Water Quality Assessment for the Similkameen River and Tributaries

British Columbia Ministry of Water, Land and Resource Stewardship

July 2024

Citation:
British Columbia Ministry of Water, Land and Resource Stewardship. 2024. Water Quality Assessment for the Similkameen River and Tributaries. Water Stewardship and Security Branch. Prov. B.C., Victoria B.C.

Cover Photographs:
Tulameen River field sampling October 2019 (Credit: Lyndsey Johnson).

Acknowledgements

Sincere thanks are extended to those who contributed to this document: B.C. Ministry of Environment and Climate Change Strategy – Lyndsey Johnson, Michelle Meier, Liz Freyman; B.C. Ministry of Water, Land and Resource Stewardship - Nicole Obee, Jessica Penno, Jolene Raggett, Kevin Rieberger.

EXECUTIVE SUMMARY

This document provides a technical assessment of water quality in the Similkameen River and its main tributaries. Water quality objectives were originally established for the Similkameen watershed in 1985 and updated in 1990. Objectives were also established for Cahill Creek and Keremeos Creek in 1987 and 2000, respectively. This assessment examines the existing water quality of the Similkameen River watershed and its tributaries.

The Similkameen River watershed is located within the territories of the Smelqmixw and Syilx people. The river flows from Manning Park through Princeton and across the Canada-U.S. border. Significant tributaries include the Tulameen River, Wolfe Creek, Hedley Creek, the Ashnola River, Red Top Gulch Creek, and Keremeos Creek. The headwaters are relatively undisturbed; land use increases downstream and includes agriculture, forestry, range, and mining activities.

The designated water uses identified for protection in the Similkameen River watershed include aquatic life, wildlife, agriculture, drinking water, recreation, and Indigenous cultural and traditional values.

Most water quality parameters increased in concentration in the Similkameen River mainstem from upstream to downstream, particularly during freshet when snowmelt and overland runoff peak, and several metals (aluminum, cobalt, copper, iron, and lead) exceeded water quality guidelines or water quality objectives on occasion. Other metals (molybdenum, selenium, and uranium) increased in concentration during low flows, likely from the increased influence of groundwater inputs and reduced dilution. An assessment of benthic invertebrate communities showed an increase in the abundance of individual organisms and a decline in sensitive taxa from upstream to downstream, consistent with increasing nutrient concentrations.

Water quality in key tributaries (Tulameen River, the Ashnola River, and Keremeos Creek) was generally within acceptable limits, however data were limited. A more comprehensive dataset would enable a more robust assessment of water quality and confirmation of the current conditions in these tributaries.

The water quality of Wolfe Creek was altered substantially downstream of Copper Mountain Mine. Several parameters exceeded water quality guidelines or objectives (sulphate, nitrate, copper, manganese, molybdenum), but conditions improved with increasing distance from the mine. Data were not collected in or downstream of Lorne Lake, Issitz Lake, or Wolfe Lake, and as such the lake conditions could not be assessed.

The Hedley Creek, Cahill Creek and Red Top Gulch Creek watersheds showed impacts on water quality from the Nickel Plate Mine (ceased operations in 1996). Hedley Creek water quality was within acceptable limits, but sulphate and cobalt concentrations increased downstream of the mine. In Cahill Creek, several parameters (aluminum, arsenic, cobalt, selenium) increased downstream of the mine, and some exceeded water quality guidelines. In Red Top Gulch Creek, several parameters (arsenic, cobalt, iron, selenium, uranium) exceeded water quality guidelines or objectives, but the pattern from upstream to downstream varied among the parameters.

CONTENTS

EXECUTIVE SUMMARY II
CONTENTS III
FIGURES VIII
TABLES X
ACRONYMS AND ABBREVIATIONS XIV
1. INTRODUCTION 1
2. INDIGENOUS NATIONS 1
3. WATERSHED DESCRIPTION 1
3.1 Upper Similkameen Tributaries 2
3.2 Mid Similkameen Tributaries 2
3.3 Lower Similkameen Tributaries 3
3.4 Climate 3
3.5 Hydrology 3
4. INFLUENCES ON WATER QUALITY 3
4.1 Mining 3
4.2 Municipal Waste 5
4.3 Water Licenses 6
4.4 Recreation 6
4.5 Agriculture 6
4.6 Forestry 7
5. WATER USES AND VALUES 7
5.1 Aquatic Life 7
5.2 Human Health 8
5.3 Wildlife 8
5.4 Cultural and Traditional Values 8
5.5 Agriculture 8
5.6 Recreation 8
6. WATER QUALITY ASSESSMENT METHODS 9
6.1 Data Sources 9
6.2 Data Assessment 9
6.3 Benthic Invertebrates 9
7. SIMILKAMEEN RIVER WATER QUALITY 10
7.1 General parameters 10
7.1.1 pH 10
7.1.2 Temperature 11
7.1.3 Dissolved Oxygen 12
7.1.4 Specific Conductivity 13
7.1.5 Hardness 14
7.1.6 Turbidity 14
7.1.7 Total Suspended Solids 16
7.2 Nutrients 17
7.2.1 Total Phosphorus 17
7.2.2 Nitrogen 19

7.3 Organic Matter 20
7.3.1 Organic Carbon 20
7.4 Major Ions and Other Inorganic Parameters 22
7.4.1 Sulphate 22
7.4.2 Cyanide 23
7.5 Metals 24
7.5.1 Aluminum 24
7.5.2 Arsenic 26
7.5.3 Chromium 27
7.5.4 Cobalt 28
7.5.5 Copper 29
7.5.6 Iron 31
7.5.7 Lead 32
7.5.8 Manganese 34
7.5.9 Mercury 35
7.5.10 Molybdenum 36
7.5.11 Nickel 37
7.5.12 Selenium 38
7.5.13 Uranium 39
7.5.14 Zinc 39
7.6 Microbiological Indicators 41
7.6.1 Fecal Coliforms and *Escherichia coli* 41
7.7 Biomonitoring 42
7.8 Similkameen River Summary 42
8. TULAMEEN RIVER WATER QUALITY 43
8.1 General Parameters 43
8.2 Nutrients 44
8.3 Organic Matter 44
8.4 Major Ions and Other Inorganic Parameters 44
8.5 Metals 44
8.5.1 Aluminum 44
8.5.2 Arsenic 44
8.5.3 Chromium 44
8.5.4 Cobalt 45
8.5.5 Copper 45
8.5.6 Iron 46
8.5.7 Lead 46
8.5.8 Manganese 46
8.5.9 Molybdenum 46
8.5.10 Nickel 46
8.5.11 Selenium 46
8.5.12 Uranium 47
8.5.13 Zinc 47
8.6 Microbiological 47
8.7 Tulameen River Summary 47
9. WOLFE CREEK AMBIENT WATER QUALITY 47
9.1 General Parameters 48

9.1.1 pH 48
9.1.2 Temperature 48
9.1.3 Dissolved Oxygen 49
9.1.4 Specific Conductivity 50
9.1.5 Hardness 50
9.1.6 Turbidity 51
9.1.7 Total Suspended Solids 52
9.1.8 Total Dissolved Solids 53
9.2 Nutrients 53
9.2.1 Phosphorus 53
9.2.2 Nitrogen 54
9.3 Organic Matter 56
9.4 Major Ions 56
9.5 Metals 57
9.5.1 Aluminum 57
9.5.2 Cobalt 59
9.5.3 Copper 59
9.5.4 Iron 60
9.5.5 Manganese 61
9.5.6 Molybdenum 62
9.5.7 Selenium 64
9.5.8 Uranium 65
9.5.9 Zinc 66
9.6 Wolfe Creek Summary 66
10. HEDLEY CREEK AMBIENT WATER QUALITY 67
10.1 General Parameters 67
10.1.1 pH 67
10.1.2 Temperature 67
10.1.3 Specific Conductivity 69
10.1.4 Hardness 69
10.1.5 Turbidity 69
10.1.6 Total Suspended Solids 70
10.2 Nutrients 70
10.3 Organic Matter 71
10.4 Major Ions and Other Inorganic Parameters 71
10.4.1 Sulphate 71
10.4.2 Cyanide 72
10.5 Metals 72
10.5.1 Aluminum 72
10.5.2 Arsenic 73
10.5.3 Chromium 73
10.5.4 Cobalt 74
10.5.5 Copper 75
10.5.6 Iron 76
10.5.7 Lead 77
10.5.8 Manganese 77
10.5.9 Mercury 78
10.5.10 Molybdenum 78

10.5.11 Nickel ... 78
10.5.12 Uranium ... 79
10.5.13 Zinc ... 79
10.6 Hedley Creek Summary ... 80
11. CAHILL CREEK AMBIENT WATER QUALITY ... 80
11.1 General Parameters ... 80
11.1.1 pH ... 80
11.1.2 Temperature ... 81
11.1.3 Specific Conductivity ... 81
11.1.4 Hardness ... 82
11.1.5 Turbidity ... 82
11.1.6 Total suspended solids ... 83
11.1.7 Total Dissolved Solids ... 84
11.2 Nutrients ... 84
11.2.1 Phosphorus ... 84
11.2.2 Nitrogen ... 85
11.3 Organic Matter ... 87
11.3.1 Organic Carbon ... 87
11.4 Major Ions and Other Inorganic Parameters ... 87
11.4.1 Sulphate ... 87
11.4.2 Cyanide ... 88
11.5 Metals ... 89
11.5.1 Aluminum ... 89
11.5.2 Arsenic ... 90
11.5.3 Cadmium ... 91
11.5.4 Chromium ... 91
11.5.5 Cobalt ... 92
11.5.6 Copper ... 94
11.5.7 Iron ... 96
11.5.8 Lead ... 97
11.5.9 Mercury ... 97
11.5.10 Molybdenum ... 97
11.5.11 Selenium ... 100
11.5.12 Silver ... 101
11.5.13 Uranium ... 102
11.5.14 Zinc ... 104
11.6 Cahill Creek Summary ... 105
12. RED TOP GULCH CREEK AMBIENT WATER QUALITY ... 105
12.1 General Parameters ... 105
12.1.1 pH ... 105
12.1.2 Temperature ... 106
12.1.3 Specific Conductivity ... 106
12.1.4 Hardness ... 107
12.1.5 Turbidity ... 107
12.1.6 Total suspended solids ... 108
12.1.7 Total Dissolved Solids ... 108

12.2 Nutrients 109
12.2.1 Phosphorus 109
12.2.2 Nitrogen 109
12.3 Organic Matter 110
12.3.1 Organic Carbon 110
12.4 Major Ions and Other Inorganic Parameters 110
12.4.1 Sulphate 110
12.4.2 Cyanide 111
12.5 Metals 112
12.5.1 Aluminum 112
12.5.2 Arsenic 113
12.5.3 Cadmium 114
12.5.4 Chromium 114
12.5.5 Cobalt 115
12.5.6 Copper 116
12.5.7 Iron 117
12.5.8 Lead 117
12.5.9 Mercury 118
12.5.10 Molybdenum 118
12.5.11 Selenium 119
12.5.12 Silver 119
12.5.13 Uranium 119
12.5.14 Zinc 120
12.6 Red Top Gulch Creek Summary 121
13. ASHNOLA RIVER AMBIENT WATER QUALITY 122
13.1 General Parameters 122
13.2 Nutrients 122
13.3 Nutrients 122
13.4 Major Ions 123
13.5 Metals 123
14. KEREMEOS CREEK AMBIENT WATER QUALITY 123
14.1 General Parameters 123
14.1.1 pH 123
14.1.2 Temperature 125
14.1.3 Dissolved Oxygen 125
14.1.4 Specific Conductivity 126
14.1.5 Turbidity 126
14.1.6 Total Suspended Solids 127
14.1.7 Total Dissolved Solids 128
14.2 Nutrients 129
14.2.1 Phosphorus 129
14.2.2 Chlorophyll *a* 129
14.2.3 Nitrogen 129
14.3 Major Ions 130
14.3.1 Chloride 130
14.3.2 Sulphate 131

14.4 Metals 131
14.5 Microbiological 131
14.6 Keremeos Creek Summary 132
15. CONCLUSIONS 133
REFERENCES 134

FIGURES

Figure 1: Similkameen River watershed including main tributaries. 2
Figure 2: Temperature and precipitation data for Princeton A station. 3
Figure 3: Average monthly discharge rates for the Similkameen River at Princeton. 4
Figure 4: Land uses within the Similkameen River watershed. 4
Figure 5. Similkameen River watershed water quality monitoring sites. 9
Figure 6: Location of CABIN biomonitoring sampling sites in the Similkameen River watershed. 10
Figure 7: Seasonal variation in pH in the Similkameen River. 11
Figure 8: Seasonal variation in water temperature in the Similkameen River. 12
Figure 9: Seasonal variation in dissolved oxygen concentrations in Similkameen River. 13
Figure 10: Seasonal variation in specific conductivity in the Similkameen River. 13
Figure 11: Seasonal variation in hardness in the Similkameen River. 14
Figure 12: Seasonal variation in turbidity in the Similkameen River. 15
Figure 13: Seasonal variation in total suspended solids in the Similkameen River. 17
Figure 14: Seasonal variation in phosphorus in the Similkameen River. 18
Figure 15: Total phosphorus as function of turbidity in the Similkameen River.. 18
Figure 16: Average total phosphorus concentrations in Similkameen River. 19
Figure 17: Seasonal variation in total nitrogen in the Similkameen River. 20
Figure 18: Average total nitrogen concentrations in the Similkameen River. 20
Figure 19: Seasonal variation in dissolved organic carbon in the Similkameen River. 21
Figure 20: Seasonal variation in sulphate in the Similkameen River. 23
Figure 21: Seasonal variation in total aluminum in the Similkameen River. 25
Figure 22: Spring freshet total aluminum concentrations and corresponding water quality guideline levels for the Similkameen River, upstream to downstream. 26
Figure 23: Seasonal variation in total and dissolved arsenic in the Similkameen River. 27
Figure 24: Seasonal variation in total chromium in the Similkameen River. 29
Figure 25: Seasonal variation in total cobalt in the Similkameen River. 30
Figure 26: Dissolved copper concentrations over time in the Similkameen River. 31
Figure 27: Seasonal variation in dissolved copper in the Similkameen River. 31
Figure 28: Seasonal variation in total and dissolved iron in the Similkameen River. 33
Figure 29: Seasonal variation in total lead in the Similkameen River. 34
Figure 30: Seasonal variation in total manganese in the Similkameen River. 35
Figure 31: Seasonal variation in molybdenum in the Similkameen River. 37
*F*igure 32: Seasonal variation in total selenium in the Similkameen River. 39
Figure 33: Seasonal variation in total uranium in the Similkameen River. 40
Figure 34: Seasonal variation in dissolved zinc in the Similkameen River. 41
Figure 35: Seasonal trends in water temperaturein Wolfe Creek. 49
Figure 36. Seasonal variation in specific conductivity Wolfe Creek. 50
Figure 37: Seasonal variation in total hardness in Wolfe Creek. 51

Figure 38: Seasonal variation in turbidity in Wolfe Creek. 52
Figure 39: Turbidity levels in Wolfe Creek over time. 52
Figure 40: Seasonal variation in total dissolved solids in Wolfe Creek. 53
Figure 41: Seasonal variation in total phosphorus and ortho-phosphate in Wolfe Creek. 54
Figure 42: Dissolved nitrate concentrations in Wolfe Creek over time. 55
Figure 43. Seasonal variation in total nitrogen and dissolved nitrate in Wolfe Creek. 56
Figure 44: Seasonal variation in dissolved organic carbon in Wolfe Creek. 56
Figure 45: Seasonal variation in dissolved sulphate in Wolfe Creek. 57
Figure 46: Seasonal variation in total aluminum in Wolfe Creek. 59
Figure 47: Seasonal variation in dissolved copper in Wolfe Creek. 60
Figure 48: Dissolved copper concentrations and water quality guideline levels in Wolfe Creek. 61
Figure 49: Seasonal variation in total manganese in Wolfe Creek. 62
Figure 50: Seasonal variation in total molybdenum in Wolfe Creek. 63
Figure 51: Total molybdenum concentrations over time in Wolfe Creek. 64
Figure 52: Seasonal variation in total selenium in Wolfe Creek. 64
Figure 53: Total selenium concentrations over time in Wolfe Creek. 65
Figure 54: Seasonal variation in total uranium in Wolfe Creek. 65
Figure 55: Seasonal variation in pH in Hedley Creek. 68
Figure 56: Seasonal variation in water temperature in Hedley Creek. 68
Figure 57: Seasonal variation in specific conductivity in Hedley Creek. 69
Figure 58: Seasonal variation in water hardness in Hedley Creek. 69
Figure 59: Seasonal variation in turbidity in Hedley Creek. 70
Figure 60: Seasonal variation in total suspended solids in Hedley Creek. 70
Figure 61: Seasonal variation in total sulphate in Hedley Creek. 72
Figure 62: Seasonal variation in total aluminum in Hedley Creek. 73
Figure 63: Dissolved cobalt concentrations over time in Hedley Creek. 75
Figure 64: Seasonal variation in dissolved cobalt in Hedley Creek. 75
Figure 65: Dissolved cobalt as a function of specific conductivity in Hedley Creek. 75
Figure 66: Seasonal variation in dissolved copper in Hedley Creek. 76
Figure 67: Seasonal variation in dissolved iron in Hedley Creek. 77
Figure 68: Seasonal variation in dissolved iron in Hedley Creek. 78
Figure 69: Seasonal variation in water temperature in Cahill Creek. 82
Figure 70: Specific conductivity over time in Cahill Creek. 82
Figure 71: Seasonal trends in total dissolved solids concentrations in Cahill Creek. 85
Figure 72: Average dissolved nitrate concentrations over time in Nickel Plate Mine Creek. 86
Figure 73: Seasonal trends in dissolved organic carbon concentrations in Cahill Creek. 87
Figure 74: Average sulphate concentrations over time in Nickel Plate Mine Creek. 88
Figure 75: Seasonal variation in total aluminum concentrations in Cahill Creek. 90
Figure 76: Total aluminum concentrations and water quality guideline values in Cahill Creek. 90
Figure 77: Total arsenic concentrations over time Cahill Creek. 91
Figure 78: Dissolved cobalt concentrations over time in Nickel Plate Mine Creek. 93
Figure 79: Dissolved cobalt concentrations over time in Sunset Creek. 94
Figure 80: Dissolved cobalt concentrations over time in Cahill Creek. 94
Figure 81: Seasonal trends in dissolved cobalt concentrations in Cahill Creek. 94
Figure 82: Seasonal trends in dissolved copper concentrations in Sunset Creek. 95
Figure 83: Seasonal trends in dissolved copper concentrations in Cahill Creek. 96
Figure 84: Dissolved molybdenum concentrationsin Nickel Plate Mine Creek 99
Figure 85: Dissolved molybdenum concentrations in Sunset Creek. 99

Figure 86: Dissolved molybdenum concentrations in Cahill Creek. 99
Figure 87: Dissolved selenium concentrations in Nickel Plate Mine Creek. 100
Figure 88: Dissolved selenium concentrations in Sunset Creek. 101
Figure 89: Dissolved selenium concentrations in Cahill Creek over time. 101
Figure 90: Dissolved selenium concentrations as a function of specific conductance in Cahill Creek..... 102
Figure 91: Dissolved uranium concentrations in Sunset Creek. 103
Figure 92: Dissolved uranium concentrations in Cahill Creek. 104
Figure 93: Seasonal variation in water temperature in Red Top Gulch Creek. 106
Figure 94: Specific conductivity over time in Red Top Gulch Creek. 107
Figure 95: Average dissolved nitrate concentrations over time in Red Top Gulch Creek. 110
Figure 96: Average sulphate concentrations over time in Red Top Gulch Creek. 111
Figure 97: Seasonal variation in total aluminum concentrations in Red Top Gulch Creek. 112
Figure 98: Total aluminum concentrations and corresponding water quality guideline values in Red Top Gulch Creek. 113
Figure 99: Seasonal variation in total arsenic concentrations in Red Top Gulch Creek. 113
Figure 100: Dissolved cadmium concentrations over time in Red Top Gulch Creek. 114
Figure 101: Dissolved cobalt concentrations over time in Red Top Gulch Creek. 115
Figure 102: Seasonal trends in dissolved copper concentrations in Red Top Gulch Creek. 116
Figure 103: Dissolved selenium concentrations in Red Top Gulch Creek. 119
Figure 104: Total uranium concentrations in Red Top Gulch Creek over time. 120
Figure 105: August water temperature in Keremeos Creek.. 125
Figure 106: Seasonal variation in specific conductivity in Keremeos Creek. 126

TABLES

Table 1. Licensed groundwater and surface water withdrawals in the Similkameen River watershed. 6
Table 2: Water uses and values for the Similkameen River watershed. 7
Table 3: Summary statistics for pH in the Similkameen River. 11
Table 4: Summary statistics for water temperature in the Similkameen River. 11
Table 5: Summary statistics for dissolved oxygen in the Similkameen River. 12
Table 6: Summary statistics for specific conductivity in Similkameen River. 13
Table 7: Summary statistics for hardness in the Similkameen River. 14
Table 8: Summary statistics for turbidity in the Similkameen River. 15
Table 9: Frequency of turbidity WQO exceedances at downstream sites on the Similkameen River. 16
Table 10: Summary statistics for total suspended solids in the Similkameen River. 17
Table 11: Summary statistics for total and dissolved phosphorus in the Similkameen River. 18
Table 12: Summary statistics for total and dissolved nitrogen in the Similkameen River. 19
Table 13: Summary statistics for dissolved organic carbon in the Similkameen River. 21
Table 14: Monthly median dissolved organic carbon concentrations for the Similkameen River. 22
Table 15: Summary statistics for sulphate in the Similkameen River. 22
Table 16: Summary statistics for weak-acid dissociable cyanide and strong-acid dissociable cyanide in the Similkameen River. 24
Table 17: Summary statistics for total aluminum in the Similkameen River. 24
Table 18: Average monthly total aluminum concentrations in the Similkameen River. 25
Table 19: Summary statistics for total and dissolved arsenic in the Similkameen River. 27
Table 20: Summary statistics for chromium in the Similkameen River. 28

Table 21: Summary statistics for cobalt in the Similkameen River. 29
Table 22: Summary statistics for dissolved copper in the Similkameen River. 30
Table 23: Summary statistics for total and dissolved iron in the Similkameen River. 32
Table 24: Summary statistics for total lead in the Similkameen River. 33
Table 25: Summary statistics for total manganese in the Similkameen River. 35
Table 26: Summary statistics for total mercury in the Similkameen River. 36
Table 27: Summary statistics for total molybdenum in the Similkameen River. 36
Table 28: Summary statistics for nickel in the Similkameen River. 38
Table 29: Summary statistics for total selenium in the Similkameen River. 38
Table 30: Summary statistics for total uraniumin the Similkameen River. 39
Table 31: Summary statistics for total and dissolved zinc in the Similkameen River. 40
Table 32: Summary statistics for microbiological indicators in the Similkameen River. 41
Table 33: Summary statistics for general water quality parameters in the Tulameen River. 43
Table 34: Summary statistics for metal concentrations in the Tulameen River. 45
Table 35: Wolfe Creek monitoring sites. 48
Table 36: Summary statistics for pH in Wolfe Creek. 48
Table 37: Summary statistics for water temperature in Wolfe Creek. 49
Table 38: Summary statistics for dissolved oxygen in Wolfe Creek. 49
Table 39: Rate of attainment for dissolved oxygen water quality guidelines in Wolfe Creek. 50
Table 40: Summary statistics for specific conductivity in Wolfe Creek. 50
Table 41: Summary statistics for total hardness in Wolfe Creek. 51
Table 42: Summary statistics for turbidity in Wolfe Creek. 52
Table 43: Summary statistics for total suspended solids in Wolfe Creek. 53
Table 44: Summary statistics for total dissolved solids in Wolfe Creek. 53
Table 45: Summary statistics for total and dissolved phosphorus by site in Wolfe Creek. 54
Table 46: Summary statistics for nitrogen in Wolfe Creek. 55
Table 47: Summary statistics for dissolved organic carbon in Wolfe Creek.. 56
Table 48: Summary statistics for dissolved sulphate in Wolfe Creek. 57
Table 49: Rate of water quality guideline attainment for dissolved sulphate in Wolfe Creek. 58
Table 50: Summary statistics for aluminum in Wolfe Creek. 58
Table 51: Summary statistics for total cobalt in Wolfe Creek. 59
Table 52: Summary statistics for dissolved copper in Wolfe Creek. 60
Table 53: Summary statistics for iron in Wolfe Creek. 61
Table 54: Summary statistics for manganese in Wolfe Creek. 62
Table 55: Summary statistics for total molybdenum in Wolfe Creek. 63
Table 56: Summary statistics for total selenium in Wolfe Creek. 64
Table 57: Summary statistics for total uranium in Wolfe Creek. 65
Table 58: Summary statistics for total zinc in Wolfe Creek. 66
Table 59: Hedley Creek monitoring sites. 67
Table 60: Summary statistics for general water quality parameters in Hedley Creek. 68
Table 61: Summary statistics for nutrients in Hedley Creek. 71
Table 62: Summary statistics for dissolved organic carbon in Hedley Creek. 71
Table 63: Summary statistics for total sulphate in Hedley Creek. 72
Table 64: Summary statistics for aluminum in Hedley Creek. 73
Table 65: Summary statistics for total arsenic in Hedley Creek. 73
Table 66: Summary statistics for total chromium in Hedley Creek. 74
Table 67: Summary statistics for cobalt in Hedley Creek. 74
Table 68: Summary statistics for copper in Hedley Creek. 76

Table 69: Summary statistics for iron in Hedley Creek. 76
Table 70: Summary statistics for total lead in Hedley Creek. 77
Table 71: Summary statistics for total manganese in Hedley Creek. 77
Table 72: Summary statistics for total mercury in Hedley Creek. 78
Table 73: Summary statistics for total molybdenum in Hedley Creek. 78
Table 74: Summary statistics for nickel in Hedley Creek. 79
Table 75: Summary statistics for total uranium in Hedley Creek. 79
Table 76: Summary statistics for zinc in Hedley Creek. 80
Table 77: Cahill Creek monitoring sites. 80
Table 78: Summary statistics for pH in Cahill Creek and tributaries. 81
Table 79: Summary statistics for temperature in Cahill Creek and tributaries. 81
Table 80: Summary statistics for specific conductivity in Cahill Creek and tributaries. 82
Table 81: Summary statistics for total hardness in Cahill Creek and tributaries. 83
Table 82: Summary statistics for turbidity in Cahill Creek and tributaries. 83
Table 83: Summary statistics for total suspended solids in Cahill Creek and tributaries. 84
Table 84: Summary statistics for total dissolved solids in Cahill Creek and tributaries 84
Table 85: Summary statistics for total phosphorus in Cahill Creek and tributaries. 85
Table 86: Summary statistics for ammonia in Cahill Creek and tributaries. 85
Table 87: Summary statistics for nitrate in Cahill Creek and tributaries. 86
Table 88: Summary statistics for dissolved organic carbon in Cahill Creek and tributaries. 87
Table 89: Summary statistics for sulphate in Cahill Creek and tributaries. 88
Table 90: Summary statistics for aluminum in Cahill Creek and tributaries. 89
Table 91: Summary statistics for total arsenic in Cahill Creek and tributaries. 91
Table 92: Summary statistics for cadmium in Cahill Creek and tributaries. 92
Table 93: Summary statistics for total chromium in Cahill Creek and tributaries. 92
Table 94: Summary statistics for cobalt in Cahill Creek and tributaries. 93
Table 95: Summary statistics for copper in Cahill Creek and tributaries. 95
Table 96: Summary statistics for iron in Cahill Creek and tributaries. 96
Table 97: Summary statistics for total lead in Cahill Creek and tributaries. 97
Table 98: Summary statistics for mercury in Cahill Creek and tributaries. 98
Table 99: Summary statistics for molybdenum in Cahill Creek and tributaries. 98
Table 100: Summary statistics for selenium in Cahill Creek and tributaries. 100
Table 101: Summary statistics for silver in Cahill Creek and tributaries. 102
Table 102: Summary statistics for uranium in Cahill Creek and tributaries. 103
Table 103: Summary statistics for zinc in Cahill Creek and tributaries. 104
Table 104: Red Top Gulch Creek monitoring sites. 105
Table 105: Summary statistics for pH in Red Top Gulch Creek. 106
Table 106: Summary statistics for temperature in Red Top Gulch Creek. 106
Table 107: Summary statistics for specific conductivity in Red Top Gulch Creek. 107
Table 108: Summary statistics for total hardness in Red Top Gulch Creek. 107
Table 109: Summary statistics for turbidity in Red Top Gulch Creek. 108
Table 110: Summary statistics for total suspended solids in Red Top Gulch Creek. 108
Table 111: Summary statistics for total dissolved solids in Red Top Gulch Creek. 108
Table 112: Summary statistics for total phosphorus in Red Top Gulch Creek. 109
Table 113: Summary statistics for ammonia in Red Top Gulch Creek. 109
Table 114: Summary statistics for nitrate in Red Top Gulch Creek. 109
Table 115: Summary statistics for dissolved organic carbon in Red Top Gulch Creek. 110
Table 116: Summary statistics for sulphate in Red Top Gulch Creek. 111

Table 117: Summary statistics for aluminum in Red Top Gulch Creek. 112
Table 118: Summary statistics for total arsenic in Red Top Gulch Creek. 113
Table 119: Summary statistics for cadmium in Red Top Gulch Creek. 114
Table 120: Summary statistics for total chromium in Red Top Gulch Creek. 115
Table 121: Summary statistics for cobalt in Red Top Gulch Creek. 115
Table 122: Summary statistics for copper in Red Top Gulch Creek. 116
Table 123: Summary statistics for iron in Red Top Gulch Creek. 117
Table 124: Summary statistics for total lead in Red Top Gulch Creek. 117
Table 125: Summary statistics for mercury in Red Top Gulch Creek. 118
Table 126: Summary statistics for molybdenum in Red Top Gulch Creek. 118
Table 127: Summary statistics for selenium in Red Top Gulch Creek. 119
Table 128: Summary statistics for silver in Red Top Gulch Creek. 120
Table 129: Summary statistics for uranium in Red Top Gulch Creek. 120
Table 130: Summary statistics for zinc in Red Top Gulch Creek. 121
Table 131: Ashnola River monitoring sites presented from upstream to downstream. 122
Table 132: Data for general water quality parameters in the Ashnola River. 122
Table 133: Data for nutrient parameters in the Ashnola River. 122
Table 134: Data for organic matter in the Ashnola River. 122
Table 135: Data for major ions in the Ashnola River. 123
Table 136: Data for metals in the Ashnola River. 123
Table 137: Summary of Keremeos Creek monitoring sites and available water quality data. 124
Table 138: Summary statistics for pH in Keremeos Creek and tributaries. 124
Table 139: Summary statistics for dissolved oxygen in Keremeos Creek and tributaries. 125
Table 140: Summary statistics for specific conductivity in Keremeos Creek and tributaries. 126
Table 141: Summary statistics for turbidity in Keremeos Creek and tributaries. 127
Table 142: Summary of attainment rates for turbidity WQOs in Keremeos Creek. 127
Table 143: Summary statistics for total suspended solids in Keremeos Creek and tributaries. 128
*T*able 144: Summary of attainment rates for total suspended solids WQOs in Keremeos Creek. 128
Table 145: Summary statistics for total dissolved solids in Keremeos Creek and tributaries. 128
Table 146: Summary statistics for phosphorus in Keremeos Creek and tributaries. 129
Table 147: Summary statistics for ammonia in Keremeos Creek and tributaries. 130
Table 148: Summary statistics for dissolved chloride in Keremeos Creek and tributaries. 130
Table 149: Summary statistics for dissolved sulphate in Keremeos Creek. 131
Table 150: Summary statistics for total metals data in Keremeos Creek. 132
Table 151: Attainment rates for fecal coliforms and *E. coli* WQOs in Keremeos Creek and tributaries. 132

ACRONYMS AND ABBREVIATIONS

ALWQG	Aquatic life water quality guideline
B.C.	British Columbia
BLM	Biotic ligand model
CABIN	Canadian Aquatic Biomonitoring Network
CCME	Canadian Council of Ministers of the Environment
CFU	Colony forming unit
CMM	Copper Mountain Mine
CN	Cyanide
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EC	Environment Canada
ECCC	Environment and Climate Change Canada
EMA	*Environmental Management Act*
EMS	Environmental Monitoring System
ENV	B.C. Ministry of Environment and Climate Change Strategy
MAC	Maximum acceptable concentration
MDL	Method detection limit
µS/cm	Microsiemans per centimeter
NFR	Nonfilterable residue
NTU	Nephelometric turbidity unit
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
SAD CN	Strong acid dissociable cyanide
SAD CN + SCN	Strong acid dissociable cyanide plus thiocyanate
SDWQG	Source drinking water quality guideline
TDS	Total dissolved solids
TOC	Total organic carbon
TSS	Total suspended solids
WAD CN	Weak acid dissociable cyanide
WLAP	B.C. Ministry of Water, Land and Air Protection
WLRS	B.C. Ministry of Water, Land and Resource Stewardship
WQG	Water quality guideline
WQO	Water quality objective
WSA	*Water Sustainability Act*
WSS	Water Science Series
WWQG	Working water quality guideline

1. INTRODUCTION

In British Columbia (B.C.), water quality objectives (WQO) are developed for specific waterbodies of regional, provincial, inter-provincial, and international significance to promote the protection and stewardship of shared water resources. Water quality objectives define conditions that represent levels of low risk to water values. They are set with the goal of protecting water values by maintaining existing water quality, improving existing water quality, or protecting water quality for a specific use. Water quality objectives formalize expectations with respect to water quality for a given waterbody and are used to inform land and resource management decisions, assess environmental conditions, and promote water stewardship. Once approved, WQOs constitute formal policy and are considered in resource management decisions affecting water quality.

Water quality objectives were originally established for the Similkameen River watershed in 1985 (ENV 1985) and updated in 1990 (ENV 1990) in response to increased mining activity in the area. Water quality objectives were also established for Cahill Creek and its tributaries in 1987 (ENV 1987) and for Keremeos Creek in 2000 (ENV 2000).

This report assesses the existing water quality of the Similkameen River and its tributaries in relation to the existing WQOs and relevant water quality guidelines.

2. INDIGENOUS NATIONS

The Similkameen River watershed lies within the traditional territories of the Smelqmixw and Syilx People of the Upper Similkameen Indian Band and Lower Similkameen Indian Band.

3. WATERSHED DESCRIPTION

The Similkameen River is 197 km long and flows from Manning Park in a north-easterly direction to Princeton, then southeast, joining the Okanogan River south of the Canada-U.S. border near Oroville, Washington. Approximately 82% (7,566 km^2) of the watershed is within B.C. and the remaining 18% (1,704 km^2) in Washington State. Several communities are located along its length from west to east including Princeton, Hedley, Keremeos, and Cawston. Significant tributaries to the Similkameen River include the Tulameen River, Wolfe Creek, Hedley Creek, the Ashnola River, Red Top Gulch Creek and Keremeos Creek (Figure 1). The headwaters of the Similkameen River in Manning Park are relatively undeveloped and land use is mainly recreational. Land use increases downstream and includes agriculture, forestry, range, and mining activities.

Interior Douglas-Fir is the most prominent biogeoclimatic zone and occurs in the low- and mid- elevation in the Okanagan-Similkameen region, with vegetation predominately consisting of Douglas fir, lodgepole pine, red cedar, larch, and grand fir. The Ponderosa Pine biogeoclimatic zone occupies a narrow band along the bottom and side valley walls of the Similkameen River and mainly consists of grassland or shrub-steppe and forested ecosystems. The Bunchgrass biogeoclimatic zone is found in small sections of the lower valley with the most common species being ponderosa pine and Douglas fir with grassland, shrub-steppe, rock outcrop, and sand dune plant communities dominating most of the landscape. The Engelmann Spruce – Subalpine Fir and Montane Spruce biogeoclimatic zones are found only at the highest elevations in the region.

The following sections describe the main tributaries to the Similkameen River from upstream (Manning Park) to downstream (U.S. border) with the Similkameen River divided into three distinct reaches: upper Similkameen River (Manning Park to Princeton), mid Similkameen River (Princeton to Keremeos), and lower Similkameen River (Keremeos to the U.S. border).

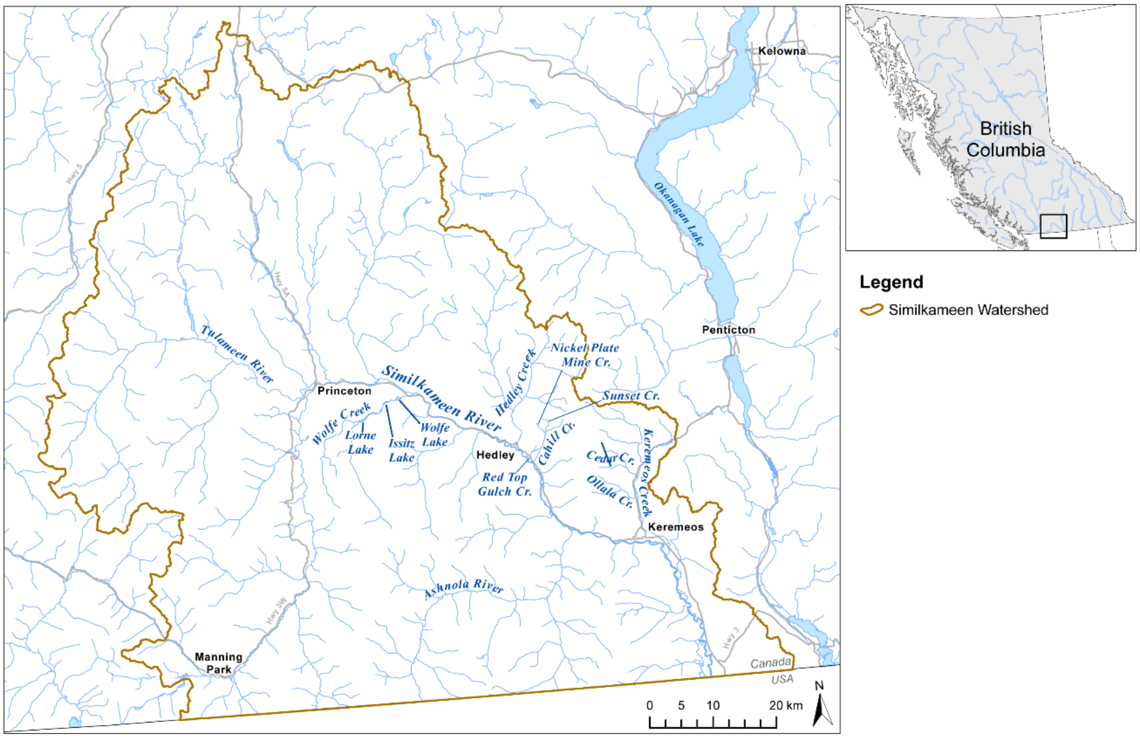

Figure 1: Similkameen River watershed including main tributaries.

3.1 Upper Similkameen Tributaries

The Tulameen River flows into the Similkameen downstream of Princeton and has a watershed area of approximately 1,760 km^2. Tributaries to the Tulameen River include Otter Creek and Vuich Creek.

Wolfe Creek, with a drainage of 215 km^2, enters the Similkameen River approximately 15 km downstream of Princeton. Wolfe Creek originates upstream near the Copper Mountain Mine and flows into Lorne Lake, Issitz Lake, and Wolfe Lake before flowing into the Similkameen River. The alignment of Wolfe Creek was modified by the Copper Mountain Mine, and major channelization has occurred upstream of the Lorne Lake area.

3.2 Mid Similkameen Tributaries

Hedley Creek (formally named Twenty Mile Creek) flows southwest into the Similkameen River at the small town of Hedley, located between Keremeos and Princeton. Hedley Creek is approximately 5 km in length with a watershed area of approximately 390 km^2.

Cahill Creek enters the Similkameen River approximately 3 km south of Hedley. Cahill Creek is approximately 9 km in length with a drainage area of approximately 25 km^2. Cahill Creek connects directly to the Similkameen River during higher flows. Sunset Creek flows into Cahill Creek approximately 5 km upstream of the Cahill Creek/Similkameen River confluence; Sunset Creek and Nickle Plate Mine Creek join Cahill Creek upstream of this junction. Sunset Creek has been modified over time as a waste rock pit from the former Nickel Plate Mine was placed directly through its natural course. Sunset Creek has now been returned to its original drainage course and continues to drain through the flooded pit.

Red Top Gulch parallels Cahill Creek to the west, and the town of Hedley is located approximately 3 km northwest.

3.3 Lower Similkameen Tributaries

The Ashnola River flows northeast from Washington into the Similkameen River between the towns of Princeton and Keremeos with a drainage area of 1,050 km^2 in BC.

Keremeos Creek flows south towards the Similkameen River, west of Skaha Lake. It has three main tributaries: South Keremeos Creek, Cedar Creek, and Olalla Creek. Keremeos Creek has a drainage area of 250 km^2.

3.4 Climate

The nearest climate station to the Similkameen River watershed is the Princeton A station located just outside of Princeton at an elevation of 701 m. From 1981 – 2010, the area received an average total annual precipitation of about 347 mm, with peak rains in May through July (total of 97 mm) and snow between November through January (total of 121 mm). Temperatures averaged -5°C in January and 18°C in both July and August (Figure 2).

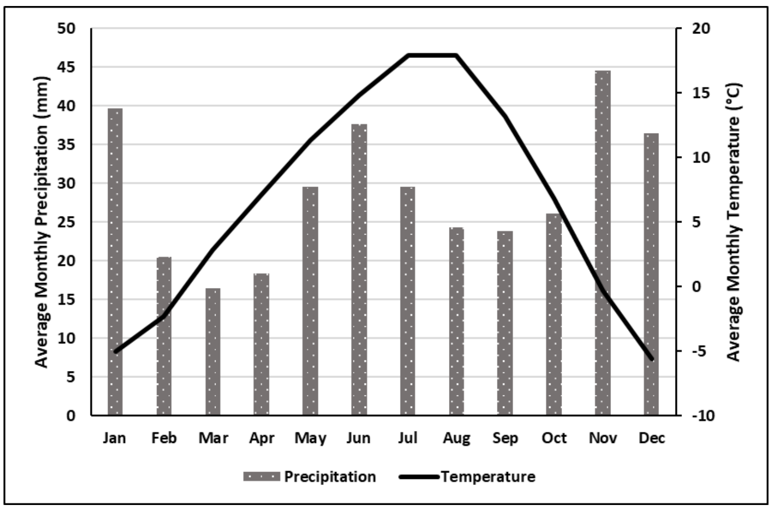

Figure 2: Temperature and precipitation data for Princeton A station (1981 to 2010).

3.5 Hydrology

Freshet in the Similkameen River typically occurs from April through July with peak flows of approximately 170 m^3/s and average flows of 80 m^3/s in May (Figure 3). The lowest flows occurred in September with a minimum of 2.2 m^3/s and an average discharge of 4.9 m^3/s.

4. INFLUENCES ON WATER QUALITY

Land use activities within the Similkameen River watershed are illustrated in Figure 4 and described in the following sections.

4.1 Mining

The Copper Mountain Mine (CMM) is located 20 km south of Princeton. The mine site occupies an elevation range of 770 m to 1,300 m and is bounded by the Similkameen River to the west and Wolfe Creek to the east. The mine opened in 1969 and suspended operations in 1996 due to poor world copper prices. The mine was reactivated in 2011 and is currently operating under *Environmental Management Act* (EMA) Authorization 261 with the latest amendment in 2022. The CMM Authorization requires monitoring of tailings pit water and mine seepages and receiving environment monitoring in the Similkameen River and Wolfe Creek. Biological effects monitoring and sediment monitoring programs are also required. Contaminants of potential concern from the CMM include sulphate, nitrate, copper, molybdenum, and selenium.

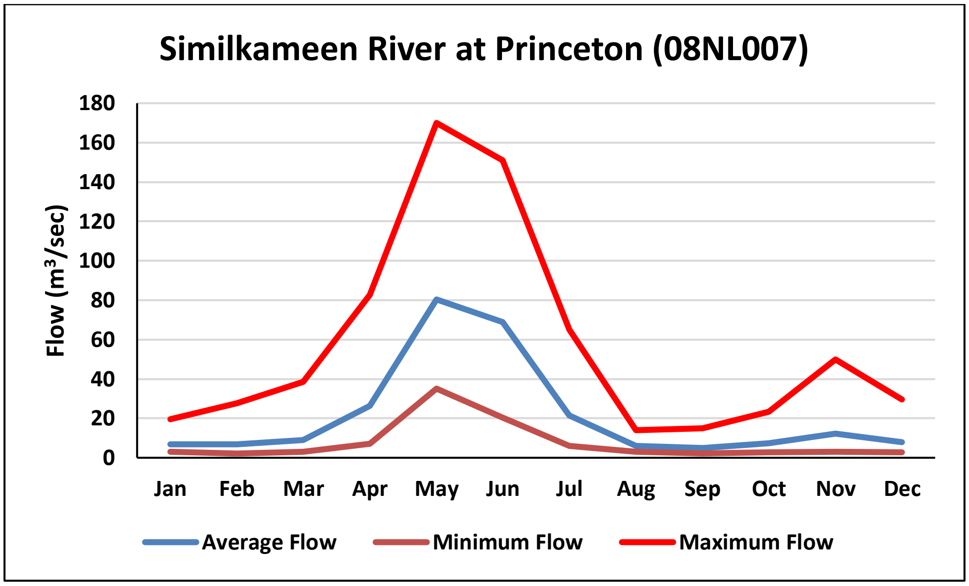

Figure 3: Average monthly discharge rates (m^3/second) for the Similkameen River at Princeton (08NL007) from 2000 – 2021.

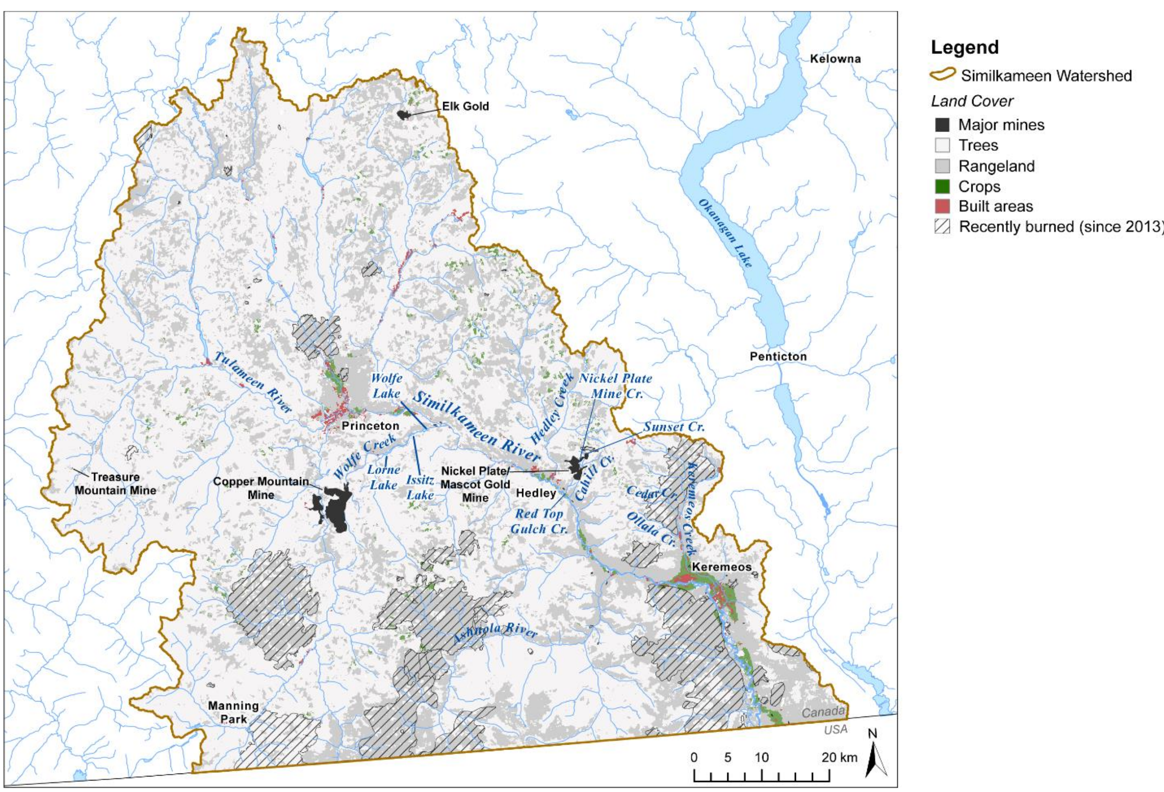

Figure 4: Land uses within the Similkameen River watershed.

The Elk Gold project, located near Merritt, is within the Similkameen Mining District and consists of 27 contiguous mineral claims and one mining lease covering 16,566 ha. The receiving environment includes Buillion Creek and Siwash Creek. The current Elk Gold mine site consists of an ore stockpile area, two rock storage areas, three sumps, and two open flooded pits. It was issued EMA Authorization 106262 in 2014. The mine site was placed on Care and Maintenance in May 2015. The contaminants of potential concern include copper, cadmium, aluminum, iron, sulphate, zinc, arsenic, and selenium.

Candorado Mines Ltd. was issued EMA Authorization 7894 in 1989 authorizing the storage of special waste, specifically cyanide solution, from a heap-leach metal recovery operation located at Hedley in a surface impoundment with complete waste recycling and no discharge to the environment. The two tailings piles at that time were located along the eastern bank of Hedley Creek, and the northern bank of the Similkameen River. The Authorization was suspended in 2006, but ongoing concerns remained about the potential contamination from the heap leach pile and ponds to the valley aquifer and the Similkameen River. The groundwater flowing beneath the Candorado Mine footprint is thought to discharge into the Similkameen River approximately 2.3 km southeast of the site. Contaminants of potential concern include cyanide, thiocyanate, cobalt, ferrocyanide, arsenic, and manganese.

The Nickel Plate Mine is located above the town of Hedley and ceased operation in 1996. The remaining mining infrastructure includes a tailings storage facility, two open pits, and three waste rock dumps. Under EMA Authorization 7613, the Nickle Plate Mine is authorized to discharge effluent from a gold mine and mill operation to Hedley Creek. Currently, seepage water is collected and treated at a water treatment plant and discharged to Hedley Creek via pipeline. The valley aquifer is thought to be recharged by Hedley Creek and the Similkameen River. Groundwater and surface water quality at the mine are influenced by mine drainage that has elevated concentrations of ions and metals such as sulphate, cyanide, arsenic, cobalt, selenium, and uranium. Uncaptured mine groundwater is expected to flow to Red Top Gulch Creek and Cahill Creek.

Other smaller historic mines in the area include the non-operational Treasure Mountain Mine, located in the headwaters of the Tulameen River and discharging under EMA Authorization 105894, and the non-operational Mascot Gold Mine, in the headwaters of Cahill Creek, with no effluent discharge.

4.2 Municipal Waste

The Town of Princeton operates a wastewater treatment plant consisting of two aerated lagoons operated in series under EMA Authorization 1236. The site is located along Highway 3, just east of Princeton. There is no discharge from the treatment plant into the Similkameen River. Contaminants of potential concern associated with the treatment plant include total nitrogen, nitrite, nitrate, ammonia, ortho-phosphate, dissolved phosphorus, sodium, chloride, and sulphate.

The Town of Princeton is also authorized to discharge effluent to the ground from septic tanks and sewage holding tanks under EMA Authorization 6873. There is no discharge into the Similkameen River.

Young Life of Canada runs Rock Ridge Canyon resort on Lorne Lake with accommodation for up to 400 people. Sewage is treated and disposed of under EMA authorization 17112.

Sunkatchers RV Park is located on the banks of the Similkameen River between Hedley and Keremeos and is authorized under EMA Authorization 13542 to discharge septic tank effluent to ground approximately 100 m from the Similkameen River. Contaminants of potential concern include nutrients, chloride, total and fecal coliforms, conductivity, turbidity, and pH.

The Regional District of Okanagan Similkameen operates a transfer station approximately 2 km north of Keremeos under EMA Authorization 5928. The transfer station is located at the junction of the Similkameen River Valley and the smaller Keremeos Creek valley. The nearest surface waterbody is

Keremeos Creek, about 1 km to the east of the site with the Similkameen River located about 2 km to the south. It has operated as a transfer station since 2007 and discharges to ground.

Apex Mountain Ski Resort is located near Penticton and the sewage treatment plant is authorized to discharge effluent to the ground under EMA Authorization 6017. The authorized works include lift stations, two aerated lagoons, infiltration basins, and related appurtenances. Groundwater and surface water monitoring occurs semi-annually. The contaminants of potential concern include nutrients (e.g., ammonia, nitrate, nitrite, total nitrogen, total phosphorus, dissolved phosphorus, and orthophosphate), anions (sulphate and chloride) and microbiological (*E. coli* and total coliforms).

4.3 Water Licenses

There are 878 licensed groundwater and/or surface water withdrawals in the Similkameen watershed, for various uses including irritation, drinking water, agriculture and livestock watering, and industrial operations. The sum of the licensed water use in the watershed is 6.122 m^3/second (Table 1).

Table 1. Licensed groundwater and surface water withdrawals in the Similkameen River watershed.

Stream Name	Number of licensed withdrawals	Sum of demand (m^3/s)
Ashnola River	11	1.003
Cahill Creek	2	unknown
Hedley Creek	2	0.049
Keremeos Creek	28	0.150
Similkameen River	98	2.449
Sunset Creek	1	0.003
Tulameen River	7	0.111
Wolfe Creek	25	0.155
Entire Watershed	**878**	**6.122**

4.4 Recreation

There are several private and public campgrounds in the Similkameen River watershed. Provincial parks include Allison Lake Provincial Park (28 km north of Princeton), Bromley Park Provincial Park (located 21 km east of Princeton off Highway 3), Otter Lake Provincial Park (33 km northwest of Princeton near Coalmount and Tulameen), Stemwider Provincial Park (located 35 km east of Princeton on Highway 3 near Hedley), Nickel Plate Provincial Park (near Apex Mountain), Cathedral Provincial Park and Protected Area (just off Highway 3, west of Keremeos), and E.C. Manning Provincial Park (52 km west of Princeton on Highway 3). Recreational activities have the potential to contribute to water quality issues, such as nutrients and bacteriology, in the watershed if not conducted in a responsible manner.

4.5 Agriculture

Agriculture is key to the economy in the Similkameen Valley. Cattle ranching is the largest agricultural activity. Approximately 86% of the agricultural land in the area is comprised of alfalfa, alfalfa mixtures, hay, or natural land for pasture. Fruit growing, including apples, cherries, grapes, and peaches, is another significant agricultural activity in the area. In 2011 there were approximately 341 farms in the area. With improper management of agricultural activities, groundwater and surface water can be negatively impacted by increased concentrations of nutrients, fecal contamination, sediment, and pesticides.

4.6 Forestry

The cumulative equivalent clear-cut area in the Similkameen River watershed was approximately 46% in 2011. Logging accounted for 19% of the total and mountain pine beetle infestation (which began in 2003) accounted for approximately 23%, with occasional forest fires contributing to the total. Forestry can lead to elevated sediment levels in nearby waterbodies from runoff, which can, in turn, negatively impact aquatic habitat and species.

5. WATER USES AND VALUES

The key water uses and values for the Similkameen River and its tributaries are listed in Table 2 and described in the following sections.

Table 2: Water uses and values for the Similkameen River watershed.

