4715 Innovation Dr., Ste. 110
Fort Collins, CO 80525
Phone: 970-225-8222

Technical Memorandum

TO: Jim Harrington, Scott Davidson (ACG)

FROM: Brent Johnson, Paul Haby

DATE: September 9, 2011

SUBJECT: 2010/2011 South McQuesten Water Quality Investigation

INTRODUCTION

Elevated metal concentrations in the South McQuesten River (SMQR) have been an ongoing concern since at least the 1950's, with metal concentrations periodically exceeding the Canadian Council of the Ministers of the Environment (CCME) guidelines (CCME, 2007) for the protection of aquatic life (Environmental Dynamics Inc., 2005). Previous SMQR water quality monitoring was conducted for the Yukon River Panel and the First Nation of the Nacho Nyak Dun between 2003 and 2005 (Environmental Dynamics Inc., 2004, 2005). This effort detected increases in total zinc in the SMQR between the confluence with Cache Creek and the confluence with Christal Creek. Additional increases in total zinc were found at the SMQR monitoring site below the confluence with Christal Creek. These findings suggested significant impacts to the SMQR resulting from both Cache and Christal Creeks, especially during the spring sampling events. Samples from near the mouths of both creeks found concentrations of zinc exceeding the CCME guideline. Concentrations of copper, iron, and aluminum were also found to occasionally exceed CCME guidelines in these creeks. The elevated zinc levels in Christal Creek were attributed to the impacts of previous hard rock mining activity in the watershed. A separate investigation into the cause of high levels of zinc and aluminum in Cache Creek (Krska, 2003) determined that they are the result of natural acid rock drainage conditions. In addition to the spatial variation in the SMQR, the Environmental Dynamics studies also found that metal concentrations vary seasonally due to seasonal changes in the metal concentrations of Cache and Christal Creeks and also due to a decrease in SMQR streamflow relative to streamflow from the two tributaries. The resulting change in mixing ratios results in less dilution of metal concentrations in the receiving waters of the SMQR during these periods.

A more recent water-quality assessment of the SMQR and surrounding water bodies was conducted for the Elsa Reclamation and Development Company by Minnow Environmental, Inc. (2008). This work utilized a database compiled from several previous and ongoing water-quality monitoring programs to evaluate water quality at 20 monitoring sites in the region. Elevated concentrations of aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, nitrite, phosphorus, selenium, silver, sulfate, and zinc at many locations, however most consistently elevated concentrations were found in tributaries to the SMQR (Christal, Flat, and No Cash Creeks) immediately downstream from mine sources. Cache Creek was not included in this study because it does not have a fixed water-quality monitoring site and was outside of the identified study area defined as the United Keno Hill Mining Property. Although SMQR tributaries contribute higher concentrations of many constituents to the SMQR, over the period of evaluation this study found median concentrations at sites along the main stem SMQR to be generally below CCME guidelines. Trend testing found statistically significant decreases in zinc concentrations at many stations with the most significant decrease occurring along Christal Creek.

In recent years, ongoing water-quality monitoring efforts have detected an increase in the zinc concentration at site number KV-1 located upstream of the historical mining district (Figure 1). The cause of this increase has been uncertain, and raises questions about the variability and erratic nature of water quality in the SMQR upstream of the UKHM claim area.

A fundamental understanding of the sources, spatial and temporal variability, and ultimate fate of water-quality contaminants is required before credible, defensible water-quality objectives can be established. Establishment of water-quality objectives without such information could result in unexpected and unexplainable exceedances of water-quality objectives. The establishment of site-specific standards without characterization of the contaminant sources and recognition of potential natural or anthropogenic pre-existing background conditions is generally considered unacceptable to regulatory bodies. The lack of a defensible, robust understanding of basic site conditions and the underlying sources could lead to difficulty in future agreements with Environment Canada with respect to water quality standards and closure objectives.

The objectives of this ongoing investigation are to develop a fundamental understanding of baseline water-quality conditions and to identify sources of metal loading in the upper SMQR. Results of this work will aid in the development of reasonable and defensible water quality goals and objectives for UKHM area closure work. In support of these objectives, an investigative study was conducted in the fall of 2010 to determine the sources contributing significant zinc concentrations to the upper SMQR. The initial phase of this study consisted of field observation and collection of screening samples to determine likely metal sources. The second phase of the study involved the collection of samples for complete chemical analysis in order to provide detailed information on the nature of the identified sources and to provide information on the change in chemical composition that occurs at sites along the main stem of the SMQR. Development of a mass loading model is ongoing and scheduled for completion in 2012.

METHODOLOGY

Initial Screening Sampling

The SMQR drainage system comprises a well-defined main channel (stem) surrounded by a complex of secondary channels, tributaries, ponds, seeps and bog areas. Because of the large number of potential loading sources and off-channel water bodies associated with the SMQR, an initial screening survey was conducted. The objective of the initial screening survey was to collect a high number of samples from water bodies throughout the region (main channel, tributaries, and small ponds) and analyze them for zinc using a low-cost analytical method. Initial screening survey sites found to have higher zinc concentrations were sampled for full-suite laboratory analysis.

The initial screening survey focused on the SMQR mainstem, its major tributaries, and any nearby water bodies occurring in the region between South McQuesten Lake downstream to fixed water-quality monitoring site KV-1. The sampling area spans a map distance of nearly 15 km and a river-channel length of just over 27 km. Field water-quality parameters were measured onsite and a sample was collected for analysis of total zinc. Zinc analysis of initial screening samples was performed via atomic adsorption spectroscopy at the Alexco Resources laboratory in Elsa. This laboratory is operated by Alexco Resources in support of ERDC activities under Care, Maintenance and Field Investigations. Flow measurements were originally planned for flowing water sampling sites, but were not conducted due to field conditions and access issues at the time of the survey.

Thirty-five sites (ISS-1 through ISS-35) were sampled as part of the initial screening survey. The locations of initial screening survey sites are shown in Figure 2. Locations ISS-1 through ISS-28 were sampled on September 14 and 15, 2010 while locations ISS-29 through ISS-35 were sampled October 13, 2010. Details of each location are presented in Table 1. An additional three screening samples (Cache-1, Cache-2, and Cache-3) were collected from Cache Creek after field personnel observed signs of ARD-impacted water in Cache Creek and followed the reddish-colored water to an apparent source. These sampling locations are shown in detail in Figure 3.

Full-Suite Analysis Sampling

Based on the results of the initial screening survey, thirteen locations were selected for follow-up sampling in which a full-suite analysis was conducted. The selected sampling locations are shown in Figure 4. Eleven sampling sites were selected along the SMQR (designated as SMcQ-xx) and two sites along Cache Creek: Sites SMcQ-CC located at the mouth of Cache Creek before it joins the SMQR and Cache-3 located in the Cache Creek headwaters where the seep producing reddish, acid water had been located during the initial screening survey. The Cache-3 sample was collected October 13, 2010 while all other full-suite samples were collected November 18 and 19, 2010.

RESULTS

General Field Observations

The South McQuesten River between South McQuesten Lake and fixed water-quality monitoring site KV-1 was found to be a low-energy river flowing through peat bogs during the Fall sampling events. It contains many meanders and oxbows which is indicative of frequent channel change. Many stagnant ponds were also observed along both banks. Occasional tributary streams entered the main stem along this stretch of river. The bogs and thick brush along the banks made access difficult. Access via canoe was attempted but proved unsuccessful due to the low-flow conditions encountered in October. Many areas had to be accessed via helicopter.

Reddish-colored water was observed entering the main stem South McQuesten River from Cache Creek. Further investigation determined that the reddishness persisted from the mouth of Cache Creek all the way up to its headwaters. At the headwaters, the reddish-colored water was observed to be coming from a seep originating at the base of a scree slope on the south side of the upper valley of the headwaters. There were no apparent mine workings or man-made impacts; however, the area was snow-covered at the time of sampling so observations were limited. The area will be surveyed during the summer in order to complete observations of the headwater area near the seep. This seep was the only obvious source of acid rock drainage (ARD) to Cache Creek.

Initial Screening Samples

Results of field-measurements of water temperature, pH, specific conductance (SC), oxidation/reduction potential (ORP), and dissolved oxygen (DO) are shown in Figure 5 through Figure 8. Water temperature varied between 0.0 and 12.3 degrees Celsius with few clear differences between sites. Measurements on Cache Creek were slightly colder than sites along the SMQR main stem. As would be expected, screening samples collected on October 13th (ISS-29 through ISS-35) were noticeably colder than samples collected in September. Most pH measurements ranged between 6 and 8 with the exception of sites ISS-3 (pH = 4.73) and ISS-6 (pH = 4.70) which are located on Cache Creek. Site ISS-9 is also designated as a Cache Creek site; however the sample was taken within the mixing zone at the mouth of Cache Creek as it flows into the main stem of the SMQR. The pH at ISS-9 was 7.18, suggesting that this sample was collected from an area that had already mixed with the SMQR to some degree.

Specific conductance varied somewhat throughout the screening area. Most SMQR sites had values between 300 and 400 µS/cm. Miscellaneous bog sites and tributaries had a greater range in values which is likely a reflection of the amount of meteoric water versus ground water comprising the water body. Cache Creek sites ISS-3 (560 µS/cm) and ISS-6 (570 µS/cm) had some of the higher readings recorded in the initial screening survey, however the highest values were found at bog sites ISS-16 (670 µS/cm) and ISS-17 (640 µS/cm) and tributary site ISS-35 (610 µS/cm). Dissolved oxygen (Figure 8) generally decreases at main stem sites in an upstream-to-downstream direction. Cache Creek sites ISS-3 and ISS-6 had the highest DO readings among the initial screening sites with 11.0 mg/L and 10.2 mg/L, respectively. Sites ISS-29 through ISS-35 had the lowest DO measurements.

Measured concentrations of total zinc in the initial screening survey samples including the additional Cache Creek samples are shown in Figure 9. Additional Cache Creek screening sample locations and the spatial distribution of total zinc concentrations are shown on the map in Figure 3. All Cache Creek screening samples (initial and additional) were found to have much higher concentrations of total zinc than any other water bodies in the survey area. Several Cache Creek samples had total zinc concentrations above 2.0 mg/L. The additional screening sample from Cache-3 near the source of the mineralized seep in the headwaters of the creek had the highest concentration of all screening survey samples with a value of 3.3 mg/L total zinc.

The South McQuesten Lake (ISS-1) and main stem SMQR site (ISS-2) just upstream of the confluence of the SMQR and Cache Creek had total zinc concentrations below the detection limit. The main stem SMQR site just downstream from Cache Creek (ISS-4) had the highest concentration (0.9 mg/L) of any non-Cache Creek site. Total zinc concentrations at main stem sites downstream from ISS-4 tend to decrease slightly. Only two pond/bog sites (ISS-5 and ISS-12) had elevated (~0.3 mg/L) zinc concentrations.

