Water quality measurements on Williams Lake and Colpitt Lake (Halifax, N.S.) Dec 7-13, 2015 with reference to possible impacts of road salt

Report to Williams Lake Conservation Company (WLCC)
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January 6, 2016

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SUMMARY

Concerns have been expressed by the Williams Lake Conservation Company (WLCC) about possible effects of renewed salting of roads close to Williams Lake on water quality of the lake. Such salting was replaced by sand and grit in the late 1980s which was maintained until January 2015 when regular salting was re-instigated.

To provide some baseline data for assessment of future changes in the limnological conditions, observations of temperature, SPC (specific conductance, a measure of salt content), DO (dissolved oxygen) and pH were made at 4 sites on Williams Lake as well as at 5 inlets and the outlet in early December 2015 using a YSI Professional Plus meter & sensor provided by the Community Based Environmental Monitoring Network at St. Mary's University. This also allowed for comparison with a set of similar observations made in 1990/91 by R. Scott during a period when use of road salt was restricted on nearby roads. Additional observations were made on Colpitt Lake. Some observations of SPC alone were made with a Hanna 9033 Conductivity meter and sensor.

At a deep water site (~20 m) in Williams Lake sampled on Dec 7, 2015, there was an abrupt change between 7 and 9 meters depth, with very low DO in the hypolimnion (6-10% oxygen saturation at depths of 9-20 m, versus 96-98% at 7.2 m and shallower), and increased SPC at depths of 9-20 m (306-307 μS/cm) compared to values at depths of 7.2 m and shallower (278-281 μS/cm); the temperature was 5.5^{o}C at all depths. In a healthy dimictic lake, the water has normally turned over by late fall and the deeper waters are well aerated which was the case on Nov 29, 1990. While the causes are not clear, the apparently delayed turnover and low oxygen in late 2015 raises concerns about the health of the lake and sensitivity to increased salt inputs.

Comparisons of the SPC value at the outlet on Dec 8, 2015 and chloride values for 2 samples within the lake taken by the WLCC on Aug 3, 2015 with historical data are suggestive that (i) the "background" levels of salt loading have increased since 1990/91 even with restricted salt use, and (2) renewed salting in 2015 has further increased salt loading.

Other observations illustrate the low salt content of water draining from undisturbed landscape (SPC values 34-59 μS/cm) which makes up about three-quarters of the watershed, and the significant salt loads in all streams draining developed landscapes (SPC values of 282-427 μS/cm where they enter the lakes). Governor's Brook appears to be the single source of high salt water entering Colpitt Lake which has SPC values similar to those of Williams Lake.

While the salt carried from developed areas is diluted by flows from the large blocks of undeveloped landscape in the Williams Lake watershed, it is clear that such dilution is not sufficient to lower salt to levels of no concern.

Follow-up studies are suggested.

INTRODUCTION

The Williams Lake watershed is located on the mainland just off of peninsular Halifax. The watershed, approximately 487 ha, includes two lakes: Williams Lake (63 ha), bordered by developed land on about one-third of its shoreline, and Colpitt Lake (22 ha) which is entirely undeveloped (Fig. 1). Colpitt Lake is the headwater lake and drains into Williams Lake which in turn drains into the NW Arm. About three-quarters of the watershed is undeveloped, an undulating mosaic of wetlands, forests and barrens with a high degree of ecological integrity. Williams Lake is a popular swimming spot, and the lake hosts significant wildlife such a pair of nesting loons, and American eel. Over the years, residents have taken various actions to protect the water quality of the lake and as much as possible, the ecological integrity of the landscape.

Concern has been expressed by the Williams Lake Conservation Company (WLCC) about the possible effects of renewed salting, including use of brine, on Williams Lake Road and environs on the water quality of Williams Lake. Such salting was replaced by sand and grit in the late 1980s which was maintained until January 2015 when regular salting was re-instigated.

> In early January, the Halifax Department of Energy and Environment reversed its long standing policy of using sand and grit instead of salt on roads around Williams Lake. The sudden change came as a surprise to long-time residents because this issue had been dealt with back in the mid-nineties when, as a result of lake water testing results and much lobbying by the WLCC, it was agreed that in the future the side roads closest to the lake, Wenlock Grove, Litchfield, McNabs, Wyndrock, Birchview, and Willowdale, would be sanded, not salted. The change in policy leaves sanding in effect only beyond the service boundary at the far end of Wenlock Grove. [1]

HRM staff maintain that the renewed salting will not be harmful as "The most recent assessment of chloride concentrations in Williams Lake indicated a median concentration of 50mg/L, and a mean concentration of 57 mg/L, both well below the CCME long-term [120 mg Cl/L] and short-term [640 mgCl/L] guideline values."[2] It was also contended that “the former practice of applying salt in some limited areas had a negligible impact on the receiving waters considering all of the watershed feeding the lakes”.[1]

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1. **WLCC Newsletter, May 2015**. Accessed at http://www.williamslakecc.org/documents/WLCC_Newsletter_2015.pdf
2. E-mail to WLCC personnel from Environmental Performance Officer for Halifax, Nov. 10, 2015: “**Halifax response to Williams Lake Conservation Company request to return to sanding in the vicinity of Williams Lake”**

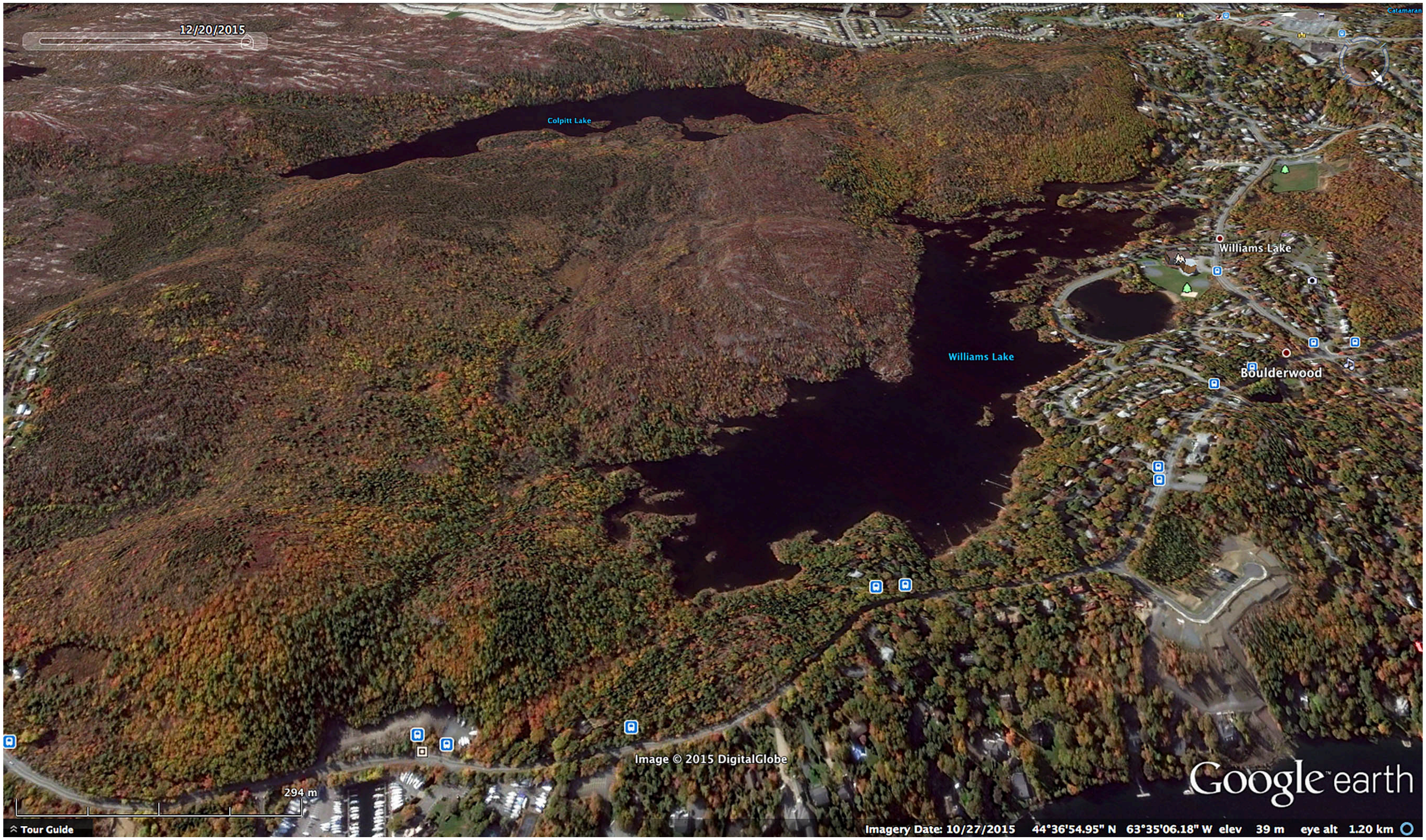

Fig. 1. **Google Earth image of the Williams lake watershed.**

Water quality testing conducted by WLCC on August 3, 2015 revealed chloride levels of 74 mg/L and 116 mg/L in samples taken from the outlet end and middle part of the Williams Lake near the Wyndrock Drive causeway, respectively. Those values are higher than the mean chloride level of 57 mg/L in Williams Lake cited in a Stantec report for the period 2006-2010 when salting was restricted on roads around William Lake. The Stantec report considered lakes with levels above 50 mg/L but less than 120 mg/L "as being influenced by road salt application, and potentially benefiting from management actions to reduce their exposure to road salt" (Stantec Consulting Ltd, 2012).

CCME guidelines focus on direct toxic effects on a range of aquatic organisms (CCME, 2011). They do not address possibilities of indirect toxicity associated with increased vertical stratification and associated development of anoxia due to salt at levels that can be below those causing direct toxic effects. Anoxia can eliminate cool deeper water habitat essential for many species, accelerate eutrophication and release heavy metals from sediments. There is evidence that such effects are becoming increasingly widespread and problematical (Novotny et al., 2008; Koretsky et al., 2012; Kronvall, 2013). Concerns have been expressed about the susceptibility of Halifax area lakes to road salt effects on the normal spring and fall mixing events (Clement et al., 2007). Small lakes and deep lakes are more susceptible than large and shallow lakes to salt-induced stratification and delay or elimination of the spring and fall turnovers in normally dimictic lakes (Novotny and Stefan, 2012). Williams Lake is small and has a deep basin (~20m) so may be especially sensitive in this regard.