	Aquatic Life	Wildlife	Agriculture	Drinking Water	Recreation	Indigenous values
Similkameen River	X	X	X	X	X	X
Tulameen River	X				X	X
Wolfe Creek	X		X			X
Hedley Creek	X	X	X	X		X
Keremeos Creek	X	X	X	X		X
Cedar Creek	X	X	X	X		X
South Keremeos Creek	X	X	X			X
Olalla Creek	X	X	X	X		X
Cahill Creek	X *	X	X	X		X
Sunset Creek		X	X			X
Nickel Plate Mine Creek		X	X			X
Red Top Gulch Creek	X *	X	X	X		X
Ashnola River	X	X	X	X		X

* Downstream of Highway 3.

5.1 Aquatic Life

The Similkameen watershed supports several native fish species including Rainbow Trout (*Oncorhynchus mykiss*), Dolly Varden (*Salvelinus malma*), Mountain Whitefish (*Prosopium williamsoni*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Bridgelip Sucker (*Catostomus columbianus*), Largescale Sucker (*Catostomus macrocheilus*), Mottled Sculpin (*Cottus bairdi hubbsi*), Slimy Sculpin (*Cottus cognatus*), Torrent Sculpin (*Cottus rhotheus*), and Leopard Dace (*Rhinichthys falcatus*). Non-native fish in the Similkameen watershed include Black Bullhead (*Ameiurus melas*), Brook Trout (*Salvelinus fontinalis*), Lake Trout (*Salvelinus namaycush*), Cutthroat Trout (*Oncorhynchus clarki lewisii*), and Kokanee (*Oncorhynchus nerka*). There are several rare or at-risk fish species in the watershed including Umatilla Dace (*Rhinichthys umatilla*), Chiselmouth (*Acrocheilus alutaceus*), and Mountain Sucker (*Catostomus platyrhynchus*). No anadromous fish are found in the Canadian portion of the Similkameen River. In general, there are low fish population densities in the Similkameen River due to cool temperatures and few nutrients (Rae, 2005). It was historically stocked with surplus hatchery fish. Fish species are valued for their recreational and cultural values and support local wildlife as a food source.

5.2 Human Health

The relationship between freshwater environments and humans through the consumption of aquatic foods has cultural, economic, and social significance in the Similkameen watershed. The Similkameen River and its tributaries supply water for several purposes including drinking water and domestic use, irrigation, and storage.

The opportunity for the Upper and Lower Similkameen Indian Bands to safely harvest fish is a key component to their cultural practice. The tangible cultural value in harvesting is inextricably linked to the health and well-being of both bands, as well as honoring the intangible values during cultural, spiritual, and ceremonial activities. These important cultural values and practices necessitate protection for future generations and support the recognition of human health as an important value to protect in the Similkameen watershed.

5.3 Wildlife

The Similkameen watershed is a unique region of Canada with a rich array of unique wildlife habitats. Typical wildlife in the Similkameen region includes California bighorn sheep, mountain goats, black bear, elk, deer, moose, and countless species of birds, including nesting bald eagles and peregrine falcons, hawks, bobolinks, long-billed curlews, western screech owls, yellow-breasted chats, wintering sharp-tail grouse, and yellow-billed cuckoo. The area also provides extensive habitat for reptiles and amphibians. There is distinct habitat for shrub-steppe and dry-forest dependent species including badgers, burrowing owls, and white-headed woodpeckers. The South-Okanagan – Similkameen area is home to one third of B.C.'s "red-listed" (endangered) wildlife species and seven wildlife species of global concern.

5.4 Cultural and Traditional Values

For the past 10,000 years the Similkameen People have lived, gathered, hunted, and fished on or in the waters of the Similkameen. As described in the Syilx Nation *Siwɬkʷ* (water) Declaration, *Siwɬkʷ* is part of the Syilx Nation and is part of all life. It must be treated with reverence and respect as it sustains their health and resiliency and is described as their lifeblood. Syilx People have inherent Aboriginal Title, Rights and Responsibilities to *Siwɬkʷ* and should be included in all planning and protection of it to protect and respect it. *Siwɬkʷ* and all things are intricately connected: what you do to one you do to all.

Under the *Siwɬkʷ* Declaration, there are strict water rules, protocols and legends that need to be respected. Most importantly is that healthy wild fish can be harvested safely, and water is safe and clean for cultural, spiritual, ceremonial, and recreational activities. Water values necessitate protection of the Similkameen River to ensure sustainability for future generations (Syilx Nation, 2014).

5.5 Agriculture

Agriculture is the largest user of water in the Similkameen watershed, with water licenses in place for irrigation and stock watering. There are over 280 ha of vineyards in the Similkameen River watershed.

5.6 Recreation

Recreational activities are extensive throughout the Similkameen watershed and within the rivers and lakes with opportunities for fishing, boating, kayaking, canoeing, tubing, and swimming. The high recreational use and the increasing residential development makes the aesthetic water quality of the Similkameen watershed an important aspect.

6. WATER QUALITY ASSESSMENT METHODS

6.1 Data Sources

The data used to assess the water quality of the Similkameen River and its tributaries were obtained from the provincial Environmental Monitoring Systems (EMS) data base and the Canada – B.C. Water Quality Monitoring Program. Available monitoring results from January 1, 2000 to June 30th 2021 were used to assess parameter concentrations and conditions for the Similkameen River. Data for the water quality assessment for the tributary streams were obtained from EMS from January 2001 to June 2023, where available. The locations of the monitoring sites are illustrated in Figure 5

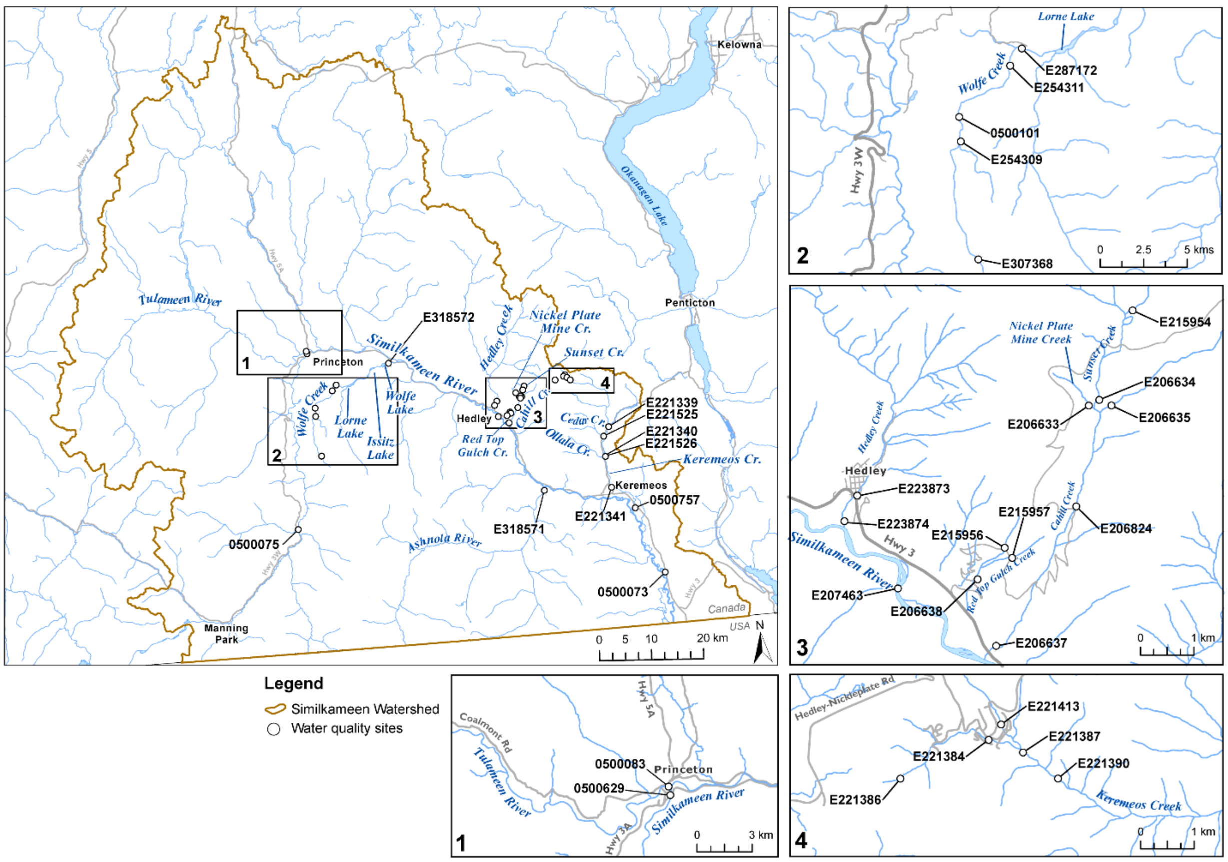

Figure 5. Similkameen River watershed water quality monitoring sites.

6.2 Data Assessment

Water quality data were compiled by site and visually inspected for outliers and obvious errors. Summary statistics were calculated, and data were presented seasonally, spatially, and temporally, as appropriate. Results were assessed against existing water quality objectives and water quality guidelines.

6.3 Benthic Invertebrates

Biomonitoring was conducted at select sites (Figure 6) on the Similkameen River following the Canadian Aquatic Biomonitoring Network (CABIN) procedures. Detailed sampling protocols are summarized in the CABIN field manual (Environment Canada 2012). Sites were chosen that targeted erosional riffle areas in wadable streams, where more pollution sensitive organisms reside, and sampled at previously established CABIN sites in conjunction with the water quality samples. At each site, standardized methods were used to characterize the habitat, water quality, and substrate composition. The benthic invertebrate communities were sampled using a 400 µm kick net and kicked for three minutes. Field data were also collected using a standardized field sheet, which included all CABIN data requirements. Benthic invertebrate samples were processed following CABIN laboratory methods (Environment Canada, 2014). All data are stored in Environment and Climate Change Canada's online database.

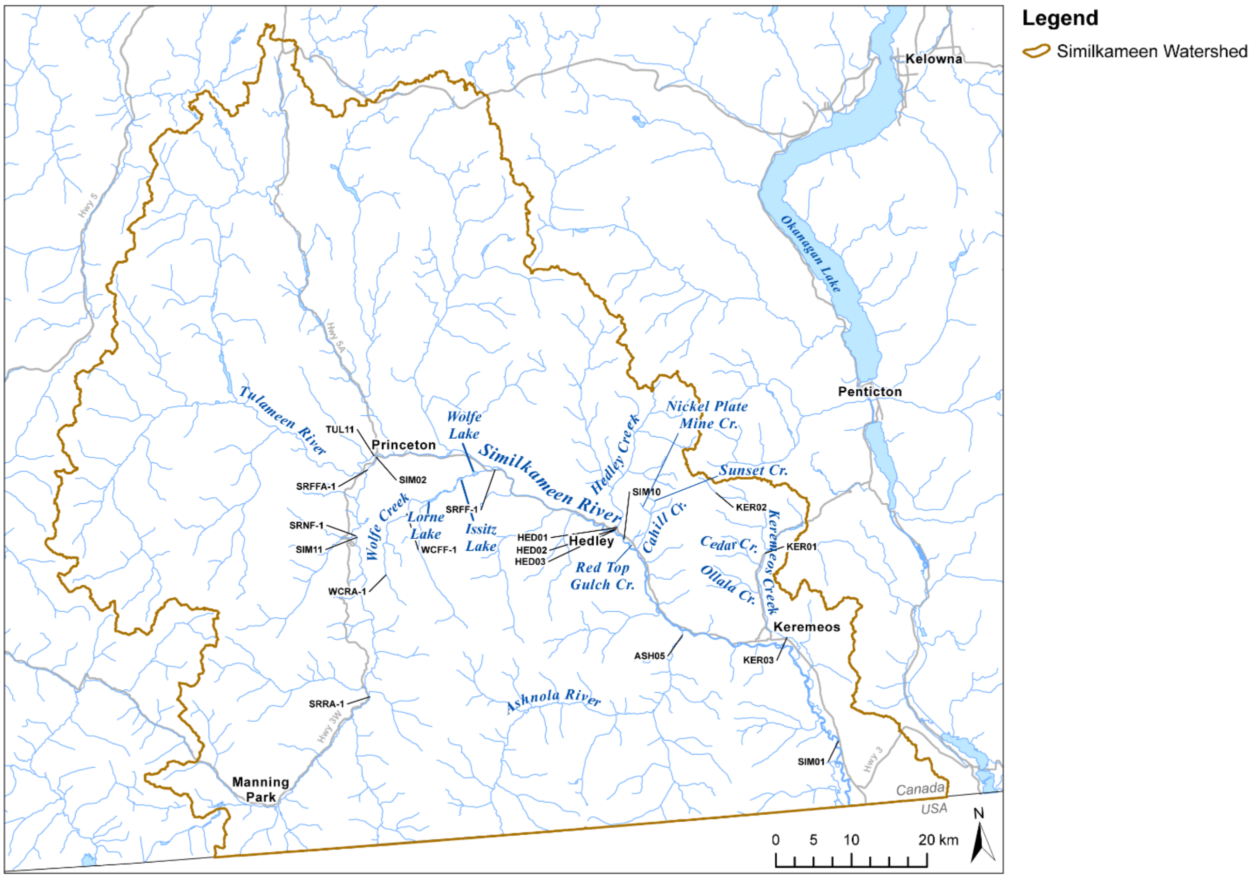

Figure 6: Location of CABIN biomonitoring sampling sites in the Similkameen River watershed.

7. <u>SIMILKAMEEN RIVER WATER QUALITY</u>

7.1 General parameters

General parameters (pH, temperature, dissolved oxygen, specific conductivity, hardness, turbidity, and total suspended solids) were assessed based on available data from three sites on the Similkameen River: 0500075 (Similkameen River upstream of Newmont); 0500629 (Similkameen River at Princeton); and 0500073 (Similkameen River near the International Border) (see Figure 5). The data assessed were from January 2000 to June 2021 unless otherwise indicated in the following sections.

7.1.1 pH

The existing WQO for pH in the Similkameen River is a range of 6.5 to 8.5, with no change greater than 0.2 if background values are outside this range (ENV 1990). The BC Aquatic Life Water Quality Guideline (ALWQG) for pH is 6.5 to 9.0 (ENV 2021a). The Similkameen River pH is slightly basic and consistent throughout with an average value of 7.9. Site 0500073 showed the widest range with a minimum pH of

6.4 and a maximum pH of 8.4 (Table 3). The seasonal variation of pH is illustrated in Figure 7. pH measurements in the Similkameen River were consistent with values previously reported ranging from 6.9 to 8.3 (ENV 1985).

Table 3: Summary statistics for pH in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	7.9	6.8	8.3	8.1	133
0500629	7.9	7.0	8.4	8.1	529
0500073	7.9	6.4	8.4	8.2	532

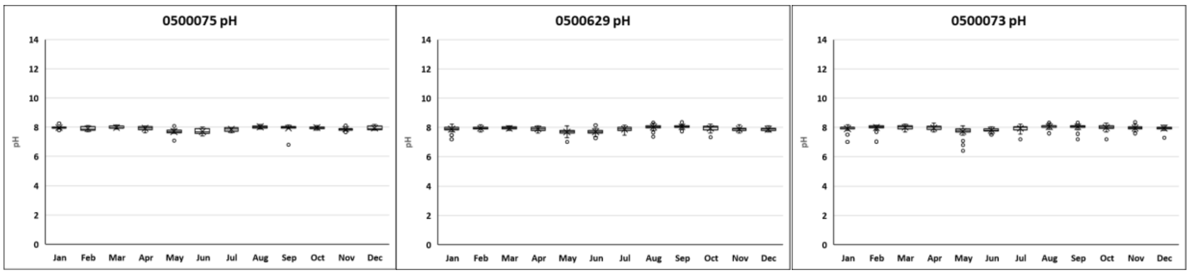

Figure 7: Seasonal variation in pH in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

7.1.2 Temperature

There is no WQO for water temperature for the Similkameen River or its major tributaries. Temperature ALWQGs are specific to fish species' life stage, and therefore change over the course of the year. For example, the optimum range for rainbow trout rearing is 16°C to 18°C (ENV 2001a) and 10°C to 12°C for incubation. The temperature ALWQG is designed to protect aquatic life from excessive fluctuations that are influenced by anthropogenic activities during sensitive periods and provides a site-specific benchmark for identified fish species of interest to assess water temperature in the Similkameen River.

Temperature data are limited to site 0500629 at Princeton and downstream at site 0500073 near the International Border (Table 4). At monitoring site 0500629 water temperature exceeded 18°C 2% of the time (10/539 samples) and exceeded the maximum incubation temperature of 12°C 16% of the time (9/53 samples), but only between June and September. At 0500073 water temperature exceeded 18°C 14% of the time (19/514 samples) and 12°C 24% of the time (121/514 samples). All measurements that exceeded 12°C occurred June to September, except in May of 2000 and 2001 (13°C and 14°C, respectively). Water temperature peaked in July and August at both sites; seasonal variations are illustrated in Figure 8.

Table 4: Summary statistics for water temperature (°C) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	8	4	14	14	11
0500629	6	0	21	16	528
0500073	9	0	21	17	382

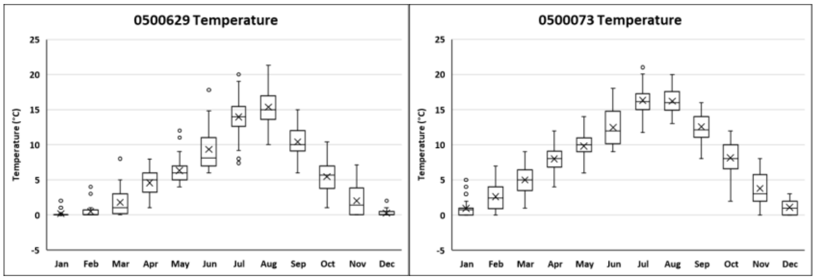

Figure 8: Seasonal variation in water temperature (°C) in the Similkameen River (2000 – 2021) near Princeton (0500629) and the international border (0500073).

7.1.3 Dissolved Oxygen

A WQO for dissolved oxygen (DO) was first adopted in 1990 (ENV 1990). The objective is a minimum concentration of 8.0 mg/L from July to March, and a minimum of 11.0 mg/L from April to June (when fish embryo/alevin are present) and was based on the Working Water Quality Guideline (WWQG) available at that time. The current approved ALWQG for DO (ENV 1997) is an instantaneous minimum of 9 mg/L and a 30-day average of 11 mg/L when fish embryo or alevin are present, and a minimum of 5 mg/L and average of 8 mg/L at other times of year.

The available DO data are summarized in Table 5. DO concentrations at 0500075 ranged from 7.9 mg/L (August 29, 2007) to 14 mg/L (May 9, 2007) with an average concentration of 10.7 mg/L. Two 30-day averaging periods were available in May and August 2007. The 30-day average in May was 12.8 mg/L and 8.5 mg/L in August meeting both the instantaneous minimum and the 30-day average WQG.

At 0500629, the lowest DO concentration measured was 7.6 mg/L on July 28, 2009. There were 18 sampling periods with the requisite sampling for determining average concentrations. The WQG was met 78% of the time (14/18). The four periods not meeting the WQG occurred in May and June 2010 and all average concentrations were 10.6 mg/L. The instantaneous WQG was met on all sampling dates except two in May and June 2013 (8.4 mg/L and 8.1 mg/L, respectively).

At 0500073, the instantaneous minimum WQG was met on all sampling dates except three: May 17, 2006 (8.6 mg/L); June 30, 2009 (8.8 mg/L); and May 19, 2021 (6.3 mg/L). The last result is suspect as DO was reported as 10.6 mg/L one week earlier. There were 13 sampling periods where the requisite sampling was conducted, 77% of these did not meet the 30-day average WQG, all of which occurred during the April – June period. April DO concentrations ranged from 9.6 mg/L to 12 mg/L; May DO concentrations ranged from 6.3 mg/L to 11.6 mg/L; and June concentrations ranged from 8.8 mg/L to 10.8 mg/L. Figure 9 shows the seasonal variation in DO concentrations at 0500629 and 0500073.

Table 5: Summary statistics for dissolved oxygen (mg/L) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	10.7	7.9	14	13.6	10
0500629	11.2	7.6	17.0	13.3	372
0500073	10.5	7.4	13.5	12.9	321

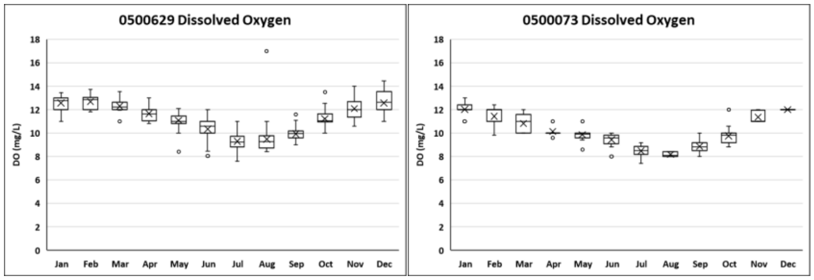

Figure 9: Seasonal variation in dissolved oxygen concentrations in Similkameen River (2000 – 2021) near Princeton (0500629) and the international border (0500073).

7.1.4 Specific Conductivity

Water with high conductivity used for crop irrigation can damage sensitive food crops, therefore, the WWQG for specific conductivity provides benchmarks for low tolerance, slightly tolerant, moderately tolerant, tolerant, and very tolerant crops, ranging from <700 µS/cm for low tolerance crops (e.g., strawberries, raspberries, beans, carrots) to <5,000 µS/cm for very tolerant crops (e.g., asparagus, oats, rye wheat, barley) (ENV 2021b).

Average specific conductivity increased from upstream (104 µS/cm) to downstream (157 µS/cm) (Table 6). Minimum values were approximately 50 µS/cm throughout, but maximum values increased from 148 µS/cm to 246 µS/cm downstream. Specific conductivity values are comparable to historical measures from 1972 to 1985 (ENV 1985) which ranged from 43 µS/cm to 153 µS/cm at 0500075; 47 µS/cm to 185 µS/cm at 0500629, and 59 µS/cm to 250 µS/cm at 0500073. The maximum specific conductivity at Similkameen River monitoring sites (246 µS/cm) is well below the most conservative benchmark for low tolerance crops (700 µS/cm).

Seasonal changes in specific conductivity show a clear pattern with the lowest levels observed during freshet in May and June when dilution is high (Figure 10).

Table 6: Summary statistics for specific conductivity (µS/cm) in Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	104	45	148	137	132
0500629	135	50	230	196	412
0500073	157	55	246	215	536

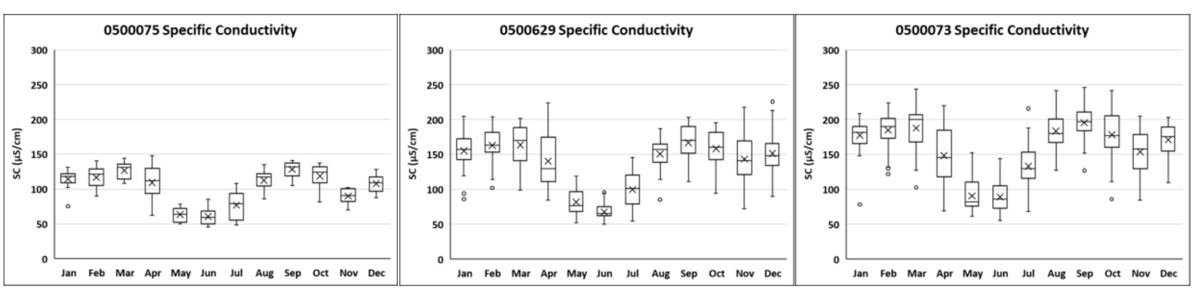

Figure 10: Seasonal variation in specific conductivity (µS/cm) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

7.1.5 Hardness

There is currently no ALWQG for water hardness. Water hardness increased upstream to downstream in the Similkameen River. Average concentrations ranged from 47 mg/L at 0500075 to 72 mg/L at 0500073 (Table 7). As with conductivity, minimum concentrations were generally consistent throughout (20 mg/L to 30 mg/L) and maximum concentrations were higher downstream (70 mg/L vs 112 mg/L).

Table 7: Summary statistics for hardness (mg/L) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	47	20	70	61	141
0500629	62	22	126	92	529
0500073	72	27	112	102	471

Total hardness at site 0500075 was comparable to historical levels. At downstream sites, 0500629 and 0500073, maximum and average concentrations have increased slightly. Historical hardness values were as follows:

- 0500075: Total hardness ranged from 26 to 81 mg/L with a mean hardness of 52 mg/L based on three samples in 1972 (ENV 1985).
- 0500629: Total hardness ranged from 20 to 84 mg/L with a mean hardness of 53 mg/L based on 85 samples from 1966 to 1979 (ENV 1985).
- 0500073: Total hardness ranged from 33 to 97 mg/L with a mean hardness of 73 mg/L based on 18 samples from 1979 to 1982 (ENV 1985), and from 1983 to 1988 total hardness ranged from 28 to 106 mg/L with a mean of 78 mg/L based on 87 samples (ENV 1990).

Water hardness fluctuates throughout the year due to natural changes in stream flow and groundwater influences. The seasonal variation in water hardness at Similkameen River sites are shown in Figure 11 for years 2000 to 2021. Hardness values are lowest in May and June and highest in September at all sites.

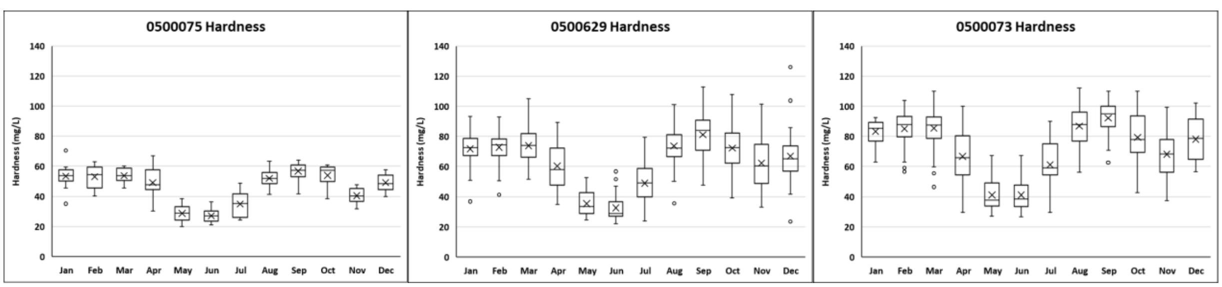

Figure 11: Seasonal variation in hardness (mg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

7.1.6 Turbidity

Turbidity is a measure of the lack of clarity or transparency of water caused by biotic and abiotic suspended or dissolved substances in water (ENV 2021c). Turbidity is measured by nephelometry (light scattering by suspend particles) and reported as nephelometric turbidity units (NTU). The higher the NTU the higher the concentrations of suspended or dissolved substances in a water sample.

High turbidity levels can impact water quality for drinking, recreation, and aquatic life. Elevated turbidity in streams can occur naturally from landslides or during periods of high-water flow when water velocity scours streambeds and banks introducing sediments and other particles into the water column. Anthropogenic land use activities that remove vegetation and disturb soils (e.g., forestry, road building, construction, mining, agriculture) can increase turbidity in nearby steams as well as untreated wastewater discharges from municipal or industrial operations. In built environments, storm water runoff collects and transports particulates and other contaminants to water ways via storm drains increasing turbidity during and after precipitation events.

Turbidity monitoring data (2000 to 2021) for the Similkameen River sites are summarized in Table 8. Average levels were 1 NTU at 0500075, 4 NTU at 0500629, and 6 NTU at 0500073, with 95th percentile values of 4 NTU, 17 NTU, and 17 NTU, respectively.

Table 8: Summary statistics for turbidity (NTU) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	1	0.1	13	4	138
0500629	4	0.1	157	17	560
0500073	6	0.1	844	17	520

Historical mean and maximum turbidity levels for the period 1972 to 1982 (ENV 1985) were 2 and 9 NTU at 0500075, 5.7 and 55 NTU at 0500629, and 6.7 and 55 NTU at 0500073. Historical turbidity maximums occurred between April and June during freshet which is consistent with more recent monitoring data (Figure 12). For the period 2000 to 2021 turbidity levels increased downstream and peaked during freshet. As illustrated, there is a noticeable difference in turbidity between 0500075 and 0500629, which is expected with development increasing from upstream to downstream.

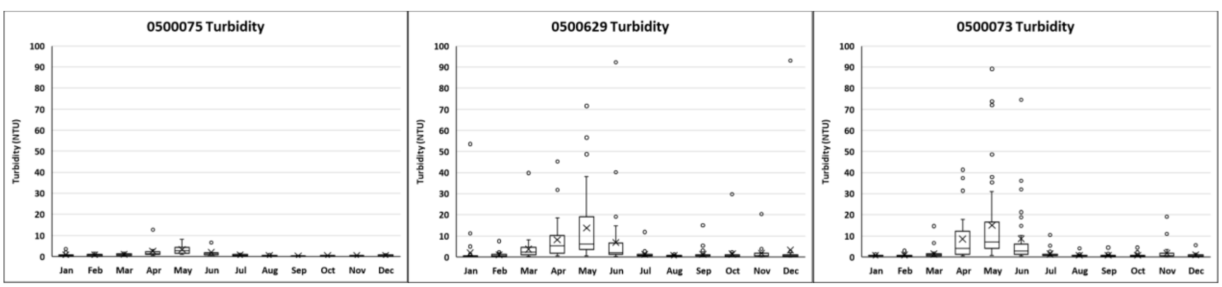

Figure 12: Seasonal variation in turbidity (NTU) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073). Note that values >100 NTU (1 at 0500629 and 3 at 0500073) are not displayed.

The turbidity WQO for the Similkameen River allows maximum increases of 1 NTU when upstream turbidity is ≤5 NTU, 5 NTU when upstream turbidity is ≤50 NTU, and 10% of upstream turbidity when upstream is >50 NTU. The Similkameen River data (2000 – 2021) were assessed for attainment of the WQO using measurements that were collected within a 24-hour period and the upstream measurement taken before the downstream measurement (Table 9). At 0500629, 44% (11/25) of results exceeded the WQO. This can be expected given the pristine and forested nature of the upstream site compared to the downstream sites exposed to various land uses. At 0500073, 12% (43/345) of results exceeded the WQO with most of these (31) occurring during freshet in April through June.

Table 9: Frequency of turbidity WQO exceedances at downstream sites on the Similkameen River (2000 – 2021).

	0500075 - 0500629		0500629 - 0500073	
	>WQO	n	>WQO	n
January	1	2	0	27
February	1	1	0	22
March	2	3	2	30
April	2	4	7	31
May	3	4	15	39
June	0	1	9	33
July	1	1	2	31
August	0	3	0	30
September	1	4	2	31
October	0	1	2	27
November	0	0	2	24
December	0	1	2	20
Total	11	25	43	345

7.1.7 Total Suspended Solids

Total suspended solids (TSS), or non-filterable residue (NFR), include all the undissolved particulate matter in water. This value is closely correlated with turbidity, however, instead of being measured optically, the sample is filtered, and the residue dried to provide the weight of residue per volume (e.g., mg/L).

The sources and effects of TSS on aquatic life are like turbidity. Soil disturbances via landslides or anthropogenic activities (e.g., forest harvesting, road building, mining) can introduce soil particles and other solids into the water column. Suspended solids can reduce light penetration for aquatic plants, clog fish gills, abrade, damage, or dislodge aquatic invertebrates as well as change stream bed composition when suspended solids are deposited.

The current WQO for TSS in the Similkameen River is a maximum increase of 10 mg/L when upstream concentration is less than or equal to 100 mg/L, or a 10% maximum increase when upstream is greater than 100 mg/L (ENV 1990). The current WQG for TSS (ENV 2021c) includes a short-term and long-term WQG in periods of clear flow (i.e., <25 mg/L TSS) and a maximum WQG for turbid flow (i.e., >25 mg/L TSS). For clear flows, the short-term WQG is a change from background TSS of 25 mg/L at any one time for a duration of 24 hours and the long-term WQG is a change from background TSS of 5 mg/L at any one time for a duration of 30 days. For turbid flows the maximum change from background TSS is 10 mg/L at any one time when background is 25 to 100 mg/L or a maximum change of 10% when background TSS is greater than 100 mg/L (ENV 2021c). Data were compared to both the WQO and WQG where possible i.e., comparing downstream results to upstream results where samples were collected within 24 hours.

The Similkameen River TSS data (2000 – 2021) are summarized in Table 10. TSS levels increased downstream at 0500629 and 0500073 (95^{th} percentile of 42 mg/L and 50 mg/L, respectively) from upstream levels at 0500075 (95^{th} percentile = 17 mg/L), however results from the two downstream sites are comparable. The seasonal trends in TSS concentrations are illustrated in Figure 13. TSS concentrations increase during spring freshet at all the sites, with the downstream sites experiencing greater increases than the upstream background site (0500075). This is expected since the upstream site is less developed.

Table 10: Summary statistics for total suspended solids (mg/L) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	5	1	52	17	138
0500629	11	1	254	42	228
0500073	12	1	330	50	196

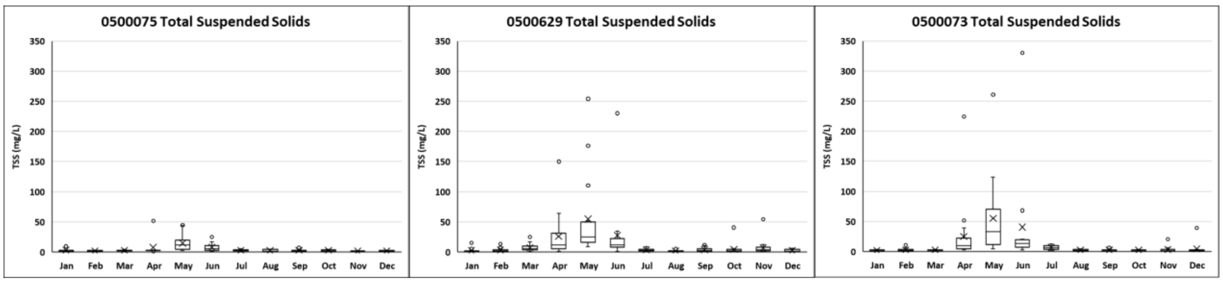

Figure 13: Seasonal variation in total suspended solids (mg/L) in the Similkameen River (2000 - 2021) from upstream (0500075) to downstream (0500073).

Assessing attainment of the WQO and WQG was difficult because concurrent sampling (i.e., upstream site sampled on the same day as downstream sites) was limited. There were 99 sampling events where downstream TSS levels could be compared against upstream levels. Of these, 84% met the WQO and 90% met the WQG. (i.e., <10 mg/L). Of the WQO exceedances, 81% (13/16) occurred during freshet (April – June); of the WQG exceedances, 9 of 10 occurred during freshet.

7.2 Nutrients

7.2.1 Total Phosphorus

Phosphorus is non-toxic to aquatic organisms at levels and forms present in the environment; however, secondary effects, such as eutrophication and oxygen depletion are serious concerns (CCME 2004). There are no provincial or national phosphorus guidelines for the protection of aquatic life in streams. Rather, the Canadian Council of Ministers of the Environment (CCME) (2004) recommends a guidance framework that accommodates the non-toxic endpoints associated with phosphorus with total phosphorus providing a meaningful indicator in surface waters. Monitoring results for total and dissolved phosphorus in the Similkameen River are summarized in Table 11.

Total phosphorus increased from upstream to downstream with average concentrations of 6 µg/L at 0500075, 20 µg/L at 0500629, and a 25 µg/L at 0500073. The highest concentration of 792 µg/L was measured at 0500073 with a 95th percentile concentration of 108 µg/L. Dissolved phosphorus concentrations were consistent throughout the Similkameen mainstem averaging approximately 5 µg/L, indicating the amount of biologically available phosphorus is generally much lower than the total phosphorus concentrations.

Table 11: Summary statistics for total and dissolved phosphorus (µg/L) in the Similkameen River (2000 – 2021).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
0500075	Total phosphorus	6	<2	95	17	120
	Dissolved phosphorus	4	<2	102	5	120
0500629	Total phosphorus	20	1	557	90	390
	Dissolved phosphorus	6	2	136	18	557
0500073	Total phosphorus	25	1	792	108	366
	Dissolved phosphorus	5	2	158	11	513

Total phosphorus varies seasonally in the Similkameen River with the highest concentrations measured in March through June coinciding with spring freshet (Figure 14). Total phosphorus concentrations were strongly influenced by turbidity events as illustrated in Figure 15.

Phosphorus monitoring data for 0500075 were not collected with sufficient frequency to calculate 30-day averages. At 0500629, 30-day average concentrations ranged from 3 µg/L to 186 µg/L from March through June and 3 µg/L to 158 µg/L July through February (Figure 16). At 0500073, March to June 30-day averages ranged from 3 µg/L to 268 µg/L and 3 µg/L to 188 µg/L July through February. Overall, 30-day average total phosphorus concentrations were well below the maximum concentrations measured at each site (see Table 11).

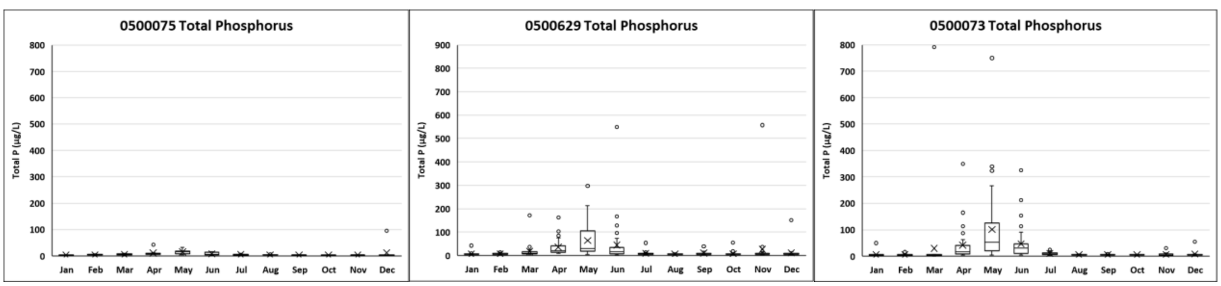

Figure 14: Seasonal variation in total and dissolved phosphorus (µg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

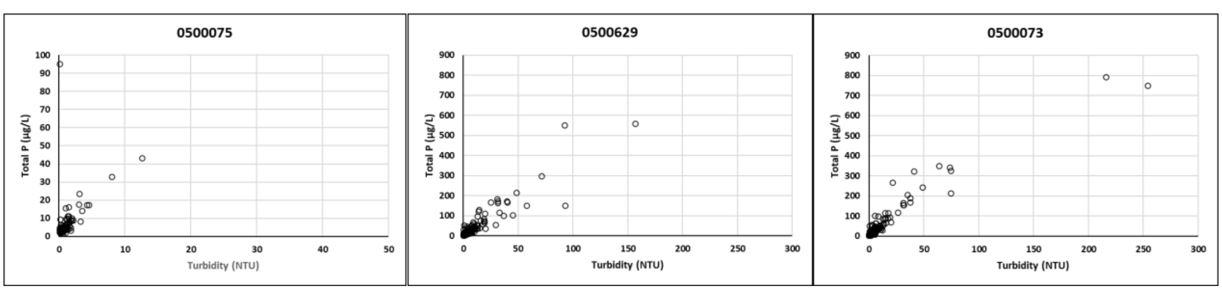

Figure 15: Total phosphorus (µg/L) as function of turbidity (NTU) in the Similkameen River. Sites are presented in order from upstream to downstream. Note the difference in values of the X and Y axes at 0500075.

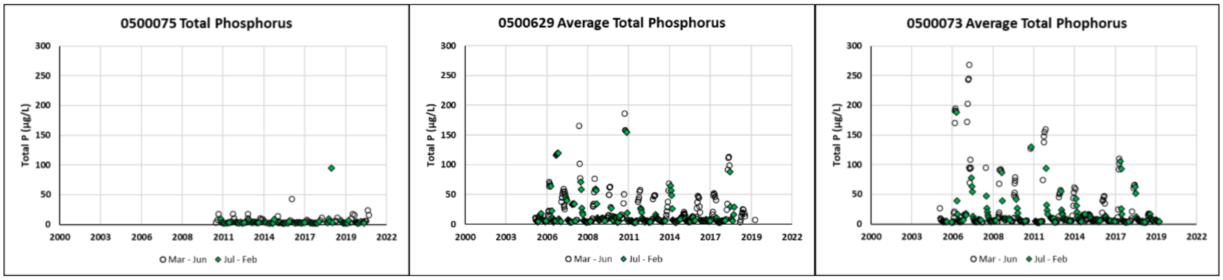

Figure 16: 30-day average total phosphorus concentrations in Similkameen River upstream to downstream. For 0500075 data presented represent all measurements, not 30-day averages. Clear circles represent values for March through April; green diamonds represent values for July through February.

7.2.2 Nitrogen

Along with phosphorus, nitrogen is a key driver in the productivity of aquatic ecosystems. The nitrate long-term chronic ALWQG is 3 mg/L (ENV 2009) and is the most conservative nitrate benchmark. The nitrite ALWQG (ENV 2021d) is based on chloride levels, which are low in the Similkameen River and result in a WQG value of 20 µg/L. Ammonia guideline values are determined by pH levels and water temperature and decrease with increasing pH and temperature (ENV 2021d). Assuming a worst-case scenario of pH at 8.4 and a water temperature of 20°C gives a long-term ammonia ALWQG of 321 µg/L. There are no WQGs for total nitrogen, therefore the sum of the values presented here (3.5 mg/L) was used to assess total nitrogen levels in the Similkameen River mainstem.

Data for the various nitrogen parameters measured in the Similkameen River are summarized in Table 12 and include total nitrogen, dissolved nitrogen, nitrate plus nitrite, and ammonia.

Table 12: Summary statistics for total and dissolved nitrogen (µg/L) in the Similkameen River (2000 – 2021).

Parameter	Site	Average	Minimum	Maximum	95th percentile	n
Total nitrogen	0500075	86	18	300	185	119
	0500629	123	20	665	256	287
	0500073	134	20	645	268	262
Dissolved nitrogen	0500075	–	–	–	–	–
	0500629	106	20	611	230	505
	0500073	113	20	630	220	447
Nitrate + nitrite	0500075	12	<2	231	33	134
	0500629	14	<3	166	78	204
	0500073	25	<3	119	69	237
Ammonia	0500075	<MDL	<5	111	<5	116
	0500629	–	–	–	–	–
	0500073	–	–	–	–	–

As with phosphorus, nitrogen concentrations increased from upstream to downstream. Average total nitrogen concentrations were 86 µg/L, 123 µg/L, and 134 µg/L, and maximum concentrations were 300 µg/L, 665 µg/L, and 645 µg/L at sites 0500075, 0500629, and 0500073, respectively. Unlike phosphorus, total nitrogen did not appear to be influenced by turbidity.

Seasonal total nitrogen levels are illustrated in Figure 17. While concentrations do increase from upstream to downstream the magnitude of change is much less, and the influence of spring freshet is not as pronounced, as was observed for total phosphorus. Concentrations were generally below 300 µg/L at each site.

Figure 18 shows a difference in total nitrogen concentrations between the March to June freshet period and the July to February low-flow period upstream at site 0500075. Thirty-day average concentrations were elevated downstream at 0500629 and 0500073, although no clear difference between the freshet and low-flow periods was observed. Overall, total nitrogen concentrations were well below the arbitrary benchmark of 3.5 mg/L.

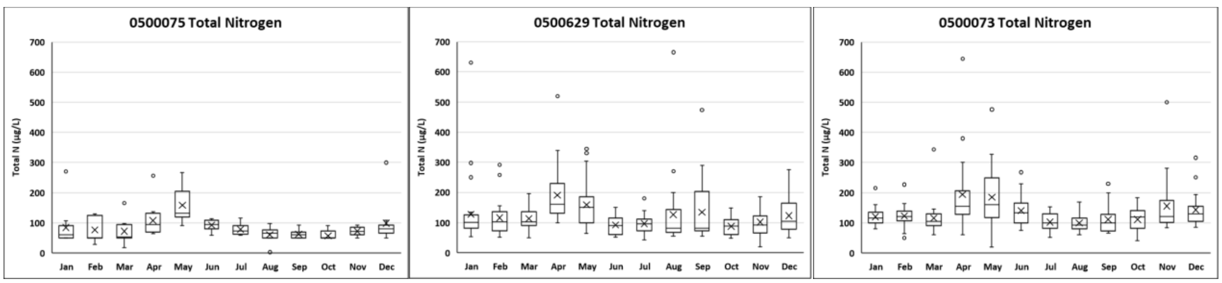

Figure 17: Seasonal variation in total nitrogen (µg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

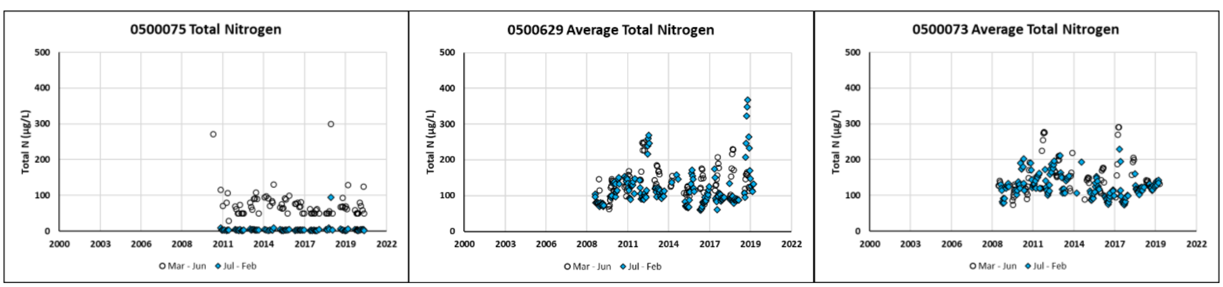

Figure 18: 30-day average total nitrogen concentrations (µg/L) in the Similkameen River from upstream to downstream. For 0500075, data presented represent all individual results, not just 30-day averages. Clear circles represent values for March through June; blue diamonds represent values for July through February.

7.3 Organic Matter

7.3.1 Organic Carbon

Organic carbon is an important water quality constituent because of its role in primary productivity, system metabolism, aquatic community structure, and metal toxicity (ENV 1998). Total organic carbon (TOC) and dissolved organic carbon (DOC) WQGs for the protection of aquatic life are based on changes from background concentrations, either historical or upstream. For both TOC and DOC, the median concentrations (based on a minimum of 5 weekly samples collected within 30 days) should be within ±20% of background levels. To prevent disinfection by-product formation and protect drinking water sources, a maximum allowable concentration of 4 mg/L TOC is set as the WQG.

A summary of DOC data for the Similkameen River (2000 – 2021) is provided in Table 13. TOC data were only available for 0500075. DOC concentrations at the upstream site (0500075) were lower than the downstream sites (0500629, 0500073) while the average, 95th percentile, minimum and maximum DOC concentrations were similar for site 0500629 and 0500073. The seasonal variation in DOC concentrations is shown in Figure 19; concentrations peak in spring (April to June) and are lowest in summer.

TOC concentrations averaged 2.2 mg/L at 0500075 ranging from 0.8 mg/L to 6.7 mg/L. Most results (93%) were less than 4.0 mg/L with most exceedances of the drinking water guideline occurring during April and May.

The long-term aquatic life WQG for DOC is ±20% of the background median concentration based on a 30-day median (ENV 2001). DOC monitoring data did not meet the 30-day median calculation requirement (e.g., 5 weekly samples collected in 30 days) for comparison to the DOC WQG, however, calculated medians for the downstream sites (0500075, 0500629) were within 20% of the background median (0500075) based on all samples collected (Table 13).

Table 13: Summary statistics for dissolved organic carbon (mg/L) in the Similkameen River (2000 – 2021). Results are presented in order, upstream to downstream.

Site	Average	Median	Minimum	Maximum	95th percentile	n
0500075	2.1	1.8	0.568	4.92	4.1	120
0500629	2.5	1.9	0.600	19.0	6.1	540
0500073	2.6	2.0	0.560	20.1	6.1	505

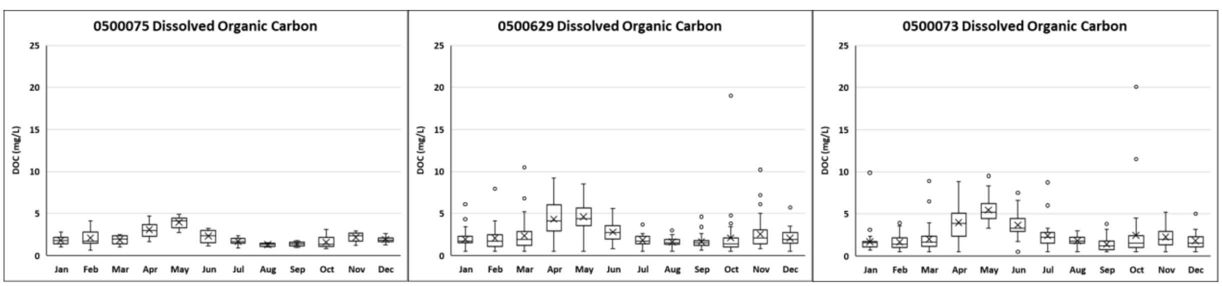

Figure 19: Seasonal variation in DOC (mg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

The available DOC data were pooled by month and site and monthly median values were calculated for each site (Table 14). The monthly median values were compared to the upstream values to determine if they were within ±20% of upstream concentrations. At 0500629, DOC concentrations only exceeded this range in April; at 0500073 the upstream range was exceeded in June and July. Based on these findings, DOC does not appear to be problematic in terms of the aquatic life WQG. It is recognized that more complete monitoring would be required to properly assess this, both in terms of the aquatic life WQG and the drinking water source WQG. It is also recognized that DOC may play an important role in reducing the toxicity of some metals and organics (e.g., PAHs and PCBs), therefore regular water quality monitoring efforts should include both TOC and DOC.

Table 14: Monthly median dissolved organic carbon (DOC) concentrations (mg/L) for the Similkameen River. Sites are presented upstream to downstream. Bolded values represent results outside ±20% of the upstream value.

	0500075	0500629	0500073
January	1.7	1.7	1.6
February	1.7	1.7	1.4
March	2.0	1.9	1.7
April	3.0	**4.1**	3.9
May	4.1	4.4	5.2
June	2.4	2.7	**3.3**
July	1.6	1.7	**2.2**
August	1.4	1.5	1.8
September	1.4	1.5	1.2
October	1.3	1.4	1.5
November	2.3	2.1	2.0
December	1.9	1.9	1.5

7.4 Major Ions and Other Inorganic Parameters

7.4.1 Sulphate

Currently there is no sulphate WQO for the Similkameen River. B.C. has sulphate WQGs to protect source drinking water, aquatic life, and livestock. The drinking water guideline for sulphate is 500 mg/L (ENV 2020a) and the livestock watering guideline is 1,000 mg/L (ENV 2021b). The sulphate ALWQG is based on water hardness and ranges from 128 mg/L to 309 mg/L for the range of hardness values reported for the Similkameen River (ENV 2013). Sulphate monitoring results for Similkameen River are summarized in Table 15.

Sulphate concentrations were low throughout the Similkameen River. Average concentrations were 4 mg/L at 0500075, 15 mg/L at 0500629, and 13 mg/L at 0500073. Based on minimum hardness levels observed at monitoring sites (≤30 mg/L), all sulphate results are well below the ALWQG of 128 mg/L.

Seasonal variation in sulphate concentrations is shown in Figure 20. At 0500075, concentrations were <10 mg/L with little variation month to month. Concentrations at 0500629 were more variable with lowest levels observed in May and June (freshet) and higher concentrations in August and September (low flow). Downstream at 0500073, concentrations were lower than 0500629 but followed a similar seasonal pattern.

Table 15: Summary statistics for sulphate (mg/L) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95^{th} percentile	n
0500075	4	1	10	6	145
0500629	15	1	41	33	198
0500073	13	1	26	22	168

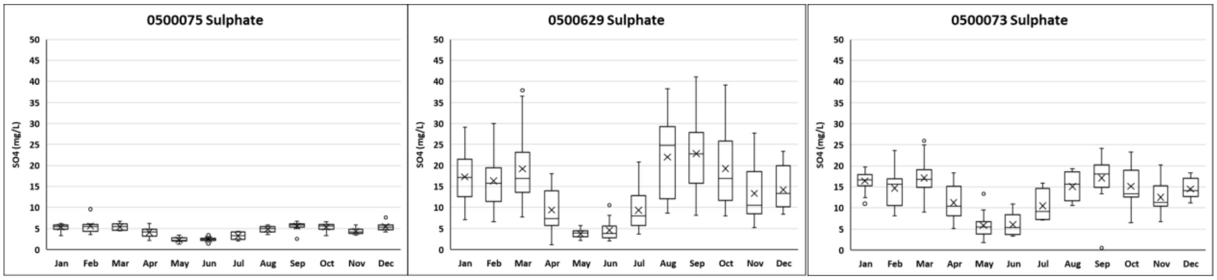

Figure 20: Seasonal variation in sulphate (mg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

7.4.2 Cyanide

Cyanide is a chemical group composed of nitrogen triply bonded to carbon that exists in a variety of inorganic and organic forms in the aquatic environment. The form of cyanide in water is largely dependent on pH but also influenced by temperature, dissolved oxygen, salinity, and the presence of other ions. Cyanide is ubiquitous in the environment and can be produced naturally by many species of plants, as well as by some species of fungi, algae, and bacteria. Anthropogenic sources to the environment are largely waste effluents from industrial processes including gas works, coke ovens, gas scrubbing in steel plants, aluminum smelters, metal cleaning, electroplating, chemical plants, and petroleum refineries. Another major source is gold mining and milling where cyanide is frequently used to extract gold from the ore (ENV 2021e).

The ALWQG for cyanide is based on concentrations of weak-acid dissociable cyanide (WAD CN) in water. WAD CN includes free, simple, and weak-acid dissociable metal cyanides such as zinc and cadmium cyanide complexes but does not measure the more stable cyanide complexes such as ferricyanide and ferrocyanide, cobalt or gold cyanide complexes, thiocyanate, and cyanate (ENV 2021e). The long-term chronic and short-term acute WQGs for WAD CN are 5 µg/L and 10 µg/L, respectively. There is no WQG for strong-acid dissociable cyanide (SAD CN).

In 1990, ENV proposed provisional WQOs for WAD CN, SAD CN, and cyanates for the Similkameen River and Hedley Creek due to potential impacts of cyanide-leaching operations to re-process tailings piles located along the banks of these streams. The provisional WQOs were 5 µg/L (average) and 10 µg/L (maximum) for WAD CN, 200 µg/L (maximum) for SAD CN and 450 µg/L (maximum) for cyanates (ENV 1990). Monitoring data for WAD CN and SAD CN for the Similkameen River are summarized in Table 16. Based on the available monitoring data, cyanide concentrations increase upstream to downstream with no exceedances of the 1990 WQOs. WAD and SAD CN monitoring data are limited to 21 results at 0500075 while downstream sites (0500629 and 0500073) had larger sample sizes. At 0500075, WAD CN results were below the average WQO value (maximum of 0.78 µg/L) with 90% (19/21) of results below method detection limits (MDL). At 0500629, 87% (462/529) of the samples were below the MDL of 0.5 µg/L or 5 µg/L, with 131 of these results using a MDL of 5 µg/L. Results greater than MDLs ranged from 0.50 µg/L to 1.7 µg/L. At 0500073 WAD CN concentrations were below the WQ, but higher than the upstream sites. Of the 496 results, 89% (440/496) were below the MDLs, with 119 of these using an MDL of 5 µg/L. Results above MDLs ranged from 0.50 µg/L to 3.9 µg/L.