Full-Analysis Suite Samples

Field samples were analyzed for a full-suite of water-quality constituents by Maxxam Analytics, Inc. in Burnaby, British Columbia. Samples were received in two batches: Batch 1 containing sample “Cache-3” (collected during an earlier sampling event) was received October 28, 2010 while Batch 2 containing sample ID’s “SMcQ-1” through “SMcQ-11” and “SMcQ-CC” were received on November 22, 2010. Both sample batches were received at the laboratory past the recommended hold time for analysis of nitrite and analysis of nitrate plus nitrite. Batch 1 was received at the laboratory with an average cooler temperature of 8.7 ^{O}C which is higher than the recommended maximum temperature of 4 ^{O}C. The four coolers comprising Batch 2 all had average temperatures below 4 ^{O}C.

A cation-anion charge balance analysis of analytical results for dissolved constituents found most samples to be within the generally accepted range of +/- 5% with the exception of sample “Cache-3” which had a slightly higher but acceptable value of 6%. Values for total dissolved solids (TDS) calculated as the sum of dissolved constituents were within 4% of the gravimetrically-determined TDS values with the exception of sample “Cache-3” which had a 20 percent higher gravimetrically-based TDS concentration compared to the calculated value. This difference suggests either an error in the gravimetrically-determined value or that a significant constituent was not analyzed or that the reported concentrations of one or more constituents were lower than the actual values.

Laboratory results for the full-suite samples are presented in Table 3 through Table 5. Figure 10 plots dissolved and total zinc in an upstream-to-downstream order for all stations along the main stem of the SMQR including sample SMcQ-CC from the mouth of Cache Creek. The spatial distribution of total zinc values at these sites is displayed on the map in Figure 4. Results for the reddish seep sample from the upper Cache Creek watershed (Cache-3) are not shown in Figure 4; however zinc concentrations were around 14 mg/L for both total and dissolved fractions (Table 3 and Table 4) – much higher than the values measured for SMcQ-CC at the mouth of Cache Creek.

The concentration of dissolved and total zinc in the SMQR upstream of the confluence of the SMQR and Cache Creek (site SMcQ-11) is below the CCME guideline for the protection of aquatic life. As was found with the initial screening survey results, Cache Creek contributes water with a high concentration of zinc to the SMQR. This contribution appears to have a large influence on zinc concentrations at the first downstream site along the main stem SMQR (SMcQ-10). This influence appears to continue downstream; however the relative magnitude of the influence appears to be dampened (either due to precipitation of the metals or dilution) at greater distances downstream. Ultimately, zinc concentrations stabilize at around 0.15 mg/L total zinc within the sampling area.

Additional constituents of potential interest (aluminum, lead, manganese, and nickel) are presented in Figure 11 through Figure 14. These constituents are all elevated at the Cache Creek site compared to upstream SMQR values as would be expected in highly-mineralized water such as Cache Creek. Total lead (Figure 12) is already elevated at the upstream site SMcQ-11 as the water leaves South McQuesten Lake. The concentration then doubles at site SMcQ-10 as a result of Cache Creek inflow. Total lead concentrations farther downstream are actually lower than at the most upstream site (SMcQ-11); however concentrations do increase slightly at the sampling sites farthest downstream (sites SMcQ-2 and SMcQ-1).

Comparison to Historical Values

As first determined through the work of Krska (2003), Cache Creek appears to continue to play a significant role in the elevated zinc concentrations found in the SMQR. Due to the lack of an ongoing monitoring program along Cache Creek, it is unclear if the recent upward trend in zinc concentrations at KV-1 (Figure 1) are correlated to either increases in zinc concentration in Cache Creek or an increase in concentration from other sources such as McQuesten Lake, during this period. A comparison of previous results of samples taken from Cache Creek at the Hanson Lake Road crossing (Environmental Dynamics Inc., 2004, 2005) to results from this study (Figure 15) show that the zinc concentration measured

November 18, 2010 at the mouth of Cache Creek was much higher than zinc concentrations observed slightly farther upstream during the sampling efforts conducted from July, 2003 through March, 2005. Additional seasonal sampling of Cache Creek at the Hanson Lake Road crossing would be required to confirm an ongoing increase in zinc and for the establishment of appropriate water quality goals and objectives for the UKHM site.

Although the results of this work provide evidence that Cache Creek plays a significant role in the elevated zinc concentrations in the SMQR, this sampling effort provides only a single snapshot in time with regard to what is likely a very dynamic system. This study provides a solid foundation for understanding metal loading in this system; however a multi-year compilation of seasonal sampling results under a variety of flow regimes would provide a higher degree of confidence in the overall conclusions with regard to causes of water-quality degradation in the SMQR.

Evidence that the complexities of metal loading in this watershed are not completely explained by a single sampling event can be seen in the plot of zinc concentrations at fixed monitoring site KV-72 located on the SMQR at the outlet of South McQuesten Lake (Figure 1). Site KV-72 is located close to this study's full-suite sampling site SMcQ-11. Both sites reflect water-quality conditions in the SMQR before the impacts of Cache Creek. Although zinc concentrations are generally very low at KV-72 (as they were in this study at SMcQ-11), a spike in concentrations occurred at KV-72 beginning in October 2008 and continued through October 2009. Several sampling events at KV-72 during this period detected zinc concentrations higher than concentrations in corresponding samples taken downstream at fixed site KV-1. The cause of the increased zinc concentrations in water originating from South McQuesten Lake is unclear, but it clearly provided a significant source of zinc load to the SMQR during this period.

SUMMARY

The following points summarize the findings of this study:

1. Most metal constituents tend to be very low in SMQR as it leaves South McQuesten Lake.
2. Metal concentrations increase sharply at the confluence of Cache Creek and SMQR.
3. Metal concentrations decrease gradually downstream from SMQR-Cache Creek confluence.
4. Metal concentrations stabilize downstream in SMQR downstream of Cache Creek at higher levels than those observed upstream of Cache Creek.
5. Cache creek was found to be a primary cause of spatial increases in zinc concentration along the main stem of the SMQR.
6. Inflows to SMQR also appear to significantly influence zinc concentrations in SMQR, however, additional data from KV-72 are required to better interpret the effects.
7. The major source of metals to Cache Creek appears to be located in a scree field in the upper headwater region of the watershed in an area off of UKHM claims

REFERENCES

Canadian Council of Ministers of the Environment. 2007. Canadian water quality guidelines for the protection of aquatic life: Introduction. In: Canadian environmental quality guidelines, 2007, Canadian Council of Ministers of the Environment, Winnipeg.

Environmental Dynamics Inc. 2004. South McQuesten water quality sampling program – year 1 (CRE 23-03). Prepared for the Yukon River Panel and the First Nation of the Nacho Nyak Dun. Whitehorse, Yukon. June, 2004.

Environmental Dynamics Inc. 2005. South McQuesten water quality sampling program – year 1 (CRE 23-04). Prepared for the Yukon River Panel and the First Nation of the Nacho Nyak Dun. Whitehorse, Yukon. June, 2005.

Krska, R. 2003. Memo Report: Summary of Water Quality Investigations in the Cache Creek Watershed. First Nation of the Nacho Nyak Dun. (included as Appendix D in Environmental Dynamics Inc. (2004).

Minnow Environmental Inc. 2008. Water quality assessment report for United Keno Hill Mines. Prepared for the Elsa Reclamation and Development Company, Whitehorse, Yukon. July, 2008.

FIGURES

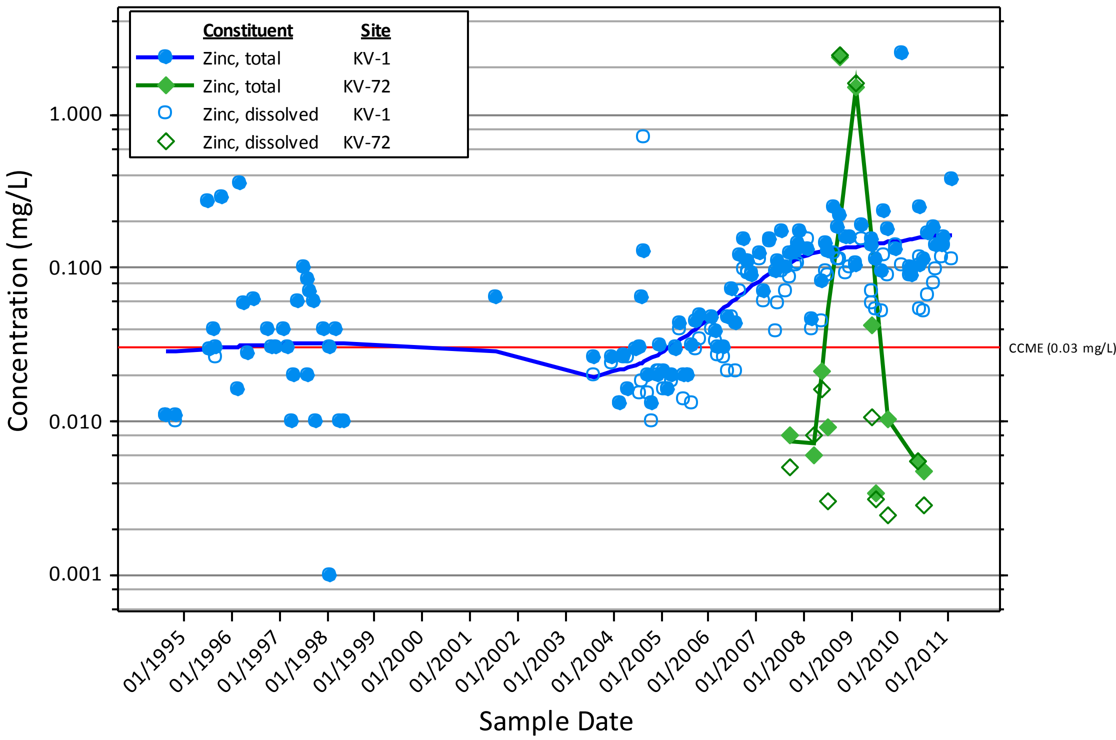

Figure 1. Historical zinc concentrations at fixed water-quality monitoring sites KV-1 and upstream site KV-72 with LOWESS smoothing lines showing general trends in total zinc.

