CANADA-BRITISH COLUMBIA WATER QUALITY MONITORING AGREEMENT

WATER QUALITY ASSESSMENT OF THE OKANAGAN RIVER NEAR OLIVER, BRITISH COLUMBIA (1990 – 2007)

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Executive Summary

This report assesses eighteen years of water quality data from the Okanagan River at Oliver, B.C. The Okanagan River originates from Okanagan Lake near Penticton and flows south before draining into Osoyoos Lake, a trans-boundary water body (Figure 1). This station was established and has been monitored on the Okanagan River since 1979 and is currently sampled biweekly (every two weeks). Urbanization, agriculture and logging are the major human impacts threatening water quality in the Okanagan River Basin.

Data that had quality assurance checks performed (i.e., known errors were removed) were compared primarily to the B.C. Environment's *Approved* and *Working Guidelines for Water Quality*, and secondarily to the *Canadian Council of Ministers of the Environment Guidelines for the Protection of Aquatic Life Guidelines*. Of special interest were water quality levels and trends that are deemed deleterious to sensitive water uses such as aquatic life and drinking water.

Conclusions

- The water quality of the Okanagan River at Oliver, for the period 1990 through 2007, is largely improving with numerous parameters with decreasing concentrations; however, there has been an increase in the concentration of specific major ions and a decreasing trend in flow.
- Many parameters had statistically significant increasing trends: dissolved chloride, fecal coliforms, hardness, extractable magnesium, molybdenum, strontium and turbidity.
- Many parameters had statistically significant decreasing trends: aluminum, chromium, colour, copper, flow, iron, lithium, manganese, pH, phosphorus, potassium and zinc.
- Although water temperature is seasonally decreasing, peak summer water temperatures continue to exceed the B.C. aquatic life guideline of 18°C.

- Although true colour, total copper, fluoride, total iron and pH measurements have historically exceeded B.C. or CCME guidelines, these parameters are currently below guideline values.
- Total aluminum concentrations seasonally exceeded the guidelines that are expressed as dissolved concentrations of the metal.
- A number of metals need to be measured differently if comparisons are to be made to guideline values as these exist. The metals and forms required to be measured are aluminum (dissolved and inorganic monomeric, when available), chromium (trivalent and hexavalent), and iron (continue to measure total but also dissolved).

RECOMMENDATIONS

We recommend the continued water quality and flow monitoring of the Okanagan River at Oliver due to its proximity to Osoyoos Lake, a trans-boundary waterbody, and to assess the impact of decreasing flow on overall water quality. We recommend that a minimum of five fecal coliform samples should be collected within a 30-day period during the summer (when coliforms are typically highest) to properly compare fecal coliform levels with B.C. guidelines, specifically to address concerns surrounding the increasing trend in fecal coliform measurements. Finally, we recommend that concentrations of the following parameters be measured in the following forms: aluminum should be measured as dissolved aluminum and chromium as Cr^{+6} and Cr^{+3}.

ACKNOWLEDGEMENTS

The data was reviewed by Ayisha Yeow and Shale Irwin, and a map of the Okanagan River Basin was created by Jennifer MacDonald of Environment Canada. This report was reviewed by Les Swain of Tri-Star Environmental, Andrea Ryan of Environment Canada and Vic Jensen of the B.C. Ministry of Environment. We thank these individuals for their contributions to this document. Any errors or omission are the responsibility of the author.

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INTRODUCTION

The Okanagan River at Oliver water quality monitoring site is located downstream from the Town of Oliver, and upstream from Osoyoos Lake in the southern central part of the B.C. (Figure 1). The drainage area above the sampling site is 7 590 km^2 (B.C. MELP and EC 2000) and extends upstream from Okanagan Lake approximately 164 km north to near Enderby. The Okangan River originates at the south end of Okanagan Lake at Penticton, and flows through Skaha and Vaseux lakes before entering Osoyoos Lake near the US border. The Town of Oliver is located in the warmer and drier part of the Okanagan Valley. Due to this favourable climate, the primary economic activities of the south Okanagan are agriculture, tourism and logging.

This trend site provides important water quality and nutrient loading information for Osoyoos Lake. Earlier studies of Osoyoos Lake found no significant change in its water quality between the mid-1970's and the mid-1990's (Bryan and Jensen 1994; Bryan 1995). The British Columbia Water Quality Status Report (Ministry of Environment, Lands and Parks 1996) ranked Osoyoos Lake as "poor" because the spring phosphorus objective (0.015 mg/L) was never met from 1987 to 1993. Recent trend assessment of Skaha and Osoyoos lakes indicates declining phosphorus in response to declining phosphorus loadings from the City of Penticton over the study period (Jensen and Epps 2002).

This report assesses water quality data collected every two weeks from the Okanagan River at Oliver by Environment Canada and B.C. Environment. Environment Canada operates a flow monitoring station at this location (08NM085).

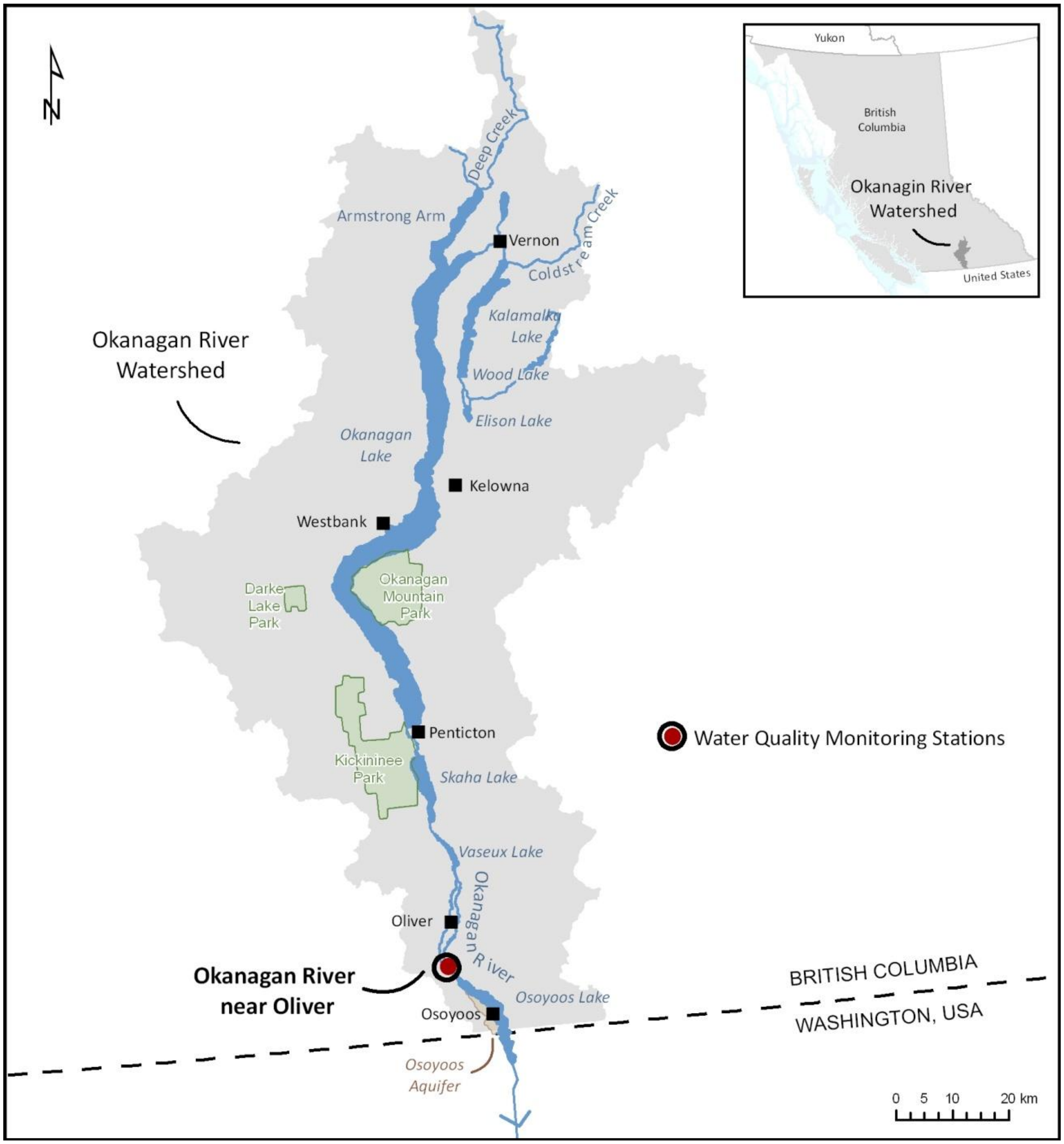


Figure 1: Map of the Okanagan River.

