coefficients from Table D1

Table D3 Rate coefficients

Rate Coef.	Symbol	Global rates at 20 C	theta**	Unit
Deoxygenation	Kd	0.2	1.075	/day
BOD removal	Kr	0.2	1.075	/day
Nitrification	Kn	0.25	1.097	/day
Reaeration	Ka	NA	1.024	/day
Ka calibration		0.5		factor
Global Temperature		17.57		C
Global SOD		0.00		$g/m^2/day$
Ratio* CARBOD ultimate to BOD5			1.58	

*Ratio = $1/(1-e^{-kd5})$
** theta used in rate adjustment for temperature

Table D4 Reach based Rate Coefficents after Recalculation for Flow and Temp.								
Reach	Temperature - C	Kd - per day	Kr - per day	Kn - per day	Ka - per day	S gm/m2/day Note 5	S mg/L/day	DO Sat mg/L
1	17.57	0.00	0.00	0.00	0.67	0.00	0.00	9.48
2	17.57	0.17	0.17	0.16	10.30	0.00	0.00	9.48
3	17.57	0.17	0.17	0.16	8.09	0.00	0.00	9.48
4	17.57	0.17	0.17	0.16	19.43	0.00	0.00	9.48
5	17.57	0.17	0.17	0.16	15.40	0.00	0.00	9.48
6	17.57	0.17	0.17	0.16	6.68	0.00	0.00	9.48
7	17.57	0.17	0.17	0.16	6.52	0.00	0.00	9.48
8	17.57	0.17	0.17	0.16	6.37	0.00	0.00	9.48
9	17.57	0.17	0.17	0.16	7.53	0.00	0.00	9.48
For Calibration Case - Based on Aug. 31, 2007 field survey								

Table D5 Input Values - Calibration Case (Aug. 31, 2007)										
	Upstream	Source	WWTP	Source	Trib	Source	Ground water	Source	Marsh Input	Source
DO mg/L	7.15	survey	5.85	survey	8.54	survey	6.00	Est.	2.70	Est.
BOD5 mg/L	2.00	survey	2.00	survey	2	survey	0.10	Est.	2.00	Est.
CarBODu mg/L *	3.16	calc	3.16	calc	3.16	calc	0.16	calc	3.16	calc
TKN mg/L	0.60	survey	0.90	survey	0.40	survey	0.10	Est.	2.80	Est.
NOD mg/L **	2.74	calc	4.11	calc	1.83	calc	0.46	calc	12.80	calc
*CarBOD = ultimate carbonaceous oxygen demand = CBODu = BOD5*ratio										
**NOD = nitrogeous OD = 4.57*TKN										

Table D6 - Dissolved Oxygen Model Prediction - Calibration Case						
Reach Number	Location	DO Sataturation	DO	CarBODu	NOD	
		mg/L	mg/L	mg/L	mg/L	
1	Head	9.48	7.150	3.164	2.742	
1	end	9.48	8.87	3.16	10.65	
2	head - mixed	9.48	6.45	3.16	5.41	
2	end	9.48	8.38	3.11	5.32	
3	end	9.48	8.84	1.90	3.32	
4	end	9.48	9.19	1.123	2.045	
5	end	9.48	9.15	0.818	1.541	
6	end	9.48	9.27	0.840	1.523	
7	end	9.48	9.25	0.792	1.446	
8	end	9.48	9.24	0.750	1.377	
9	end	9.48	9.25	0.712	1.316	

Table D7 - Black Creek Reach Geometry and Hydraulic Coefficients - Scenario 2										
Reach	Length (m)	Upst. Flow m3/s	WWTP Flow m3/s	Tributary/ groundwater flow m3/s	Mixed Flow - m3/s	Travel time hours	Cumulative Travel time hrs	Velocity* m/s	Depth* m	Width* m
1	2770	0.0029		0.00546	0.0084	85.6	85.6	0.01	0.36	2.786
2	1000	0.0084	0.0526		0.0610	2.2	87.8	0.12	0.23	1.9029
3	1920	0.0610		0.0077	0.0687	4.1	91.9	0.13	0.25	1.9257
4	1920	0.0687		0.0092	0.0779	2.8	94.7	0.19	0.15	2.1645
5	1920	0.0779		0.0092	0.0870	2.7	97.4	0.20	0.16	2.2449
6	1960	0.0870		0.0030	0.0900	2.8	100.1	0.20	0.27	2.497
7	1960	0.0900		0.0045	0.0945	2.7	102.8	0.20	0.27	2.5372
8	1960	0.0945		0.0045	0.0990	2.7	105.5	0.20	0.28	2.5762
9	1570	0.0990		0.0045	0.1035	2.5	108.0	0.18	0.22	2.4463

Based on 7Q20 low flow of 0.0162 m3/s as natural flow at head of reach 3.