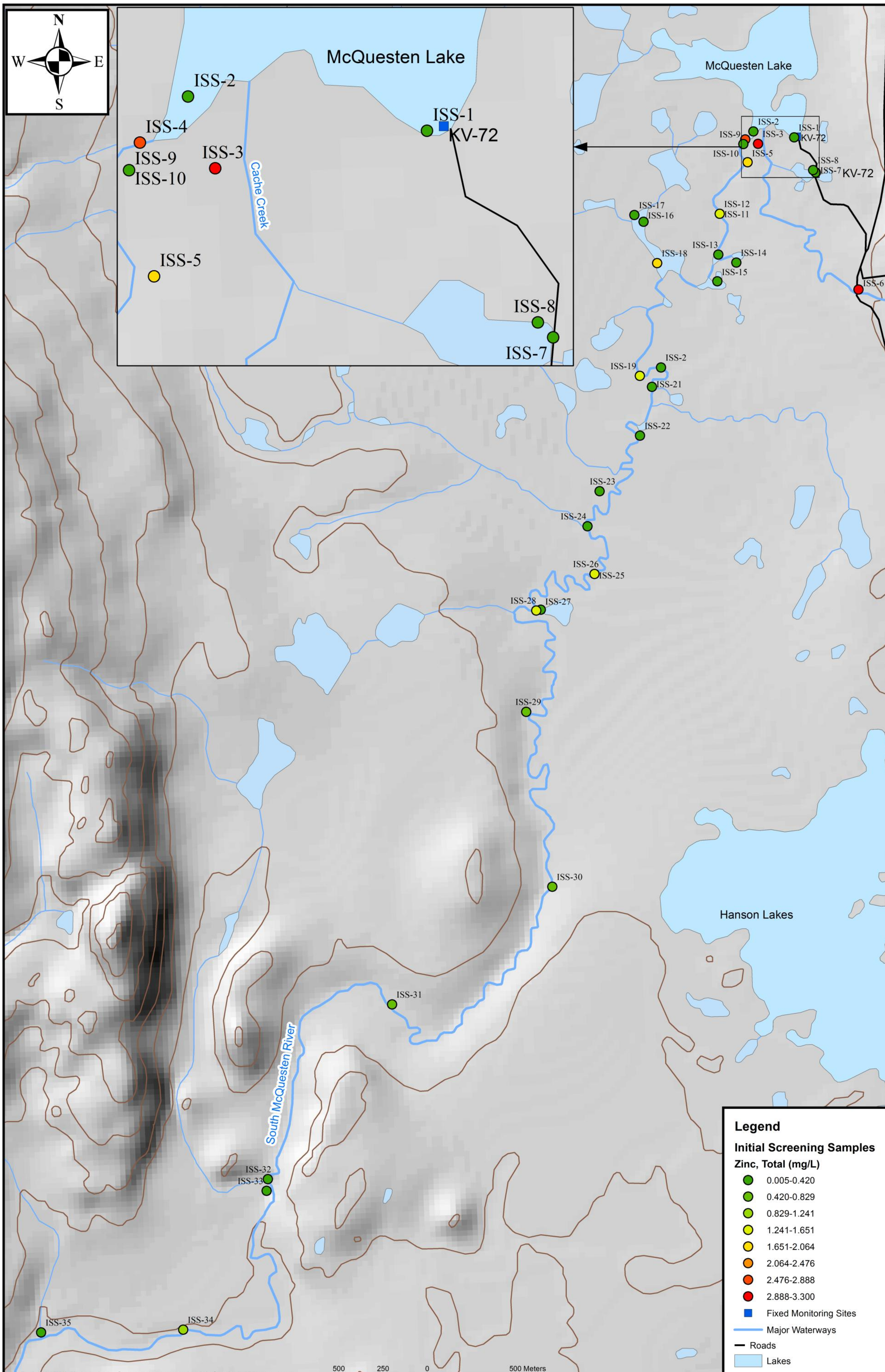

Figure 2. Primary screening sample locations and total zinc concentrations.

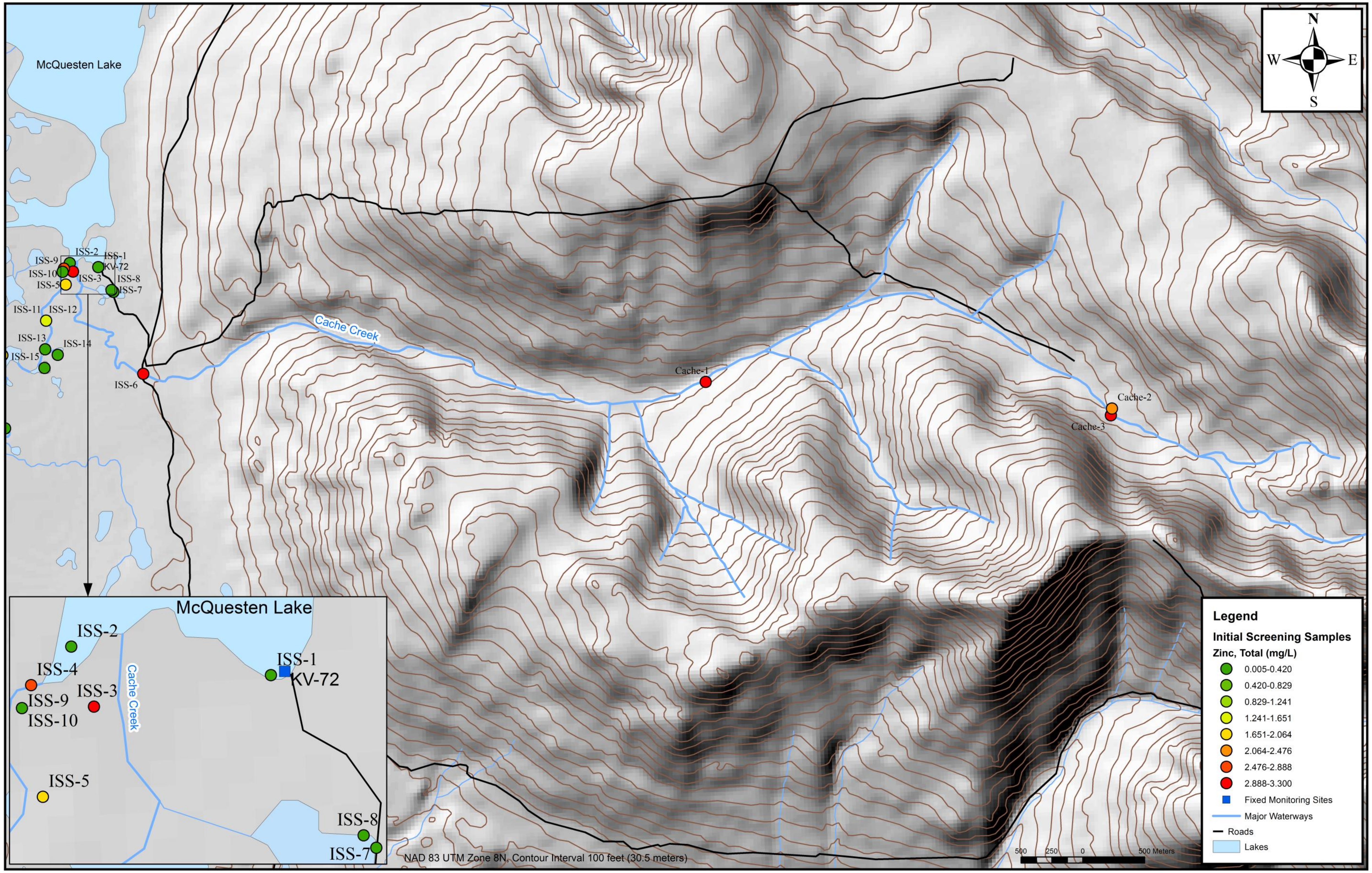

Figure 3. Additional screening sample locations and total zinc concentrations along Cache Creek.

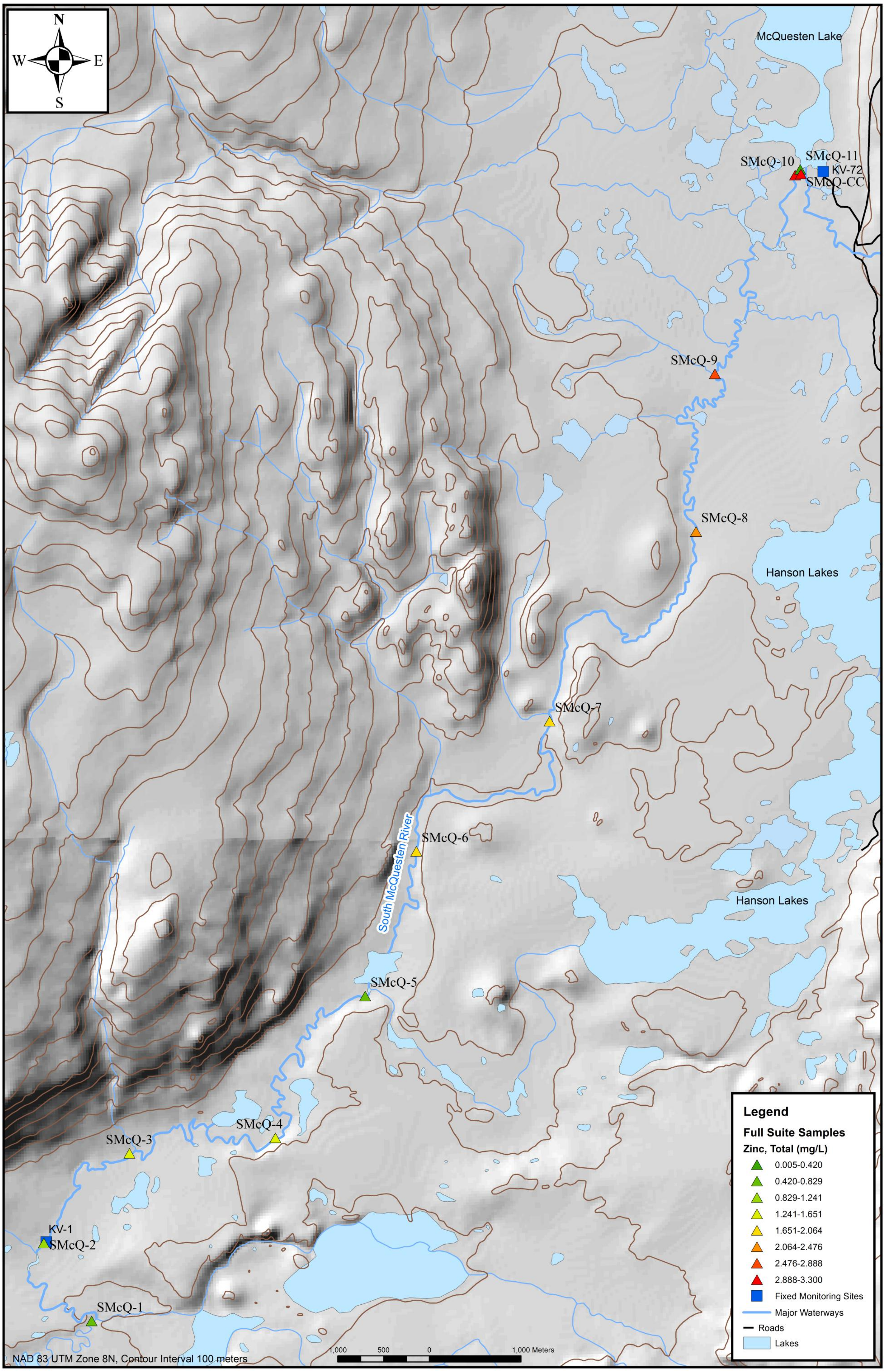

Figure 4. Full-suite sampling locations and total zinc concentrations.