A study of Williams Lake for WLCC in 1990/91 funded by the Nova Scotia Department of the Environment provides comprehensive baseline data on water quality variables in Williams Lake, including vertical profiles in the deepest areas of the lake, and measurements taken at several inlets and at the outlet (Scott, 1992). In discussion of road salt issues with WLCC member Kathleen Hall in early December of 2015, I suggested that we might repeat some of those observations using equipment that can be borrowed from the Community Based Environmental Monitoring Network (www.cbemn.ca/) based at Saint Mary's University, and I volunteered to conduct the observations. We obtained a YSI Professional Plus meter & probe from the SMU group and proceeded to conduct observations at Williams Lake and Colpitt Lake.

The YSI Professional Plus meter & probe measures temperature, oxygen, specific conductance and pH. Some more extensive observations of specific conductance alone were made at Colpitt Lake and on the Colpitt Lake outlet stream with a Hanna 9033 Conductivity meter.

Specific conductance (SPC) is a measure of total dissolved ions in a water sample and is influenced most by the more abundant ions. Scott (1992) observed a close linear relationship between chloride – the most direct measure of road salt in water - and specific conductance:

Chloride (mg/L) = 0.202 (specific conductance umhos/cm) + 2.48
($r2 = 0.981$, $n = 68$)

Thus, in general, the SPC values reflect concentrations of road salt.

METHODS

Observations at the four lake stations on Williams Lake cited by Scott (1992) were conducted from a rowboat on the afternoon of Dec 7, 2015 (sunny, ~8 ^{o}C, mostly calm, periodic winds). The positions, identified on a map in Scott, 1992 (Fig. 2 below), were located by sightings on prominent land features.

Observations of temperature, SPC (specific conductance), DO (dissolved oxygen) and pH were made with A YSI Professional Plus meter & sensor probe on a 25 m cord obtained on loan from the Community Based Environmental Monitoring Network at St. Mary's University in Halifax (www.cbemn.ca). CBEMN maintains these instruments and calibrates them before loaning them out; users must perform on-site calibrations for oxygen. We measured the depths of the observations from markings on the probe cord. At Station 1 we sampled at intervals from the surface to the bottom as did Scott (1992) but at Station 4, we sampled only at the surface and at the bottom as we were having difficulty maintaining our position. Stations 3 and 4 are in the shallow basin where Scott sampled only the surface water. At those stations we sampled the surface water and water at the bottom.

On Dec 8, 2015, observations with the YSI instrument were made from shore at 5 inlets and at the outlet at Williams Lake (cloudy, ~ 4 ^{o}C).

On December 10, 2015 (mostly cloudy, ~6 ^{o}C), I walked around the perimeter of Colpitt Lake to conduct observations on streams entering the lake, the outlet and in the lake along the shore. SPC was measured at all sites with a Hanna 9033 Conductivity meter, and at a subset of sites measurements were also made with the YSI instrument. The Hanna meter was calibrated to give the same reading as the YSI instrument on a sample of tap water (83µS/cm).

On December 13, 2015 (mixed sun and cloud, ~ 4 ^{o}C), I sampled the stream leading from the outlet at Colpitt Lake to the inlet of Williams Lake, measuring SPC at all sites with the Hanna meter. Measurements were also made with the YSI instrument at the outlet from Colpitt Lake and the inlet to Williams Lake.

A site on Frog Pond and another on a fen draining into Frog pond were sampled on Dec 8, 2015. A site on the MacIntosh Run by Drysdale Road was sampled on Dec 9. These measurements were made with the YSI meter.

Precipitation and average temperatures for Halifax International Airport immediately preceding and during the period of observations are shown below.

Temperature and precipitation at Halifax Airport Dec 1 to 13, 2015.

Day in Dec, 2015	**Precipitation** (mm)	**Avg Temperature** ^{o}C
1	0.2	-1.1
2	6.8	4.5
3	19.6	5.0
4	Trace	-1.6
5	0	-0.3
6	0	5.6
7	0	4.7
8	0	-0.3
9	Trace	1.3
10	0.8	3.6
11	8.4	8.4
12	0	6.7
13	0	2.0

Source: http://climate.weather.gc.ca/climateData/dailydata_e.html?StationID=50620

RESULTS & DISCUSSION

Figure 1 (above) is a Google Earth Image of the Williams lake watershed.

Figure 2 shows sampling sites on Williams Lake.

Figure 3 shows the locations of inlets and outlets for both lakes on a hydrological map.

Figure 4 shows sampling sites on Colpitt Lake and SPC values obtained with the Hanna meter.

Figure 5 shows the specific conductance values by location along the outlet stream from Colpitt Lake measured with the Hanna meter.

The numerical results of all observations with the YSI meter and some with the Hanna meter (to check cross calibration of the two instruments) are given in Tables 1- 5.

Tables 6 and 7 below do not present new data, but allow comparison of some of the 2015 observations with those of Scott (1992) for 1990/91.

The Appendix summarizes some of the post-1960s history of Williams Lake and environs gleaned from documents in WLCC archival files including data on pH, DO and SPC in Williams Lake and Colpitt Lake other than those of Scott (1992).

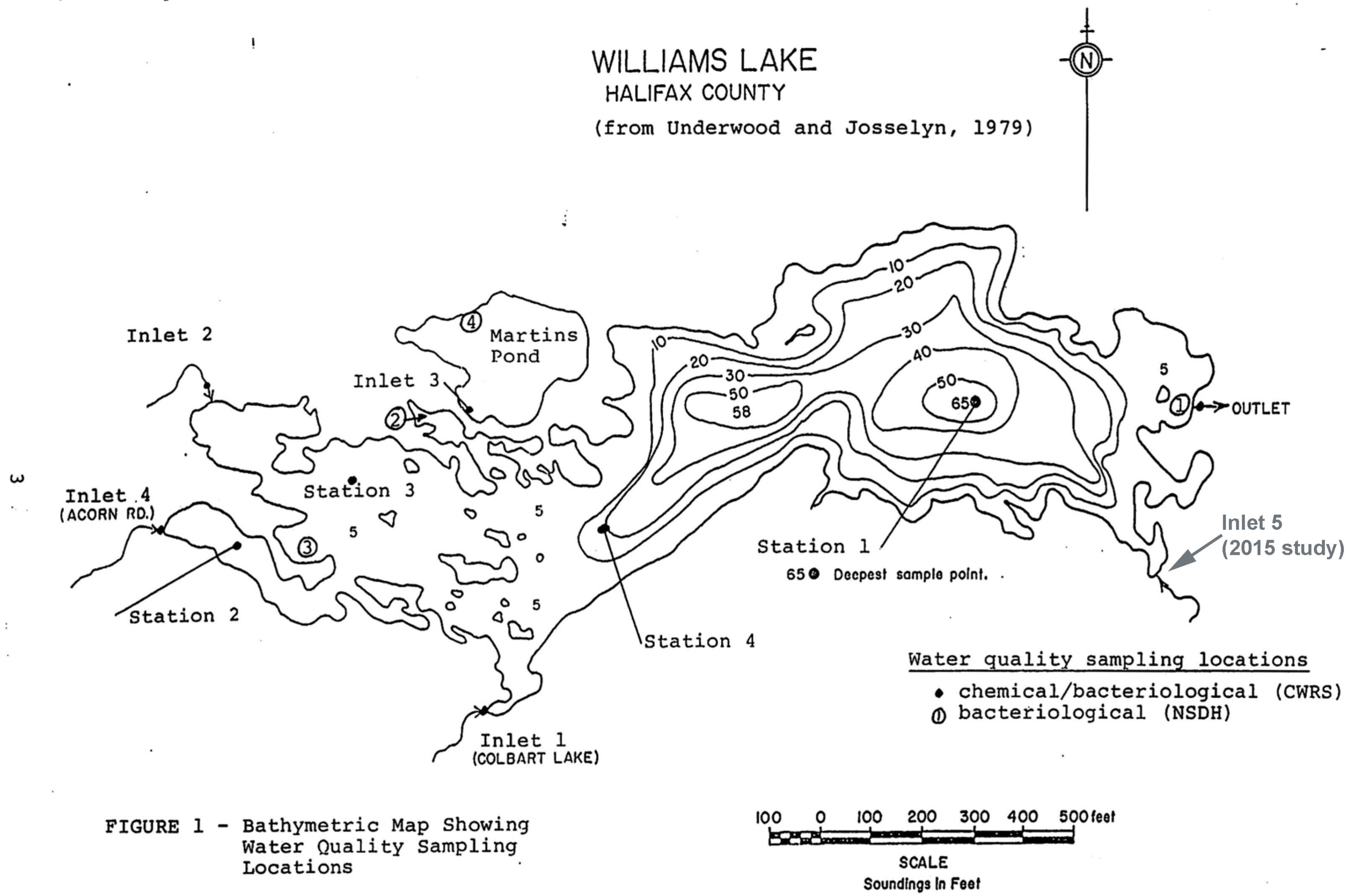

Fig. 2. **Scott's (1992) map showing hydrology and sampling sites in 1990/91**. The location of Inlet 5 not sampled in 1990/91 but sampled in 2015 is inserted on the map.