* Calculated using regime equation and coefficients from Table D1

Tale D8 - Black Creek Input Parameters - Design Scenarios										
	Upstream	Source	WWTP	Source	Trib	Source	Ground water	Source	Marsh Input	Source
DO mg/L	7.8	75th %ile	5.85	survey	6.00	survey	6.00	est	8.00	est
BOD5 mg/L	5.45	75th %ile	5.00	CofA lim	1.3	survey	0.10	est	5.45	est
CarBOD mg/L *	8.62	calc	7.91	calc	2.06	calc	0.16	calc	8.62	calc
TKN mg/L	1.84	75th %ile	3.53	CofA lim	0.40	survey	0.10	est	2.80	est
mg/L **	8.41	calc	16.11	calc	1.83	survey	0.46	calc	12.80	calc

*CarBOD = ultimate carbonaceous oxygen demand = CBODu = BOD5*ratio

**NOD = nitrogeous OD = 4.57*TKN

Table D9 - Reach based Rate Coefficents after Recalculation for Flow and Temp.								
Temperature - C	Kd - per day	Kr - per day	Kn - per day	Ka - per day	S gm/m2/day	S mg/L/day	DO Sat mg/L	
20.4	0.21	0.21	0.21	0.74	0.00	0.00	8.93	
20.4	0.21	0.21	0.21	9.75	0.00	0.00	8.93	
20.4	0.21	0.21	0.21	9.20	0.00	0.00	8.93	
20.4	0.21	0.21	0.21	30.03	0.00	0.00	8.93	
20.4	0.21	0.21	0.21	27.96	0.00	0.00	8.93	
20.4	0.21	0.21	0.21	10.32	0.00	0.00	8.93	
20.4	0.21	0.21	0.21	10.09	0.00	0.00	8.93	
20.4	0.21	0.21	0.21	9.88	0.00	0.00	8.93	
20.4	0.21	0.21	0.21	13.60	0.00	0.00	8.93	

For Design Case (Scen 2)and 75th percentile Temperature

Table D10 - Effluent Flow Rate	m^3/day	m^3/s	L/s
Current CofA	4545	0.0526	52.60
Scenario 1	5600	0.0648	64.81
Scenario 2	7000	0.0810	81.02

TableD11 - Dissolved Oxygen Model Prediction - Existing CofA

Reach Number	Location	DO Saturation	DO	CarBODu	NOD
		mg/L	mg/L	mg/L	mg/L
1	head	8.93	7.800	8.622	8.409
1	end	8.93	4.22	8.62	11.26
2	mixed head	8.93	5.65	8.00	15.51
2	end	8.93	7.33	7.84	15.21
3	end	8.93	8.21	7.00	13.35
4	end	8.93	8.78	6.108	11.664
5	end	8.93	8.80	5.398	10.321
6	end	8.93	8.65	5.157	9.787
7	end	8.93	8.61	4.906	9.222
8	end	8.93	8.60	4.678	8.709
9	end	8.93	8.68	4.476	8.254

Table D12 - Dissolved Oxygen Model Prediction - Scenario 1

Reach Number	Location	DO Saturation	DO	CarBODu	NOD
		mg/L	mg/L	mg/L	mg/L
1	head	8.93	7.800	8.622	8.409
1	end	8.93	4.18	8.62	11.26
2	mixed head	8.93	5.66	7.99	15.55
2	end	8.93	7.11	7.85	15.28
3	end	8.93	8.04	7.07	13.55
4	end	8.93	8.74	6.221	11.939
5	end	8.93	8.78	5.536	10.636
6	end	8.93	8.63	5.311	10.142
7	end	8.93	8.57	5.059	9.571
8	end	8.93	8.56	4.828	9.052
9	end	8.93	8.64	4.624	8.590

Table D13 - Dissolved Oxygen Model Prediction - Scenario 2

Reach Number	Location	DO Saturation	DO	CarBODu	NOD	
		mg/L	mg/L	mg/L	mg/L	
1	head	8.93	7.800	8.622	8.409	
1	end	8.93	4.18	8.62	11.26	
2	mixed head	8.93	5.69	7.98	15.65	
2	end	8.93	6.92	7.85	15.40	
3	end	8.93	7.86	7.18	13.91	
4	end	8.93	8.69	6.429	12.469	
5	end	8.93	8.75	5.805	11.268	
6	end	8.93	8.60	5.586	10.788	
7	end	8.93	8.54	5.339	10.233	
8	end	8.93	8.52	5.112	9.723	
9	end	8.93	8.60	4.909	9.265	

