MPERG Report 2007-5

2006 Regional Water Quality, Sediment and Benthic Invertebrate Assessment for the South MacMillan River Watershed, MacMillan Pass, Yukon

By

Gartner Lee Limited

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Prepared for:

Mining and Petroleum Environmental Research Group (MPERG)

Submitted by:

Gartner Lee Limited
April 2007

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Table of Contents

Letter of Transmittal

Page

1. Introduction and Project Objective 1

2. Methods 1

2.1 Water Quality and Stream Flow Sampling 1
2.2 Sediment Sampling 2
2.3 Benthic Invertebrates 3

3. Results and Discussions 3

3.1 Water Quality 3
3.2 Geological Considerations 5
3.3 Stream Sediment 6
3.4 Benthic Invertebrates 7

4. Conclusion 7

5. Recommendation 8

6. Acknowledgements 8

7. References 10

List of Figures

Back of Report

List of Tables

Back of Report

Appendix A – photo log

Back of Report

1. Introduction and Project Objective

The Macmillan Pass in east-central Yukon (Figure 1) near the border with the Northwest Territories, is a highly mineralized area. The significant presence of metallic minerals in the MacMillan Pass area is reflected by the naturally elevated metal concentrations in both the soil and water (Soroka and Jack 1983, Kwong and Whitley 1993). A recent surge in metal prices has sparked renewed interest in mineral exploration and development at MacMillan Pass. Consequently, a broader understanding of the regional stream geochemistry is particularly important to help establish environmentally meaningful water quality objectives for the region.

The objective of this project was to carry out a regional water quality, stream sediment quality, and benthic invertebrate 'snapshot' assessment of the upper South Macmillan watershed.

2. Methods

2.1 Water Quality and Stream Flow Sampling

The sampling program consisted of 19 sites that were visited in the field on July 10th to July 12th, 2006. All samples were collecting using stream sampling protocols. Samples of general chemistry (500 mL), total (250 mL) and dissolved metals (125 mL) were collected at each site. Where possible samples were collected from mid-stream and approximately 20 cm under the surface. All samples were collected with the mouth of the sampling bottle facing upstream.

Appropriate measures were taken to prevent sample contamination from all sources: all bottle sets were comprised of laboratory polyurethane bottles, total and dissolved metal samples were preserved with certified, pure, pre-measured nitric acid preservative and field staff wore disposable latex gloves when sampling. Samples were collected by appropriately trained personnel and labeled, preserved, stored and shipped according to the relevant sampling protocol. Dissolved metals were vacuum filtered in the field through 0.45 micron disposable filterware and preserved with nitric acid immediately after filtration. *Insitu* data, including pH, conductivity, dissolved oxygen, and temperature, were collected using a YSI multi-probe (556) The multi-probe was rinsed thoroughly at the end of each day and calibration was checked every other day.

All samples were kept cold (between 0 and 4ºC), but not allowed to freeze, at all times between sample collection and delivery to the laboratory. Samples were shipped to Vancouver via Air

North Cargo to Environment Canada laboratory in Vancouver, British Columbia. Chain of custody forms was prepared and accompanied the samples.

Quality assurance/quality control protocols are a necessary component to any environmental sampling program. For the purposes of maintaining data quality, field replicates were collected. Replicate samples provide a measure of repeatability of sampling. Replicate samples were collected at a frequency of 10 % of the total number of water samples. Replicate sample locations were chosen randomly and two samples collected sequentially at each for each field visit.

Velocity was primarily measured using a Marsh-McBirney Flow-mate 2000. Discharge calculations were conducted following the United States Geological Survey (USGS) mid-section method. The width of the stream was divided into panels depending on the total width of the stream and the variation in velocity across the section. A velocity measurement was taken in the middle of each panel. In most instances the number of panels was such that only between 5% to 10% of the flow passed though each panel. Only at locations where the velocity and depth were very uniform did each panel include up to 15% to 20% of the discharge. Velocity measurements were taken at 60% of the total depth at each measurement point in the cross section. At points with depths greater than 40 cm, two velocity measurements were taken: one at 20% of the total depth and the other at 80% of the total depth. The velocity was calculated at each point and the average of the two flows was used as the contribution of flow from that panel.

At sites were flow was too deep/fast to measure using the Marsh-McBirney velocity meter, the float method was employed. To calculate flow using the float method, a floating object was placed within the water and its travel time over a fixed distance downstream was recorded.

2.2 Sediment Sampling

The stream bottom sediment was collected at all 19 water quality sample locations using established protocol from depositional areas of the streams (RIC 1994). Where possible stream sediment samples were collected directly by using the jar provided by the analytical lab as a scoop. Observations were noted after the sample was collected and capped. For all sediment sample collection, the inside of sample containers were not touched by anything other than the sample itself. The sample containers were kept in a clean area, away from dust, dirt, fumes and fuel. Field staff wore disposable latex gloves while collecting the sample. All samples were preserved with 90% ethanol and kept cold until arrival at the Environment Canada lab in Vancouver, British Columbia.

2.3 Benthic Invertebrates

Benthic invertebrate samples were collected from 12 locations in the South MacMillan Watershed. The collection of individuals consisted of a three-minute kick and sweep survey conducted along a representative section of the stream (approx. 10 m^2 area). The full sample was stored wet in a plastic jar. All samples were stored in the dark until transport to the Environment Canada laboratories in Vancouver British Columbia for taxonomic identification and enumeration. Once at the laboratory, the entire sample (due to low numbers present) was sampled with a Marchant box sub-sampler. The lab guarantees a minimum sorting efficiency of 95%.

3. Results and Discussions

3.1 Water Quality

The summary for sample site location specifics, including: GPS coordinates, pH, conductivity, and streamflow are shown in table 1. The water quality summaries of general chemistry parameters, total metals and dissolved metals are displayed in tables 2 through 4, respectively. Figure 2 shows the downstream trend in pH along the South MacMillan River (starting at 1 km - site M7). The blue line represents the pH trend along the mainstem of the South MacMillan, whereas the red dots indicate pH values for tributaries at the point of entry into the mainstream.

In general, the pH of the South MacMillan River gradually increases from downstream to upstream (Figure 2). However, it's apparent that several tributaries have a strong, local influence on the pH of the mainstem of the South MacMillan. For example, the relatively high pH recorded at tributary M1 (7.6) appears to increase the pH along the mainstem of the South MacMillan until the acidic conditions of tributary M2 (3.3) lower the pH in the mainstem. This pattern repeats itself as alkaline conditions from tributaries M5 (8.0) and M6 (7.8) cause the pH to increase drastically within the mainstem of the South MacMillan. A short ways downstream however, the two most acidic creeks that were sampled; M9 (Sekie #2 - 2.9) and M11 (MacIntosh Creek - 2.9), immediately lowers the pH in the mainstem of the South MacMillan. The pH slightly increases within the mainstem of the South MacMillan for the last 45 km within the study area (Figure 2). This trend suggests that all other unsampled tributaries within the study area are low pH as well, keeping the overall pH depressed in the mainstem.

Figures 3 through 6 display the downstream trends in total zinc, copper, arsenic and cadmium respectively. The blue line on figures 3 to 6 represent the zinc, copper, arsenic, and cadmium levels recorded in the mainstem of the South MacMillan River, whereas the red dots represent these metal values for tributaries at the point of entry into the mainstream. The dashed black line represents the CCME Aquatic Life guideline value for the metal in question.

The general downstream trend of total zinc concentration within the mainstem of the South MacMillan river (Figure 3) is fairly consistent when comparing the most upstream site (M7 – 0.489 mg/L) to the most downstream site (M21 – 0.354 mg/L). However, there is a notable spike (increase by a factor or 10) in total zinc concentration at mainstem sites M24 (3.696 mg/L) and M25 (3.634 mg/L), which is most likely due to the high total zinc concentrations that enter the South MacMillan river from tributaries M9 (Sekie #2 - 8.78 mg/L) and M11 (MacIntosh - 5.49 mg/L). Downstream of Sekie #2 (M9) and MacIntosh Creek (M11) the concentration of zinc decreases within the South MacMillan River as tributaries that are relatively lower in zinc (M13 and M20) dilute the mainstem concentration of zinc back to background levels (e.g. on the order of 0.3 to 0.5 mg/L).

Figure 4 illustrates the downstream trend in total copper along the South MacMillan River. Overall, the trend in copper concentration appears to slightly decrease downstream in the South MacMillan River. Tributary M2 (0.14 mg/L) appears to increase the concentration of copper within the mainstream of the South MacMillan River between sites M22 (0.0238 mg/L) and M23 (0.066 mg/L). However, the two sites with the highest concentration of copper; M9 (0.256 mg/L) and M11 (0.508 mg/L), Sekie #2 and MacIntosh Creeks respectively, do not appear to increase the total zinc concentration within the mainstem of the South MacMillan measurably (Figure 4).

Figure 5 displays the downstream trend in total arsenic concentrations along the South MacMillan River. Total arsenic is first detected in the mainstem of the South MacMillan River at site M23, which is likely due to the presence of arsenic entering the mainstem from tributary M2. The concentration of arsenic reaches its highest level in the mainstem of the South MacMillan river at site M25 (0.0008 mg/L), due to the high levels of arsenic (exceeding CCME Aquatic Life guidelines) found upstream at tributaries M9 (Sekie #2 - 0.0085 mg/L) and M11 (MacIntosh Creek - 0.0361 mg/L). Downstream of site M25, the concentration of arsenic in the South MacMillan River appears to stabilize around 0.0006 to 0.0008 mg/L.

The downstream trend in total cadmium for the South MacMillan watershed is shown in figure 6. Overall, the concentration of cadmium is constant from the most upstream site on the MacMillan River (M7 – 0.00821) to the most downstream site (M21 – 0.00684). The concentration of cadmium along the South MacMillan River does increase slightly at M23 through to M24 (figure 6), a likely result from the high concentrations of cadmium entering at this point along the mainstem from sites M2 (0.0309), M9 (0.238) and M11 (0.156). The concentration of cadmium at all sites sampled greatly exceeded the CCME guideline recommended concentration of 0.000017 mg/L.

As seen in Figures 3 through 6, sites M9 (Sekie #2) and M11 (MacIntosh Creek) contain the highest concentrations of zinc, copper, arsenic and cadmium, and the lowest pH (figure 2) in comparison to all other sample sites respectively. In addition, sites M9 and M11 also contain the highest concentrations of aluminum, beryllium, boron, chromium, cobalt, lithium, manganese, nickel, selenium, thallium and uranium than any other site sampled. The majority of the concentrations for all metals at all sites occur within the dissolved phase.

Past water quality studies in the South MacMillan area have identified similar trends to those presented here. In particular, Sekie #2 (M9) and MacIntosh Creek (M11) have been routinely identified as acidic streams that contribute high concentration of dissolved copper, zinc and cadmium to the South MacMillan River (Soroko and Jack 1983, Kwong and Whitley 1993). In addition, Kwong and Whitley (1992) also noted a tributary in the upper reaches of the South MacMillan watershed (M2 is this study) as being an acidic stream with high concentrations of cadmium, copper, and zinc.

3.2 Geological Considerations

Figure 7 illustrates the various geological bedrock formations that form the South MacMillan watershed. Reviewing the stream chemistry data (tables 2 through 4) within the context of geological bedrock types, its possible to better explain the variations seen among the water quality sites sampled within the South MacMillan watershed. The Tom Sequence in Figure 6 represents black fissile shale that was formed under anoxic conditions and has little to no buffering capacity (Abbott 1983). This black shale contains pyrite up to 2%; an extremely high concentration. This black shale weathers quite rapidly, allowing the formation of sulfuric acid in the presence of water. Tributaries with portions of their watershed that have eroded through the Tom Sequence (shown in dark purple on Figure 7) are characterized by low pH, low alkalinity, and high concentrations of dissolved metals. As mentioned earlier, the pH in the South MacMillan remains depressed through the lower reaches (Figure 2), this is likely the result of tributaries draining the west side of the South MacMillan valley which are eroding through the Tom Sequence deposit (Figure 7).

Tributary sites with a significant portion of their watershed within the Tom Sequence include: M2, M9 (Sekie #2), M11 (MacIntosh Creek) and M18. It is interesting to note, that site M9 (Sekie #2) is currently receiving acid water drainage from the Tom Valley property and consequently exhibits a low pH and high dissolved metal concentrations. Sites M2 and M11 (MacIntosh Creek) however, are not receiving acid mine drainage and are their natural state, yet exhibit very similar stream chemistry to Sekie #2 (M9). On the north side of the South MacMillan watershed there are tributaries that have a portion of their watershed eroding the Rabbittkettle formations, which is composed of limestone's, and are characterized by high pH, high alkalinity and lower levels of dissolved metal concentrations. Tributary sites M1, M5 and

M6 have a portion of their watershed eroding through the Rabbittkettle formations and are characterized by high pH, high alkalinity and relatively low metal concentrations, similar results were found by Kwong and Whitley (1992). These tributaries provide local, limited buffering capacity to the South MacMillan River. However, this limited buffering capacity is insufficient to raise the mainstem to a neutral pH.