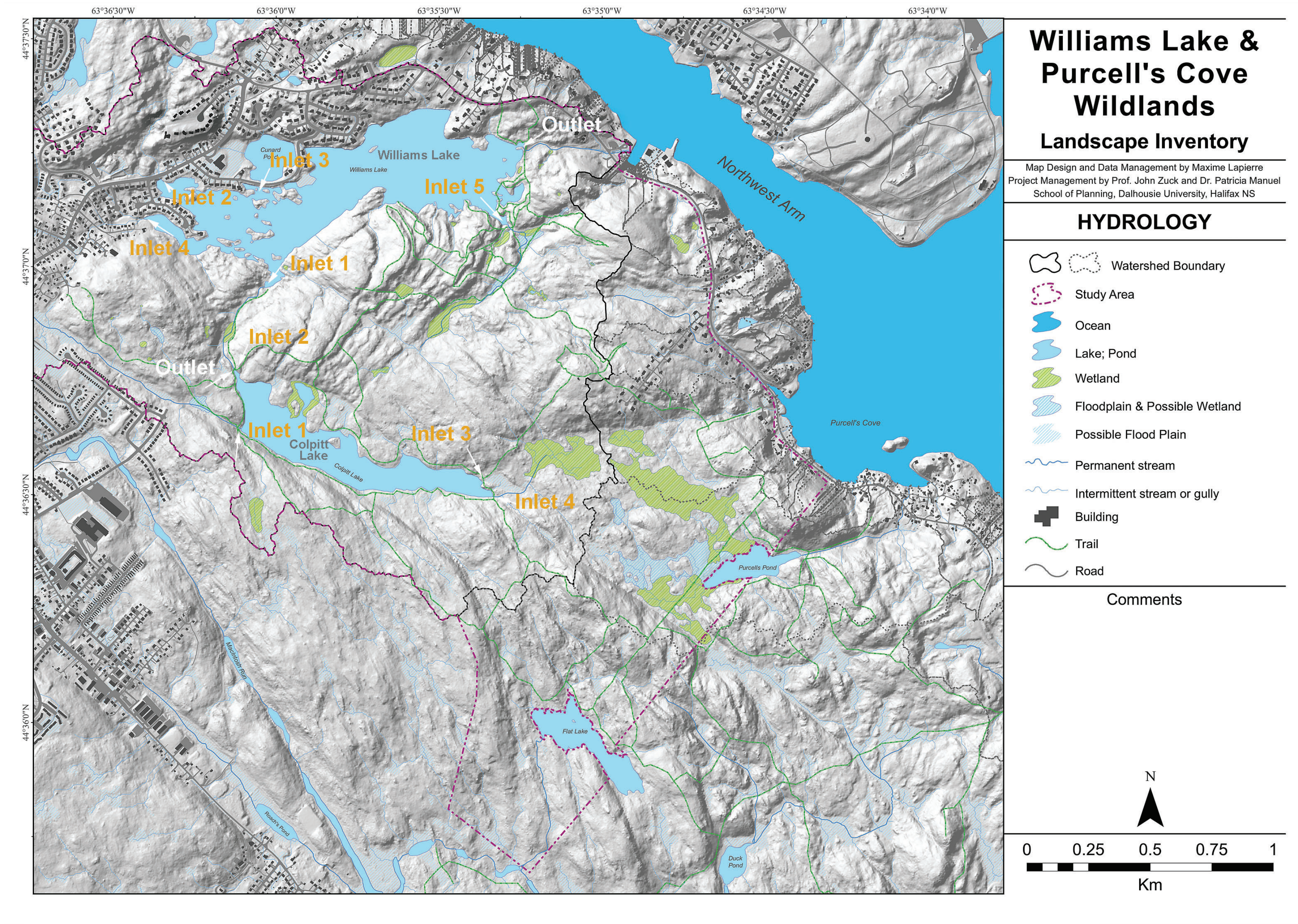

Fig 3. **Inlets, outlets and hydrology.** Hydrology map courtesy of Prof. Patricia Manuel, School of Planning, Dalhousie University.

Table 1. Williams Lake: vertical profiles of temperature, dissolved oxygen, specific conductance and pH on Dec 7, 2015. Sampled from a boat. Scott refers to sites sampled by Scott (1992). See Fig. 2 for all sites. Numbers in red highlight low DO and high SPC values in the hypolimnion.

Station/location	**Depth**	**Temp °C**	**DO** % sat'n	**DO** mg/L	**SPC µS/cm**	**pH**
SCOTT (1992) SITES						
Scott Stn 1	Surface	5.5	98	12.3	**277.7**	6.57
	1.8 m	5.5	97	12.3	277.8	6.62
	3.6 m	5.5	97	12.2	277.8	6.64
	5.4 m	5.5	97	12.2	277.8	6.70
	7.2 m	5.5	96	12.1	281.2	6.76
	9.0 m	5.5	**8**	1.0	307.4	6.65
	10.8 m	5.5	**8**	1.0	307.0	6.64
	12.6 m	5.5	**6**	1.0	307.0	6.63
	14.4 m	5.5	**8**	1.0	306.9	6.60
	16.2 m	5.5	**8**	1.1	306.7	6.51
	18.0 m	5.5	**9**	1.1	306.7	6.40
	19.8 m	5.5	**10**	1.3	306.0	6.28
Scott **Stn 2**	Surface	5.2	96	12.1	**261.2**	6.40
	1.4 m	5.0	85	10.9	261.5	6.37
Scott Stn 3	Surface	5.4	98	12.4	**278.4**	6.5
	Bottom, 3.6 m	5.3	97	12.2	278.4	6.50
Scott Stn 4	Surface	5.5	96	12.1	**278.3**	6.59
	Bottom, 27 m	5.4	**9**	1.2	307.2	6.52
OTHER SITES (2015 only)						
Wharf	Surface	6.5	100	12.4	**277.2**	6.60
	Bottom, 1.1 m	6.1	95	11.8	277.8	6.27
By Storm Water inlet	Surface	6.4	111	13.6	**277.5**	6.52
	Bottom ~1 m	6.3	117	14.4	277.5	6.54
By **Colpitt Lake Inlet***	Surface	5.3	98	12.5	288.0	6.14
	Bottom ~1 m	5.2	104	13.3	289.8	6.20

- 5 m off the shore on south side; about 30 m from the cascade inlet waters.

Table 2. Williams Lake inlets and outlet: temperature, dissolved oxygen, specific conductance and pH on Dec 8, 2015.
See Table 4 for Scott Inlet 1

Sampled from shore, Dec. 8, 2015

Station/location	**Depth**	**Temp °C**	**DO% sat'n**	**DO** mg/L	**SPC µS/cm**	**pH**
Scott Inlet 3 from Martins Pond	Surface	6.0	96	11.9	427	7.05
Scott Inlet 4	Surface	8.6	83	9.6	410	6.58
Scott Inlet 2	Surface	7.6	91	10.8	282	6.61
Scott Outlet	Surface	5.3	116	14.7	278	6.57
Inlet from south wetlands	Surface	6.0	87	10.8	33.7	4.45

Table 3. Colpitt Lake temperature, dissolved oxygen, specific conductance and pH of surface samples on Dec 10, 2015.
Sampled from shore.

Station/location	**Depth**	**Temp °C**	**DO%** sat'n	**DO** mg/L	**SPC µS/cm**	**pH**
Governor's Brook, site 1* (upstream) 44.612568,-63.604047	Surface	5.6	95	12.0	450 H: 429	6.26
Stream/Seep 44.612568,-63.604047	Surface	6.4	66	8.1	42.9 H: 45.9	4.43
Governor's Brook Site 2 (at lake)*	Surface	6.0	99	12.3	392 H: 351	5.56
Outlet to Williams Lake	Surface	4.4	105	13.6	305 H: 286	5.61
Inlet 4 in marshy area at SE extremity of lake	Surface	6.3	91	11.2	49.2 H: 48	4.29

*Values with Hanna meter on Dec 13, 2015: 404 µS/cm at Gov Brook site 1; 369 µS/cm at Site 2 where it enters the lake.

Table 4. Colpitt Outlet and stream to Williams Lake: specific conductance measured with Hanna meter and measurements with YSI meter at selected sites on Dec 13, 2015. WP refers to Waypoint on Garmin GPS 62

Location	**SPC Hanna**	**SPC YSI**	**Temp °C**	**pH YSI**	**DO YSI % O2 sat**	**DO YSI mg/L**
Outlet from Colpitt Lake, top, WP41 15 m downstream	288 µS/cm	300.1 µS/cm	4.8	5.68	91	11.7
WP43	289					
WP44	287					
WP47	287					
WP50	280					
WP51	277					
WP52	279					
WP54	277					
WP55	275					
WP56	275					
WP67 just before Williams Lake*	271	279.9	4.5	5.84	90	11.7
WP61 on Williams Lake	252	269.9	4.6	6.28	100	12.9

*Scott Inlet 1

Table 5. Frog Pond, outlet from fen feeding into Frog Pond, and MacIntosh Run: temperature, dissolved oxygen, specific conductance and pH on Dec 8 and 9, 2015. Sampled from shore.

Station/location	**Depth**	**Temp °C**	**DO% Sat'n**	**DO** mg/L	**SPC µS/cm**	**pH**
Frog Pond by road (Dec 8)	Surface	4.2	114	14.9	335	5.35
Open water/fen feeding into FP (Dec 8)	Surface	4.7	81	10.4	34.1	5.02
Mac Run Below bridge on Drysdale (Dec 9)	Surface	5.8	83	10.4	292 Hanna: 293	5.73

Comparison of vertical profiles in 2015 with Scott's (1992) observations in 1990 and 1991

Stations 1 and 4 are located in the deep basin of the lake which has a maximum depth of about 65 feet or 20 m (Fig 2). Our observations for Station 1 (Table 1 above) are shown together with those of Scott (1992) for 1990/91 in Table 6.

The pH values for Station 1 in 2015 are in the same general range as the 1990/91 values. However, the SPC values do not overlap (range for 2015: 278-307, for 1990/91: 110-276, or 186-228 when March is excluded (when there was ice), or 227-228 for the late fall, 1990 sampling alone. This suggests increased SPC overall between 1990/91 and 2015.

More significant, the Dec 7, 2015 Station 1 profile shows pronounced vertical stratification in SPC and DO, but not in temperature, with an abrupt change between 7 and 9 meters depth, and very low DO in the hypolimnion (6-10% oxygen saturation at 9-20 m, versus 96-98% at 7.2 m and shallower). In a healthy dimictic, oligotrophic lake, the water has normally turned over by late fall and the deeper waters are well aerated (Wentzell, 2001) as was the case in Nov 29, 1990. This was not the case in early December of 2015, with vertical stratification still evident and near anoxia in the hypolimnion.

Scott's 1990/91 profiles at Station 4 (approx. 20 m depth) were similar to those at Station 1. In 2015, we observed only the surface and bottom values at at Station 4; these values were similar to those at Station 1 with higher SPC and near anoxia (9% oxygen saturation) at the bottom (Table 1).

Thus turnover of the water column in the deeper waters of Williams Lake was clearly delayed in 2015 compared to 1990. The difference in density between surface and deep waters associated with a difference in SPC of ~27 µS/cm was likely too small to stop turnover, given that the water was isothermal at the time, and the water column may have turned over subsequently. The sharp change in values of DO and SPC which occurred between 7.2 and 9 m likely reflects the location of the summer thermocline which was at a similar depth in 1991 (Table 6).

Table 6. Vertical profiles of temperature, DO, specific conductivity and pH for the Dec 7, 2015, and reported in Scott (1992) for five dates in 1990 and 1991. Depth is to the nearest meter.