Table D14 Summary of Dissolved Oxygen Model Predictions - All Scenarios

Reach Number	Location	CofA	Scenario 1	Difference	Scenario 2	Difference
		mg/L	mg/L	mg/L	mg/L	mg/L
1	head	7.80	7.80	0.00	7.80	0.00
1	end	4.22	4.18	0.00	4.18	0.00
2	mixed head	5.65	5.66	0.03	5.69	0.07
2	end	7.33	7.11	-0.19	6.92	-0.39
3	end	8.21	8.04	-0.15	7.86	-0.33
4	end	8.78	8.74	-0.03	8.69	-0.09
5	end	8.80	8.78	-0.02	8.75	-0.05
6	end	8.65	8.63	-0.03	8.60	-0.05
7	end	8.61	8.57	-0.03	8.54	-0.07
8	end	8.60	8.56	-0.03	8.52	-0.07
9	end	8.68	8.64	-0.04	8.60	-0.08

APPENDIX E

Temperature Model Description

Introduction

The model was first developed for the Laurel Creek Watershed study, (Weatherbe, 1995). The model was further developed and applied in the Torrance Creek Subwatershed Study (Weatherbe *et al,* 1999**).**

Many species of fish are sensitive to elevated temperature levels in streams during various stages of their life cycle. Higher temperatures reduce dissolved oxygen saturation levels, and also increase the toxicity of some contaminants such as ammonia. Fish (and other organisms) respond to higher temperatures by increasing respiration, thus requiring more oxygen. These factors combined can cause worst-case conditions in streams for fish biota

Urbanization typically proceeds with construction of buildings and roadways, which increase imperviousness, and reduces the amount of water infiltrating into the ground. Along with the construction of storm drainage systems this results in increased rates and volume of runoff. The increased runoff rate usually causes natural channels to increase in depth and width as banks are eroded by the greatly increased frequency of channel-full events.

Heated stormwater pond discharges and reductions to baseflow further elevate temperatures. For example, Galli (1990) reports that the baseflow temperature was elevated over 8 degrees C after flowing through an in-line stormwater detention pond. Measures to offset the temperature increases in ponds and to increase infiltration can improve the thermal regime. In addition it is often proposed that the stream banks be revegetated in order to provide canopy and shade from solar heat inputs.

Channel modifications are also often proposed to rehabilitate the fishery and reproduce a natural habitat. This could include addition of meanders, creation of a natural pool and riffle system, and addition of a low flow channel that has the effect of narrowing and deepening the flow during baseflow conditions. All these changes to discharges, stream bank and channel can have an impact on the thermal regime. The removal of ponds or placing ponds fully or partially off-line can reduce the impact.

Heat Balance Considerations

The temperature of a body of water is dependent on the rate at which heat energy is exchanged between the water and the surroundings. If more heat energy is entering the water than leaving, then the temperature rises. The heat balance of a body of water, H, is expressed as the sum of all the energy input and output terms:

$$H = Hs + Ha - Hbr - He +/- Hc - Hsr - Har \qquad (1)$$

where: H = heat loss or gain, mj/m2/day
Hs = short-wave solar radiation, mj/m2/day
Ha = long wave atmospheric radiation, mj/m2/day
Hbr = long wave back radiation, mj/m2/day
He = evaporative heat loss, mj/m2/day
Hc = conductive heat loss or gain, mj/m2/day
Hsr = reflected solar radiation, mj/m2/day
H_{ar} = atmospheric reflection, mj/m^2/day

The sign indicates the typical direction of the heat flow. If the sum of positive terms (heat gain) is larger than the sum of negative terms (heat loss), then the temperature of the body of water rises. Models are available that account for all the terms in the heat balance, such as those described in Xie and James (1994). A simplified procedure, suitable for screening or planning purposes is described below.

Equilibrium Temperature

The concept of equilibrium temperature is used in a simplified modelling procedure recommended by the US EPA (EPA 1985). If all the heat terms are in balance, or equilibrium (H = 0), then the body of water is at the equilibrium temperature, E. Further, the concept assumes that the surface water temperature will move towards the equilibrium temperature as described in the excess temperature model (see following section). Edinger *et al* (1974) shows that the equilibrium temperature may be estimated by:

$$E = T_d + H_s/K \qquad (2)$$

where: T_d = the dewpoint temperature, Deg. C
H_s = the net rate of solar radiation, mj/m^2/day
K = the thermal exchange coefficient, mj/m^2/day/^{o}C

This formulation assumes that at night, evaporative heat losses would drive stream temperature towards the dew point temperature (where evaporation is zero). During the day, equilibrium temperature is increased by the net solar input, divided by the thermal exchange coefficient. The thermal exchange coefficient accounts for the rate of evaporation. The equation ignores several terms of the heat balance as it assumes that long wave atmospheric radiation is approximately balanced by the back radiation and conductive heat losses.