3.3 Stream Sediment

Table 5 displays the stream sediment metal concentrations for all sites sampled. Figures 8 through 12 illustrate the downstream trends in stream sediment concentration for zinc, copper, arsenic, cadmium, and lead respectively. The blue line represents the stream sediment concentrations in the mainstem of the South MacMillan River, whereas the red dots represent the stream sediment concentrations in tributaries at point of entry into the South MacMillan River. The black dashed line represents the Interim Sediment Quality Guidelines (ISQG) for the metal in question (ISQG 2006).

The highest concentration of zinc within the stream sediments (figure 8) was found at tributary M1, slightly downstream the South MacMillan River the zinc concentration increases as well (M22). After this point the concentration of zinc within the South MacMillan River remains elevated above the ISQG guideline level to the furthest downstream point sampled – M15. The highest concentrations of zinc were found at tributary sites M18 and M20 (Table 5).

Figure 9 shows the concentration of copper within the stream sediments along the South MacMillan watershed. Within the mainstem of the South MacMillan River, the concentration of copper is elevated above the ISWG guidelines and remains fairly constant downstream. The lowest concentration of copper in the stream sediment was found at tributary sites M9, M11 and M13.

Figure 10 represents the downstream trend in arsenic concentration within stream sediments along the South MacMillan watershed. The level of arsenic found at all sites exceeded the recommended concentration suggested by the ISQG. The concentration of arsenic along the mainstem of the South MacMillan River remains fairly constant along the entire study area.

Figure 11 shows the downstream sediment trend in cadmium along the South Macmillan watershed. Site M1 has the highest concentration of cadmium of all sites sampled. Immediately downstream on the mainstem there is an abrupt rise in cadmium found within the sediment at site M22 along the South MacMillan River. Downstream of site M22 the cadmium concentration in the stream sediment gradually decreases (Figure 11). The concentration of cadmium slightly increase at the mainstem site M26.

Figure 12 shows the downstream sediment trend in lead along the South MacMillan watershed. In general, the concentration of lead within the stream sediments of the South MacMillan river gradually increases downstream. Site M9 (306) has the highest concentration along with mainstem site M25 (46.5), which both exceed ISQG guidelines for lead concentrations.

In general it appears that the pH of tributaries entering the mainstem of the South MacMillan River are responsible for the concentration of zinc and cadmium observed within the stream sediments. For example, tributary M1 raised the pH in the mainstem at site M22 (Figure 2); allowing zinc and cadmium to precipitate on the stream bed. In fact, the entire downstream trend of zinc (Figure 8) and cadmium (Figure 11) concentrations within the South MacMillan River are very similar to the pH trend observed in Figure 2. In contrast, sites M9 (Seki #2) and M11 (MacIntosh Creek) are associated with low pH, yet display high arsenic concentrations within the stream sediments.

3.4 Benthic Invertebrates

Figures 13 and 14 display the benthic invertebrate diversity (# of order per site) and abundance (# of organism) for each site sampled. In regards to diversity, site M7 and M1 have the most diversity of benthic invertebrates (Figure 13), with three different classes of invertebrates found for each site. With the exception of site M2 (two orders found), all other sites only contained one order of benthic invertebrates (Figure 13). Sites M7 and M2 contain the highest number of benthic invertebrates found for all sites (Figure 14). Overall the abundance and diversity of benthic invertebrates shown in figures 13 and 14 are quite low in comparison to other rivers in the Yukon. The values of abundance and diversity of benthic invertebrates shown here a consistent with past studies along Sekie #2 (M9) and MacIntosh (M11) Creek (Soroka and Jack 1983).

It is interesting to note that site M2 was observed to have the highest abundance (Figure 14) of benthic invertebrates and the second highest diversity (Figure 13), yet this site was also characterized as having a low pH (Figure 2) and high dissolved metal concentrations. This result suggests that other environmental factors (stream morphology, sediment size, sediment mobility) are influencing the benthic invertebrate population here.

4. Conclusion

The water and sediment quality characteristics of the South MacMillan watershed are dominated by the regional geology. The Tom Sequence geologic formation has created naturally acidic stream conditions that are characterized by high concentrations of dissolved metals (zinc, copper arsenic, and cadmium in particular). Although Sekie Creek #2 (M9) is receiving acidic drainage from an old exploration adit, other creeks in their natural state and within the same area (M11 and M2) are equally acidic and contain high concentrations of dissolved metals. Tributaries draining portions of the Tom Sequence have a profound influence on the stream and sediment chemistry along the mainstem of the South MacMillan River. In addition, tributaries draining the north side of the South MacMillan watershed (M5 and M6) provide local, but insufficient buffering capacity for the South MacMillan River. Overall however, the South MacMillan River (at the most downstream site M21) is acidic and contains numerous dissolved metal concentrations that exceed CCME water quality and ISQG guidelines. These unique stream characteristics provide poor environmental conditions for benthic invertebrates to thrive, as shown by data presented here (figures 13 and 14) and by past studies (Soroka and Jack 1983).

In regards to potential mining exploration and development activities in the South MacMillan watershed, it is recommended that the unique and natural water quality characteristics are considered when establishing water quality objectives for future mining activities that may be proposed for the area. For example, treating drainage water according to CCME guidelines without considering the ambient water quality characteristics of the South MacMillan River would result in treated water being completely different in chemistry than water naturally occurring in the environment. This scenario could cause ecological consequences to the surrounding area's unique aquatic ecosystems.

5. Recommendation

It is recommended that a routine water quality and benthic invertebrate assessment be established to provide a regional context for the development of representative water quality objectives for this unique environment. In addition to yearly water quality monitoring, we recommend that a comprehensive analysis of the hydrology of the South MacMillan watershed would be necessary to properly quantify mineral loadings within the South MacMillan River. This would also help determine which tributaries are contributing the most to the water quality within the mainstem of the South Macmillan River.

6. Acknowledgements

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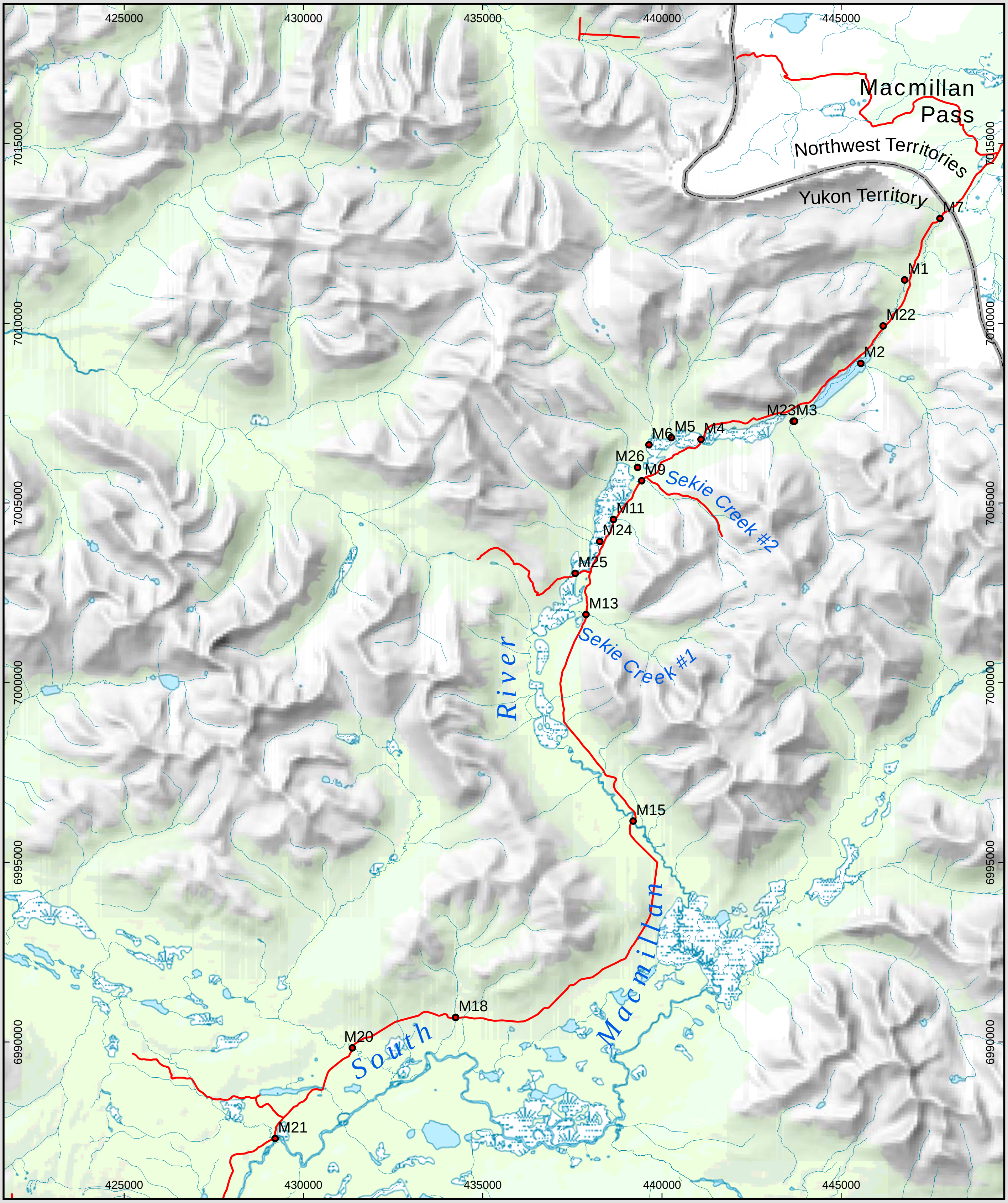
List of Figures



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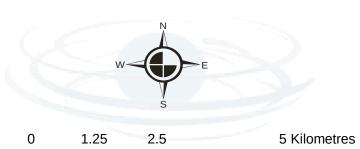
- Territorial Boundary
- River
- Road
- Wetland
- Lake
- Veg