QUALITY ASSURANCE

Efforts were taken to ensure quality control and quality assurance throughout the sample period. Duplicate or triplicate samples and field blanks were scheduled at regular intervals to assess potential sources of sample contamination and precision. The water quality results were reviewed in advance of the preparation of this report and questionable or erroneous values were removed from the dataset. Total dissolved nitrogen results were known to be contaminated between 2003 and 2005 from filters used in analyses and thus, this parameter was not considered in this report.

STATISTICS

Non-parametric statistical tests were used since most water quality parameters are not normally distributed. Time series trend analyses were conducted using the Mann-Kendall trend (MK) and the Seasonal Kendall trend tests (SK). Sen's slope estimate was used to approximate change over time.

The MK test is used to determine significant changes over time, but it cannot account for seasonal changes in a parameter, such as changing concentrations due to freshet events. To account for seasonality in the results, the SK trend test is used. Here, the data is grouped seasonally and the MK test is computed on each individual season (Helsel and Hirsh 2001). Seasonality was defined for all parameters based on month, as suggested by Helsel and Hirsh (2001), and then tested using the Kruskal-Wallis test. Parameters which had significant seasonal differences were further test for trends using the SK trend test.

WATER QUALITY ASSESSMENT

No site-specific water quality objectives have been developed for this portion of the Okanagan River. Therefore, the state of the water quality was determined by comparing the results to the B.C. Environment's *Approved Water Quality Guidelines (*Nagpal *et al*. 2006a*)* and *Working Criteria for Water Quality* (Nagpal *et al*. 2006b), and the *Canadian Council of Ministers of the Environment Guidelines for the Protection of Aquatic Life Guidelines* (2007). Substances which met or rarely exceeded guidelines and displayed no significant trends include the following: alkalinity, antimony, arsenic, barium, beryllium, bismuth, boron, calcium, cobalt, specific conductivity, gallium, lanthanum, lead, nickel, nitrogen and its constituents, rubidium, selenium, silver, sulphate, TDS, TSS, thallium, tin, uranium and vanadium.

Parameters with significant increasing or decreasing trends are outlined below and summarized in Table 1. Parameters which exceeded guidelines are described below.

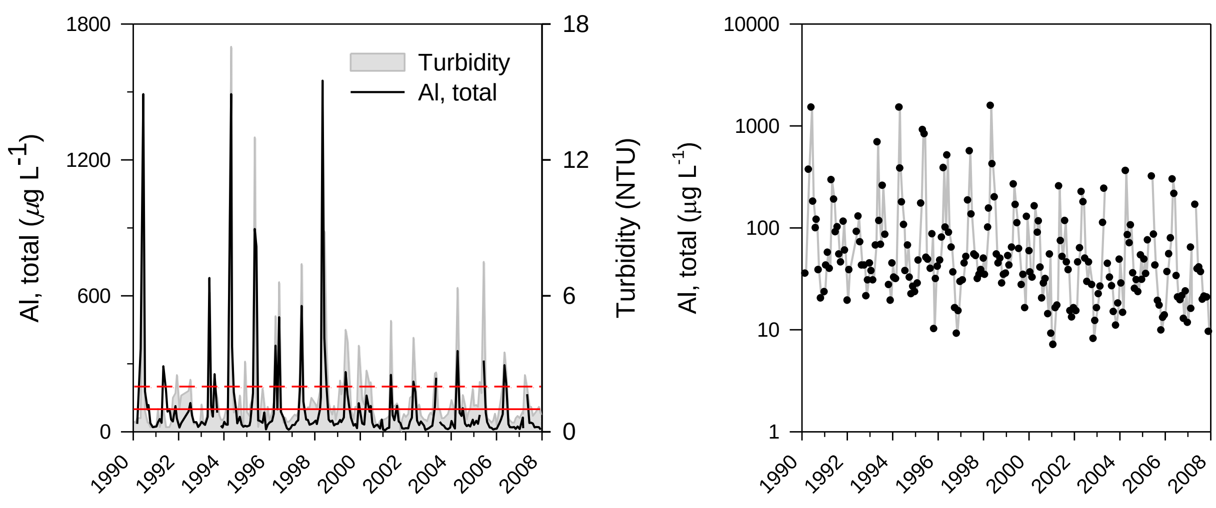
Table 1: Mann-Kendall and Seasonal Kendall results with Sen's Slope Estimation for parameters with statistically significant trends.

Parameter	Mann Kendall (Flow-Transformed)		Seasonal Kendall (Flow-Transformed)	
	P-value	Slope (units $year^{-1}$)	*P*-value	Slope (units $year^{-1}$)
Aluminum, total ($\mu g\ L^{-1}$)	<0.01	-1.7611	<0.01	-1.7467
Chloride, dissolved ($mg\ L^{-1}$)	<0.01	0.1147	<0.01	0.1077
Chromium, total ($\mu g\ L^{-1}$)*	<0.01	-0.0181	<0.01	-0.0179
Colour (units)*	<0.01	-0.3239	<0.01	-0. 3552
Copper, total ($\mu g\ L^{-1}$)	<0.01	-0.0242	<0.01	-0.0243
Fecal Coliforms (CFU cL^{-1})	<0.05	0.8360	<0.01	0.9850
Flow ($m^3\ s^{-1}$)	ns	na	<0.05	-0.0988
Hardness, total ($mg\ L^{-1}$)	ns	na	<0.01	0.3563
Iron, total ($\mu g\ L^{-1}$)	<0.01	-2.0284	<0.01	-1.9449
Lithium, total ($\mu g\ L^{-1}$)	<0.01	-0.1223	<0.01	-0.1228
Magnesium, extractable ($mg\ L^{-1}$)	<0.01	0.0725	<0.01	0.0769
Manganese, total ($\mu g\ L^{-1}$)	<0.05	-0.1114	<0.01	-0.1342
Molybdenum, total ($\mu g\ L^{-1}$)	<0.01	0.0261	<0.01	0.0272
pH (units)	<0.01	-0.0047	<0.01	-0.0050
Phosphorus, total ($mg\ L^{-1}$)	<0.01	-0.0003	<0.01	-0.0003
Potassium ($mg\ L^{-1}$)	ns	na	<0.01	-0.0267
Strontium, total ($\mu g\ L^{-1}$)	<0.05	1.2454	<0.01	1.2800
Turbidity (NTU)	<0.05	0.0148	ns	na
Zinc, total ($\mu g\ L^{-1}$)	<0.01	-0.0173	<0.01	-0.0193

*Decrease likely due to changing MDLs
ns, non-significant
na, not applicable

Aluminum: Total aluminum varies greatly seasonally and has a strong positive correlation with turbidity (Spearman Correlation, $r_s = 0.63$; Figure 2) which suggests that spikes are related to suspended sediment. There is a statistically significant decreasing trend in total aluminum in the Okanagan River (MK, $p < 0.01$; slope = -1.7611 μg L^{-1} year^{-1}; SK, $p < 0.01$; slope = -1.7611 μg L^{-1} year^{-1}; Table 1). Current B.C. water quality guidelines are established for dissolved aluminum. Total aluminum concentrations often exceed the B.C. water quality guidelines for aquatic life and drinking water for dissolved aluminum (100 μg L^{-1} and 200 μg L^{-1}, respectively). However, since these seasonal spikes are highly correlated with turbidity, they are likely bound with particulate matter and not biologically available. Furthermore, turbidity-driven exceedences in total aluminum have been decreasing and are currently near guidelines for dissolved aluminum (Figure 2).

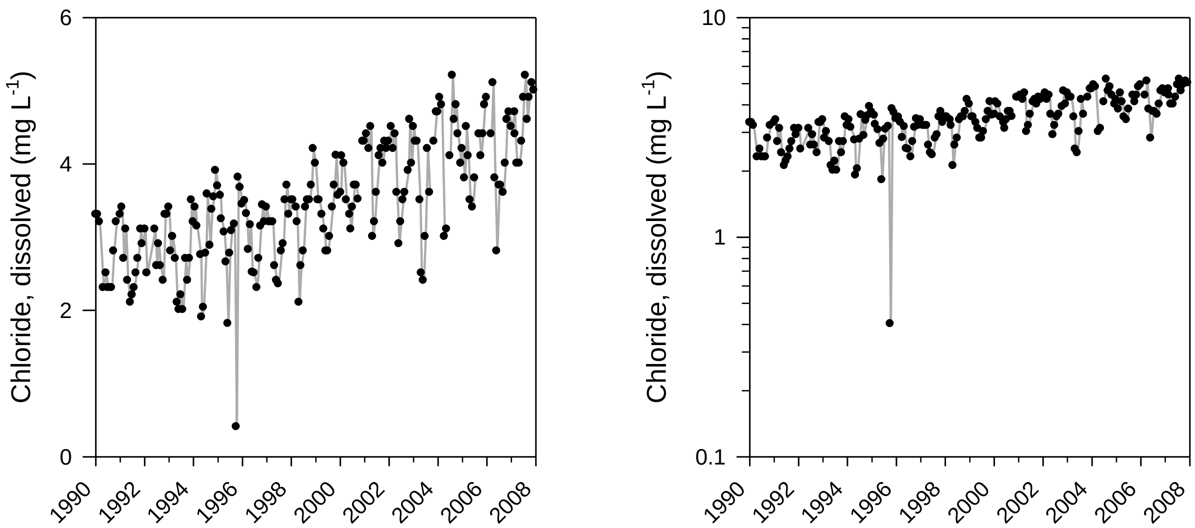
Figure 2: Total aluminum and turbidity (left) and total aluminum log-scale (right) concentrations from 1990 to 2008.