The thermal exchange coefficient, K, is dependent on wind speed and an empirically derived relationship as follows:

$$K = [4.48 + (B + .47)\ f(w) + .05T_s]\ 0.0864\ \text{mj/m}^2\text{/day/}^o\text{C} \qquad (3)$$

where:

$$f(w) = 9.2 + .0355\ w^2 \qquad (4)$$

w = wind speed in km/hr

$$B = .35 + .015\ T_m + .0012\ T_m^2\ \text{mm-Hg/}^o\text{C} \qquad (5)$$

T_s = surface water temperature, Deg. C

$$T_m = (T_s + T_d)/2 \qquad (6)$$

The initial value of the surface water temperature term, T_s (which is unknown) may be approximated by the equilibrium temperature, E, thus setting up an equation that has the same term on both sides. This can be solved iteratively, with a guess at the initial value of E (suggested as E = T_d). This iterative solution was set up in a spreadsheet for the Laurel Creek study (Weatherbe, 1995) and used as the basis for the Torrance Creek application. In trials the result was stable after three iterations, consequently the spreadsheet was set up to complete four iterations routinely.

Channel Temperature Model

Once the equilibrium temperature is calculated, the steady-state temperature distribution downstream from a point where initial temperatures are known, can be estimated by an excess temperature model:

$$(T_x - E) = (T_0 - E)e^{-0.011574Kx/\rho C_p UD} \tag{7}$$

where, T_x = Temperature (Deg.C) at any point x (km) downstream from the initial point, x = 0

T_o = Temperature (Deg.C) at x = 0

E = Equilibrium temperature, Deg.C

K = Thermal exchange coefficient, mj/m^2/day/^{o}C

ρ = Water density, g/m^3

C_p = Heat capacity of water, mj/g/Deg.C

ρC_p = 4.186 mj/m^3/Deg.C

U = Stream velocity, m/s

D = depth, m

The equation can also be formulated with x/U (units of time) equal to travel time.
The term (T_x - E) is termed the excess temperature, (note the origins of the model in the electric power generation industry).

Pond Temperature Model

For modelling shallow ponds, a continuous flow stirred tank reactor (CFSTR) model is used. With this model, it is assumed that substances, including heat, introduced to the pond (tank) are completely mixed throughout immediately. The formulation for this is given below using the excess temperature model terminology:

$$(T - E) = \frac{Q}{V}\frac{(T_0 - E)}{\beta}\left(1 - e^{-\beta t}\right) + (T_i - E)e^{-\beta t} \tag{8}$$

where: T = Temperature at time t in days

T_0 = Temperature of inflow at time 0

T_i = Temperature of pond at time 0

$$\beta = \left(\frac{k}{D} + \frac{Q}{V} \right) \qquad (9)$$

k = $K/\rho C_p$
K = Thermal exchange coefficient, mj/m^2/day/^{o}C
D = Pond depth, m
Q = Flow rate in pond, m^3/d (m^3/s X 86,000)
V = Pond volume, m^3

Water Loss in Ponds

The water loss due to evaporation in ponds can be calculated from the following (Edinger et al, 1974):

$$Q_a = B(T_s - T_d) f(w) \Big/ \rho \Delta e \qquad (10)$$

Where: $B = 0.035 + 0.015T_m + 0.0012T_m^2$ mm Hg/C (11)

ρ = Water density, 1000 Kg/m^3
Δe = Latent heat of vaporization, equal to 2450 J/g at 20 C.
Q_a = Unit rate of evaporation m/s

To calculate the rate for an individual pond in volumetric units (m^3/s), the value of Q_a is multiplied by pond area in square metres.

Hydraulic Relationships

Variations in velocity and depth with flow are given by (Leopold and Maddock, 1953) :

$$U = aQ^b \qquad (12)$$

$$D = cQ^d \qquad (13)$$

$$W = eQ^f \qquad (14)$$

where: W = width, m
Q = flow. m^3/s
a,b,c,d,e,f are dimensionless empirical coefficients,
such that ace = 1, and b + d + f = 1

McCutcheon (1989) suggests values for the exponents. For example, for a rectangular channel, the velocity exponent, b, is 0.40, the depth exponent, d, is 0.60, and the width exponent, f, is 0.0.