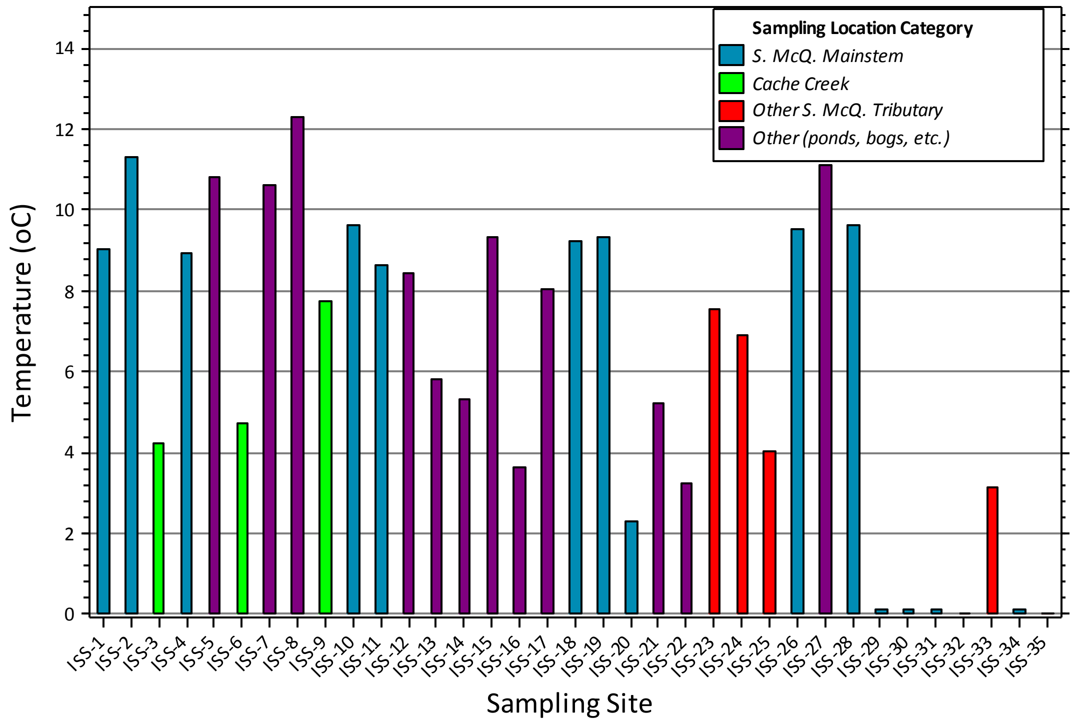

Figure 5. Water temperature of initial screening site samples.

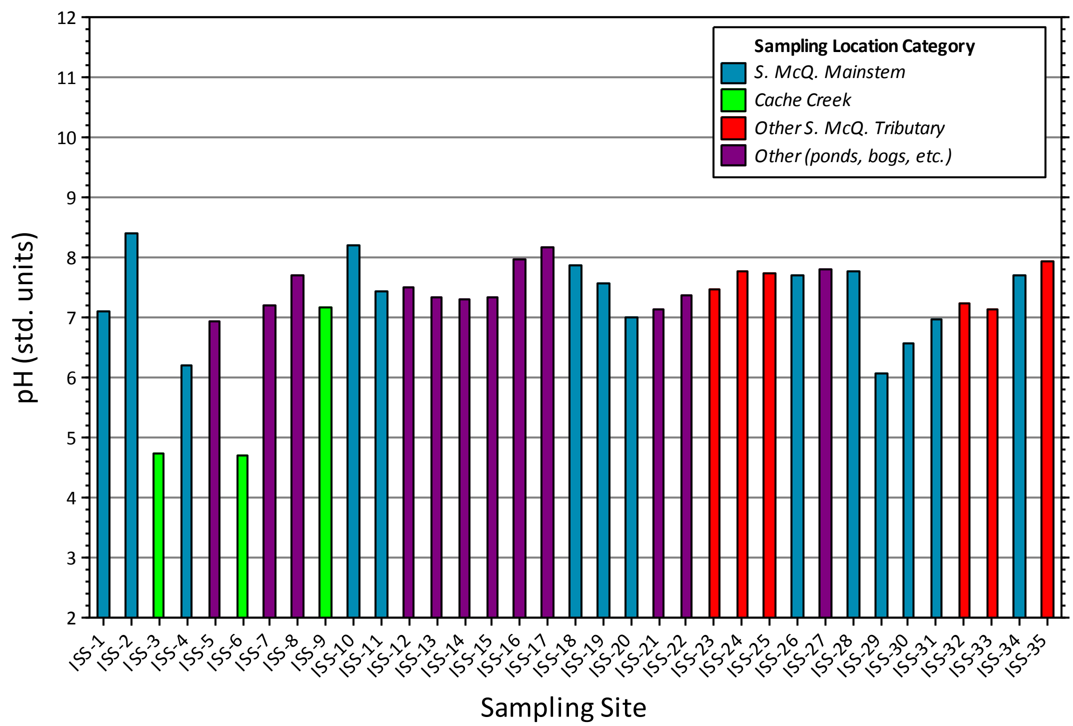

Figure 6. pH of initial screening site samples.

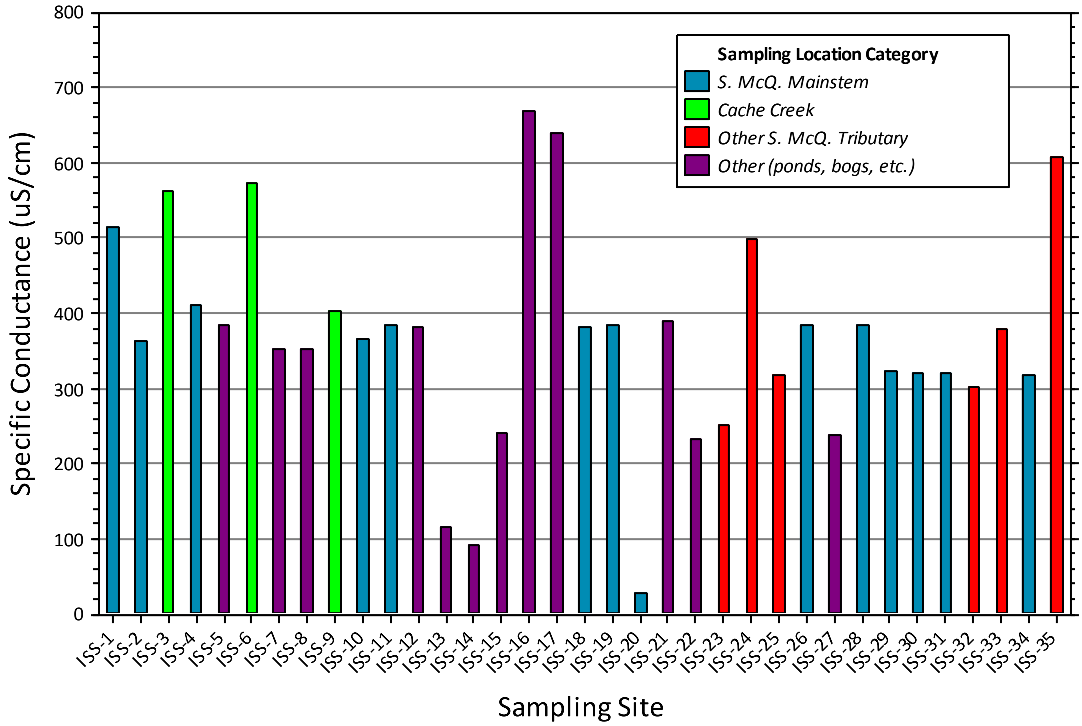

Figure 7. Specific conductance of initial screening site samples.

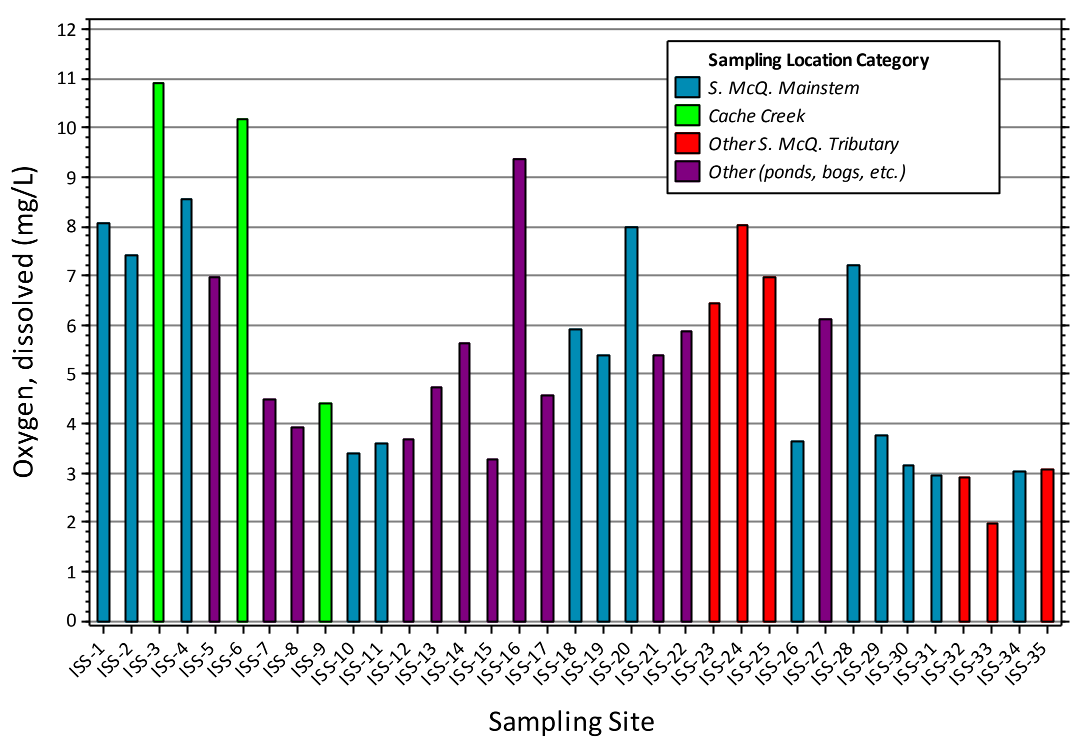

Figure 8. Dissolved oxygen concentrations of initial screening site samples.