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NAD83 Albers

Macmillan Pass
MPERG

July 2006
Sample Locations

Proj # 60567

Gartner Lee

Figure1
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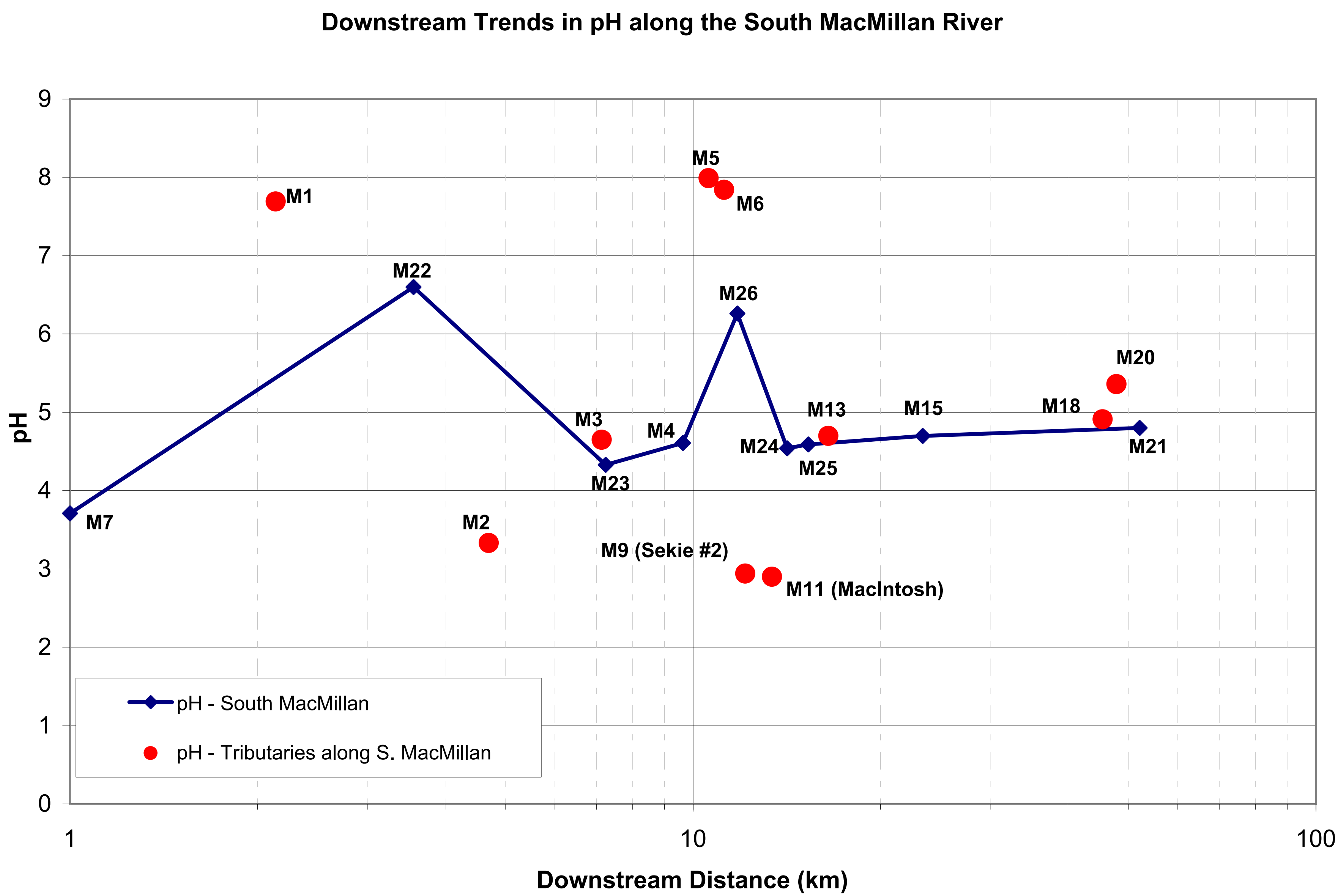
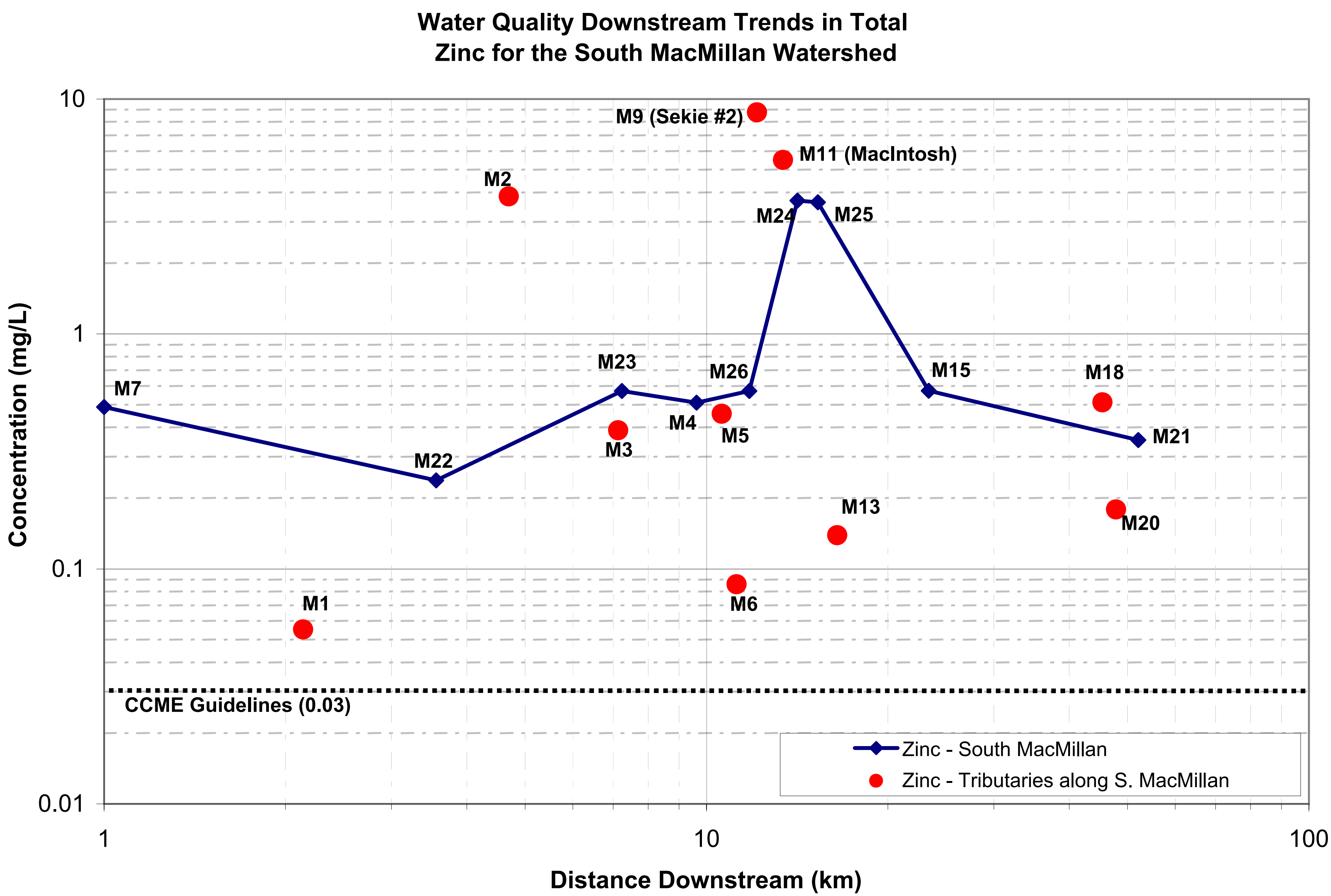


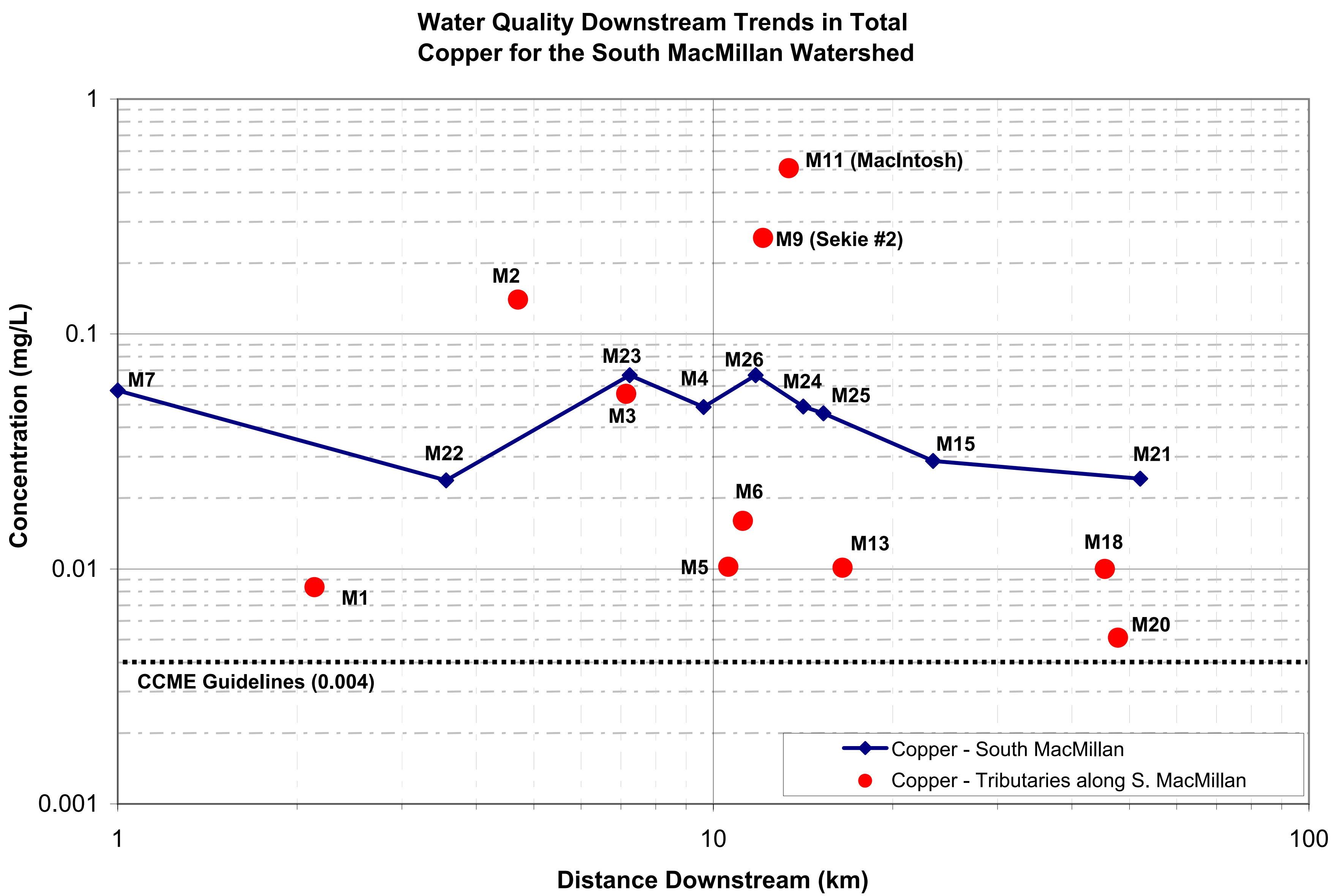
Downstream Trends in pH along the South MacMillan River
9
8
7
6
5
4
3
2
1
0
pH
1
10
100
Downstream Distance (km)
M1
M5
M6
M22
M26
M20
M3
M4
M13
M15
M18
M24
M21
M25
M23
M7
M2
M9 (Sekie #2)
M11 (MacIntosh)
pH - South MacMillan
pH - Tributaries along S. MacMillan

Figure 2



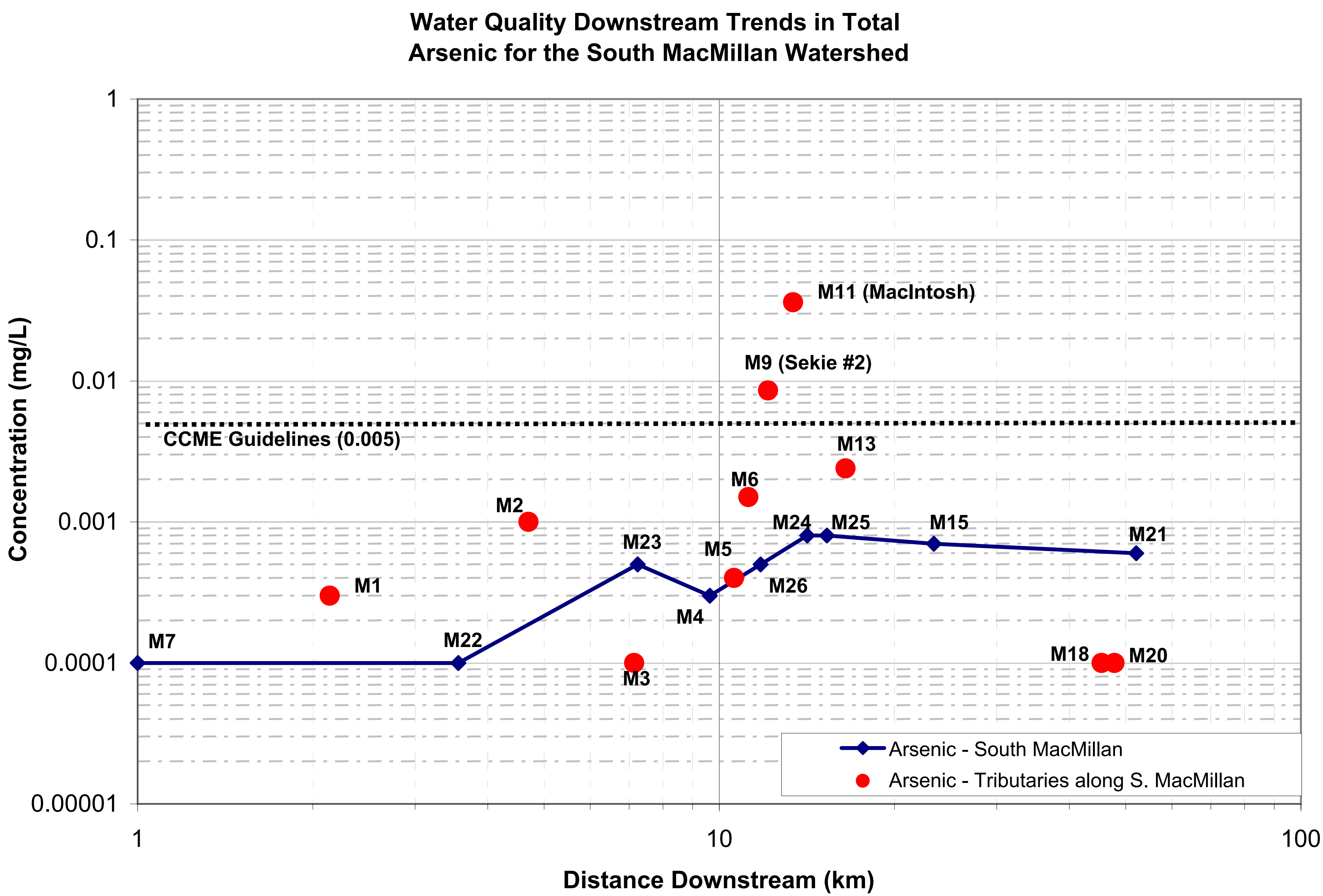
Water Quality Downstream Trends in Total
Zinc for the South MacMillan Watershed
Concentration (mg/L)
Distance Downstream (km)
10
1
0.1
0.01
1
10
100
M9 (Sekie #2)
M11 (MacIntosh)
M2
M24
M25
M23
M26
M15
M18
M7
M4
M5
M3
M22
M21
M13
M20
M1
M6
CCME Guidelines (0.03)
Zinc - South MacMillan
Zinc - Tributaries along S. MacMillan