Note: Dashed red line refers to the B.C. drinking water guideline for dissolved aluminum; the solid red line refers to the B.C. Aquatic Life Guideline for dissolved aluminum.

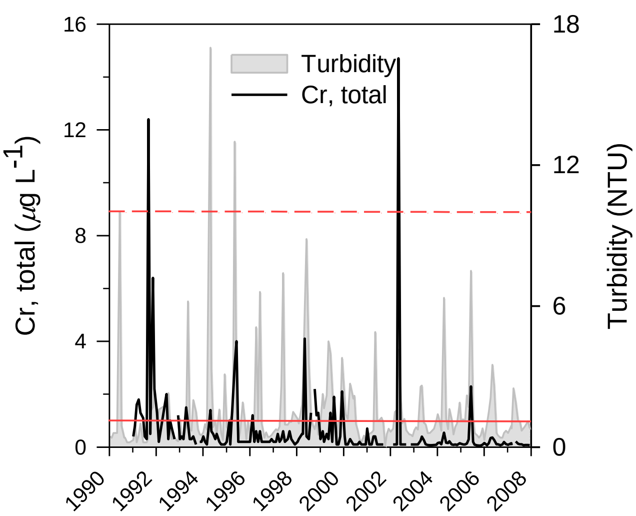
Chloride: Dissolved chloride concentrations have been significantly increasing since 1990 (MK, $p < 0.01$; slope = 0.1147 mg L^{-1} $year^{-1}$; SK, $p < 0.01$; slope = 0.1077 mg L^{-1} $year^{-1}$; Table 1;Figure 3). Dissolved chloride concentrations are currently well below B.C. water quality guidelines.

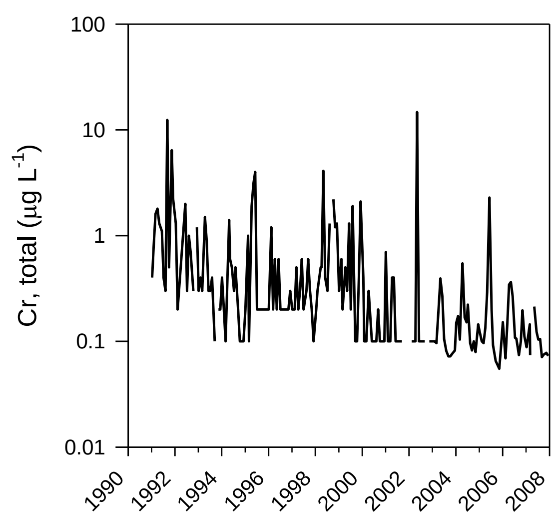
Figure 3: Normal (left) and log-scale (right) dissolved chloride concentrations from 1990 to 2008.



Chromium: Similar to other metals, total chromium varies greatly seasonally and is weakly correlated with turbidity (Spearman Correlation, $r_s = 0.27$; Figure 4) suggesting that spikes may be related to suspended sediments. Although both MK and SK tests resulted in significant decreasing trends (MK, $p < 0.01$, slope = -0.0181 μg L^{-1} $year^{-1}$; SK, $p < 0.01$, slope = -0.0179 μg L^{-1} $year^{-1}$; Table 1), changing (lowering) detection limits over time limit our ability to conclude that total chromium concentrations are decreasing (see log-scale total chromium concentrations in Figure 4). The current B.C. working water quality guideline for aquatic life for chromium is 1 μg L^{-1} (Cr VI) and 8.9 μg L^{-1} (Cr III). Total chromium exceeds these guidelines seasonally, although recent chromium results suggest that current concentrations rarely exceed the guideline for Cr VI (Figure 4).

Figure 4: Total chromium and turbidity (left) and total chromium log-scale (right) concentrations from 1990 to 2008.

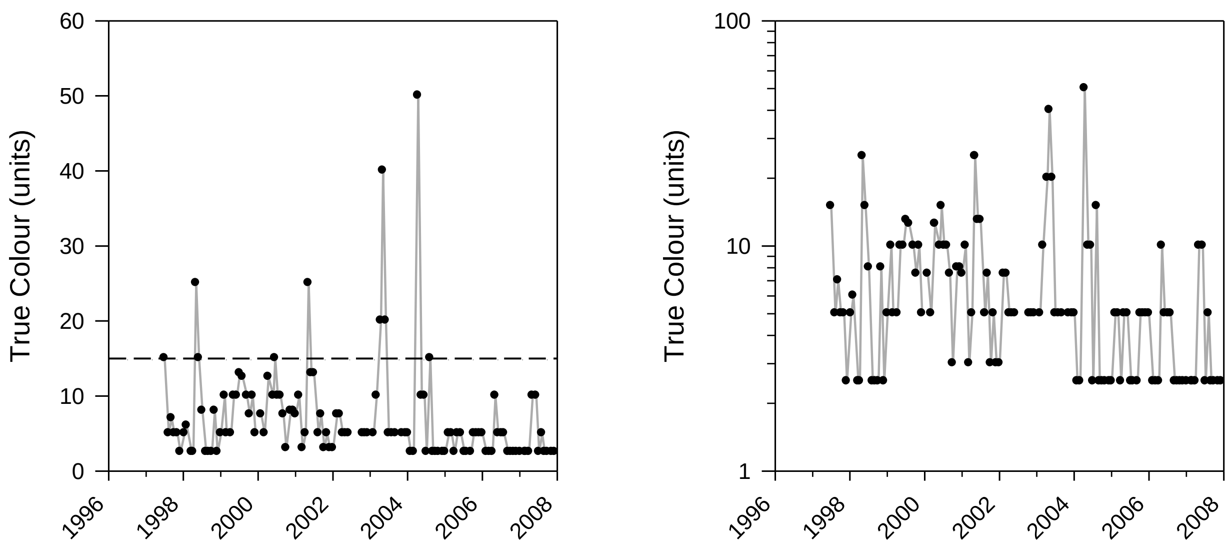




Note: The solid red line denotes the B.C. Working Aquatic Life Water Quality Guideline for Cr VI; the dashed-red line denotes the B.C. Working Aquatic Life guideline for Cr III.

Colour: True colour has been measured from 1997 to present. Colour measurements were negatively correlated with specific conductivity (Spearman Correlation, r_s = -0.44). Statistical test suggest a decreasing trend in true colour since 1990 (MK, p < 0.01, slope = -0.3239 units L^{-1} $year^{-1}$; SK, p < 0.01, slope = -0.3552 units L^{-1} $year^{-1}$; Table 1; Figure 5); lowering laboratory detection limits over time have likely interfered with the statistical analyses (see Figure 5, true colour log-scale over time) and therefore, we cannot conclude that colour concentrations have been significantly decreasing since 1997. True colour measurements periodically exceeded the B.C. drinking water quality guideline of 15 mg/L Pt seasonally; however, recent true colour results suggest that concentrations are below the drinking water guideline.

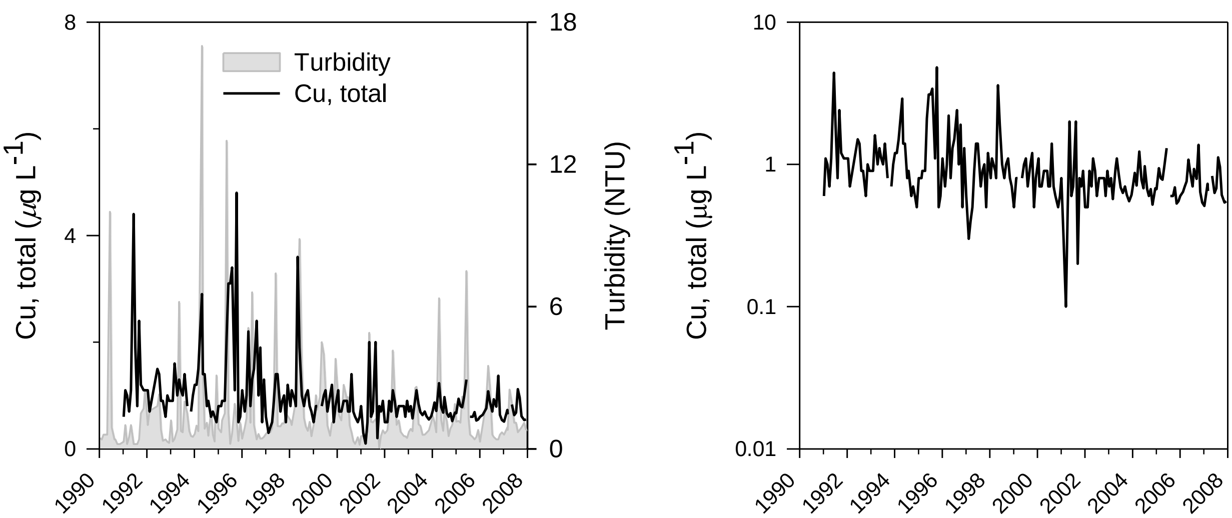
Figure 5: True colour measurements from 1997 to 2008.