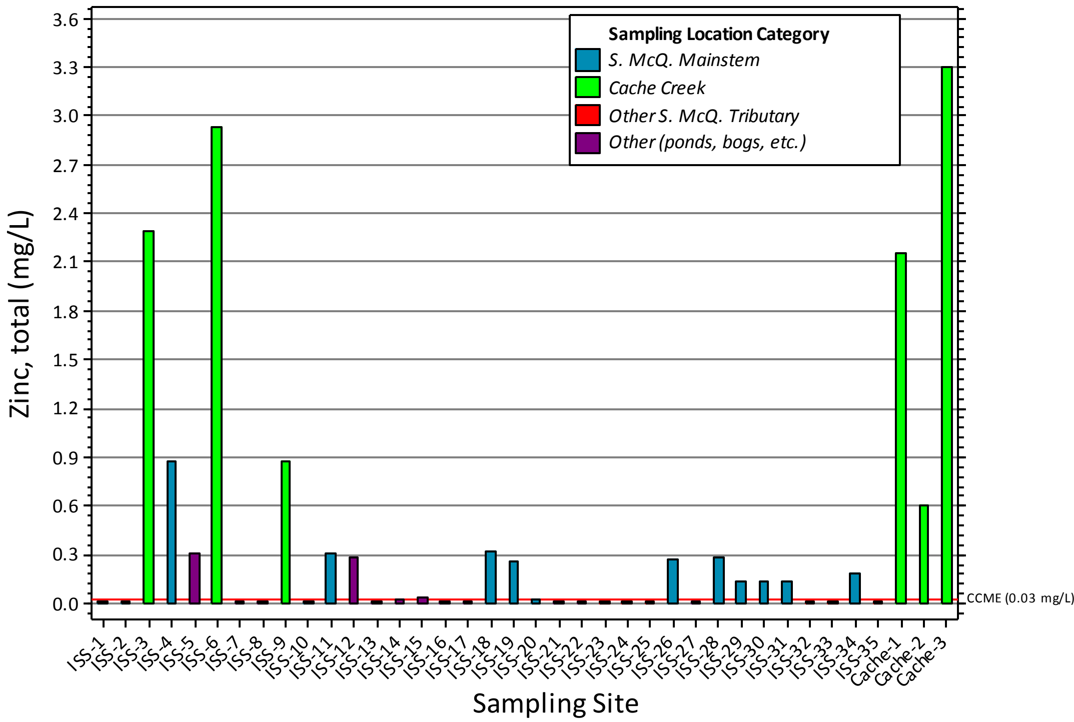

Figure 9. Concentrations of total zinc in initial screening survey samples.

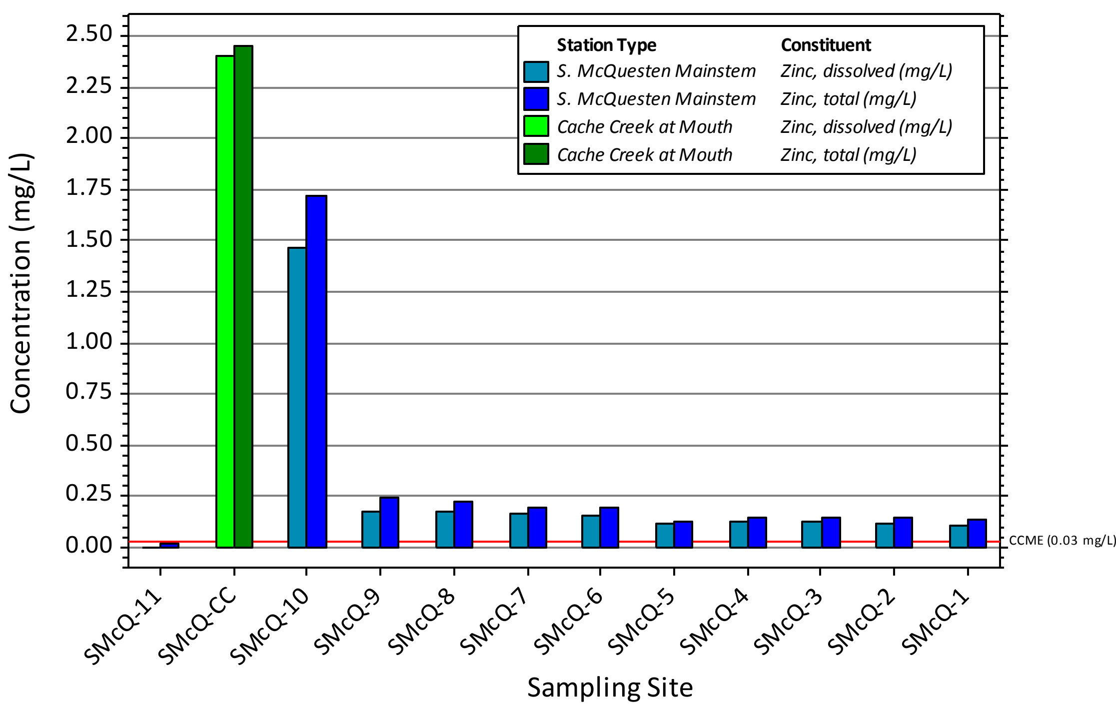

Figure 10. Dissolved and total zinc concentrations for full-suite samples along the main stem of the South McQuesten River.

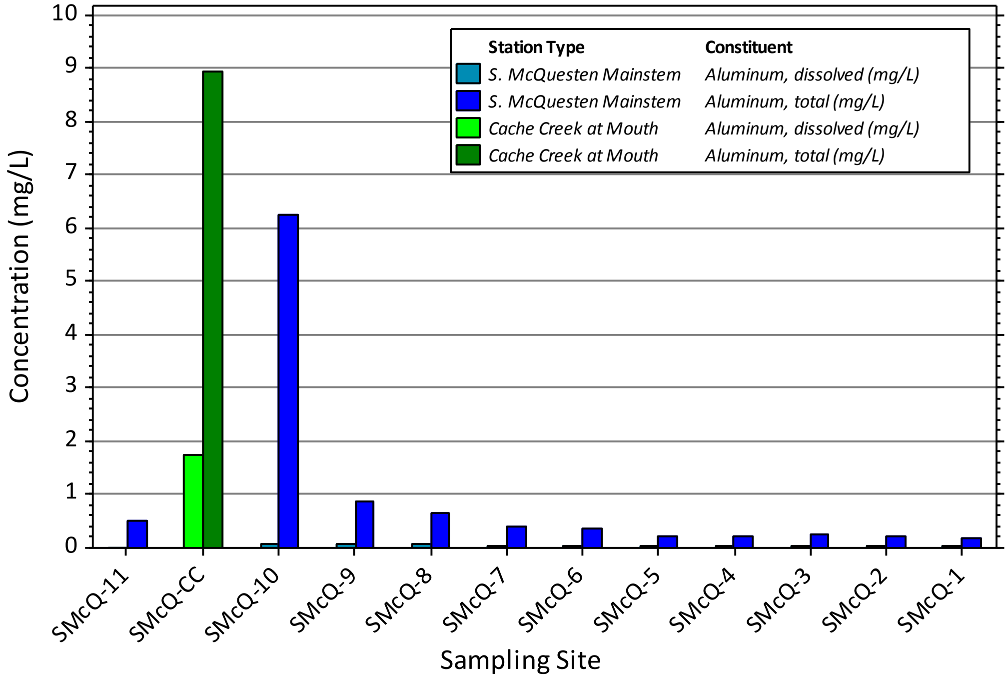

Figure 11. Dissolved and total aluminum concentrations for full-suite samples along the main stem of the South McQuesten River.

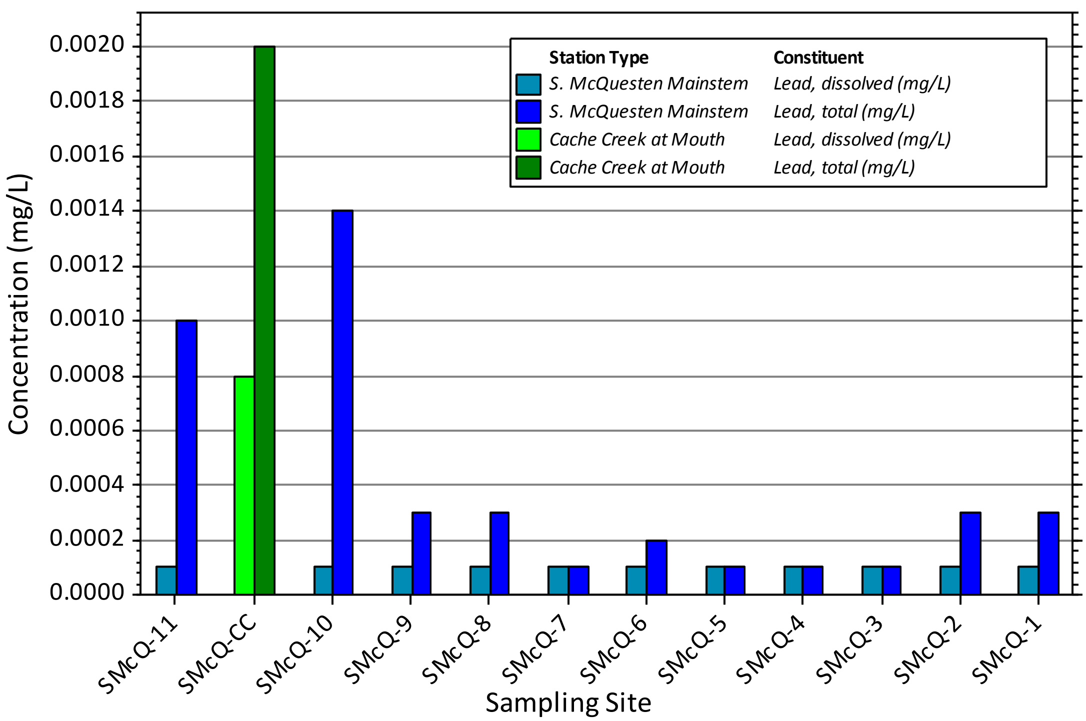

Figure 12. Dissolved and total lead concentrations for full-suite samples along the main stem of the South McQuesten River.