Figure 3



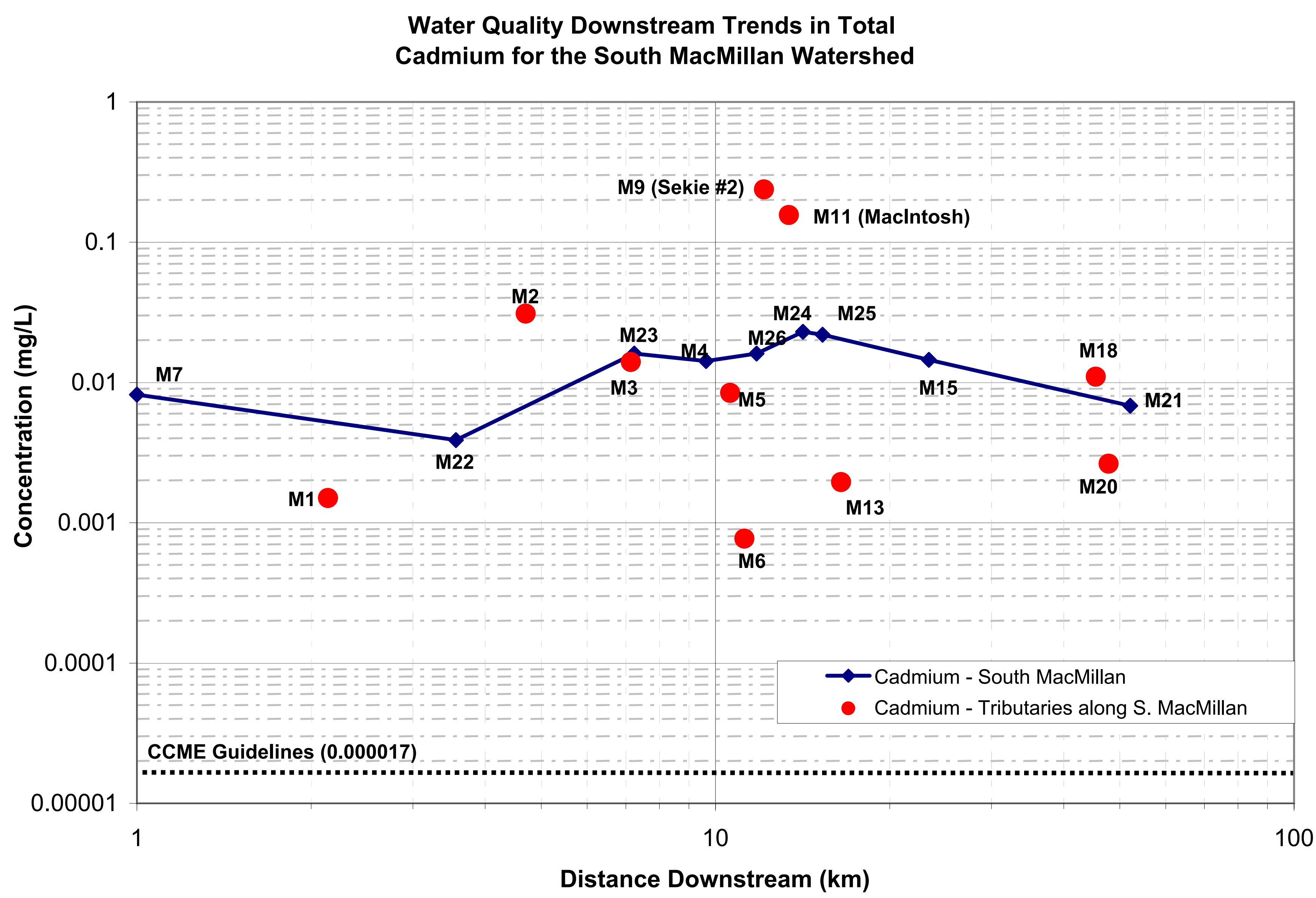
Water Quality Downstream Trends in Total
Copper for the South MacMillan Watershed
Concentration (mg/L)
1
0.1
0.01
0.001
Distance Downstream (km)
1
10
100
M7
M22
M23
M4
M26
M24
M25
M15
M21
M1
M2
M3
M5
M6
M9 (Sekie #2)
M11 (MacIntosh)
M13
M18
M20
CCME Guidelines (0.004)
Copper - South MacMillan
Copper - Tributaries along S. MacMillan

Figure 4



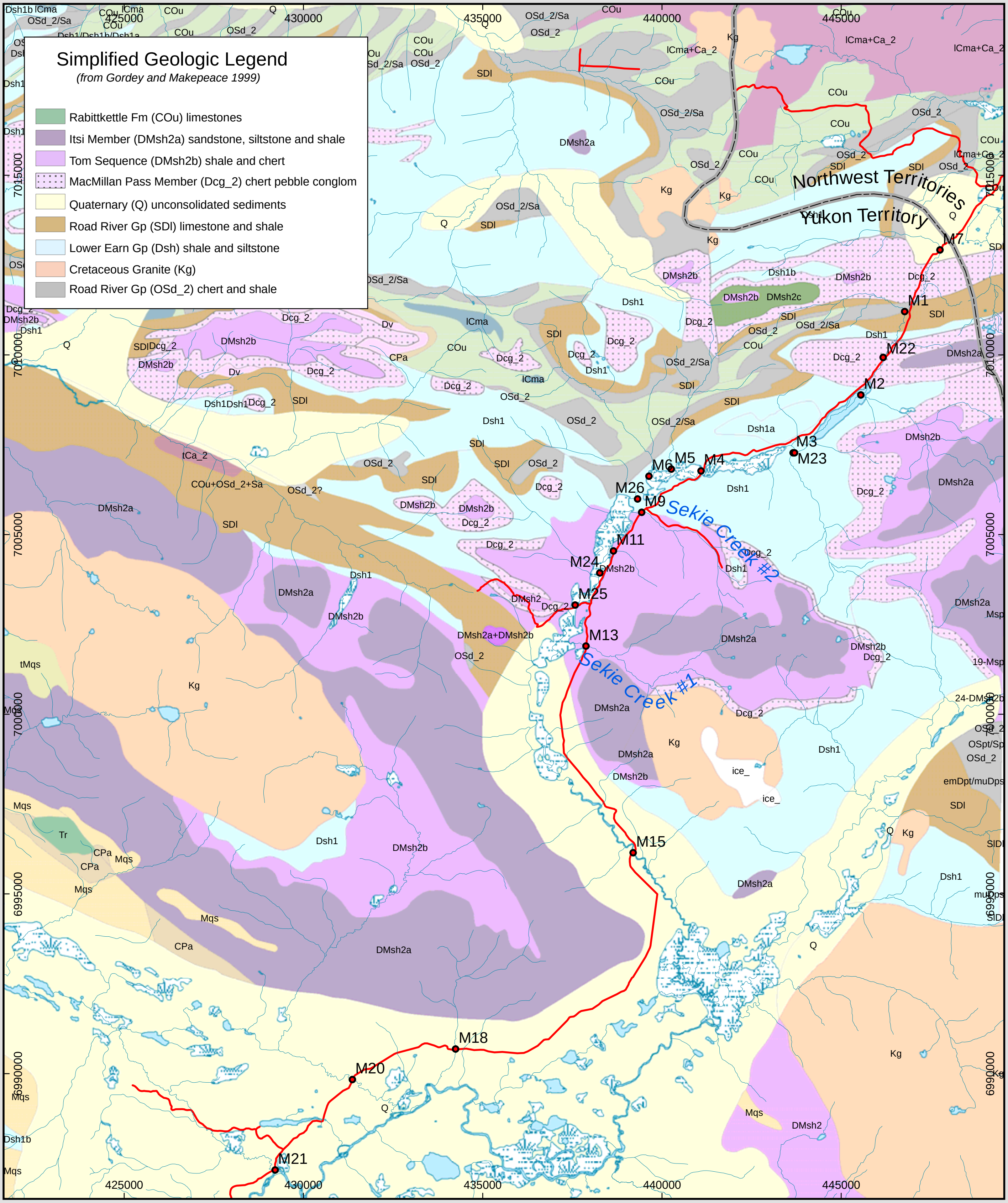
Water Quality Downstream Trends in Total
Arsenic for the South MacMillan Watershed
Concentration (mg/L)
1
0.1
0.01
0.001
0.0001
0.00001
1
10
100
Distance Downstream (km)
CCME Guidelines (0.005)
M11 (MacIntosh)
M9 (Sekie #2)
M13
M6
M2
M24
M25
M15
M21
M23
M5
M26
M1
M4
M7
M22
M3
M18
M20
Arsenic - South MacMillan
Arsenic - Tributaries along S. MacMillan

Figure 5



Water Quality Downstream Trends in Total
Cadmium for the South MacMillan Watershed
Concentration (mg/L)
1
0.1
0.01
0.001
0.0001
0.00001
Distance Downstream (km)
1
10
100
M9 (Sekie #2)
M11 (MacIntosh)
M2
M24
M25
M23
M26
M4
M18
M7
M3
M5
M15
M21
M22
M20
M1
M13
M6
Cadmium - South MacMillan
Cadmium - Tributaries along S. MacMillan
CCME Guidelines (0.000017)

Figure 6



Legend

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W
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1:150,000

NAD83 Albers

- Sample Sites, July 2006
- Territorial Boundary
- River
- Road
- Wetland
- Lake
- Veg

Macmillan Pass

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July 2006
Sample Locations

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Figure 7

Version 1

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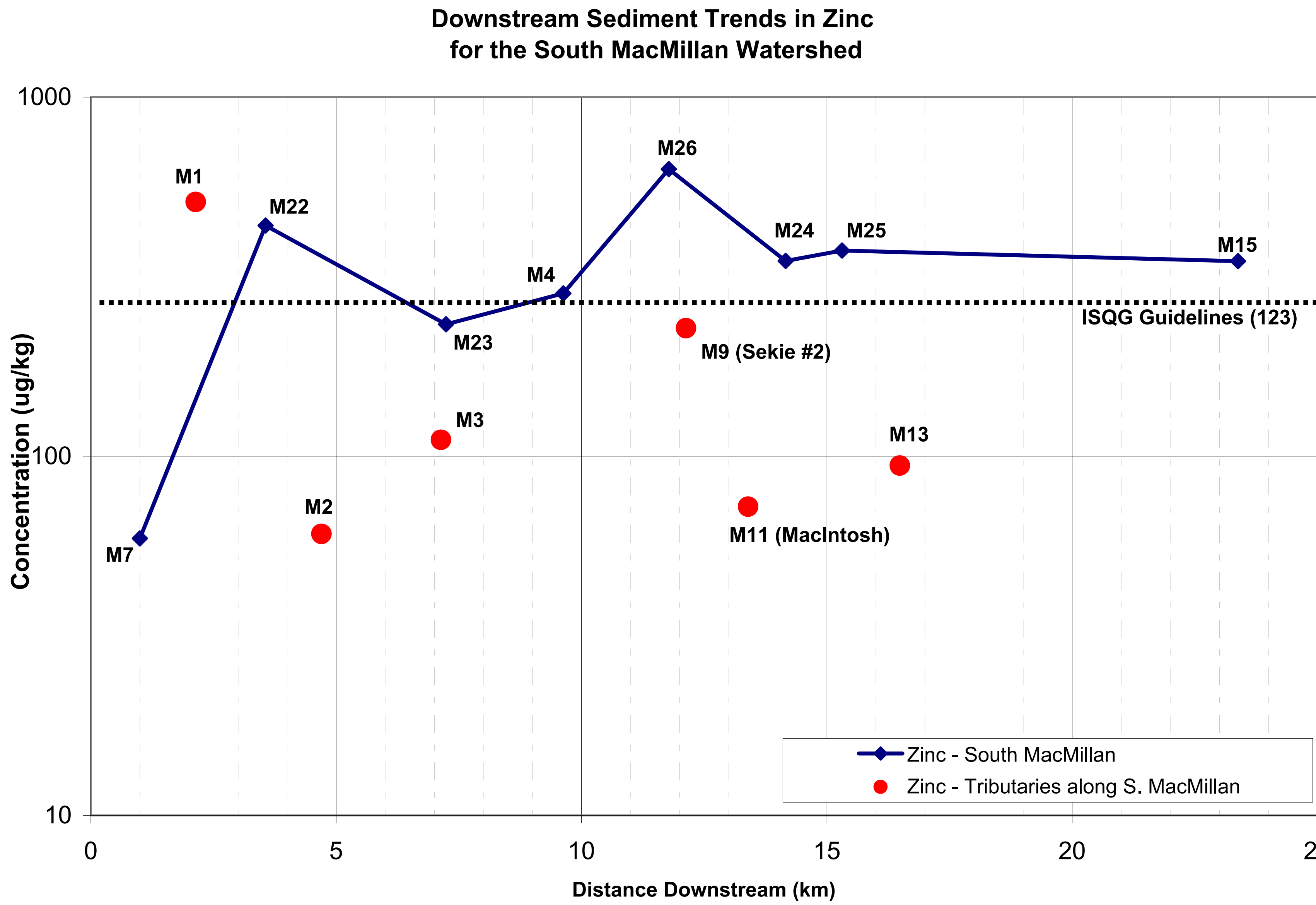