	Dec 7, 2015			Nov 29, 1990			Mar 11, 1991**		
Dep m	**T** °C	**DO** %Sat/ mg/L	**SC** µS/cm	**T** °C	**DO** %Sat/ mg/L	**SC** µS/cm	**T** °C	**DO** %Sat/ mg/L	**SC** µS/cm
0	5.5	98/ 12.3	278	4.7	97/12.0	228	3.3	98/12.6	110
1							4.1	99/12.5	
2	5.5	97/12.3	277				4.1	97/12.3	152
3							3.8	96/12.2	
4	5.5	97/12.2	278				3.2	90/11/7	
5	5.5	97/12.2	278	4.7	97/12.0	228	3.2	88/11.4	198
6							3.2	88/11.4	
7	5.5	96/12.1	281				3.3	88/11.4	
8							3.3	87/11.2	
9	5.5	**8/1.0**	307				3.1	86/11.2	
10				4.5	94/11.8	228	3.1	84/10.9	217
11	5.5	**8/1.0**	307						
12							3.2	83/10.8	
13	5.5	**6/1.0**	307	4.3	93/11.8				
14	5.5	**8/1.0**	307				3.2	80/10.4	
15				4.3	93/11.8	228	3.2	80/10.4	260
16	5.5	**8/1.1**	307				3.3	80/10.4	
17									
18	5.5	**9/1.1**	307				3.3	80/10.4	
19									
20	5.5	**10/1.3**	307	4.3	93/11.8	227	3.3	80/10.4	276
pH*	6.6, 6.3			6.6, 6.5			5.1, 6.0		

*pH values are surface & bottom values
**March 11, 1991: 19 cm ice thickness

Table continues on next page

Table 6, concluded

May 21, 1991			**Jul 15, 1991**			**Sep 9, 1991**		
T °C	**DO** %Sat/ mg/L	**SC** µS/cm	**T** °C	**DO** %Sat/ mg/L	**SC** µS/cm	**T** °C	**DO** %Sat/ mg/L	**SC** µS/cm
13.8	98/12.6	192	19.6	98/8.7	229	18.4	100/9.1	208
13.7	98/9.8							
13.6	98/9.8		19.6	98/8,7		18.4	100/9.1	
13.6	97/9.8					18.4	100/9.1	
13.6	97/9.8		19.6	98/8,7		18.4	100/9.1	
13.4	97/9.8	192	19.6	98/8,7	228	18.4	99/9.0	208
13.4	97/9.8		19.4	97/8,6		18.3	99/9.0	
13.2	96/9.8		17.2	85/8.0		18.1	94/8.6	208
12.4	94/9.7		14.1	74/7.4	224	17.9	91/8.4	
11.5	92/9.7		11.7	68/7.2		14.8	47/4.6	208
7.8	84/9.7	190	9.3	64/7.2	218	10.5	36/3.9	
7.1	82/9.7		8.4	63/7.2		9.3	36/4.0	199
6.9	82/9.7		7.7	62/7.2		8.3	35/4.0	
6.9	82/9.7		7.2	60/7.1		7.9	30/3.5	
6.7	85/10.1		7.0	59/7.0		7.2	29/3.4	
6.5	84/10.0	186	6.9	58/6.9	214	7.1	26/3.1	198
6.4	83/10.0		6.8	57/6.9		7.0	24/2.9	
6.3	82/9.9		6.8	54/6.5		6.9	20/2.4	
6.3	82/9.9		6.7	52/6.2		2.2	18/2.2	
6.3	81/9.7		6.6	49/5.7		2.2	18/2.2	199
6.3	81/9.7	187	6.6	41/4.9	212			
6.4, 6.1			6.7, 5.9			6.7, 5.5		

The delay in turnover is a matter of concern. We would need observations on the ionic composition of the water and vertical profiles at other times of year to determine whether and how such a development (in comparison to 1990) might be related to renewed use of road salt which can be complex (Novotny and Stefan, 2012, Siebert et al., 2015).[3,4,5] Regardless, the delayed turnover points to increased fragility of the lake compared to 1990/1991 and increased salt inputs could only exacerbate conditions.

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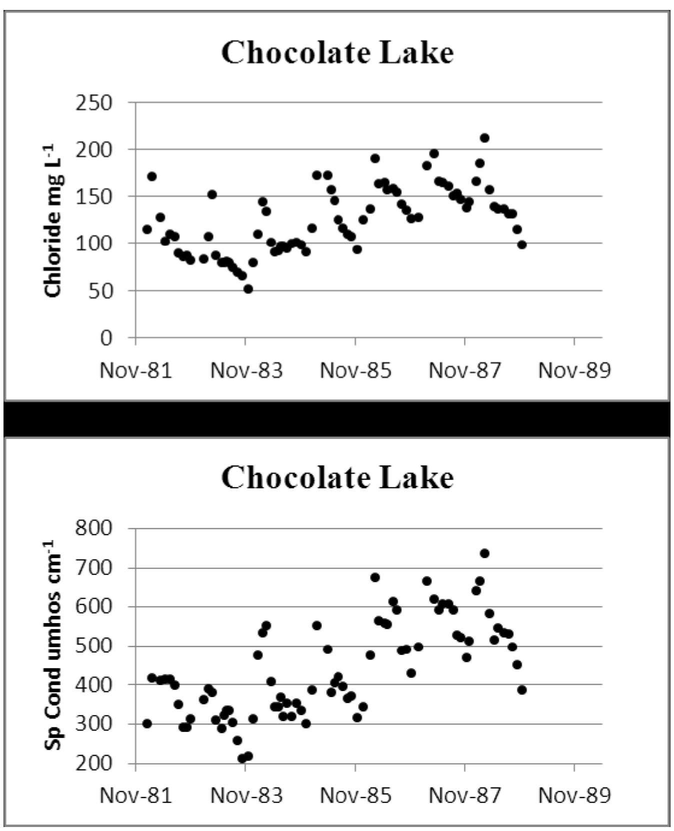
3. A local example: Habitat biologist Bob Rutherford working with the Oathill Lake Conservation Society (Dartmouth, NS) commented in a personal communication that they observed increased conductivity near the lake bottom in the spring due to sodium and chloride; conductivity rose even higher later in the summer due to release of iron and manganese from the sediments when the oxygen dropped below 1 mg/l. An aerator was subsequently installed to aerate the bottom which increased oxygen and lowered conductivity due to metals.

4. A concise overview of the mixing processes, including redox stratification and effects of road salt, is given in a thesis by D.A. Wyman 2014, pp 1-7 available at http://scholarworks.wmich.edu/cgi/viewcontent.cgi?article=1545&context=masters_theses

5. Typically salt levels in lakes subject to elevated inputs from roadsalt are highest in the late winter/early spring and lowest in the late fall (Novotny and Stefan, 2012), a pattern observed locally for Chocolate Lake by R. Scott:



Temporal variability in chloride and SPC in Chocolate Lake over 8 years.

The peak weighted average concentrations occurred in March and the minimum weighted average concentrations in November.

Suggested factors playing a role in annual peak differences are total salt load and flushing rate in any given year (e.g. the winter of 1988 experienced the highest chloride and conductivity levels of the 8-year data set as well as the greatest percent recovery).

Figure and comments courtesy of R. Scott.

Data source: Halifax Urban Watersheds Program, Water Studies, Dalhousie University

Comparison of SPC values at the outlet and inlets of Williams Lake in 2015 with those of Scott (1992) for 1990/91

The inlets are identified in Fig. 2 above and are shown on a hydrology map for the area in Fig 3 above. Inlet 1 receives inflow from Colpitt Lake. Inlets 2 and 4 receive waters that flow off developed areas, some of them on higher standing rock outcrops with generally thin soils. Inlet 3 is at the base of a causeway that separates a corner of Williams Lake from the rest of the lake. These four inlets were sampled by Scott (1992). Inlet 5, on the southeast side of the lake that receives water from a large area of undeveloped landscape was not sampled by Scott, although it is identified in his map. We sampled water at all 5 inlets and at the outlet on Dec 8, 2015.

In Table 7, Williams Lake inlet and outlet values for Dec 8, 2015 (Table 2 above) are shown with values given by Scott (1992) for 1990/91. The SPC measured at the outlet for Dec 8, 2015 was 278 μS/cm. This is higher than any of the outlet values for 5 dates sampled by Scott (1992). The Nov 29, 1990 value was the highest (226) but was still substantially less than our figure for Dec 7, 2015. Thus the outlet data suggest increased salt loading on the lake in the late fall of 2015 compared to late fall of 1990.

Scott's observations were made when regular salt applications had not been made for several years. (Precisely when they were stopped is not clear.) He remarked:

> Sodium chloride levels in Williams Lake have declined over the previous 5 or 6 years. A study performed in 1976-77 observed a mean chloride value of 58.9 mg/L while this study found a mean chloride content of 45.0 mg/L. The main reasons for this change are thought to be related to the adoption of sand instead of salt as a traction agent used during the winter months and the removal of a Department of Transportation salt storage facility from the watershed.

According to a Stantec Report (Stantec Consulting Ltd., 2012), the mean chloride level in Williams Lake for the period 2006-2010 when salting was still restricted on roads around William Lake was 57 mg/L, so there is some evidence that even then, levels had risen above the 1990/91 levels.

The SPC value for the outlet observed on Dec 8, 2015 (278 μS/cm) corresponds to 58.6 mg/L chloride using the conversion formula given by Scott (1992). This is close to the mean value cited above (58.9 mg/) for 1976-77 when regular salting was conducted and well above the 45.0 mg/L cited for 1990/91 when salting had been restricted for 5+ years. The Aug 3, 2015 chloride values of 74 mg/L and 116 mg/L in samples taken from the outlet end and middle part of the Williams Lake near the Wyndrock

Drive causeway are substantially higher than the calculated value for Dec 8, 2015 (58.6 mg/L).

These rather fragmentary observations and comparisons are suggestive that (i) the "background" levels of salt loading have increased since 1990/91 even with restricted salt use, and (2) renewed salting in 2015 has further increased salt loading. It's possible that the increase in background levels (if real) is largely associated with salt inputs from areas in the watershed that are outside of those where salt use has been restricted.

SPC values for Inlets 1, 2 and 3 on Dec 8, 2015 were all higher than the equivalent values for Nov. 29, 1990 (Table 7; Inlet 4 was not sampled on Nov. 29, 1990, but it was sampled on other dates). However not much can be concluded about such differences given the very limited data for 2015.

Table 7. Williams Lake inlet and outlet values of temperature, DO, specific conductivity and pH for the Dec 7, 2015, and reported in Scott (1992) for five dates in 1990 and 1991.