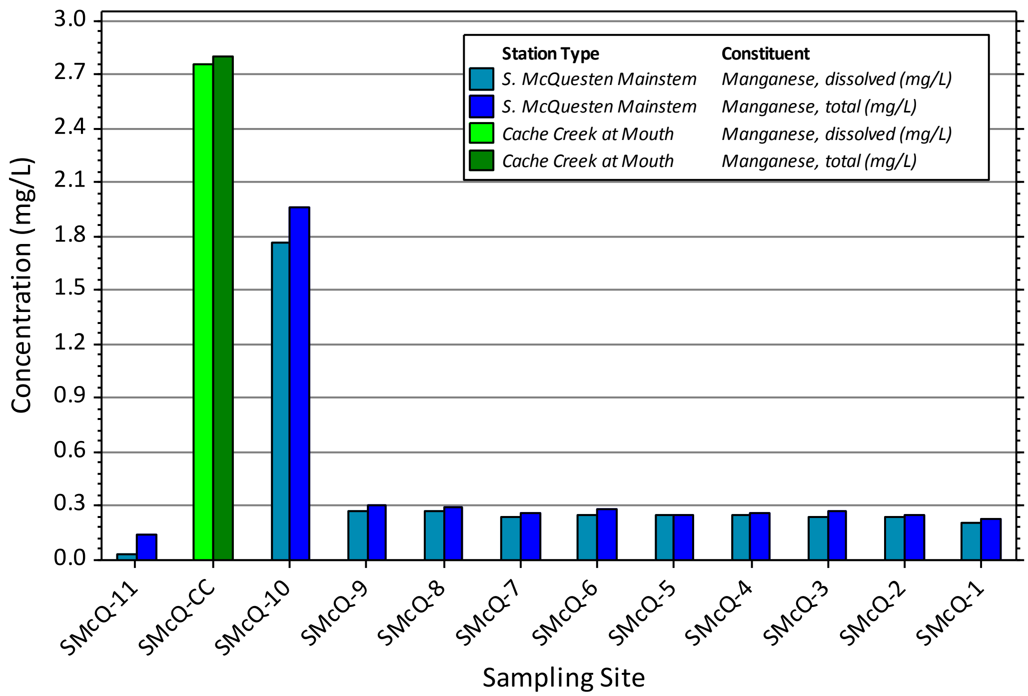

Figure 13. Dissolved and total manganese concentrations for full-suite samples along the main stem of the South McQuesten River.

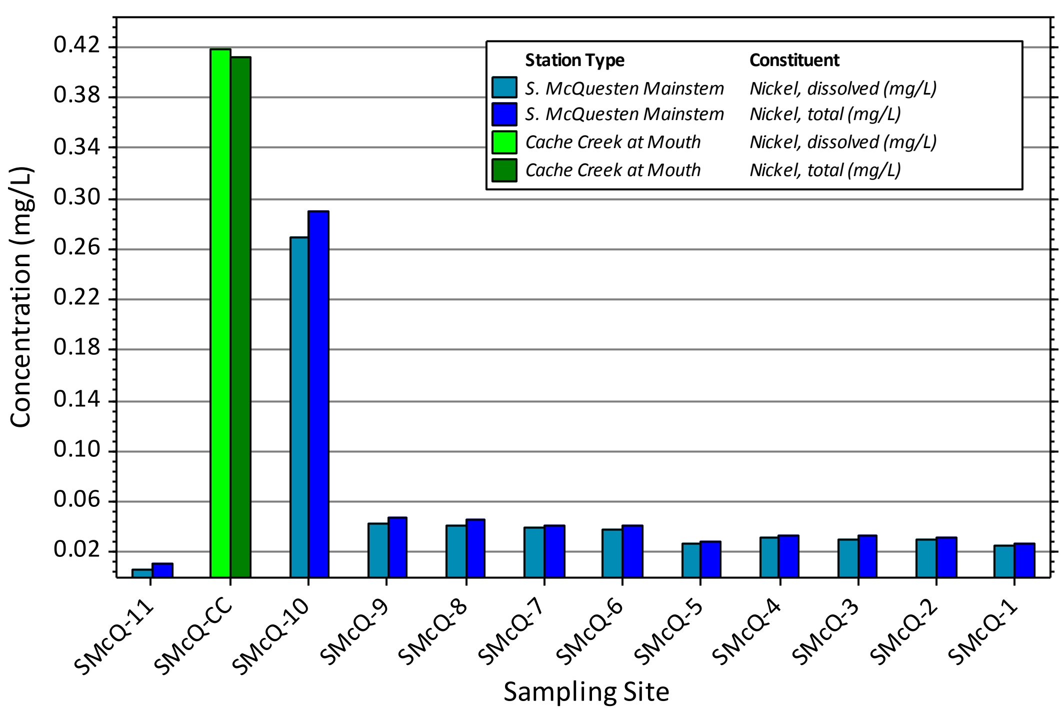

Figure 14. Dissolved and total nickel concentrations for full-suite samples along the main stem of the South McQuesten River.

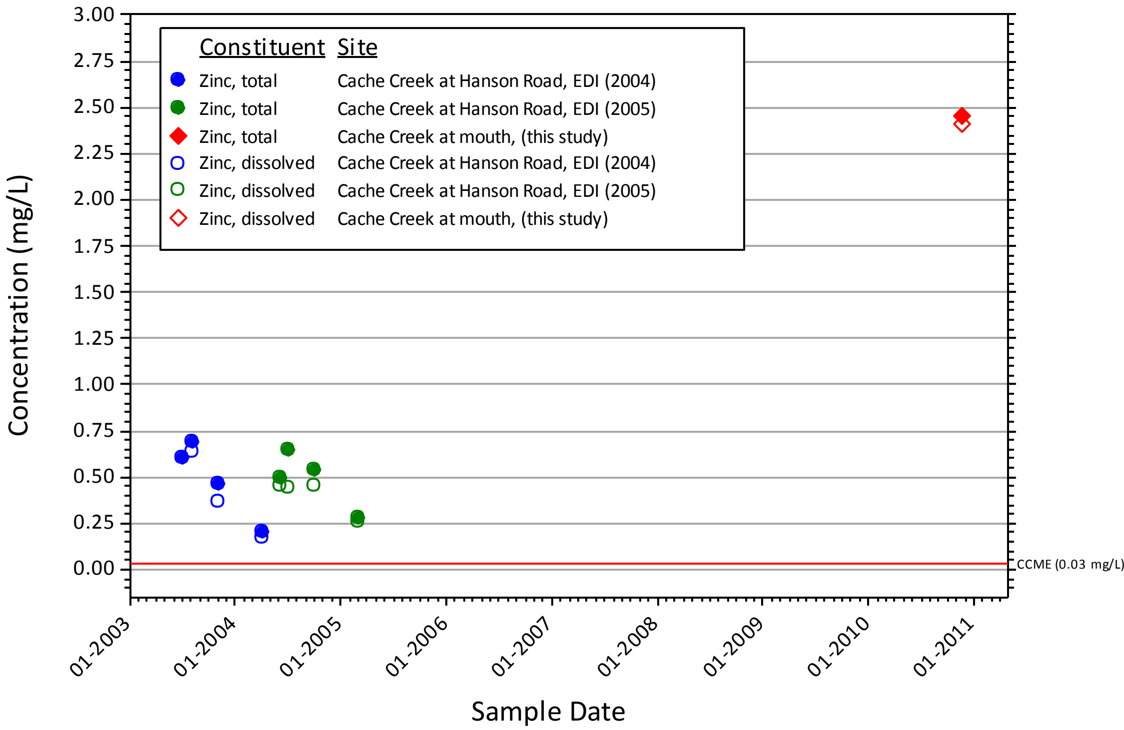

Figure 15. Recent and previous total and dissolved zinc concentrations in Cache Creek.

TABLES

Table 1. Initial screening survey sample information.