Downstream Sediment Trends in Zinc
for the South MacMillan Watershed
1000
100
10
0
5
10
15
20
25
Concentration (ug/kg)
Distance Downstream (km)
M1
M22
M26
M24
M25
M15
M4
M23
ISQG Guidelines (123)
M9 (Sekie #2)
M3
M13
M2
M7
M11 (MacIntosh)
Zinc - South MacMillan
Zinc - Tributaries along S. MacMillan

Figure 8

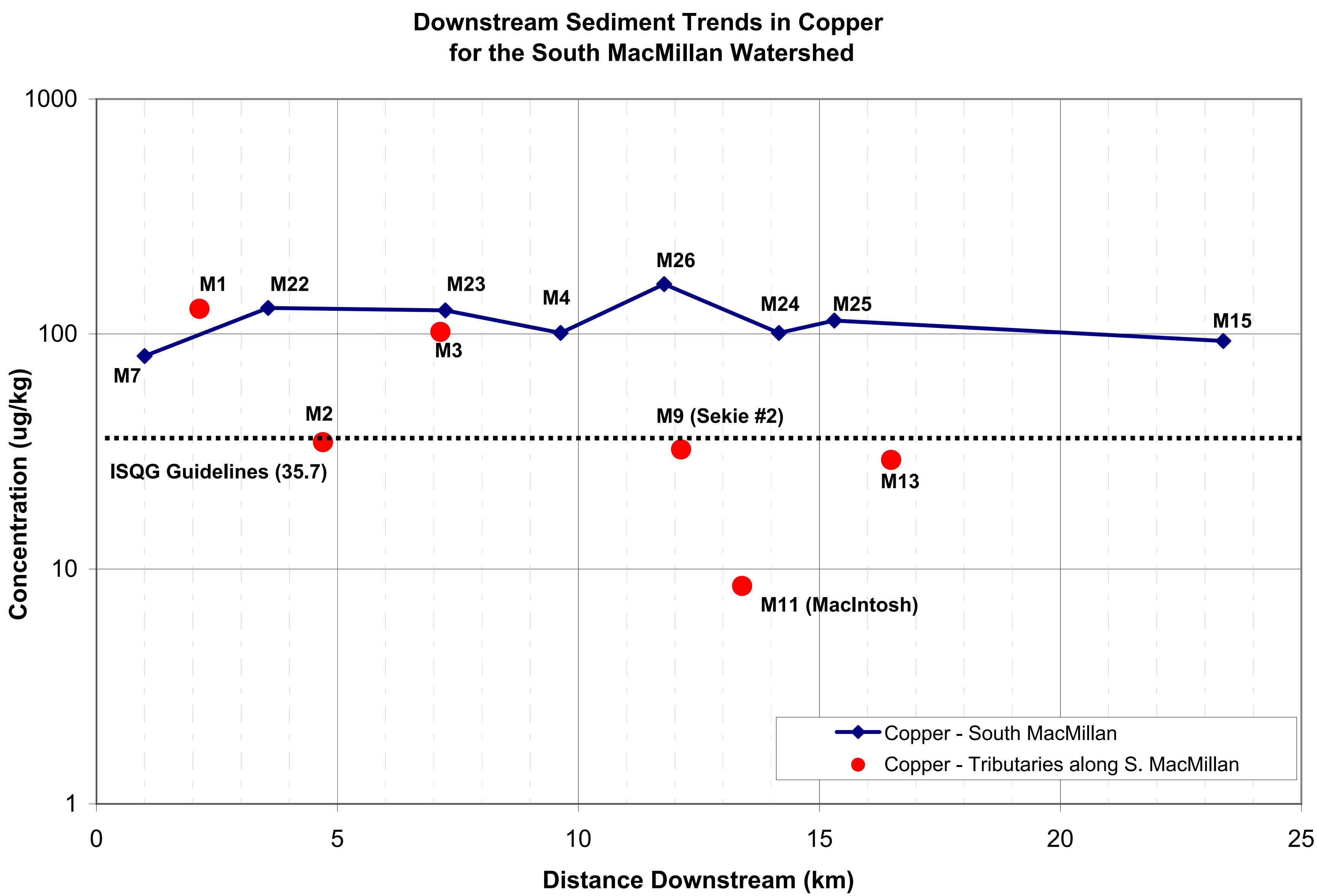
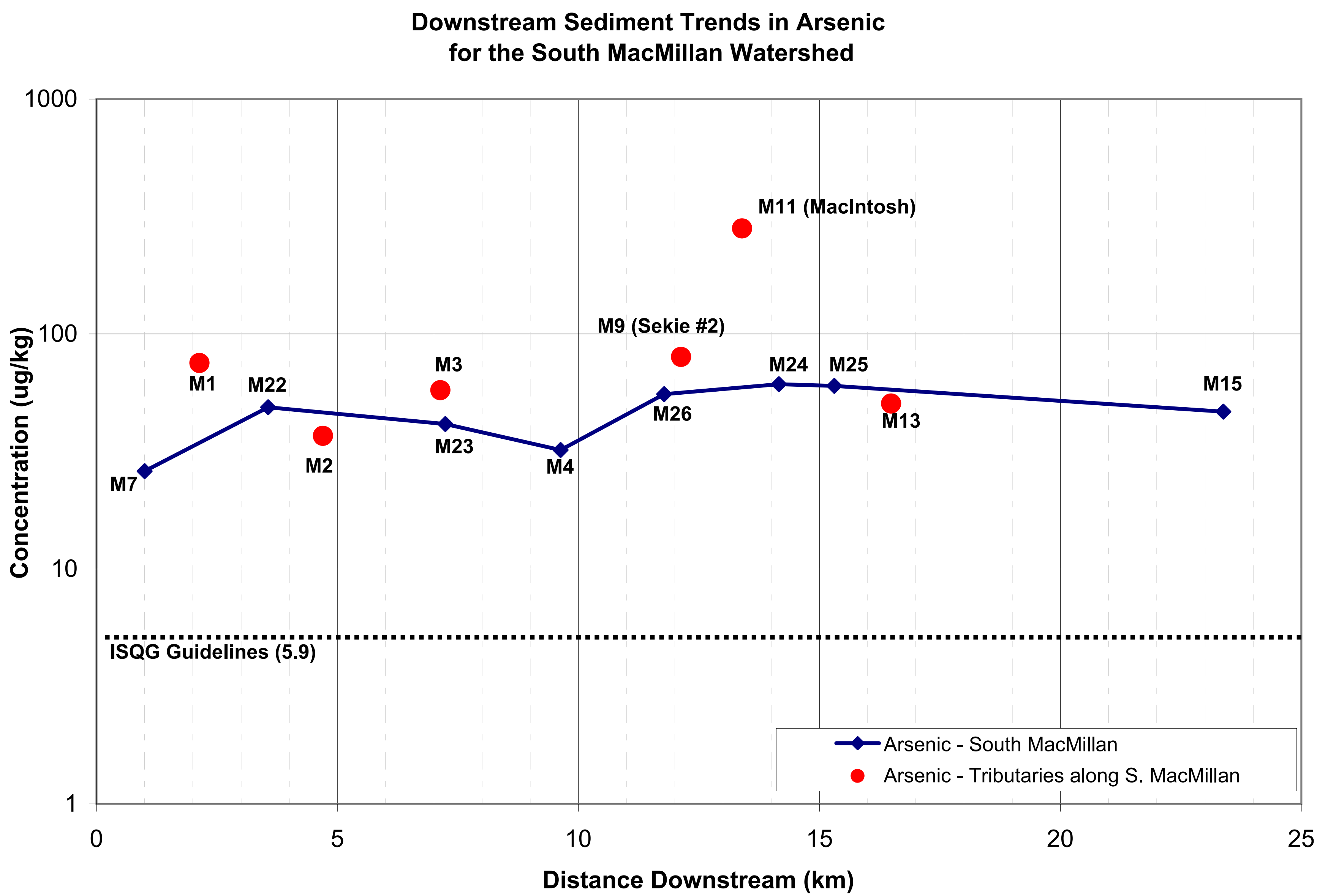

Downstream Sediment Trends in Copper
for the South MacMillan Watershed
Concentration (ug/kg)
Distance Downstream (km)
1000
100
10
1
0
5
10
15
20
25
M1
M22
M23
M4
M26
M24
M25
M15
M7
M3
M2
M9 (Sekie #2)
ISQG Guidelines (35.7)
M13
M11 (MacIntosh)
Copper - South MacMillan
Copper - Tributaries along S. MacMillan

Figure 9



Downstream Sediment Trends in Arsenic
for the South MacMillan Watershed
1000
100
10
1
Concentration (ug/kg)
0
5
10
15
20
25
Distance Downstream (km)
M11 (MacIntosh)
M9 (Sekie #2)
M1
M22
M3
M24
M25
M15
M26
M13
M2
M23
M4
M7
ISQG Guidelines (5.9)
Arsenic - South MacMillan
Arsenic - Tributaries along S. MacMillan