Variables/ location	Dec 8 or 9, 2015	Nov 29, 1990	Mar 11, 1991	May 21, 1991	Jul 15, 1991	Sep 9, 1991
Temp. ^{o}C						
Inlet 1	6.0	6.5	2.5	13.0	15,5	16.5
Inlet 2	7.6	8.0	1.8	12.0		
Inlet 3	6.0	5.8	3.5	15.0	21.0	19.0
Inlet 4	8.6		3.0	7.0	13.0	12.5
Inlet 5	6.0					
Outlet	5.3	5.0	4.5	13.8	19.0	18.0
DO % Sat/ mg/L						
Inlet 1	105/13.6					
Inlet 2	91/10.8					
Inlet 3	96/11.9					
Inlet 4	83/9.6					
Inlet 5	87/10.8					
Outlet	116/14.7					
SPC µS/cm						
Inlet 1	305	177.0	123	212	212	231
Inlet 2	282	66.9	134	59.4		
Inlet 3	427	414.0	328	367	441	404
Inlet 4	410		855	481	793	705
Inlet 5	**33.7**					
Outlet	**278**	**226.0**	**127**	**192**	**222**	**208**
pH						
Inlet 1	5.61	5.3	4.8	5.5	5.4	5.5
Inlet 2	6.61	4.8	5.1	5.1		
Inlet 3	7.05	6.8	6.5	6.6	6.8	7.0
Inlet 4	6.58		6.3	6.4	6.4	6.3
Inlet 5	**4.45**					
Outlet	6.57	6.5	5.2	6.3	6.4	6.5

The values for inlet 1 in 2015 were for lake water close to the inlet but not at the inlet. Other values included only water that had not yet entered the lake.

Williams Lake Inlet 5

Scott (1992) did not conduct observations at Inlet 5, although its presence was indicated in his map. The flow of water from Inlet 5 is substantial and on Dec 8, 2015 appeared to be of similar magnitude to water cascading into the lake that we observed the previous day at Inlet 1 which is the water coming from Colpitt Lake. The water entering the lake at Inlet 5 comes from a large part of the catchment area south of the lake, all of which is undeveloped and essentially undisturbed except by natural events. The SPC value was 33.7 µS/cm, which is roughly 10 fold less than values for the other inlets and is of the magnitude cited by Clement et al. (2007) for the lowest values amongst 50 metro lakes sampled in 2000. Those authors commented:

> A wide range of conductivity readings is found in Metro Area lakes... The lowest readings, on the order of 30 µS or less, reflect natural levels of conductivity which are caused by dissolved ions derived from the weathering of rock and precipitation of sea salt. Not surprisingly, these low levels are found in lakes with relatively undisturbed watersheds (Spider, Parr, Spruce Hill, Major, and Bell). The rest of the lakes have levels that have been increased by human activity, some to a considerable degree. As expected, lakes with the highest readings have well-developed watersheds (Whimsical, Bissett, Cranberry, Penhorn and Russell).

The pH on Dec 8, 2015 at Inlet 5 (4.45) was also much lower than values for the other inlets (5.6 for inlet from Colpitt Lake; 6.14-7.05 for inlets 2,3,4), as well as values for the lake and inlets cited in Scott (1992). Acidic water is expected on this type of landscape in the absence of significant human activity (Ouimet et al., 2006).

The Williams Lake outlet water SPC on Dec 8, 2015 was 278 µS/cm. Inlets 1 to 4 had values of 282-427 µS/cm, with an avg 356 µS/cm. An estimate of the contribution of Inlet 5 water to lake water can be made by calculating the proportion of water with SPC 33.7 µS/cm (the value for Inlet 5) that would be required in a mix with water of 356 µS/cm (the average of values for Inlets 1-4) to give water with a SPC equivalent to that at the outlet (278 µS/cm). That works out 24%. This is an admittedly very rough estimate, but its magnitude is in the region of what one might guess from simply observing the inflows from the 5 inlets on Dec 8, 2015. (It ignores other flows into the lake from undeveloped landscape but they would probably have low SPC as at Inlet 5, so the estimate could be considered to apply to all inputs from undeveloped landscape.)

Clearly, the waters entering the lake at Inlet 5, and by seasonal and subsurface flows along the south side of Williams Lake as well as rain entering the lake directly are crucial to keeping the salt content of Williams

Lake as low as it is. Conversely, inputs from the other inlets are keeping the water SPC well above pristine values.

Likewise, Inlet 5 water (pH 4.45) is contributing much more acidity than the other inlets (pH 5.60 for Inlet 1 from Colpitt lake, pH 6.58 – 7.05 for Inlets 2,3,4) to the lake water. The outlet water pH (6.57) reflects the result of mixing of these disparate sources. (Note that a 1-fold difference in pH is equivalent to a ten fold difference in H^+ concentration, so the Inlet 5 water has a more than ten-fold greater H^+ concentration than the Inlet 1 water and more than a 100-fold greater H^+ concentration than water entering at inlets 2,3 and 4.)

<u>Colpitt lake</u>
The water coming from Colpitt Lake and environs via Inlet 1 on Williams Lake is the largest single site input to Williams Lake. Williams Lake Inlet 1 SPC values for 3 of the 5 sampling dates of Scott (1992) were lower than the lake outlet values, and on two dates were higher (Table 7). The Inlet 1 value for Dec 8, 2015 (305 µS/cm) was substantially higher than the equivalent figure for Nov 29, 1990 (177 µS/cm) and was higher than the lake outlet value (226 µS/cm). Thus Colpitt lake water is adding to the solute load in Williams Lake (or is not lowering it), at least at certain times. To provide some characterization and baseline data on salt inputs to Colpitt Lake and the outputs to Williams Lake, I conducted some quick surveys of SPC values along the shoreline and down the outlet stream (Table 4; Figs. 4 & 5).

There appear to be four streams running aboveground into Colpitt Lake for all or most of the year. Governor's Brook is likely the foremost in terms of volume and appears to be the only one running above ground over most of its course. Runoff from developed areas including parts of Williams Lake Road and environs close to Herring Cove Road enters Governor's Brook. (The recent Governor's Brook development above Colpitt Lake appears to drain mostly into the MacIntosh run, but this bears some examination.)

Three more streams with significant flows into the lake (versus a trickle) were observed on Dec 9, 2015 and I have observed significant flows at these sites at other times of year. I have labeled the sites Inlets 2, 3 and 4 in Figs 3 & 4. The Inlet 2 stream emerges from a small wetland/plain that lies at the bottom of a trough between NE/SW oriented embankments (Fig 3). The stream at Inlet 3 likely receives water from higher elevations just to the north of it, while Inlet 4 receives waters from wetland complexes as identified on the hydrology map of Prof P. Manual (Fig 3). The streams at Inlets 2,3 and

4 are at the surface only close to the lake, emerging from the ground short distances upstream.

In addition to visible streams with significant flows of water at these four outlets, more limited patches of open water exhibiting “trickles” of water movement towards the lake were observed at sites around the lake (see gold coloured S-labeled numbers in Fig 4). These “seeps” emerged from the ground nearby, and in some cases went back underground, in others remained above ground as they entered the lake. There were undoubtedly more as I could not walk right on the lakeshore through much of the area, also more would likely be seen and with larger flows during or shortly following precipitation events. As well, there are many small gullies with mountain holly in the rockscape around the lake which are areas of seasonal water flow, and otherwise, considerable seasonal flows likely take place below the surface in this landscape (Hill and Patriquin, 2014). A lot of water likely filters through the large wetland close to the northwest end of the lake; it lies below troughs and boulder fields in the rocky embankments behind it (Figs. 3 & 4).

SPC values for Inlets 2, 3 and 4 and six seeps by the lake (Fig. 4) were in the range 44 to 57 µS/cm. The SPC value for Inlet 1 (Governor’s Brook) by contrast was 369 µS/cm, suggesting there is a single source of water with high solute concentration entering Colpitt Lake. SPC values of the lake water sampled from shore are in the range 80 to 350 µS/cm with only 2 values of 200 or less, those at the east end of the lake close to Inlets 3 and 4. The SPC values for Colpitt Lake as a whole are high compared to values of the order of 30 µS/cm for pristine lakes in this region (Clement et al., 2007). Historically they have increased over time (see Appendix Table 3, below).

A crude estimate of the contribution of Governor’s Brook to Colpitt Lake output water is made by calculating the proportion of water with SPC 369 µS/cm (the value at Governor’s Brook inlet) that would be required in a mix with water of 50 µS/cm (the mean value for Inlets 2,3,4) to give water with a SPC equivalent to that at the outlet (286 µS/cm). That works out to 74%. It’s likely that the Governor’s Brook water has more influence on the outlet water than on the lake as a whole, as the outlet is only about 200 m from the Governors Brook Inlet while the lake is about 1 km in length. A calculation utilizing the average value of 19 measurements in the lake on Dec 9, 2015