Sample Number	Site Name (as recorded)	Site Number	Site Description	Site Type	Easting	Northing	Date	Time	Sample Type
01	1QstLk	ISS-1	McQuesten Lk	S. McQ. Mainstem	482475.89	7104471.63	09/14/10	12:56	Surface Water
02	2Mouthriv	ISS-2	Mouth of river	S. McQ. Mainstem	482244.78	7104504.66	09/14/10	1:39	Surface Water
03	3Creek	ISS-3	Cache Creek	Cache Creek	482271.08	7104435.23	09/14/10	2:19	Surface Water
04	4Dncreek	ISS-4	Downstream of Creek McQuesten River	S. McQ. Mainstem	482198.23	7104460.11	09/14/10	2:49	Surface Water
05	5Stag	ISS-5	Stag Water	Other (ponds, bogs, etc.)	482211.92	7104330.90	09/14/10	3:12	Surface Water
06	6Cache	ISS-6	Cache Creek	Cache Creek	482839.95	7103609.94	09/14/10	4:10	Surface Water
07	7EBOG	ISS-7	East Bog Near McQuesten Lake	Other (ponds, bogs, etc.)	482597.83	7104271.86	09/14/10	4:46	Surface Water
08	8WBOG	ISS-8	West Bog Near McQuesten Lake	Other (ponds, bogs, etc.)	482583.09	7104286.36	09/14/10	5:01	Surface Water
09	9Cache	ISS-9	Water collected near river mouth where water is turbid (shallow side of creek)	Cache Creek	482187.71	7104433.41	09/15/10	10:01	Surface Water
10	10Cache	ISS-10	Clear Water Side of Creek near McQuesten Mouth	S. McQ. Mainstem	482187.71	7104433.41	09/15/10	10:01	Surface Water
11	11RIV	ISS-11	South McQuesten River	S. McQ. Mainstem	482053.48	7104038.62	09/15/10	10:37	Surface Water
12	12RIV	ISS-12	McQuesten River Side Pond	Other (ponds, bogs, etc.)	482053.48	7104038.62	09/15/10	10:37	Surface Water
13	13Pond	ISS-13	South McQuesten Side Pond	Other (ponds, bogs, etc.)	482046.19	7103807.46	09/15/10	11:02	Surface Water
14	14POND	ISS-14	South McQuesten Pond/Bog	Other (ponds, bogs, etc.)	482147.66	7103762.25	09/15/10	11:16	Surface Water
15	15Pond	ISS-15	South McQuesten River Side Pond	Other (ponds, bogs, etc.)	482040.51	7103656.68	09/15/10	11:46	Surface Water
16	16Pond	ISS-16	South McQuesten Side Pond	Other (ponds, bogs, etc.)	481622.34	7103993.88	09/15/10	12:06	Surface Water
17	17Pond	ISS-17	Side Pond near small bog/swamp	Other (ponds, bogs, etc.)	481570.57	7104031.50	09/15/10	12:15	Surface Water
18	18Riv	ISS-18	River Sample (McQuesten)	S. McQ. Mainstem	481699.87	7103759.21	09/15/10	12:51	Surface Water
19	19Riv	ISS-19	River Sample [Next to 98 Fire]	S. McQ. Mainstem	481601.46	7103120.32	09/15/10	1:27	Surface Water
20	20STREAM	ISS-20	Stream Sample McQuesten	S. McQ. Mainstem	481721.16	7103168.39	09/15/10	1:44	Surface Water
21	21Bog	ISS-21	Missing Sample	Other (ponds, bogs, etc.)	481669.88	7103058.56	09/15/10	1:58	Surface Water
22	22Bog	ISS-22	Bog Near McQuesten River	Other (ponds, bogs, etc.)	481602.43	7102781.91	09/15/10	2:23	Surface Water
23	23Creek	ISS-23	Creek Sample (Small source to McQuesten)	Other S. McQ. Tributary	481372.94	7102467.18	09/15/10	2:53	Surface Water
24	24Creek	ISS-24	Missing Sample	Other S. McQ. Tributary	481304.90	7102269.15	09/15/10	3:12	Surface Water
25	25	ISS-25	Creek in Marshy area with lots of Rodents	Other S. McQ. Tributary	481344.52	7101999.02	09/15/10	3:45	Surface Water
26	26	ISS-26	River Sample by 98 Fire area	S. McQ. Mainstem	481344.52	7101999.02	09/15/10	3:45	Surface Water
27	27Lake	ISS-27	Lake (no apparent stream to/from MQR) marsh/bog surrounding area	Other (ponds, bogs, etc.)	481039.89	7101796.47	09/15/10	4:42	Surface Water
28	28Lake	ISS-28	River near stopping point (by lake Sample 27)	S. McQ. Mainstem	481014.16	7101791.88	09/15/10	4:52	Surface Water
29	Site#29MCQ	ISS-29	McQ	S. McQ. Mainstem	480957.08	7101218.09	10/13/10	2:58	Surface Water
30	Site#30MCQ	ISS-30	McQ	S. McQ. Mainstem	481105.37	7100227.21	10/13/10	3:26	Surface Water
31	Site#31MCQ	ISS-31	McQ	S. McQ. Mainstem	480197.28	7099560.50	10/13/10	3:50	Surface Water
32	Site#32CREEK	ISS-32	Creek	Other S. McQ. Tributary	479493.95	7098571.04	10/13/10	4:25	Surface Water
33	Site#33CREEK	ISS-33	Creek	Other S. McQ. Tributary	479486.92	7098504.71	10/13/10	4:36	Surface Water
34	Site#34MCQ	ISS-34	McQ	S. McQ. Mainstem	479014.40	7097718.65	10/13/10	5:16	Surface Water
35	Site#35CREEK	ISS-35	Creek	Other S. McQ. Tributary	478208.75	7097703.00	10/13/10	5:42	Surface Water
36	Cache-1	Cache-1	Cache-1	Cache Creek	n/a	n/a			Surface Water
37	Cache-2	Cache-2	Cache-2	Cache Creek	n/a	n/a			Surface Water
38	Cache-3	Cache-3	Cache-3	Cache Creek	7103274.00	490666.00			Surface Water

Table 2. Initial screening survey results for field measurements and total zinc.

Sample Number	Site Name (as recorded)	Site Number	Site Type	pH	Temp. (deg C)	Conductivity (µS/cm)	ORP (mV)	DO (mg/L)	Zn Conc (mg/L)
01	1QstLk	ISS-1	S. McQ. Mainstem	7.09	9	515.8	85.2	8.07	< 0.005
02	2Mouthriv	ISS-2	S. McQ. Mainstem	8.39	11.3	362.9	103.3	7.42	< 0.005
03	3Creek	ISS-3	Cache Creek	4.73	4.2	562.4	284.8	10.92	2.295
04	4Dncreek	ISS-4	S. McQ. Mainstem	6.21	8.9	410.6	244.6	8.57	0.876
05	5Stag	ISS-5	Other (ponds, bogs, etc.)	6.92	10.8	383.3	161.9	6.97	0.310
06	6Cache	ISS-6	Cache Creek	4.7	4.7	572.8	281.2	10.19	2.935
07	7EBOG	ISS-7	Other (ponds, bogs, etc.)	7.21	10.6	352.6	184.4	4.49	< 0.005
08	8WBOG	ISS-8	Other (ponds, bogs, etc.)	7.71	12.3	352.8	166.8	3.91	< 0.005
09	9Cache	ISS-9	Cache Creek	7.18	7.7	403.1	183.5	4.42	0.875
10	10Cache	ISS-10	S. McQ. Mainstem	8.21	9.6	364.3	164.9	3.38	< 0.005
11	11RIV	ISS-11	S. McQ. Mainstem	7.45	8.6	382.7	166.3	3.58	0.302
12	12RIV	ISS-12	Other (ponds, bogs, etc.)	7.51	8.4	382.1	159.9	3.68	0.286
13	13Pond	ISS-13	Other (ponds, bogs, etc.)	7.33	5.8	114.9	63.6	4.73	0.012
14	14POND	ISS-14	Other (ponds, bogs, etc.)	7.29	5.3	89.7	35.1	5.64	0.022
15	15Pond	ISS-15	Other (ponds, bogs, etc.)	7.33	9.3	240.6	94.7	3.29	0.030
16	16Pond	ISS-16	Other (ponds, bogs, etc.)	7.95	3.6	668.1	117	9.36	< 0.005
17	17Pond	ISS-17	Other (ponds, bogs, etc.)	8.15	8	639.5	111.5	4.58	< 0.005
18	18Riv	ISS-18	S. McQ. Mainstem	7.86	9.2	382.2	129.6	5.9	0.318
19	19Riv	ISS-19	S. McQ. Mainstem	7.55	9.3	384	145.7	5.39	0.257
20	20STREAM	ISS-20	S. McQ. Mainstem	7.01	2.3	25.8	142.6	8.01	0.019
21	21Bog	ISS-21	Other (ponds, bogs, etc.)	7.14	5.2	389.8	28.7	5.4	< 0.005
22	22Bog	ISS-22	Other (ponds, bogs, etc.)	7.36	3.2	230.9	-80.4	5.89	< 0.005
23	23Creek	ISS-23	Other S. McQ. Tributary	7.48	7.5	251.2	26.8	6.44	< 0.005
24	24Creek	ISS-24	Other S. McQ. Tributary	7.77	6.9	498.9	61.7	8.02	< 0.005
25	25	ISS-25	Other S. McQ. Tributary	7.73	3.99	316.7	14	6.96	< 0.005
26	26	ISS-26	S. McQ. Mainstem	7.71	9.5	384.6	14.2	3.66	0.265
27	27Lake	ISS-27	Other (ponds, bogs, etc.)	7.81	11.1	236.6	95.1	6.14	< 0.005
28	28Lake	ISS-28	S. McQ. Mainstem	7.78	9.6	384.6	108.8	7.21	0.278
29	Site#29MCQ	ISS-29	S. McQ. Mainstem	6.07	0.1	321.5	237	3.77	0.139
30	Site#30MCQ	ISS-30	S. McQ. Mainstem	6.56	0.1	319.8	179.1	3.14	0.129
31	Site#31MCQ	ISS-31	S. McQ. Mainstem	6.95	0.1	320.7	142.9	2.94	0.138
32	Site#32CREEK	ISS-32	Other S. McQ. Tributary	7.25	0	300	137.3	2.92	< 0.005
33	Site#33CREEK	ISS-33	Other S. McQ. Tributary	7.12	3.1	378.8	138.3	1.99	< 0.005
34	Site#34MCQ	ISS-34	S. McQ. Mainstem	7.69	0.1	318.2	124.1	3.03	0.185
35	Site#35CREEK	ISS-35	Other S. McQ. Tributary	7.94	0	607.4	135.6	3.06	< 0.005
36	Cache-1	Cache-1	Cache Creek	n/a	n/a	n/a	n/a	n/a	2.156
37	Cache-2	Cache-2	Cache Creek	n/a	n/a	n/a	n/a	n/a	0.605
38	Cache-3	Cache-3	Cache Creek	n/a	n/a	n/a	n/a	n/a	3.300

Table 3. Results of full-suite analysis samples: metals aluminum through manganese.