Spreadsheet Model Operation

The calculations in the spreadsheet model proceed in several steps, given below assuming a channel section (reach 1) precedes a pond section (Pond A) as shown in Figure 1:

1. A temperature balance calculation (similar to a mass balance) takes place at the head of a reach to mix upstream channel flow, Q_u , with runoff, Q_r, and groundwater, Q_{gw},

to calculate an initial temperature, T_o.

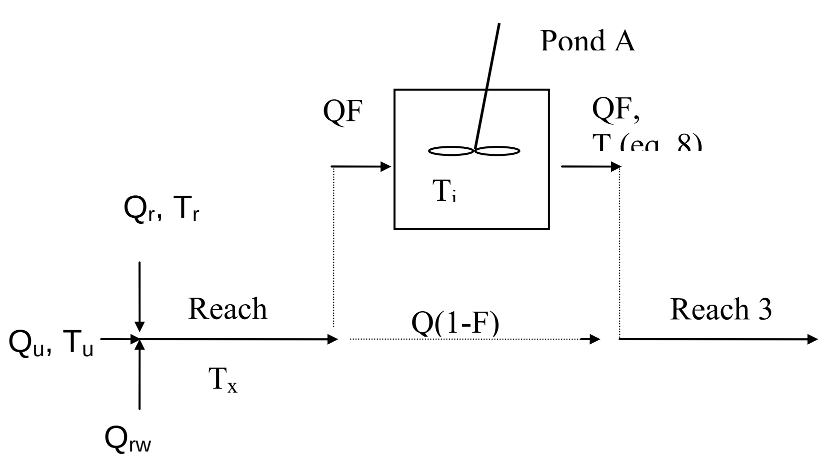
$$T_o = \frac{Q_u T_u + Q_r T_r + Q_{gw} T_{gw}}{Q_u + Q_r + Q_{gw}} \tag{15}$$

Similarly, the water balance is calculated:

$$Q_o = Q_u + Q_r + Q_{gw} \tag{16}$$

2. Equilibrium temperature, E, is calculated for a two hour steady state condition using equations 3 to 6 (repeated iteratively as described above). This is repeated each two hours during the day to give a 24 hour temperature variation. The sunlight intensity for each two hour timestep is adjusted according to the canopy in each reach.
3. For channel sections, temperature, T_x, is calculated using equation 7 for each 2 hour time-of-travel (x/U) step in the reach and at the end of the reach, assuming a steady state plug flow. Hydraulic coefficients are stored in a table in the spreadsheet and used in the calculations for the resulting channel flow (equation 14). The calculation of T_x is repeated for every two hour time period, producing a diurnal curve for each time step.
4. At the start of the next reach (a pond), flows are split according to the degree, F, that the pond is online (100% online, F =100%).
5. Pond temperatures are calculated according to equation 8.
6. For the next reach, a temperature and flow balance is calculated using the proportion of flow from the upstream reach or pond according to the flow splitting factor F. Note that if F= 100%, then the pond is in-line.
7. The sequence is repeated until the temperature is calculated for the entire system.
8. If tributaries are modelled, the tributary flows and temperature are calculated independently. Data is merged using a node worksheet that mixes the two flow streams to calculate the mixed flow and temperature in a manner similar to step 1 above.

Figure 1 Tempmod Channel and Pond General



Discussion

The spreadsheet model described is useful as a screening tool, primarily to evaluate the importance of major inputs or changes in the geometry.

The model is sensitive to solar radiation inputs, input flows of different temperatures, variations in flow, changes in canopy and channel modifications. The inclusion of a simplified one dimensional pond model is useful for prediction surface temperatures and downstream impacts in channel sections; however, it does not predict the vertical distribution of temperature in the pond.

The equilibrium component of the model formulation makes simplifying assumptions that ignore several heat sources and sinks. The assumption that the ignored terms cancel out is suitable for a screening model; however may not be suitable if absolute values of temperature are required. The estimation of equilibrium temperature, E, is thought to be within 2^{o} C or less of more complicated approaches (EPA, 1985).