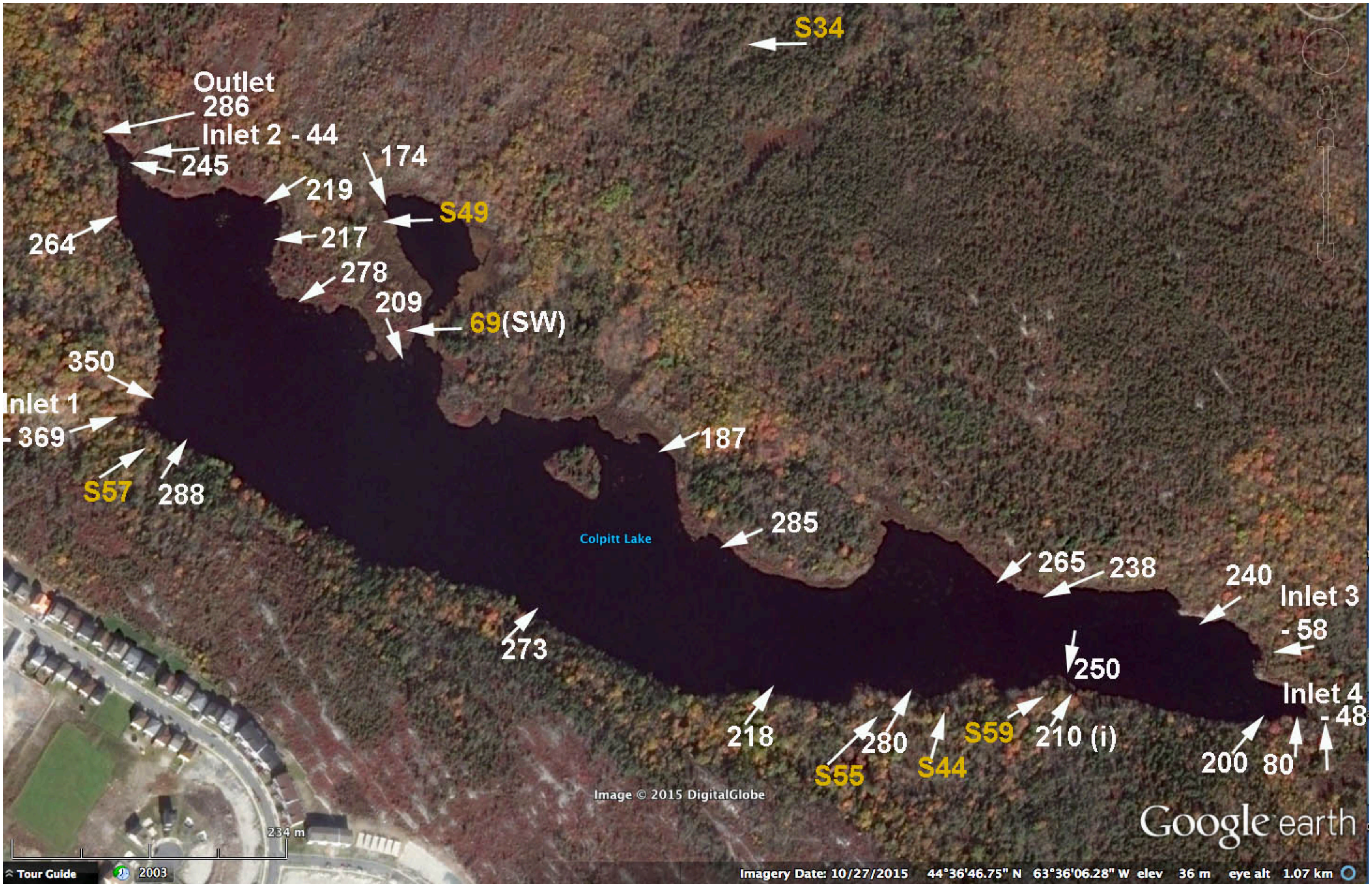


Fig. 4 **Colpitt Lake SPC values (uS/cm) on Dec 10, 2015.** The gold-highlighted values are for seeps (see text). SW: Standing Water

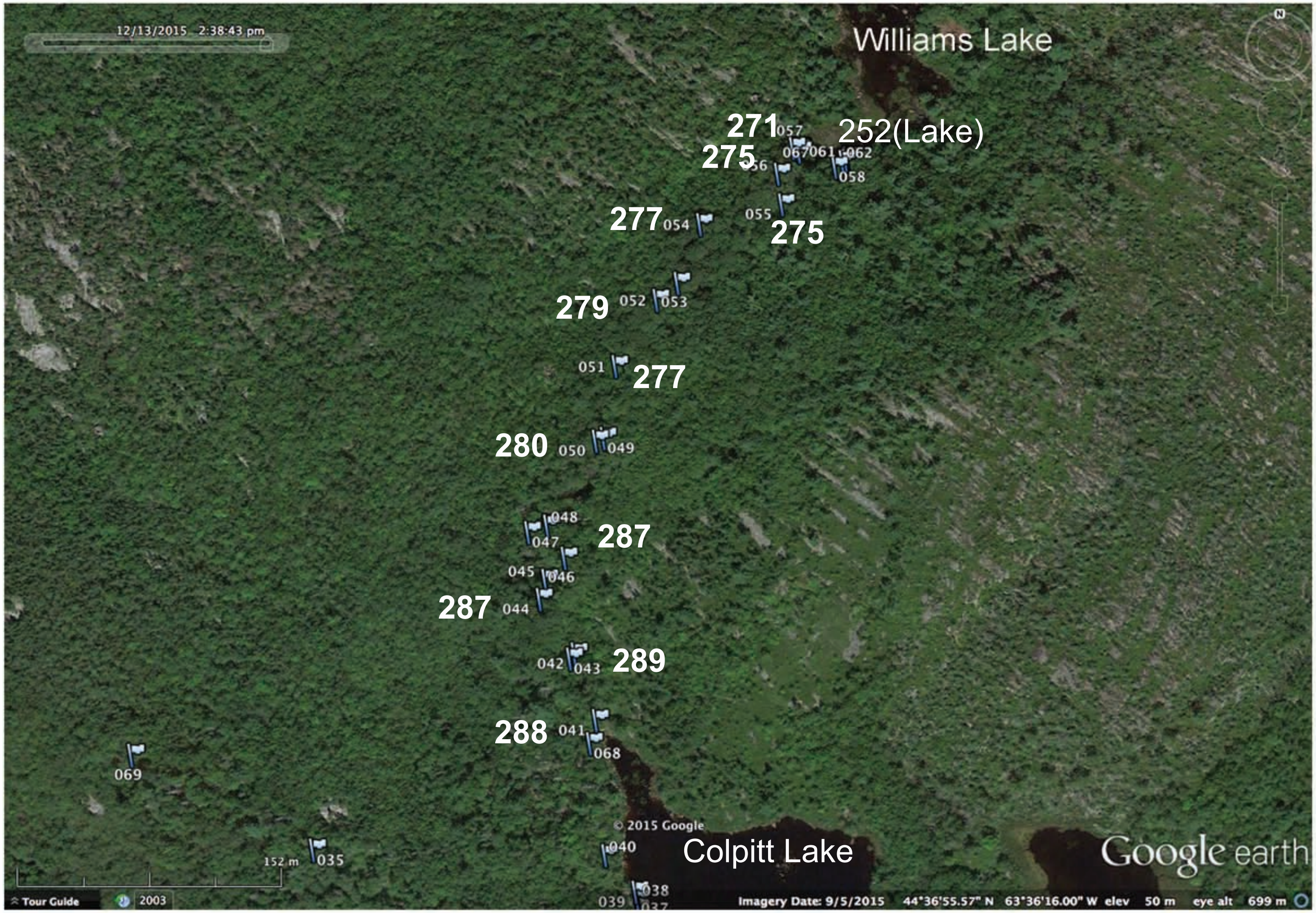


Fig. 5. Specific Conductance values (uS/cm) on the stream running between Colpitt Lake and Williams Lake on Dec 13, 2015.

(237 µS/cm) suggests Governor's Brook was contributing of the order of 58% of the water in the lake as a whole.

These are crude estimates based on one set of data and do not take into account a host of variables and changes over time. Nevertheless, they do suggest that Governor's Brook has a very substantive impact on the solute content of the Colpitt lake as a whole, and to the outlet water and consequently to Williams Lake water quality.

SPC of Governor's Brook measured approximately 250 m upstream from the point where it enters Colpitt Lake on two separate days was higher at the upstream site (450, 392 µS/cm) than at its outlet on Colpitt Lake (305, 369 µS/cm) (Table 3, above.) This can be attributed to dilution of the salts contributed upstream in developed landscape by lateral flows of purer water into Governor's Brook as it flows through undeveloped landscape. Similarly, observations along the outflow stream from Colpitt to Williams Lake (approx 350 m in length) on Dec 13, 2015 illustrate progressive dilution as the water moves downstream (Fig 5). In this case the upstream value was 288 µS/cm and the value at Williams end, 271 µS/cm. Evidently, the lateral flows are subsurface flows - no lateral surface flows were observed along the course of this stream. The landscape is very bouldery with steep embankments, which would not be conducive to surface flows except perhaps during intense storm activity or during snowmelt.

While the salt carried from developed areas is diluted by flows from the large blocks of undeveloped landscape in the Williams Lake watershed, it is very clear that such dilution is not sufficient to eliminate negative impacts of road salt.

CONCLUSION

Williams Lake is one of the lakes included in an exceptional study by Ginn et al. (2015) which employed a paleontological approach "to determine the amount (and likely causes) of environmental changes over the past ~100–150 years in 51 urban lakes from Halifax, Nova Scotia". They noted:

> "Of our 51 lakes, 22 (including some experiencing pH, TP, or showing floristic changes linked to climate changes) had increases in measured conductivity (1980–2002) and, correspondingly, increased relative abundances of halophilic diatom taxa. These lakes, often with catchments containing high surface areas of impervious surfaces, are examples of a trend of increasing salinity in northeastern North American lakes likely related to winter application of deicing (road) salt."

Williams Lake was not one of those 22 lakes. Sampling for diatoms was conducted in 2005/2006 which was during a period when salt use was being restricted in the vicinity of Williams Lake. Likewise salt use was restricted during most or all of the interval between 1980 and 2002 for which they had limnological data (from Clement et al., 2007). Use of road salt in Halifax dates back to 1958 (Ginn et al. , 2015). Salt use in the vicinity of Williams Lake was restricted sometime in the late 1970s to mid 1980s. The studies by Ginn (2015) and Scott (1992) thus suggest that Williams Lake was not being severely affected by salt from at least 1990 or earlier through to 2005/2006.

The conditions in 1990/91 were considered an improvement over the period when salt use was not restricted and when there had been a salt storage facility on Williams Lake Road as cited by Scott (1992), comparing his observations with those of Underwood for 1976/77 (see also Appendix Tables 1 and 2 below). Scott also noted that "a comparison of mean-annual chloride values for the four inlets shows that the sub-watershed treated with sand (Inlet 2) during the winter months is the lowest."

So historically there is evidence that salt inputs and their impacts on Williams Lake have fluctuated with management of road salt. Given the apparently fragility of the lake in 2015 and the evidence that, overall, salt inputs to the lake have increased compared to 1990/91, it seems only prudent to continue to restrict salt inputs as much as possible.

Roughly three-quarters of the Williams Lake watershed is undeveloped land which simplifies management. However, it does not eliminate the need to restrict salt and nutrient inputs in order to avoid significant ecological damage to both Williams Lake and Colpitt Lake.

Four major conclusions pertaining to the road salt issue can be drawn from the current study:

1. The water column in the deeper waters of Williams Lake on Dec 7, 2015 was isothermal but incompletely mixed and the deeper waters had elevated SPC and were near anoxic. This contrasts sharply with 1990/91 when a normal spring and fall turnovers were observed. It's possible that the deeper waters were fully anoxic earlier in the year. While the causes are not clear, the apparently delayed turnover in 2015 raises concerns about the health of the lake and sensitivity to increased salt inputs.

2. Clearly the large areas of undeveloped land in the watershed are critical for maintenance of desirable water quality in both Colpitt Lake and Williams Lake. However the flows from undeveloped land are not sufficient to eliminate negative impacts of road salt.