No data for cyanates were available.

Table 16: Summary statistics for weak-acid dissociable cyanide (WAD CN) (µg/L) and strong-acid dissociable cyanide (SAD CN) in the Similkameen River (2000 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
0500075	WAD CN	0.25	<0.50	0.78	0.63	21
	SAD CN	0.25	<0.50	0.81	0.68	21
0500629	WAD CN	0.73	<0.50	1.7	1.4	529
	SAD CN	0.75	<0.50	2.6	1.6	329
0500073	WAD CN	0.84	<0.50	3.9	1.7	496
	SAD CN	0.81	<0.50	1.8	1.3	313

7.5 Metals

7.5.1 Aluminum

The 1990 aluminum WQO for the Similkameen River is based on dissolved aluminum and was set at the ALWQG level. This WQO recognized the risk associated with the high aluminum concentrations in mine tailing piles adjacent to Hedley Creek, in Hedley Creek groundwater, and in the Similkameen River downstream of Hedley Creek outflow (ENV 1990). The aluminum WQO is an average concentration of 0.05 mg/L dissolved aluminum and a maximum concentration of 0.10 mg/L when pH is greater than 6.5. The B.C. source drinking water quality guideline (SDWQG) is a maximum acceptable concentration (MAC) of 9.5 mg/L.

In 2022, Environment and Climate Change Canada (ECCC) published an updated Federal Environmental Quality Guideline for total aluminum for the protection of freshwater aquatic life as the total aluminum fraction corresponds better with aluminum toxicity than the dissolved fraction (ECCC 2022). B.C. has adopted this guideline (WLRS 2023a) which accounts for the effects of site-specific conditions (pH, DOC, and hardness) on the toxicity of aluminum to aquatic life. The assessment of aluminum in the Similkameen River and its tributaries is therefore based on total aluminum.

Total aluminum concentrations in the Similkameen River for the period 2000 to 2021 are summarized in Table 17. Total aluminum concentrations increased from upstream to downstream with the highest average, maximum and 95th percentile concentrations measured at 0500073.

Table 17: Summary statistics for total aluminum (mg/L) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	0.096	0.008	1.47	0.350	146
0500629	0.297	0.017	11.9	1.16	551
0500073	0.378	0.001	21.2	1.47	518

The seasonal variation in total aluminum concentrations is illustrated in Figure 21. Total aluminum concentrations were highest in May at all sites with the two downstream sites showing much higher concentrations during freshet. The increase in total aluminum levels downstream of 0500075 suggests possible inputs from sources other than natural ambient levels. Potential sources include seepage from mining activities on the west and east side of Similkameen River downstream of 0500075 (i.e., Copper Mountain) and historical mining and tailing piles in the Hedley Creek and Cahill Creek sub-basins which drain into Similkameen River downstream of 0500629. Land disturbances from other forms of development (urban development, forestry, agriculture) could also contribute to the elevated aluminum concentrations seen downstream.

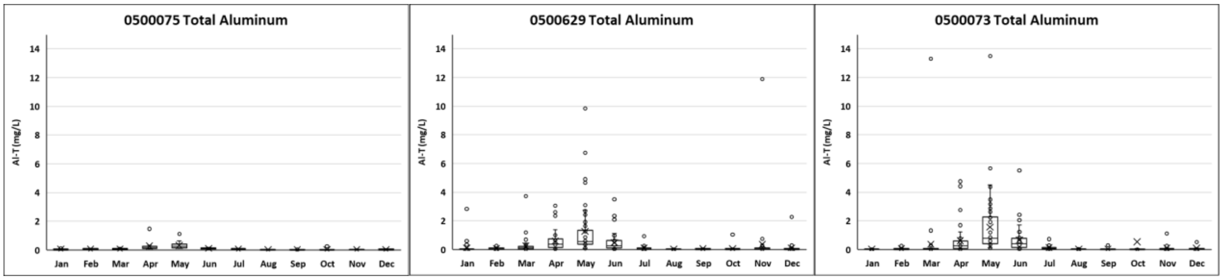

Figure 21: Seasonal variation in total aluminum (mg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073). Note that an October value of 21.2 mg/L for 0500073 is not shown.

Monthly average total aluminum concentrations were calculated and compared to monthly average total aluminum WQG values for sites 0500629 and 0500073 (Table 18). Average total aluminum concentrations exceeded WQG values at both sites from March through June with the greatest exceedances occurring in May and June. At 0500629 the average WQG was also exceeded in November and at 0500073 the WQG was exceeded in October. Both these exceedances were driven by one high value at each site (11.9 mg/L and 21.2 mg/L, respectively).

Table 18: Average monthly total aluminum concentrations (mg/L) in the Similkameen River (2000 – 2021) compared to corresponding water quality guideline levels. Sites are presented upstream to downstream. Bold values indicate an exceedance of the guideline.

	0500629		0500073	
	Total Al	Al WQG	Total Al	Al WQG
January	0.098	0.180	0.030	0.170
February	0.071	0.183	0.052	0.176
March	**0.245**	0.208	**0.368**	0.196
April	**0.587**	0.300	**0.611**	0.301
May	**1.260**	0.261	**1.553**	0.322
June	**0.472**	0.171	**0.651**	0.246
July	0.097	0.154	0.126	0.206
August	0.032	0.163	0.028	0.197
September	0.044	0.177	0.035	0.164
October	0.056	0.175	**0.537**	0.200
November	**0.356**	0.202	0.086	0.205
December	0.107	0.182	0.087	0.183

The period of March through June is when total aluminum concentrations are likely to be substantially elevated. To assess risk to aquatic life during this period, rolling average total aluminum concentrations were calculated where a minimum of five results were available from March through June each year. These values were then compared to WQG levels calculated from the corresponding available pH, DOC, and hardness data (Figure 22). The rate of WQG exceedance was greater at 0500629 at 93% (99/106) than 0500073 at 78% (80/102). It should be noted that the preferred rate of sampling for assessing long-term WQGs and WQOs (i.e., average concentrations calculated from 5 weekly samples collected within 30 days) was not achieved and the results presented here should be viewed with some caution.

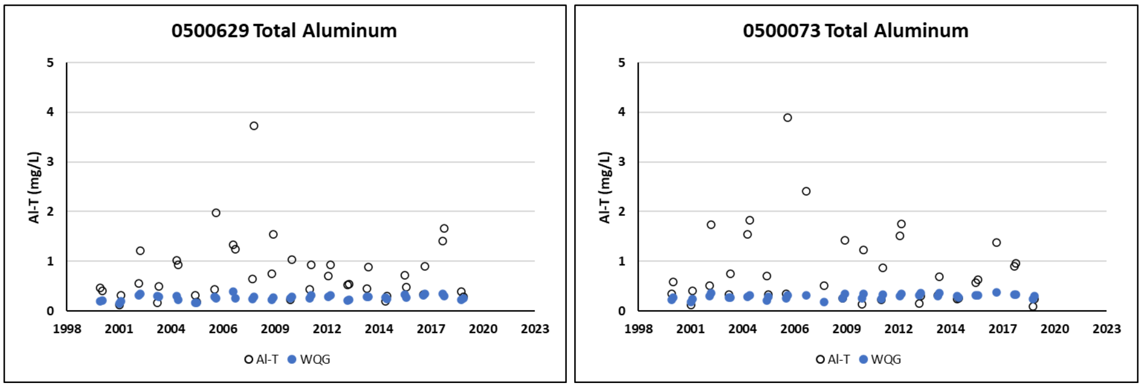

Figure 22: Spring freshet (March through June) average total aluminum concentrations (mg/L) and corresponding water quality guideline levels (mg/L) for the Similkameen River, upstream to downstream.

The available data clearly show elevated total aluminum values at downstream sites compared to upstream conditions. The upstream site (0500075) is relatively pristine, forested, and undeveloped. The downstream sites (0500629 and 0500073) are exposed to a valley bottom landscape and a variety of land development, therefore higher concentrations of total aluminum are not surprising, especially during freshet. Background concentrations can be elevated at minimally impacted sites throughout B.C., with measured concentrations as high as 28.2 mg/L in the Okanagan region (WLRS 2023a) and it is possible that the elevated concentrations are partly due to natural conditions. Although data from some tributaries to the Similkameen are limited, concentrations as high as 1.25 mg/L have been reported in the Tulameen River. Additional monitoring at the required frequency should be conducted to confirm the findings presented here.

7.5.2 Arsenic

A WQO for total arsenic was first set in 1990 for the Similkameen River from Princeton to the International Border and its tributary streams - Hedley Creek, Cahill Creek, and Nickel Mine Creek (ENV 1990). The WQO was set at a maximum concentration of 50 µg/L to account for high arsenic concentrations in mine tailing piles adjacent to Hedley Creek and the groundwater (ENV 1990). Since that time B.C. has updated its arsenic ALWQG (30-day average total arsenic concentration ≤5 µg/L) (ENV 2021f) and adopted Health Canada's drinking water guideline (MAC of 10 µg/L) (ENV 2020a). These levels provided the benchmarks used in this assessment. Dissolved arsenic was also assessed to estimate the fraction of bioavailable arsenic in the Similkameen River mainstem.

Total and dissolved arsenic data for sites 0500075, 0500629 and 0500073 are summarized in Table 19. Arsenic concentrations increase downstream of 0500629 suggesting inputs between this site and 0500073. Inputs from past mining activities, waste rock, and tailing piles to Hedley Creek, Cahill Creek and

Red Top Gulch Creek are likely causes of the elevated arsenic concentrations observed at 0500073 (see Sections 10, 11, and 12).

Table 19: Summary statistics for total and dissolved arsenic (µg/L) in the Similkameen River (2000 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
0500075	Total arsenic	0.554	0.350	1.32	0.751	134
	Dissolved arsenic	0.485	0.340	0.900	0.629	103
0500629	Total arsenic	0.520	0.100	5.03	0.820	549
	Dissolved arsenic	0.457	0.200	1.15	0.590	224
0500073	Total arsenic	1.46	0.300	14.9	3.49	518
	Dissolved arsenic	0.894	0.300	5.17	1.64	220

The total arsenic WQG was met at 0500629 and 0500073 during all periods with sufficient data available (i.e., 5 results in 30 days), although these periods were limited at both sites. There were seven sampling periods for 0500629 with all average concentrations less than 1.0 µg/L except one (1.63 µg/L in May 2008). At 0500073, there nine sampling events with sufficient data and all average concentrations were ≤4.0 µg/L.

Seasonal arsenic levels are illustrated in Figure 23. Background levels of both total and dissolved arsenic were consistently <1 µg/L at 0500075 throughout the year. At 0500629, total arsenic was elevated during freshet in April through June but still generally <1 µg/L for both fractions. Increased concentrations are seen downstream at 0500073 especially during freshet, however average levels are still below the total arsenic ALWQG of 5 µg/L. During the summer low flow period from July through September dissolved arsenic increased and represents most of the total arsenic measured, suggesting an increased influence from groundwater inputs at this time. Overall, total arsenic levels were well below both the aquatic life WQG and the drinking water source WQGs.

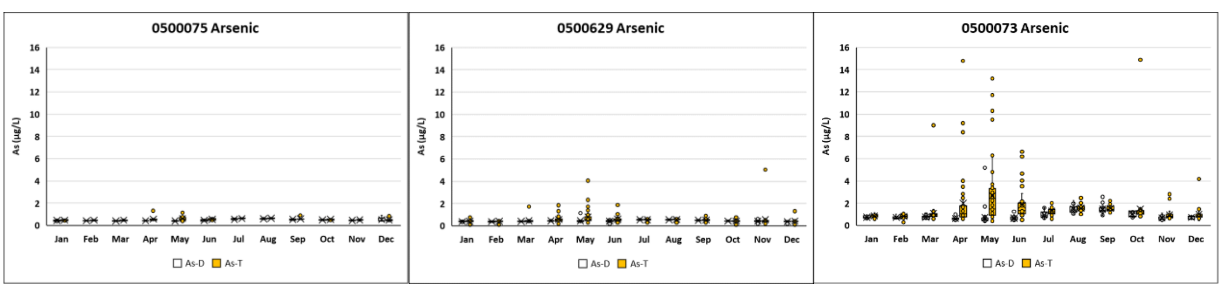

Figure 23: Seasonal variation in total and dissolved arsenic (µg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

7.5.3 Chromium

The 1990 WQO for total chromium (Cr) in the Similkameen River downstream of Princeton is an average concentration of 2 µg/L and a maximum concentration of 20 µg/L and was based on the available WWQGs at that time. This WQO recognized that historical mine tailing piles adjacent to Hedley Creek contained chromium concentrations of 13 to 24 mg/L which could be mobilized into surface water and groundwater if the piles are disturbed (ENV 1990). The current WWQG for chromium (ENV 2021b) was adopted from CCME (1999) and is specific to the valency. For hexavalent chromium [Cr(VI)] the WWQG is an average of 1 µg/L and for trivalent chromium [Cr(III)] the WWQG is an average of 8.9 µg/L. The data available for this assessment include both total and dissolved chromium but do not specify valency. Total chromium measurements include particulate chromium which may affect the validity of measurements at freshet when erosion and turbidity is high. Under these conditions total chromium results may exceed WQG levels with no adverse impacts on biota (CCME 1999). In unfiltered samples (i.e., total chromium), 10% - 60% of the total chromium is Cr(VI) in the dissolved form and in filtered samples (i.e., dissolved chromium) the range is 70% - 90% (CCME 1999). B.C. also has a total chromium WQG for the protection of drinking water sources of 50 mg/L.

Summary statistics for chromium in the Similkameen River monitoring sites are shown in Table 20 for the period 2000 to 2021.

Total chromium concentrations increased upstream to downstream with average concentrations ranging from 0.209 µg/L at 0500075 to 0.578 µg/L at 0500073. Maximum concentrations coincided with elevated turbidity levels and generally at spring freshet. Dissolved chromium concentrations were low and consistent throughout the Similkameen River mainstem.

Table 20: Summary statistics for chromium (µg/L) in the Similkameen River (2000 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95^{th} percentile	n
0500075	Total chromium	0.209	<0.100	1.40	0.440	143
	Dissolved chromium	0.119	<0.100	<0.500	0.200	105
0500629	Total chromium	0.365	0.060	10.7	1.30	541
	Dissolved chromium	0.112	0.040	0.755	0.260	214
0500073	Total chromium	0.578	0.070	35.8	2.09	507
	Dissolved chromium	0.106	0.060	0.310	0.178	207

Seasonal variations in dissolved and total chromium concentrations are illustrated in Figure 24. Total chromium concentrations peaked during freshet with increased flows and turbidity. The highest monthly average total chromium concentrations were seen in May at both 0500629 (1.25 µg/L) and 0500073 (1.94 µg/L). All other average monthly total chromium concentrations were <1 µg/L except October at 0500073 (1.06 µg/L) which was influenced by one high value of 35.8 µg/L resulting from a high turbidity event. Monthly average concentrations for dissolved chromium were low throughout the year at <0.3 µg/L.

7.5.4 Cobalt

Currently there is no WQO for cobalt for Similkameen River. The current ALWQG is a long-term average concentration or 4 µg/L (total cobalt) (WLAP 2004), however B.C. is planning to adopt the hardness-based federal environmental quality guideline (EC 2017) with an uncertainty factor of 3. The federal guideline is bound by a hardness range of 52 mg/L – 396 mg/L with corresponding guideline values of 0.78 µg/L and 1.8 µg/L, respectively. Applying an uncertainty factor of 3 provides a benchmark of 0.26 µg/L for waters with a water hardness of ≤52 mg/L and 0.6 µg/L for waters with a hardness ≥396 mg/L.

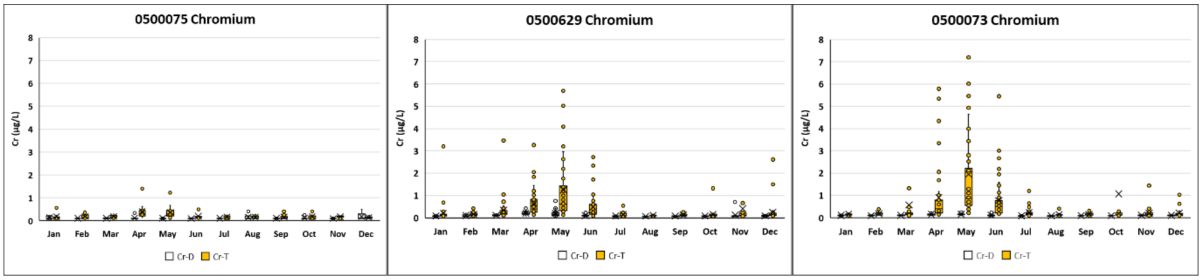

Figure 24: Seasonal variation in total chromium in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073). Note that individual values greater than 10 µg/L are not displayed.

The ALWQG value for waters with a hardness of 53 mg/L – 395 mg/L is determined using the equation provided in EC (2017). The drinking water guideline is a MAC of 1 µg/L.

Water quality results for total cobalt for the Similkameen River are summarized in Table 21. Average total cobalt concentrations increased from 0.104 µg/L at 0500075 to 0.464 µg/L at 0500073. The proposed ALWQG was met in 97% of results at 0500075 with any exceedances occurring during April and May. At 0500629, the ALWQG was met in 89% (462/519) of reported results with concurrent hardness data. Of the exceedances, most (58/66) occurred during May through June. The rate of exceedances increased at 0500073 with only 55% (282/514) of results with concurrent hardness data meeting the proposed ALWQG. The exceedances occurred throughout the year with 46% (107/232) measured during freshet.

Table 21: Summary statistics for cobalt (µg/L) in the Similkameen River (2000 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
0500075	Dissolved cobalt	0.088	<0.005	<0.100	0.100	108
	Total cobalt	0.104	0.012	0.620	0.149	144
0500629	Dissolved cobalt	0.039	0.004	1.31	0.093	215
	Total cobalt	0.188	0.011	6.53	0.708	550
0500073	Dissolved cobalt	0.135	0.027	1.37	0.271	209
	Total cobalt	0.464	0.64	21.5	1.16	519

The drinking water guideline of 1 µg/L was exceeded occasionally for total Co at 0500629 (22/541 or 4%) and 0500073 (28\519 or 5%), however the dissolved cobalt concentrations were almost always <1 µg/L, with only one exceedance of this at 0500629 and 0500073 each. Any elevated cobalt concentrations in either form occurred during turbid conditions.

The seasonal variation in total cobalt concentrations is illustrated in Figure 25. Concentrations were generally below the ALWQG throughout the year at all sites but increased during the spring freshet period.

7.5.5 Copper

In natural waters, most copper binds to suspended particles, eventually settling into sediments where it is bound to mineral or organic materials with a fraction remaining in the dissolved form. Changes in water chemistry (e.g., pH) or physical changes (e.g., temperature) can increase or decrease the ratio of dissolved copper to particulate copper. The B.C. ALWQG for copper (ENV 2019a) is based on the dissolved fraction and is calculated using a biotic ligand model (BLM) to account for site-specific toxicity-modifying factors including pH, dissolved organic carbon, and water hardness.

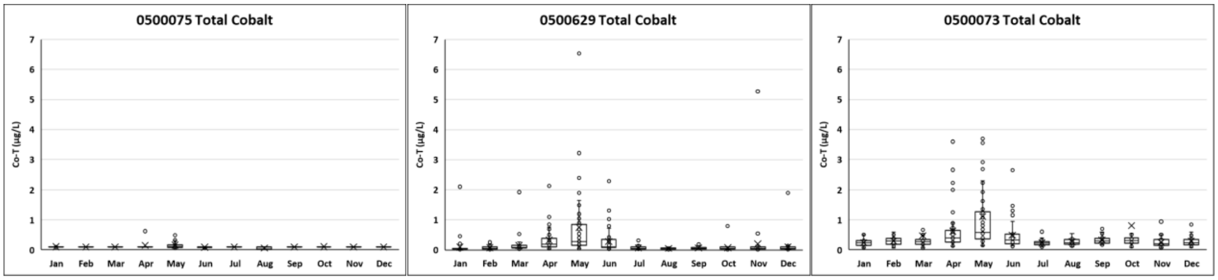

Figure 25: Seasonal variation in total cobalt (µg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073). Note that values greater than 7 µg/L (3 results ranging from 9.33 µg/L to 21.5 µg/L) are not shown in the 0500073 plot.

For the protection of human health, the source drinking WQG for total copper is a MAC of 2 mg/L. To protect aesthetic quality of water the WQG is 1 mg/L (total copper) (ENV 2020a).

The 1990 Similkameen River WQO for copper was based on the previous WQG for total copper; this assessment reflects the current ALWQG. Dissolved copper concentrations for the Similkameen River are summarized in Table 22Table 22 for the period 2000 to 2021. Concentrations were lowest upstream at 0500075 and highest at the midstream station (0500629) with an average concentration of 1.17 µg/L, a maximum of 8.33 µg/L, and a 95th percentile of 2.49 µg/L. The maximum value at 0500075 occurred in January 2011, while maximum values at 0500629 and 0500073 occurred in May during freshet.

Table 22: Summary statistics for dissolved copper (µg/L) in the Similkameen River (2000 – 2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
0500075	0.383	0.190	0.820	0.670	108
0500629	1.17	0.320	8.33	2.49	213
0500073	0.919	0.260	3.75	1.88	207

Dissolved copper concentrations from 2000 to 2021 are illustrated in Figure 26Figure 26. While concentrations are above background at 0500629 and 0500073, there does not appear to be an increase in concentrations downstream over time.

The seasonal variation in dissolved copper concentrations is illustrated in Figure 27. There is no clear seasonal pattern for dissolved copper upstream at 0500075. Downstream at 0500629 and 0500073, dissolved copper concentrations were highest during freshet (April through June).

Site specific pH, DOC, and hardness data were used to calculate the ALWQG guideline and assess the dissolved copper levels in the Similkameen River. It should be noted that the copper BLM is sensitive to changes in the dependent variables, especially pH, and accurate measurements are very important to ensure the proper assessment of risk.

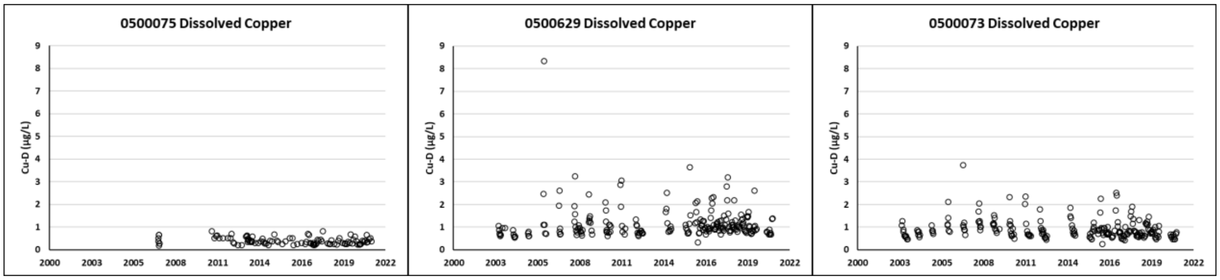

Figure 26: Dissolved copper concentrations (µg/L) over time in the Similkameen River. Sites are presented from upstream (0500075) to downstream (0500073).

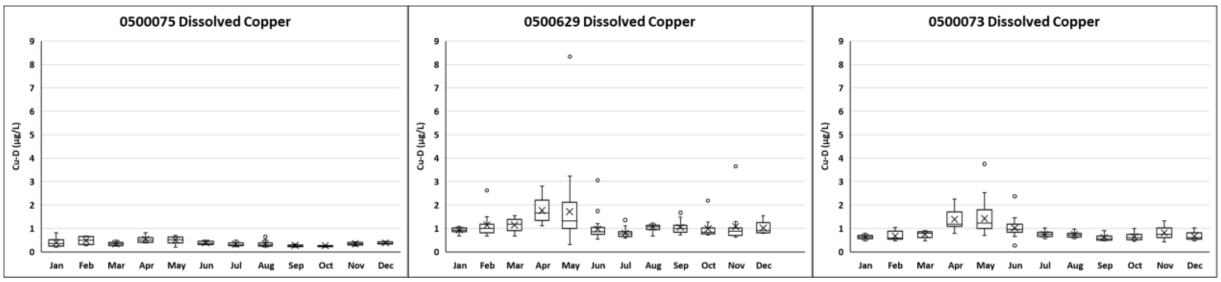

Figure 27: Seasonal variation in dissolved copper (µg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

Of the 108 individual results for 0500075, 87 had concurrent measures of pH, DOC, and hardness. The required frequency of sampling (5 weekly samples in 30 days) was not conducted at this site therefore each result was compared directly to the chronic WQG. Of these, 2% (2/87) exceeded the ALWQG. On both occasions, the reported pH (6.8 and 7.1) was below the typical pH measured at this site (an average of 7.9 and 95th percentile of 8.1) and these exceedances should be viewed with caution.

Of the 213 dissolved copper results for 0500629, 192 had concurrent measures of pH, DOC, and hardness. The ALWQG was exceeded in 44% of these (85/192), with nearly half of the exceedances based on pH values lower than the average pH (7.9) for the site. There were three 5-in-30 sampling periods to calculate the long-term average concentration, two of which exceeded the ALWQG. Both exceedances occurred during spring freshet.

At 0500073, 168 of 207 dissolved copper results had concurrent measures of pH, DOC, and hardness. Of these, 11% (19/168) exceeded the guideline with most exceedances (14/19) occurring when the recorded pH was less than the average pH of 7.9 for this site. There were six 5-in-30 sampling periods in the data set allowing for comparison to the chronic ALWQG, all of which were met.

7.5.6 Iron

The 1990 WQO for total iron is a maximum concentration of 0.3 mg/L (ENV 1990). The ALWQG for total iron and dissolved iron is a maximum concentration of 1.0 mg/L and 0.35 mg/L, respectively (ENV 2008). The SDWQG to protect the aesthetic quality of drinking water is also 0.3 mg/L total iron (ENV 2020a). Total and dissolved iron concentrations in the Similkameen River are summarized in Table 23.

Table 23: Summary statistics for total and dissolved iron (mg/L) in the Similkameen River (2000 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
0500075	Total iron	0.092	0.012	1.46	0.270	134
	Dissolved iron	0.015	0.009	0.046	0.030	102
0500629	Total iron	0.307	0.004	12.1	1.31	547
	Dissolved iron	0.047	0.002	2.61	0.154	213
0500073	Total iron	0.469	0.002	32.6	2.03	520
	Dissolved iron	0.031	0.003	1.10	0.117	208

Total and dissolved iron concentrations were lowest at 0500075 with average concentrations of 0.092 mg/L and 0.015 mg/L, respectively. Total iron exceeded the WQO in 4% (6/134) of results while the ALWQG was exceeded in 1% (2/134) of results. These exceedances corresponded with elevated turbidity levels measured during April and May. The dissolved iron concentrations met the ALWQG at this site and were an order of magnitude lower than the guideline level.

Average total iron (0.307 mg/L) and dissolved iron (0.047 mg/L) concentrations increased at 0500629. The total iron WQO and SDWQG were exceeded 18% of the time (96/547) with most exceedances occurring during spring freshet. The total iron ALWQG was exceeded 6% of the time (33/547) and the dissolved iron ALWQG was exceeded 2% of the time (5/213). The dissolved iron exceedances occurred in May and represented a large portion of the corresponding total iron fraction.

Downstream at 0500073, the average total iron concentration increased to 0.469 mg/L and the average dissolved iron concentration was consistent with upstream conditions at 0.031 mg/L. The total iron ALWQG was exceeded 8% of the time (44/520) and less than <1% of the time for dissolved iron ALWQG (1/208). The Similkameen River WQO for total iron and the SDWQG was exceeded 23% of the time (119/520) at 0500073. The maximum total iron concentration was 32.6 mg/L measured in October 2003 on a day when turbidity was measured at 844 NTU.

Seasonal plots of total and dissolved iron concentrations are shown in Figure 28. Concentrations tend to increase during freshet (April to June) and are more pronounced at the midstream (0500629) and downstream site (0500073).

Overall, the total and dissolved iron ALWQGs were met most of the time but exceedances occurred during high flows at all sites. The more stringent Similkameen River WQO and SDWQG for total iron (0.3 mg/L) were exceeded at all sites and more frequently at downstream sites and during freshet. The ALWQG for dissolved iron was only exceeded during freshet.

7.5.7 Lead

The toxicity of lead to aquatic life in ambient waters decreases with increasing hardness. To account for this variability the average and maximum ALWQGs are calculated for waters above 8 mg/L hardness using the site-specific hardness. Below 8 mg/L hardness the ALWQG is a maximum of 3 µg/L (ENV 2021g). For drinking water, the SDWQG is a MAC of 5 µg/L.

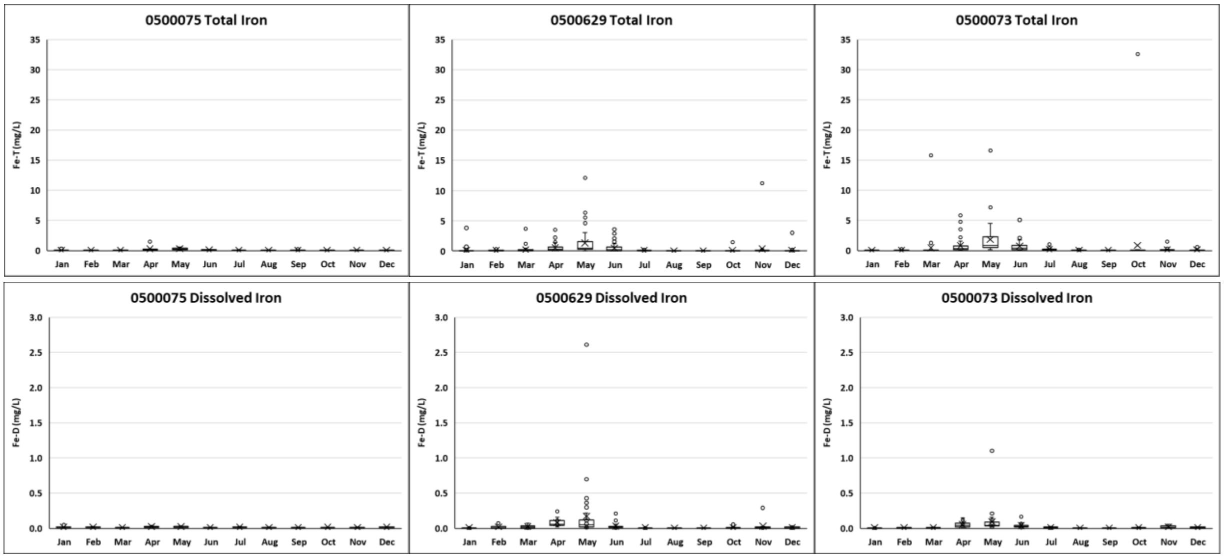

Figure 28: Seasonal variation in total and dissolved iron (mg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

In 1990, the ALWQG for total lead was adopted as the Similkameen River WQO due to elevated lead levels in groundwater near mine tailing piles close to Hedley Creek and the Similkameen River, and because of mining influences in the Cahill Creek and Red Top Gulch Creek watersheds. The average and maximum WQO for total lead in the Similkameen River were calculated using site-specific average hardness in the following equations:

$$\text{30-day average total lead WQO } (\mu g/L) \le 3.31 + e^{[1.273 \ln (\text{average hardness in mg/L}) - 4.705]}$$

$$\text{Maximum total lead WQO } (\mu g/L) \le e^{[1.273 \ln (\text{average hardness in mg/L}) - 1.460]}$$

In addition, a fish tissue WQO for total lead of 0.8 µg/g wet weight was defined to address concerns of lead in the edible tissues of fish caught downstream of Princeton. No data, however, were available to assess attainment of this WQO. If data become available in the future, they should be assessed against the appropriate human health screening values (see WLRS 2023b*)*.

Table 24 presents the average, minimum, maximum and 95th percentile values of total lead for Similkameen River monitoring sites for years 2000 to 2021.

Table 24: Summary statistics for total lead (µg/L) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	0.058	<0.010	0.362	0.099	144
0500629	0.331	<0.005	8.25	1.28	548
0500073	0.301	<0.005	18.0	1.12	514

At 0500075, the lowest hardness concentration reported was 20 mg/L resulting in a calculated WQO value of 3.72 µg/L. The maximum concentration measured at this site was 0.362 µg/L with a 95th percentile concentration of 0.099 µg/L, well below the WQO value. Of the 144 samples collected none exceeded the Similkameen WQO or the SDWQG for total lead.

Total lead concentrations followed the same general pattern as other metals at 0500629 with the highest average concentrations seen during high flow conditions (Figure 29), however, elevated total lead concentrations were observed throughout the year. There were no exceedances of the maximum WQO based on the corresponding hardness measurement for the same date. The average total lead concentration did not exceed the WQO in seven periods with the requisite 5-in-30 sampling. There were four results, out of 526, that exceeded the SDWQG which generally occurred during turbid conditions.

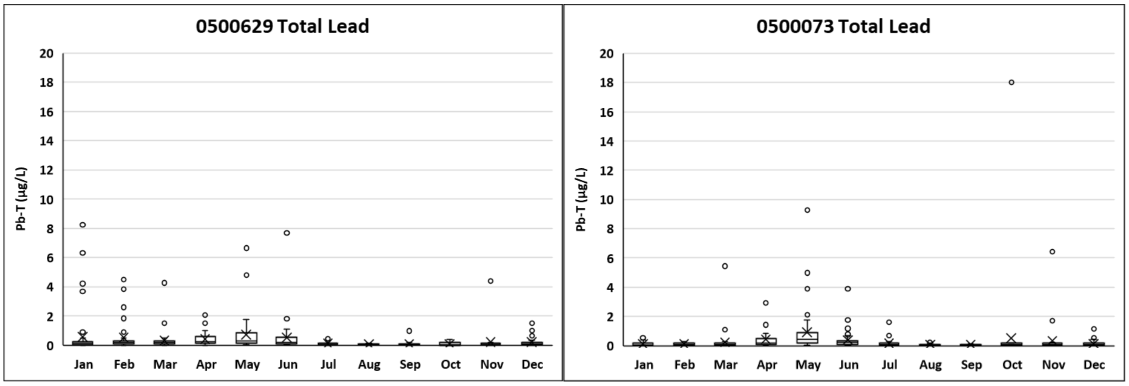

Figure 29: Seasonal variation in total lead (µg/L) in the Similkameen River at site 0500629 and site 0500073 (2000 – 2021). Sites are presented upstream to downstream.

Total lead concentrations at 0500073 were consistent with those at 0500629. The average concentration was 0.301 µg/L with a 95th percentile concentration of 1.12 µg/L. The highest concentration measured was 18.0 µg/L in October 2003 corresponding with a turbidity measurement of 844 NTU. None of the individual results exceeded the maximum WQO at 0500073 and there were no exceedances of the average WQO where the requisite 5-in-30 sampling was completed (11 times). The SDWQG was exceeded 1% of the time (4/514).

Overall, total lead levels were low in the Similkameen River mainstem but may be elevated above the SDWQG level during turbid flows.

7.5.8 Manganese

The 1990 WQO for total manganese in Similkameen River is a maximum concentration of 50 µg/L and was based on criteria to protect the aesthetic quality of drinking water (ENV 1990). The WQO was adopted due to exceedances of this benchmark at 0500073 and because of high levels of manganese in mine tailing piles adjacent to Hedley Creek and Similkameen River which could be mobilized. The current ALWQG for total manganese is variable depending on water hardness and is based on a 30-day average concentration (ENV 2001b). The SDWQG for total manganese is a MAC of 120 µg/L to protect human health and an aesthetic WQG of 20 µg/L to minimize the discolouration of water in homes (ENV 2020a). The current ALWQGs provide more appropriate benchmarks and are used as the basis for this assessment of manganese.

The data for total manganese in the Similkameen River mainstem are summarized in Table 25. At site 0500075 the average manganese concentration was 3.5 µg/L with values ranging from 0.75 µg/L to 44 µg/L and a 95th percentile concentration of 10.7 µg/L. Elevated concentrations occurred during turbid flow periods with concentrations generally below 5 µg/L at other times. The lowest hardness concentration reported for this site was 20 mg/L which gives a long-term chronic ALWQG of 693 µg/L. All results for this site were well below this level indicating manganese is not a concern at this site.

Table 25: Summary statistics for total manganese (µg/L) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	3.53	0.750	44.4	10.7	144
0500629	10.1	0.300	380	41.9	550
0500073	18.5	2.50	1,260	64.5	520

At 0500629 the average manganese concentration was 10.1 µg/L with a maximum of 380 µg/L and a 95th percentile concentration of 41.9 µg/L. The ALWQG was always met but the SDWQG for aesthetic quality was exceeded 9% of the time (47/550) and the MAC for drinking water was exceeded 1% of the time (8/550), mostly during freshet.

Average concentrations were highest downstream at 0500073 (18.5 µg/). This was largely influenced by elevated concentrations during turbid flow periods. The minimum hardness at this site was 26 mg/L resulting in a chronic ALWQG of 719 µg/L, which was always met except on October 21, 2003. On this date, turbidity was 844 NTU and manganese was 12,600 µg/L. The SDWQG MAC was exceeded 2% of the time (11/520) and the aesthetic WQG was exceeded 14% of the time (75/520), again with most exceedances occurring during freshet.

Seasonal trends for total manganese concentrations are illustrated in Figure 30. Concentrations tend to increase during freshet (April to June) at all sites, with concentrations higher at the downstream sites. Overall, manganese levels were well below the ALWQGs and usually met the SDWQG to protect human health. The aesthetic SDWQG was exceeded at times at all sites and was influenced by flow conditions (e.g., turbidity) at the time of sampling.

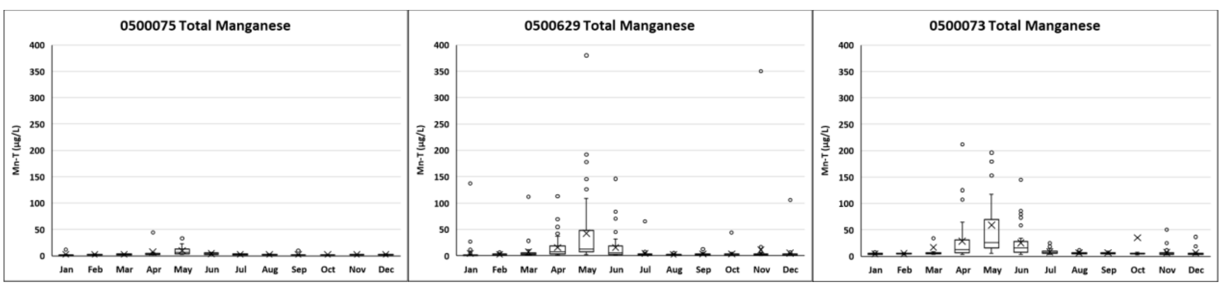

Figure 30: Seasonal variation in total manganese (µg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073). Note that individual values >400 µg/L are not shown in the plots for 0500073.

7.5.9 Mercury

A WQO for total mercury was first adopted in 1990 for Similkameen River and Hedley Creek due to mining activities in tributary sub-basins and the potential for leaching of mercury from mine tailing piles near the Similkameen River. The provisional WQO was set at an average concentration of ≤0.02 µg/L and a maximum concentration of 0.1 µg/L. A fish muscle tissue WQO was set to 0.8 µg/g wet weight (ENV 1990).

The SDWQG for mercury is a maximum concentration of 1 µg/L and the ALWQG varies based on site-specific concentrations of methyl mercury and total mercury to derive a site-specific WQG using the equation (ENV 2001c):

$$Mercury\ WQG\ (\frac{\mu g}{L}) = \frac{0.00001}{(\frac{MeHg}{total\ Hg})}$$

Total mercury monitoring data in the Similkameen River were limited to 46 samples collected at site 0500075. Mercury concentrations for downstream sites 0500629 and 0500073 were not available for the period of study with the last results reported in 1995. No methyl mercury data were available to calculate the mercury ALWQG. In the absence of methyl mercury data, mercury results were compared to the CCME ALWQG of 0.026 µg/L (CCME 2003).

Table 26 summarizes mercury concentrations at 0500075. All results were below MDLs except for two samples collected in May (0.005 µg/L) and August 2019 (0.006 µg/L). None of the results exceeded the SDWQG and compared to the CCME WQG, all results were below 0.026 µg/L except for one result which had a MDL above the CCME WQG (<0.050 µg/L).

Table 26: Summary statistics for total mercury (µg/L) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	<0.008	<0.005	<0.050	<0.010	46
0500629	NA	NA	NA	NA	NA
0500073	NA	NA	NA	NA	NA

The mercury concentration in fish tissue downstream of the Hedley Creek confluence is unknown and could not be assessed. Only one fish tissue sample collected in 1986 at site E207463 was available in the provincial EMS database. The mercury tissue concentration was reported as below the MDL of 0.05 µg/g (wet weight) which is below the 1990 WQO level. Similarly, the potential impacts of mercury on aquatic life downstream of 0500075 cannot be assessed without mercury monitoring results at 0500629 and 0500073.

7.5.10 Molybdenum

The 1990 WQO for total molybdenum in the Similkameen River is an average concentration of 10 µg/L and a maximum concentration of 50 µg/L during the irrigation season (May to September) (ENV 1990). The molybdenum WQO was first developed to protect livestock and irrigation crops from elevated molybdenum levels given the importance of the Similkameen River to agriculture, and because detectable levels were measured at 0500073 and in the mine tailings adjacent to Hedley Creek and Similkameen River which could be mobilized if disturbed.

B.C. has total molybdenum WQGs for various water uses including source drinking water (maximum allowable concentration of 88 µg/L), aquatic life (average of 7.6 mg/L, maximum of 46 mg/L), livestock watering (average of 16 µg/L), irrigation water (average of 20 µg/L), and ruminant wildlife (average of 34 µg/L) (ENV 2021h).

Water quality results for total molybdenum for Similkameen River monitoring sites for the period 2000 to 2021 are summarized in Table 27.

Table 27: Summary statistics for total molybdenum (µg/L) in the Similkameen River (2000 – 2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
0500075	0.717	0.370	2.37	1.05	144
0500629	1.14	0.100	4.74	2.30	551
0500073	1.48	0.214	2.77	2.36	519

Molybdenum concentrations increased from upstream to downstream averaging from 0.717 µg/L to 1.48 µg/L with maximum concentrations ranging from 2.37 µg/L to 4.74 µg/L. All results were below the 1990 WQO and all B.C. molybdenum WQGs.

Seasonal molybdenum trends are shown in Figure 31. Total molybdenum concentrations in the Similkameen River consisted mainly of dissolved molybdenum. At 0500629, molybdenum concentrations were considerable higher in 2019 during the low flow conditions in February, March, August, and September. There is no obvious explanation for this peak, but molybdenum concentrations may be linked to flow suggesting possible groundwater inputs. Subsequent results were consistent with levels typically seen (i.e., 1 – 2 µg/L) at 0500073. To summarize, molybdenum levels in the Similkameen River mainstem were well below levels expected to impact the most sensitive uses of ruminant livestock and wildlife watering.

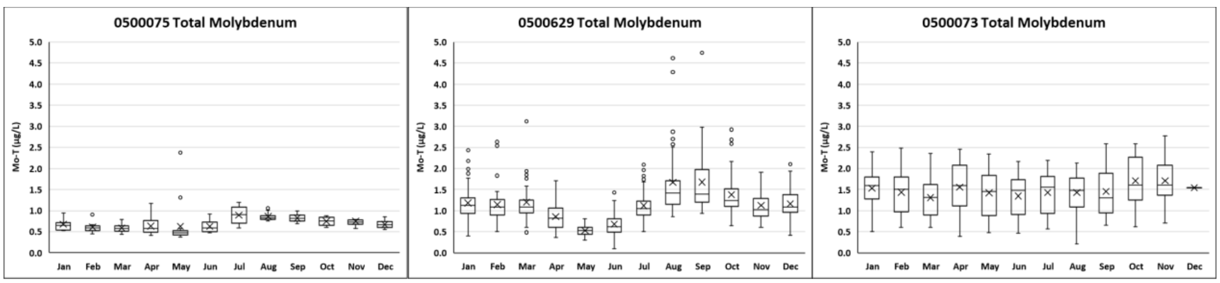

Figure 31: Seasonal variation in molybdenum (µg/L) in the Similkameen River (2000 – 2021). Sites are presented upstream (0500075) to downstream (0500073).

7.5.11 Nickel

The 1990 WQO for total nickel in the Similkameen River is an average of ≤25 µg/L when water hardness is ≤65 mg/L and an average concentration of ≤65 µg/L when water hardness is >65 mg/L (ENV 1990). The nickel WQO was based on the 1987 WWQG for nickel and was adopted to address concerns related to potential inputs from mine tailing piles adjacent to Hedley Creek and Similkameen River (ENV 1990).

The current WWQGs for total nickel include a hardness-based chronic guideline for protection of aquatic life where total nickel concentrations should not exceed 25 µg/L in waters with a hardness value ≤60 mg/L (ENV 2021b). For waters with a hardness of 60 – 180 mg/L, the chronic nickel WWQG is calculated from a hardness-based equation with a maximum value of 150 µg/L. An updated ALWQG is under development based on dissolved nickel with chronic and acute guidelines determined using a BLM and site-specific hardness, DOC, and pH data (WLRS 2023c).

Other WWQGs for nickel include livestock watering (1 mg/L) and irrigation water (200 µg/L) (ENV 2021b). The SDWQG for nickel is a maximum acceptable concentration of 80 µg/L (ENV 2020a).

Nickel results for Similkameen River monitoring sites for the period 2000 to 2021 are summarized in Table 28Table 28. Nickel concentrations were low throughout the Similkameen River. At 0500075, 88% (126/144) of total nickel results were below the MDL (<0.5 µg/L) and all results were well below the WQO level of 25 µg/L (based on the lowest reported hardness of 20 mg/L). For dissolved nickel, 89% (96/108) results were below the MDL.

At 0500629, total nickel concentrations ranged from <0.020 to 10.0 µg/L with an average value of 0.377 µg/L and a 95th percentile concentration of 1.26 µg/L. The highest concentrations occurred predominantly during freshet. All results were below the nickel WQO based on a minimum hardness of 22 mg/L. The average dissolved nickel concentration was lower than the upstream average, but this was due to the upstream results reported mostly as below the MDL of 0.500 µg/L. Dissolved nickel results with corresponding hardness, DOC, and pH data were compared against the draft chronic ALWQGs. All results were at least an order of magnitude below the ALWQG level. The lowest guideline level of 1.2 µg/L corresponded with a dissolved nickel concentration of 0.070 µg/L, while the highest dissolved nickel concentration of 0.910 µg/L corresponded with a guideline level 3.2 µg/L.

Table 28: Summary statistics for nickel (µg/L) in the Similkameen River (2000 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
0500075	Total nickel	0.453	<0.050	1.19	<0.500	144
	Dissolved nickel	0.436	<0.050	<0.500	<0.500	108
0500629	Total nickel	0.377	<0.020	10.0	1.26	551
	Dissolved nickel	0.154	<0.020	2.07	0.362	215
0500073	Total Ni	0.649	<0.020	46.1	2.18	518
	Dissolved Ni	0.151	<0.020	0.670	0.320	207

At 0500073, nickel concentrations were higher than upstream and ranged from 0.02 to 46 µg/L with an average concentration of 0.6 µg/L and 95th percentile value of 2.3 µg/L. Like 0500629, the highest concentrations for both dissolved and total nickel generally occurred during freshet. Based on a minimum hardness of 27 mg/L, only one result (46 µg/L) exceeded the nickel WQO (25 µg/L) in October 2003 which occurred during a period of extreme turbidity. Dissolved nickel results with corresponding hardness, DOC, and pH data were again compared against the draft chronic ALWQGs. The lowest guideline level of 1.2 µg/L corresponded with a dissolved nickel concentration of 0.140 µg/L, while the highest dissolved nickel concentration of 0.670 µg/L corresponded with a guideline level 4.4 µg/L.

7.5.12 Selenium

Currently there is no selenium WQO for the Similkameen River. B.C. WQGs for selenium include safe levels for source drinking water and protection of aquatic life (ENV 2014). The SDWQG for selenium is a maximum concentration of 10 µg/L and the ALWQG is an average of 2 µg/L with an alert level of 1 µg/L.

Selenium monitoring results for the Similkameen River are summarized in Table 29 and show increasing concentrations from upstream to downstream. At 0500075, background selenium concentrations averaged 0.091 µg/L with a maximum and 95th percentile concentration of 0.200 µg/L. Nearly half of the results reported, 49% (70/144), were below MDLs. Downstream at 0500629, selenium concentrations ranged from 0.030 to 0.720 µg/L. The average concentration was 0.148 µg/L and the 95th percentile concentration was 0.270 µg/L. Selenium concentrations were similar at 0500073 with an average concentration of 0.181 µg/L and a maximum concentration of 0.830 µg/L. The 95th percentile concentration was 0.300 µg/L. Selenium concentrations were lowest during freshet at both 0500629 and 0500073 suggesting inputs from groundwater rather than overland runoff (Figure 32). Overall, selenium concentrations were below the alert level of 1.0 µg/L for the protection of aquatic life.

Table 29: Summary statistics for total selenium (µg/L) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	0.091	0.040	0.200	0.200	144
0500629	0.148	0.030	0.720	0.270	550
0500073	0.181	0.020	0.830	0.300	519

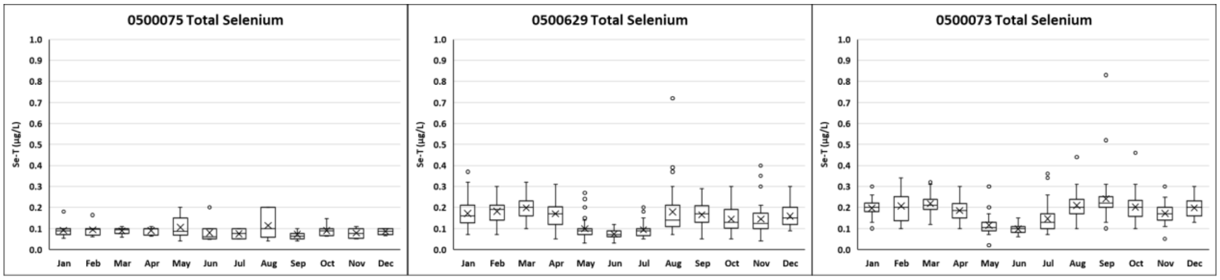

Figure 32: Seasonal variation in total selenium (µg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

7.5.13 Uranium

The 1990 WQO for total uranium (U) in the Similkameen River is an average concentration of ≤10 µg/L and a maximum concentration of 100 µg/L (ENV 1990) and was proposed to address concerns of high uranium levels in mine tailing piles adjacent to the Similkameen River and Hedley Creek. B.C. has uranium WWQGs for freshwater aquatic life (average ≤8.5 µg/L), irrigation water (average ≤10 µg/L) and livestock watering (average ≤200 µg/L) (ENV 2021b). There is also a uranium SDWQG of 20 µg/L (maximum allowable concentration) (ENV 2020a).

Water quality results for total uranium in the Similkameen River for the period 2000 to 2021 are summarized in Table 30. Concentrations increased upstream to downstream. At 0500075, concentrations ranged from 0.047 µg/L to 0.153 µg/L with an average concentration of 0.094 µg/L and a 95th percentile concentration of 0.135 µg/L. At 0500629, the average concentration doubled to 0.187 µg/L. The 95th percentile concentration was 0.306 µg/L, and a maximum concentration of 1.14 µg/L was recorded in November 2011. Downstream at 0500073, the average concentration increased again to 0.475 µg/L with a 95th percentile concentration of 0.725 µg/L. A maximum concentration of 1.52 µg/L was recorded in October 2003 corresponding with a turbidity level of 844 NTU.

Table 30: Summary statistics for total uranium (µg/L) in the Similkameen River (2000 – 2021).

Site	Average	Minimum	Maximum	95th percentile	n
0500075	0.094	0.047	0.153	0.135	144
0500629	0.187	0.059	1.14	0.306	465
0500073	0.475	0.155	1.52	0.726	438

Seasonal patterns are illustrated in Figure 33. At 0500075, uranium concentrations remained low throughout the year (<0.2 µg/L) with little variation. A seasonal pattern is evident with the lowest concentrations occurring during freshet and higher concentrations seen during the low flow period suggesting inputs from groundwater rather than overland runoff. This is supported by the observation that total uranium consists mostly of the dissolved fraction in the Similkameen River. Overall, uranium concentrations are well below the WQG and WQO levels.

7.5.14 Zinc

The 1990 WQOs for total zinc of 10 µg/L (average) and 30 µg/L (maximum) were based on the WWQGs available at that time. The current ALWQGs (WLRS 2023d) are based on dissolved zinc and account for the toxicity-modifying influences of water hardness, pH, and DOC. The maximum allowable concentration of zinc to protect drinking water is 3.0 mg/L.

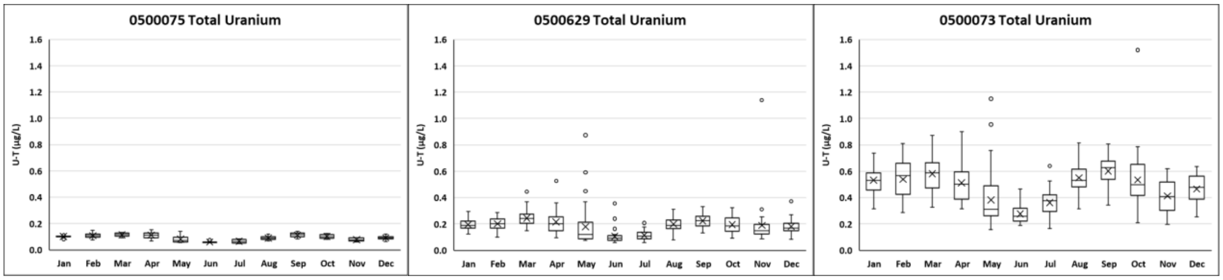

Figure 33: Seasonal variation in total uranium (µg/L) in the Similkameen River (2000 – 2021) from upstream (0500075) to downstream (0500073).

Water quality results for total and dissolved zinc for Similkameen River monitoring sites are summarized in Table 31. At 0500075, 82% of total zinc (118/144) and 84% (92/109) of dissolved zinc measurements were below MDLs. The average total zinc concentration of 2.73 µg/L was influenced by several results reported as below the MDL of 3.0 µg/L. The maximum total zinc concentration reported was 7.2 µg/L. The average dissolved zinc concentration was 1.11 µg/L with a maximum of 3.5 µg/L and a 95th percentile concentration of 3.0 µg/L (also influenced by several reported results of <3.0 µg/L). One dissolved zinc result at this site did not meet the average ALWQG. The maximum dissolved zinc concentration of 3.5 µg/L (November 14, 2013) has a corresponding guideline value of 3.45 µg/L. The reported result is suspect however because the total zinc concentration for the same day was reported as <3.0 µg/L.