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APPENDIX F

Temperature Model Inputs and Results

Table F1 - Meteorological Data for Aug. 31, 2007				
Hour	Air Temp. Deg. C	Dewpoint Deg. C	Wind km/hr	Sol. Rad. mJ/m^2/hr
1	11.25	9.775	7.625	0
2	10.825	9.925	6.725	0
3	10.675	10.075	6.625	0
4	10.425	9.925	8.05	0.0001
5	10.35	9.875	7.875	0.0001
6	9.975	9.575	7.6	0.0019
7	9.725	9.325	6.35	0.22375
8	11.2	10.775	5.275	1.05055
9	15.375	12.75	4.35	1.917
10	18.95	10.275	12.8	2.743075
11	21.15	7.4	16.475	3.436925
12	21.95	6.625	18.225	3.9194
13	22.425	7	27.125	4.142925
14	22.975	6.075	18.525	4.0879
15	23.125	4.3	19.075	3.766875
16	23.025	3.075	18.825	3.1838
17	22.7	3.775	18.525	2.400625
18	22.325	3.725	14.4	1.48465
19	21	4.325	15.075	0.59725
20	18.425	4.7	7.625	0.033925
21	16.05	5.425	6.4	0.0006
22	14.075	6.25	2.05	0.0014
23	12.75	6.6	5.925	0.0009
24	12.3	7.725	5.225	0.0006
Data taken at Caledon Landill by CVC Data used for Calibration				

Table F2 - Meteorological Data for June 13, 2007				
	Air Temp.	Dewpoint	Wind	Sol. Rad.
Hour	Deg. C	Deg. C	km/hr	mJ/m^2/hr
1	18.3	9.875	7.975	0.0001
2	17.95	9.85	9.225	0.0002
3	17.55	9.825	9.275	0.0002
4	16.925	9.975	9.675	0.0004
5	16.875	9.95	10.275	0.0003
6	16.975	10.275	10.575	0.21275
7	18.85	11.175	7.475	0.87855
8	23.025	11.475	8.475	1.7939
9	25.1	11.25	18	2.64085
10	25.5	11.6	17.225	2.156325
11	27.275	11.4	10.7	4.14905
12	27.7	13.075	19.175	4.052075
13	28.2	15.05	16.325	4.64005
14	28.925	15.7	11.05	3.9095
15	29.6	15.25	9.3	4.2094
16	29.775	15.475	18.325	3.680875
17	29.125	14.725	16.825	2.767325
18	27.55	14.15	22.575	1.31675
19	25.05	12.625	7.775	0.446225
20	23.925	12.725	11.925	0.18245
21	22.3	13.025	4.55	0.024525
22	19.35	14.65	5.325	0.0008
23	17.775	16	4.575	0.0001
24	16.625	15.5	5.15	0
Data taken at Caledon Landill by CVC				
Data used for Verification				

Table F3 - Meteorological Data for August 3, 2007				
Hour	Air Temp. Deg. C	Dewpoint Deg. C	Wind km/hr	Sol. Rad. mJ/m^2/hr
1	23.1	19.2	16.95	0.0009
2	22.925	18.825	13.5	0.0011
3	21.575	18.575	13.825	0.0006
4	21.325	18.375	14.625	0.0002
5	21.175	18.375	13.15	0.0004
6	20.525	18.425	4.725	0.017775
7	20.4	18.475	6.525	0.330175
8	22.1	19.175	6.5	0.9464
9	23.4	19.475	5.9	1.621225
10	25.7	19.075	7.275	2.7749
11	26.925	17.575	12.425	3.787125
12	27.95	15.575	22.55	4.413725
13	29.025	13.8	21.15	4.5287
14	29.5	13.125	17.775	4.489025
15	29.8	10.375	23.4	4.22375
16	29.65	9.7	25.275	3.6831
17	28.875	8.125	26.075	2.970725
18	28	7.925	17.775	2.101775
19	26.8	7.65	19.3	1.1808
20	25.075	9.075	6.075	0.334175
21	21.05	10.525	5.025	0.008875
22	18.075	12.1	2.85	0.0005
23	16.1	12.5	4.7	0.0002
24	16	11.85	5.4	0.0002

Data taken at Caledon Landill by CVC
Data used for Low flow - hot summer day

Table F4 Inputs and Calibration Parameters		
Surface Flow Temp TQin	19	Deg C
Groundwater Temp TQgw	15	Deg C
Global wind adjustment factor	0.90	
Global coudiness adjust	1.00	
Canopy Global adjustment factor	0.80	

Table F5 Canopy Estimate -		
	Canopy	Canopy adjusted
Reach	%	%
1	40	32
2	40	32
3	40	32
4	40	32
5	40	32
6	40	32
7	40	32
8	20	16
9	20	16