Note: The dashed line denotes the B.C. Drinking Water Guideline for true colour.

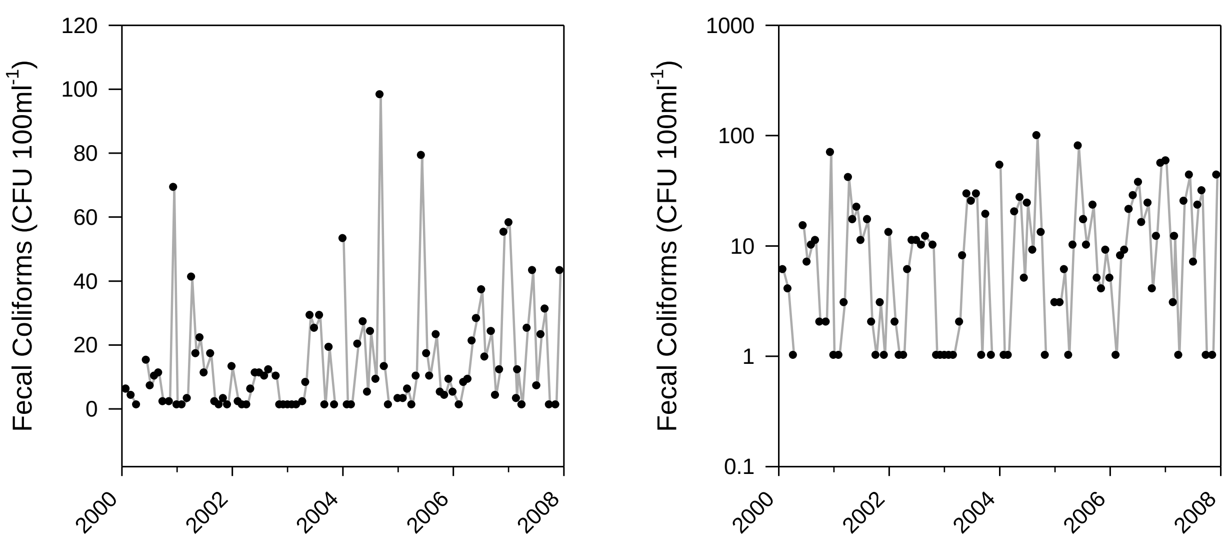
Copper: Total copper varies greatly seasonally and has a weak positive correlation with turbidity (Spearman Correlation, $r_s = 0.26$). There has been a significant decreasing trend in total copper since 1991 (MK, $p < 0.01$, slope = -0.0242 μg L^{-1} year^{-1}; SK, $p < 0.01$, slope = -0.0243 μg L^{-1} year^{-1}; Table 1; Figure 6). The B.C. aquatic life guideline for copper is hardness dependant and ranged from 10 to 16 μg L^{-1} (median of 14 μg L^{-1}) during the sample period, but total copper results are well below these thresholds (Figure 6).

Figure 6: Total copper and turbidity (left) and total copper log-scale (right) concentrations from 1990 to 2008.



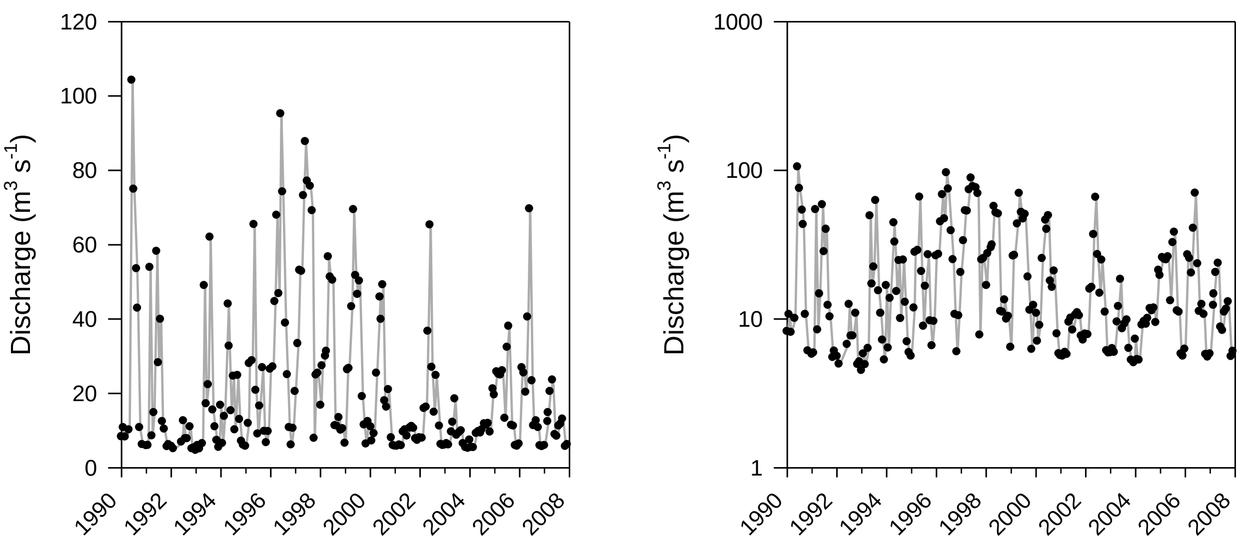
Fecal Coliforms: Fecal coliform measurements have been significantly increasing since 1990 (MK, $p < 0.05$, slope = 0.8360 CFU cL^{-1} $year^{-1}$; SK, $p < 0.01$, slope = 0.9850 CFU cL^{-1} $year^{-1}$; Table 1; Figure 7). Currently, B.C. water quality guidelines for fecal coliforms are based on a 5 sample in 30 day sampling regime and thus, we cannot compare fecal coliform results with guideline values. The values are all below the recreational guideline but above various drinking water guidelines depending on level of treatment. Trend tests suggest that coliform concentrations are increasing at a rate of nearly 1 unit per year (Table 1).

Figure 7: Fecal Coliform results from the Okanagan River at Oliver from 1990 to 2008.



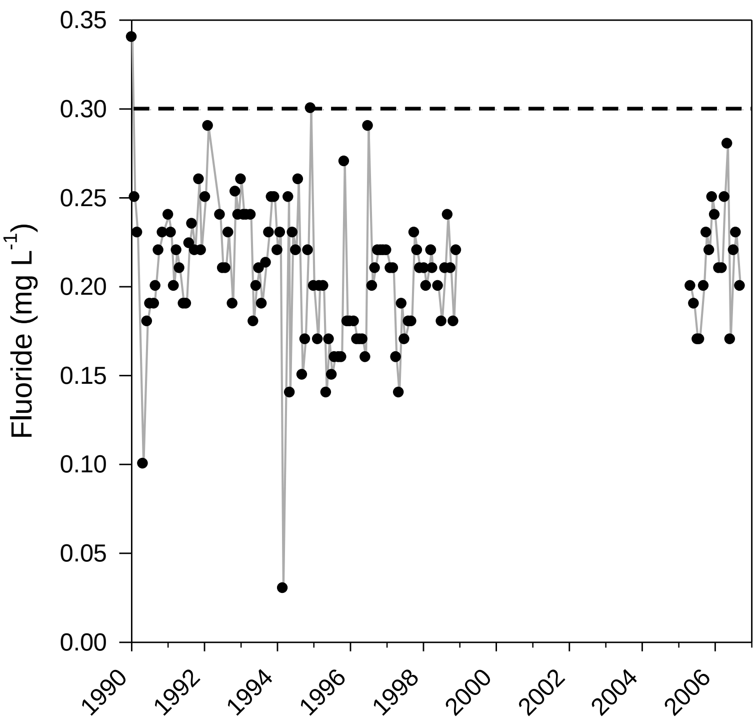
Flow: Daily average discharge is measured at a collocated hydrometric station. Peak river flows occur during May, June and July while base flows occur during the winter months. A Seasonal Kendall test was performed on daily average discharge measurements on sample days and resulted in a significant decreasing trend from 1990 to 2008 (SK, $p < 0.05$, slope = -0.0988 $m^3\ s^{-1}\ year^{-1}$; Table 1). River flow may be related to changing precipitation patterns or a result of water withdrawals for municipal, agricultural and industrial uses, and may negatively impact aquatic habitat.