Table 31: Summary statistics for total and dissolved zinc (µg/L) in the Similkameen River (2000 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
0500075	Total zinc	2.73	<0.100	7.20	<3.00	146
	Dissolved zinc	1.11	<0.100	3.50	<3.00	109
0500629	Total zinc	1.33	<0.050	61.1	4.90	545
	Dissolved zinc	0.290	<0.200	1.60	0.700	159
0500073	Total zinc	1.82	<0.050	109	6.79	519
	Dissolved zinc	0.356	<0.200	9.00	0.600	157

At 0500629 the average total zinc concentration was 1.33 µg/L with a maximum concentration of 61.1 µg/L and a 95th percentile concentration of 4.90 µg/L. Dissolved zinc averaged 0.290 µg/L with a maximum of 1.60 µg/L and 95th percentile concentration of 0.700 µg/L. Of the 159 dissolved zinc measures, 46% (74/159) were below MDLs. Based on the available hardness, pH, and DOC data for this site, the minimum average ALWQG for dissolved zinc was 1.77 µg/L. Because the maximum dissolved zinc concentration for 0500629 was less than this value it is assumed levels are meeting the ALWQGs. The maximum ALWQG was exceeded on November 11, 2006 (34.5 µg/L, ALWQG = 27.2 µg/L) and on May 20, 2008 (61.1 µg/L, ALWQG = 18.3 µg/L). These results were likely influenced by turbid conditions reported for those dates (157 NTU and 57 NTU, respectively).

Zinc concentrations increased downstream at 0500073. The average total zinc concentration was 1.82 µg/L with a maximum concentration of 109 µg/L and a 95th percentile concentration of 6.79 µg/L. Dissolved zinc averaged 0.356 µg/L with a maximum of 9.00 µg/L and 95th percentile concentration of

0.600 µg/L. Of the 157 dissolved zinc measures, 47% (74/157) were below detection limits. All individual dissolved zinc results met both the average and maximum ALWQGs.

Seasonal trends are illustrated in Figure 34. Dissolved zinc concentrations were higher during freshet with occasional elevated levels at other times of the year coinciding with turbid conditions. The effect of censored data is evident in the dissolved zinc plot for 0500075 where most results were reported below the MDL (<1.0 µg/L and <3.0 µg/L). Actual concentrations are likely to be much lower at this site.

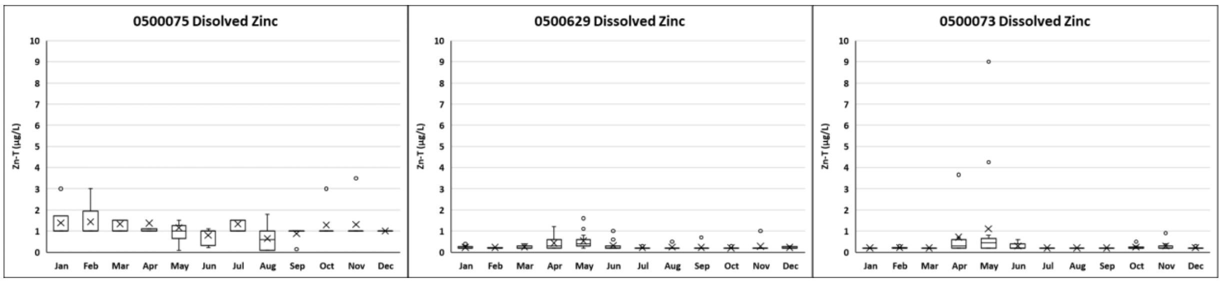

Figure 34: Seasonal variation in dissolved zinc (µg/L) in the Similkameen River (2000 – 2021). Sites are presented upstream (0500075) to downstream (0500073).

7.6 Microbiological Indicators

7.6.1 Fecal Coliforms and **Escherichia coli**

In 1990, WQOs for microbiological indicators were adopted for the Similkameen River to manage its use as a source drinking water supply. The WQOs were set at ≤10 CFU/100 mL (90th percentile concentration) for fecal coliforms and *Escherichia coli* and ≤3 CFU/100 mL (90th percentile concentration) for enterococci (ENV 1990). The WQOs are equivalent to the current BC SDWQGs for *E. coli* and enterococci but fecal coliforms are no longer considered a good indicator of waterborne illness in humans (ENV 2020a).

Monitoring data for microbiological indicators is limited to *E. coli* for years 2007 and 2013 at site 0500075 and fecal coliforms at 0500629 and 0500073 for years 2000 to 2021. No enterococci results were available. Table 32 summarizes the available monitoring results.

Table 32: Summary statistics for microbiological indicators in the Similkameen River (2000 – 2021).

Parameter	Site	Average	Minimum	Maximum	90th percentile	n
Fecal coliforms (CFU/100 mL)	0500075	-	-	-	-	-
	0500629	20	0	6,900	14	530
	0500073	13.2	<1	220	31	454
E. coli (CFU/100 mL)	0500075	6.2	<1	29	22	19
	0500629	-	-	-	-	-
	0500073	-	-	-	-	-

At 0500075, three 5-in-30 sampling periods were available to allow the calculation of 90th percentile values. Requisite sampling periods occurred in May/June of 2007 and 2013, and August/September in 2013. The 90th percentiles were 4.2 CFU/100 mL and 5.6 CFU/100 mL in 2007 and 2013, respectively, and

26 CFU/100 mL 2013. The results were below the *E. coli* WQO for spring periods but above the WQO in summer 2013. The maximum *E. coli* concentration of 29 CFU/100 mL was measured in August 2013.

Only fecal coliforms were measured at 0500629 and 0500073. Site 0500629 had an overall 90th percentile concentration of 14 CFU/100 mL. Of 26 sampling periods with the requisite number of samples, 11 exceeded the WQO (42%) of 10 CFU/100 mL. Site 0500073 had an overall 90th percentile concentration of 31 CFU/100 mL. Of the 28 requisite sampling periods, 24 (86%) exceeded the fecal coliform WQO of 10 CFU/ 100 mL and 22 of these periods occurred in April to June.

Assessing the water quality of the Similkameen River mainstem based on microbiological indicators is difficult given the limited information available. Future monitoring efforts should focus on consistent measurements of *E. coli* at the required frequency, preferably during high and low flow conditions.

7.7 Biomonitoring

Biomonitoring data, focussed on the benthic macroinvertebrate communities in the Similkameen River watershed, was evaluated to support a more comprehensive assessment of the state of the aquatic ecosystem. Biomonitoring is an important component of aquatic monitoring programs as it provides a direct measure of the condition of aquatic biota. ENV collaborates with Environment and Climate Change Canada (ECCC) to promote the use of the nationally standardized Canadian Aquatic Biomonitoring Network (CABIN) program in B.C. CABIN provides a consistent, scientifically defensible approach using benthic macroinvertebrate communities to assess freshwater ecosystems across Canada and throughout B.C.

Details of the study are provided in ENV 2020b. The results suggested the benthic community was stressed at all sites downstream of the Copper Mountain Mine. A change in the benthic community was evident between Copper Mountain and the Tulameen River for the 2015 – 2019 period. Compared to reference conditions, the benthic community in this reach showed a significant increase in abundance of individual organisms, suggesting a nutrient enrichment, along with a significant decline in sensitive taxa (i.e., Ephemeroptera and Plecoptera). This is consistent with the increase in total phosphorus concentrations from upstream at 0500075 to downstream at 0500629 and 0500073. Results from the furthest downstream site, representing the cumulative inputs from the entire Similkameen watershed, showed a progressive and gradual decline in the benthic community condition between 2006, when the community was mildly divergent from reference, and 2019, when it was highly divergent from reference.

7.8 Similkameen River Summary

Water quality guidelines and objectives were generally met in the Similkameen River with most exceedances occurring during high flow conditions. Most measured parameters increased in concentration from upstream to downstream (e.g., water hardness, specific conductance, cyanide, nutrients, sulphate, and metals) with the highest levels for most parameters occurring during freshet.

Total aluminum exceeded ALWQG levels during freshet and may be naturally elevated in this watershed. Cobalt concentrations increased from upstream to downstream and frequently exceeded the draft ALWQGs at the downstream site (0500073). The exceedances of the copper ALWQGs were associated with concurrent pH measurements lower than the site average and generally occurred during freshet.

Molybdenum, selenium, and uranium were highest during low flow periods (but within WQGs) suggesting inputs from groundwater sources. The CABIN biomonitoring results showed a gradual decline in benthic invertebrate communities at the downstream site which may be indicative of nutrient enrichment in the Similkameen River mainstem.

8. TULAMEEN RIVER WATER QUALITY

Water quality monitoring data were collected between 2000 and 2019 at the mouth of Tulameen River near its confluence with the Similkameen River (site 0500083) (Figure 5). Although limited, these data provide an initial indication of water quality conditions in the Tulameen River and the basis for benchmarks for future assessments. For consistency, the parameters previously assessed for the Similkameen River mainstem are considered here. A review of the available monitoring data did not identify any other potential parameters of concern.

8.1 General Parameters

Summary statistics for the general water quality parameters are presented in Table 33. pH ranged from 7.7 to 8.3 with an average of 8.0 and was consistent with conditions in the Similkameen River. All results were within the ALWQG for pH.

Table 33: Summary statistics for general water quality parameters in the Tulameen River (2002 – 2019).

Parameter	Average	Minimum	Maximum	95th percentile	n
pH	8.0	7.7	8.3	8.2	12
Temperature (°C)	10.5	4.7	16.4	16.1	10
Dissolved Oxygen (mg/L)	10.2	7.8	11.8	11.6	11
Specific Conductivity (µS/cm)	143	58	213	212	14
Total Hardness (mg/L)	71	32	110	109	24
Turbidity (NTU)	14	0.2	69	63	14
Total Suspended Solids (TSS) (mg/L)	33	3	136	114	17

Water temperature data were limited to 10 measurements in 2013 from May to September. The maximum result was 16.4°C measured in mid-August with subsequent temperatures decreasing in September. All temperature results were within the range seen in the Similkameen River.

Dissolved oxygen ranged from 7.2 mg/L to 11.8 mg/L. The 30-day average concentration (May – June 2013) was 11.2 mg/L and meets the ALWQG (ENV 1997) for buried embryo/alevin life stages (11.0 mg/L). All individual results met the instantaneous minimum ALWQG of 9.0 mg/L. The 30-day average concentration measured in August and September of 2013 was 9.3 mg/L and met the general ALWQG minimum of 8 mg/L (for all life stages other than buried embryo/alevin) with all individual results meeting the instantaneous minimum of 5 mg/L. These levels were consistent with what has been measured in the Similkameen River mainstem.

Specific conductivity ranged from 58 µS/cm to 213 µS/cm and water hardness ranged from 32 mg/L to 110 mg/L; both were consistent with conditions in the Similkameen River. Hardness levels were lowest during freshet and highest during low flow periods.

Turbidity ranged from 0.2 NTU to 763 NTU, with the highest levels occurring during freshet and levels below 1 NTU in the summer and fall months. As expected, the same pattern was seen for total suspended solids which ranged from <3 mg/L to 136 mg/L. The highest levels were seen during freshet; however, these concentrations were below the maximum levels reported in the Similkameen River mainstem.

8.2 Nutrients

Nutrient data are very limited for the Tulameen River. There were only two total phosphorous results, 3.9 µg/L in August 2013 and <2 µg/L in October 2019, and one result for total nitrogen of 117 µg/L (October 2019). Dissolved nitrate + nitrite concentrations ranged from <2 µg/L to 33.4 µg/L and are well below the ALWQG levels.

8.3 Organic Matter

Only one result was reported for dissolved organic carbon, 1.52 mg/L measured in October 2019.

8.4 Major Ions and Other Inorganic Parameters

The total sulphate ALWQG for the corresponding hardness levels (moderately soft to hard) is an average concentration of 309 mg/L. Dissolved sulphate concentrations ranged from 2.4 mg/L to 14.6 mg/L and are well below the guideline level.

Cyanide (CN) was identified as a parameter of concern in the 1990 Similkameen River WQOs (ENV 1990) associated with mining activities in the area. The ALWQG for WAD (weak-acid dissociable) CN is an average concentration of ≤5 µg/L and a maximum concentration of 10 µg/L. WAD CN concentrations in the Tulameen River ranged from <0.500 µg/L to a maximum of 1.59 µg/L. There were two periods with at least 5 samples collected in a 30-day period, both of which were below the ALWQG level. Average concentrations of 0.548 µg/L and 0.797 µg/L were reported for May/June 2013 and August/September 2013, respectively.

8.5 Metals

Data for metal concentrations in the Tulameen River are summarized in Table 34. Samples were collected intermittently between 2000 and 2019. Where sufficient data were available, 30-day average concentrations were calculated to compare against WQGs.

8.5.1 Aluminum

Total aluminum concentrations ranged from 9 µg/L to 1,250 µg/L. The ALWQG (WLRS 2023a) for total aluminum is based on pH, hardness, and DOC and the data available for the Tulameen River result in a guideline value of approximately 130 µg/L. Concentrations were higher during freshet with 30-day average concentrations of 622 µg/L and 293 µg/L recorded in 2007 and 2013, respectively. During non-freshet periods, the 30-day average concentrations were 15 µg/L and 22 µg/L for the same years.

8.5.2 Arsenic

Total arsenic concentrations ranged from 0.100 µg/L to 0.551 µg/L with an average of 0.280 µg/L. All results were below the ALWQG (ENV 2021d) of 5 µg/L. In most cases, dissolved arsenic made up most of the total arsenic which is reflected in the average dissolved arsenic concentration of 0.227 µg/L.

8.5.3 Chromium

Total chromium (Cr) concentrations ranged from 0.11 µg/L to 11.0 µg/L with an average of 0.803 µg/L. The high value of 11 µg/L was measured in May 2000 and was likely related to high flow conditions (although this could not be confirmed without additional information, such as turbidity). The WWQG for Cr(VI) is an average of 1.0 µg/L. Without specific information on the valency of chromium, a conservative benchmark of 1.0 µg/L total chromium is reasonable. Thirty-day average concentrations of 0.740 µg/L and 0.492 µg/L were measured during freshet in 2007 and 2013, respectively, and <0.200 µg/L and 0.140 µg/L in August for the same years. Dissolved chromium concentrations were much lower with several results reported as below the MDL.

Table 34: Summary statistics for metal concentrations in the Tulameen River (2000 – 2019).

Parameter	Average	Minimum	Maximum	95th percentile	n
Total Aluminum (µg/L)	255	9	1,250	1,102	24
Total Arsenic (µg/L)	0.280	0.100	0.551	0.500	24
Dissolved Arsenic (µg/L)	0.227	0.093	0.300	0.300	18
Total Chromium (µg/L)	0.803	0.110	11.0	1.39	24
Dissolved Chromium (µg/L)	0.163	<0.100	0.600	0.268	18
Dissolved Cobalt (µg/L)	0.025	0.006	0.067	0.045	18
Dissolved Copper (µg/L)	0.663	<0.050	1.19	1.01	18
Total Iron (mg/L)	0.242	0.006	1.26	1.25	14
Dissolved Iron (mg/L)	0.012	0.002	0.045	0.032	13
Total Lead (µg/L)	0.339	<0.005	2.21	0.977	23
Total Manganese (µg/L)	18.6	1.10	94.3	90.2	23
Total Molybdenum (µg/L)	0.553	0.190	0.890	0.866	23
Total Nickel (µg/L)	0.780	<0.050	3.75	2.53	23
Dissolved Nickel (µg/L)	0.189	<0.050	0.471	0.355	18
Total Selenium (µg/L)	0.173	0.040	0.600	0.219	23
Total Uranium (µg/L)	0.146	0.037	0.236	0.229	23
Dissolved Uranium (µg/L)	0.154	0.037	0.249	0.247	18
Total Zinc (µg/L)	1.76	<0.100	6.70	6.20	24
Zinc Dissolved (µg/L)	0.356	<0.100	0.730	0.713	18

8.5.4 Cobalt

Total cobalt levels ranged from 0.011 µg/L to 1.54 µg/L with an average of 0.284 µg/L. The current ALWQG is a long-term average concentration or 4 µg/L (total cobalt) (WLAP 2004), however B.C. is planning to adopt the hardness-based federal environmental quality guideline (EC 2017) with an uncertainty factor of 3. The drinking water guideline is a maximum allowable concentration of 1 µg/L.

The proposed ALWQG was met in 75% of results with exceedances occurring only in May and June. The SDWQG was exceeded occasionally during periods of elevated turbidity. For example, a total cobalt concentration of 1.39 µg/L was measured on May 13, 2013, coinciding with a turbidity of 81 NTU. Dissolved cobalt on the same day was very low at 0.067 µg/L, the highest result for this site.

8.5.5 Copper

Dissolved copper ranged from <0.050 µg/L to 1.19 µg/L and averaged 0.663 µg/L. Assessing dissolved copper against the ALWQG (ENV 2019a) requires concurrent measurements of pH, hardness, and DOC. This was not included in previous Tulameen River monitoring efforts, particularly DOC, so data from 0500629 on the Similkameen River was used to approximate the appropriate ALWQG level. In addition, some of the pH data were measured in the field and some were measured in the lab. The field measured pH levels were considerably lower than the lab results and have a strong influence on the resulting guideline values. With that considered, dissolved copper exceeded the ALWQG during freshet (2013 data only) and met the ALWQG in late summer (2007 and 2013 data). Additional data would be required to properly assess dissolved copper conditions in the Tulameen River.

Total copper ranged from 0.441 µg/L to 12.1 µg/L with an average of 2.28 µg/L. All results were below the SDWQG MAC (2 mg/L) and the aesthetic guideline (1 mg/L).

8.5.6 Iron

Total iron concentrations ranged from 0.006 mg/L to 1.26 mg/L with an average of 0.242 mg/L. All results were below the ALWQG level of 1 mg/L (ENV 2008) except one (1.26 mg/L) which occurred during turbid flow conditions. This result also exceeded the SDWQG aesthetic objective of 0.3 mg/L. The dissolved iron ALWQG (0.35 mg/L) was always met averaging 0.012 mg/L.

8.5.7 Lead

Total lead ranged from <0.005 µg/L to 2.21 µg/L with an average of 0.339 µg/L. The ALWQGs (ENV 2021e), based on the available hardness data, ranged from 4.06 µg/L to 6.91 µg/L, and the SDWQG is 5 µg/L. The 30-day average concentrations during freshet were 0.610 µg/L and 0.889 µg/L for 2007 and 2013, respectively, and 0.022 µg/L and 0.029 µg/L during clear flows for the same years. All results were well below the guideline levels.

8.5.8 Manganese

The ALWQG for total manganese (ENV 2001b) is based on hardness and ranged from 746 µg/L to 1,090 µg/L for the hardness data available for the Tulameen River. There is also a SDWQG MAC of 120 µg/L. Total manganese ranged from 1.10 µg/L to 94.3 µg/L with an average of 18.6 µg/L. The 30-day average concentrations were considerably higher during freshet at 51.6 µg/L (2007) and 25.4 µg/L (2013) than clear flow conditions (1.8 µg/L and 2.1 µg/L for 2007 and 2013, respectively). The SDWQG MAC was met for all results.

8.5.9 Molybdenum

Total molybdenum concentrations ranged from 0.190 µg/L to 0.890 µg/L with an average of 0.553 µg/L. All results were below the most conservative WQG of 16 µg/L to protect ruminant livestock (ENV 2021f).

8.5.10 Nickel

The nickel ALWQG is currently being updated (WLRS 2023c); it will be based on dissolved nickel and derived from site-specific hardness, pH, and DOC levels. The available data indicate the minimum chronic dissolved nickel ALWQG expected would be approximately 1.2 µg/L.

Dissolved nickel concentrations ranged from <0.050 µg/L to 0.471 µg/L with a 90^{th} percentile concentration of 0.355 µg/L. This is well below the assumed minimum ALWQG level but should be confirmed through further monitoring.

Total nickel concentrations ranged from <0.050 µg/L to 3.75 µg/L with an average of 0.780 µg/L. This is well below the SDWQG of 80 µg/L.

8.5.11 Selenium

Total selenium concentrations ranged from 0.040 µg/L to 0.600 µg/L with an average of 0.219 µg/L. Six of 23 results (32%) were below the MDL (0.200 µg/L). The highest concentrations were seen during August and September of 2013 with a 30-day average of 0.153 µg/L. All results were well below the ALWQG alert level of 1 µg/L (ENV 2014).

8.5.12 Uranium

Total uranium concentrations ranged from 0.037 µg/L to 0.236 µg/L with an average of 0.146 µg/L. Uranium is predominantly in the dissolved form with the highest concentrations occurring during low flow conditions. All results were well below the total uranium ALWQG level of 8.5 µg/L (ENV 2021).

8.5.13 Zinc

The zinc ALWQG (WLRS 2023d) is based on dissolved zinc and derived from site-specific hardness, pH, and DOC levels.

Dissolved zinc concentrations ranged from below MDLs (<0.100 µg/L) to 0.730 µg/L with an average of 0.356 µg/L. Based on the available data, the chronic dissolved zinc ALWQG ranged from 4.8 µg/L to 10.0 µg/L.

Total zinc concentrations ranged from <0.100 µg/L to 6.70 µg/L with an average of 1.76 µg/L. All results were below the current ALWQG (7.5 µg/L) and the WQG for livestock water supply (2 mg/L).

8.6 Microbiological

E. coli concentrations ranged from <1 to 72 CFU/100 ml. The SDWQG (ENV 2020a) is ≤10 CFU/100 mL (90th percentile); the recreational use guideline (ENV 2019b) is a geometric mean of ≤200 CFU/100 mL and a maximum of ≤400 CFU/100 mL at any time. There were two periods with the requisite frequency of sampling to compare results to the guideline values. The SDWQG was met in May 2013 (7 CFU/100 mL) but exceeded in August of that year (60 CFU/100 mL). The recreational use guidelines were always met. The *E. coli* data are extremely limited and additional data would be required to properly assess conditions in the Tulameen River.

8.7 Tulameen River Summary

The available data suggest the water quality of the Tulameen River is good, however the data are limited. Some drinking water guidelines (e.g., cobalt and iron) were exceeded during turbid flows but, overall, the reported results were generally below guideline levels. More data are required to properly assess water quality in the Tulameen River.

9. <u>WOLFE CREEK AMBIENT WATER QUALITY</u>

Wolfe Creek originates near Copper Mountain south of Princeton and flows north, then eastward through Lorne, Issitz, and Wolfe Lakes to the Similkameen River (Figure 1). Copper Mountain Mine (CMM) is an active copper mine on the west side of upper Wolfe Creek with a tailings pond known as “Smelter Lake” adjacent to Wolfe Creek. The east and west ends of Smelter Lake are dammed; to address concerns of mine seepage from Smelter Lake into Wolfe Creek, CMM realigned a portion of the creek further east away from the mine site.

The available water quality monitoring data for the period between 2007 and 2021 were used to assess the water quality of Wolfe Creek. For consistency, the parameters previously assessed for the Similkameen River mainstem are considered here, in addition to those with provisional WQOs proposed in 1985 (ENV 1985) and others identified more recently as parameters of concern. Water quality monitoring data for Wolfe Creek are limited to the upper portion above Lorne Lake. There are two monitoring sites located on lower Wolfe Creek above the confluence with the Similkameen River (E318572 and E105925), however the available data are limited and/or dated (pre-1990). There are no monitoring data for Lorne, Issitz, or Wolfe lakes limiting the water quality assessment to the upper portion of Wolfe Creek.

Table 35 lists the monitoring sites used in the Wolfe Creek assessment and the locations are illustrated in Figure 5.

Table 35: Wolfe Creek monitoring sites.

EMS Site ID	Location
E307368	Background site, upstream of Copper Mountain Mine (CMM)
E254309	Downstream of CCM, Tailings Management Facility (TMF), sediment outlet pond
0500101	Approximately 900 m downstream of CMM TMF, near former Fergusson Ranch
E254311	Approximately 5 km downstream of Copper Mountain Road
E287172	Upstream of Lorne Lake, downstream of Willis Creek

9.1 General Parameters

9.1.1 pH

A provisional WQO for pH in Wolfe Creek was proposed in 1985 specifying unrestricted change within a range of 6.5 – 8.5. The B.C. ALWQG for pH is unrestricted change within a range of 6.5 – 9.0.

Wolfe Creek pH is slightly basic ranging from a mean of 7.8 to 8.2 from site E307368 to site E287172 above Lorne Lake (Table 36). The provisional pH WQO was met at all sites with few exceptions. At 0500101, pH was occasionally below the 6.5 benchmark (2% of results). There was no consistency in the timing of these exceedances, and it is not clear if these results are real or due to sampler error. For example, in 2020 pH was reported as 7.7, 6.0, and 7.8 on April 21, 27, and 30, respectively. More recent results for this site are consistent with the average value of 8.0.

Table 36: Summary statistics for pH by site in Wolfe Creek (2007-2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	7.8	6.6	8.8	8.3	130
E254309	7.9	5.9	8.4	8.2	328
0500101	8.0	6.0	8.8	8.3	409
E254311	8.2	6.7	9.1	8.4	103
E287172	7.9	6.4	8.4	8.2	94

9.1.2 Temperature

Average water temperatures ranged from 5.5°C at E307368 to 8.6°C at E254309 (Table 37). Elevated water temperature is a concern with respect to aquatic life and the 95th percentile values provide a good indicator of temperature extremes; the highest 95th percentile temperature was 14.4°C at E254309. Site 0500101 has the most complete temperature data set and provides a good illustration of seasonal trends in water temperature for upper Wolfe Creek (Figure 35). Temperatures are below 5°C during January and February and gradually increase peaking in July, then decrease throughout the fall months. Water temperatures do not exceed the maximum optimum temperature range for rainbow trout (ENV 2001a).

Table 37: Summary statistics for water temperature (°C) by site in Wolfe Creek (2007-2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	5.5	0.0	12.2	11.6	120
E254309	8.6	0.1	15.5	14.4	221
0500101	7.8	0.0	16.8	13.8	390
E254311	6.4	0.0	13.3	12.8	99
E287172	6.4	0.0	18.5	14.2	88

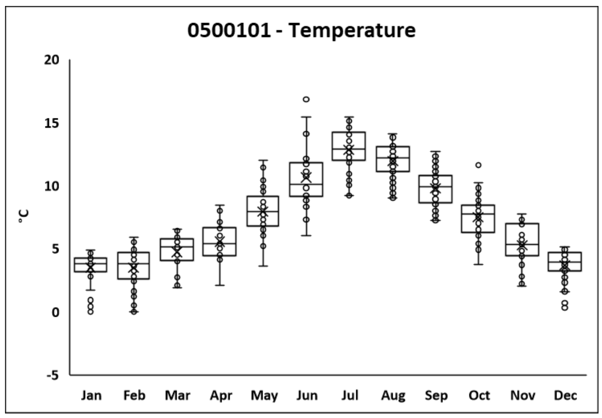

Figure 35: Seasonal trends in water temperature (°C) in Wolfe Creek at site 0500101 (2007-2021).

9.1.3 Dissolved Oxygen

There is no dissolved oxygen WQO for Wolfe Creek and so the ALWQGs (ENV 1997) were used to assess conditions. The ALWQGs (ENV 1997) specify an instantaneous minimum of 9 mg/L and a 30-day average of 11 mg/L when fish embryo or alevin are present (April through June) and an instantaneous minimum of 5 mg/L and a 30-day average of 8 mg/L at all other times. Summary statistics for dissolved oxygen are provided in Table 38. Overall average concentrations ranged from 9.0 mg/L (E287172) to 11.0 mg/L (E254311). The instantaneous minimum was met on most sampling dates (Table 39). The lower attainment rate at E287172 may be related to the nature of the site, i.e., wetland versus free-flowing creek. Data with sufficient frequency to assess the 30-day average ALWQGs were limited to E254309 and 0500101. Non-attainment of the ALWQGs at E254309 occurred between May and November 2021. It is unclear what might have caused this result as concurrent concentrations downstream at 0500101 were generally much higher.

Table 38: Summary statistics for dissolved oxygen (mg/L) by site in Wolfe Creek (2011-2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	10.8	7.4	14.9	13.1	100
E254309	9.2	4.6	15.0	12.8	234
0500101	10.8	6.0	14.9	13.6	295
E254311	11.0	6.1	14.7	13.8	76
E287172	9.0	3.3	14.1	12.1	64

Table 39: Rate of attainment for dissolved oxygen water quality guidelines (WQG) in Wolfe Creek (2011-2021). Sites are presented upstream to downstream.

Site	Instantaneous Minimum WQG	30-Day Average WQG
E307368	100% (100/100)	No data
E254309	96% (224/234)	62% (10/16)
0500101	97% (286/295)	95% (21/22)
E254311	96% (73/76)	No data
E287172	84% (54/64)	No data

9.1.4 Specific Conductivity

Specific conductivity data are summarized in Table 40. Specific conductivity increased substantially from background below the CMM site. Upstream at E307368 specific conductivity averaged 121 µS/cm with a 95th percentile of 185 µS/cm. At E254309 immediately downstream of CMM the average conductivity increased to 947 µS/cm with a 95th percentile value of 1,400 µS/cm. Levels decreased slightly with distance from CMM. Seasonal trends are illustrated in Figure 36. Levels were lowest during freshet in April through May.

Table 40: Summary statistics for specific conductivity (µS/cm) by site in Wolfe Creek (2007-2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	121	50	195	185	98
E254309	947	219	1,560	1,400	226
0500101	921	248	1,430	1,300	252
E254311	853	252	1,330	1,215	91
E287172	835	306	1,180	1,125	72

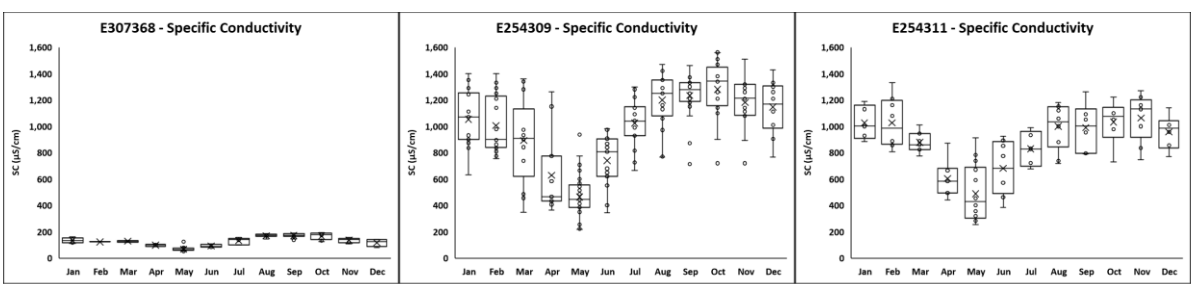

Figure 36. Seasonal variation in specific conductivity (µS/cm) in upper Wolfe Creek (2000-2021) from upstream (E307368) to downstream (E54311) above Lorne Lake.

9.1.5 Hardness

Water hardness is an important parameter given its role in modifying the toxicity of other constituents (e.g., metals). As expected, water hardness followed the same pattern as specific conductivity. Concentrations were lowest upstream at E307368 averaging 54 mg/L and increased substantially below CMM at E254309 (average = 413 mg/L) then decreased with distance from CMM to an average of 365 mg/L at E287172 (Table 41). One result from the limited data set at Wolfe Creek above the confluence of the Similkameen River (E318572) in October 2019 had a water hardness of 145 mg/L.

Table 41: Summary statistics for total hardness (mg/L) by site in Wolfe Creek (2007-2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	54	224	88	82	98
E254309	413	92	695	601	223
0500101	383	115	632	545	258
E254311	366	113	617	516	90
E287172	365	134	511	495	71

The seasonal variation of water hardness for upper Wolfe Creek is illustrated in Figure 37. Hardness values are lowest in May through June at all sites and increase with decreasing flow during other times of the year.

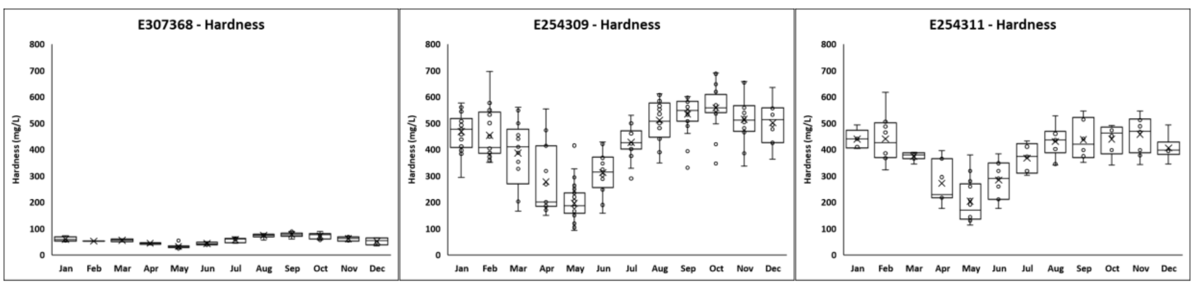

Figure 37: Seasonal variation in total hardness (mg/L) in upper Wolfe Creek (2007-2021) from upstream (E307368) to downstream (E254311) above Lorne Lake.

9.1.6 Turbidity

Turbidity increased from a background 95th percentile level of 1.6 NTU (E307368) to 9.5 NTU at E254309, then decreased progressively downstream with distance from CMM (Table 42). Levels were generally highest at spring freshet for most sites except E254309 which had the highest turbidity levels during February and March (Figure 38).

The turbidity ALWQGs specify a maximum change over background of 8 NTU and average change over background of 2 NTU during clear flow conditions. Since total suspended solids concentrations are generally below 25 mg/L, defining clear flow conditions (ENV 2021c), these benchmarks were used to assess turbidity in Wolfe Creek. Based on concurrent turbidity measurements, the maximum ALWQG was not exceeded at E254309. There were, however, results exceeding 8 NTU when background concentrations were not available, so it is possible the benchmark was exceeded. There were three periods in 2021 where 30-day averages could be calculated and one of these, in August, exceeded the average ALWQG with an increase of 3.2 NTU over background. The guidelines were always met at 0500101, the next site downstream, and turbidity generally decreased in concurrent measurements compared to E254309.

Table 42: Summary statistics for turbidity (NTU) by site in Wolfe Creek (2007-2021). Sites are presented upstream to downstream.

Site	Average	Min	Max	95th percentile	n
E307368	0.9	<0.1	33.6	1.6	100
E254309	3.0	0.1	66.6	9.5	226
0500101	1.7	0.1	6.8	5.4	255
E254311	2.1	0.3	8.7	5.2	91
E287172	1.0	0.3	4.3	2.9	73

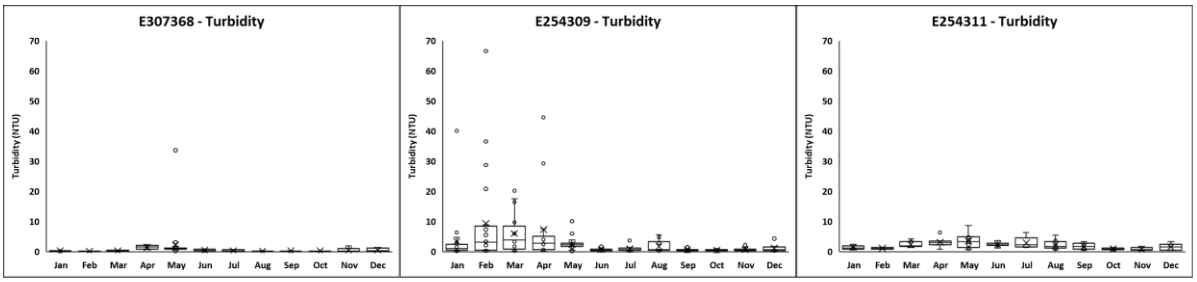

Figure 38: Seasonal variation in turbidity (NTU) in Wolfe Creek from upstream (E307368) to downstream (E254311) (2007-2021).

Turbidity levels over time at E254309 are illustrated in Figure 39. A spike in turbidity levels was caused by a spill of mill slurry (process water and sediments) on December 10, 2014, when the pipeline to the Tailings Management Facility was blocked. The containment berms failed resulting in slurry and berm sediments flowing into Wolfe Creek.

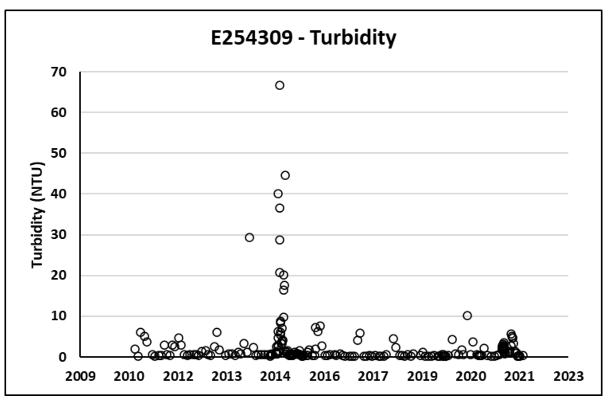

Figure 39: Turbidity levels (NTU) in Wolfe Creek over time.

9.1.7 Total Suspended Solids

Monitoring results for total suspended solids in Wolfe Creek are summarized in Table 43. Concentrations followed the same pattern as turbidity with the highest levels seen directly below the CMM site and an overall decrease in levels with the distance downstream.

Table 43: Summary statistics for total suspended solids (mg/L) by site in Wolfe Creek (2007 – 2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	4.1	<1.0	153	4.9	98
E254309	6.8	<1.0	132	18.5	223
0500101	4.9	<1.0	27.4	12.1	252
E254311	7.0	1.1	33.2	16.0	90
E287172	2.6	<1.0	12.0	6.9	71

9.1.8 Total Dissolved Solids

Monitoring results for total dissolved solids in Wolfe Creek are summarized in Table 44. A provisional WQO of 500 mg/L (average) was set in 1985. Concentrations averaged 103 mg/L at E307368 and increased to 705 mg/L at E254309, then decreased with distance from CMM. Seasonal trends in total dissolved solids are illustrated in Figure 40. The results show that the WQO was exceeded downstream of CMM at most times except when high flows diluted concentrations.

Table 44: Summary statistics for total dissolved solids (mg/L) by site in Wolfe Creek (2011 – 2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	103	60	213	145	98
E254309	705	170	1,240	1,079	223
0500101	682	183	1,160	975	237
E254311	618	183	977	917	90
E287172	600	238	859	789	71

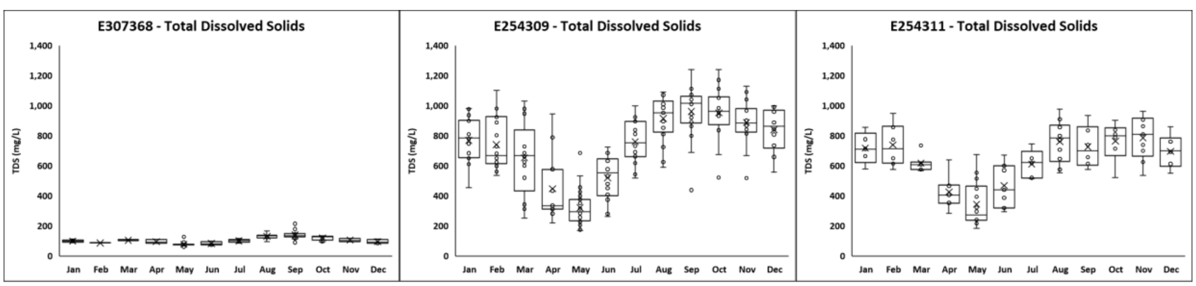

Figure 40: Seasonal variation in total dissolved solids (mg/L) in Wolfe Creek from upstream (E307368) to downstream (E254311) (2011 – 2021).

9.2 Nutrients

9.2.1 Phosphorus

There are no B.C. ALWQGs for phosphorus in streams and no WQOs specific to Wolfe Creek. The available phosphorus data are summarized in Table 45. Phosphorus concentrations increased downstream of CMM, with average concentrations of about 50 µg/L downstream of E254309. Much of the total phosphorus was in the dissolved form, and the majority of that was ortho-phosphate.

Seasonal trends in total phosphorus and ortho-phosphate are illustrated in Figure 41. Concentrations were consistent throughout the year with elevated levels occurring during July, August, and September, presumably because of reduced dilution during the low flow period of the year.

Table 45: Summary statistics for total and dissolved phosphorus (µg/L) by site in Wolfe Creek (2011-2021). Sites are listed upstream to downstream.

Parameter	Site	Average	Minimum	Maximum	95th percentile	n
Total phosphorus (µg/L)	E307368	10.7	2.70	58.6	20.4	87
	E254309	39.2	21.7	97.5	57.3	165
	0500101	50.7	26.4	127	78.3	160
	E254311	50.8	28.9	129	76.1	88
	E287172	49.1	20.5	166	93.2	71
Dissolved phosphorus (µg/L)	E307368	9.04	4.20	31.9	15.4	88
	E254309	32.9	16.1	62.3	45.9	165
	0500101	42.7	19.5	79.2	61.2	165
	E254311	42.0	18.2	90.5	61.0	87
	E287172	45.1	20.6	156	81.1	71
Ortho-phosphate (µg/L)	E307368	5.49	1.30	15.5	9.24	88
	E254309	29.4	8.40	54.7	41.6	163
	0500101	38.0	16.9	80.2	78.3	160
	E254311	37.4	15.1	85.0	53.8	88
	E287172	39.0	13.7	116	71.8	69

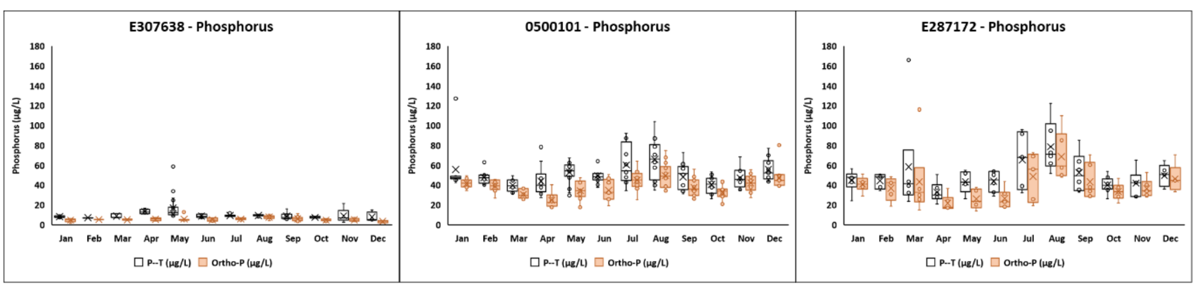

Figure 41: Seasonal variation in total phosphorus and ortho-phosphate (µg/L) in Wolfe Creek from upstream (E307368) to downstream (E254311) (2011-2021).

9.2.2 Nitrogen

Nitrogen data are summarized in Table 46. Total nitrogen concentrations increased substantially over background levels directly below CMM at E254309, then decreased with distance downstream.

Ammonia concentrations throughout Wolfe Creek were low and well below ALWQGs (ENV 2021d). For example, the maximum ammonia concentration reported at E287172 (0.083 mg/L) corresponds to a chronic guideline value of 1.26 mg/L. All results were below the most stringent WQG value of 0.102 mg/L, based conservatively on an assumed pH of 9.0 and a water temperature of 20 °C.

Table 46: Summary statistics for nitrogen (mg/L) by site in Wolfe Creek. Sites are arranged in order, upstream to downstream.

Parameter	Site	Average	Minimum	Maximum	95th percentile	n
Total Nitrogen (mg/L) (2011 – 2021)	E307368	0.190	<0.050	1.25	0.386	88
	E254309	2.78	0.010	7.95	6.05	168
	0500101	1.86	0.059	5.84	4.18	162
	E254311	1.31	0.080	4.28	3.76	88
	E287172	0.771	.099	3.11	2.44	71
Ammonia (mg/L) (2012 – 2021)	E307368	0.005	<0.005	0.007	0.006	92
	E254309	0.010	<0.005	0.012	0.010	157
	0500101	0.011	<0.005	0.040	0.022	154
	E254311	0.008	<0.005	0.046	0.014	78
	E287172	0.021	<0.005	0.083	0.056	64
Dissolved Nitrate (mg/L) (2007 – 2021)	E307368	0.027	<0.005	0.796	0.097	98
	E254309	2.52	0.059	8.12	5.90	177
	0500101	1.56	0.025	5.51	3.82	195
	E254311	1.05	0.014	4.08	3.44	90
	E287172	0.537	<0.005	2.86	2.14	71

The ALWQG for nitrate (ENV 2009) is a 30-day average of 3.0 mg/L and the drinking water guideline is a MAC of 10 mg/L. Background concentrations at E307638 were generally below MDLs (0.005 mg/L), but increased directly below CCM at E254309, possibly related to blasting at the mine, then decreased with distance downstream from the mine site. The average ALWQG was exceeded by 34% of the individual results at E254309 with a maximum concentration of 8.12 mg/L. The rate of exceedance decreased downstream at 0500101 (15%) and E254311 (9%) with all reported results below the guideline level at E287172. Nitrate concentrations over time are illustrated in Figure 42. Concentrations appear to have peaked in 2018 and the most recent results were generally less than 3 mg/L.

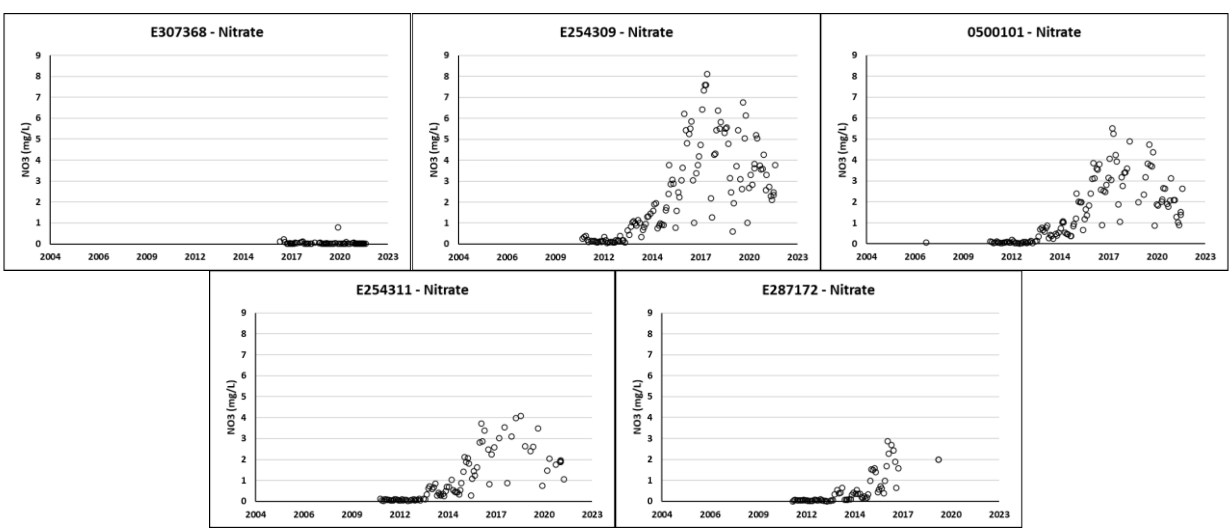

Figure 42: Dissolved nitrate concentrations (mg/L) in Wolfe Creek over time. Sites are presented upstream to downstream.

There was no consistent seasonal pattern with total nitrogen or nitrate concentrations (Figure 43) but a clear decrease in concentrations with distance from the mine. Figure 43 also shows that nitrate accounts for most of the total nitrogen measured, which likely results from the upstream mining activity.

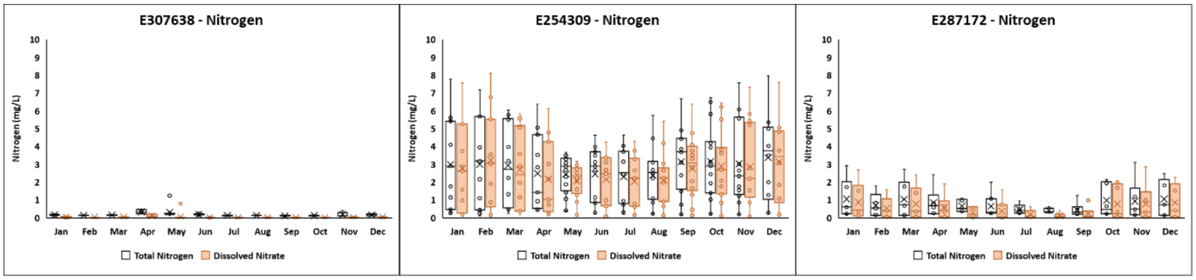

Figure 43. Seasonal variation in total nitrogen and dissolved nitrate (mg/L) in Wolfe Creek from upstream (E307368) to downstream (E254311) (2000-2021).

9.3 Organic Matter

Dissolved organic carbon data are summarized in Table 47 with seasonal trends illustrated in Figure 44. Concentrations were slightly higher upstream at E307368 with an average of 6.3 mg/L and lower downstream with an average of about 4.3 mg/L. The seasonal trends showed the highest concentrations in April and May, coinciding with freshet.

Table 47: Summary statistics for dissolved organic carbon (mg/L) by site in Wolfe Creek (2011 – 2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	6.3	3.2	16.5	11.7	85
E254309	4.2	1.5	15.1	10.7	162
0500101	4.3	1.7	14.6	10.0	158
E254311	4.4	1.6	14.0	10.3	88
E287172	4.3	2.2	11.9	8.7	71

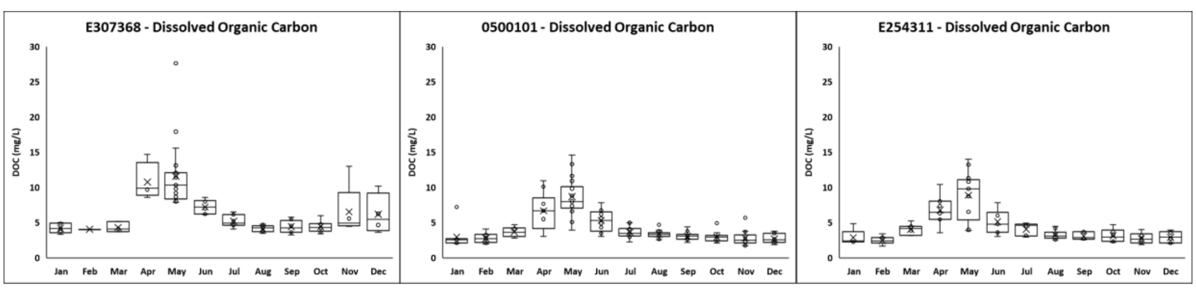

Figure 44: Seasonal variation in dissolved organic carbon (mg/L) in Wolfe Creek upstream (E307368) to downstream (E287172) above Lorne Lake (2011-2021).

9.4 Major Ions

Dissolved sulphate data are summarized in Table 48. Like total dissolved solids and water hardness, sulphate concentrations increased substantially downstream of CMM, and decreased gradually downstream with distance from the mine site. Seasonal trends in sulphate concentrations are illustrated in Figure 45 and show the lowest concentrations occurred during freshet downstream of CMM.

The ALWQG for sulphate (ENV 2013) is based on hardness measured concurrently at the site in question with WQG values increasing with hardness. The ALWQG is based on toxicity studies at a water hardness of 250 mg/L or less. The guideline value for very hard water (181 mg/L to 250 mg/L) is an average concentration of 429 mg/L and provides the benchmark in this assessment. It should be noted that the ALWQG is based on total sulphate, but most of the sulphate data for Wolfe Creek is for the dissolved fraction. Total sulphate values would likely be higher at certain times of the year (e.g., freshet).

Table 48: Summary statistics for dissolved sulphate (mg/L) by site in Wolfe Creek (2007 – 2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	13	3	31	26	98
E254309	340	49	592	523	177
0500101	299	56	506	459	211
E254311	272	56	467	432	90
E287172	259	70	398	381	71

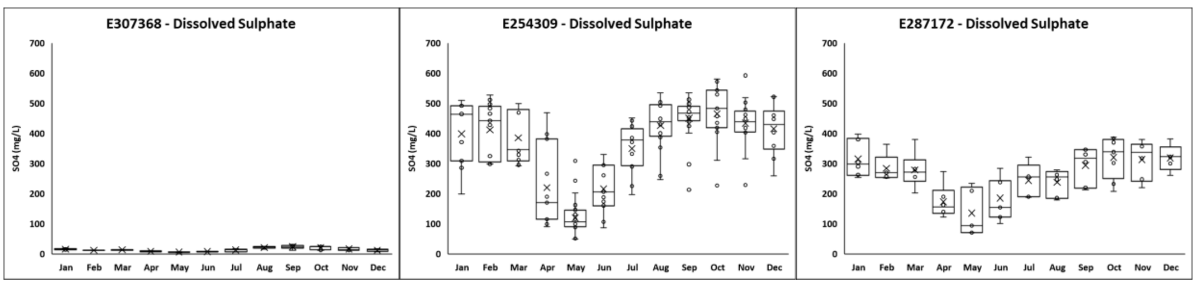

Figure 45: Seasonal variation in dissolved sulphate (mg/L) in Wolfe Creek upstream (E307368) to downstream (E287172) above Lorne Lake (2007-2021).

When water hardness was ≤250 mg/L the ALWQG was met at all sites (Table 49). At E307368 the ALWQG values ranged from 128 mg/L (very soft water) to 309 mg/L (moderately soft/hard to hard). The maximum reported concentration was 31 mg/L and well below the ALWQG levels. Sulphate increased substantially downstream at E254309 with an average of 340 mg/L and a maximum of 592 mg/L. All results with a water hardness ≤250 mg/L were below the ALWQG; 48% of results with a water hardness >250 mg/L exceeded the sulphate benchmark of 429 mg/L. The rate of benchmark exceedance (hardness >250 mg/L) decreased downstream with 20% and 11% of values having sulphate concentrations greater than 429 mg/L at sites 0500101 and E254311, respectively. Downstream at E287172 all sulphate results were again below the benchmark level.

9.5 Metals

Metals with WQOs set in 1985 for Wolfe Creek include copper, iron, manganese, molybdenum, and zinc. Other metals of concern identified include aluminum, cobalt, selenium, and uranium. These are discussed in detail in the following sections.

Table 49: Rate of water quality guideline attainment for dissolved sulphate (mg/L) by site in Wolfe Creek (2007 – 2021) at water hardness concentrations less than and greater than 250 mg/L. The "Total" column represents the number of results that met the water quality guideline with a benchmark of 429 mg/L used for results with water hardness >250 mg/L. Sites are presented upstream to downstream.

Site	WQG met at ≤250 mg/L	WQG met at >250 mg/L	Total
E307368	100%	-	100%
E254309	100%	52%	62%
0500101	100%	80%	84%
E254311	100%	89%	91%
E287172	100%	100%	100%

9.5.1 Aluminum

Total aluminum data for Wolfe Creek are summarized in Table 50. Concentrations increased over background below CMM then gradually decreased with distance from the mine site and were lower than background at the most downstream site. The highest concentrations were measured at E254309 with an average of 196 µg/L and a 95th percentile concentration of 727 µg/L. These levels were driven by high concentrations resulting from the December 2014 slurry spill at CMM. Dissolved aluminum concentrations were highest at the background site (E307368) with an average concentration of 37 µg/L and decreased downstream. At E254309, dissolved aluminum represented a small fraction of the total aluminum with an average concentration of 9 µg/L and a 95th percentile concentration of 40 µg/L.

Table 50: Summary statistics for aluminum (µg/L) by site in Wolfe Creek (2007 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E307368	Total aluminum	74	7	486	243	97
	Dissolved aluminum	37	5	182	128	96
E254309	Total aluminum	196	4	3,600	727	223
	Dissolved aluminum	9	<1	99	40	173
0500101	Total aluminum	110	3	682	363	258
	Dissolved aluminum	6	<1	67	29	200
E254311	Total aluminum	135	3	657	395	90
	Dissolved aluminum	8	<1	70	28	52
E287172	Total aluminum	47	7	234	170	71
	Dissolved aluminum	4	<1	39	13	30

The ALWQG for aluminum is based on total aluminum and determined by site-specific pH, hardness, and DOC (WLRS 2023a). Results where concurrent measurements of these parameters were available were compared to the long-term chronic guidelines. The ALWQGs were generally met at all sites with 99% attainment at E307368, 96% at E254309, 97% at 0500101, 98% at E254311, and 100% attainment at E287172.