3. Streams coming from developed areas, including Governor's Brook via Colpitt Lake and Inlet 1 on Williams Lake and streams entering at Inlets 2,3 and 4 on Williams Lake are the major contributors to the elevated SPC (salt) in Williams Lake.

4. Governor's Brook appears to have a very significant impact on salt content of Colpitt Lake.

SUGGESTED FOLLOW-UP

1. Seek reversal of the decision to reinstate salting of roads in the immediate vicinity of Williams Lake.

2. Monitor salt (SPC) at the outlet of Williams Lake, weekly as possible. Have water samples from the outlet analyzed for chloride bi-monthly.

3. As possible, monitor SPC at the inlets 2,3 and 4 to Williams Lake, in Martin's Pond and at the Governor's Brook Inlet to Colpitt Lake through the winter and into the spring.

4. Inlet 5 on Williams Lake could be monitored in conjunction with the above as a measure of change in waters coming from unsalted, natural landscape.

5. Frog Pond (by the road) and/or MacIntosh Run below the bridge on Drysdale (see Table 5) are easily accessible and could be monitored as references in other systems subject to runoff of roadsalt.

6. Through 2016, examine the vertical profile of temperature, dissolved oxygen, specific conductance and pH at Station 1 on Williams Lake on dates close to those of Scott, 1992 (March 11, May 21, Jul 15, Sep 9, Nov 29) to determine the degree of anoxia and salt levels. As possible, take at least two water samples on each sampling date, one from the surface and one close to the bottom for analysis of constituent ions.

7. In 2016, examine the vertical profiles of water quality variables in the deepest areas of Colpitt Lake in the mid-to-late summer to determine if salt is contributing to stratification and if oxygen depletion occurs in the deeper areas (see map with depth contours in Appendix 1). Take at least 2 water samples on each sampling date, one from the surface and one close to the bottom for analysis of constituent ions.

8. Conduct a survey to find out how much salting on public and private roads and properties is conducted within the watershed, with particular reference to the Governor's Brook and streams entering Inlets 2,3 and 4 on Williams Lake. This might be conducted in conjunction with an effort to inform residents of the need to minimize salt and fertilizer use to protect and improve the ecological integrity of Williams Lake and Colpitt Lake.

9. Further investigations should attempt to determine whether areas outside of those where salt has traditionally been restricted are now contributing a lot of the salt, e.g. from the Herring Cove Road area.

10. Over the long term, the WLCC is encouraged to pursue a comprehensive approach to assessing the health of Williams Lake and Colpitt Lake and how it can be improved. The current trophic status of Williams Lake and Colpitt Lake needs to be assessed and information on the watershed and lakes in WLCC files and in the literature compiled and reviewed.

11. Seek further advice and feedback from professionals in aquatic systems and hydrology at Dalhousie University and Saint Mary's University and through consultation with other watershed groups.

ACKNOWLEDGMENTS

Kathleen Hall assisted in observations on Dec 7 and 8, 2015 and Marilynne Bell contributed the rowboat. Graham Patriquin assisted on Dec 13, 2015. The Community Based Environmental Network at Saint Mary's University provided invaluable assistance through the loan of a well maintained and calibrated YSI meter. Bob Rutherford, habitat biologist and President of Thaumas Environmental Consutants Ltd (Dartmouth, N.S.) and Richard Scott (recently retired from the Dalhousie Centre for Water Resources) provided very helpful feedback on a draft of this report.

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Appendix: Historical data on pH, DO and SPC in Williams Lake and Colpitt Lake

WLCC archival files contain a number of reports going back to 1971 with data on water quality of Williams Lake and Colpitt Lake. A report by John Underwood and D.M Josselyn in 1979 on "The extent of road salt and nutrient stressing of Williams Lake, Halifax", NS NSDOE Report #1960-Hal-W7-79 would be very pertinent but is not available in these files and we have not yet been able to locate it otherwise; for example NSDOE has not retained a copy. However the WLCC archival files contain some datasheets from his studies.

Reports in the 1970s cite issues with overflow from the sewage pumping station by Williams Lake Road contaminating the lake and stimulating excessive growth of aquatic plants in the shallow basin; it was noted that chloride (salt) was coming primarily from sources other than Colpitt Lake, with mention of "salting of Williams Lake Road, Acorn, Birchview, and Wyndrock Drive plus a large contribution from the stockpile of salt on the Department of Highway's property on Williams Lake Road….The salt in Colbart Lake would be primarily due to the salting of Herring Cove Road and the few side streets in Spryfield which are in our watershed (Allan Simpson, Report on Williams Lake, 1972).

A newsletter to members announcing the WLCC AGM for 1973 cites "significant quantities of raw sewage each time there was a rainfall in excess of ½ inch in 6-8 hours due to overflow of the gravity sewer adjacent to the pumping station on Williams Lake Road….road salt…dredging of the small bat abutting Acorn Drive, filling of Williams Lake and alteration of the shoreline.." as issues of the day.

A. Mackinnon comments in 1991 that "Halifax installed storm drains in the 1980s, effectively bypassing "the marshes and streams which once filtered runoff to carry pollutants directly into the lake."

Some of the results from the 1990/91 observations reported by Scott (1992) have been cited above and are given in Table 6 and 7. Scott considered Williams Lake to be oligototrophic, based on the mean annual chlorophyll, nitrate and phosphate values.

Scott (1992) noted that fecal bacterial counts at the dam (outlet) monitored by the N.S. Dept of Health were well below the closure limit, although some high counts were recorded in the restricted Martin's Pond, and by Birchview

Drive at the upper reach of the lake. Evidently, issues related to overflow from the sewage pumping station going into storm drains that empty into the lake that had plagued the lake in the 1970s were being controlled. Likewise, road salts were also being adequately controlled:

> For the study period November 1990 to September 1991, the mean whole-lake chloride concentration was 45.1 mg/L. There was a slight chemical gradient moving west to east in the lake which could probably be attributed to dilution effects. The highest chloride concentrations were observed in Inlet 4 (Acorn Drive). A comparison of mean-annual chloride values for the four inlets shows that the sub-watershed treated with sand during the winter months is the lowest. Current rates of de-icing salt application in the Williams Lake watershed, if continued, should not result in objectionable chloride levels in the lake.
>
> Lobbying efforts of the Williams Lake Conservation Company have resulted in the application of sand instead of salt on roads in the vicinity of the lake during the winter months. As a result, the concentration of sodium chloride in Williams Lake has decreased from 58.9 mg/4 measured in 1976-77 (Underwood) to 45.0 recorded in 1990-91 (this study). The decrease in levels observed for the two study periods may be a reflection of any or all of the following: the amount of salt applied to the entire watershed varied, the removal of the Department of Transportation salt storage facility on Williams Lake Road, and/or the replacement of salt with sand in portions of the watershed.

Scott (19920 commented on impacts of high salt loading:

> Elevated sodium chloride levels in lakes can have a number of impacts on the aquatic ecosystem. In extreme cases, formation of a dense saline laver in the bottom strata of a lake inhibits the complete circulation of the water body in the spring and fall seasons preventing reoxygenation of this zone. This is turn forces organisms requiring oxygen for respiration to move to oxic environments.or die. Fish may have to retreat to less desireable warmer water during the summer months, placing unnecessary stress on the species.

Except for the March 11, 1991, Scott's observations in the deep basin (Table 6 above) do not reveal any significant salt induced stratification. For March there is some stratification which was partly due to ice melt causing reduction in SPC in the surface 5 m, but dissolved oxygen remained high throughout the profile (80% saturation at the bottom).

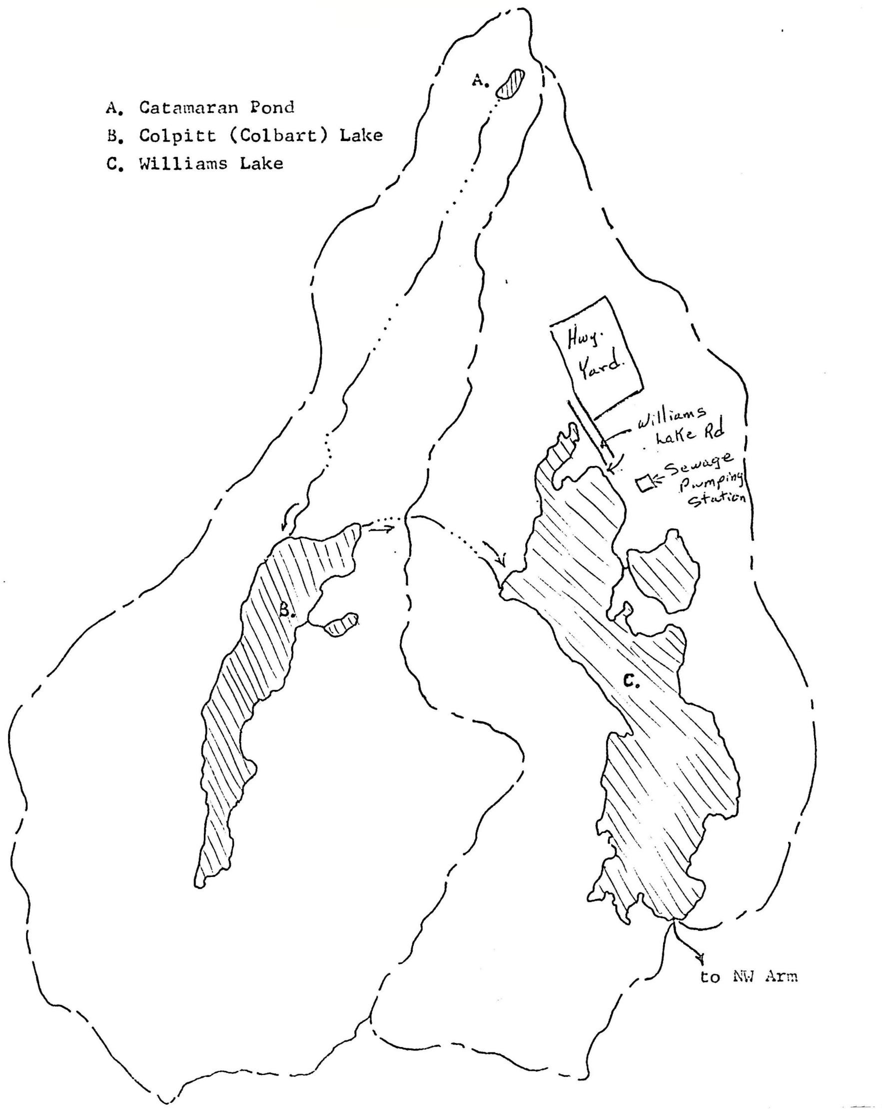
Below are some of the other historical data that are most pertinent to the salt issue. Some comments are appended to each table.