Figure 8: Average river discharge on water sampling days from 1990 to 2008.



Fluoride: Fluoride was measured continuously up to 1999 and then again starting in 2005 to 2007. Although past concentrations periodically exceeded the B.C. aquatic life guideline of 0.3 mg L^{-1}, current concentrations remain below this guideline (Figure 9).

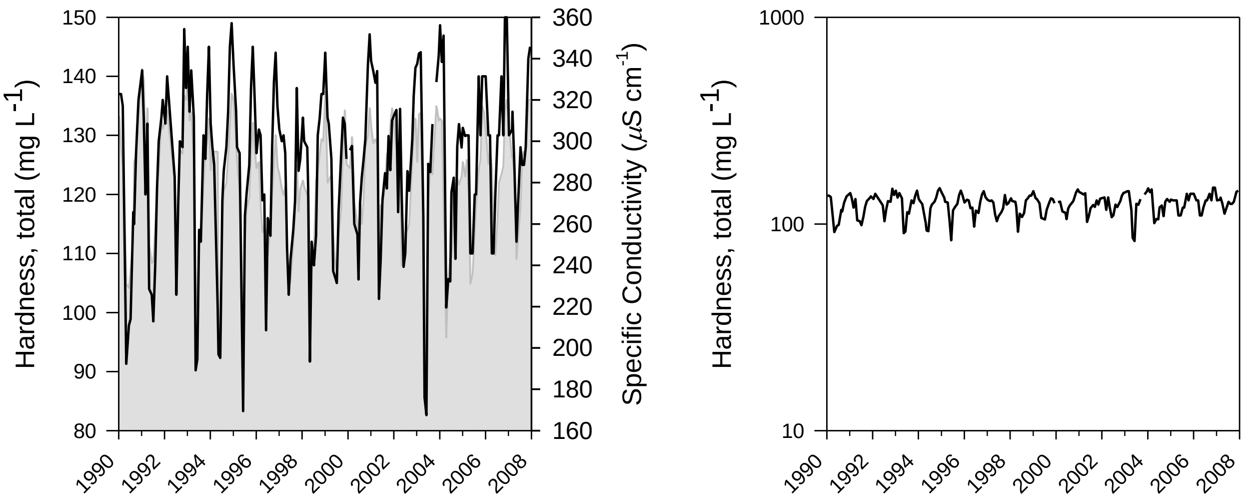
Figure 9: Fluoride concentrations in the Okanagan River from 1990 to 1999 and 2005 to 2007.



Note: The dash-line represent the B.C. aquatic life guideline for fluoride in water bodies with total hardness greater than 50 mg L^{-1}.

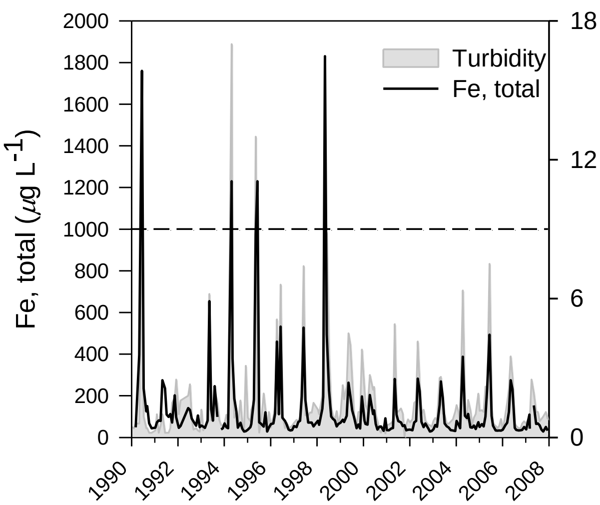
Hardness: Total hardness concentrations in the Okanagan River have been significantly increasing since 1990 (SK test, $p < 0.01$, slope = 0.3563 mg L^{-1} $year^{-1}$; Table 1; Figure 10). Total hardness is a function of calcium and magnesium concentrations, and its increase is largely accounted for by the increase in magnesium concentrations (see below). There are no guidelines for total hardness.

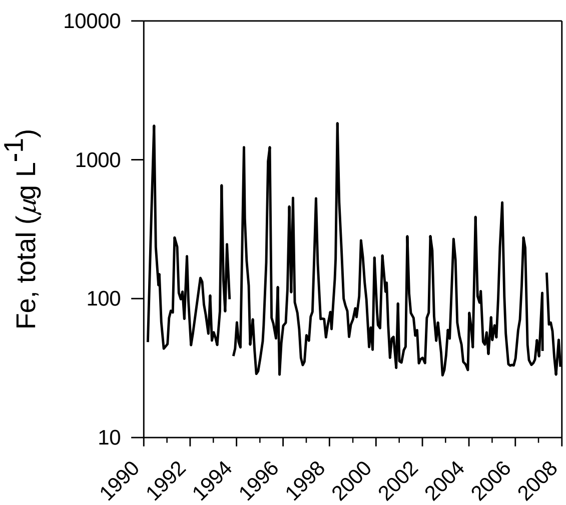
Figure 10: Total hardness concentrations in the Okanagan River from 1990 to 2008.



Iron: Total iron concentrations have significantly decreased in the Okanagan River from 1990 to 2008 (MK, $p < 0.01$, slope = -2.0284 μg L^{-1} $year^{-1}$; SK, $p < 0.01$, slope = -1.9449 μg L^{-1} $year^{-1}$; Table 1; Figure 11). Total iron concentrations are positively correlated with turbidity measurements (Spearman correlation, $r_s = 0.59$) and turbidity-driven spikes periodically exceeded the B.C. aquatic life guideline of 1000 μg L^{-1}; recent (post-1998) concentrations are below the B.C. aquatic life guideline (Figure 11).

Figure 11: Normal (left) and log-scale (right) total iron concentrations in the Okanagan River from 1990 to 2008.

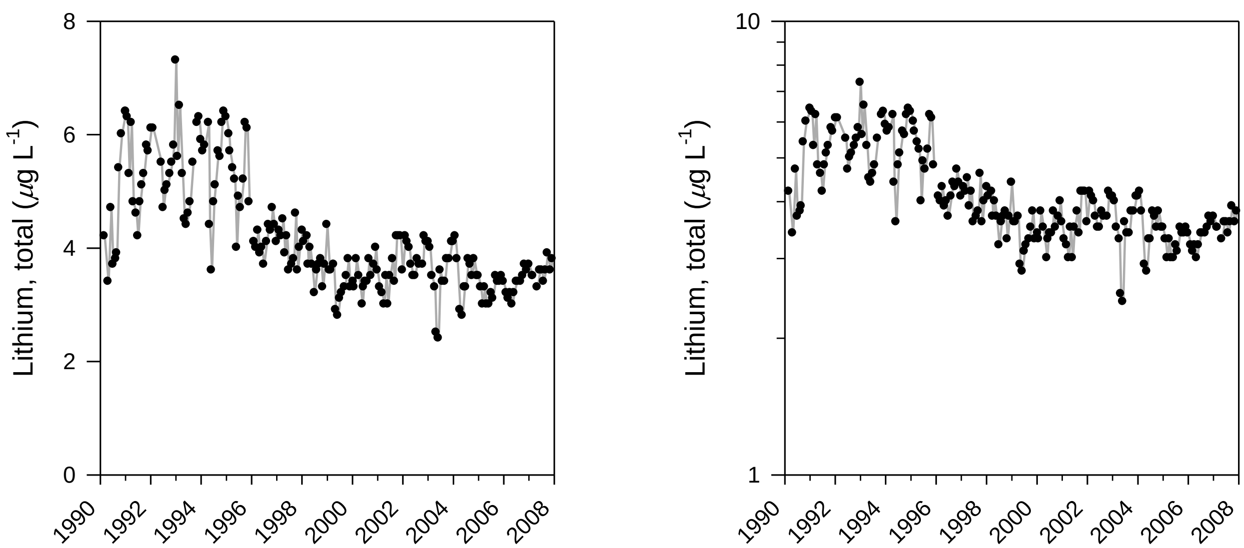




Note: The dashed line represents the B.C. Aquatic Life Water Quality Criterion of 1000 μg L^{-1}.