Seasonal trends in total aluminum are illustrated in Figure 46. Concentrations are greatest during freshet in April and May throughout Wolfe Creek, except for E254309 when very high concentrations were measured in January through March of 2015 following the December 2014 slurry spill (see Section 9.1.6).

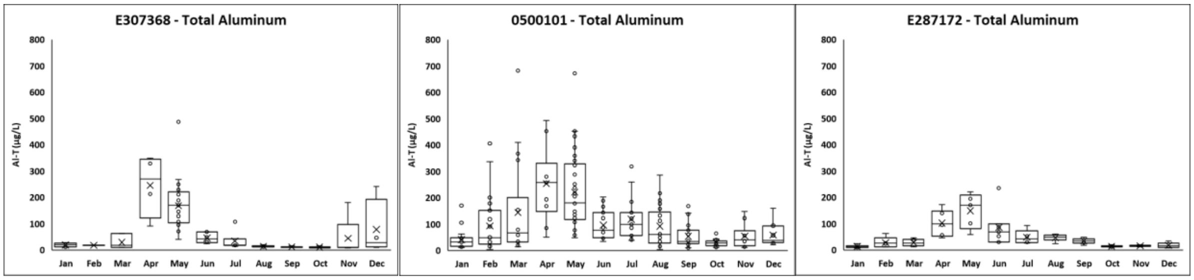

Figure 46: Seasonal variation in total aluminum (µg/L) in Wolfe Creek upstream (E307368) to downstream (E287172) above Lorne Lake (2007-2021).

9.5.2 Cobalt

Total cobalt concentrations are generally low (<1 µg/L) in ambient conditions in B.C. with higher concentrations generally associated with industrialized or mining areas (ENV 2004). The current ALWQG is a long-term average concentration or 4 µg/L (total cobalt), however B.C. is planning to adopt the hardness-based federal environmental quality guideline (EC 2017) with an uncertainty factor of 3. The federal guideline is bound by a hardness range of 52 mg/L – 396 mg/L with corresponding guideline values of 0.78 µg/L and 1.8 µg/L, respectively. Applying an uncertainty factor of 3 provides a benchmark of 0.26 µg/L for waters with a water hardness of ≤52 mg/L and 0.6 µg/L for waters with a hardness ≥396 mg/L. The drinking water guideline is a maximum allowable concentration of 1 µg/L.

The available total cobalt data for Wolfe Creek are summarized in Table 51. Total cobalt concentrations were elevated slightly at E254309 where the proposed ALWQG benchmark was exceeded in 11% of samples and the drinking water guideline was exceeded in 3% of results. Guidelines were met at all other sites ≥99% of the time.

Table 51: Summary statistics for total cobalt (µg/L) by site in Wolfe Creek (2007 – 2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	0.123	<0.100	1.90	0.112	98
E254309	0.319	<0.100	2.44	0.764	223
0500101	0.173	0.020	0.500	0.330	258
E254311	0.154	<0.100	0.490	0.296	90
E287172	0.108	0.043	0.200	0.160	71

9.5.3 Copper

Copper is of particular concern in Wolfe Creek given the location of the CMM. A WQO for dissolved copper was set in 1985 based on water hardness: an average of ≤10 µg/L and a maximum of 15 µg/L when hardness is >100 mg/L; and an average of ≤6 µg/L and a maximum of 8 µg/L when hardness is <100 mg/L. The ALWQG for copper is based on dissolved copper and determined by concurrent measurements of toxicity-modifying factors including pH, DOC, and water hardness (ENV 2019a). The available dissolved copper data are summarized in Table 52. Background concentrations at E307368 were high with an average of 4.21 µg/L and a 95th percentile concentration of 7.59 µg/L. Concentrations increased downstream at E254309 and gradually decreased with distance downstream. Although data are limited, levels were considerably lower than background at E287172 with an average concentration of 1.87 µg/L and a 95th percentile concentration of 5.27 µg/L.

Table 52: Summary statistics for dissolved copper (µg/L) by site in Wolfe Creek (2011 – 2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	4.21	2.07	8.95	7.59	96
E254309	4.69	1.39	16.0	14.4	173
0500101	3.21	1.01	13.1	11.3	200
E254311	3.14	1.05	12.1	9.72	52
E287172	1.87	0.750	6.79	5.27	30

The seasonal trends in dissolved copper are illustrated in Figure 47. Concentrations were highest during freshet peaking in May at all sites.

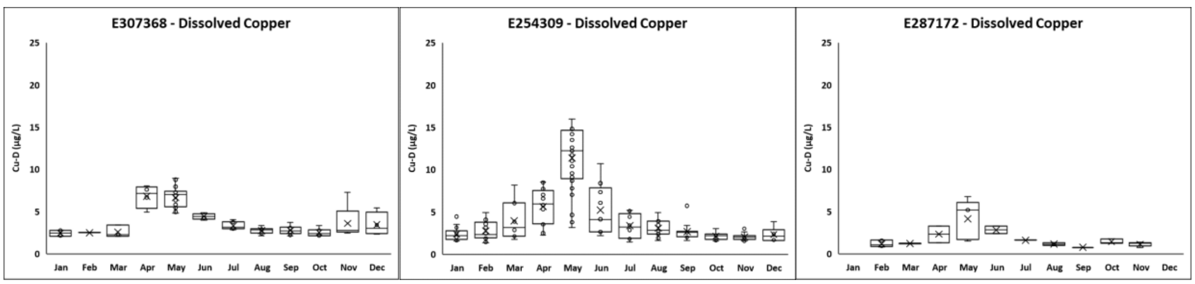

Figure 47: Seasonal variation in dissolved copper (µg/L) in Wolfe Creek. Sites are presented upstream (E307368) to downstream (E287172) above Lorne Lake (2011-2021).

Chronic ALWQG values were calculated where concurrent measurements of pH, DOC, and hardness were available and compared to dissolved copper concentrations. Background concentrations at E307368 were elevated above ALWQG levels with only 2% (2/82) of results meeting guidelines. Guideline attainment increased downstream with 32% (41/129) attainment at E254309, 86% at 0500101 (118/136), 86% at E254311 (43/50), and 96% (27/28) at E287172. Dissolved copper concentrations and corresponding guideline levels, over time, are illustrated in Figure 48. The peaks in dissolved copper during freshet are evident, as are the peaks in ALWQG levels. The elevated guideline levels are driven by increased DOC levels during freshet. The decreasing frequency of guideline exceedance is also illustrated in this figure.

9.5.4 Iron

There is a dissolved iron WQO for Wolfe Creek of 0.3 mg/L, maximum, at any time (ENV 1985). The ALWQG for iron is a maximum concentration of 1 mg/L for total iron and 0.35 mg/L for dissolved iron (ENV 2008). The total iron drinking water guideline is a maximum of 0.3 mg/L to prevent taste, odour, and colour issues (ENV 2020a). The available iron data for Wolfe Creek are summarized in Table 53. Like many other parameters, concentrations in total iron increased over background immediately below CMM, then gradually decreased with distance downstream. Dissolved iron concentrations were consistent throughout Wolfe Creek ranging from 0.025 mg/L (E254309) to 0.038 mg/L (E307368).

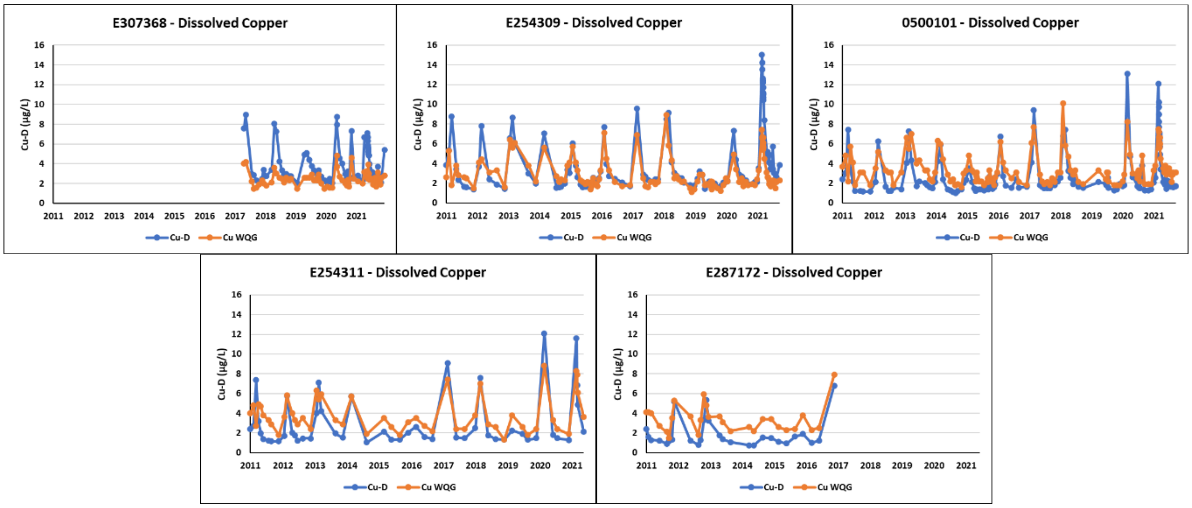

Figure 48: Dissolved copper concentrations (µg/L) and chronic water quality guideline levels over time in Wolfe Creek. Sites are presented upstream (E307368) to downstream (E287172) above Lorne Lake.

Table 53: Summary statistics for iron (mg/L) by site in Wolfe Creek (2007 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E307368	Total iron	0.107	<0.010	3.33	0.268	98
	Dissolved iron	0.038	<0.010	0.166	0.120	96
E254309	Total iron	0.251	0.011	4.090	0.957	223
	Dissolved iron	0.025	<0.010	0.116	0.059	173
0500101	Total iron	0.162	0.017	0.778	0.438	248
	Dissolved iron	0.031	<0.010	0.102	0.066	200
E254311	Total iron	0.176	0.031	0.824	0.479	90
	Dissolved iron	0.028	<0.010	0.103	0.074	52
E287172	Total iron	0.092	0.018	0.316	0.204	71
	Dissolved iron	0.034	0.009	0.076	0.074	30

The dissolved iron WQO and ALWQG was met at all sites. The total iron ALWQG was exceeded once at E307368 and 10 times at E254309. All exceedances occurred concurrently with elevated turbidity levels and typically between February and May. The drinking water guideline was exceeded occasionally, most frequently at E254309 (21%) followed by E254311 (17%), 0500101 (14%), E307368 (4%), and E287172 (1%).

9.5.5 Manganese

There is a dissolved manganese WQO for Wolfe Creek of 200 µg/L, maximum (ENV 1985). The ALWQG is based on water hardness (ENV 2001b). The drinking water guideline is a maximum allowable concentration of 120 µg/L to protect human health and 20 µg/L to protect the aesthetic quality (ENV 2020a).

The total manganese data for Wolfe Creek are summarized in Table 54. Total manganese concentrations increased downstream of CCM then decreased with distance from the mine site. All results were well below the most conservative long-term guideline values (ranging from 710 µg/L at E307368 to 1,190 µg/L at E287172) calculated from the available hardness data. The dissolved manganese WQO was always met, and the human health guideline was generally met at all sites. The aesthetic guideline was frequently exceeded with the highest rate of exceedance at 05000101 (87%). Background concentrations at E307368 exceeded the guideline 40%, and downstream at E287172 it was exceeded 35% of the time. To summarize, total manganese levels appear to be naturally elevated in Wolfe Creek but influenced by land use downstream of the CMM. The levels are well below the ALWQG for the protection of aquatic life and the human health guidelines, but frequently exceed the drinking water aesthetic guideline.

Table 54: Summary statistics for manganese (µg/L) by site in Wolfe Creek (2007 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E307368	Total manganese	4.80	0.170	203	6.38	98
	Dissolved manganese	1.51	<0.100	43.6	3.53	96
E254309	Total manganese	32.5	4.74	152	80.5	223
	Dissolved manganese	20.1	0.130	93.8	61.4	173
0500101	Total manganese	33.9	1.44	78.8	60.2	258
	Dissolved manganese	25.6	0.190	59.4	46.7	200
E254311	Total manganese	21.0	5.27	54.5	40.2	90
	Dissolved manganese	9.13	0.360	41.5	17.9	52
E287172	Total manganese	22.0	6.48	113	48.6	71
	Dissolved manganese	14.7	5.03	48.2	32.3	30

Seasonal trends in total manganese concentrations are illustrated in Figure 49. No consistent pattern was evident in comparing sites, but this could be related to varying sample sizes. At E254309, concentrations were lowest in May and June with increasing dilution during freshet.

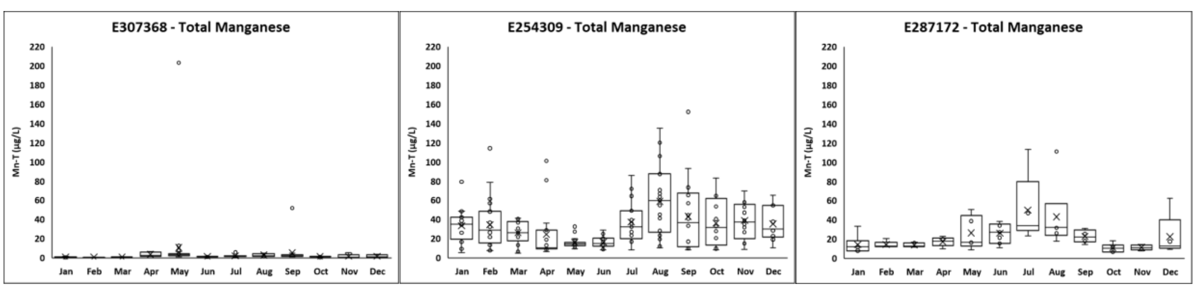

Figure 49: Seasonal variation in total manganese (µg/L) in Wolfe Creek. Sites are presented upstream (E307368) to downstream (E287172) above Lorne Lake (2011-2021).

9.5.6 Molybdenum

The 1985 WQO for dissolved molybdenum is an average of 20 µg/L and a maximum of 50 µg/L from May to September during the irrigation season. B.C. has total molybdenum WQGs for various water uses including source drinking water (maximum allowable concentration of 88 µg/L), aquatic life (average of 7.6 mg/L, maximum of 46 mg/L), livestock watering (average of 16 µg/L), irrigation water (average of 20 µg/L), and ruminant wildlife (average of 34 µg/L) (ENV 2021h).

The available total and dissolved molybdenum data are summarized in Table 55. Molybdenum concentrations increased above background levels downstream of the CMM, then decreased with distance from the mine site. Most of the total molybdenum was in the dissolved form throughout Wolfe Creek.

Table 55: Summary statistics for total molybdenum (µg/L) by site in Wolfe Creek (2007 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E307368	Total molybdenum	1.07	0.516	1.93	1.56	98
	Dissolved molybdenum	1.02	0.473	1.79	1.56	96
E254309	Total molybdenum	37.1	2.60	90.6	71.8	223
	Dissolved molybdenum	37.0	2.34	92.3	70.2	172
0500101	Total molybdenum	33.8	3.52	69.6	56.4	258
	Dissolved molybdenum	32.9	3.22	63.9	56.0	200
E254311	Total molybdenum	28.0	3.78	68.2	54.7	90
	Dissolved molybdenum	26.7	3.44	67.0	57.4	52
E287172	Total molybdenum	21.3	5.54	42.2	38.0	70
	Dissolved molybdenum	18.9	5.06	37.0	36.7	30

All results were well below the ALWQG, and most results were below the source drinking water guideline. However, the guidelines for other uses were frequently exceeded downstream of CMM. The most relevant of these is likely the ruminant wildlife guideline of 34 µg/L. Results exceeded this benchmark 47% (105/223) of the time at E254309, 56% (145/258) at 0500101, 47% (33/90) at E254311, and 40% (12/30) at E287172.

For dissolved molybdenum, results exceeded the average WQO value in 58% (45/77) of individual results for May through September at E254309, 54% (52/97) of results at 0500101, 36% (10/28) at E254311, and 25% (3/12) at E287172. The maximum WQO value was exceeded in 35% of results from E254309, 12% at 0500101, and 4% at E254311. Dissolved molybdenum did not exceed 50 µg/L at E287172.

Seasonal trends for total molybdenum concentrations are illustrated in Figure 50. Concentrations were lowest during freshet which is expected given the dominant form is dissolved and dilution would be greatest at this time. Figure 51 shows total molybdenum concentrations over time. An increasing trend downstream of E307368 is clear. The lower concentrations measured in recent years generally occurred during freshet.

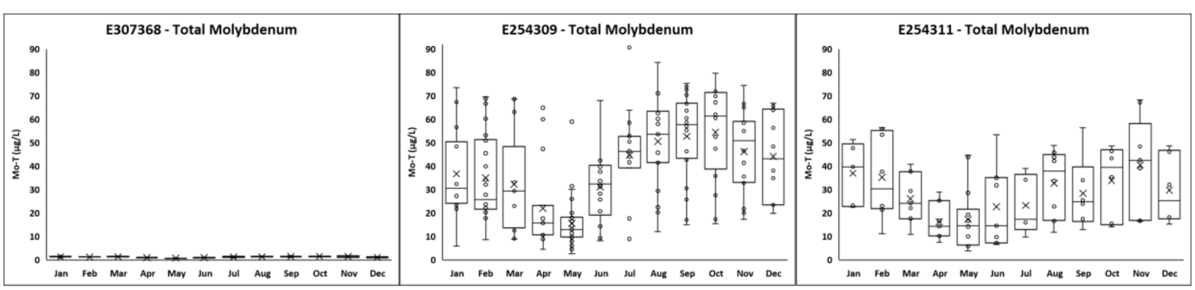

Figure 50: Seasonal variation in total molybdenum (µg/L) in Wolfe Creek. Sites are presented upstream (E307368) to downstream (E287172) above Lorne Lake (2011-2021).

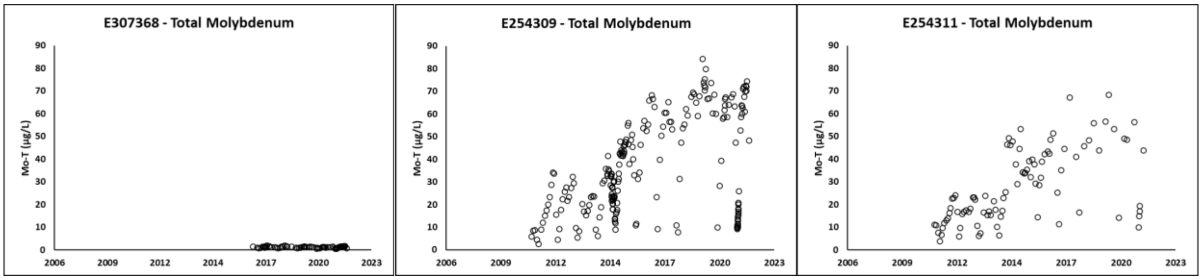

Figure 51: Total molybdenum concentrations (µg/L) over time in Wolfe Creek. Sites are presented upstream (E307368) to downstream (E287172) above Lorne Lake.

9.5.7 Selenium

The ALWQG for total selenium is a long-term average concentration of 2 µg/L with an alert level of 1 µg/L (ENV 2014). There is also a drinking water guideline of 10 µg/L (ENV 2020a).

The total selenium data for Wolfe Creek are summarized in Table 56. Concentrations increased downstream of CMM then decreased with distance downstream. No seasonal trend was obvious (Figure 52), however because most of the total selenium was in the dissolved form it is likely concentrations decrease with increased flow (e.g., site E254309 in Figure 52).

Table 56: Summary statistics for total selenium (µg/L) by site in Wolfe Creek (2011 – 2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	0.189	0.071	0.507	0.325	98
E254309	1.32	0.330	3.74	2.66	223
0500101	0.908	0.200	2.69	1.69	258
E254311	0.837	0.320	2.07	1.64	90
E287172	0.634	0.103	1.42	1.27	71

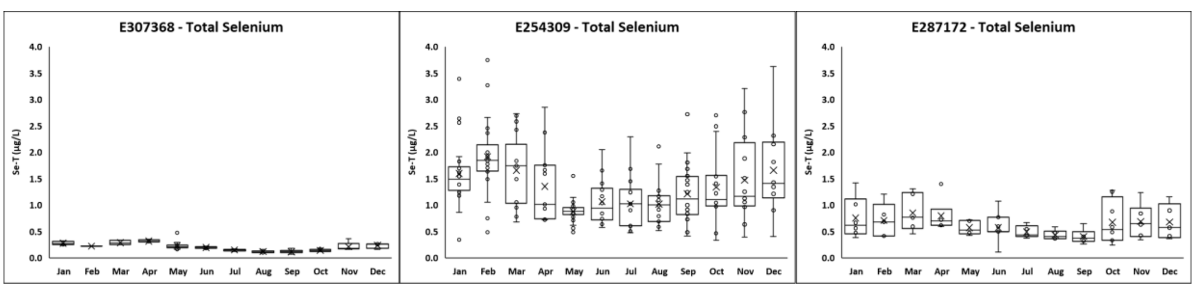

Figure 52: Seasonal variation in total selenium (µg/L) in Wolfe Creek. Sites are presented upstream (E307368) to downstream (E287172) above Lorne Lake (2011-2021).

Background concentrations at E307368 were well below all guideline levels. Downstream at E254309, average concentrations were above the alert level for the protection of aquatic life (1.32 µg/L) with the 95th percentile concentration exceeding the ALWQG level of 2 µg/L. At this site, 30% of results exceeded the ALWQG and 60% exceeded the alert level. The rate of exceedance decreased with distance downstream. At 0500101, 2% of results exceeded the ALWQG and 36% exceeded the alert level. At E254311, 1% exceeded the ALWQG and 28% exceeded the alert level, and at E287172, only the alert level was exceeded in 15% of results.

Total selenium concentrations over time are illustrated in Figure 53. The increases in concentrations may have peaked between 2017 and 2018 and, based on the available data, appear to be lower in recent years but still substantially greater than background concentrations.

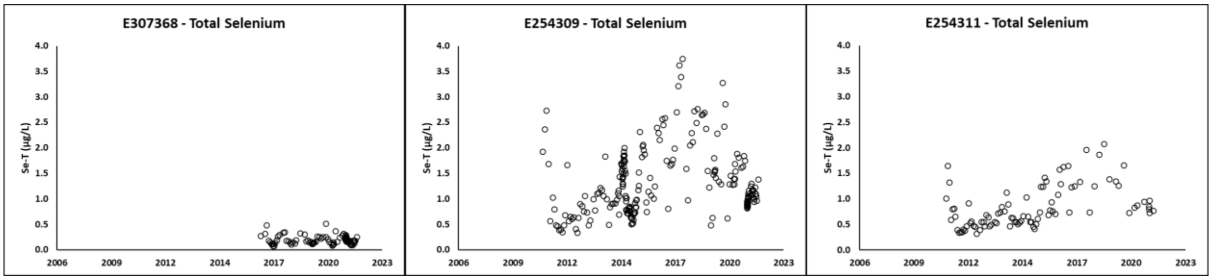

Figure 53: Total selenium concentrations (µg/L) over time in Wolfe Creek. Sites are presented upstream (E307368) to downstream (E287172) above Lorne Lake.

9.5.8 Uranium

Total uranium data for Wolfe Creek are summarized in Table 57. The ALWQG for total uranium is 8.5 µg/L (ENV 2021b) and the drinking water guideline is 20 µg/L (ENV 2020a).

Uranium concentrations increased downstream of CMM and then decreased slightly with distance downstream. All values were below the ALWQG level. Concentrations were lowest during freshet with most of the uranium present in the dissolved form. Seasonal trends in uranium concentrations are illustrated in Figure 54.

Table 57: Summary statistics for total uranium (µg/L) by site in Wolfe Creek (2007 – 2021). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	0.032	0.014	0.270	0.047	98
E254309	2.63	0.396	5.98	4.89	219
0500101	2.28	0.477	4.61	4.02	258
E254311	2.25	0.469	4.19	3.74	90
E287172	1.98	0.414	3.56	3.14	70

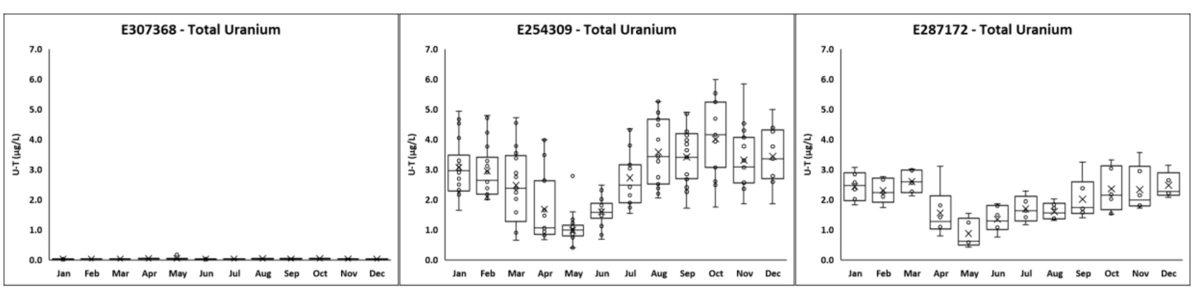

Figure 54: Seasonal variation in total uranium (µg/L) in Wolfe Creek. Sites are presented upstream (E307368) to downstream (E287172) above Lorne Lake (2011-2021).

9.5.9 Zinc

The total zinc data for Wolfe Creek are summarized in Table 58. Concentrations were consistent throughout the stream with most results (90%) reported as below the MDL of 3 µg/L. The detection limit value was used to calculate the summary statistics; with many results reported as <3 µg/L it is not surprising the average concentrations are close to 3 µg/L. The highest concentration reported was 25 µg/L at E307368 and occurred in conjunction with a high turbidity measurement of 34 NTU.

The dissolved zinc WQO for Wolfe Creek is an average concentration of ≤50 µg/L and a maximum of 320 µg/L when water hardness is >100 mg/L, and a maximum concentration of 180 µg/L when hardness is <100 mg/L. The B.C. ALWQG (WLRS 2023d) for dissolved zinc is based on site-specific concurrent measurements of water hardness, pH, and DOC. All results (total and dissolved zinc) were below the resulting guideline value except the 25 µg/L measured at E307368 which exceeded the guideline value of 9.4 µg/L. It should be noted that this is a long-term chronic guideline and is typically based on an average of five weekly measurements collected in a 30-day period. If the requisite sampling had been conducted the guideline may not have been exceeded.

The maximum allowable concentration for the protection of drinking water is 3 mg/L and all results were well below this threshold.

Table 58: Summary statistics for total zinc (µg/L) by site in Wolfe Creek (2007 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E307368	Total zinc	3.29	<3.00	25.0	3.23	98
	Dissolved zinc	1.29	<1.00	6.30	2.20	96
E254309	Total zinc	3.32	<3.00	14.6	4.95	223
	Dissolved zinc	1.32	<1.00	12.7	3.00	173
0500101	Total zinc	2.90	<0.100	15.9	3.03	258
	Dissolved zinc	1.25	0.480	5.20	3.00	200
E254311	Total zinc	3.06	<3.00	5.20	3.26	90
	Dissolved zinc	1.73	<1.00	6.10	3.61	52
E287172	Total zinc	2.98	0.450	4.70	3.00	71
	Dissolved zinc	2.43	0.330	23.0	4.50	30

9.6 Wolfe Creek Summary

The water quality of Wolfe Creek changes substantially from background to downstream of the CMM with several parameters exceeding WQG or WQO levels. Total dissolved solids exceeded the 1985 WQO downstream of CMM except during high flow periods when dilution was greater. Sulphate concentrations increased below CMM and frequently exceeded guideline levels at E254309, with the rate of exceedance decreasing with distance from the mine site. Phosphorus concentrations increased substantially below CMM with ortho-phosphate the dominant form. Nitrate was the dominant form of nitrogen present and exceeded the guideline level, particularly at E254309. The rate of guideline exceedance decreased downstream with distance from CMM.

Several metals exceeded WQG levels in Wolfe Creek. Background dissolved copper concentrations exceeded the ALWQGs at E307368, however guideline attainment increased downstream with increasing water hardness and DOC. Background total manganese concentrations were also elevated with further increases downstream of the CMM. Total manganese levels were well below the ALWQG for the protection of aquatic life and the human health guidelines, but frequently exceeded the drinking water aesthetic guideline. Molybdenum concentrations were well below the ALWQG but frequently exceeded the guideline to protect ruminant wildlife.

A spike in turbidity resulting from the December 2014 slurry spill at CMM influenced average levels of several metals including total aluminum, copper, iron, cobalt, and chromium.

The availability of data is limited to sites above Lorne Lake. As a result, the condition of Lorne, Issitz, and Wolfe Lakes, and Wolfe Creek below Wolfe Lake cannot be assessed at this time.

10. HEDLEY CREEK AMBIENT WATER QUALITY

Hedley Creek flows southwest to the Similkameen River near the town of Hedley. Provisional WQOs were set in 1990 (ENV 1990) because of potential impacts to water quality from tailings piles left by past mining operations. Hedley Creek receives water from the Nickel Plate Mine tailings facility via a diffuser located just downstream of Highway 3. The WQOs, along with current WQGs, provide the benchmarks to assess the water quality in Hedley Creek.

The available monitoring data for the period of 2000 to 2023 were used to assess the water quality of Hedley Creek. For consistency, the parameters previously assessed for the Similkameen River mainstem are considered here, in addition to those with provisional WQOs proposed in 1985 (ENV 1985) and others identified more recently as parameters of concern. Table 59 lists the monitoring sites used in the Hedley Creek assessment and the locations are illustrated in Figure 5.

Table 59: Hedley Creek monitoring sites.

EMS Site ID	Location
E223873	Hedley Creek upstream of the Nickel Plate diffuser
E223874	Hedley Creek 100 m downstream of the Nickel Plate diffuser

10.1 General Parameters

Table 60 provides summary statistics for general parameters including pH, temperature, specific conductivity, hardness, turbidity, and total suspended solids. Each of these parameters are discussed in further detail in the following sub-sections.

10.1.1 pH

A provisional WQO for pH was based on the potential release of alkaline solutions from the tailing ponds (ENV 1990) and allows unrestricted changes within the range of 6.5 to 8.5 to protect drinking water supplies. The ALWQG is unrestricted change within a range of 6.5 to 9.0 (ENV 2021a).

The pH values from the two sites (E223873 and E223874) on Hedley Creek averaged 7.6 and 7.5, respectively. pH did not exceed the upper threshold at either site but was below the lower threshold occasionally (<2% at both sites). There was very little seasonal variation in pH and both sites are generally consistent, as shown in Figure 55.

10.1.2 Temperature

There is no WQO for water temperature on Hedley Creek. Temperature ALWQGs are specific to fish species and life stage, and therefore vary over the course of the year (ENV 2001a). Rainbow trout are present in Hedley Creek with the greatest densities found within 250 m of the mouth (ENV 1990). The ALWQG for streams with known populations of rainbow trout is a range of 10.0°C – 15.5°C during spawning (late April to July) and 16.0°C – 18.0°C for rearing (summer to fall).

Water temperature data were only available to February 2015. Water temperature was highest in the summer months (July and August) and coolest in the winter (December to February) (Figure 56). Maximum temperatures at E223873 and E223874 were 17.4 °C and 18.1°C, respectively.

Table 60: Summary statistics for general water quality parameters in Hedley Creek (2000 – 2023).

Parameter	Site	Average	Minimum	Maximum	95th percentile	n
pH	E223873	7.6	5.9	8.5	8.1	1,115
	E223874	7.5	5.9	8.2	7.9	1,115
Temperature (°C)	E223873	4.9	0.0	17.4	13.7	821
	E223874	4.9	0.0	18.1	14.1	3,924
Specific conductivity (µS/cm)	E223873	55	21	301	78	1,096
	E223874	119	23	586	248	1,069
Hardness (mg/L)	E223873	22	9	50	35	233
	E223874	32	9	181	60	232
Turbidity (NTU)	E223873	1.1	0.02	34.7	3.2	1,002
	E223874	1.2	0.02	38.7	3.6	1,002
Total suspended solids (mg/L)	E223873	1.63	0.040	45.4	4.43	935
	E223874	1.78	<0.010	51.9	4.60	936

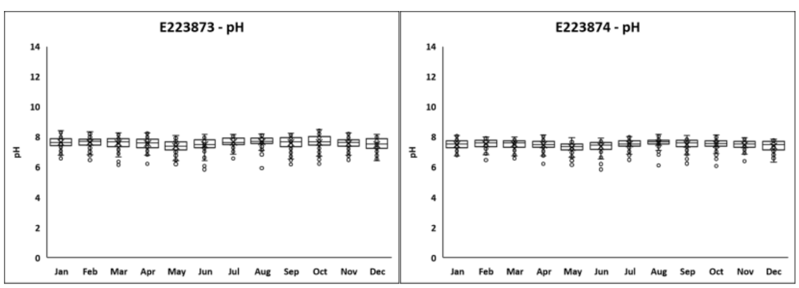

Figure 55: Seasonal variation in pH in Hedley Creek (2000 - 2023). Sites are presented upstream to downstream.

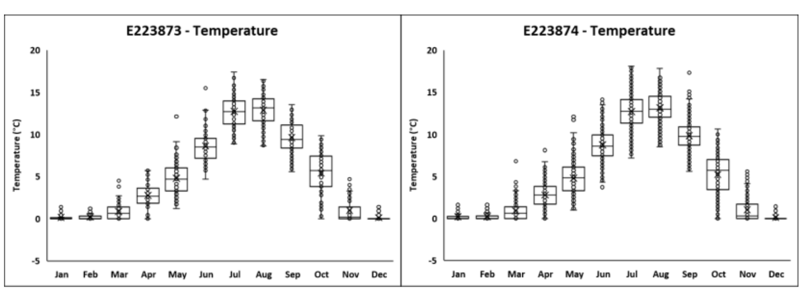

Figure 56: Seasonal variation in water temperature (°C) in Hedley Creek (2000-2015). Sites are presented upstream to downstream.

10.1.3 Specific Conductivity

Conductivity concentrations increased from upstream at E223873 (average of 55 µS/cm, 95th percentile of 78 µS/cm) to a downstream average of 119 µS/cm and a 95th percentile of 248 µS/cm suggesting a possible influence of the Nickle Plate Mine diffuser.

Seasonal trends in conductivity are illustrated in Figure 57. Specific conductivity was lowest during May and June when flow is typically highest.

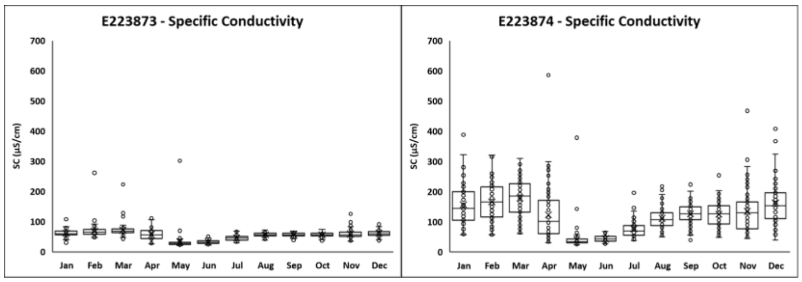

Figure 57: Seasonal variation in specific conductivity (µS/cm) in Hedley Creek (2000-2023). Sites are presented upstream (E223873) to downstream (E223874).

10.1.4 Hardness

Water hardness increased from upstream to downstream on Hedley Creek. At E223873, hardness averaged 22 mg/L with a 95th percentile concentration of 35 mg/L. Downstream at E223874 the average concentration was 32 mg/L with 95th percentile concentration of 60 mg/L. Seasonal trends in water hardness are illustrated in Figure 58. Concentrations were lowest during freshet in May and June.

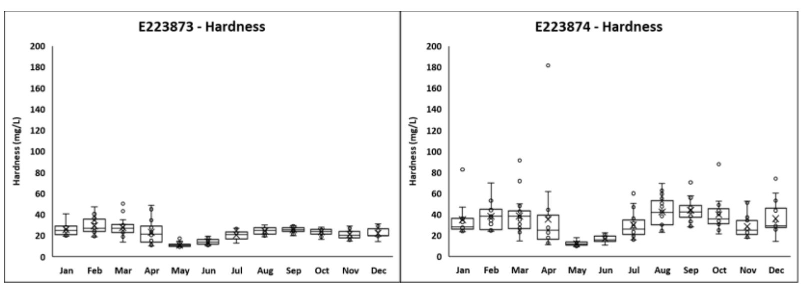

Figure 58: Seasonal variation in water hardness (mg/L) in Hedley Creek (2000-2023). Sites are presented upstream (E223873) to downstream (E223874).

10.1.5 Turbidity

The WQO for turbidity in Hedley Creek is a maximum increase of 1 NTU when upstream turbidity is <5 NTU and a maximum increase of 5 NTU when upstream turbidity is >5 NTU and <50 NTU. Turbidity levels were low at both sites averaging 1.1 NTU at E223873 and 1.2 NTU at E223874. The WQO was met on most sampling dates with only 6% (55/988) of results exceeding the WQO. Upstream turbidity was <5 NTU for all but one of the exceedances.

Seasonal trends in turbidity are illustrated in Figure 59. As expected, turbidity peaked during freshet with the majority of WQO exceedances also occurring at this time.

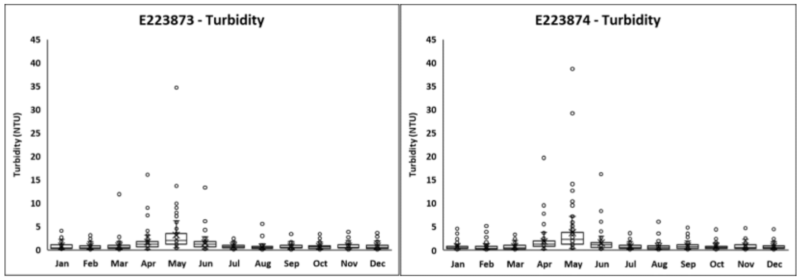

Figure 59: Seasonal variation in turbidity (NTU) in Hedley Creek (2000-2023). Sites are presented upstream (E223873) to downstream (E223874).

10.1.6 Total Suspended Solids

The total suspended solids (TSS) WQO for Hedley Creek is a maximum increase of 10 mg/L when upstream concentrations are ≤100 mg/L and a maximum increase of 10% when upstream concentrations are >100 mg/L.

TSS concentrations at E223873 ranged from 0.040 to 45.4 mg/L with an average concentration of 1.63 mg/L and a 95th percentile of 4.43 mg/L. At E223874, concentrations ranged from <0.010 to 51.9 mg/L with an average concentration of 1.78 mg/L and 95th percentile of 4.60 mg/L.

TSS followed the same seasonal pattern at both sites with the highest levels observed during freshet in May and June (Figure 60). The WQO was almost always met with only two exceedances (out of 918 sampling dates) occurring in May 2008 and June 2011.

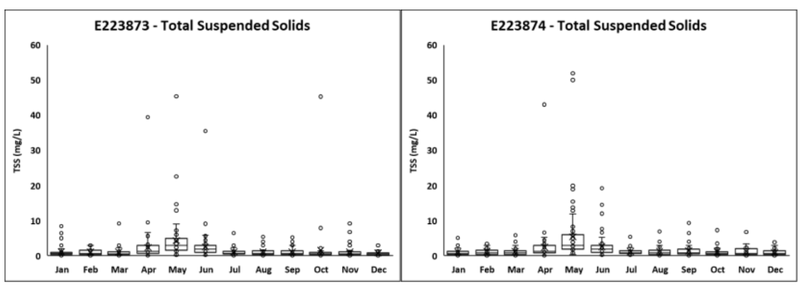

Figure 60: Seasonal variation in total suspended solids (mg/L) in Hedley Creek (2000-2023). Sites are presented upstream (E223873) to downstream (E223874).

10.2 Nutrients

The available nutrient data for Hedley Creek are summarized in Table 61. There is no phosphorus WQO for Hedley Creek and data are limited. At both sites, all results were below MDLs (ranging from <3 µg/L to <300 µg/L). A chlorophyll *a* WQO of 100 mg/m^2 was set and is based on the average of five samples collected from natural substrates. The available data, however, are limited. In August of 2013, five samples were collected from each site and averaged 4 mg/m^2 at E223873 and 20 mg/m^2 at E223874, however phosphorus was not measured. Monthly samples were collected in 2015 from each site between March and December averaging 258 mg/m^2 at E223873 and 376 mg/m^2 at E223874. Only one sample at either site (E223873, November 30, 2015) was less than the WQO (70 mg/m^2). It is difficult to comment on the 2015 results given the current total phosphorus results for these sampling dates are reported as less than the MDL of 300 µg/L.

Table 61: Summary statistics for nutrients (µg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Parameter	Site	Average	Minimum	Maximum	95th percentile	n
Total Phosphorus (2000 – 2023)	E223873	129	<3.00	<300	<300	189
	E223874	129	<3.00	<300	<300	188
Total Ammonia (2015 – 2023)	E223873	5.61	<5.00	24.4	8.50	140
	E223874	5.67	<5.00	39.3	8.11	139
Dissolved Nitrate (2000 – 2023)	E223873	25.8	<2.00	97.0	49.4	1,107
	E223874	33.6	<3.00	321	60.0	4,181

An ammonia WQO was set at the WQG (ENV 2021d) level, which is based on concurrent measurements of pH and temperature. Most results at both sites (approximately 85%) were below the MDL of 5 µg/L. No temperature data were available for either site, but all results were well below the most stringent WQG value for the range of pH values reported (1.22 mg/L).

Dissolved nitrate data were available although there is no WQO for this parameter. The chronic ALWQG is ≤3 mg/L and all results were well below this level. The average concentration at E223873 was 25.8 µg/L with a 95th percentile concentration of 49.4 µg/L. Concentrations increased at E223874 but were still well below the ALWQG level averaging 33.6 µg/L with a 95th percentile concentration of 60.0 µg/L.

10.3 Organic Matter

Dissolved organic carbon is an important constituent with respect to the toxicity of other parameters (e.g., metals). Data were not abundant for Hedley Creek; however, the available data are recent (2019 – 2023) and can be used to assess water quality with some caution. The dissolved organic carbon data are summarized in Table 62. The highest concentrations were measured in May and June of 2022 at both sites.

Table 62: Summary statistics for dissolved organic carbon (mg/L) by site in Hedley Creek (2019 – 2023). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	4.69	2.40	14.4	10.1	21
E254309	4.74	2.35	14.1	10.4	21

10.4 Major Ions and Other Inorganic Parameters

10.4.1 Sulphate

The sulphate data for Hedley Creek are summarized in Table 63. Total sulphate was measured until 2015 and only dissolved sulphate was measured from 2016 on, therefore, results for both fractions were pooled for the purposes of this assessment. Concentrations increased downstream, particularly during low flow periods. The ALWQG for sulphate is based on water hardness (ENV 2013). The most stringent value is 128 mg/L for soft water (0 – 30 mg/L). All measurements at E223873 were below this threshold. At E223874, the 95th percentile total hardness concentration of 60 mg/L corresponds with a sulphate ALWQG value of 218 mg/L. Only three values exceeded this level ranging from 222 mg/L to 253 mg/L.

Seasonal trends in sulphate concentrations are illustrated in Figure 61. As noted, concentrations were higher downstream at E223874 except during freshet in May and June.

Table 63: Summary statistics for total sulphate (mg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	2.69	0.600	28.4	4.88	1,008
E254309	30.8	0.640	253	74.6	4,177

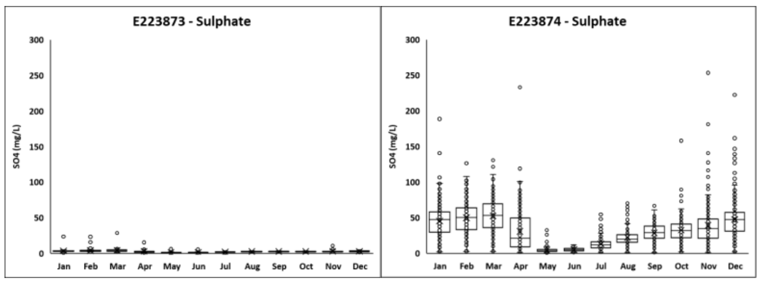

Figure 61: Seasonal variation in total sulphate (mg/L) in Hedley Creek (2000-2023). Sites are presented upstream (E223873) to downstream (E223874).

10.4.2 Cyanide

Water quality objectives for cyanide were set for Hedley Creek because of potential impacts from tailings piles. The WQO for weak acid dissociable cyanide (WAD CN) is an average concentration of 5 µg/L and a maximum concentration of 10 µg/L. The WQO for strong acid dissociable cyanide + thiocyanate (SAD CN + SCN) is a maximum concentration of 200 µg/L.

Nearly all WAD CN results (approximately 99%) at both sites were less than the MDL of 5 µg/L. At E223873, 92% of SAD CN + SCN results were below the WQO and 91% met the WQO at E223874. The rate of WQO attainment may have been higher as many of the results reported were suspect (e.g., reported as <0.229 mg/L). Regardless of this observation, cyanide does not appear to be an issue in Hedley Creek as the most recent results are consistently below the level of detection.

10.5 Metals

Water quality objectives were set for several metals to address potential concerns of inputs from tailings piles adjacent to Hedley Creek.

10.5.1 Aluminum

The 1990 aluminum WQO specified dissolved aluminum and was based on the ALWQG available at that time. The WQO was set because of potential inputs from the mine tailing piles adjacent to Hedley Creek. The current aluminum ALWQG (WLRS 2023a) is based on the total fraction and is based on concurrent measurements of pH, DOC, and hardness; this was the benchmark used in this assessment. Dissolved organic carbon data are not abundant for Hedley Creek so monthly average concentrations were used to fill data gaps for the purpose of calculating a guideline value.

The available aluminum data are summarized in Table 64. Concentrations were consistent between sites. At E22873, 92% (184/199) of individual results were below the long-term chronic ALWQG. Where average concentrations could be calculated, (i.e., a minimum of five samples collected within 30 days) 50% (5/10) exceeded the guideline. All exceedances occurred in May or April. Results were similar downstream at E223874. Most results (94%) met the corresponding ALWQG and 33% (3/9) exceeded the chronic guideline where average concentrations could be calculated. All exceedances occurred in May.

Seasonal trends in total aluminum concentrations are illustrated in Figure 62. Concentrations peaked during freshet in April through June.

Table 64: Summary statistics for aluminum (µg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E223873	Total aluminum	73.1	7.40	422	250	199
	Dissolved aluminum	47.1	5.40	230	154	237
E223874	Total aluminum	73.5	6.00	430	247	199
	Dissolved aluminum	45.9	4.40	216	148	240

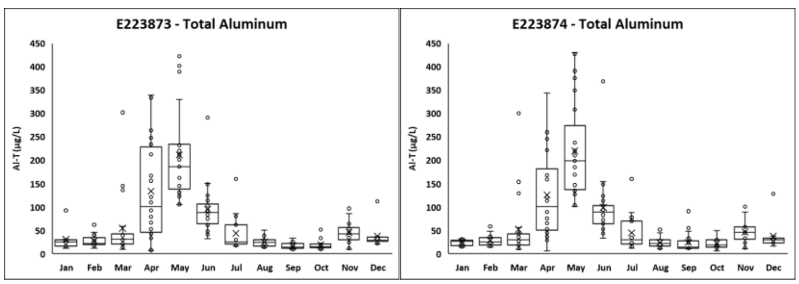

Figure 62: Seasonal variation in total aluminum (µg/L) in Hedley Creek. Sites are presented upstream (E223873) to downstream (E223874) (2000 - 2023).

10.5.2 Arsenic

A WQO for arsenic of 50 µg/L was set in 1990. The ALWQG for total arsenic is a maximum concentration of 5 µg/L (ENV 2021f) and the SDWQG is 10 µg/L (ENV 2020a). The total arsenic data for Hedley Creek are summarized in Table 65. Concentrations were well below the ALWQG throughout Hedley Creek with only one result at each site exceeding the 5 µg/L benchmark.

Table 65: Summary statistics for total arsenic (µg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E307368	0.552	0.100	9.00	1.10	997
E254309	0.602	0.100	6.20	1.20	1,002

10.5.3 Chromium

The WQO for total chromium (Cr) in Hedley Creek is an average concentration of ≤2 µg/L and a maximum concentration of 20 µg/L. The WWQGs are an average concentration of ≤8.9 µg/L for Cr(III) and ≤1 µg/L for Cr(VI) (ENV 2021b). Speciation data are not available, so a total chromium concentration of 1 µg/L provides a conservative benchmark for assessing water quality.

The available chromium data are summarized in Table 66. Concentrations were consistent between sites and generally well below the WQO and WWQG levels. Most results were reported as below the MDL (ranging from 0.1 µg/L to 1.0 µg/L) at both E223873 (63%) and E223874 (54%).

Table 66: Summary statistics for total chromium (µg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E223873	0.242	<0.100	1.10	<0.500	196
E223874	0.241	<0.100	1.43	<0.500	197

10.5.4 Cobalt

There is no WQO for cobalt in Hedley Creek. The current ALWQG is a long-term average concentration of 4 µg/L (total cobalt) (WLAP 2004), however B.C. is planning to adopt the hardness based federal environmental quality guideline (EC 2017) with an uncertainty factor of 3. The federal guideline is bound by a hardness range of 52 mg/L – 396 mg/L with corresponding guideline values of 0.78 µg/L and 1.8 µg/L, respectively. Applying an uncertainty factor of 3 provides a proposed ALWQG of 0.26 µg/L for waters with a water hardness of ≤52 mg/L and 0.6 µg/L for waters with a hardness ≥396 mg/L. The ALWQG value for waters with a hardness of 53 mg/L – 395 mg/L is determined using the equation provided in EC (2017). The drinking water guideline is a MAC of 1 µg/L.

The available cobalt data are summarized in Table 67. Results for E223873 prior to 2015 are complicated by inconsistent MDLs so only data from 2015 to 2023 are considered in this assessment. Most results at the upstream site were typically below the MDL of 0.1 µg/L: 93% for dissolved cobalt and 86% for total cobalt. Water hardness at this site was <52 mg/L so the proposed ALWQG of 0.26 µg/L was used to assess the data. For both total and dissolved cobalt, 94% of results were below the guideline level. The highest reported concentrations coincided with high specific conductance (e.g., >100 µS/cm) suggesting increased cobalt levels with decreasing flow and possible inputs from groundwater.

Table 67: Summary statistics for cobalt (µg/L) by site in Hedley Creek. Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E223873 (2015 – 2023)	Total Co	0.226	<0.100	6.09	0.226	182
	Dissolved Co	0.212	<0.100	5.72	0.199	182
E223874 (2020 – 2023)	Total Co	4.23	<0.100	64.2	12.1	196
	Dissolved Co	10.8	<0.100	77.0	33.0	1,010

Cobalt concentrations were much higher downstream at E223874 averaging 4.23 µg/L for total cobalt and 10.8 µg/L for dissolved cobalt with most of the total cobalt consisting of dissolved cobalt. The proposed ALWQG was exceeded on all dates where concurrent water hardness data were available. The drinking water guideline (1 µg/L) was exceeded in 86% of results (899/1,045) for dissolved cobalt and in 65% (128/198) of results for total cobalt. Dissolved cobalt concentrations have shown a general decreasing trend in recent years (Figure 63) but remain high relative to guideline levels. Seasonal patterns in dissolved cobalt are illustrated in Figure 64. A sharp decrease in concentrations is seen in May and June coinciding with higher flows. There is also a strong correlation between dissolved cobalt and specific conductivity (Figure 65) suggesting inputs from groundwater.

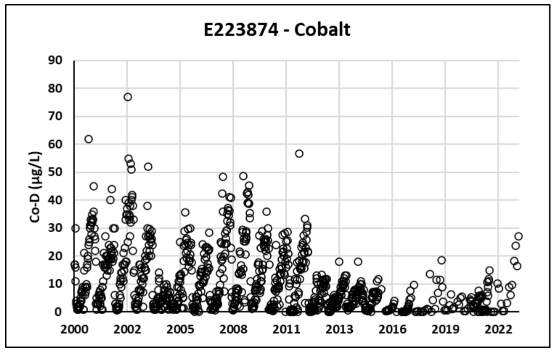

Figure 63: Dissolved cobalt concentrations (µg/L) over time in Hedley Creek at site E223874.

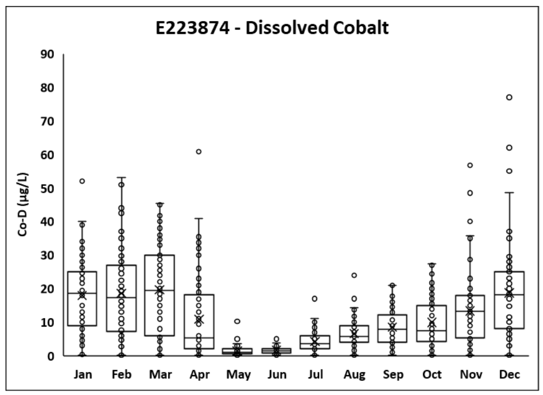

Figure 64: Seasonal variation in dissolved cobalt (µg/L) in Hedley Creek at site E223874 (2000-2023).

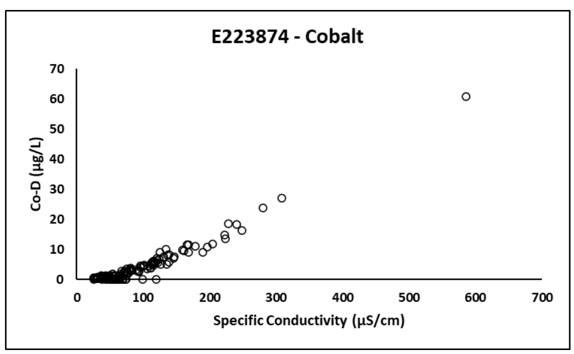

Figure 65: Dissolved cobalt (µg/L) as a function of specific conductivity (µS/cm) in Hedley Creek at site E223874 (2016-2023).

10.5.5 Copper

A WQO was set for total copper in 1995 based on the ALWQG available at that time. Since then, the ALWQG has been updated and is now based on dissolved copper and takes site-specific toxicity-modifying factors into account (pH, DOC, and water hardness) (ENV 2019a).

The available copper data for Hedley Creek are summarized in Table 68 and the seasonal trends for dissolved copper are illustrated in Figure 66. Concentrations were consistent between sites and showed no obvious seasonal pattern.

Table 68: Summary statistics for copper (µg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E223873	Total copper	1.28	0.100	13.6	3.13	996
	Dissolved Cu	0.807	<0.100	7.10	<2.00	995
E223874	Total Cu	1.50	0.100	130	3.00	1,007
	Dissolved Cu	0.825	<0.100	6.60	<2.00	994

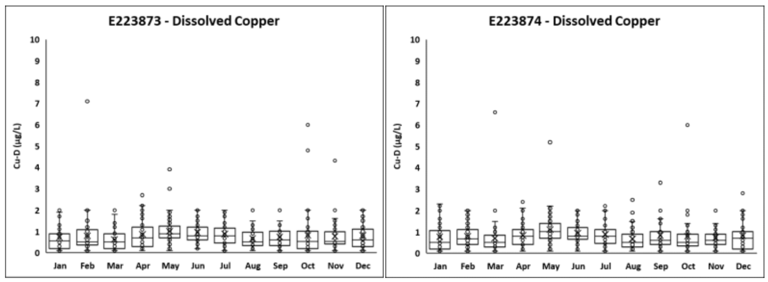

Figure 66: Seasonal variation in dissolved copper (µg/L) in Hedley Creek (2000-2023). Sites are presented upstream (E223873) to downstream (E223874).