Figure 10

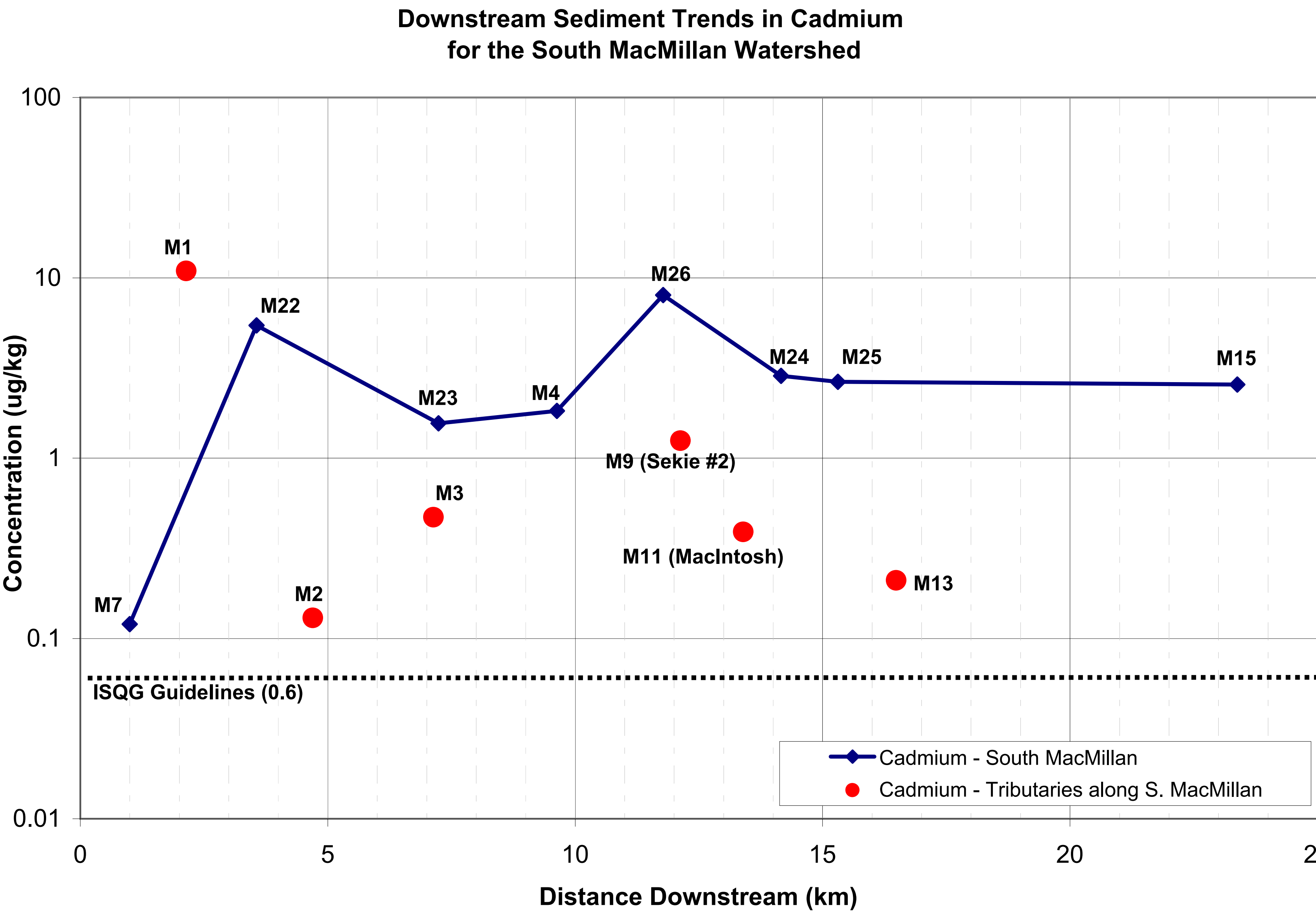
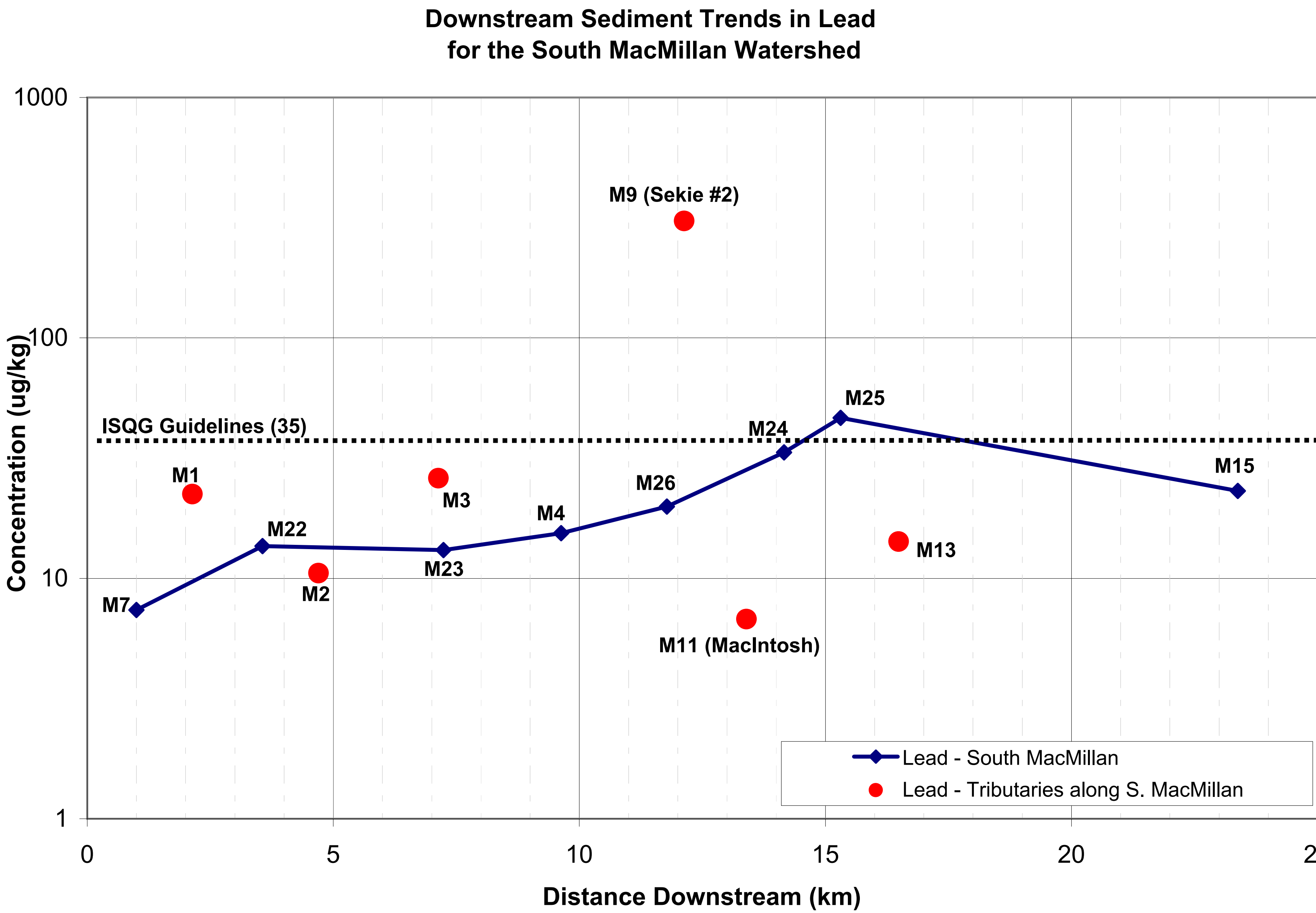

Downstream Sediment Trends in Cadmium
for the South MacMillan Watershed
Concentration (ug/kg)
100
10
1
0.1
0.01
0
5
10
15
20
25
Distance Downstream (km)
M1
M22
M26
M24
M25
M15
M23
M4
M9 (Sekie #2)
M3
M11 (MacIntosh)
M13
M7
M2
ISQG Guidelines (0.6)
Cadmium - South MacMillan
Cadmium - Tributaries along S. MacMillan

Figure 11



Downstream Sediment Trends in Lead
for the South MacMillan Watershed
1000
100
10
1
Concentration (ug/kg)
0
5
10
15
20
25
Distance Downstream (km)
ISQG Guidelines (35)
M9 (Sekie #2)
M25
M24
M15
M1
M26
M3
M4
M22
M13
M23
M2
M7
M11 (MacIntosh)
Lead - South MacMillan
Lead - Tributaries along S. MacMillan

Figure 12

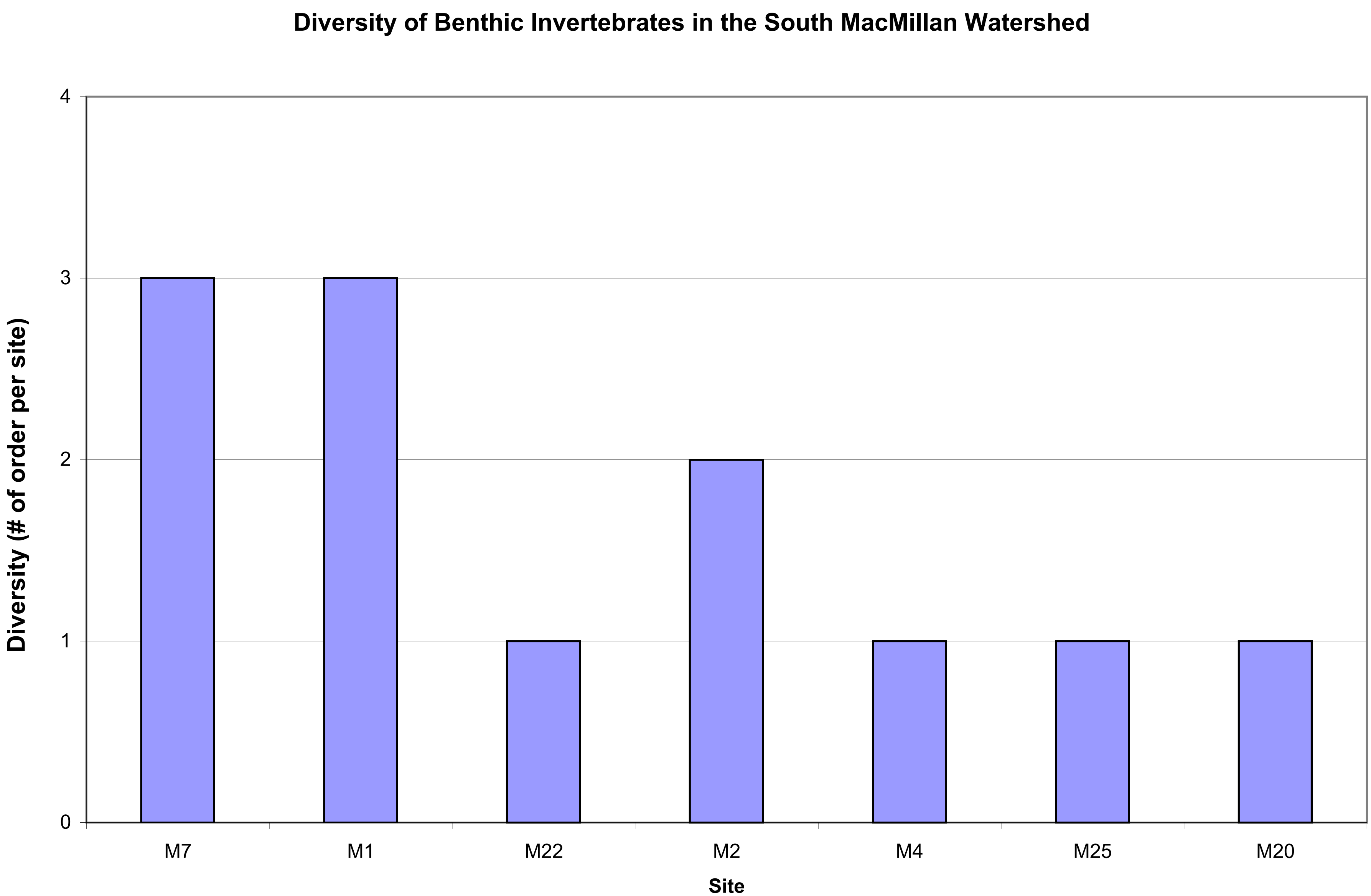
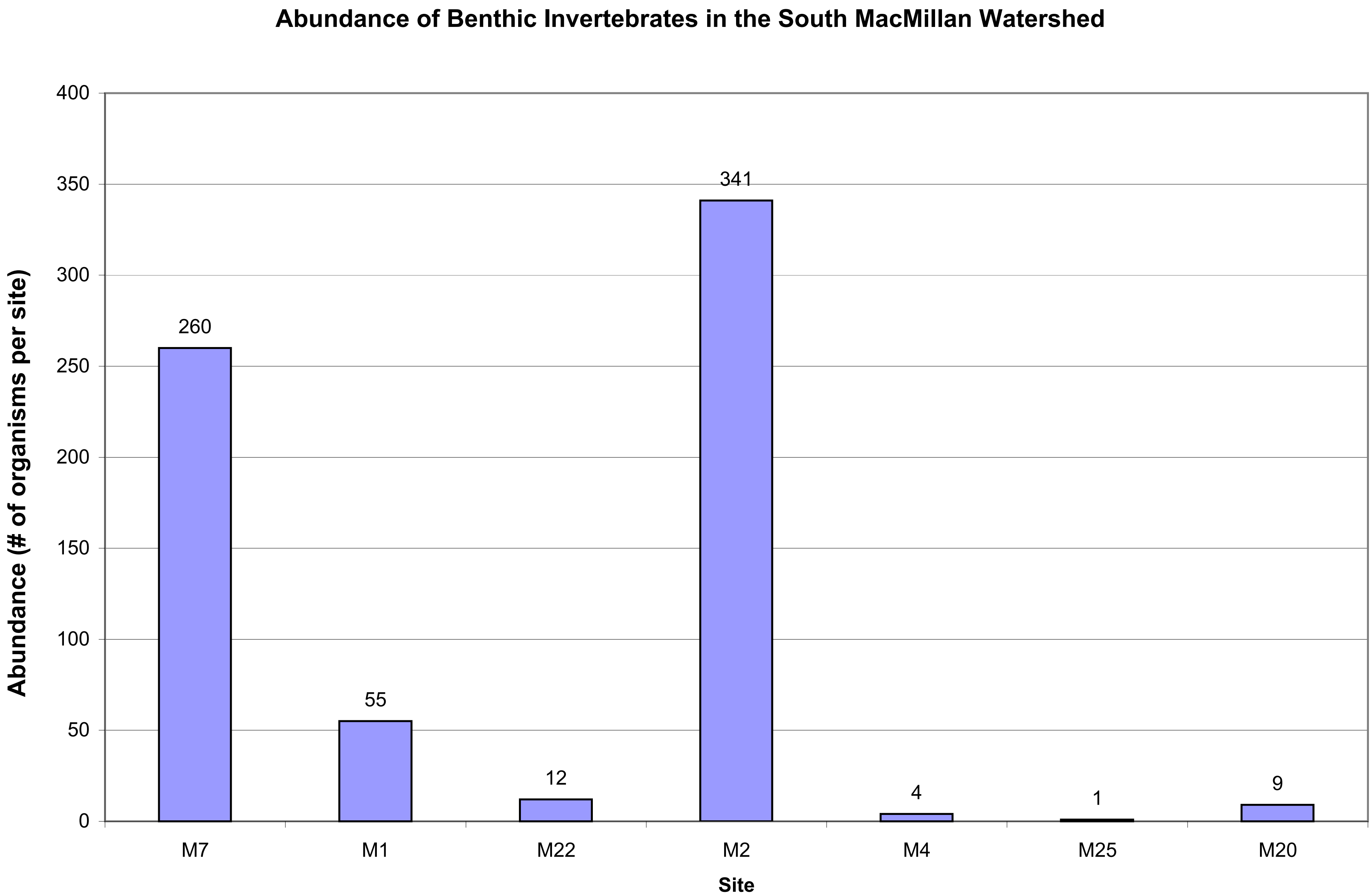