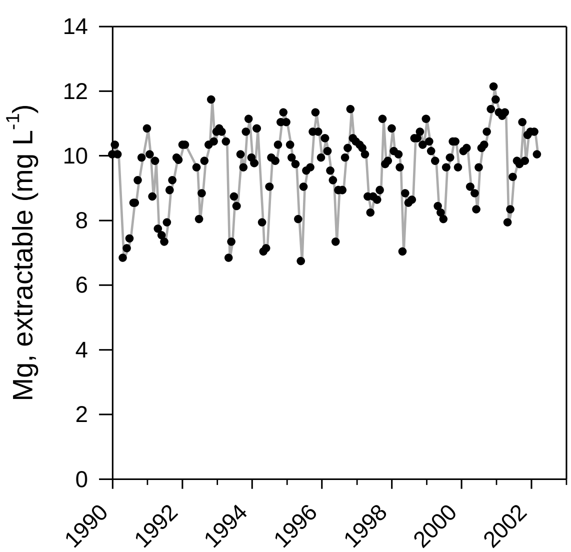
Lithium: Total lithium concentrations have significantly decreased in the Okanagan River since 1990 (MK test, $p < 0.01$, slope = -0.1223 μg L^{-1} $year^{-1}$; SK test, $p < 0.01$, slope = -0.1228 μg L^{-1} $year^{-1}$; Table 1; Figure 12). Current total lithium concentrations are well below the B.C. working water quality guidelines.

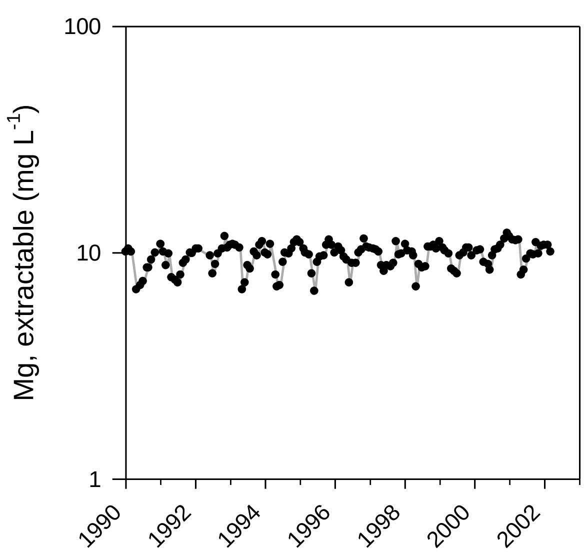
Figure 12: Total lithium concentrations in the Okanagan River from 1990 to 2008.



Magnesium: Extractable magnesium concentrations had been significantly increasing in the Okanagan River from 1990 to 2002 (MK test, $p < 0.01$, slope = 0.0725 mg L^{-1} $year^{-1}$; SK test, $p < 0.01$, slope = 0.0769 mg L^{-1} $year^{-1}$; Table 1; Figure 13). The increasing trend in total hardness very likely a result of the increasing trend in magnesium, since magnesium is a major component in the calculation of total hardness. There are currently no B.C. drinking water or aquatic life guidelines for magnesium.

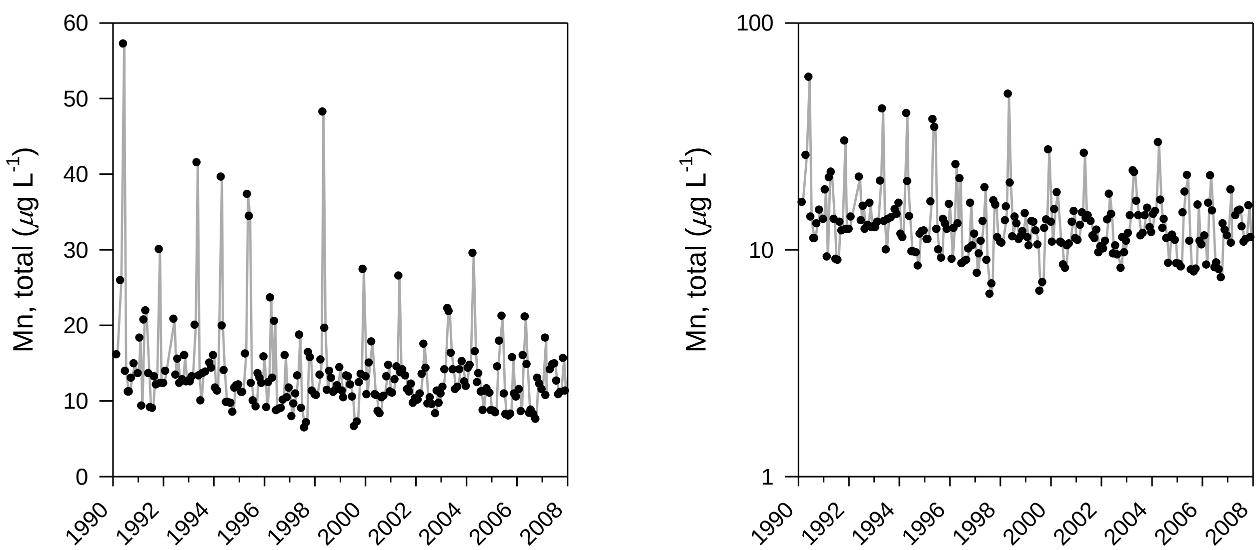
Figure 13: Normal (left) and log-scale (right) extractable magnesium concentrations in the Okanagan River from 1990 to 2002.





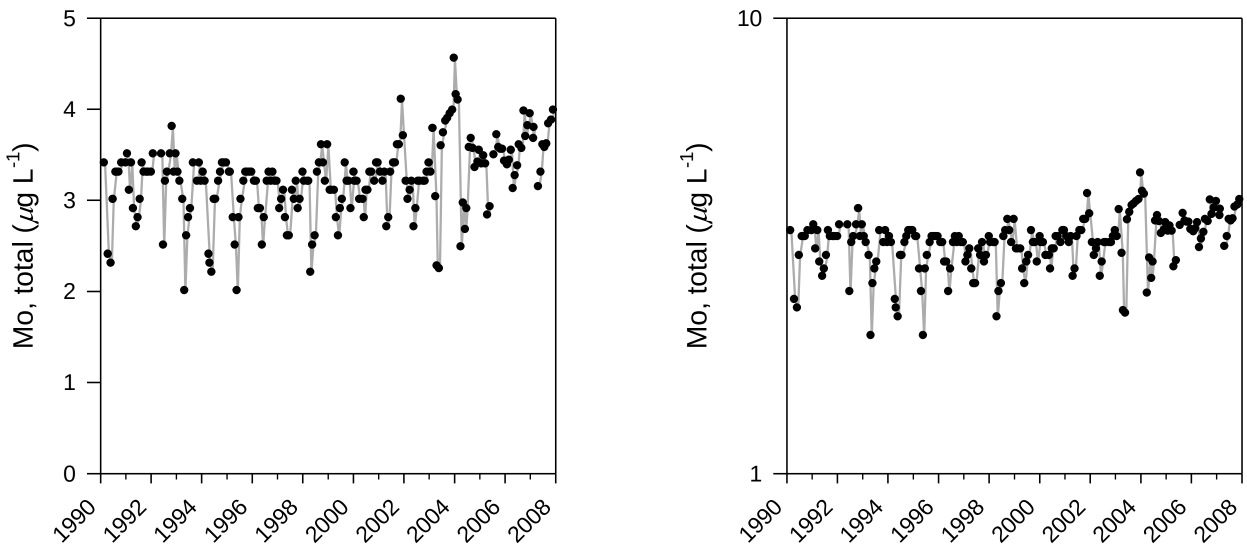
Manganese: Total manganese concentrations have been steadily decreasing since 1990 (MK test, $p < 0.05$, slope = -0.1114 μg L^{-1} $year^{-1}$; SK test, $p < 0.01$, slope = -0.1342 μg L^{-1} $year^{-1}$; Table 1; Figure 14). Past and current total manganese concentrations are well below the B.C. aquatic life guideline and the B.C. working water guideline for irrigation.

Figure 14: Normal (left) and log-scale (right) total manganese concentrations in the Okanagan River from 1990 to 2008.



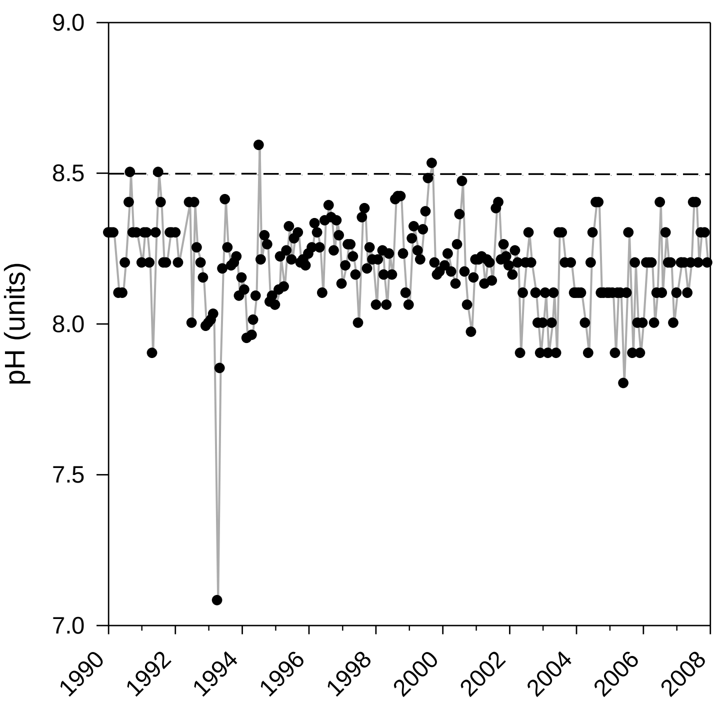
Molybdenum: Total molybdenum concentrations have been significantly increasing since 1990 (MK test, $p < 0.01$, slope = 0.0261 $\mu g\ L^{-1}\ year^{-1}$; SK test, $p < 0.01$, slope = 0.0272 $\mu g\ L^{-1}\ year^{-1}$; Table 1; Figure 15). Although total molybdenum is increasing in the Okanagan River, concentrations are well below B.C. water quality guidelines.