Table F6 Record of Calibration/Verification and Scenario Temperature Predictions

Calibration Aug 31 07											
	U/S	Rch1end	ch2UpMixe	Rch3mix	Rch3	Rch4	Rc5	Rch6	Rch7	Rch8	Rch9
	0	2770	2770	3770	5690	7610.00	9530	11490	13450	15410	16980
Max	24.195	19.30	19.06	18.64	20.39	20.47	19.40	19.45	18.54	19.12	19.63
Min	20.031	14.26	18.06	16.22	15.41	13.05	13.14	12.96	14.56	14.36	14.25
Canopy	1.6	1.6	1.6	1.6	1.6	3.2	3.2	3.2	3.2	1.6	1.6
Obs. Max	24.195	17.938		18.343				20.031			19.841
Obs. Min	20.031	14.888		15.055				14.888			15.629
Verifiction June 13 2007											
	U/S	Rch1end	ch2UpMixe	Rch3mix	Rch3	Rch4	Rc5	Rch6	Rch7	Rch8	Rch9
	0	2770	2770	3770	5690	7610.00	9530	11490	13450	15410	16980
Max	25.016	23.40	20.84	19.86	21.93	23.78	24.75	24.45	23.93	23.78	23.84
Min	22.74652	18.20	18.10	16.80	16.56	15.89	15.29	15.88	15.74	15.68	16.17
Canopy %,	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.6	1.6
Obs. Max	25.016	22.321		21.056				23.4			23.28
Obs. Min	23.088	17.486		16.534				16.963			18.699
Low flow case - existing WWTP			date copiec	4-Jan-11			wwtp flow :	0.052604	m3/s		
	U/S	Rch1end	ch2UpMixe	Rch3mix	Rch3	Rch4	Rc5	Rch6	Rch7	Rch8	Rch9
	0	2770	2770	3770	5690	7610.00	9530	11490	13450	15410	16980
Max	25.016	24.72	21.17	23.11	25.55	27.26	28.01	28.39	27.51	27.73	28.25
Min	22.74652	16.46	20.03	18.62	17.81	16.33	15.44	15.12	14.90	15.02	15.27
Canopy %,	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.6	1.6
Low flow case - Expanded WWTP 2			date copiec	4-Jan-11			wwtp flow :	0.081019	m3/s		
	U/S	Rch1end	ch2UpMixe	Rch3mix	Rch3	Rch4	Rc5	Rch6	Rch7	Rch8	Rch9
	0	2770	2770	3770	5690	7610.00	9530	11490	13450	15410	16980
Max	25.016	24.72	20.99	22.98	25.15	26.91	27.71	27.99	27.10	27.20	27.61
Min	22.74652	16.46	20.21	19.00	18.23	16.84	15.98	15.62	15.39	15.53	15.86
Canopy %,	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	1.6	1.6

APPENDIX G

Monthly Total Phosphorus Analysis

Table G1 Monthly total phosphorus concentration upstream of Acton WWTP

	Mean	Median	75th Percentile	Min	Max	PWQO/ Guideline	% Violation	# of Data Points
Jan	0.038	0.028	0.034	0.015	0.124	0.030	38%	16
Feb	0.037	0.029	0.051	0.013	0.064	0.030	44%	9
Mar	0.030	0.032	0.036	0.014	0.056	0.030	56%	9
Apr	0.020	0.019	0.022	0.017	0.024	0.030	0%	6
May	0.045	0.032	0.046	0.024	0.127	0.030	63%	8
Jun	0.038	0.037	0.045	0.026	0.050	0.030	70%	10
Jul	0.051	0.052	0.061	0.023	0.068	0.030	90%	10
Aug	0.064	0.040	0.051	0.015	0.303	0.030	70%	10
Sep	0.042	0.042	0.045	0.029	0.072	0.030	90%	10
Oct	0.040	0.033	0.054	0.020	0.069	0.030	70%	10
Nov	0.057	0.038	0.044	0.020	0.164	0.030	67%	9
Dec	0.094	0.066	0.078	0.035	0.288	0.060	1.042	
Annual	0.042	0.034	0.048	0.013	0.303	0.030	61%	107
Note	December estimate = avg Nov and jan				No December data			
	Data from	4-Jan-00	to	24-Feb-10				
	All values mg/L							

Table G2 Mixed in-stream total phosphorus downstream of Acton with effl. flow Scenario 1