Constituent	SMcQ-1	SMcQ-CC	SMcQ-2	SMcQ-3	SMcQ-4	SMcQ-5	SMcQ-6	SMcQ-7	SMcQ-8	SMcQ-9	SMcQ-10	SMcQ-11	Cache-3	Canadian Environmental Quality Guidelines for the Long-Term Protection of Aquatic Life
Aluminum, dissolved (mg/L)	0.029	1.75	0.034	0.036	0.039	0.028	0.047	0.052	0.063	0.08	0.076	0.009	102	
Aluminum, total (mg/L)	**0.189**	**8.95**	**0.233**	**0.247**	**0.231**	**0.223**	**0.352**	**0.397**	**0.648**	**0.857**	**6.25**	**0.496**	**101**	0.005 (ph<6.5) or 0.1 (pH ≥ 6.5)
Antimony, dissolved (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	
Antimony, total (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0002	
Arsenic, dissolved (mg/L)	0.0008	0.0002	0.0008	0.0008	0.0008	0.0009	0.0004	0.0004	0.0002	0.0002	0.0001	0.0004	0.0076	
Arsenic, total (mg/L)	0.0009	<0.0001	0.0009	0.0009	0.0009	0.001	0.0004	0.0002	<0.0001	0.0001	<0.0001	0.0012	**0.0069**	0.005
Barium, dissolved (mg/L)	0.061	0.048	0.061	0.061	0.06	0.074	0.052	0.053	0.05	0.049	0.05	0.051	0.0149	
Barium, total (mg/L)	0.067	0.052	0.066	0.067	0.064	0.075	0.057	0.055	0.053	0.053	0.053	0.068	0.0148	
Beryllium, dissolved (mg/L)	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.005	
Beryllium, total (mg/L)	<0.0001	0.0004	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	0.005	
Bismuth, dissolved (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005	
Bismuth, total (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.00005	
Boron, dissolved (mg/L)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.5	
Boron, total (mg/L)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.5	1.5
Cadmium, dissolved (mg/L)	0.00063	0.0143	0.00065	0.0007	0.00074	0.00071	0.001	0.00108	0.00116	0.0012	0.00905	0.00002	0.0611	
Cadmium, total (mg/L)	**0.00075**	**0.0145**	**0.0008**	**0.00083**	**0.00077**	**0.00076**	**0.00119**	**0.00116**	**0.00136**	**0.00137**	**0.0101**	**0.00016**	**0.0594**	Eq.
Calcium, dissolved (mg/L)	63.7	50.1	57.3	58.6	60	60.5	58.2	51.1	51.6	50.7	48.1	51.5	94.3	
Calcium, total (mg/L)	68.1	51.3	61.4	62.8	60.2	59.8	61	54.1	54.3	53.6	52.5	56.2	92.2	
Chromium, dissolved (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	
Chromium, total (mg/L)	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.006	
Cobalt, dissolved (mg/L)	0.0029	0.0713	0.0036	0.0038	0.004	0.0036	0.0049	0.0052	0.006	0.0063	0.046	<0.0005	1.67	
Cobalt, total (mg/L)	0.0031	0.0702	0.0039	0.0042	0.004	0.0036	0.0055	0.0055	0.0064	0.0068	0.049	0.0009	1.64	
Copper, dissolved (mg/L)	0.0018	0.0491	0.0021	0.0021	0.0023	0.002	0.003	0.0033	0.0041	0.0038	0.0101	0.0011	0.628	
Copper, total (mg/L)	0.0051	**0.0537**	0.0048	0.0049	0.0041	0.0036	**0.0052**	**0.0052**	**0.0065**	**0.007**	**0.038**	0.003	**0.614**	Eq.
Iron, dissolved (mg/L)	0.036	0.035	0.041	0.045	0.042	0.056	0.046	0.015	0.016	0.01	0.017	0.018	67	
Iron, total (mg/L)	0.24	**1.68**	0.254	0.265	0.244	0.269	0.253	0.142	0.209	0.228	**1.19**	**1.44**	**64.8**	0.3
Lead, dissolved (mg/L)	<0.0002	0.0008	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0131	
Lead, total (mg/L)	0.0003	0.002	0.0003	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	0.0003	0.0003	0.0014	0.001	0.0132	Eq.
Lithium, dissolved (mg/L)	0.007	0.027	0.008	0.008	0.008	0.007	0.008	0.008	0.008	0.008	0.02	0.006	0.244	
Lithium, total (mg/L)	0.007	0.028	0.007	0.008	0.007	0.007	0.008	0.008	0.008	0.008	0.02	0.006	0.247	
Magnesium, dissolved (mg/L)	20.9	34.1	21.3	21	21.4	21.3	20.5	19.4	18.9	18.8	27.3	17.3	167	
Magnesium, total (mg/L)	20.9	32.1	20.9	21.5	20.4	19.7	20.6	18.8	19	18.9	27.7	17.6	164	
Manganese, dissolved (mg/L)	0.21	2.76	0.235	0.243	0.251	0.248	0.249	0.239	0.271	0.271	1.77	0.028	65.4	
Manganese, total (mg/L)	0.228	2.81	0.256	0.271	0.261	0.249	0.28	0.26	0.294	0.301	1.97	0.143	64.1	

Values in **Bold** exceed applicable CCME guideline

Table 4. Results of full-suite analysis samples: metals mercury through zircomium

Constituent	SMcQ-1	SMcQ-CC	SMcQ-2	SMcQ-3	SMcQ-4	SMcQ-5	SMcQ-6	SMcQ-7	SMcQ-8	SMcQ-9	SMcQ-10	SMcQ-11	Cache-3	Canadian Environmental Quality Guidelines for the Long-Term Protection of Aquatic Life
Mercury, dissolved (mg/L)	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002		
Mercury, total (mg/L)	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.0001	
Molybdenum, dissolved (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0042	
Molybdenum, total (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0058	0.073
Nickel, dissolved (mg/L)	0.025	**0.419**	0.03	0.03	0.032	0.027	0.038	0.04	0.042	0.043	0.27	0.006	4.26	
Nickel, total (mg/L)	0.027	0.413	0.031	0.033	0.033	0.028	0.042	0.041	0.046	0.047	**0.29**	0.011	**4.16**	Eq.
Potassium, dissolved (mg/L)	0.59	0.31	0.6	0.6	0.6	0.74	0.42	0.38	0.39	0.31	0.29	0.34	<0.5	
Potassium, total (mg/L)	0.6	0.29	0.63	0.63	0.6	0.69	0.44	0.37	0.38	0.32	0.3	0.44	<0.5	
Selenium, dissolved (mg/L)	0.0005	0.002	0.0005	0.0005	0.0005	0.0004	0.0006	0.0006	0.0006	0.0006	0.0014	0.0005	0.0029	
Selenium, total (mg/L)	0.0006	**0.0021**	0.0006	0.0007	0.0006	0.0005	0.0007	0.0007	0.0007	0.0008	**0.0016**	0.0007	**0.0031**	0.001
Silicon, dissolved (mg/L)	2.48	4.93	2.31	2.36	2.42	2.68	2.07	1.95	1.92	1.91	3.57	1.67	14.8	
Silicon, total (mg/L)	2.77	5.52	2.6	2.68	2.57	2.8	2.33	2.17	2.2	2.19	4.33	2.85	14.3	
Silver, dissolved (mg/L)	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	0.00035	
Silver, total (mg/L)	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	<0.00002	0.00002	**0.00035**	0.0001
Sodium, dissolved (mg/L)	2.1	0.94	2.21	2.18	2.23	2.5	1.63	1.34	1.32	1.24	0.98	1.29	0.7	
Sodium, total (mg/L)	2.18	0.84	2.3	2.32	2.2	2.34	1.67	1.26	1.29	1.23	0.98	1.26	0.7	
Strontium, dissolved (mg/L)	0.248	0.189	0.253	0.258	0.252	0.255	0.258	0.243	0.243	0.241	0.204	0.254	0.228	
Strontium, total (mg/L)	0.266	0.19	0.268	0.273	0.26	0.252	0.278	0.251	0.258	0.255	0.216	0.266	0.23	
Sulphur, Dissolved (mg/L)	42	97	39	38	39	36	41	36	36	36	73	28	664	
Sulphur, Total (mg/L)	42	95	40	39	37	34	40	34	36	37	76	29	644	
Thallium, dissolved (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00023	
Thallium, total (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00021	0.0008
Tin, dissolved (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0001	
Tin, total (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.0001	
Titanium, dissolved (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Titanium, total (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.008	<0.005	
Uranium, dissolved (mg/L)	0.0009	0.0007	0.0008	0.0008	0.0008	0.0007	0.0009	0.0006	0.0005	0.0005	<0.0001	0.0008	0.0138	
Uranium, total (mg/L)	0.001	0.001	0.0009	0.0009	0.0008	0.0008	0.001	0.0007	0.0007	0.0008	0.001	0.0009	0.0136	0.015
Vanadium, dissolved (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.002	
Vanadium, total (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.002	
Zinc, dissolved (mg/L)	0.108	2.41	0.116	0.121	0.128	0.114	0.157	0.163	0.17	0.177	1.47	<0.005	14.3	
Zinc, total (mg/L)	**0.132**	**2.46**	**0.142**	**0.148**	**0.147**	**0.129**	**0.195**	**0.198**	**0.226**	**0.244**	**1.72**	0.021	**13.9**	0.03
Zirconium, dissolved (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	
Zirconium, total (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	

Values in **Bold** exceed applicable CCME guideline

Table 5. Results of full-suite analysis samples: additional constituents.

Constituent	SMcQ-1	SMcQ-CC	SMcQ-2	SMcQ-3	SMcQ-4	SMcQ-5	SMcQ-6	SMcQ-7	SMcQ-8	SMcQ-9	SMcQ-10	SMcQ-11	Cache-3	Canadian Environmental Quality Guidelines for the Long-Term Protection of Aquatic Life
Alaklinity, Carbonate CO3 (mg CaCO3/L)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Alkalinity, Bicarbonate HCO3 (mg CaCO3/L)	150	1.1	150	150	150	160	130	130	120	120	37	140	<0.5	
Alkalinity, Hydroxide OH (mg CaCO3/L)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Alkalinity, Phenolphelyne (mg CaCO3/L)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Alkalinity, Total (mg CaCO3/L)	130	0.9	120	120	120	130	110	110	100	98	31	120	<0.5	
Carbon, Dissolved Organic (mg/L)	3.6	0.6	3.5	3.3	2.5	2.5	3	3.8	4.1	3.6	1.1	4	<0.5	
Carbon, Total Organic (mg/L)	3.7	1	3.6	3.1	2.6	2.7	3.5	3.9	4	3.7	1.3	4.2	<0.5	
Chloride (mg/L)	4	<0.5	1.2	0.6	0.9	1.7	1.2	<0.5	<0.5	<0.5	0.6	<0.5		
Conductivity, Laboratory (uS/cm)	456	517	434	434	438	435	422	388	387	384	463	377	2530	
Hardness calculated from dissolved metal scan (mgCaCO3/L)	245	266	231	233	238	239	229	207	206	204	232	200	923	
Hardness calculated from total metal scan (mgCaCO3/L)	256	260	239	245	234	231	237	213	214	211	245	213	907	
Nitrate Nitrogen, as N (mg/L)	0.03	0.13	0.02	0.02	0.02	0.03	<0.02	<0.02	<0.02	<0.02	0.09	<0.02	0.07	13
Nitrite and Nitrate Nitrogen, as N (mg/L)	0.03	0.13	0.02	0.02	0.02	0.03	<0.02	<0.02	<0.02	<0.02	0.09	<0.02	0.09	
Nitrite Nitrogen, as N (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.014	0.06
Nitrogen, total N (mg/L)	0.25	0.23	0.24	0.24	0.23	0.23	0.23	0.25	0.56	0.21	0.22	0.23	0.14	
pH, Laboratory (pH units)	8.02	**5.25**	8	7.96	8	8	8	7.99	7.99	7.99	7.19	8.02	**3.12**	6.5 to 9.0
Phosphorus, Total Reactive (Ortho) Phosphate as P (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	
Sulphate, Dissolved (mg/L)	110	260	110	110	110	99	110	99	100	100	200	84	1500	
Total Dissolved Solids (mg/L)	290	350	270	270	270	270	260	230	230	230	300	230	2500	
Total Suspended Solids (mg/L)	2	33	2	3	2	3	3	2	3	4	25	53		

Values in **Bold** exceed applicable CCME guideline