Diversity of Benthic Invertebrates in the South MacMillan Watershed
Diversity (# of order per site)
0
1
2
3
4
M7
M1
M22
M2
M4
M25
M20
Site

Figure 13



Abundance of Benthic Invertebrates in the South MacMillan Watershed
Abundance (# of organisms per site)
400
350
300
250
200
150
100
50
0
260
55
12
341
4
1
9
M7
M1
M22
M2
M4
M25
M20
Site

Figure 14

List of Tables

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Table 1. July 10, 11 & 12 2006 Surface Water Sampling and Flow Measurements

Weather: On July 10th - Over cast July 11th - Clear skies and warm, light breeze. July 12th - Partly cloudy

Date	Station Name	Location in Watershed (km)"	Easting*	Northing*	Electrical Conductivity (uS/cm @ 25°C)	Temperature (°C)	pH	Flow (m^3/s)	Comments
July 10th	**M7**	**1**	**447,754**	**7,012,917**	**288**	**5.73**	**2.94**	**0.54**	**South Macmillan River**
July 10th	M1	2.14	446,772	7,011,205	389	4.35	7.10	0.53	Tributary of South Macmillan River
July 10th	**M22**	**3.56**	**446,171**	**7,009,926**	**245**	**6.4**	**6.54**	**1.32**	**South Macmillan River**
July 10th	M2	4.7	445,549	7,008,882	413	7.84	2.63	1.11	Tributary of South Macmillan River
July 10th	M3	7.14	443,660	7,007,273	325	5.4	4.41	0.77	Tributary of South Macmillan River
July 10th	**M23**	**7.24**	**443,697**	**7,007,274**	**272**	**9.96**	**3.93**	**2.20**	**South Macmillan River**
July 10th	**M4**	**9.63**	**441,090**	**7,006,767**	**189**	**9.37**	**4.30**	**4.08**	**South Macmillan River**
July 12th	M5	10.6	440,262	7,006,818	532	3.7	8.07	0.32	Accessed site by canoe. Tributary of South Macmillan River
July 12th	M6	11.22	439,639	7,006,621	390	5.2	7.92	0.45	Accessed site by canoe. Tributary of South Macmillan River
July 12th	**M26**	**11.78**	**439,322**	**7,005,987**	**302**	**7.92**	**5.66**	**2.98**	**South Macmillan River. Sampled at river access from airport.**
July 11th	M9	12.13	439,436	7,005,615	1171	8.22	2.81	0.27	Sekie Creek # 2, Tributary of South Macmillan River
July 11th	M11	13.4	438,651	7,004,541	1712	11.5	2.74	0.039	Macintosh Creek, Tributary of South Macmillan River
July 11th	**M24**	**14.16**	**438,270**	**7,003,928**	**334**	**8.4**	**4.56**	**12.46**	**South Macmillan River, float method used to determine stream flow.**
July 11th	**M25**	**15.31**	**437,579**	**7,003,037**	**329**	**9.4**	**4.62**	**5.53**	**South Macmillan River, float method used to determine stream flow.**
July 11th	M13	16.49	437,882	7,001,894	87.6	7.9	4.77	0.86	Sekie Creek # 1, Tributary of South Macmillan River
July 11th	**M15**	**23.38**	**439,199**	**6,996,144**	**260**	**9.6**	**4.50**	**-**	**South Macmillan River. Staff gauge measured to be 10cm from bottom of gauge or first 0.3.**
July 12th	M18	45.45	434,246	6,990,681	304	9.75	4.60	0.22	Dewhurst Creek, Tributary of South Macmillan River
July 12th	M20	47.84	431,367	6,989,834	97	10.19	5.01	2.76	Hess Creek, Tributary of South Macmillan River
July 12th	**M21**	**52.1**	**429,213**	**6,987,314**	**198**	**11.49**	**4.34**	**-**	**South Macmillan river. Flow was not taken as channel was to deep/wide.**

Notes ** UTM Zone 9, NAD83*

Bold rows are sites on the South MacMillan River

"sites are ordered from most upstream to downstream.

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Table 2 Surface Water Samples from MacMillan River, 2006

General Chemistry Analysis (mg/L)

MacMillan River Sites

Station	Detection Limits	Water Quality Guidelines	M7	M22	M23	M4	M26	M24	M25	M15*	M21
Date		CCME [a]	10-Jul-06	10-Jul-06	10-Jul-06	10-Jul-06	12-Jul-06	11-Jul-06	11-Jul-06	11-Jul-06	12-Jul-06
Distances DS (km)			1	3.56	7.24	9.63	11.78	14.16	15.31	23.38	52.1
Physical Tests											
Temperature (°C) (field)			5.73	6.4	9.96	9.37	7.92	8.4	9.4	9.6	11.49
Conductivity (lab) (uS/cm)	0.2		253	245	264	262	289	331	321	263	198
Conductivity (field) (uS/cm)	-		288	245	272	189	302	334	329	260	198
Hardness CaCO3	-		74.7	106	104	118	124	141	137	112	77.8
pH (lab)	0.1	6.5-9.0	3.71	6.6	4.33	4.61	6.26	4.54	4.59	4.7	4.8
pH (field)	-		2.94	6.54	3.93	4.30	5.66	4.56	4.62	4.50	4.34
Turbidity (NTU)	0.1		0.1	4.32	10.8	7.61	12.4	22.7	20.2	15.7	7.6
Total Disolved Solids (TDS)			184	179	253	218	238	291	282	199	158
Total Suspended Sediment (TSS)	5		5	12	10	5	19	22	5	21	8
Dissolved Anions											
Alkalinity-Total CaCO3	5		0.5		0.5	0.5		0.5	0.5	0.5	0.5
Chloride			0.8	0.1	1.3	0.1	0.1	0.1	0.1	0.1	0.2
Floride			0.14	0.22	0.07	0.03	0.29	0.05	0.03	0.41	0.43
Sulphate SO4	0.5		191	97	216	192	131	284	265	215	98
Bromide			0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nutrients											
Ammonia Nitrogen	0.05	1.78-38.6[a]	0.005	0.005	0.026	0.026	0.013	0.061	0.041	0.031	0.006
Nitrate Nitrogen	0.1	13	0.03	0.032	0.041	0.051	0.053	0.054	0.052	0.044	0.037
Nitrite Nitrogen	0.05	0.06	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Dissolved ortho-phosphate	0.01		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total Phosphorus	0.02		0.005	0.009	0.036	0.025	0.027	0.057	0.052	0.037	0.013

Tributaries of the South MacMillan River

Station	Detection Limits	Water Quality Guidelines	M1	M2	M3	M5	M6	M9*	M11	M13	M18	M20
Date		CCME [a]	10-Jul-06	10-Jul-06	10-Jul-06	12-Jul-06	12-Jul-06	11-Jul-06	11-Jul-06	11-Jul-06	12-Jul-06	12-Jul-06
Distances DS (km)			2.14	4.7	7.14	10.6	11.22	12.13	13.4	16.49	45.45	47.84
Physical Tests												
Temperature (°C) (field)			4.35	7.84	5.4	3.7	5.2	8.22	11.5	7.9	9.75	10.19
Conductivity (lab) (uS/cm)	0.2		377	418	320	536	383	1170	1690	98	297	95
Conductivity (field) (uS/cm)	-		389	413	325	532	390	1171	1712	87.6	304	97
Hardness CaCO3	-		194	123	157	284	198	476	845	31.2	129	36.9
pH (lab)	0.1	6.5-9.0	7.69	3.33	4.65	7.99	7.84	2.94	2.9	4.7	4.91	5.36
pH (field)	-		7.10	2.63	4.41	8.07	7.92	2.81	2.74	4.77	4.60	5.01
Turbidity (NTU)	0.1		2.94	33.8	2.36	8	2.01	4.59	20.8	1.2	3.71	2.86
Total Disolved Solids (TDS)			287	243	330	400	295	1010	1980	65	218	216
Total Suspended Sediment (TSS)	5		5	5	5	5	5	5	5	5	5	11
Dissolved Anions												
Alkalinity-Total CaCO3	5		68.6	0.5	0.5	128	88.2	0.5	0.5	0.5	0.5	0.5
Chloride			0.1	2.4	0.1	0.1	0.1	0.1	0.1	0.6	0.1	0.1
Floride			0.14	0.66	0.04	0.32	0.3	0.59	1.19	0.13	0.79	0.12
Sulphate SO4	0.5		122	362	210	166	114	1510	16800	87	174	42
Bromide			0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nutrients												
Ammonia Nitrogen	0.05	1.78-38.6[a]	0.005	0.084	0.018	0.005	0.005	0.62	1.29	0.005	0.005	0.005
Nitrate Nitrogen	0.1	13	0.051	0.045	0.092	0.134	0.035	0.002	0.002	0.044	0.042	0.008
Nitrite Nitrogen	0.05	0.06	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Dissolved ortho-phosphate	0.01		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total Phosphorus	0.02		0.016	0.066	0.005	0.048	0.035	0.058	0.8	0.008	0.002	0.006

All units mg/L unless otherwise noted

[a] *Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2005*

**Average of sample and replicate*

[#] *Lab error, no chloride test could be completed*

a) Varies with temperature and pH: 1.78 at pH=7.5 and Temp =15 °C and 38.6 at pH=6.5 and Temp =5oC

Italic	*results exceed CCME Aquatic Life Guidelines*

Gartner Lee

Table 3 Surface Water Samples from South MacMillan Watershed, 2006

Total Metals Analysis (mg/L)