	WWTP			Upstream		Downstream Mixed	
Month	Scen 1 flow	Objective	Limit	Low flow	TP	at Objective	at Limit
	m3/s	mg/L	mg/L	m3/s	mg/L	mg/L	mg/L
Jan	0.0700	0.1	0.2	0.0304	0.034	0.080	0.150
Feb	0.0679	0.1	0.2	0.0328	0.051	0.084	0.151
Mar	0.0714	0.1	0.2	0.0314	0.036	0.080	0.150
Apr	0.0738	0.1	0.2	0.0714	0.022	0.062	0.112
May	0.0711	0.1	0.2	0.0715	0.046	0.073	0.123
June	0.0652	0.1	0.2	0.0414	0.045	0.079	0.140
July	0.0572	0.1	0.2	0.0313	0.061	0.086	0.151
Aug	0.0552	0.1	0.2	0.0213	0.051	0.086	0.159
Sept	0.0588	0.1	0.2	0.011	0.045	0.091	0.176
Oct	0.0589	0.1	0.2	0.013	0.054	0.092	0.174
Nov	0.0640	0.1	0.2	0.0321	0.044	0.081	0.148
Dec	0.0644	0.1	0.2	0.0334	0.078	0.093	0.158
Annual	0.0648	0.1	0.2	0.0162	0.048	0.090	0.170

Table G3 Mixed in-stream total phosphorus downstream of Acton with effl. flow Scenario 2

	WWTP			Upstream		Downstream Mixed	
Month	Scen 1 flow	Objective	Limit	Low flow	TP	Effluent at Objective	Effluent at Limit
	m3/s	mg/L	mg/L	m3/s	mg/L	mg/L	mg/L
Jan	0.0875	0.1	0.2	0.0304	0.034	0.083	0.157
Feb	0.0849	0.1	0.2	0.0328	0.051	0.086	0.158
Mar	0.0892	0.1	0.2	0.0314	0.036	0.083	0.157
Apr	0.0922	0.1	0.2	0.0714	0.022	0.066	0.122
May	0.0888	0.1	0.2	0.0715	0.046	0.076	0.131
June	0.0815	0.1	0.2	0.0414	0.045	0.081	0.148
July	0.0715	0.1	0.2	0.0313	0.061	0.088	0.158
Aug	0.0690	0.1	0.2	0.0213	0.051	0.088	0.165
Sept	0.0735	0.1	0.2	0.011	0.045	0.093	0.180
Oct	0.0736	0.1	0.2	0.013	0.054	0.093	0.178
Nov	0.0800	0.1	0.2	0.0321	0.044	0.084	0.155
Dec	0.0805	0.1	0.2	0.0334	0.078	0.094	0.164
Annual	0.0810	0.1	0.2	0.0162	0.048	0.091	0.175

APPENDIX H

Acton WWTP
Water Softener Chloride Balance

Appendix H Acton WWTP - Water Softener Chloride Balance

Acton Annual Flow CofA 4545.0 **m3/day**

Effluent Flow Rate

	m^3/day	m^3/s	L/s
Current CofA	4545.0	0.053	52.6
Scenario 1	5600.0	0.065	64.8
Scenario 2	7000.0	0.081	81.0

Mass balance equation

C1xQ1 + CsxQs = C3xQ3

C1 = upstream concentration - typically 75th percentile of the background data
Cs = sewage conc. - based on Certificate of Approval
C3 = mixed, downstream concentration
Q1 = upstream flow - typically 7Q20
Qs = sewage flow
Q3 = Q1 + Q2 = mixed flow
C3 = (C1xQ1+CsxQs)/Q3
Q units m3/s
C units mg/L
Q x C = load or mass units/time, kg/day

				total out	
Background Chloride	57.6	mg/L	Water supply avg. 2006		
Effluent Chloride	307.70	mg/L	Average		
Effluent flow	4038	m^3/day	Current year		
Calculated addition*	1,010	kg/d	current	1,242	
(*above background)	1,137	kg/d	at capacity	1,398	
	1,401	kg/d	At expansion uncontrolled	1,723	
	1,295	kg/d	At expansion 1 with efficient softeners	1,618	
	1,505	kg/d	At expansion 2 with efficient softeners	1,908	
Unit salt usage	0.2501	kg/m^3	Current		
Efficiency	0.6		Compared to curren softeners		
Efficient salt usage	0.15006	kg/m^3	With efficient softeners		
Effluent Concentration	307.7	mg/L	current		
	307.7	mg/L	at capacity		
	307.7	mg/L	At expansion uncontrolled		
	289	mg/L	At expansion 1 with efficient softeners		288.8532
	6.1	%	% reduction in concentration		
	273		At expansion 2 with efficient softeners		
	11.4		% reduction in concentration		

Load with new development using efficient softeners — At expansion 1 with efficient softeners

1,618	kg/d		
6.1	%	% reduction in load compared to uncontrolled	

Load with expanded flow 1 — Assume all units more efficient

Added Load	840	kg/d		Total load out	1,163	kg/d
	208	mg/L	Effluent concentration			
	32.5	%	% reduction			
Expanded Flow 2	1050	kg/d		Total load out	1,454	kg/d
	208	mg/L	Effluent concentration			
	32.5	%	% reduction			