Appendix Table 1. Data cited by Allan Simpson for 1971 in "Report on Williams Lake"

	Temp (deg C)	**pH**	**DO (mg/L)**	**SPC (µS/cm)**
WILLIAMS LAKE Aug 17, 1971				
Inlet ex Colbart	-	-	7.8	83
Surface	19.3	-	7.8 (84%)	260
65 ft	4.5	-	2.75 (21%)	600
Outlet	-	-	7.25	278
COLPITT LAKE Aug 31, 1971				
Inlet	-	-	8.25	163
Surface	20.3	-	7.25	**64**
39 ft	-	-	1.50	118
Outlet	-	-	7.8	**82**

Comments: The SPC value of 600 µS/cm at 65 feet in Williams Lake is the highest I have seen for the deep water and there was a very large difference between the bottom value and the surface. At that time a salt storage yard was located close to the lake. It is notable, however, that there was still 21% oxygen saturation on the bottom.

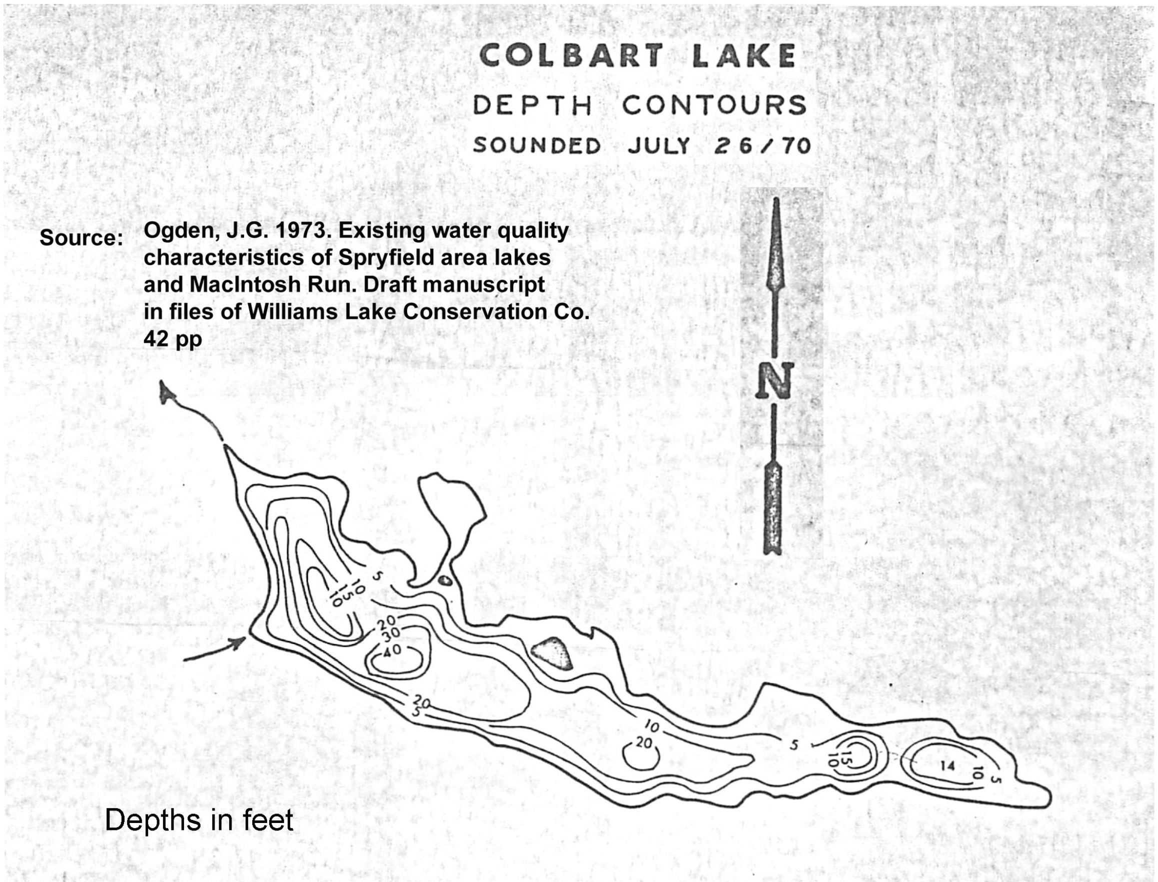
Also notable are the low SPC values for Colpitt Lake compared to those for 2015. However, the Colpitt Lake inlet (Governors' Brook) value was elevated and even then apparently caused some stratification in the lake (compare SPC values for Colpitt Lake at the surface and 39 ft.)



Williams Lake: Elevation above sea level 62 ft ; Surface area 115 acres; Shoreline length 14,560 ft; Shoreline development 1.73; Watershed area including Colpitt Lake 1420 acres; Max depth 66 ft; Mean depth 8.1 ft Vol 71.4 x 10^6 ft^3; Capacity 445.1 x 10^6 Imperial gallons; Flushing time 8 months

Colpitt Lake: Elevation above sea level 114 ft ; Surface area 55 acres; Shoreline length 9053 ft; Shoreline development 1.65; Watershed area 490 acres; Max depth 40 ft; Mean depth 18.3 ft; Vol 43.92 x 10^6 ft^3 ; Capacity 273.6 x 10^6 Imperial gallons; Flushing time 1 year

Appendix Fig 1. Watersheds and location of Hwy Yard (where salt was stored) and sewage pumping station. From Allan Simpson, Report on Williams Lake, 1972 (WLCC files).



Appendix Fig. 2. Bathymetric map of Colpitt Lake.

Appendix Table 2. Data collected by J.K Underwood and D.M Josselyn in 1976 and 1977. There was no map attached to the datasheets. Inflow 1 is described as "highways", Inflow 2 as "launch", and inflow 3 as "Colbart" (older name for Colpitt Lake). The "Bay" refers to the shallow basin, "Deep" to the deep basin. The "Pond" refers to Martin's Pond which was a section of Williams Lake that is separated by a causeway from the larger lake. Units are not given, but can be assumed to be µS/cm for SPC, and mg/L for D.O. No temperatures are given so % saturation values for D.O. cannot be calculated. A number of other variables are given in Underwood's data such as chorophyll and nitrate, phosphate. Some unidentified Inflows measured on Feb 10, 1977 had conductivity values up to 4500 µS/cm.

Table 2a: 1976

Sites	**Oct 5, 1976**		**Oct 19, 1976**		**Nov 3, 1976**	
	pH	SPC	pH	SPC	pH	SPC
Deep 0 ft	6.9	260	7.8	260	-	250
10 ft	6.9	260	7.7	260	-	250
20 ft	6.9	260	7.3	260	-	250
30 ft	6.9	260	7.1	260	-	250
40 ft	6.8	260	6.9	260	-	250
50 ft	6.9	260	6.7	260	-	250
60 ft	6.0	280	6.3	260	-	250
Bay 0 ft	6.1	290	6.2	290	-	250
4 ft	6.2	300	6.4	300	-	250
Inflow 1 (Highways)	6.2	1200	6.0	850	-	560
Inflow 2 (Launch)	6.3	450	6.6	300	-	300
Inflow 3 (Colpitt Lake)	6.5	150	5.4	200	-	150
Outflow	6.6	250	5.9	260	-	250

Table 2b: 1977

Site	March 7, 1977			July 4, 1977			Sep 18, 1977		
	pH	DO	SPC	pH	DO	SPC	pH	DO	SPC
Deep 0 ft	4.9	12.4	56	6.7	8.38	240	6.7	8.00	230
10 ft	5.7	11.5	210	6.7	8.26	250	6.4	8.45	250
20 ft	5.8	10.7	260	6.7	8.55	250	6.2	8.25	240
30 ft	5.9	10.5	340	6.5	8.39	250	6.3	6.70	245
40 ft	5.9	9.78	400	6.3	7.98	260	6.2	5.85	270
50 ft	5.8	9.80	440	6.1	7.66	250	6.5	4.70	270
62 ft	5.8	9.70	440	6.2	7.25	260	6.2	3.90	270
Bay 0 ft				6.4	8.09	230			
2 ft							6.7	8.00	230
4 ft				6.5	8.15	240			
Inflow 1	5.5		700	6.9	5.79	600	5.4	5.85	105
Inflow 2	6.1		510	6.8	3.00	650	6.7	0.85	580
Inflow 3	4.8		96	6.4	4.86	116	-	-	-
Outflow	5.1		120	6.5	8.54	240	6.4	8.35	250
Pond 0 ft							6.9	7.15	850
Pond 9 ft							6.9	3.75	1340

Comments: The SPC values for the Inlet from Colpitt Lake (120-250 µS/cm) suggest increased salt load from Colpitt compared to 1971 (Appendix Table 1: 83 µS/cm).

Except in March of 1977, there were not strong SPC gradients and DO was maintained at higher levels close to the bottom than in 2015.

There were some high SPC values in some of the inlet waters and in the Pond.

Appendix Table 3. **From "WLCC Water Quality Testing Results for Williams and Colpitt Lake 1980-2015**. The data are in a table with data for metals, alkalinity etc.

Lake	Date	pH	SPC uS/cm	Chloride mg/L
Williams Lake	Aug 14, 1980	5.9	136	46.0
Williams Lake	Aug 16, 1991	6.4	176	41.2
Williams Lake	Nov 13, 1997	6.2	238	56.2
Williams Lake – dam end	Aug 8, 2008	6.5	301	72.0
Williams Lake –dam end	Aug 3, 2015	7.0	285	74.1
Williams Lake – Wms L Rd end	Aug 7, 2008	6.1	401	65.0
Williams Lake- Wms Lake Rd end	Aug 3, 2015	7.2	350	81.8
Williams Lake- near causeway	Aug 3, 2015	7.3	446	116.0
Colpitt Lake	Aug 14, 1980	4.9	109	36.0
Colpitt Lake	Aug 16, 1991	5.6	275	74.8
Colpitt Lake	Nov 13, 1997	5.5	291	74.5
Colpitt Lake	Aug 7, 2008	6.3	337	84.0
Copitt Lake	Aug 3, 2015	6.8	388	102.0

Comment: These data show the progressive increase in SPC in Williams Lake and Colpitt Lake over time and a highly elevated SPC and chlroide near the causeway in Williams Lake in 2015.