Dissolved copper ALWQG levels were calculated based on concurrent measurements of pH, DOC, and hardness. Dissolved organic carbon data are not abundant for Hedley Creek so monthly average concentrations were used to fill data gaps for the purpose of calculating a guideline value. At E223873, 93% (181/195) of individual results were below the corresponding long-term ALWQG level. Where a 30-day average concentration could be calculated, 86% (6/7) of results met the long-term guideline. At E223874, 94% (179/190) of results met the corresponding ALWQG. All 30-day average concentrations (5/5) met the ALWQG for dissolved copper.

10.5.6 Iron

The total iron WQO for Hedley Creek is a maximum of 3 mg/L. The ALWQG for total iron is a maximum of 1 mg/L and a maximum of 0.35 mg/L for dissolved iron (ENV 2008).

The available iron data for Hedley Creek are summarized in Table 69. Concentrations were consistent between sites and below both WQO and ALWQG levels. Only one result exceeded a benchmark, a dissolved iron result of 0.360 mg/L at E223873 on May 22, 2006. The seasonal trends in dissolved iron are illustrated in Figure 67. Concentrations increased with flow during freshet in April and May but were otherwise low throughout the year.

Table 69: Summary statistics for iron (µg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E223873	Total iron	106	<10.0	676	349	198
	Dissolved iron	46.7	0.600	360	144	1,001
E223874	Total iron	106	<10.0	663	340	197
	Dissolved iron	45.6	<0.100	290	140	997

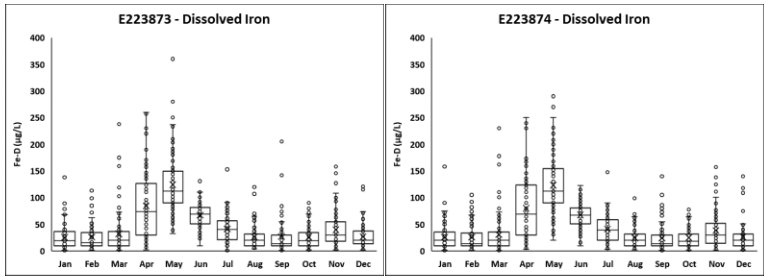

Figure 67: Seasonal variation in dissolved iron (µg/L) in Hedley Creek (2000-2023). Sites are presented upstream (E223873) to downstream (E223874).

10.5.7 Lead

The WQO for total lead in Hedley Creek is based on the ALWQG (ENV 2021g) and determined from concurrent hardness measurements. The available total lead data are summarized in Table 70. Concentrations were consistent between sites. Long-term average WQG values were calculated from corresponding hardness measurements. All concentrations were well below the guideline values. At E223873 the highest total lead concentration was 2.07 µg/L and the corresponding ALWQG was 3.87 µg/L. The next highest concentration was 0.614 µg/L with a ALWQG of 3.81 µg/L. Concentrations downstream at E223874 were lower with a maximum reported concentration of 0.962 µg/L (ALWQG was 3.87 µg/L).

Table 70: Summary statistics for total lead (µg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E223873	0.082	0.010	2.07	0.162	196
E223874	0.074	0.009	0.962	0.173	197

10.5.8 Manganese

The manganese WQO for Hedley Creek is a maximum concentration of 50 µg/L (total Mn). The ALWQG (ENV 2001b) for manganese is hardness-based and provides both long-term average guidelines and short-term maximum guidelines. For example, at a water hardness of 50 mg/L the long-term average guideline is 825 µg/L, and the short-term maximum guideline is 1,091 µg/L.

The total manganese data for Hedley Creek are summarized in Table 71. Concentrations are consistent between sites and well below both the WQO and ALWQG levels. At the lowest hardness measured (9 mg/L) the corresponding guideline is 645 µg/L and the reported total manganese concentrations at E223873 and E223874 were 15.0 µg/L and 10.5 µg/L, respectively.

Table 71: Summary statistics for total manganese (µg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E223873	2.94	0.180	31.5	12.2	199
E223874	3.05	0.350	31.4	12.0	198

Seasonal trends in total manganese are illustrated in Figure 68. Concentrations peaked during freshet and were generally <5 µg/L throughout the remainder of the year.

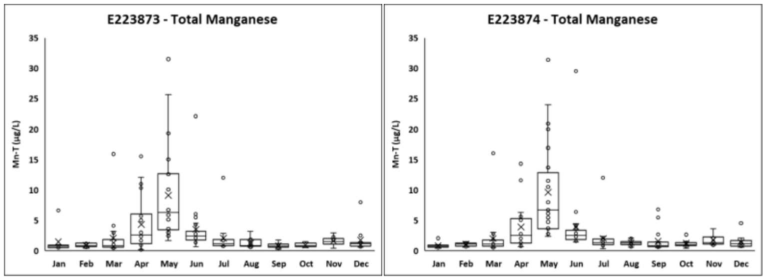

Figure 68: Seasonal variation in dissolved iron (µg/L) in Hedley Creek. Sites are presented upstream (E223873) to downstream (E223874).

10.5.9 Mercury

The WQO for total mercury in Hedley Creek is an average concentration of ≤0.02 µg/L and a maximum of 0.10 µg/L. The ALWQG (ENV 2001c) is determined using the ratio of methyl mercury to total mercury; methyl mercury data were not available. The SDWQG for mercury is ≤1.0 µg/L.

The total mercury data for Hedley Creek are summarized in Table 72. Concentrations were low at both sites with 89% (49/55) and 80% (89/111) of results below the MDL of 0.005 µg/L at E223873 and E223874, respectively. Only one individual value exceeded the average WQO, 0.021 µg/L at E223874; the 30-day average concentration, which included this result, was 0.011 µg/L and meets the WQO.

Table 72: Summary statistics for total mercury (µg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E223873	0.005	<0.005	0.009	0.007	55
E223874	0.006	<0.005	0.021	0.011	111

10.5.10 Molybdenum

The WQO for total molybdenum in Hedley Creek is an average concentration of ≤10 µg/L and a maximum concentration of 50 µg/L from May to September. The B.C. ALWQG has since been updated (ENV 2021h) and is now an average of 7.6 mg/L. Other uses have lower guideline values (e.g., ruminant livestock: 16 µg/L; ruminant wildlife: 34 µg/L) and were used to assess Hedley Creek water quality.

The available total molybdenum data are summarized in Table 73. Molybdenum concentrations are consistent throughout Hedley Creek and well below guideline levels.

Table 73: Summary statistics for total molybdenum (µg/L) by site in Hedley Creek (2000 – 2023). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E223873	0.983	<0.050	20.0	1.46	196
E223874	1.15	0.320	<10.0	2.03	198

10.5.11 Nickel

The total nickel WQO for Hedley Creek is an average concentration of 25 µg/L when water hardness is ≤65 mg/L and 65 µg/L when hardness is >65 mg/L. The ALWQG is an average concentration of 25 µg/L when hardness is ≤60 mg/L and 150 µg/L when hardness is >180 mg/L (ENV 2021b). The guideline values are calculated for hardness levels between 61 mg/L and 180 mg/L. Th ALWQG is currently being updated and will be based on dissolved nickel using a BLM to account for site-specific toxicity-modifying factors such as hardness, DOC, and pH. Using conservative estimates of these factors (e.g., hardness = 20 mg/L, DOC = 5 mg/L, pH = 7) provides a chronic benchmark of 1.5 µg/L.

The Hedley Creek nickel data are summarized in Table 74. Concentrations are consistent at both sites with no exceedances of the WQOs or guidelines. Most results (>90%) were below the MDL of 0.5 µg/L.

Table 74: Summary statistics for nickel (µg/L) in Hedley Creek (2000 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E223873	Total nickel	0.484	<0.050	<1.00	<0.500	195
	Dissolved nickel	0.482	0.086	0.890	<0.500	195
E223874	Total nickel	0.484	<0.050	1.08	<0.500	196
	Dissolved nickel	0.481	0.078	0.970	<0.500	196

10.5.12 Uranium

The WQO for total uranium on Hedley Creek is an average concentration of ≤10 µg/L and a maximum concentration of 100 µg/L. The ALWQG is an average concertation of ≤8.5 µg/L (ENV 2021b) and the SDWQG is a maximum concentration of 20 µg/L (ENV 2020a). The available data are summarized in Table 75. All values we re well below the WQOs and guideline levels.

Table 75: Summary statistics for total uranium (µg/L) by site in Hedley Creek (2001 – 2023). Sites are presented upstream to downstream.

Site	Average	Minimum	Maximum	95th percentile	n
E223873	0.597	0.300	2.79	0.989	196
E223874	0.599	0.311	2.73	0.953	197

10.5.13 Zinc

The WQO for total zinc in Hedley Creek is a 30-day average concentration of ≤10 µg/L and a maximum concentration of 30 µg/L. The current ALWQGs (WLRS 2023d) are based on dissolved zinc and account for the toxicity-modifying influences of water hardness, pH, and DOC. The maximum allowable concentration of zinc to protect drinking water is 3.0 mg/L.

Zinc data for Hedley Creek are summarized in Table 76. Dissolved zinc concentrations were assessed against the ALWQG where the requisite data were available. Where DOC data were missing, monthly average concentrations were used to calculate the guideline level. At E223873, 87% (173/199) of the total zinc results were reported as below the MDL of either 3.0 µg/L or 5.0 µg/L. For dissolved zinc, 46% of results were below the detection limits ranging from 0.1 µg/L to 5.0 µg/L. Most results (95%) were below the corresponding chronic guideline level. At E223874, only one result exceeded the chronic total zinc WQO (17.9 µg/L) and 85% (170/199) of results were below the MDL of 1.0 µg/L. For dissolved zinc, 49% (490/993) of results were below the MDL ranging from 0.1 µg/L to 10.0 µg/L. Compared to the draft ALWQG, 97% (190/195) of dissolved zinc results were below the corresponding guideline level.

Table 76: Summary statistics for zinc (µg/L) in Hedley Creek (2000 – 2021). Sites are presented upstream to downstream.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E223873	Total zinc	3.06	0.300	14.0	3.41	199
	Dissolved zinc	1.92	<0.100	88.0	5.00	604
E223874	Total zinc	3.03	0.250	17.9	3.41	199
	Dissolved zinc	1.71	<0.100	37.0	5.00	993

10.6 Hedley Creek Summary

Except for sulphate and cobalt, there was very little difference in the water quality parameters assessed on Hedley Creek between the upstream and downstream sites. Sulphate was higher downstream of the Nickel Plate Mine discharge, but still within the ALWQG levels. The lower concentrations seen during freshet suggest sulphate may be influenced by groundwater inputs to Hedley Creek. Cobalt concentrations were much higher downstream in Hedley Creek frequently exceeding guideline levels. Like sulphate, there appears to be a strong connection to flow, and cobalt levels may be influenced by groundwater as well.

11. CAHILL CREEK AMBIENT WATER QUALITY

Cahill Creek is a tributary to the Similkameen River, flowing from the northeast downstream of Hedley Creek (Figure 1). Two tributaries join Cahill Creek in its upper reaches, Nickel Plate Mine Creek and Sunset Creek. Water quality objectives were developed for these streams in 1987 (ENV 1987) to address concerns associated with the mining activities of the Nickel Plate Mine, which operated until 1996.

Water quality monitoring data for the period between 2000 and 2023 were used to assess the water quality of Cahill Creek and its tributaries. For consistency, the parameters previously assessed for the Similkameen River mainstem are considered here, in addition to those with WQOs proposed in 1987 (ENV 1987) and others identified more recently as parameters of concern.

Table 77 lists the monitoring sites used in the Cahill Creek assessment with the site locations illustrated in Figure 5.

Table 77: Cahill Creek monitoring sites.

EMS Site ID	Location
E206633	Nickel Plate Mine Creek upstream of Cahill Creek and Sunset Creek
E215954	Sunset Creek upstream of Canty Pit
E206634	Sunset Creek upstream of Cahill Creek
E206635	Cahill Creek upstream of Sunset Creek and Nickel Plate Mine Creek
E206824	Cahill Creek downstream of tailings pond
E206637	Cahill Creek at Highway 3 upstream of culvert

11.1 General Parameters

11.1.1 pH

The pH WQG permits unrestricted change within the range of 6.5 to 9.0 (ENV 2021a). The available pH data for Cahill Creek and its tributaries are summarized in Table 78. pH levels were consistent throughout Cahill Creek with 95th percentile levels ranging from 8.0 to 8.4. No results exceeded the maximum of the acceptable range; however, results were occasionally (0.4% of all results) below the lower end of the range.

Table 78: Summary statistics for pH in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	8.2	7.4	8.5	8.4	479
E215954	7.6	6.4	8.8	8.0	171
E206634	7.9	6.3	8.3	8.2	268
E206635	7.5	6.4	8.3	8.0	228
E206824	7.8	5.9	8.3	8.2	1,041
E206637	7.9	6.1	8.4	8.3	1,018

11.1.2 Temperature

The ALWQG for water temperature in streams with known populations of rainbow trout is a range of 10.0°C – 15.5°C for spawning (late April to July) and 16.0°C – 18.0°C for rearing (summer through fall) (ENV 2001a). There is no temperature WQO for Cahill Creek. Rainbow Trout, Brook Trout and Longnose Dace have been documented in Cahill Creek and the 1987 WQOs specify the protection of aquatic life in lower reaches of Cahill Creek.

Temperature data are summarized in Table 79. Average water temperatures increased from upstream to downstream in Cahill Creek with maximum temperatures of approximately 16°C recorded in July and August at E206637. The seasonal trends in water temperature in Cahill Creek are illustrated in Figure 69. All temperatures were typically below the maximum levels specified in the ALWQGs.

Table 79: Summary statistics for temperature (°C) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	2.7	0.0	14.2	5.9	3,755
E215954	3.2	0.0	14.7	9.2	149
E206634	3.3	0.0	11.3	9.9	180
E206635	2.8	0.0	10.8	9.1	175
E206824	3.2	0.0	14.7	9.6	5,182
E206637	5.1	0.0	16.6	13.3	3,746

11.1.3 Specific Conductivity

Specific conductivity data are summarized in Table 80. The highest concentrations were seen on Nickel Plate Mine Creek (E206633) with an average of 1,318 µS/cm and a 95th percentile concentration of 1,534 µS/cm. Upstream of its confluence with Sunset Creek and Nickel Plate Mine Creek, Cahill Creek conductivity was relatively low with an average of 88 µS/cm and a 95th percentile of 103 µS/cm (E206635). Specific conductivity increased downstream to an average of 379 µS/cm at E206637 before Cahill Creek flows into the Similkameen River, likely reflecting the influence of Nickel Plate Mine Creek and Sunset Creek.

There was no obvious seasonal pattern in the Cahill Creek system and concentrations appear to be stable (Figure 70).

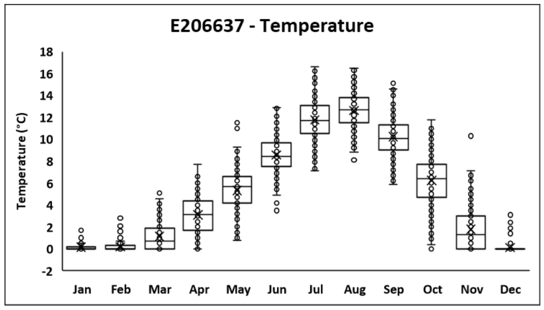

Figure 69: Seasonal variation in water temperature (°C) in Cahill Creek (E206637) (2000-2023).

Table 80: Summary statistics for specific conductivity (µS/cm) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	1,318	949	1,620	1,534	321
E215954	84	49	182	106	170
E206634	285	49	767	601	253
E206635	88	41	319	103	229
E206824	354	128	737	549	1,046
E206637	379	140	726	562	1,028

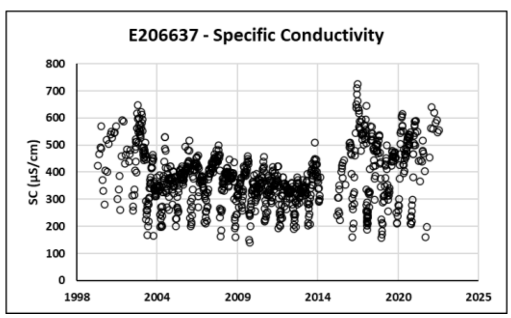

Figure 70: Specific conductivity (µS/cm) over time in Cahill Creek (E206637).

11.1.4 Hardness

Total hardness data were limited and are summarized in Table 81. As expected, results followed the patterns noted for specific conductance with the highest concentrations seen in Nickel Plate Mine Creek (E206633). Concentrations were lower in Sunset Creek and Cahill Creek.

11.1.5 Turbidity

The 1987 WQO for turbidity in Cahill Creek is a maximum increase of 5 NTU when background levels are ≤50 NTU and a maximum increase of 10% when background levels are >50 NTU. For Nickle Plate Creek and Sunset Creek, the WQO is a maximum increase of 10 NTU when background levels are ≤50 NTU and a maximum increase of 20% when background levels are >50 NTU.

Table 81: Summary statistics for total hardness (mg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	712	542	819	800	46
E215954	26	26	26	n/a	1
E206634	205	20	383	356	30
E206635	33	18	43	39	20
E206824	185	75	347	289	112
E206637	192	71	372	292	108

The ALWQG during clear flows is a maximum increase over background of 8 NTU and an average 30-day increase of 2 NTU. When background levels are 8 – 50 NTU, the maximum increase is 5 NTU and when background levels are >50 NTU the maximum increase is 10% of background (ENV 2021c).

The available turbidity data are summarized in Table 82. Turbidity was low in Sunset Creek and levels decreased from upstream (E215954) to downstream (E206634) with average concentrations of 1.1 NTU and 0.7 NTU, respectively. The WQO was always met while the ALWQG was met 96% (154/160) of the time. In Cahill Creek, turbidity increased slightly from upstream to downstream. The average concentration at E206635 was 1.5 NTU with a 95th percentile concentration of 5.6 NTU, increasing to an average of 1.9 NTU and a 95th percentile of 7.1 NTU at E206637. The WQO was met 98% (321/329) of the time at E206637 and the more conservative ALWQG was met 94% (308/329) of the time. Most exceedances occurred during freshet from April to June.

Table 82: Summary statistics for turbidity (NTU) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	0.511	0.060	29.2	1.30	515
E215954	1.06	0.100	17.0	4.10	161
E206634	0.697	0.073	7.94	2.15	259
E206635	1.49	0.170	8.47	5.62	196
E206824	1.37	0.062	17.3	5.04	355
E206637	1.94	0.085	28.1	7.14	343

11.1.6 Total suspended solids

For the lower reaches of Cahill Creek (i.e., from the highway crossing to the Similkameen River) the total suspended solids WQO is a maximum increase over background of 10 mg/L when upstream concentrations are ≤100 mg/L, and a 10% maximum increase when background is >100 mg/L. For the upper reaches (i.e., from the headwaters to the highway crossing), the WQO is a maximum increase over background of 20 mg/L when background is 100 mg/L, and a 20% maximum increase when background is >100 mg/L. This same objective applies to Nickel Plate Mine Creek and Sunset Creek.

The available TSS data are summarized in Table 83. Data are limited for all sites. Average concentrations increased from upstream to downstream on Cahill Creek, however 78% (38/49) of results met the WQO at E206637. Most of the exceedances occurred during May 2018. The concentrations on Sunset Creek above its confluence with Cahill Creek (E206634) were low with an average of 2.98 mg/L and 87% (47/54) of results reported as below the MDL of 3.0 mg/L.

Table 83: Summary statistics for total suspended solids (mg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	4.04	0.800	20.1	8.66	38
E215954	5.16	<3.00	22.6	11.0	18
E206634	2.98	0.200	4.50	3.48	54
E206635	3.81	0.800	20.1	4.91	23
E206824	5.97	<1.00	41.9	20.6	96
E206637	12.7	<1.00	73.2	51.8	58

11.1.7 Total Dissolved Solids

A WQO for total dissolved solids (TDS) for Cahill Creek was set in 1987 because of concerns for the potential increase of TDS concentrations from mining activities. TDS could be increased in Nickel Plate Mine Creek from the waste rock stockpile and by seepage from the tailings impoundment in Cahill Creek. The WQO for TDS is a maximum concentration of 500 mg/L and applies to Nickel Plate Mine Creek and Cahill Creek.

The available TDS data are summarized in Table 84. In Nickel Plate Mine Creek (E206633) the WQO was exceeded in all samples ranging from 692 mg/L to 1,370 mg/L. In Cahill Creek, all results were below the WQO with maximum concentrations of 498 mg/L and 489 mg/L at E206384 and E206637, respectively. In Cahill Creek, TDS concentrations varied seasonally with the lowest concentrations seen during freshet (Figure 71).

Table 84: Summary statistics for total dissolved solids (mg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	1,008	692	1,370	1,116	69
E215954	61	50	78	74	12
E206634	273	56	574	503	66
E206635	82	69	115	97	20
E206824	289	132	498	446	101
E206637	292	136	489	435	98

11.2 Nutrients

11.2.1 Phosphorus

There are no WQOs for phosphorus in Cahill Creek. The available data are summarized in Table 85. Most results at all sites were below the MDLs ranging from 50 µg/L to 300 µg/L. In May 2018, total phosphorus concentrations were above the MDL of 50 µg/L at E206824 (five results ranging from 51 µg/L to 390 µg/L) and E206637 (seven results ranging from 51 µg/L to 108 µg/L) during elevated turbidity levels.

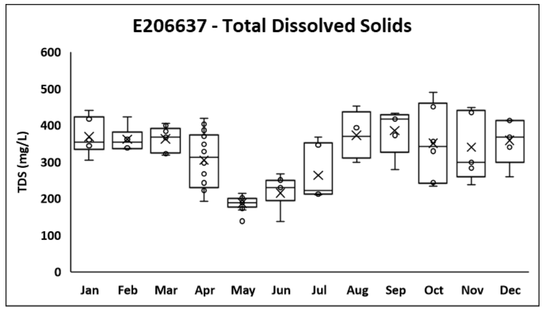

Figure 71: Seasonal trends in total dissolved solids (TDS) concentrations (mg/L) in Cahill Creek (E206637) (2001-2023).

Table 85: Summary statistics for total phosphorus (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	101	<50.0	<300	<300	45
E215954	<50.0	<50.0	<50.0	<50.0	1
E206634	50.6	<50.0	63.0	<50.0	23
E206635	<50.0	<50.0	<50.0	<50.0	10
E206824	84.7	<50.0	390	<300	75
E206637	83.7	5.40	<300	<300	72

11.2.2 Nitrogen

An ammonia WQO was set for the lower reaches of Cahill Creek (E206637) at the ALWQG level (ENV 2021d). The guideline levels are determined by the temperature and pH of the water at the time of sampling. The available ammonia data for Cahill Creek are summarized in Table 86.

Table 86: Summary statistics for ammonia (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	5.39	<5.00	45.4	<5.00	125
E215954	5.39	<5.00	8.70	7.22	12
E206634	6.69	<5.00	67.4	9.92	60
E206635	5.45	<5.00	11.0	7.94	19
E206824	6.74	<5.00	80.4	12.9	157
E206637	5.60	<5.00	45.5	6.68	153

At E206633, 97% (121/125) of results were reported as below the MDL of 5 µg/L. At E206637, 85% (130/153) of results were below the same detection limit. Ammonia ALWQG values decrease with increasing water temperature and pH. Concurrent temperature and pH data were not consistently available; the most stringent ALWQG value, based on a water temperature of 17°C and a pH of 8.8 (the highest reported values) is 174 µg/L. All results were well below this benchmark.

The nitrate WQO for Cahill Creek is a maximum concentration of 10 mg/L (for the protection of drinking water) and in Nickel Plate Mine Creek the WQO is a maximum of 100 mg/L (for the protection of wildlife). There is no WQO for Sunset Creek. The ALWQG for nitrate is a 30-day average concentration of 3.0 mg/L and a maximum concentration of 32.8 mg/L.

The available nitrate data are summarized in Table 87. The highest concentrations were seen in Nickel Plate Mine Creek (E206633) with a 95th percentile concentration of 37.6 mg/L. The 95th percentile concentration in Cahill Creek (E206637) was lower at 2.95 mg/L.

Table 87: Summary statistics for nitrate (mg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	16.9	<0.030	51.7	37.6	4,198
E215954	0.044	<0.005	<0.300	0.117	167
E206634	0.555	<0.005	4.03	1.35	267
E206635	0.054	0.004	0.790	0.120	244
E206824	1.43	0.016	7.60	3.54	5,762
E206637	1.25	<0.030	6.13	2.95	4,201

Nitrate concentrations decreased over time (Figure 72). In Nickel Plate Mine Creek (E206633) the monthly average nitrate concentration decreased from approximately 50 mg/L in 2000 to 2 mg/L in 2023 and in Cahill Creek (E206637) the monthly average decreased from 4 mg/L in 2000 to <1 mg/L in 2023.

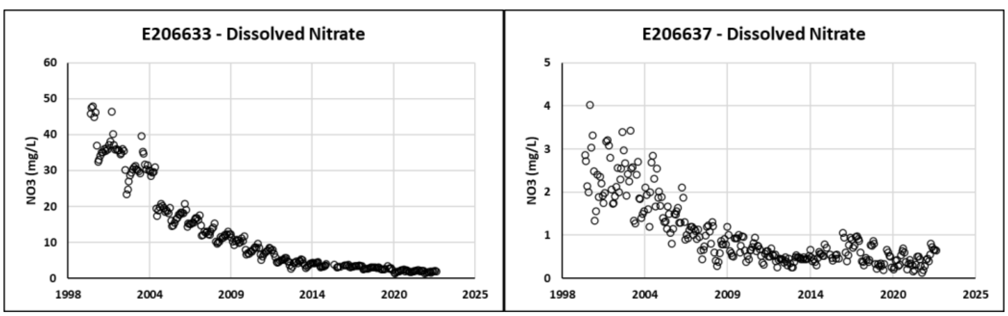

Figure 72: Monthly average dissolved nitrate concentrations (mg/L) over time in Nickel Plate Mine Creek (E206633) and Cahill Creek (E206637). Note the variation in values on the y-axis.

The nitrite WQO for Cahill Creek is an average concentration of 0.02 mg/L and a maximum concentration of 0.06 mg/L downstream of the Highway 3 crossing and a maximum concentration of 1 mg/L upstream of the Highway 3 crossing. In Nickel Plate Mine Creek, the WQO is a maximum of 10 mg/L (for the protection of wildlife). There is no WQO for Sunset Creek. The ALWQG for nitrite is based on site-specific chloride concentrations and ranges from 0.02 mg/L for chloride concentration <2 mg/L to 0.20 mg/L for chloride concentration >10 mg/L.

Most results for both total nitrite and dissolved nitrite were below the MDLs (ranging from <0.001 mg/L to 0.300 mg/L) at all sites. In recent years (2020 to the present) only dissolved nitrite has been measured and results have been below the MDL of 0.001 mg/L or 0.005 mg/L. Where concurrent chloride data were available the nitrite results were compared to the ALWQG levels with all results meeting the guideline.

11.3 Organic Matter

11.3.1 Organic Carbon

Dissolved organic carbon is an important parameter to measure as it is required for determining guideline values for several metals. The limited dissolved organic carbon data for the Cahill Creek system are summarized in Table 88. In Cahill Creek, dissolved organic carbon averaged about 6.5 mg/L with maximum concentrations measured during freshet in April through June (Figure 73). Concentrations were lower upstream in Nickel Plate Mine Creek with an average concentration of 2.30 mg/L at E206633.

Table 88: Summary statistics for dissolved organic carbon (mg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	2.30	1.56	4.94	3.21	47
E215954	4.11	4.11	4.11	n/a	1
E206634	2.55	1.76	4.55	3.88	15
E206635	7.11	4.18	10.5	10.4	5
E206824	6.35	1.13	20.5	12.6	54
E206637	6.49	3.19	22.0	13.1	50

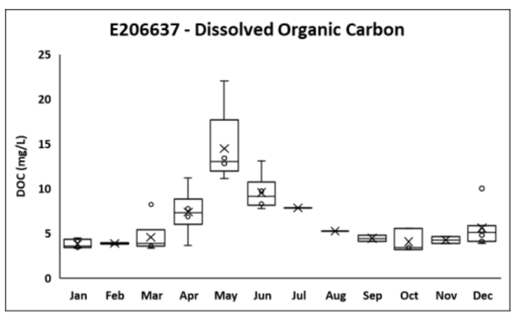

Figure 73: Seasonal trends in dissolved organic carbon concentrations (mg/L) in Cahill Creek (E206637) (2000-2023).

11.4 Major Ions and Other Inorganic Parameters

11.4.1 Sulphate

The WQO for total sulphate in Cahill Creek and Nickel Plate Mine Creek is an average concentration of 50 mg/L and a maximum concentration of 150 mg/L. The ALWQG (ENV 2013) is based on hardness and average values range from 128 mg/L in very soft water (0 mg/L – 30 mg/L $CaCO_3$) to 429 mg/L in very hard water (181 mg/L – 250 mg/L $CaCO_3$). The ALWQG more accurately reflects the current knowledge on sulphate toxicity and is used to assess sulphate levels rather than the 1987 WQO.

The available data are summarized in Table 89. Both total and dissolved sulphate data are presented; total sulphate was reported from 2000 to 2015 and dissolved sulphate was reported from 2016 on.

The highest total sulphate concentrations were measured in Nickel Plate Mine Creek (E206633) with an average of 556 mg/L and a 95th percentile concentration of 623 mg/L. Water hardness exceeded the upper range for the total sulphate ALWQG (250 mg/L $CaCO_3$) so a direct comparison was not possible, however 99% of results exceeded the upper guideline level of 429 mg/L. Sulphate concentrations were consistent over time at E206633 with no obvious increasing or decreasing trend (Figure 74).

Table 89: Summary statistics for sulphate (mg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total sulphate	556	352	740	623	3,795
	Dissolved sulphate	559	402	677	624	192
E215954	Total sulphate	3.19	1.44	5.10	4.16	116
	Dissolved sulphate	3.58	1.50	11.8	5.50	51
E206634	Total sulphate	48.4	7.87	126	98.9	143
	Dissolved sulphate	83.1	2.526	298	231	120
E206635	Total sulphate	9.58	2.06	71.9	12.8	133
	Dissolved sulphate	9.91	3.97	58.0	12.0	73
E206824	Total sulphate	90.3	16.2	244	156	5,267
	Dissolved sulphate	120	22.0	246	207	238
E206637	Total sulphate	96.3	19.8	270	159	3,779
	Dissolved sulphate	129	31.8	242	213	221

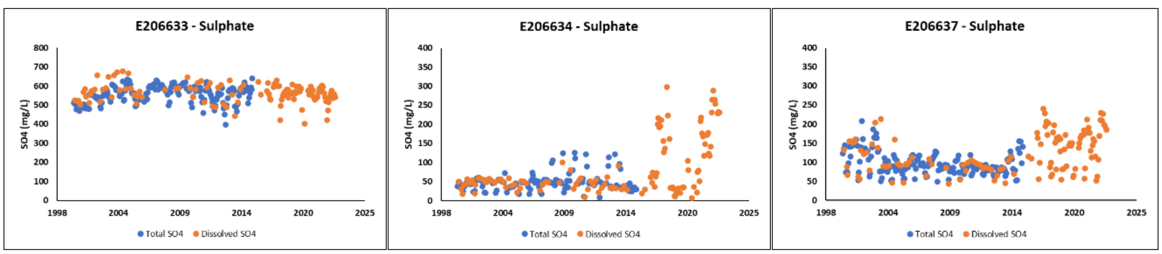

Figure 74: Monthly average sulphate concentrations (mg/L) over time in Nickel Plate Mine Creek (E206633), Sunset Creek (E206634), and Cahill Creek (E206637). Note the variation in values on the y-axis.

On Sunset Creek, total and dissolved sulphate concentrations increased from upstream (E215954) to downstream (E206634) but always met the ALWQGs. Results from recent years suggest an increase in dissolved sulphate concentrations.

Total sulphate concentrations on Cahill Creek also increased upstream (E206635) to downstream (E206637) with average concentrations of 9.58 mg/L and 96.3 mg/L, respectively. Results were within the range of guideline values and consistent over time (Figure 74).

11.4.2 Cyanide

Objectives for cyanide were set in Cahill Creek because of the potential for inputs from the Mascot Gold Mine operation. The WQO for weak acid dissociable cyanide (WAD CN) is an average concentration of ≤5 µg/L and a maximum concentration of 10 µg/L in the lower reaches of Cahill Creek. The WQO for strong acid dissociable cyanide plus thiocyanate (SAD CN + SCN) is a maximum concentration of 20 µg/L throughout Cahill Creek. There is also a WQO for cyanates (maximum concentration of 45 mg/L), but no data were available for this parameter.

In Cahill Creek (E206637) 88% (784/894) of the WAD CN results were below MDLs ranging from 0.5 µg/L to 5 µg/L. The maximum reported concentration was 8.3 µg/L and the 95th percentile concentration was <5 µg/L.

The SAD CN + SCN data were not assessed. There were several sampling dates with two reported results differing by an order of magnitude. This discrepancy could not be reconciled therefore the data were considered unreliable.

11.5 Metals

Water quality objectives for several metals were set in the Cahill Creek watershed to address concerns of seepage from a tailings impoundment and runoff from waste rock piles. These are discussed in the following sections.

11.5.1 Aluminum

A WQO for total aluminum was set in the downstream reaches of Cahill Creek of 300 µg/L (maximum concentration) or a 20% increase over upstream levels, whichever is greater. The ALWQG is based on concurrent measurements of pH, DOC, and water hardness. As the ALWQG (WLRS 2023a) is more recent than the WQOs, it is used to assess total aluminum levels in this review. Dissolved organic carbon data were limited so monthly average concentrations were used where needed for the purpose of calculating a guideline value.

The available aluminum data are summarized in Table 90 with the seasonal trends at the downstream site (E206637) illustrated in Figure 75. Total aluminum concentrations were low in Nickel Plate Mine Creek (E206633) and Sunset Creek (E206634) and met the ALWQGs. Concentrations were much higher in Cahill Creek (E206824, E206637) with the highest concentrations measured during April and May. This was driven by daily measurements from late April to late May in 2018 with concentrations ranging from 573 µg/L to 1,370 µg/L at E206824 and from 479 µg/L to 2,220 µg/L at E206637. The ALWQGs were met 75% and 78% of the time at E206824 and E206637, respectively. The only exceedances occurred during the 2018 April and May sampling period (Figure 76) when changes in water quality resulted from the discharge of untreated tailings seepage water from Nickel Plate Mine to Cahill Creek in response to a major power failure at the treatment facility.

Table 90: Summary statistics for aluminum (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total aluminum	20.5	3.20	197	59.9	45
	Dissolved aluminum	5.48	0.500	200	15.0	122
E215954	Total aluminum	52.1	52.1	52.1	n/a	1
	Dissolved aluminum	11.5	3.00	72.7	18.5	41
E206634	Total aluminum	22.3	6.00	88.1	75.0	23
	Dissolved aluminum	8.55	<1.00	82.2	26.9	118
E206635	Total aluminum	189	25.5	617	562	10
	Dissolved aluminum	113	3.00	535	436	66
E206824	Total aluminum	262	5.70	1,370	836	77
	Dissolved aluminum	33.8	2.60	238	114	179
E206637	Total aluminum	327	5.20	2,220	1,435	74
	Dissolved aluminum	22.3	1.10	200	95.0	149

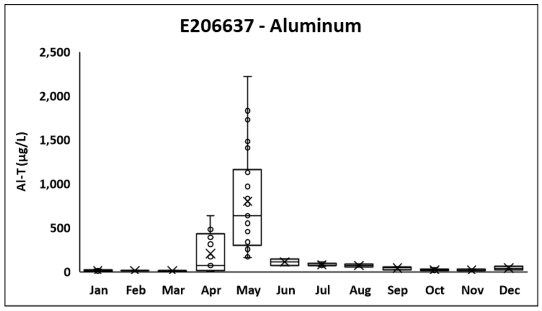

Figure 75: Seasonal variation in total aluminum concentrations (µg/L) in Cahill Creek (E206637) (2000-2023).

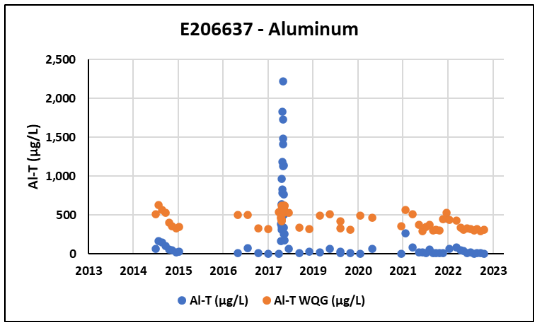

Figure 76: Total aluminum concentrations (µg/L) and water quality guideline values over time in Cahill Creek (E206637).

11.5.2 Arsenic

Water quality objectives were set for arsenic in Cahill Creek and Nickel Plate Mine Creek due to the potential for inputs from mining activities (ENV 1987). The total arsenic WQO for Cahill Creek is a maximum concentration of 50 µg/L. For Nickel Plate Mine Creek, the WQO is a maximum of 500 µg/L. The ALWQG for total arsenic is a maximum concentration of 5 µg/L (ENV 2021f) and the SDWQG is a maximum concentration of 10 µg/L (ENV 2020a). The 1987 arsenic WQOs were based on the WWQGs available at that time. The current WQGs were used in this assessment.

The total arsenic data are summarized in Table 91. Arsenic concentrations were elevated throughout Cahill Creek and its tributaries except in the upstream reaches of Cahill Creek (E206635) where the ALWQG was met on most sampling days. At all other sites the drinking water guideline was frequently exceeded. Arsenic inputs from Nickel Plate Mine Creek and Sunset Creek appear to have increased levels in Cahill Creek downstream of the confluence. The average concentration at the downstream site (E206637) was 14.1 µg/L with a 95th percentile concentration of 18.2 µg/L. The ALWQG was always exceeded while the drinking water guideline was exceeded in 97% (789/817) of results. While concentrations in Cahill Creek increased in the downstream sites the levels have remained consistent over time (Figure 77). No seasonal pattern in total arsenic concentrations was seen in Cahill Creek or its tributaries.

Table 91: Summary statistics for total arsenic (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	14.2	4.03	18.1	16.3	155
E215954	8.31	0.700	56.5	19.8	21
E206634	29.8	20.1	51.3	39.9	74
E206635	1.64	0.400	49.5	2.95	136
E206824	15.4	4.80	30.0	19.5	764
E206637	14.1	10.0	25.9	18.2	817

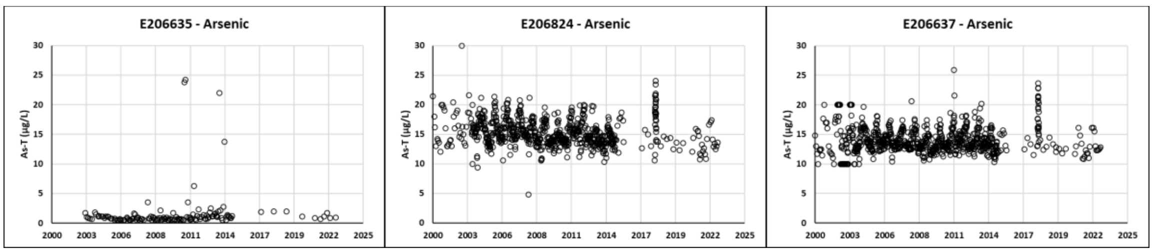

Figure 77: Total arsenic concentrations (µg/L) over time Cahill Creek. Sites are presented upstream to downstream.

11.5.3 Cadmium

The 1987 WQOs for cadmium in Cahill Creek and its tributaries were based on the WWQGs available at that time. For Cahill Creek the WQO downstream of the highway (E206637 and E206638, respectively) is a maximum total cadmium concentration of 0.2 µg/L to protect aquatic life. Upstream, the WQO is a maximum total cadmium concentration of 5 µg/L to protect drinking water, irrigation, and livestock water. In Nickel Plate Mine Creek, the WQO is a maximum concentration of 20 µg/L to protect livestock water. The more recent cadmium ALWQG (ENV 2015) is based on dissolved cadmium and accounts for the ameliorating effects of water hardness. The drinking water guideline is a maximum acceptable concentration of 5 µg/L.

The available cadmium data are summarized in Table 92. At all sites the dissolved cadmium data are dominated by results reported as below the MDL prior to 2016. More recent data (2016 – present) applied MDLs and better reflect current conditions with respect to dissolved cadmium concentrations. All cadmium WQGs and WQOs were met throughout Cahill Creek with no evidence of an increasing trend in concentrations over time.

11.5.4 Chromium

There are no WQOs for chromium in Cahill Creek. The ALWQG is 1 µg/L for hexavalent chromium and 8.9 µg/L for trivalent chromium (ENV 2021b), therefore 1 µg/L provides a conservative benchmark for the assessment of total chromium. The SDWQG is a maximum total chromium concentration of 50 µg/L.

The available total chromium data are summarized in Table 93. Results were typically less than 1 µg/L and often reported as less than the MDL. All results exceeding 1 µg/L occurred during freshet and concurrent measurements of dissolved chromium were very low (e.g., <0.2 µg/L). In the lower reaches of Cahill Creek (E206637) all results >1 µg/L occurred in May of 2018 (see Section 11.5.1).

Table 92: Summary statistics for cadmium (µg/L) in Cahill Creek and tributaries.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633 (2013 – 2023)	Total cadmium	0.098	0.077	0.143	0.119	45
	Dissolved cadmium	0.093	0.073	0.130	0.110	88
E215954 (2015 – 2022)	Total cadmium	0.007	0.007	0.007	n/a	1
	Dissolved cadmium	0.007	<0.005	0.018	0.016	13
E206634 (2015 – 2023)	Total cadmium	0.032	<0.005	0.059	0.053	23
	Dissolved cadmium	0.021	<0.005	0.052	0.043	72
E206635 (2015 – 2023)	Total cadmium	0.008	<0.005	0.016	0.015	10
	Dissolved cadmium	0.006	<0.005	0.014	0.010	20
E206824 (2015 – 2023)	Total cadmium	0.038	0.007	0.643	0.088	75
	Dissolved cadmium	0.017	<0.005	0.039	0.027	111
E206637 (2015 – 2023)	Total cadmium	0.026	<0.005	0.107	0.084	69
	Dissolved cadmium	0.012	<0.005	0.027	0.022	105

Table 93: Summary statistics for total chromium (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	0.446	0.190	<1.00	0.590	45
E215954	<0.500	<0.500	<0.500	n/a	1
E206634	0.473	0.160	0.510	<0.500	23
E206635	0.411	0.110	<0.500	<0.500	10
E206824	0.553	<0.100	9.75	0.978	76
E206637	0.473	<0.100	2.03	1.18	73

11.5.5 Cobalt

There is no WQO for cobalt in Cahill Creek or its tributaries. The current ALWQG (ENV 2004) will be replaced with the federal freshwater WQG (EC 2017) with an uncertainty factor of 3 to account for the limitations of the data set (e.g., data for only one salmonid). This ALWQG is based on water hardness and limited to a hardness range of 52 mg/L to 396 mg/L. The guideline value is determined from the following equation:

$$ALWQG = (\exp^{\{(0.414 \times [\ln(hardness)]) - 1.887\}})/3$$

The SDWQG for cobalt is a maximum allowable concentration of 1 µg/L.

The available cobalt data are summarized in Table 94. In Nickel Plate Mine Creek (E206633) cobalt concentrations were high and exceeded the proposed ALWQG. Dissolved cobalt concentrations peaked in 1995 at 183 µg/L then decreased over time and have typically been <5 µg/L in recent years (Figure 78). On a seasonal basis, concentrations were lowest in May and June during freshet suggesting inputs from groundwater. Concurrent hardness measurements were all above the upper range for the ALWQG (i.e., 396 mg/L) and all cobalt results exceeded the corresponding ALWQG value of 0.6 µg/L.

Table 94: Summary statistics for cobalt (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total cobalt	4.10	0.800	7.91	7.23	47
	Dissolved cobalt	13.8	0.700	70.0	50.0	326
E215954	Total cobalt	<0.100	<0.100	<0.100	n/a	1
	Dissolved cobalt	6.33	<0.100	70.0	20.0	171
E206634	Total cobalt	1.10	<0.100	2.04	1.97	25
	Dissolved cobalt	4.39	0.064	60.0	10.0	261
E206635	Total cobalt	0.138	<0.100	0.26	0.245	11
	Dissolved cobalt	4.31	0.074	44.0	10.0	201
E206824	Total cobalt	2.40	0.280	10.7	7.16	78
	Dissolved cobalt	8.87	<0.100	71.3	25.0	863
E206637	Total cobalt	5.31	0.580	19.7	15.6	74
	Dissolved cobalt	11.9	<0.100	71.8	33.8	845

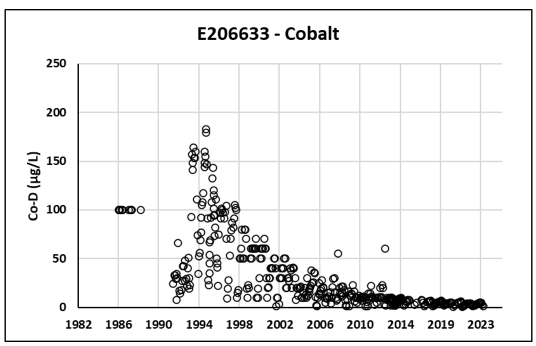

Figure 78: Dissolved cobalt concentrations (µg/L) over time in Nickel Plate Mine Creek.

At the upstream site on Sunset Creek (E215954), dissolved cobalt concentrations were highest in 2012 at 70 µg/L but have been below the MDL of 0.1 µg/L since August 2015. At E206634, dissolved cobalt concentrations peaked in June 2013 at 60 µg/L and have been lower since 2015 when lower MDLs were used (Figure 79). On a seasonal basis, concentrations were lowest during freshet. Where concurrent hardness concentrations were available, 56% of dissolved cobalt results (41/73) met the ALWQG.

Upstream in Cahill Creek at E206635, dissolved cobalt and total cobalt averaged 4.31 µg/L and 0.138 µg/L, respectively (2000 – 2023). Dissolved cobalt concentrations were greatest in 2008 but have subsequently decreased and since 2015 and are typically reported as less than the MDL of 0.1 µg/L (Figure 80). Downstream at E206824, average dissolved and total cobalt concentrations increased to 8.87 µg/L and 2.40 µg/L, respectively. Dissolved cobalt concentrations were lower overall from 2015 on, however 94% of results (109/116) exceeded the WQG value where concurrent hardness data were available. Cobalt concentrations increased further at E206637 with an average dissolved cobalt concentration of 11.9 µg/L and an average total concentration of 5.31 µg/L. All results with concurrent hardness measurements (2015 – present) exceeded the proposed ALWQG. Dissolved cobalt concentrations peaked at 71.8 µg/L in January 2008 and have decreased since that time. Seasonal trends are best illustrated in data collected since 2015 with concentrations peaking in April followed by a sharp decrease in May presumably from dilution with freshet. Concentrations gradually increased throughout the remainder of the year peaking again prior to freshet (Figure 81).

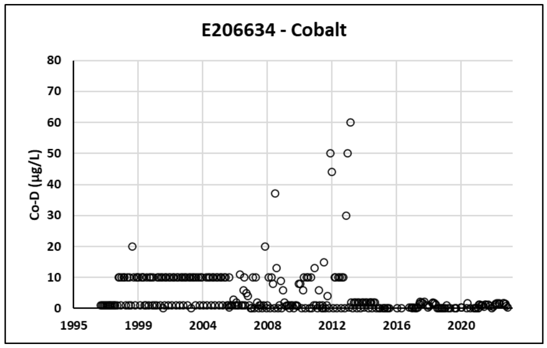

Figure 79: Dissolved cobalt concentrations (µg/L) over time in Sunset Creek.

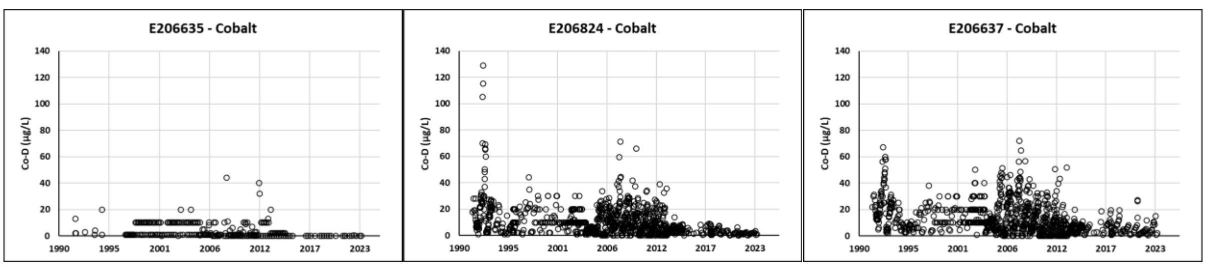

Figure 80: Dissolved cobalt concentrations (µg/L) over time in Cahill Creek. Sites are presented from upstream (E206635) to downstream (E206637).

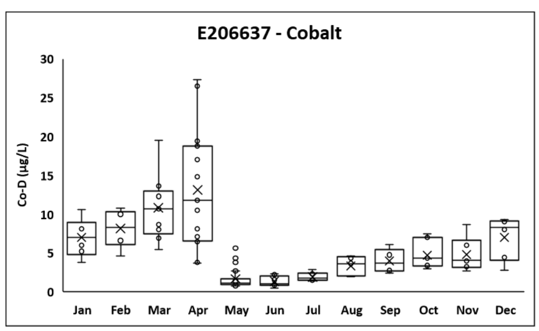

Figure 81: Seasonal trends in dissolved cobalt concentrations (µg/L) in Cahill Creek (2000-2023).

11.5.6 Copper

The 1987 WQO for copper in Cahill Creek is an average total copper concentration of ≤5 µg/L and a maximum total copper concentration of 7 µg/L in the downstream reaches (E206637). In the upstream reaches the WQO is a maximum total copper concentration of 200 µg/L. The total copper WQO in Nickel Plate Mine Creek is a maximum concentration of 300 µg/L. The ALWQG (ENV 2019a) is based on dissolved copper and determined by concurrent measurements of toxicity-modifying constituents (e.g., pH, DOC, water hardness). The irrigation WQG is a maximum total copper concentration of 200 µg/L, the wildlife/livestock water WQG is an average total copper concentration of 200 µg/L (ENV 2019a), and the SDWQG is a maximum acceptable total copper concentration of 2 mg/L to protect human health and 1 mg/L to protect the aesthetic quality (ENV 2020a).

The available copper data are summarized in Table 95. The data were skewed from the higher MDLs used prior to 2015, therefore the assessment is based on data collected between 2015 and 2023. Site-specific DOC and water hardness data were limited, and monthly average concentrations were used to calculate ALWQG values where data for dependent parameters were not available.

Table 95: Summary statistics for copper (µg/L) in Cahill Creek and tributaries (2015 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total copper	0.946	<0.500	2.57	2.17	44
	Dissolved copper	0.658	0.430	2.04	0.964	77
E215954	Total copper	<0.500	<0.500	<0.500	n/a	1
	Dissolved copper	0.352	<0.200	1.00	0.742	12
E206634	Total copper	0.755	0.500	1.55	1.07	24
	Dissolved copper	0.674	0.370	1.89	1.14	75
E206635	Total copper	2.27	1.03	3.94	3.90	10
	Dissolved copper	1.87	0.910	3.66	3.16	23
E206824	Total copper	2.58	0.640	7.48	6.23	75
	Dissolved copper	1.63	0.610	3.83	3.41	113
E206637	Total copper	2.76	0.660	858	6.97	70
	Dissolved copper	1.61	0.530	4.06	3.53	106

Dissolved copper concentrations in Nickel Plate Mine Creek (E206633) averaged 0.658 µg/L with values consistently below the corresponding ALWQG level.

On Sunset Creek, average dissolved copper concentrations increased from upstream (E215954) to downstream (E206634) at 0.352 µg/L to 0.674 µg/L, respectively. Concentrations peaked during freshet but were typically <1 µg/L throughout the remainder of the year (Figure 82). The ALWQG was met in 89% (67/75) of results. Exceedances occurred when the corresponding pH value was well below the site average of 7.9.

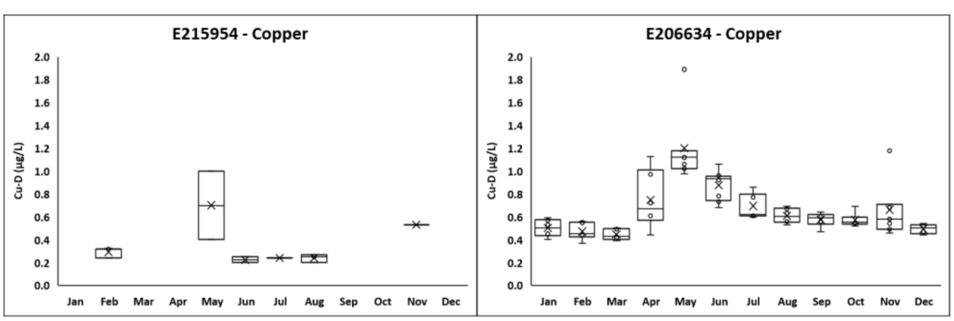

Figure 82: Seasonal trends in dissolved copper concentrations (µg/L) in Sunset Creek (2015-2023). Sites are presented upstream (E215954) to downstream (E206634).

Average dissolved copper concentrations decreased in Cahill Creek from upstream (1.87 µg/L at E206635) to downstream (1.63 µg/L and 1.61 µg/L at E206824 and E206637, respectively). Seasonal trends are illustrated in Figure 83 and show concentrations peaking during freshet in May and June. The ALWQG was met 99% of the time at both downstream sites (113/114 and 105/106).

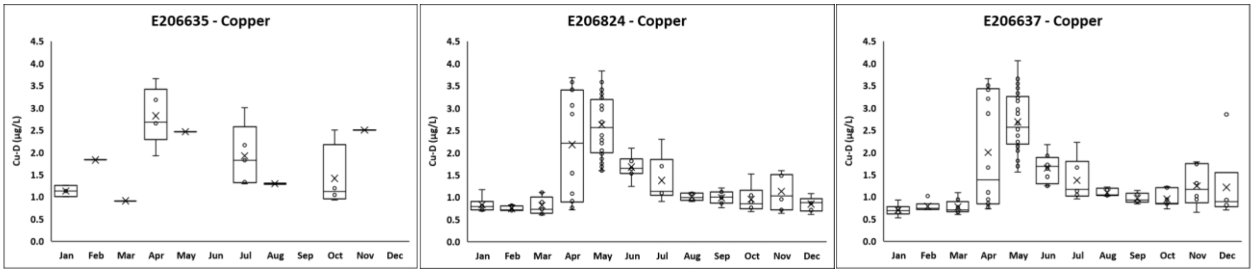

Figure 83: Seasonal trends in dissolved copper concentrations (µg/L) in Cahill Creek (2015-2023). Sites are presented upstream (E206635) to downstream (E206637).

11.5.7 Iron

The WQO for iron in Cahill Creek and Nickel Plate Mine Creek is a maximum dissolved iron concentration of 0.3 mg/L. The ALWQG is a maximum total iron concentration of 1 mg/L and a maximum dissolved iron concentration of 0.35 mg/L (ENV 2008). The SDWQG is a maximum total iron concentration of 0.3 mg/L.