Figure 15: Total molybdenum normal (left) and log-scale (right) concentrations in the Okanagan River from 1990 to 2008.



pH: The Okanagan River is slightly basic with pH measurements often between 8 and 8.5 pH units. pH measurements have been slowly decreasing in the Okanagan River since 1990 (MK test, $p < 0.01$, slope = -0.0047 units year^{-1}; SK test, $p < 0.01$, slope = -0.0050 units year^{-1}; Table 1; Figure 16); however, this trend may be due to a change in pH analytical methods to low-ionic strength meters during the sample period, and these meters provide more accurate results. Previous pH measurements in the Okanagan River periodically exceeded the upper threshold of the B.C. drinking water quality guideline of 8.5 pH units, but recent measurements (since 2000) have not exceeded this upper threshold.

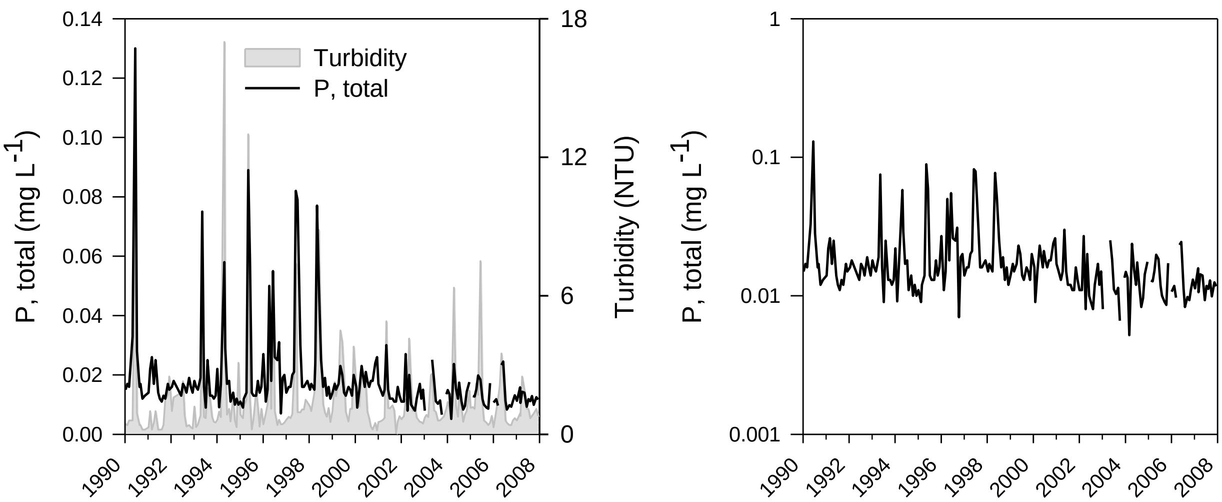
Figure 16: pH measurements in the Okanagan River from 1990 to 2008.



Note: Dashed line represent the upper threshold for the B.C. drinking water guideline for pH.

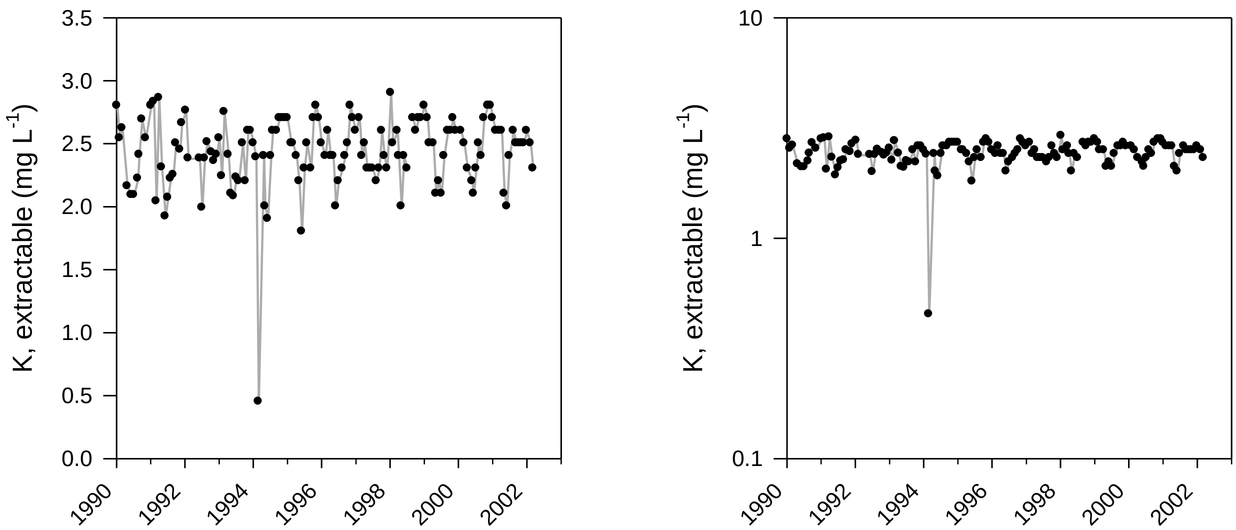
Phosphorus: Total phosphorus concentrations have been gradually decreasing since 1990 (MK test, $p < 0.01$, slope = -0.0003 mg L^{-1} $year^{-1}$; SK test, $p < 0.01$, slope = -0.0003 mg L^{-1} $year^{-1}$; Table 1; Figure 17) and particularly since 1998. Previous total phosphorus concentrations exceeded 0.1 mg L^{-1}, but recent concentrations typically range from 0.01 to 0.02 mg L^{-1} (Figure 17). There is no B.C. water quality guideline for total phosphorus for rivers and streams.

Figure 17: Total phosphorus and turbidity (left) and total phosphorus log-scale (right) concentrations from 1990 to 2008.



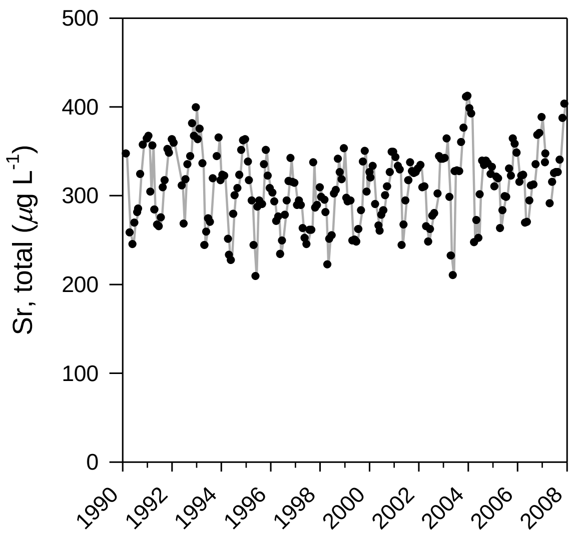
Potassium: Potassium concentrations have been seasonally decreasing in the Okanagan River since 1990 (SK test, $p < 0.01$, slope = -0.0267 mg L^{-1} $year^{-1}$; Table 1; Figure 18). Potassium concentrations are well below the B.C. working aquatic life guideline of 373 to 432 mg L^{-1}.

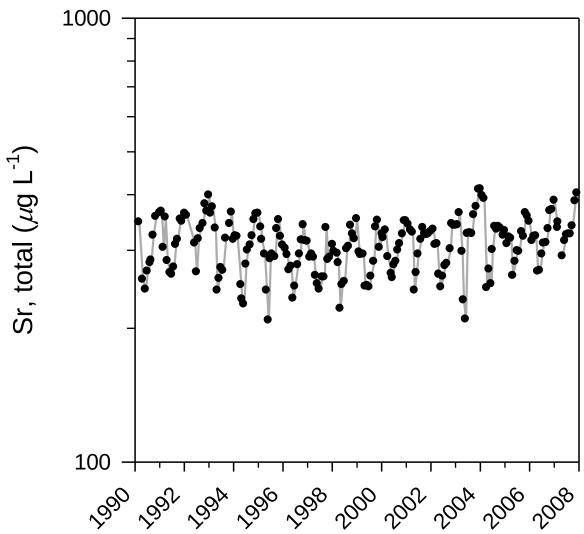
Figure 18: Potassium normal (left) and log-scale (right) concentrations from 1990 to 2008.