The available iron data are summarized in Table 96. All results in Nickel Plate Mine Creek (E206633) and Sunset Creek (E215954, E206634) were below the most conservative guideline value of 0.3 mg/L.

Table 96: Summary statistics for iron (mg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total iron	0.026	<0.010	0.183	0.124	45
	Dissolved iron	0.013	<0.001	0.070	0.030	213
E215954	Total iron	0.035	0.035	0.035	n/a	1
	Dissolved iron	0.029	0.006	0.259	0.049	47
E206634	Total iron	0.026	<0.010	0.139	0.077	23
	Dissolved iron	0.019	0.002	0.109	0.030	131
E206635	Total iron	0.158	0.021	0.488	0.451	10
	Dissolved iron	0.067	<0.001	0.490	0.260	179
E206824	Total iron	0.242	<0.010	1.39	0.807	76
	Dissolved iron	0.025	<0.001	0.260	0.100	840
E206637	Total iron	0.306	<0.010	2.13	1.36	73
	Dissolved iron	0.020	<0.001	0.234	0.076	795

In the upstream reach of Cahill Creek (E206635) the dissolved iron ALWQG was met in 99% (174/179) of results and the total iron ALWQG was met 100%. The SDWQG was met in 80% (8/10) of results with exceedances (maximum of 0.488 mg/L) occurring in April. For dissolved iron, 96% (171/179) of results were <0.3 mg/L with higher values measured during the freshet months. At E206384, dissolved iron concentrations were always below the guideline levels for all water uses. Total iron met the ALWQG in 96% (73/76) of results and the SDWQG in 68% (52/76) of results. All exceedances occurred in April and May of 2018 when daily concentrations were reported between April 25 and May 25. Downstream at E206637, the dissolved iron ALWQG was always met. The total iron SDWQG was met in 70% (51/73) of results and the ALWQG was met in 89% (65/73) of results. All exceedances occurred in April and May of 2018.

11.5.8 Lead

The 1987 WQO for total lead in the downstream reaches of Cahill Creek is an average concentration of ≤5 µg/L and a maximum concentration of 15 mg/L. In the upstream reaches the WQO is a maximum concentration of 50 µg/L to protect drinking water sources. In Nickel Plate Mine Creek, the WQO is a maximum concentration of 100 µg/L. The ALWQG for total lead is hardness-based and determined from concurrent measurements of water hardness. The drinking water guideline is a maximum allowable concentration of 5 µg/L. The WQG to protect livestock water and wildlife is a maximum concentration of 100 µg/L (ENV 2021g).

The available total lead data are summarized in Table 97. Total lead data were only available from 2015 on and were typically well below guideline levels and often below MDLs at all sites. One result exceeded the drinking water guideline: 5.80 µg/L measured on May 9, 2018, at E206824. This result should be viewed with caution as the reported concentration on the previous day was 0.517 µg/L and 1.20 µg/L on the following day.

Table 97: Summary statistics for total lead (µg/L) in Cahill Creek and tributaries (2015 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E206633	0.058	<0.050	0.147	0.118	45
E215954	<0.050	<0.050	<0.050	n/a	1
E206634	0.052	<0.050	0.086	0.052	23
E206635	0.074	<0.050	0.141	0.139	10
E206824	0.235	<0.050	5.80	0.603	77
E206637	0.174	0.015	1.05	0.718	71

11.5.9 Mercury

The WQOs for total mercury in Cahill Creek is a maximum concentration of 0.1 µg/L in the downstream reaches and a maximum concentration of 1 µg/L in the upstream reaches. In Nickel Plate Mine Creek, the WQO is a maximum total mercury concentration of 3 µg/L. The ALWQG (ENV 2001c) is determined using the ratio of methylmercury to total mercury; methylmercury data are not available. The source drinking water guideline for mercury is 1.0 µg/L.

The available mercury data are summarized in Table 98. Both total and dissolved mercury concentrations were low at all sites. The more recent results were typically below the MDL of 0.005 µg/L.

11.5.10 Molybdenum

The WQO for total molybdenum in Cahill Creek is an average concentration of ≤10 µg/L and a maximum concentration of 50 µg/L from May to September. In Nickel Plate Mine Creek, the WQO is a maximum concentration of 50 µg/L. The B.C. ALWQG has since been updated (ENV 2021h) and is now an average of

7.6 mg/L. Other uses have lower guideline values (e.g., ruminant livestock: 16 µg/L; ruminant wildlife: 34 µg/L; drinking water: 88 µg/L) and were used in this assessment.

Table 98: Summary statistics for mercury (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total mercury	0.006	<0.005	0.017	0.011	18
	Dissolved mercury	0.019	<0.005	<0.050	<0.050	41
E215954	Total mercury	–	–	–	–	–
	Dissolved mercury	0.018	<0.005	<0.050	<0.050	35
E206634	Total mercury	<0.005	<0.005	<0.005	n/a	1
	Dissolved mercury	0.020	<0.005	<0.050	<0.050	36
E206635	Total mercury	<0.005	<0.005	<0.005	<0.005	2
	Dissolved mercury	0.019	<0.005	<0.050	<0.050	38
E206824	Total mercury	0.006	<0.005	0.017	0.016	17
	Dissolved mercury	0.026	<0.005	<0.050	<0.050	63
E206637	Total mercury	0.005	<0.005	0.011	0.005	17
	Dissolved mercury	0.005	<0.005	<0.050	<0.050	39

The available total molybdenum data are summarized in Table 99. Total molybdenum consisted mostly of dissolved molybdenum, therefore both fractions are used in this assessment. Molybdenum concentrations were consistently below the most conservative benchmark of 16 µg/L. At Nickel Plate Mine Creek (E206633) concentrations exceeded this level on a few occasions but were typically lower. Concentrations peaked in June during freshet and appear to be increasing over time (Figure 84).

Table 99: Summary statistics for molybdenum (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total molybdenum	8.60	5.32	16.1	12.9	45
	Dissolved molybdenum	7.08	1.40	17.5	12.7	120
E215954	Total molybdenum	0.605	0.605	0.605	n/a	1
	Dissolved molybdenum	0.769	0.370	4.27	<1.00	41
E206634	Total molybdenum	5.44	0.724	8.80	8.08	21
	Dissolved molybdenum	4.69	0.468	10.4	7.49	117
E206635	Total molybdenum	0.506	0.353	0.711	0.681	10
	Dissolved molybdenum	0.469	0.316	3.04	0.587	58
E206824	Total molybdenum	3.80	1.58	6.28	5.36	78
	Dissolved molybdenum	3.01	1.00	6.15	5.00	176
E206637	Total molybdenum	3.48	1.55	5.47	4.85	72
	Dissolved molybdenum	2.99	1.44	5.24	4.58	146

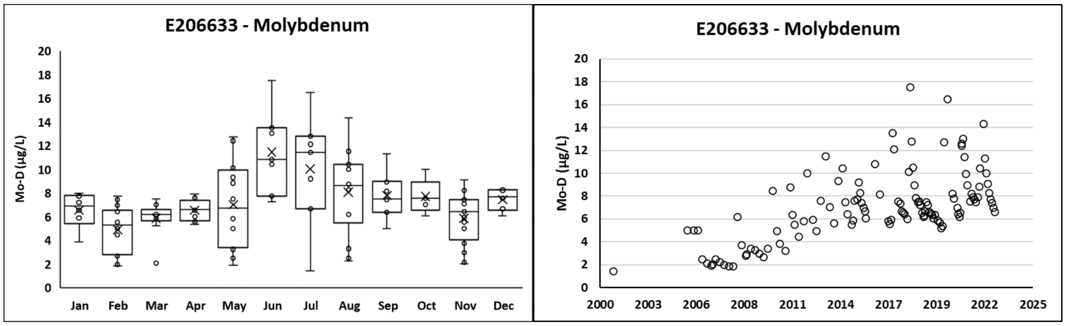

Figure 84: Dissolved molybdenum concentrations (µg/L) in Nickel Plate Mine Creek (2000-2023). Seasonal trends are illustrated in the left panel and concentrations over time are illustrated in the right panel.

On Sunset Creek, dissolved molybdenum concentrations increased from upstream to downstream with average concentrations of 0.769 µg/L and 4.69 µg/L at sites E215954 and E206634, respectively. At the downstream site, dissolved molybdenum concentrations were consistent both seasonally and temporally (Figure 85) and below all guideline values.

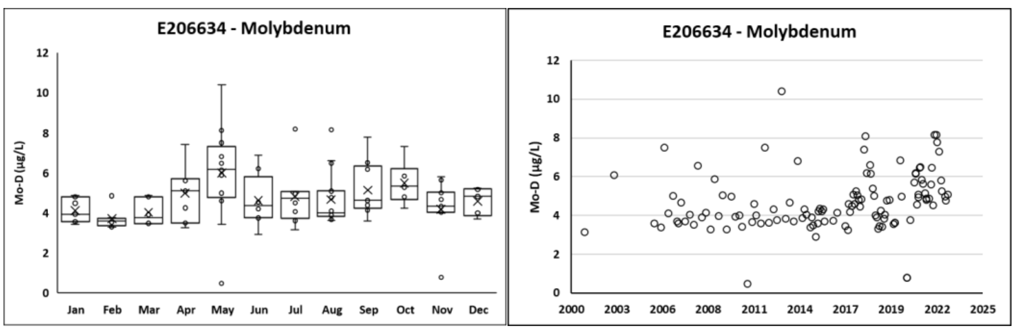

Figure 85: Dissolved molybdenum concentrations (µg/L) in Sunset Creek. Seasonal trends are illustrated in the left panel and concentrations over time are illustrated in the right panel.

Dissolved molybdenum concentrations were much lower on Cahill Creek but increased from upstream to downstream averaging 0.469 µg/L and 2.99 µg/L at E206635 and E206637, respectively. Concentrations were consistent on a seasonal basis but appear to be increasing over time while remaining well below guideline levels (Figure 86). The cause of the increase over time has not been determined.

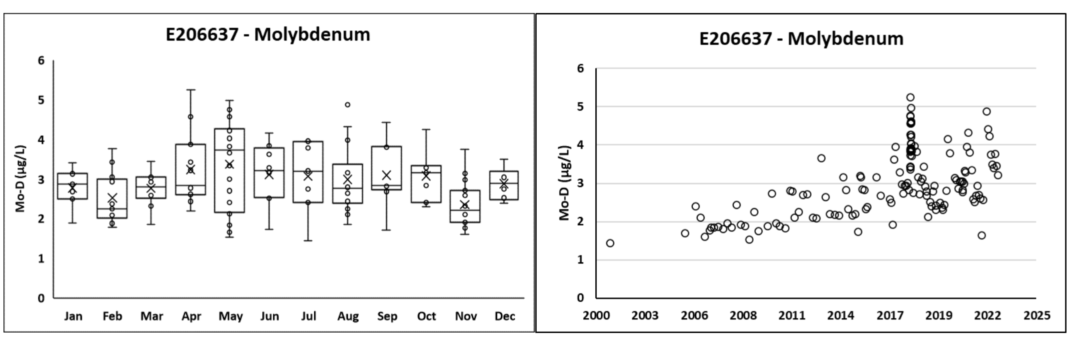

Figure 86: Dissolved molybdenum concentrations (µg/L) in Cahill Creek. Seasonal trends are illustrated in the left panel and concentrations over time are illustrated in the right panel.

11.5.11 Selenium

The WQO for total selenium in Cahill Creek is a maximum concentration of 1 µg/L in the downstream reaches and a maximum concentration of 10 µg/L in the upstream reaches. In Nickel Plate Mine Creek, the WQO is a maximum total selenium concentration of 50 µg/L. The ALWQG (ENV 2014) is an average concentration of ≤2 µg/L and an alert level of 1 µg/L. The source drinking water guideline for selenium is 10 µg/L.

The available selenium data are summarized in Table 100. Total selenium data were limited for most sites therefore dissolved selenium data are included in this assessment. High selenium levels were previously reported for Nickel Plate Mine Creek, Sunset Creek, and Cahill Creek (ENV 1987). In Nickel Plate Mine Creek (E206633) both total and dissolved selenium concentrations were high and well above the drinking water guideline of 10 µg/L. Dissolved and total selenium concentrations averaged 17.8 µg/L and 18.4 µg/L, respectively, with no apparent seasonal trend or change in concentration over time in dissolved selenium (Figure 87).

Table 100: Summary statistics for selenium (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total selenium	18.4	14.0	26.8	24.5	45
	Dissolved selenium	17.8	9.00	38.9	24.2	188
E215954	Total selenium	0.139	0.139	0.139	n/a	1
	Dissolved selenium	0.179	0.103	0.608	0.349	13
E206634	Total selenium	5.89	0.123	10.3	9.52	23
	Dissolved selenium	3.56	0.076	9.86	8.42	72
E206635	Total selenium	0.178	0.092	0.328	0.314	10
	Dissolved selenium	0.157	0.072	0.332	0.271	20
E206824	Total selenium	3.46	1.35	7.89	6.19	77
	Dissolved selenium	2.92	0.400	7.66	5.36	325
E206637	Total selenium	3.20	1.28	6.69	5.81	72
	Dissolved selenium	2.86	<0.200	6.35	5.13	214

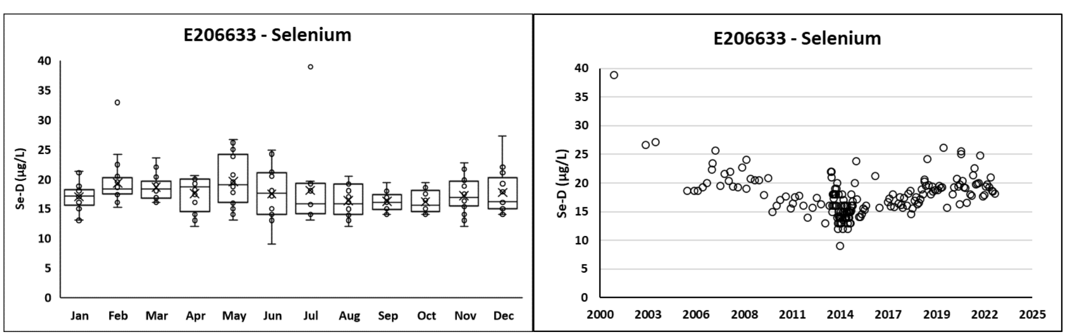

Figure 87: Dissolved selenium concentrations (µg/L) in Nickel Plate Mine Creek. Seasonal trends are illustrated in the left panel and concentrations over time are illustrated in the right panel.

Dissolved selenium concentrations were very low in Sunset Creek at E215954 averaging 0.179 µg/L with a 95th percentile concentration of 0.349 µg/L. Data prior to August 2015 were dominated by results below MDLs and were not included in the summary. Downstream at E206634, average concentrations increased substantially averaging 3.56 µg/L and 5.89 µg/L for dissolved and total selenium, respectively. Various trends in dissolved selenium concentrations at E206634 are illustrated in Figure 88. Concentrations were lower during freshet (May to July) and the strong relationship between dissolved selenium and specific conductance suggests inputs from groundwater sources. Selenium concentrations have increased over time with the highest measurements recorded in recent years.

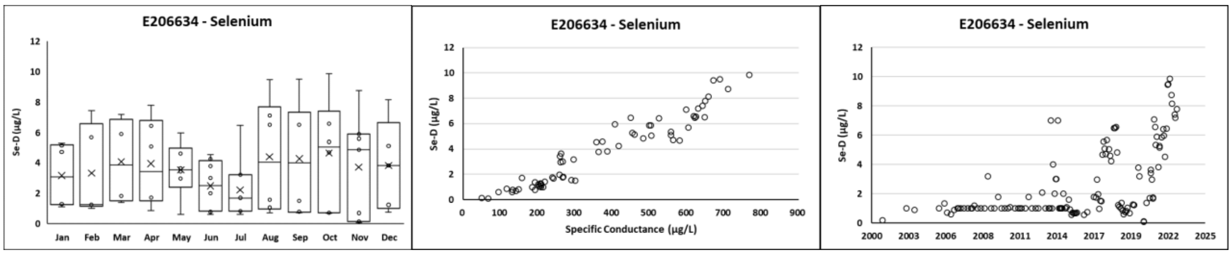

Figure 88: Dissolved selenium concentrations (µg/L) in Sunset Creek. Seasonal trends are illustrated in the left panel, dissolved selenium as a function of conductivity is illustrated in the center panel, and concentrations over time are illustrated in the right panel.

Background selenium concentrations in Cahill Creek (E206635) were low and below guideline levels. Dissolved selenium averaged 0.157 µg/L and total selenium averaged 0.178 µg/L, based on results reported after August 2015. Concentrations for both fractions increased downstream at E206824 and E206637 with average dissolved selenium concentrations of 2.92 µg/L and 2.86 µg/L, respectively. The data show that most of the total selenium is in the dissolved fraction. There was no clear seasonal pattern at these downstream sites, but results suggest concentrations have increased in recent years (Figure 89). As was the case with Sunset Creek, selenium concentrations in the downstream sites of Cahill Creek appear to be strongly influenced by groundwater inputs as demonstrated by the correlation with specific conductivity (Figure 90).

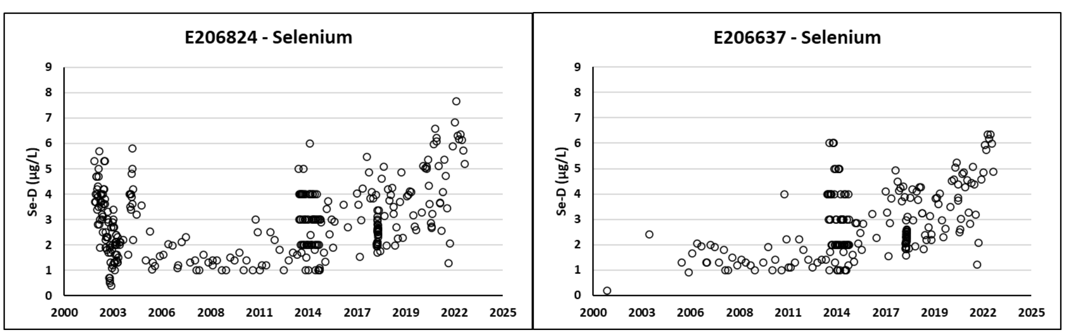

Figure 89: Dissolved selenium concentrations (µg/L) in Cahill Creek over time. Sites are presented upstream (E206824) to downstream (E206637).

11.5.12 Silver

The WQO for total silver in the downstream reaches of Cahill Creek is a maximum concentration of 0.1 µg/L and a maximum concentration of 50 µg/L in the upstream reaches. In Nickel Plate Mine Creek, the WQO is a maximum total silver concentration of 50 µg/L. The ALWQG (WLAP 1996) is an average total silver concentration of ≤0.05 µg/L when water hardness is ≤100 mg/L and 1.5 µg/L when hardness is >100 mg/L. The CCME ALWQG (CCME 2015) for long-term exposure is 0.25 µg/L; this updated WQG will be adopted by B.C. likely with an uncertainty factor of 2 for a final ALWQG value of 0.125 µg/L.

The available silver data are summarized in Table 101. Values were low at all sites and met the proposed ALWQGs or were below MDLs.

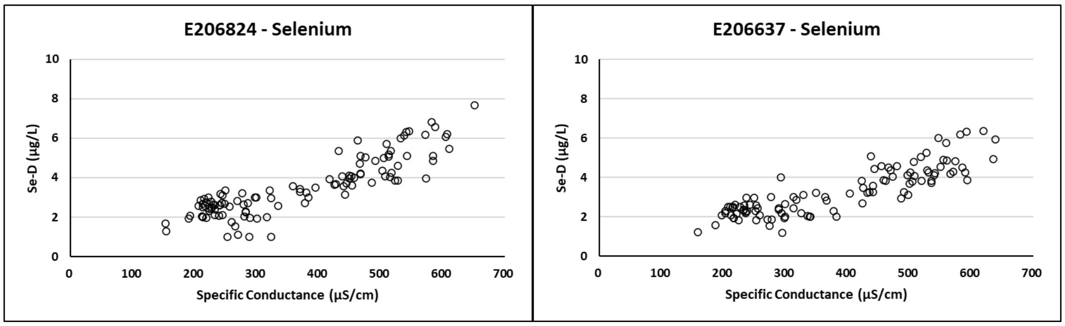

Figure 90: Dissolved selenium concentrations (µg/L) as a function of specific conductance (µS/cm) in Cahill Creek Sites are presented upstream (E206824) to downstream (E206637).

Table 101: Summary statistics for silver (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total silver	0.012	<0.010	0.069	<0.010	45
	Dissolved silver	<0.010	<0.010	<0.010	<0.010	78
E215954	Total silver	<0.010	<0.010	<0.010	n/a	1
	Dissolved silver	0.019	<0.010	<0.100	<0.100	41
E206634	Total silver	<0.010	<0.010	<0.010	<0.010	23
	Dissolved silver	0.017	<0.010	<0.500	0.012	117
E206635	Total silver	0.018	<0.010	0.033	0.033	10
	Dissolved silver	0.019	<0.010	<0.100	0.092	64
E206824	Total silver	0.020	<0.010	0.093	0.045	75
	Dissolved silver	0.021	<0.010	<0.100	<0.100	168
E206637	Total silver	0.018	<0.005	0.054	0.048	70
	Dissolved silver	0.013	<0.005	<0.100	0.017	145

11.5.13 Uranium

There are no WQOs for uranium in Cahill Creek. The WWQGs for total uranium are 8.5 µg/L for the protection of freshwater aquatic life, 10 µg/L for irrigation, 200 µg/L for livestock watering, and 20 µg/L for drinking water (ENV 2021b).

The available uranium data are summarized in Table 102. Uranium levels were below guideline levels in Nickel Plate Mine Creek averaging about 2.3 µg/L for both the total and dissolved fractions. Concentrations were consistent over time and the data did not suggest a seasonal pattern.

Table 102: Summary statistics for uranium (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total uranium	2.33	1.69	2.75	2.63	45
	Dissolved uranium	2.30	1.60	2.79	2.63	79
E215954	Total uranium	0.050	0.050	0.050	n/a	1
	Dissolved uranium	0.073	0.031	0.305	0.219	13
E206634	Total uranium	1.00	0.425	1.56	1.48	23
	Dissolved uranium	0.711	0.144	1.49	1.37	76
E206635	Total uranium	0.061	0.030	0.108	0.095	10
	Dissolved uranium	0.051	0.025	0.091	0.090	23
E206824	Total uranium	0.695	0.223	2.06	1.31	78
	Dissolved uranium	0.674	0.187	1.53	1.26	114
E206637	Total uranium	0.803	0.213	2.21	1.74	72
	Dissolved uranium	0.826	0.177	2.11	1.79	108

On Sunset Creek, dissolved uranium concentrations increased from upstream to downstream but were well below guideline levels. Concentrations were lowest during freshet and appear to be consistent over time (Figure 91).

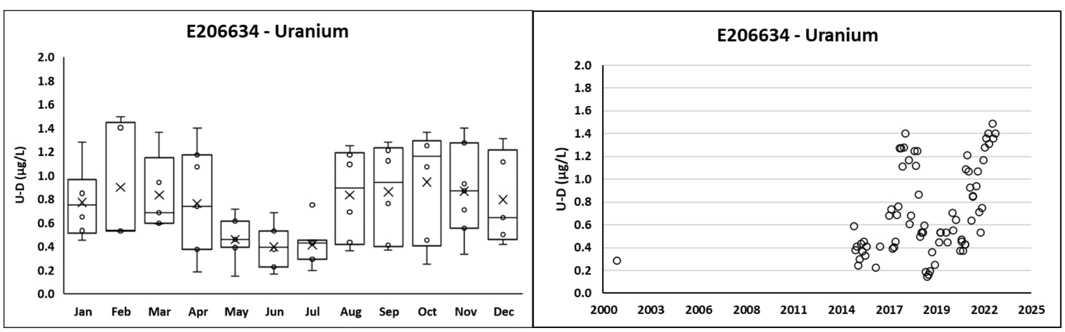

Figure 91: Dissolved uranium concentrations (µg/L) in Sunset Creek. Seasonal trends are illustrated in the left panel and concentrations over time are illustrated in the right panel.

On Cahill Creek, total uranium consisted mostly of the dissolved fraction. Dissolved uranium concentrations increased from upstream (E206635) to downstream (E206637) averaging 0.051 µg/L and 0.826 µg/L, respectively. Concentrations for both total and dissolved uranium were consistent over time, however there was a strong seasonal pattern with the lowest concentrations occurring during freshet (Figure 92). The influence of groundwater inputs is evident in the relationship between dissolved uranium and specific conductance (Figure 92).

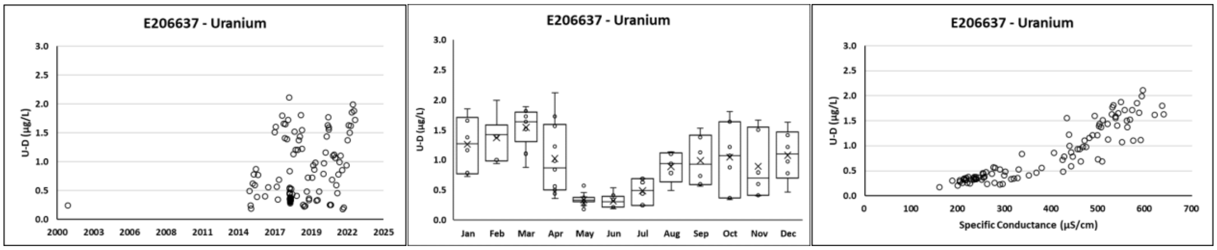

Figure 92: Dissolved uranium concentrations (µg/L) in Cahill Creek. Concentrations over time are illustrated in the left panel, seasonal trends are illustrated in the centre panel, and dissolved uranium as a function of conductivity is illustrated in the right panel.

11.5.14 Zinc

The WQO for total zinc in Cahill Creek and Nickel Plate Mine Creek is a maximum concentration of 50 µg/L. The zinc ALWQG (WLRS 2023d) is based on dissolved zinc and derived from site-specific hardness, pH, and DOC levels. The maximum allowable concentration of zinc to protect drinking water is 3.0 mg/L (ENV 2020a).

The available zinc data are summarized in Table 103. Average dissolved zinc concentrations were consistent throughout Cahill Creek ranging from 2.36 µg/L at E206824 to 3.18 µg/L at E206635. Concentrations were similar in Nickel Plate Mine Creek and Sunset Creek at 3.09 µg/L (E206633) and 2.95 µg/L (E206634), respectively.

The majority (60%; 1,598/2,644) of dissolved zinc results were below the MDL which ranged from 0.100 µg/L to 15.0 µg/L. As such, there was no obvious seasonal trend for dissolved zinc. Additionally, it is difficult to assess dissolved zinc concentrations against the updated WQG because concurrent measurements of water hardness, pH, and DOC were not available for most sampling dates. Where data were available, the reported concentrations were well below the WQG levels.

Table 103: Summary statistics for zinc (µg/L) in Cahill Creek and tributaries (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E206633	Total zinc	3.07	<3.00	<6.00	<3.00	45
	Dissolved zinc	3.09	<0.100	<15.0	<10.0	316
E215954	Total zinc	<3.00	<3.00	<3.00	n/a	1
	Dissolved zinc	3.95	<0.500	11.6	<10.0	172
E206634	Total zinc	<3.00	<3.00	<3.00	<3.00	23
	Dissolved zinc	2.95	<0.500	<15.0	<10.0	261
E206635	Total zinc	<3.00	<3.00	<3.00	<3.00	10
	Dissolved zinc	3.18	<0.100	<15.0	<10.0	203
E206824	Total zinc	4.35	1.14	55.7	7.78	76
	Dissolved zinc	2.36	<0.200	23.0	<10.0	861
E206637	Total zinc	3.70	0.320	<15.0	7.37	72
	Dissolved zinc	2.45	0.200	18.0	<10.0	830

11.6 Cahill Creek Summary

WQOs were developed in 1987 to address concerns of potential impacts to water quality from mining activities related to the Nickel Plate Mine.

Specific conductance and water hardness were high in Nickel Plate Mine Creek and increased upstream to downstream in Sunset Creek and Cahill Creek. Total dissolved solids exceeded the WQO in Nickel Plate Mine Creek. In Cahill Creek, the total dissolved solids WQO was met however levels increased from upstream to downstream; concentrations were lowest during freshet suggesting inputs from groundwater sources.

Nutrients were generally low with many reported results below the MDL. Nitrate concentrations have decreased over time in Nickel Plate Mine Creek and Cahill Creek, and currently meet the ALWQG.

Some metals exceeded WQG and/or WQO levels. Total aluminum concentrations in Cahill Creek exceeded guideline levels because of untreated seepage water being discharged to the creek from a tailings pond at Nickel Plate Mine following a power failure in April 2018. Levels were otherwise generally within guideline levels. Total chromium concentrations were also elevated in Cahill Creek in May 2018 with concentrations generally <1 µg/L during other times. Arsenic levels exceeded guideline levels in all waterbodies increasing from upstream to downstream in Cahill Creek and Sunset Creek. Dissolved cobalt exceeded WQGs in Cahill Creek; the highest concentrations occurred during low flows suggesting inputs from groundwater sources. Cobalt levels have decreased substantially over time but are still above WQG levels. Selenium concentrations exceeded the drinking water guideline in Nickel Plate Mine Creek and the ALWQG in Sunset Creek and Cahill Creek. Selenium levels appear to be influenced by groundwater inputs and have increased in recent years. All other metals were below WQO and WQG levels.

12. RED TOP GULCH CREEK AMBIENT WATER QUALITY

Red Top Gulch Creek is a small tributary to the Similkameen River paralleling Cahill Creek to the west. Water quality objectives were developed for this stream in 1987 (ENV 1987) to address concerns associated with the mining activities of the Nickel Plate Mine, which operated until 1996.

Water quality monitoring data for the period between 2000 and 2023 were used to assess the water quality of Red Top Gulch Creek. For consistency, the parameters previously assessed for the Similkameen River mainstem are considered here, in addition to those with WQOs proposed in 1987 (ENV 1987) and others identified more recently as parameters of concern. Table 104 lists the monitoring sites used in the Red Top Gulch Creek assessment with the site locations illustrated in Figure 5.

Table 104: Red Top Gulch Creek monitoring sites.

EMS Site ID	Location
E215956	Red Top Gulch Creek West Fork
E215957	Red Top Gulch Creek East Fork
E206638	Red Top Gulch Creek at Access Road below tailings

12.1 General Parameters

12.1.1 pH

The pH WQG permits unrestricted change within the range of 6.5 to 9.0. The available pH data for Red Top Gulch Creek are summarized in Table 105. pH levels were consistent throughout Red Top Gulch Creek with 95th percentile levels ranging from 8.2 to 8.4. No results exceeded the maximum of the acceptable range and only one measurement was below the acceptable range.

Table 105: Summary statistics for pH in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	7.8	6.3	8.4	8.2	161
E215957	8.1	7.5	8.4	8.3	61
E206638	8.2	7.6	8.5	8.4	261

12.1.2 Temperature

The ALWQG (ENV 2001a) for water temperature in streams with known populations of rainbow trout is a range of 10.0°C – 15.5°C for spawning (late April to July) and 16.0°C – 18.0°C for rearing (summer through fall). There is no temperature WQO for Red Top Gulch Creek. Rainbow Trout, Brook Trout and Longnose Dace have been documented in Cahill Creek. The 1987 WQOs specify the protection of aquatic life in the lower reaches of Red Top Gulch Creek.

Temperature data are summarized in Table 106. Temperatures increased downstream with a maximum of 13.8°C recorded in July at E206638. The seasonal trends in water temperature are illustrated in Figure 93. All temperatures were typically below the maximum levels specified in the ALWQGs.

Table 106: Summary statistics for temperature (°C) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	5.4	0.0	12.0	9.6	110
E215957	5.4	0.0	11.6	9.1	64
E206638	7.1	0.0	13.8	10.8	744

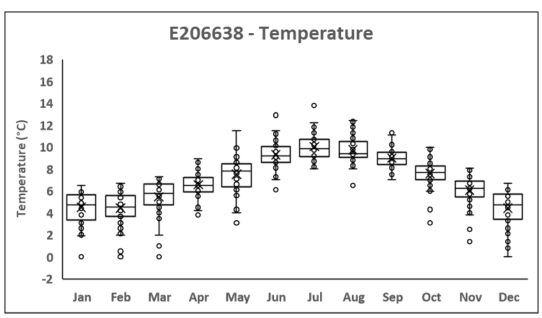

Figure 93: Seasonal variation in water temperature (°C) in Red Top Gulch Creek (E206638) (2000-2023).

12.1.3 Specific Conductivity

Specific conductivity data are summarized in Table 107. Specific conductivity was higher in the upper reach of Red Top Gulch Creek with an average concentration of 2,101 µS/cm at E215956. Conductivity was lower in the East Fork (E215957) resulting in a lower average concentration of 1,003 µS/cm at E206638 before flowing into the Similkameen River.

There was no obvious seasonal pattern, however the available data suggest that specific conductivity concentrations may be increasing over time in Red Top Gulch Creek (Figure 94).

Table 107: Summary statistics for specific conductivity (µS/cm) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	2,101	150	4,010	3,724	157
E215957	844	401	3,930	1,502	61
E206638	1,003	571	1,436	1,335	253

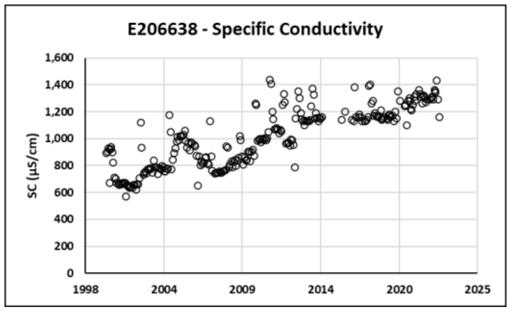

Figure 94: Specific conductivity (µS/cm) over time in Red Top Gulch Creek (E206638).

12.1.4 Hardness

Total hardness data were limited and are summarized in Table 108. Concentrations were highest upstream at E215956 and decreased downstream at E206638 below the confluence with the East Fork. There is only one data point prior to 2015 at E206638 (347 mg/L in 2001) suggesting a similar increasing trend in concentrations over time as seen with specific conductance (see Figure 94).

Table 108: Summary statistics for total hardness (mg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	1,694	107	2,198	2,023	50
E215957	1,944	1,680	2,209	2,182	2
E206638	716	467	953	818	74

12.1.5 Turbidity

The 1987 WQO for turbidity in Red Top Gulch Creek is a maximum increase of 5 NTU when background levels are ≤50 NTU and a maximum increase of 10% when background levels are >50 NTU. The ALWQG during clear flows is a maximum increase over background of 8 NTU and an average 30-day increase of 2 NTU. When background levels are 8 NTU – 50 NTU, the maximum increase is 5 NTU and when background levels are >50 NTU the maximum increase is 10% of background (ENV 2021c).

The available turbidity data are summarized in Table 109. Average turbidity levels decreased from upstream (E215956) to downstream (E206638). Maximum turbidity measurements were generally recorded during freshet in April and May. When concurrent measurements were taken at the upstream and downstream sites, the WQO was met 90% (142/157) of the time and the ALWQG was met 86% (136/158) of the time.

Table 109: Summary statistics for turbidity (NTU) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	19.6	0.250	496	57.3	135
E215957	12.2	0.600	124	52.3	44
E206638	9.71	0.087	842	18.9	260

12.1.6 Total suspended solids

For the lower reaches of Red Top Gulch Creek (i.e., from the highway crossing to the Similkameen River) the total suspended solids (TSS) WQO is a maximum increase over background of 10 mg/L when upstream concentrations are ≤100 mg/L, and a 10% maximum increase when background is >100 mg/L. For the upper reaches (i.e., from the headwaters to the highway crossing), the WQO is a maximum increase over background of 20 mg/L when background is 100 mg/L, and a 20% maximum increase when background is >100 mg/L.

The available TSS data are summarized in Table 110. Data were limited for all sites. Average concentrations were higher at the downstream site (E206638), but this was driven by one extreme value of 1,380 mg/L measured on May 5, 2014. Concurrent measurements on the same day upstream at E215956 (West Fork) and downstream at E206638 were generally higher upstream suggesting possible dilution from the East Fork of Red Top Gulch Creek, but no data were available to confirm this. The WQO was met on all but two sampling dates at E206638, May 5 and August 4 of 2014.

Table 110: Summary statistics for total suspended solids (mg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	19.7	<3.00	142	60.2	46
E215957	28.3	14.9	41.7	40.4	2
E206638	69.3	<1.00	1,380	199	28

12.1.7 Total Dissolved Solids

A WQO for total dissolved solids (TDS) for Red Top Gulch Creek was set in 1987 because of concerns for the potential increase of TDS concentrations from mining activities, specifically discharges from a settling basin at Nickel Plate Mine. The WQO for total dissolved solids is a maximum concentration of 500 mg/L.

The available TDS data are summarized in Table 111. All results upstream at E215956 were above the WQO averaging 3,229 mg/L. Concentrations decreased downstream at E206638 but still exceeded the WQO on most days ranging from 470 mg/L to 1,610 mg/L. The data did not demonstrate a seasonal pattern and concentrations were generally between 800 mg/L and 1,200 mg/L.

Table 111: Summary statistics for total dissolved solids (mg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	3,229	808	3,650	3,601	40
E215957	3,580	3,200	3,960	3,922	2
E206638	1,013	470	1,610	1,195	71

12.2 Nutrients

12.2.1 Phosphorus

There are no WQOs for phosphorus in Red Top Gulch Creek. The available data are summarized in Table 112. Most results at all sites were below the MDLs ranging from 50 µg/L to 300 µg/L. As such, there are no apparent seasonal trends in concentrations for this parameter.

Table 112: Summary statistics for total phosphorus (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	198	<50.0	<300	<300	50
E215957	220	190	<250	247	2
E206638	81.6	6.40	<300	<300	73

12.2.2 Nitrogen

An ammonia WQO was set for the lower reaches of Red Top Gulch Creek (E206638) at the ALWQG level (ENV 2021d). The guideline levels are determined by the temperature and pH of the water at the time of sampling. The available ammonia data for Red Top Gulch Creek are summarized in Table 113.

At E206638, 91% (60/66) of results were below the MDL of 5 µg/L. Ammonia ALWQG values decrease with increasing water temperature and pH. Concurrent temperature and pH data were not consistently available; the most stringent ALWQG value, based on a water temperature of 14°C and a pH of 8.5 (the highest reported values for Red Top Gulch Creek) is 366 µg/L. All results were well below this benchmark.

Table 113: Summary statistics for ammonia (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	16.6	<5.00	28.1	26.9	2
E215957	6.40	6.40	6.40	n/a	1
E206638	5.71	<5.00	33.9	8.15	66

The nitrate WQO for Red Top Gulch Creek is a maximum concentration of 10 mg/L (for the protection of drinking water) The ALWQG for nitrate is a 30-day average concentration of 3.0 mg/L and a maximum concentration of 32.8 mg/L (ENV 2009).

The available nitrate data are summarized in Table 114. Nitrate increased from upstream to downstream in Red Top Gulch Creek (E206638) averaging 0.888 mg/L at E215956 and 5.36 mg/L at E206638. Nitrate concentrations decreased over time at E206638 from 13 mg/L in 2000 to 3 mg/L in 2023 (Figure 95).

Table 114: Summary statistics for nitrate (mg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	0.888	0.021	6.90	2.96	172
E215957	1.62	<0.100	13.7	3.79	62
E206638	5.36	1.20	13.8	8.83	847

The nitrite WQO for Red Top Gulch Creek is an average concentration of 0.02 mg/L and a maximum concentration of 0.06 mg/L downstream of the Highway 3 crossing and a maximum concentration of 1 mg/L upstream of the Highway 3 crossing. The ALWQG for nitrite is based on site-specific chloride concentrations and ranges from 0.02 mg/L for chloride concentration <2 mg/L to 0.20 mg/L for chloride concentration >10 mg/L.

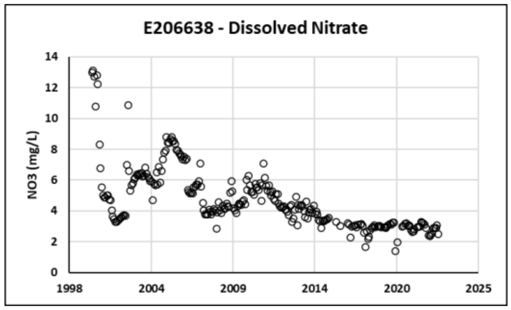

Figure 95: Monthly average dissolved nitrate concentrations (mg/L) over time in Red Top Gulch Creek (E206638).

Most results for both total nitrite and dissolved nitrite were below the MDLs (ranging from <1 µg/L to 300 µg/L) at all sites. In recent years (2020 to the present) dissolved nitrite has been measured and results have been below the MDL of 1 µg/L or 5 µg/L. Where concurrent chloride data were available the nitrite results were compared to the ALWQG levels. All results were below the guideline levels except for five results from the upstream site (E215956) which exceeded the long-term average guideline of 200 µg/L ranging from 281 µg/L to 595 µg/L during freshet.

12.3 Organic Matter

12.3.1 Organic Carbon

Dissolved organic carbon is an important parameter to measure as it is required for determining guideline values for several metals. The limited dissolved organic carbon data for Red Top Gulch Creek are summarized in Table 115. Dissolved organic carbon averaged 2.4 mg/L in Red Top Gulch Creek and no seasonal trend was evident given the limited data.

Table 115: Summary statistics for dissolved organic carbon (mg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	30.5	5.17	41.4	40.6	5
E215957	–	–	–	–	–
E206638	2.40	1.69	3.43	3.05	21

12.4 Major Ions and Other Inorganic Parameters

12.4.1 Sulphate

The WQO for total sulphate in Red Top Gulch Creek is an average concentration of 50 mg/L and a maximum concentration of 150 mg/L. The ALWQG (ENV 2013) is based on hardness and average values range from 128 mg/L in very soft water (<30 mg/L $CaCO_3$) to 429 mg/L in very hard water (181 mg/L – 250 mg/L $CaCO_3$). The ALWQG more accurately reflects the current knowledge on sulphate toxicity and is used to assess sulphate levels rather than the 1987 WQO.

The available data are summarized in Table 116. Both total and dissolved sulphate data are presented; total and dissolved sulphate was reported through 2015 and from 2016 on only dissolved sulphate was reported.

Table 116: Summary statistics for sulphate (mg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total sulphate	830	40.3	1,860	1,622	90
	Dissolved sulphate	1,396	24.5	2,240	2,159	82
E215957	Total sulphate	214	75.2	624	590	41
	Dissolved sulphate	431	116	2,620	1,770	21
E206638	Total sulphate	284	107	690	526	718
	Dissolved sulphate	429	42.2	695	605	125

Sulphate concentrations were high throughout Red Top Gulch Creek. Total sulphate concentrations averaged 284 mg/L with a 95th percentile concentration of 526 mg/L at E206638. All reported hardness values exceeded the upper range specified by the ALWQG (i.e., 250 mg/L) so comparison to the guidelines is not possible. An increasing trend in dissolved sulphate concentrations is evident in Figure 96.

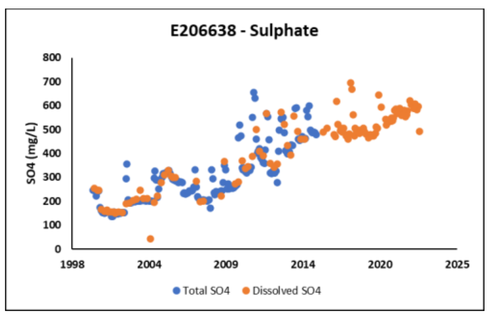

Figure 96: Monthly average sulphate concentrations (mg/L) over time in Red Top Gulch Creek (E206638).

12.4.2 Cyanide

Water quality objectives for cyanide were set in Red Top Gulch Creek because of the potential for inputs from the Mascot Gold Mine operation. The WQO for weak acid dissociable cyanide (WAD CN) is an average concentration of ≤5 µg/L and a maximum concentration of 10 µg/L in the lower reaches of Red Top Gulch Creek. The WQO for strong acid dissociable cyanide plus thiocyanate (SAD CN + SCN) is a maximum concentration of 20 µg/L throughout Red Top Gulch Creek. There is also a WQO for cyanates (maximum concentration of 45 mg/L), but no data are available for this parameter.

The WAD CN results were low in Red Top Gulch Creek with 83% (219/263) of results below the MDLs ranging from 1 µg/L to 10 µg/L at E206638; most results were reported as <5 µg/L. The maximum reported concentration at this site was 20 µg/L and the 95th percentile concentration was 6.0 µg/L.

The SAD CN + SCN data were not assessed. There were several sampling dates with two reported results differing by an order of magnitude. This discrepancy could not be reconciled therefore the data were considered unreliable.

12.5 Metals

Water quality objectives for several metals were set in Red Top Gulch Creek to address concerns of seepage from a tailings impoundment and runoff from waste rock piles. These are discussed in the following sections.

12.5.1 Aluminum

A WQO for total aluminum was set in the downstream reaches of Red Top Gulch Creek of 300 µg/L (maximum concentration) or a 20% increase over upstream levels, whichever is greater. The ALWQG is based on concurrent measurements of pH, DOC, and water hardness (WLRS 2023a). As the guideline is more recent than the WQOs, it is used to assess total aluminum levels in this review. Dissolved organic carbon data were limited so monthly average concentrations were used where needed for the purpose of calculating a guideline value.

The available aluminum data are summarized in Table 117 with the seasonal trends at the downstream sites illustrated in Figure 97. Total aluminum levels increased upstream to downstream in Red Top Gulch Creek with average and 95th percentile concentrations increasing from 28.3 µg/L and 124 µg/L to 59.6 µg/L and 311 µg/L at E215956 and E206638, respectively. The ALWQG was met 93% (68/73) of the time at the downstream site (E206638). All exceedances occurred in May or June with the highest reported concentration of 1,060 µg/L occurring in May of 2018 (Figure 98).

Table 117: Summary statistics for aluminum (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total aluminum	28.3	4.10	253	124	49
	Dissolved aluminum	7.36	1.50	150	15.0	75
E215957	Total aluminum	501	15.0	987	938	2
	Dissolved aluminum	3.48	1.60	<6.00	5.55	10
E206638	Total aluminum	59.6	<3.00	1,060	311	73
	Dissolved aluminum	2.81	<0.02	27.0	10.8	118

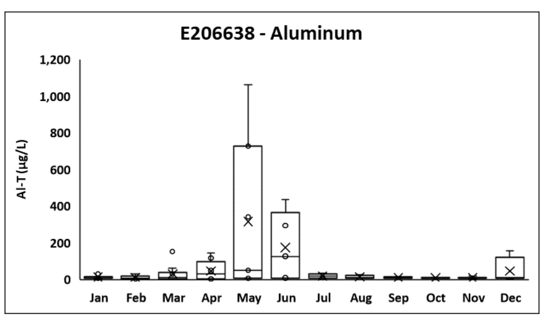

Figure 97: Seasonal variation in total aluminum concentrations (µg/L) in Red Top Gulch Creek (E206638) (2000-2023).

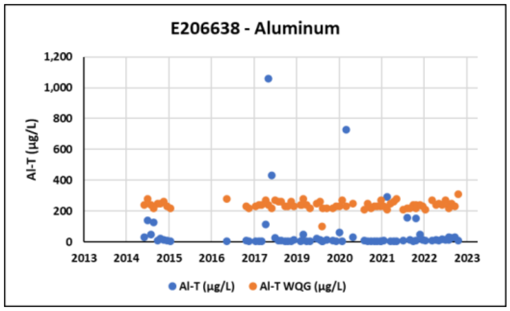

Figure 98: Total aluminum concentrations (µg/L) and corresponding water quality guideline values over time in Red Top Gulch Creek (E206638).

12.5.2 Arsenic

Water quality objectives were set for arsenic in Red Top Gulch Creek due to the potential for inputs from mining activities (ENV 1987). The total arsenic WQO for Red Top Gulch Creek is a maximum concentration of 50 µg/L. The ALWQG for total arsenic is a maximum concentration of 5 µg/L and the drinking water guideline is a maximum concentration of 10 µg/L (ENV 2021f). The 1987 arsenic WQOs were based on the WWQGs available at that time. The current WQGs were used in this assessment.

Total arsenic concentrations were high in Red Top Gulch Creek, especially in the upper reaches (average concentration of 193 µg/L) (Table 118). Concentrations decreased downstream at E206638 with an average concentration of 9.82 µg/L and 95th percentile concentration of 19.2 µg/L. The ALWQG was exceeded in all results while the drinking water guideline was only exceeded in 14% (36/253) of results. Total arsenic concentrations in the lower reach of Red Top Gulch Creek (E206638) were greatest in May through July (Figure 99).

Table 118: Summary statistics for total arsenic (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	193	18.3	1,992	477	78
E215957	40.4	18.8	169	116	9
E206638	9.82	6.97	48.0	19.2	253

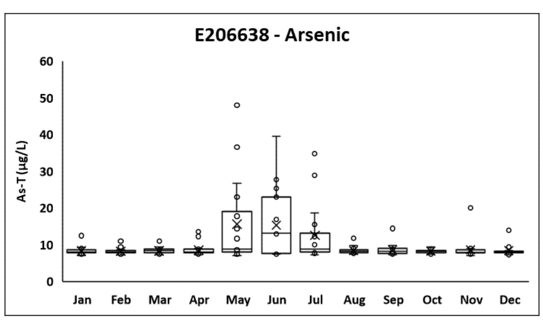

Figure 99: Seasonal variation in total arsenic concentrations (µg/L) in Red Top Gulch Creek (E206638).

12.5.3 Cadmium

The 1987 WQOs for cadmium in Red Top Gulch Creek were based on the WWQGs available at that time. Downstream of the highway (E206638) the WQO is a maximum total cadmium concentration of 0.2 µg/L to protect aquatic life. Upstream, the WQO is a maximum total cadmium concentration of 5 µg/L to protect drinking water, irrigation, and livestock water. The more recent cadmium ALWQG (ENV 2015) is based on dissolved cadmium and accounts for the ameliorating effects of water hardness. The drinking water guideline is a MAC of 5 µg/L.

The available cadmium data are summarized in Table 119. At all sites the dissolved cadmium data are dominated by results reported as <MDL prior to 2016. More recent data (2016 – present) applied lower MDLs and better reflect current conditions with respect to dissolved cadmium concentrations. All cadmium WQGs and WQOs were consistently met throughout Red Top Gulch Creek and there was no evidence of an increasing trend in concentrations over time (Figure 100).

Table 119: Summary statistics for cadmium (µg/L) in Red Top Gulch Creek.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956 (2015 – 2023)	Total cadmium	0.023	<0.010	0.092	0.058	46
	Dissolved cadmium	0.018	<0.010	0.058	0.032	46
E215957 (2017 – 2018)	Total cadmium	0.152	0.031	0.273	0.261	2
	Dissolved cadmium	<0.025	<0.025	<0.025	<0.025	2
E206638 (2015 – 2023)	Total cadmium	0.010	<0.005	0.043	0.023	69
	Dissolved cadmium	0.008	<0.005	0.059	0.019	77

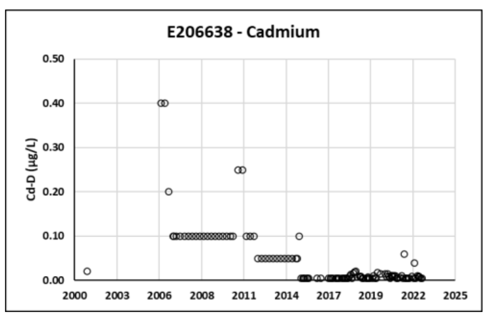

Figure 100: Dissolved cadmium concentrations (µg/L) over time in Red Top Gulch Creek (E206638). Values prior to 2016 were generally reported as below the method detection limit.

12.5.4 Chromium

There are no WQOs for chromium in Red Top Gulch Creek. The ALWQG is 1 µg/L for hexavalent chromium and 8.9 µg/L for trivalent chromium (ENV 2021b), therefore 1 µg/L provides a conservative benchmark for the assessment of total chromium. The drinking water guideline is a maximum total chromium concentration of 50 µg/L.

The available total chromium data are summarized in Table 120. Results were typically less than 1 µg/L and often reported as less than the MDL. All results exceeding 1 µg/L occurred during freshet and concurrent measurements of dissolved chromium were very low (e.g., <0.2 µg/L). In the lower reach of Red Top Gulch Creek (E206638), all results >1 µg/L occurred in May of 2018.

Table 120: Summary statistics for total chromium (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	0.504	<0.200	<2.50	1.90	49
E215957	1.18	<0.500	1.86	1.79	2
E206638	0.417	0.170	1.15	0.583	72

12.5.5 Cobalt

There is no WQO for cobalt in Red Top Gulch Creek. The current ALWQG (WLAP 2004) will be replaced with the federal freshwater WQG (EC 2017) with an uncertainty factor of 3 to account for the limitations of the data set (e.g., data for only one salmonid). The drinking water guideline for cobalt is a MAC of 1 µg/L.

The available cobalt data are summarized in Table 121. Dissolved and total cobalt concentrations in Red Top Gulch Creek (E215956) were very high averaging 799 µg/L and 1,406 µg/L, respectively. The available data suggest an increasing trend in dissolved cobalt concentrations from 2009 to the present (Figure 105). Cobalt data were limited at E215957. The average dissolved cobalt concentration was lower at 150 µg/L; however, the most recent results followed the increase in concentrations seen upstream at E215956. Average concentrations were lower downstream at E206638 at 47.8 µg/L and 95.9 µg/L for dissolved and total cobalt, respectively. Despite the lower concentrations an increasing trend in concentrations was evident in recent years (Figure 101). All results with concurrent hardness measurements were well above guideline levels. There was no obvious seasonal pattern in dissolved cobalt at any site and all results were well above guideline levels.

Table 121: Summary statistics for cobalt (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total cobalt	1,406	73.6	1,760	1,722	49
	Dissolved cobalt	799	9.00	2,000	1,577	167
E215957	Total cobalt	1,605	1,390	1,820	1,799	2
	Dissolved cobalt	150	8.00	1,790	409	62
E206638	Total cobalt	95.9	<6.00	168	160	76
	Dissolved cobalt	47.8	7.08	171	144	266

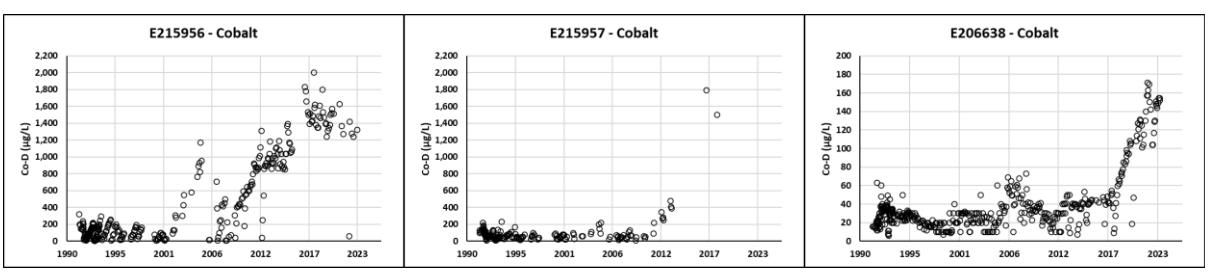

Figure 101: Dissolved cobalt concentrations (µg/L) over time in Red Top Gulch Creek. Sites are presented from upstream (E215956) to downstream (E206638). Note the different Y-axis scale used for E206638.

12.5.6 Copper

The 1987 WQO for copper in Red Top Gulch Creek is an average total copper concentration of ≤5 µg/L and a maximum total copper concentration of 7 µg/L in the downstream reach (E206638). In the upstream reaches the WQO is a maximum total copper concentration of 200 µg/L. The ALWQG (ENV 2019a) is based on dissolved copper and determined by concurrent measurements of toxicity-modifying constituents (e.g., pH, DOC, water hardness). The irrigation WQG is a maximum total copper concentration of 200 µg/L, the wildlife/livestock water WQG is an average total copper concentration of 200 µg/L (ENV 2019a), and the drinking water WQG is a MAC of 2 mg/L to protect human health and 1 mg/L to protect the aesthetic quality (ENV 2020a).

The available copper data are summarized in Tables 122. The data were skewed from the higher MDLs used prior to 2015 therefore the assessment is based on data collected between 2015 and 2023. Site-specific DOC and water hardness data were limited, and monthly average concentrations were used to calculate ALWQG values where data for dependent parameters were not available.

Table 122: Summary statistics for copper (µg/L) in Red Top Gulch Creek (2015 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total copper	1.74	<1.00	4.41	2.50	45
	Dissolved copper	0.657	<0.400	3.49	<1.00	45
E215957	Total copper	8.90	2.50	15.3	14.7	2
	Dissolved copper	1.30	<1.00	1.60	1.57	2
E206638	Total copper	0.940	0.487	8.35	2.44	72
	Dissolved copper	0.462	0.280	2.16	0.895	80

Average dissolved copper concentrations decreased from 0.657 µg/L at E215956 to 0.462 µg/L at E206638. Results were typically below the MDLs (<0.4 µg/L and <1.0 µg/L) at E215956; the only result above detection (3.49 µg/L) occurred in April 2022 with a concurrent total copper concentration of 4.41 µg/L. Seasonal trends in dissolved copper are illustrated in Figure 102 showing concentrations peaking during freshet at E206638. The ALWQG was met in all results at this site.

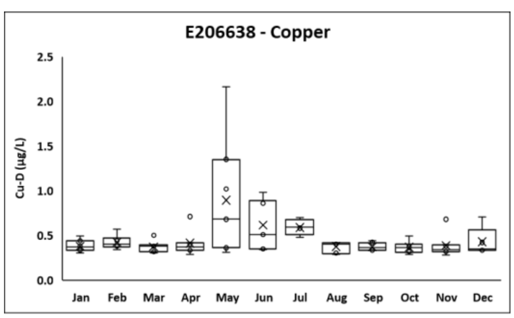

Figure 102: Seasonal trends in dissolved copper concentrations (µg/L) in Red Top Gulch Creek (E206638) (2015-2023).

12.5.7 Iron

The WQO for iron in Red Top Gulch Creek is a maximum dissolved iron concentration of 0.3 mg/L. The ALWQG (ENV 2008) is a maximum total iron concentration of 1 mg/L and a maximum dissolved iron concentration of 0.35 mg/L. The drinking water guideline is a maximum total iron concentration of 0.3 mg/L.

The available iron data are summarized in Table 123. Total iron concentrations were considerably higher at the upstream site (E215956) on Red Top Gulch Creek averaging 5.98 mg/L with a 95th percentile concentration of 28.2 mg/L. Both the drinking water and the aquatic life guidelines were typically exceeded at this site. Dissolved iron concentrations were much lower overall and often below MDLs, however reported concentrations in recent years were often >1 mg/L. Downstream at E206638, both total and dissolved iron concentrations were much lower averaging 0.112 mg/L and 0.017 mg/L, respectively. The drinking water guideline was met 92% (67/73) of the time and the total iron ALWQG was met 97% of the time (71/73). Dissolved iron results were typically (95% of results) below the MDLs ranging from 0.010 mg/L to 0.030 mg/L.

Table 123: Summary statistics for iron (mg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total iron	5.98	0.055	49.5	28.2	49
	Dissolved iron	0.187	<0.002	2.37	1.50	88
E215957	Total iron	2.71	1.38	4.04	3.91	2
	Dissolved iron	0.031	0.003	<0.050	<0.050	11
E206638	Total iron	0.112	<0.010	2.30	0.400	73
	Dissolved iron	0.017	<0.001	<0.030	<0.030	132

12.5.8 Lead

The 1987 WQO for total lead in the downstream reaches of Red Top Gulch Creek is an average concentration of ≤5 µg/L and a maximum concentration of 15 mg/L. In the upstream reaches the WQO is a maximum concentration of 50 µg/L to protect drinking water sources. The ALWQG for total lead (ENV 2021e) is hardness-based and determined from concurrent measurements of water hardness. The drinking water guideline is a MAC of 5 µg/L. The WQG to protect livestock water and wildlife is a maximum concentration of 100 µg/L.

The available total lead data are summarized in Table 124. Total lead data were only available from 2015 on and were typically well below guideline levels and often below MDLs at all sites.

Table 124: Summary statistics for total lead (µg/L) in Red Top Gulch Creek (2015 – 2023).

Site	Average	Minimum	Maximum	95th percentile	n
E215956	0.269	0.068	4.91	0.250	49
E215957	0.430	<0.250	0.610	0.592	2
E206638	0.068	0.019	0.413	0.135	72

12.5.9 Mercury

The WQOs for total mercury in Red Top Gulch Creek is a maximum concentration of 0.1 µg/L in the downstream reaches and a maximum concentration of 1 µg/L in the upstream reaches. The ALWQG (ENV 2001c) is determined using the ratio of methyl mercury to total mercury however methyl mercury data are not available. The source drinking water guideline for mercury is ≤1.0 µg/L (ENV 2020a).

The available mercury data are summarized in Table 125. Both total and dissolved mercury concentrations were low at all sites. The more recent results were typically below the MDL of 0.005 µg/L.

Table 125: Summary statistics for mercury (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total mercury	0.045	<0.005	<0.250	<0.250	16
	Dissolved mercury	0.059	<0.010	<1.00	<0.050	23
E215957	Total mercury	<0.050	<0.050	<0.050	n/a	1
	Dissolved mercury	0.023	<0.005	<0.050	<0.050	6
E206638	Total mercury	<0.005	<0.005	0.006	<0.005	41
	Dissolved mercury	0.021	<0.005	<0.050	<0.050	10

12.5.10 Molybdenum

The 1987 WQO for total molybdenum in Red Top Gulch Creek is an average concentration of ≤10 µg/L and a maximum concentration of 50 µg/L from May to September. The B.C. ALWQG has since been updated (ENV 2021h) and is now an average of 7.6 mg/L. Other uses have lower guideline values (e.g., ruminant livestock: 16 µg/L; ruminant wildlife: 34 µg/L; drinking water: 88 µg/L) and were used in this assessment.

The available total molybdenum data are summarized in Table 126. Total molybdenum consisted mostly of dissolved molybdenum, therefore both fractions are used in this assessment. All guideline values were met on Red Top Gulch Creek and concentrations decreased from upstream to downstream with average dissolved molybdenum concentrations of 10.3 µg/L and 5.68 µg/L at E215956 and E206638, respectively. There were no seasonal or temporal trends in dissolved molybdenum concentrations.

Table 126: Summary statistics for molybdenum (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total molybdenum	10.9	1.74	14.9	13.6	49
	Dissolved molybdenum	10.3	1.63	14.1	12.9	75
E215957	Total molybdenum	6.06	1.42	10.7	10.2	2
	Dissolved molybdenum	2.62	1.17	10.1	6.45	11
E206638	Total molybdenum	5.89	2.16	7.03	6.67	72
	Dissolved molybdenum	5.68	2.21	6.61	6.44	117

12.5.11 Selenium

The WQOs for total selenium in Red Top Gulch Creek are a maximum concentration of 1 µg/L in the downstream reaches and a maximum concentration of 10 µg/L in the upstream reaches. The ALWQG is an average concentration of ≤2 µg/L with an alert level of 1 µg/L (ENV 2014). The source drinking water guideline for selenium is 10 µg/L (ENV 2020a).

The available selenium data are summarized in Table 127. Total selenium data were limited for most sites so dissolved selenium data are included in this assessment. Background selenium concentrations were below guideline levels on Red Top Gulch Creek averaging 0.539 µg/L and 0.466 µg/L for dissolved and total selenium, respectively, at E215956. Concentrations increased substantially downstream at E206638 with dissolved selenium averaging 10.3 µg/L and total selenium averaging 10.9 µg/L. There was no clear seasonal pattern for dissolved selenium and while concentrations have increased over time they may have stabilized in recent years (Figure 103). Most of the total selenium is in the dissolved form and groundwater inputs appear to be a strong driver of dissolved selenium concentrations as suggested by the relationship with specific conductance (Figure 103).

Table 127: Summary statistics for selenium (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total selenium	0.466	0.175	2.74	1.08	46
	Dissolved selenium	0.539	0.250	2.66	1.09	46
E215957	Total selenium	2.82	0.490	5.14	4.91	2
	Dissolved selenium	2.65	0.600	5.00	4.55	11
E206638	Total selenium	10.9	6.60	18.9	13.9	73
	Dissolved selenium	10.3	2.90	19.3	14.3	128

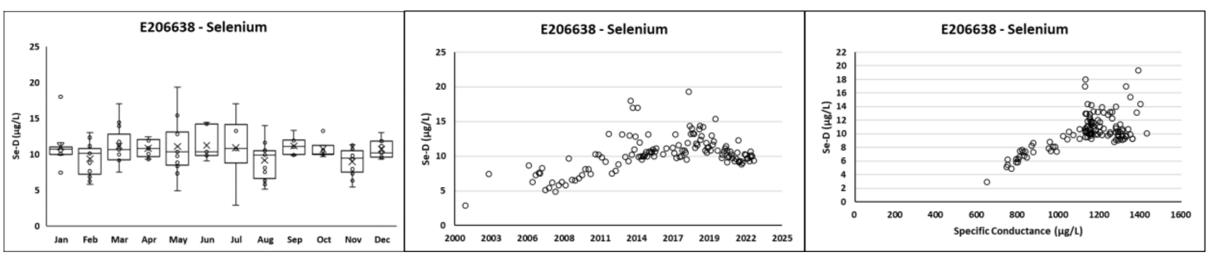

Figure 103: Dissolved selenium concentrations (µg/L) in Red Top Gulch Creek. Seasonal trends are illustrated in the left panel, concentrations over time are illustrated in the center panel, and dissolved selenium as a function of specific conductivity is illustrated in the right panel.

12.5.12 Silver

The WQO for total silver in the downstream reaches of Red Top Gulch Creek is a maximum concentration of 0.1 µg/L and a maximum concentration of 50 µg/L in the upstream reaches. The ALWQG (WLAP 1996) is an average total silver concentration of ≤0.05 µg/L when water hardness is ≤100 mg/L and 1.5 µg/L when hardness is >100 mg/L. The CCME ALWQG (CCME 2015) for long-term exposure is 0.25 µg/L; this updated WQG will be adopted by B.C. likely with an uncertainty factor of 2 for a final ALWQG value of 0.125 µg/L.

The available silver data are summarized in Table 128. Values were low at all sites and met the proposed ALWQGs or were below MDLs.

Table 128: Summary statistics for silver (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total silver	0.033	<0.010	<0.050	<0.050	36
	Dissolved silver	0.032	<0.020	<0.050	<0.050	36
E215957	Total silver	0.054	<0.050	0.057	0.057	2
	Dissolved silver	0.023	<0.010	<0.050	<0.050	10
E206638	Total silver	<0.010	<0.005	<0.020	<0.010	73
	Dissolved silver	0.013	<0.005	<0.050	<0.020	114

12.5.13 Uranium

There are no WQOs for uranium in Red Top Gulch Creek. The WWQGs for total uranium are 8.5 µg/L for the protection of freshwater aquatic life, 10 µg/L for irrigation, 200 µg/L for livestock watering (ENV 2021b), and 20 µg/L for drinking water (ENV 2020a).

The available uranium data are summarized in Table 129. Uranium concentrations exceeded guideline levels throughout Red Top Gulch Creek. Average concentrations increased from about 9 µg/L at the upstream site (E215956) to 30 µg/L at the downstream site (E206638). Dissolved and total uranium concentrations increased substantially over time at E206638 where concentrations were typically <5 µg/L in 1986 (Figure 104).

Table 129: Summary statistics for uranium (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total uranium	9.41	2.89	13.7	12.6	49
	Dissolved uranium	9.21	2.75	12.7	12.3	49
E215957	Total uranium	7.03	5.12	8.93	8.74	2
	Dissolved uranium	6.44	4.91	7.96	7.81	2
E206638	Total uranium	31.0	9.40	38.8	36.7	72
	Dissolved uranium	30.1	9.45	38.4	36.0	81

12.5.14 Zinc

The WQO for total zinc in Red Top Gulch Creek is a maximum concentration of 50 µg/L. The zinc ALWQG (WLRS 2023d) is based on dissolved zinc and derived from site-specific hardness, pH, and DOC levels. The maximum allowable concentration of zinc to protect drinking water is 3.0 mg/L (ENV 2020a).

The available zinc data are summarized in Table 130. In Red Top Gulch Creek, dissolved zinc concentrations decreased upstream to downstream from 4.07 µg/L at E215956 to 2.93 µg/L at E206638.

The majority (73%; 354/485) of dissolved zinc results were below the MDL which ranged from 0.100 µg/L to 15.0 µg/L. As such, there was no obvious seasonal trend for dissolved zinc. Additionally, it is difficult to assess dissolved zinc concentrations against the updated WQG because concurrent measurements of water hardness, pH, and DOC were not available for most sampling dates. Where data were available, the reported concentrations were well below the WQG levels.

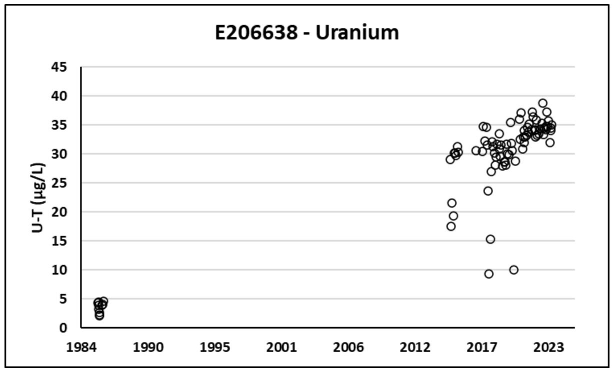

Figure 104: Total uranium concentrations (µg/L) in Red Top Gulch Creek over time.

Table 130: Summary statistics for zinc (µg/L) in Red Top Gulch Creek (2000 – 2023).

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E215956	Total zinc	10.0	4.40	<15.0	<15.0	49
	Dissolved zinc	4.07	<0.500	<15.0	<10.0	165
E215957	Total zinc	11.8	8.50	<15.0	14.7	2
	Dissolved zinc	4.04	<0.500	11.0	<10.0	62
E206638	Total zinc	3.22	0.520	11.8	4.28	73
	Dissolved zinc	2.93	0.240	<15.0	<10.0	258

12.6 Red Top Gulch Creek Summary

WQOs were developed in 1987 to address concerns of potential impacts to water quality from mining activities related to the Nickel Plate Mine. Specific conductance decreased from upstream to downstream but showed an increasing trend over time. Total dissolved solids exceeded the WQO in Red Top Gulch Creek.

Nutrients were generally low with many reported results below the MDL. Nitrate concentrations have decreased over time and currently meet the ALWQG.

Some metals exceeded WQG and/or WQO levels. Arsenic levels exceeded guideline levels in Red Top Gulch Creek with concentrations decreasing from upstream to downstream. Dissolved cobalt exceeded WQGs with the highest concentrations occurring during low flow conditions suggesting inputs from groundwater sources. Cobalt concentrations were lower downstream than upstream and have increased substantially in recent years. Total iron concentrations exceeded guideline levels at the upstream site but decreased downstream to levels below the guidelines. Selenium exceeded the ALWQG in the lower reaches. Most of the total selenium is in the dissolved form and appears to be influenced by groundwater inputs. Uranium exceeded the ALWQG and drinking water guideline levels at the downstream site increasing substantially in recent years. All other metals met the WQO and WQG levels.

13. ASHNOLA RIVER AMBIENT WATER QUALITY

Water quality monitoring data for the Ashnola River are limited to three sites with only one sampling date each (Table 131). These data are summarized below for information only (Tables 132 – 136); further water quality monitoring and data collection is required to properly assess the state of water quality in the Ashnola River.

Table 131: Ashnola River monitoring sites presented from upstream to downstream.

EMS Site ID	Location	Date of sample
E267983	Ashnola River upstream of Ewart Creek	Sept. 17, 2020
E318571	Ashnola River upstream of bridge	Oct. 3, 2019
E208831	Ashnola River at bridge	May 23, 2002

13.1 General Parameters

Table 132: Data for general water quality parameters in the Ashnola River.

Parameter	E267983	E318571	E208831
pH	8.1	7.6	–
Temperature (°C)	11.1	5.9	5
Dissolved oxygen (mg/L)	10.2	–	–
Specific conductivity (µS/cm)	106	74	46
Hardness (mg/L)	45	31	–
Turbidity (NTU)	0.2	0.2	1.3
Total suspended solids (mg/L)	<3	<3	<4

13.2 Nutrients

Table 133: Data for nutrient parameters (µg/L) in the Ashnola River.

Parameter	E267983	E318571	E208831
Total phosphorus	<2	4.7	–
Total nitrogen	52	143	–
Nitrate	<3	<3	–
Nitrite	<1	<1	–
Ammonia	<5	<5	–

13.3 Nutrients

Table 134: Data for organic matter (mg/L) in the Ashnola River.

Parameter	E267983	E318571	E208831
Dissolved organic carbon	1.6	2.9	–

13.4 Major Ions

Table 135: Data for major ions (mg/L) in the Ashnola River.

Parameter	E267983	E318571	E208831
Sulphate	8.1	6.4	–

13.5 Metals

Table 136: Data for metals (µg/L) in the Ashnola River.

Parameter	E267983	E318571	E208831
Total aluminum	7.01	22.6	122
Total arsenic	0.019	0.018	0.200
Dissolved cadmium	0.0007*	<0.005	0.010
Total chromium	0.200	0.110	<0.200
Total cobalt	0.0001	0.023	0.058
Dissolved copper	0.272*	0.372	0.800
Total iron	8.60	30.2	–
Total lead	<0.005	0.011	0.080
Total manganese	1.37	2.11	5.42
Total molybdenum	0.919	1.93	0.860
Total Nickel	0.051	0.095	0.130
Total selenium	0.061	0.089	0.200
Total uranium	0.350	0.235	0.314
Dissolved zinc	0.550*	0.620	10.9

*Total fraction

14. KEREMEOS CREEK AMBIENT WATER QUALITY

Water quality objectives were developed for Keremeos Creek in 2000 (ENV 2000) to address water quality concerns associated with land development (e.g., Apex Mountain Resort), livestock, forestry, and recreational uses. The designated uses include aquatic life, drinking water, livestock watering, and irrigation. The available monitoring data were collected inconsistently and are limited for some sites, especially site 0500757 (Keremeos Creek at the mouth), where data were only available from 2001-2003. The assessment presented here, therefore, should be viewed with caution; additional data would be required to properly assess the water quality of Keremeos Creek.

Table 137 summarizes the monitoring sites used and years with data available. The locations of select sites are illustrated in Figure 5.

14.1 General Parameters

14.1.1 pH

The pH WQO is 6.5 to 8.5 for Keremeos, Olalla, and Cedar Creeks, and is 6.5 to 9.0 for South Keremeos Creek; the available data are summarized in Table 138. The WQOs were always met except for two reported results at 0500757 of 8.6 on August 20 and 27, 2001. No data were available for South Keremeos Creek.

Table 137: Summary of Keremeos Creek monitoring sites and years of available water quality data. Sites are presented upstream to downstream. Bold type denotes tributaries to Keremeos Creek.

EMS Site ID (CABIN Site ID)	Stream name	General location	Years of available data
E221386	Keremeos Creek	West fork of Keremeos Creek at the Gunbarrel reservoir intake	2000-2003, 2010, 2017
E221384	Keremeos Creek	West Fork of Keremeos Creek, upstream of Apex Mountain Resort parking lot	2001-2003, 2010, 2017
E221413	Keremeos Creek	North Fork of Keremeos Creek upstream of confluence with West Fork and Apex parking lot	2001-2003, 2010, 2017
E221387	Keremeos Creek	Downstream of Apex parking lot, upstream of sewage treatment plant	2001-2003, 2010, 2017
E221390	Keremeos Creek	400 m downstream of Apex sewage treatment plant, directly below the triple chair lift	2000-2003, 2010, 2017
E221339	Keremeos Creek	Keremeos Creek at Highway 3A upstream of Cedar Creek	2001-2003, 2007, 2010, 2017
E221525	**Cedar Creek**	Cedar Creek upstream of Highway 3A crossing.	2001-2003, 2010, 2017
E221340	Keremeos Creek	Upstream of Olalla Creek confluence and # 6 Road in Olalla	2001-2003
E221526	**Olalla Creek**	Olalla Creek downstream of Highway 3A crossing in Olalla	2001-2003, 2010, 2017
E221341	Keremeos Creek	Upstream of old Highway 3A crossing, south of Upper Bench Road in Keremeos	2001-2003, 2010, 2017
0500757	Keremeos Creek	Keremeos Creek upstream of confluence with Similkameen River in Cawston	2001-2003

Table 138: Summary statistics for pH at select sites on Keremeos Creek and its tributaries (2000 – 2017). Sites are presented upstream to downstream. Bold type denotes tributaries to Keremeos Creek.

Site	Average	Minimum	Maximum	95th percentile	n
E221386	7.5	7.0	8.3	7.7	35
E221413	7.5	6.9	7.7	7.7	10
E221387	7.7	7.4	7.9	7.9	14
E221390	7.6	7.2	8.2	7.9	39
E221339	8.1	8.0	8.3	8.2	29
E221525	8.2	8.0	8.3	8.3	29
E221340	8.2	8.1	8.3	8.3	20
E221526	8.3	8.2	8.4	8.4	35
E243528	8.3	7.9	8.5	8.4	15
E243529	8.2	7.6	8.4	8.3	15
0500757	8.3	8.0	8.6	8.5	17

14.1.2 Temperature

The water temperature WQO for Keremeos Creek is a maximum weekly average of 17°C, however, data were not collected with sufficient frequency to calculate weekly temperature averages or characterize on a seasonal basis. The available water temperature data from August, presumably the warmest month, are summarized in Figure 105, with the sites presented in an upstream to downstream order. The results show increasing temperatures upstream to downstream and indicate the potential for the temperature WQO to be exceeded in the lower reaches. As Keremeos Creek has been identified as an important contributor to rainbow trout populations in the Similkameen River (ENV 2000), more comprehensive monitoring is warranted to better characterize the thermal regime of this tributary.

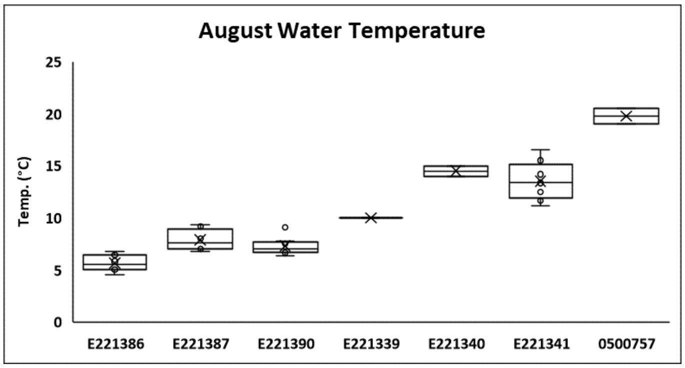

Figure 105: Summary of August water temperature (°C) data for select sites on Keremeos Creek. Sites are presented upstream to downstream.

14.1.3 Dissolved Oxygen

The WQO for dissolved oxygen in Keremeos Creek and its tributaries is a minimum of 11.0 mg/L when salmonoid embryos and larvae are present and a minimum of 8.0 mg/L at all other times. Data are limited but the available results (Table 139) suggest that dissolved oxygen levels are not a concern.

Table 139: Summary statistics for dissolved oxygen (mg/L) at select sites on Keremeos Creek and its tributaries (2000 – 2017). Sites are presented upstream to downstream. Bold type denotes tributaries to Keremeos Creek.

Site	Average	Minimum	Maximum	95th percentile	n
E221386	10.3	9.4	12.3	11.0	21
E221384	10.5	9.5	11.2	11.0	11
E221413	9.6	10.6	10.1	10.3	11
E221387	9.3	12.0	9.9	10.3	10
E221390	10.3	9.4	11.7	11.0	21
E221525	11.3	9.6	14.0	12.9	31
E221340	10.3	8.0	11.2	11.2	12
E221526	11.4	9.2	13.5	13.0	34
E243528	10.5	9.2	11.6	11.6	13
E243529	10.9	9.2	13.0	12.1	12
E221341	11.2	9.2	14.4	12.8	31
0500757	11.1	9.4	14.8	12.1	12

14.1.4 Specific Conductivity

Specific conductivity data are summarized in Table 140. Average concentrations increased from a background of 78 µS/cm at E221386 to 296 µS/cm downstream at 0500757. Concentrations were lowest during freshet as illustrated in Figure 106.

Table 140: Summary statistics for specific conductivity (µS/cm) at select sites on Keremeos Creek and its tributaries (2000 – 2017). Sites are presented upstream to downstream. Bold type denotes tributaries to Keremeos Creek.

Site	Average	Minimum	Maximum	95th percentile	n
E221386	78	46	140	96	37
E221390	141	27	296	199	44
E221339	232	127	341	278	34
E221525	209	83	276	270	34
E221340	348	139	503	429	26
E221526	242	106	310	302	39
E221341	347	142	479	422	35
0500757	296	137	460	395	30

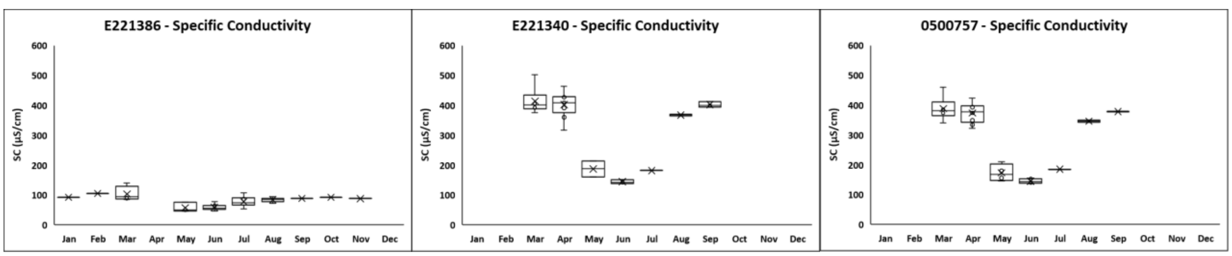

Figure 106: Seasonal variation in specific conductivity (µS/cm) at select sites on Keremeos Creek (2000 – 2017). Sites are presented upstream (E221386) to downstream (0500757).

14.1.5 Turbidity

Turbidity WQOs are set for Keremeos Creek and its tributaries, with downstream conditions being compared against background conditions upstream. The WQOs for Keremeos Creek are an average of 2.5 NTU and a maximum of 5 NTU at the Gunbarrel Intake (E221386). Downstream of E221386 the WQOs are an average increase of 2 NTU and a maximum increase of 8 NTU during clear flow conditions, and an increase of 5 NTU during turbid flow conditions. In Olalla Creek and Cedar Creek, the WQOs are an increase of 1 NTU during clear flows and 5 NTU during turbid flows. The WQOs South Keremeos Creek are an average increase of 2 NTU and a maximum increase of 8 NTU during clear flows and an increase of 5 NTU during turbid flows.

The turbidity data are summarized in Table 141. The data are limited but show a general increasing pattern from upstream to downstream as would be expected. The highest turbidity levels occurred in May and June throughout the watershed. Where data were available, the results were compared to the WQOs to check for attainment (Table 142). Attainment rates varied however most exceedances occurred in May and June during freshet.

Table 141: Summary statistics for turbidity (NTU) at select sites on Keremeos Creek and its tributaries (2000 – 2017). Sites are presented upstream to downstream. Bold type denotes tributaries to Keremeos Creek.

Site	Average	Minimum	Maximum	95th percentile	n
E221386	0.9	0.2	22.3	1.2	56
E221384	9.1	0.5	53.7	46.2	31
E221413	0.8	0.2	3.2	1.6	30
E221387	3.3	0.4	31.0	13.8	29
E221390	6.2	0.3	87.0	19.9	60
E221339	1.2	0.1	6.3	4.6	39
E221525	0.4	0.1	2.3	1.1	39
E221340	2.7	0.4	13.2	11.6	31
E221526	0.6	0.1	6.2	1.6	45
E221341	2.0	0.4	12.4	6.9	44
0500757	3.0	0.3	15.5	9.4	35

Table 142: Summary of attainment rates for turbidity water quality objectives at select sites on Keremeos Creek.

Site	WQO	24 hours	n	30 days	n
E221386	Maximum 5 NTU Average ≤2.5 NTU	95%	56	70%	10
E221384	When background is <8 NTU: 8 NTU increase in 24 hours; 2 NTU increase in 30 days. When background is 8 – 50 NTU: 5 NTU increase. When background is >50 NTU: 10% increase.	68%	31	14%	7
E221387		90%	29	40%	5
E221339		100%	39	50%	2
E221340		94%	31	100%	1
E221341		98%	44	100%	2
0500757		89%	35	50%	2

14.1.6 Total Suspended Solids

Total suspended solids (TSS) WQOs are set for Keremeos Creek and its tributaries, with downstream conditions being compared against the background conditions upstream. The WQO for Keremeos Creek is a maximum of 10 mg/L at the Gunbarrel Intake (E221386). Downstream of E221386 the WQOs are an average increase of 5 mg/L and a maximum increase of 25 mg/L during clear flow conditions, an increase of 10 mg/L when background TSS is 25 mg/L – 100 mg/L, and an increase of 10% when background is >100 mg/L.

The TSS data are summarized in Table 143 and WQO attainment rates are provided in Table 144. As with turbidity, TSS concentrations increased from upstream to downstream with the highest levels reported in May during freshet. The WQOs were met at most sites, however it should be noted that data are limited, and additional data would be needed to properly assess TSS levels. Overall, levels were low with many results reported as less than the MDL.

Table 143: Summary statistics for total suspended solids (mg/L) at select sites on Keremeos Creek and its tributaries (2000 – 2017). Sites are presented upstream to downstream. Bold type denotes tributaries to Keremeos Creek.

Site	Average	Minimum	Maximum	95th percentile	n
E221386	4.6	<1.0	77	7.8	56
E221384	79	4.0	1,470	86	31
E221413	4.5	1.0	11	7.0	31
E221387	17	<1.0	154	70	29
E221390	21	<1.0	294	35	59
E221339	6.1	1.0	30	12	43
E221525	3.9	<1.0	6.0	5.0	38
E221340	7.9	1.0	47	11	31
E221526	4.7	<1.0	16	5.7	44
E221341	8.3	1.0	53	16	40
0500757	9.8	<1.0	66	16	35

Table 144: Summary of attainment rates for total suspended solids water quality objectives at select sites on Keremeos Creek (2000-2017).

<table>
<tr><th>Site</th><th>WQO</th><th>24 hours</th><th>n</th><th>30 days</th><th>n</th></tr>
<tr><td>E221386</td><td>Maximum ≤ 20 mg/L
Average ≤10 mg/L</td><td>95%</td><td>56</td><td>75%</td><td>12</td></tr>
<tr><td>E221384</td><td rowspan="6">When background is <25 mg/L:
25 mg/L increase in 24 hours;
5 mg/L increase in 30 days.
When background is 25 – 100 mg/L:
10 mg/L increase.
When background is >100 mg/L:
10% increase.</td><td>61%</td><td>31</td><td>14%</td><td>7</td></tr>
<tr><td>E221387</td><td>90%</td><td>29</td><td>50%</td><td>6</td></tr>
<tr><td>E221339</td><td>100%</td><td>43</td><td>86%</td><td>7</td></tr>
<tr><td>E221340</td><td>97%</td><td>31</td><td>83%</td><td>6</td></tr>
<tr><td>E221341</td><td>95%</td><td>40</td><td>86%</td><td>7</td></tr>
<tr><td>0500757</td><td>94%</td><td>35</td><td>71%</td><td>7</td></tr>
</table>

14.1.7 Total Dissolved Solids

The total dissolved solids (TDS) WQO for the lower reaches of Keremeos Creek, Olalla Creek, and Cedar Creek is a maximum concentration of 500 mg/L. In South Keremeos Creek, the WQO is a maximum increase of 20% above background levels, however there were no TDS data available for this stream. The available TDS data are summarized in Table 145; all values were below the WQO level.

Table 145: Summary statistics for total dissolved solids (mg/L) at select sites on Keremeos Creek and its tributaries (2000 – 2017). Sites are presented upstream to downstream. Bold type denotes tributaries to Keremeos Creek.

Site	Min	Max	Average	95th Percentile	n
E221339	130	228	171	190	24
E221525	124	220	158	168	19
E221340	186	340	254	280	15
E221526	130	220	170	192	25
E221341	150	320	236	296	33
0500757	188	304	234	273	14

14.2 Nutrients

14.2.1 Phosphorus

There are no WQOs for phosphorus in Keremeos Creek and no WQGs in lotic environments. The available data are summarized in Table 146. Phosphorus concentrations were consistent throughout Keremeos Creek averaging 7 µg/L for total phosphorus at E221386 and 9 µg/L for dissolved phosphorus at 0500757. A maximum total phosphorus value of 148 µg/L at E221390 occurred during freshet conditions in May of 2000.

14.2.2 Chlorophyll a

The WQO for chlorophyll *a* in Keremeos Creek is an average of 50 mg/m^2, based on at least five randomly located samples from natural substrates. The only chlorophyll *a* results available were from samples collected at E221341 in August 2017. The average was 13.9 mg/m^2.

14.2.3 Nitrogen

The WQOs for ammonia are based on the ammonia ALWQGs (ENV 2021d), which decrease with increasing pH and temperature. The most conservative guideline value is an average concentration 102 µg/L based on a water temperature of 20 °C and a pH of 9.0. The ammonia data are summarized in Table 147. The only reported result >102 µg/L was 120 µg/L from Olalla Creek (E221526), which was below the ALWQG value of 571 µg/L based on concurrent measurements of water temperature at 11 °C and pH at 8.3.

The WQOs for nitrite are based on the nitrite ALWQGs (ENV 2021d). The nitrite WQOs are determined by chloride concentrations when the concentration is greater than 2 mg/L, and are set at 0.02 mg/L when chloride concentrations are less than 2 mg/L. Most dissolved nitrite results were at or below the MDLs, and results above the minimum detection level were typically an order of magnitude below the most conservative WQO level.

The nitrate + nitrite WQO for Keremeos Creek, Olalla Creek, and Cedar Creek is a maximum concentration of 10 mg/L, while in South Keremeos Creek, the WQO is a maximum concentration of 100 mg/L and an average concentration of 40 mg/L. All results reported were less than 1 mg/L and well below the WQO. There were no data available for South Keremeos Creek.

Table 146: Summary statistics for phosphorus (µg/L) at select sites on Keremeos Creek and its tributaries (2000 – 2017). Bold type denotes tributaries to Keremeos Creek.

Site	Parameter	Average	Minimum	Maximum	95th percentile	n
E221386	Total P	7	3	33	16	15
E221390	Total P	17	<2	148	38	25
E221339	Dissolved P	7	<2	13	13	10
E221525	Dissolved P	6	2	12	10	11
E221340	Dissolved P	12	3	32	19	10
E221526	Dissolved P	5	2	10	9	11
E243528	Dissolved P	9	2	33	28	14
E243529	Dissolved P	9	2	28	23	14
0500757	Dissolved P	9	2	20	16	10

Table 147: Summary statistics for ammonia (µg/L) at select sites on Keremeos Creek and its tributaries (2000 – 2017). Bold type denotes tributaries to Keremeos Creek.

Site	Average	Minimum	Maximum	95th percentile	n
E221386	10	<5	40	37	28
E221387	12	<5	69	50	25
E221390	8	5	47	10	26
E221339	5	<5	31	<5	40
E221525	7	<5	64	6	45
E221340	11	<5	88	17	31
E221526	11	<5	120	13	49
E221341	15	<5	88	31	46
0500757	8	<5	22	17	31

14.3 Major Ions

14.3.1 Chloride

The dissolved chloride WQO is a maximum concentration of 100 mg/L and applies to the lower reaches of Keremeos Creek. The ALWQG (WLAP 2003) is an average concentration of 150 mg/L and a maximum concentration of 600 mg/L. The available dissolved chloride data are summarized in Table 148. All results were well below the WQO level.

Table 148: Summary statistics for dissolved chloride (mg/L) at select sites on Keremeos Creek and its tributaries (2000 – 2017). Bold type denotes tributaries to Keremeos Creek.

Site	Average	Minimum	Maximum	95th percentile	n
E221386	0.5	0.2	2.2	1.1	32
E221384	9.0	3.6	17	16	21
E221413	13	5.3	37	26	21
E221387	14	45	25	20	29
E221390	16	6.7	31	28	44
E221339	7.9	4.7	10	10	31
E221525	0.66	<0.5	2.4	0.90	21
E221340	8.3	3.7	13	12	20
E221526	0.81	<0.5	3.5	1.5	20
E221341	10	3.5	15	14	20
0500757	6.4	2.9	11	9.7	21

14.3.2 Sulphate

There is no sulphate WQO for Keremeos Creek; the ALWQG (ENV 2013) is based on water hardness and the limited hardness data suggest Keremeos Creek could be categorized as "moderately soft to hard" with a ALWQG value of 309 mg/L (long-term average).

The available sulphate data are summarized in Table 149. All results were well below the ALWQG level.

Table 149: Summary statistics for dissolved sulphate (mg/L) at select sites on Keremeos Creek (2000 – 2017).

Site	Average	Minimum	Maximum	95th percentile	n
E221386	12.7	6.00	17.0	16.8	13
E221384	9.55	5.40	11.3	11.1	13
E221413	8.13	7.30	9.20	8.96	13
E221387	9.44	6.50	12.0	11.0	21
E221390	9.63	6.00	12.0	10.9	23
E221339	25.4	18.7	36.5	32.5	10
0500757	19.2	14.3	23.4	22.7	6

14.4 Metals

The available metals data for Keremeos Creek are very limited with only the total fraction reported. The background site (E221386) has a reasonable data set with results report from to 2010 to 2017. These are summarized in Table 150. Data collected downstream at 0500757 are also presented, however these are limited to five sampling days in May and June 2002 and may overestimate levels given these were likely collected during high flows.

All average metal concentrations were higher at the downstream site than the upstream site except for total nickel which was 1.02 µg/L at E221386 and 0.204 µg/L at the 0500757. Total aluminum and total copper were higher downstream, but the ALWQG is based on the dissolved fraction, and this was not reported. Also, the dependent parameters (DOC, pH, hardness) required for some guidelines were not measured further complicating the assessment. Additional and more complete monitoring would be useful to determine if these and other metals are of concern in Keremeos Creek.

14.5 Microbiological

WQOs were set for fecal coliforms at E221386 (90th percentile ≤10 CFU/100 mL) and throughout the lower reaches (90th percentile ≤100 CFU/100 mL). There are also WQOs specified for Olalla Creek and Cedar Creek (90th percentile ≤10 CFU/100 mL), and South Keremeos Creeks (90th percentile ≤200 CFU/100 mL). Table 151 summarizes attainment rates for the fecal coliform WQOs and includes results for *E. coli* (considered a more reliable indicator of risks to human health) using the same numerical value as the fecal coliform WQO for a benchmark, with the sites presented upstream to downstream. The results are based on 90th percentile calculations from 5 results collected within a 30-day period.

The results suggest that fecal indicator levels can be elevated, even at the upstream background site (E221386). Attainment rates were >50% throughout most of the watershed except for E221341 where the fecal coliform WQO was never met, and the *E. coli* levels only met the desired benchmark 14% of the time.

Table 150: Summary statistics for total metals data (µg/L) at select sites on Keremeos Creek. Sites are presented upstream to downstream.

Metal	E221386					0500757				
	Avg.	Min	Max	95th percentile	n	Avg.	Min	Max	95th percentile	n
Aluminum	43	13	137	123	20	127	45	199	188	5
Arsenic	0.261	0.200	0.360	0.341	20	0.920	0.800	1.10	1.10	5
Cadmium	0.009	0.005	0.020	0.015	20	0.014	<0.010	0.030	0.022	5
Chromium	0.161	<0.100	0.300	0.300	20	0.280	<0.200	0.500	0.420	5
Cobalt	0.050	0.024	0.155	0.122	20	0.160	<0.005	0.030	0.022	5
Copper	0.685	0.389	2.02	1.27	20	1.58	1.04	2.31	2.22	5
Lead	0.028	0.006	0.095	0.088	20	0.204	0.060	0.390	0.342	5
Manganese	3.39	1.53	14.0	5.87	20	20.8	7.88	34.5	31.6	5
Molybdenum	0.936	0.601	1.17	1.61	20	1.04	0.880	1.18	1.18	5
Nickel	1.02	0.780	1.73	1.46	20	0.204	0.060	0.390	0.342	5
Selenium	0.197	0.160	0.242	0.240	20	0.420	0.300	0.500	0.500	5
Uranium	0.041	0.023	0.111	0.076	20	0.226	0.161	0.360	0.302	5
Zinc	0.819	0.310	2.24	2.01	20	3.54	<0.100	9.80	8.44	5

Table 151: Attainment rates for fecal coliforms and E. coli *WQOs on Keremeos Creek and tributaries (2000-2017). Sites are presented upstream to downstream. Bold type denotes tributaries to Keremeos Creek.*

Site	WQO (CFU/100 mL)	Fecal coliform	n	*E. coli*	n
E221386	≤10	73%	11	50%	8
E221387	≤100	Insufficient data		100%	1
E221390	≤100	100%	5	100%	6
E221339	≤100	100%	4	100%	4
E221525	≤10	75%	4	67%	6
E221340	≤100	40%	5	80%	5
E221526	≤10	50%	4	71%	7
E221341	≤100	0%	5	14%	7
0500757	≤100	17%	6	50%	6

14.6 Keremeos Creek Summary

The available water quality data for Keremeos Creek and its tributaries are limited and were collected inconsistently, therefore a proper assessment of the conditions is not possible at this time. The results were generally within WQO and WQG levels but did indicate a pattern of increasing levels from upstream to downstream. Summer water temperature increased spatially with downstream temperatures in August potentially exceeding the WQO at the most downstream site. Suspended solids concentrations and metals concentrations also increased from upstream to downstream.

15. CONCLUSIONS

In the Similkameen River mainstem, most parameters increased in concentration from upstream to downstream, with the highest levels usually occurring during freshet when snowmelt and overland runoff peak. Parameters that exceeded WQGs or WQOs include aluminum, cobalt, copper, iron, and lead, although aluminum may be naturally elevated. Molybdenum, selenium, and uranium concentrations appear to be influenced by groundwater inputs and reduced dilution during low flow conditions but remained below WQGs. Benthic invertebrate results showed an increase in abundance and a decline in sensitive taxa from upstream to downstream, consistent with the increase in total phosphorus.

Water quality in the Tulameen River was generally within acceptable limits. Some drinking water guidelines were exceeded during turbid flows, but overall, the reported results were generally below guideline levels. More data are required for a proper assessment.

The water quality of Wolfe Creek changed substantially downstream of CMM. Several parameters exceeded WQGs or WQOs, including TDS, sulphate, nitrate, copper, manganese, and molybdenum, however conditions improved with increasing distance from the mine. Phosphorus was also elevated downstream, relative to upstream concentrations. Data were limited to sites upstream of Lorne Lake, and the condition of Lorne Lake, Issitz Lake, and Wolfe Lake could not be assessed.

The water quality in Hedley Creek was within acceptable limits. Sulphate and cobalt were higher downstream of the discharge from the Nickel Plate Mine and appear to be influenced by groundwater. Cobalt frequently exceeded the WQG.

In the Cahill Creek watershed, specific conductance, hardness, and TDS were high in Nickel Plate Mine Creek and increased in Sunset and Cahill Creeks downstream of the confluence. Arsenic, cobalt, and selenium exceeded the WQGs. Cobalt has decreased over time, whereas selenium has increased. The concentrations of these parameters were lowest during freshet, suggesting inputs from groundwater.

In Red Top Gulch Creek, TDS exceeded the WQO, and arsenic, cobalt, iron, selenium, and uranium exceeded the WQGs. Specific conductance, arsenic, cobalt, and iron were higher at the upstream site compared to downstream, whereas selenium and uranium showed the opposite pattern. Cobalt and uranium have increased substantially in recent years.

More data are required for a proper assessment of water quality in the Ashnola River.

Data were limited for Keremeos Creek. Most parameters were generally within WQGs or WQOs but increased from upstream to downstream.

REFERENCES

CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Water Quality Guidelines for the Protection of Aquatic Life - Chromium. Canadian Council of Ministers of the Environment, Winnipeg. Available at: https://ccme.ca/en/res/chromium-en-canadian-water-quality-guidelines-for-the-protection-of-aquatic-life.pdf

CCME (Canadian Council of Ministers of the Environment). 2003. Canadian water quality guidelines for the protection of aquatic life: Inorganic mercury and methylmercury. In: Canadian Environmental Quality Guidelines, 1999. Canadian Council of Ministers of the Environment, Winnipeg.

CCME (Canadian Council of Ministers of the Environment). 2004. Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. Available at: https://ccme.ca/en/res/phosphorus-en-canadian-water-quality-guidelines-for-the-protection-of-aquatic-life.pdf

CCME (Canadian Council of Ministers of the Environment). 2015. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Silver. Available at: https://ccme.ca/en/res/silver-en-canadian-water-quality-guidelines-for-the-protection-of-aquatic-life.pdf

EC (Environment Canada). 2012. Canadian Aquatic Biomonitoring Network: Field Manual for Wadeable Streams. Available at: https://publications.gc.ca/collections/collection_2012/ec/En84-87-2012-eng.pdf

EC (Environment Canada). 2014. CABIN Laboratory Methods: Processing, Taxonomy, and Quality Control of Benthic Macroinvertebrate Samples. Environment Canada, May 2014. Available at: https://publications.gc.ca/site/eng/9.895039/publication.html

EC (Environment Canada). 2017. Federal Environmental Quality Guidelines – Cobalt. Available at: https://www.ec.gc.ca/ese-ees/92F47C5D-24F5-4601-AEC0-390514B3ED75/FEQG%20Cobalt%20Final%20EN.pdf

ECCC (Environment and Climate Change Canada). 2022. Federal Environmental Quality Guidelines – Aluminum. Available at: https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/federal-environmental-quality-guidelines-aluminium.html

ENV (Ministry of Environment). 1985. Similkameen River Sub-Basin Water Quality Assessment and Objectives. Technical Appendix. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-objectives/wqo_report_similkameen.pdf

ENV (Ministry of Environment and Parks). 1987. Cahill Creek and its Tributaries: Water Quality Assessment and Objectives. Technical Appendix. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-objectives/wqo_tech_cahill.pdf

ENV (Ministry of Environment and Climate Change Strategy). 1990. Ambient Water Quality Objectives for the Similkameen River Okanagan Area. First Update. Overview Report. Water Protection and Sustainability Branch. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-objectives/similkameen_river_okanagan_area.pdf

ENV (Ministry of Water, Land and Air Protection). 1997. Ambient Water Quality Criteria for Dissolved Oxygen. Overview Report. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/dissolvedoxygen-or.pdf

ENV (Ministry of Water, Land and Air Protection). 1998. Ambient Water Quality Criteria for Organic Carbon in British Columbia. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/organic-carbon-tech.pdf

ENV (Ministry of Environment, Lands and Parks). 2000. Keremeos Watershed Water Quality Assessment and Objectives. Technical Appendix. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-objectives/wqo_tech_keremeos.pdf

ENV (Ministry of Environment, Lands and Parks). 2001a. Towards a Water Quality Guideline for Temperature in the Province of British Columbia. Prepared by G.G. Oliver and L.E. Fidler, Aspen Applied Sciences Ltd., Cranbrook, B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/temperature-tech.pdf

ENV (Ministry of Environment). 2001b. Ambient Water Quality Guidelines for Manganese. Overview Report. Prov. BC., Victoria B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/manganese-or.pdf

ENV (Ministry of Environment). 2001c. Ambient Water Quality Guidelines for Mercury. Overview Report – First Update. Environment and Lands Headquarters Division. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_env_mercury_waterqualityguideline_overview.pdf

ENV (Ministry of Water, Land and Air Protection). 2004. Technical Report – Water Quality Guidelines for Cobalt. Water, Air and Climate Change Branch. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/cobalt_tech.pdf

ENV (Ministry of Environment). 2008. Ambient Water Quality Guidelines for Iron. Technical Appendix. Ministry of Environment, Science and Information Branch, Water Stewardship Division. Victoria, B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/iron-tech.pdf

ENV (Ministry of Environment). 2009. Water Quality Guidelines for Nitrogen (Nitrate, Nitrite, and Ammonia). Addendum to Technical Appendix. Ministry of Environment, Water Stewardship Division. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/nitrogen-addendum.pdf

ENV (Ministry of Environment). 2013. Ambient Water Quality Guidelines for Sulphate. Technical Appendix. Water Protection and Sustainability Branch. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/sulphate/bc_moe_wqg_sulphate.pdf

ENV (Ministry of Environment). 2014. Ambient Water Quality Guidelines for Selenium. Technical Report Update. Water Protection and Sustainability Branch. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_moe_se_wqg.pdf

ENV (Ministry of Environment). 2015. Ambient Water Quality Guidelines for Cadmium – Technical Report. Water Protection & Sustainability Branch, B.C. Ministry of Environment. Available at: /cadmium https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/cadmium.pdf

ENV (Ministry of Environment and Climate Change Strategy). 2019a. Copper Water Quality Guideline for the Protection of Freshwater Aquatic Life-Technical Report. Water Quality Guideline Series, WQG-03-1. Prov. B.C., Victoria BC. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/copper/bc_copper_wqg_aquatic_life_technical_report.pdf

Ministry of Environment and Climate Change Strategy (ENV). 2019b. B.C. Recreational Water Quality Guidelines: Guideline Summary. Water Quality Guideline Series, WQG-02. Prov. B.C., Victoria B.C. Water Protection and Sustainability Branch. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/drinking-water-and-recreation/recreational_water_quality_guidelines_bcenv.pdf

ENV (Ministry of Environment and Climate Change Strategy). 2020a. B.C. Source Drinking Water Quality Guidelines.: Guideline Summary. Water Quality Guideline Summary. Water Quality Guideline Series, WQG-01. Prov. B.C., Victoria, B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/drinking-water-and-recreation/source_drinking_water_quality_guidelines_bcenv.pdf

ENV (Ministry of Environment and Climate Change Strategy). 2020b. Biomonitoring Assessment of the Similkameen River Watershed. Water Protection and Sustainability Branch. Prov. B.C., Victoria, B.C.

ENV (Ministry of Environment and Climate Change Strategy). 2021a. pH Water Quality Guidelines (Reformatted Guideline from 1991). Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_env_ph_waterqualityguidelines_technical.pdf

ENV (Ministry of Environment and Climate Change Strategy). 2021b. B.C. Working Water Quality Guidelines: Aquatic Life, Wildlife and Agriculture. Water Quality Guideline Series, WQG-08. Prov. B.C., Victoria B.C. Water Protection and Sustainability Branch. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/bc_env_working_water_quality_guidelines.pdf

ENV (Ministry of Environment and Climate Change Strategy). 2021c. Ambient Water Quality Guidelines for Turbidity and Suspended and Benthic Sediments (Reformatted from original 1997 version). Water Quality Guideline Series, WQG-18. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_env_turbidity_waterqualityguideline_technical.pdf

ENV (Ministry of Environment and Climate Change Strategy). 2021d. Nitrogen Water Quality Guidelines (reformatted from: British Columbia Ministry of Environment and Parks, 1986. Water Quality Criteria for Nitrogen (Nitrate, Nitrite, and Ammonia)). Water Quality Guideline Series, WQG-15. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_env_nitrate_waterqualityguideline_technical.pdf

ENV (Ministry of Environment and Climate Change Strategy). 2021e. Cyanide Water Quality Guidelines (Reformatted from: British Columbia Ministry of Environment, Lands and Parks, 1988. Water quality criteria for cyanide). Water Quality Guideline Series, WQG-11. Prov. BC., Victoria B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_env_cyanide_waterqualityguideline_technical.pdf

ENV (Ministry of Environment and Climate Change Strategy). 2021f. Ambient Water Quality Guidelines for Arsenic. Overview report. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_env_arsenic_waterqualityguideline_overview.pdf

ENV (Ministry of Environment and Climate Change Strategy). 2021g. Lead Water Quality Guidelines (reformatted from: British Columbia Ministry of Environment and Parks, 1987. Water quality criteria for lead). Water Quality Guideline Series, WQG-12. Prov. BC., Victoria B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_env_lead_waterqualityguideline_technical.pdf

ENV (Ministry of Environment and Climate Change Strategy). 2021h. Molybdenum Water Quality Guidelines for the Protection of Freshwater Aquatic Life, Livestock, Wildlife and Irrigation, Water Quality Guideline Series, WQG-07. Prov. B.C., Victoria B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/molybdenum/bc_env_molybdenum_waterqualityguideline_technical.pdf

Sylix Nation. 2014. Syilx Nation *Siwɬkʷ* Declaration. Available at: https://www.syilx.org/wp/wp-content/uploads/2016/11/Okanagan-Nation-Water-Declaration_Final_CEC_Adopted_July_31_2014.pdf

WLAP (Ministry of Water, Land and Air Protection). 1996. Ambient Water Quality Criteria for Silver. Water Quality Branch, Ministry of Water, Land and Parks. Victoria B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/silver-tech.pdf

WLAP (Ministry of Water, Land and Air Protection). 2003. Ambient Water Quality Guidelines for Chloride – Overview. Water, Air and Climate Branch, Ministry of Water, Land and Air Protection. Available at:

https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/chloride-or.pdf

WLAP (Ministry of Water, Land and Air Protection). 2004. Technical Report – Water Quality Guidelines for Cobalt. Water, Air and Climate Change Branch, Ministry of Water, Land and Air Protection. Victoria B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/cobalt_tech.pdf

WLRS (Ministry of Water, Land, and Resource Stewardship). 2023a. Aluminum Water Quality Guidelines – Freshwater Aquatic Life. Water Quality Guideline Series, WQG-09-1. Prov. B.C., Victoria B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/aluminum/bc_aluminum_water_quality_guidelines_-_aquatic_life.pdf

WLRS (Ministry of Water, Land, and Resource Stewardship). 2023b. Derivation of Screening Values for Contaminants in Fish Tissue. Prov. B.C., Victoria B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-reference-documents/bc_fish_tissue_screening_derivation_feb_2023.pdf

WLRS (Ministry of Water, Land, and Resource Stewardship). 2023c. *In draft*. Nickel Water Quality Guidelines for the Protection of Freshwater Aquatic Life – Technical Report. Water Quality Guideline Series, WQG-21. Prov. B.C., Victoria B.C. Available at:

WLRS (Ministry of Water, Land, and Resource Stewardship). 2023d. Zinc Water Quality Guidelines – Freshwater Aquatic Life. Water Quality Guideline Series, WQG-19-1. Prov. B.C., Victoria B.C. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_water_quality_guideline_zinc_aquatic_life.pdf