Strontium: Total strontium concentrations have been steadily increasing in the Okanagan River since 1990 (MK test, $p < 0.05$, slope = 1.2454 μg L^{-1} $year^{-1}$; SK test, $p < 0.01$, slope = 1.28 μg L^{-1} $year^{-1}$; Table 1; Figure 19). There are currently no B.C. water quality guidelines for strontium.

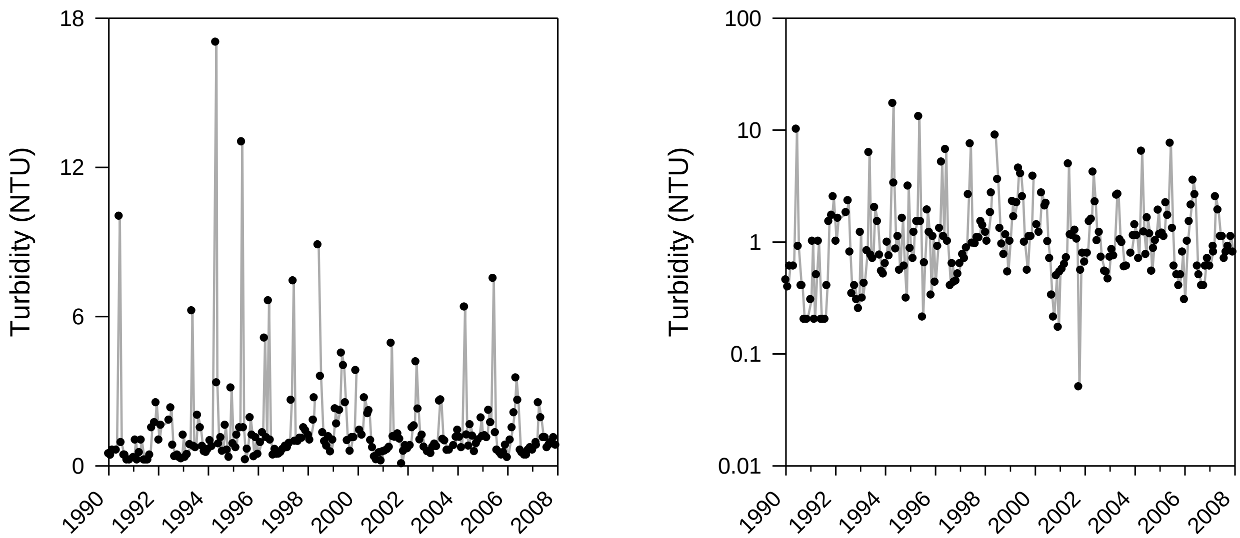
Figure 19: Total strontium normal (left) and log-scale (right) concentrations from 1990 to 2008.





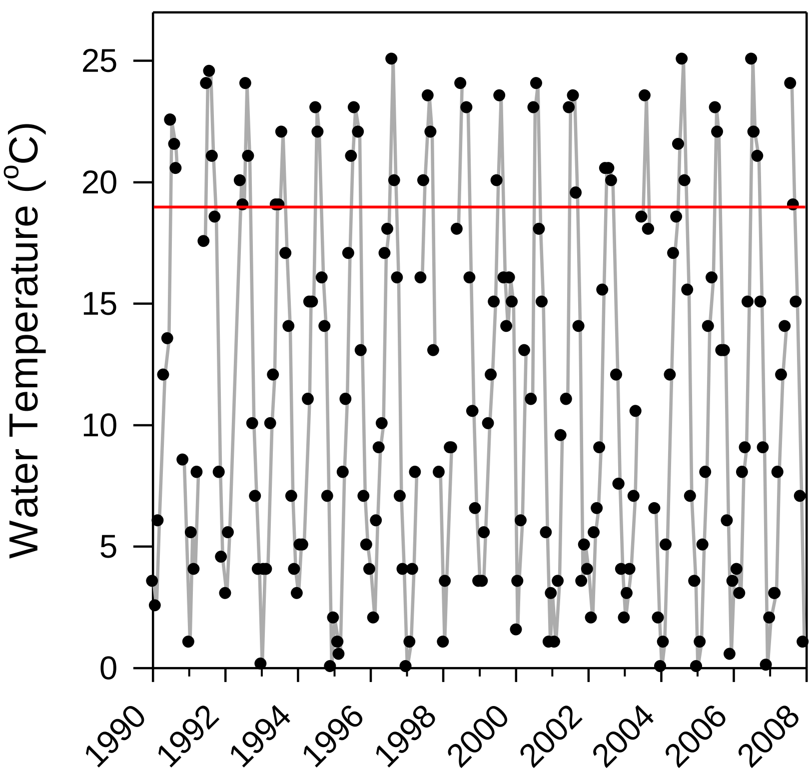
Turbidity: Turbidity measurements have been gradually increasing since 1990 (MK test, $p < 0.05$, slope = 0.0148 NTU $year^{-1}$; Table 1; Figure 20) but remain relatively low. Current B.C. water quality guidelines are background-derived guidelines (based on the difference between upstream and downstream sites). Since we do not have an upstream site, we cannot determine if guidelines have been exceeded.

Figure 20: Turbidity normal (left) and log-scale (right) measurements from 1990 to 2008.



Water Temperature: Surface water temperature was measured at each site visit using a thermometer. There was no significant trend in the surface water temperature at the Okanagan River at Oliver since 1990. However, summer peak surface water temperatures are consistently above the B.C. aquatic life guideline of a maximum temperature of 19°C (Figure 21).

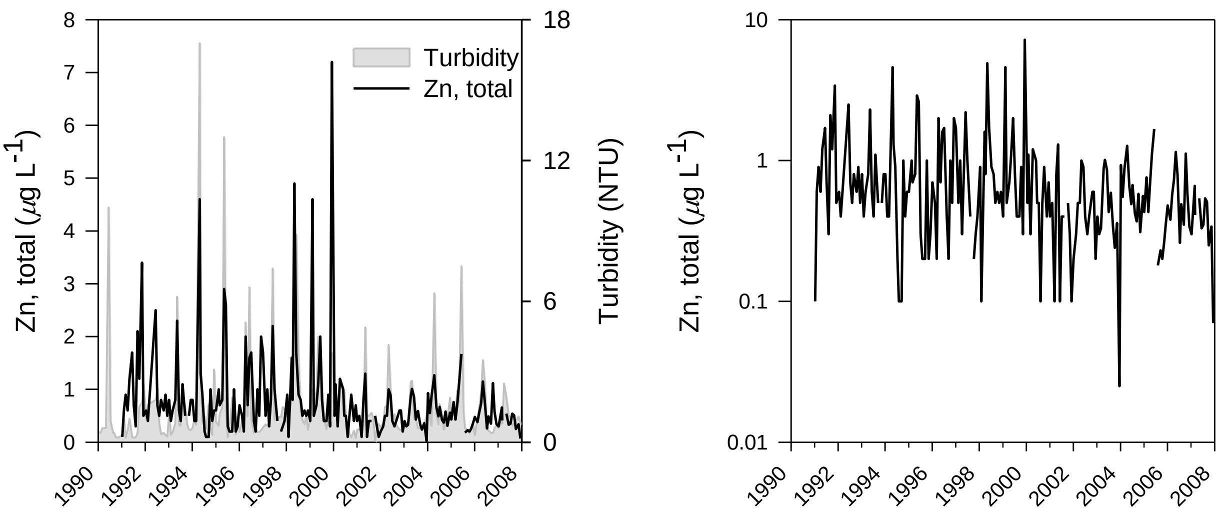
Figure 21: Surface water temperature as measured at the Okanagan River at Oliver from 1990 to 2008.



Note: Red line denotes the B.C. aquatic life guideline for the maximum daily temperature for streams with unknown fish distribution.

Zinc: Total zinc concentrations have been steadily decreasing in the Okanagan River since 1990 (MK test, $p < 0.01$, slope = -0.0173 μg L^{-1} $year^{-1}$; SK test, $p < 0.01$, slope = -0.0193 μg L^{-1} $year^{-1}$; Table 1; Figure 22). B.C. aquatic life guidelines are based on hardness-dependent calculations. During the sample period, the B.C. aquatic life guideline ranged from 33 to 78 μg L^{-1}, well above historical and current total zinc concentrations.

Figure 22: Total zinc and turbidity (left) and total zinc log-scale (right) concentrations in the Okanagan River from 1990 to 2008.



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