MacMillan River Sites

Station	Detection Limits	Water Quality Guidelines	M7	M22	M23	M4	M26	M24	M25	M15*	M21
Date	ICP-MS	CCME [a]	10-Jul-06	10-Jul-06	10-Jul-06	10-Jul-06	12-Jul-06	11-Jul-06	11-Jul-06	11-Jul-06	12-Jul-06
Distances DS (km)			1	3.56	7.24	9.63	11.78	14.16	15.31	23.38	52.1
Total Metals											
Aluminum (Al)	0.0002	0.005-0.1[b]	7.955	3.481	6.791	5.035	6.791	7.532	7.414	4.575	2.619
Antimony (Sb)	0.000005		0.00002	0.000014	< 0.000005	< 0.000005	< 0.000005	0.000046	0.00005	0.000046	0.000012
Arsenic (As)	0.0001	0.005	< 0.0001	< 0.0001	0.0005	0.0003	0.0005	0.0008	0.0008	0.0007	0.0006
Barium (Ba)	0.00002		0.0261	0.0392	0.0329	0.0285	0.0329	0.0378	0.0359	0.0408	0.0362
Berylium (Be)	0.000002		0.000526	0.000151	0.000341	0.00025	0.000341	0.000328	0.000251	0.0002	0.000174
Bismuth (Bi)	0.00002		0.00004	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00007	0.00006	< 0.00002
Boron (B)	0.002		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.003	< 0.002	< 0.002
Cadmium (Cd)	0.00001	0.000017	0.00821	0.00389	0.0161	0.0142	0.0161	0.023	0.0219	0.0145	0.00684
Chromium (Cr)	0.0002	0.001	0.0009	0.0003	0.003	0.0016	0.003	0.0041	0.0037	0.0022	0.0008
Cobalt (Co)	0.000005		0.0242	0.0106	0.0248	0.0204	0.0248	0.0224	0.0216	0.0144	0.0135
Copper (Cu)	0.00005	0.002-0.004[c]	0.0575	0.0238	0.0667	0.0489	0.0667	0.0491	0.0459	0.0288	0.0242
Lead (Pb)	0.00001	0.001-0.007[d]	0.00023	0.00013	0.00015	0.0002	0.00015	0.00146	0.00139	0.00079	0.00027
Lithium (Li)	0.00005		0.0148	0.00812	0.0132	0.0118	0.0132	0.0117	0.0113	0.00884	0.0089
Magnesium (Mg)	0.00005		2.63	7.73	6.42	8.03	6.42	11.36	11.03	8.23	6.19
Manganese (Mn)	0.000005		0.256	0.121	0.321	0.349	0.321	0.309	0.298	0.207	0.204
Molybdenum (Mo)	0.00005	0.073	0.00012	0.00061	0.00015	0.00007	0.00015	0.00048	0.00045	0.00039	< 0.00005
Nickel (Ni)	0.00005	0.025-0.15[e]	0.165	0.0836	0.162	0.152	0.162	0.192	0.185	0.129	0.0906
Selenium (Se)	0.0002	0.001	0.002	0.0017	0.0016	0.0016	0.0016	0.0019	0.0016	0.0016	0.001
Silver (Ag)	0.00002	0.0001	0.0002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00015	< 0.00002	< 0.00002
Strontium (Sr)	0.000005		0.0671	0.089	0.0708	0.0895	0.0708	0.107	0.105	0.0884	0.0717
Thallium (Tl)	0.000002	0.0008	0.000049	0.000021	0.000177	0.000112	0.000177	0.000176	0.000171	0.000106	0.000034
Tin (Sn)	0.00001		0.00045	0.00019	0.00026	0.00032	0.00026	0.00014	0.00044	0.00017	0.00091
Uranium (U)	0.000002		0.0014	0.00181	0.00269	0.00174	0.00269	0.00262	0.00248	0.00169	0.000906
Vanadium (V)	0.00005		0.00015	0.0004	0.00455	0.00263	0.00455	0.0116	0.0113	0.00687	0.00219
Zinc (Zn)	0.0001	0.03	0.489	0.238	0.572	0.51	0.572	3.696	3.634	0.573	0.354

Tributaries of the South MacMillan River

Station	Detection Limits	Water Quality Guidelines	M1	M2	M3	M5	M6	M9*	M11	M13	M18	M20
Date	ICP-MS	CCME [a]	10-Jul-06	10-Jul-06	10-Jul-06	12-Jul-06	12-Jul-06	11-Jul-06	11-Jul-06	11-Jul-06	12-Jul-06	12-Jul-06
Distances DS (km)			2.14	4.7	7.14	10.6	11.22	12.13	13.4	16.49	45.45	47.84
Total Metals												
Aluminum (Al)	0.0002	0.005-0.1[b]	0.723	11.85	3.8	1.298	0.332	62.42	142.5	1.358	1.49	0.57
Antimony (Sb)	0.000005		0.000076	< 0.000005	< 0.000005	0.000205	0.000182	0.000052	0.00011	0.000007	0.000037	0.000019
Arsenic (As)	0.0001	0.005	0.0003	0.001	< 0.0001	0.0004	0.0015	0.00855	0.0361	0.0024	< 0.0001	< 0.0001
Barium (Ba)	0.00002		0.0354	0.0211	0.0226	0.0606	0.0426	0.03125	0.00899	0.0245	0.037	0.0391
Berylium (Be)	0.000002		0.000037	0.000553	0.000245	0.000023	0.000015	0.00151	0.0043	0.000159	0.000151	0.000042
Bismuth (Bi)	0.00002		< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00045	< 0.00002	< 0.00002
Boron (B)	0.002		< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	0.0065	0.017	< 0.002	< 0.002	< 0.002
Cadmium (Cd)	0.00001	0.000017	0.0015	0.0309	0.014	0.00843	0.00077	0.238	0.156	0.00195	0.011	0.00264
Chromium (Cr)	0.0002	0.001	< 0.0002	0.0089	0.0005	< 0.0002	0.0003	0.05065	0.178	< 0.0002	< 0.0002	0.0004
Cobalt (Co)	0.000005		0.00245	0.0382	0.0245	0.00849	0.00302	0.1105	0.153	0.00638	0.0262	0.00392
Copper (Cu)	0.00005	0.002-0.004[c]	0.00836	0.14	0.0556	0.0102	0.016	0.256	0.508	0.0101	0.01	0.00509
Lead (Pb)	0.00001	0.001-0.007[d]	0.00013	0.00013	0.0004	0.00011	0.0001	0.0266	0.00015	0.00018	0.00012	0.00009
Lithium (Li)	0.00005		0.00325	0.0186	0.0132	0.00381	0.00555	0.02255	0.0595	0.00326	0.0178	0.00471
Magnesium (Mg)	0.00005		15.78	3.93	17.157	21.9	0.0196	8.985	17.6	< 0.00005	< 0.00005	2.86
Manganese (Mn)	0.000005		0.0183	0.395	0.748	0.0564	0.0612	1.188	0.945	0.0679	0.854	0.0732
Molybdenum (Mo)	0.00005	0.073	0.00132	< 0.00005	< 0.00005	0.00169	0.00279	0.00014	0.00138	0.00042	< 0.00005	< 0.00005
Nickel (Ni)	0.00005	0.025-0.15[e]	0.0312	0.228	0.15	0.116	0.0538	0.905	1.958	0.0404	0.106	0.0328
Selenium (Se)	0.0002	0.001	0.002	0.0015	0.0014	0.0037	0.0018	0.00485	0.0207	0.0008	0.0042	0.0005
Silver (Ag)	0.00002	0.0001	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	0.00012	0.00003	0.00007	< 0.00002	< 0.00002
Strontium (Sr)	0.000005		0.127	0.034	0.163	0.202	0.119	0.0771	0.0581	0.0326	0.1	0.0394
Thallium (Tl)	0.000002	0.0008	0.000025	0.000363	0.000037	0.000006	< 0.000002	0.001565	0.00176	0.000012	< 0.000002	0.000046
Tin (Sn)	0.00001		0.0001	0.0003	0.00027	0.00062	0.00009	0.00013	< 0.00001	0.00056	0.00021	0.0006
Uranium (U)	0.000002		0.00275	0.00436	0.000841	0.00504	0.0029	0.01405	0.0482	0.00118	0.000182	0.000199
Vanadium (V)	0.00005		0.00046	0.0134	0.00019	0.00114	0.00112	0.1845	0.738	0.00023	0.0002	0.00017
Zinc (Zn)	0.0001	0.03	0.0553	3.852	0.389	0.457	0.0861	8.78	5.496	0.139	0.512	0.179

All units mg/l and tested using ICPMS analysis unless otherwise noted

a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2005

b) 0.005mg/L at pH < 6.5, [Ca2+] < 4 mg/L, DOC < 2 mg/L: 0.1 mg/L at pH ≥ 6.5, [Ca2+] ≥ 4 mg/L, DOC ≥ 2 mg/L

c) 0.002 mg/L at [CaCO3] = 0 - 120 mg/L; 0.003 mg/L at [CaCO3] =120 - 180 mg/L; 0.004 mg/L at [CaCO3] >180mg/L

d) 0.001 mg/L at [CaCO3] = 0 - 60 mg/L; 0.002 mg/L at [CaCO3] =60 - 120 mg/L; 0.004 mg/L at [CaCO3] =120 -180mg/L; 0.007 mg/L at [CaCO3] > 180mg/L

e) 0.025 mg/L at [CaCO3] = 0 - 60 mg/L; 0.065 mg/L at [CaCO3] =60 - 120 mg/L; 0.110 mg/L at [CaCO3] =120 -180mg/L; 0.150 mg/L at [CaCO3] > 180mg/L

**Average of sample and replicate*

Italic results exceed CCME Aquatic Life Guidelines

Gartner Lee

Table 4 Surface Water Samples from South MacMillan Watershed, 2006

Dissolved Metals Analysis (mg/L)

MacMillan River Sites

Station	Detection Limits	Water Quality Guidelines	M7	M22	M23	M4	M26	M24	M25	M15*	M21
Date	ICP-MS	CCME [a]	10-Jul-06	10-Jul-06	10-Jul-06	10-Jul-06	12-Jul-06	11-Jul-06	11-Jul-06	11-Jul-06	12-Jul-06
Distances Downstream (km)			0	3.56	7.24	9.63	11.78	14.16	15.31	23.38	52.1
Dissolved Metals											
Aluminum (Al)	0.0002	0.005-0.1[b]	7.804	0.0341	5.887	4.176	0.0988	3.847	3.589	1.684	1.216
Antimony (Sb)	0.000005		0.000014	0.000067	0.00002	0.000031	0.000068	0.000045	0.000046	0.000053	0.000058
Arsenic (As)	0.0001	0.005	0.0002	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0002	0.0002	0.0002	0.0002
Barium (Ba)	0.00002		0.0249	0.0356	0.0275	0.0266	0.0306	0.0296	0.0297	0.0348	0.032
Berylium (Be)	0.000002		0.000595	0.000071	0.000556	0.00032	0.000153	0.000318	0.00035	0.000277	0.000255
Bismuth (Bi)	0.00002		< 0.00002	< 0.00002	< 0.00002	0.00004	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002
Boron (B)	0.002		0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003
Cadmium (Cd)	0.00001	0.000017	0.009	0.00401	0.0169	0.0156	0.0129	0.0241	0.0234	0.0166	0.00691
Chromium (Cr)	0.0002	0.001	0.0008	0.0002	0.0015	0.0007	< 0.0002	0.0007	0.0006	0.0003	< 0.0002
Cobalt (Co)	0.000005		0.0241	0.0111	0.0241	0.0211	0.0172	0.0224	0.0212	0.015	0.013
Copper (Cu)	0.00005	0.002-0.004[c]	0.0558	0.00414	0.0658	0.0487	0.0219	0.0423	0.0407	0.0281	0.0205
Lead (Pb)	0.00001	0.001-0.007[d]	0.00011	0.00006	0.00004	0.00005	< 0.00001	0.0005	0.00043	0.0002	0.00007
Lithium (Li)	0.00005		0.0162	0.0125	0.0196	0.0137	0.0168	0.0176	0.0173	0.0143	0.0118
Magnesium (Mg)	0.00005		2.63	10.23	8.15	10.341	14.8	14.38	14.05	10.94	7.54
Manganese (Mn)	0.000005		0.27	0.124	0.324	0.381	0.273	0.304	0.296	0.213	0.191
Molybdenum (Mo)	0.00005	0.073	0.00008	0.0008	< 0.00005	0.00016	0.00035	< 0.00005	< 0.00005	0.00007	0.0001
Nickel (Ni)	0.00005	0.025-0.15[e]	0.173	0.0907	0.168	0.162	0.151	0.198	0.193	0.142	0.0899
Selenium (Se)	0.0002	0.001	0.0023	0.0017	0.0016	0.0014	0.0017	0.0019	0.0017	0.0016	0.001
Silver (Ag)	0.00002	0.0001	0.00006	< 0.00002	0.00004	< 0.00002	< 0.00002	< 0.00002	0.00003	< 0.00002	< 0.00002
Strontium (Sr)	0.000005		0.0666	0.0854	0.0629	0.0883	0.103	0.0994	0.0961	0.0842	0.0662
Thallium (Tl)	0.000002	0.0008	0.00006	0.000048	0.000159	0.000133	0.000113	0.000185	0.000176	0.000128	0.000059
Tin (Sn)	0.00001		< 0.00001	< 0.00001	< 0.00001	0.00002	< 0.00001	< 0.00001	< 0.00001	< 0.00001	0.00004
Uranium (U)	0.000002		0.0014	0.000015	0.000628	0.000079	0.000004	0.000042	0.000042	0.000058	0.000064
Vanadium (V)	0.00005		0.00011	0.00011	0.00005	0.00007	0.00007	< 0.00005	0.00008	0.00007	0.00006
Zinc (Zn)	0.0001	0.03	0.627	0.262	0.655	0.704	0.567	1.004	0.955	0.754	0.42

Tributaries of the South MacMillan River

Station	Detection Limits	Water Quality Guidelines	M1	M2	M3	M5	M6	M9*	M11	M13	M18	M20
Date	ICP-MS	CCME [a]	10-Jul-06	10-Jul-06	10-Jul-06	12-Jul-06	12-Jul-06	11-Jul-06	11-Jul-06	11-Jul-06	12-Jul-06	12-Jul-06
Distances Downstream (km)			2.14	4.7	7.14	10.6	11.22	12.13	13.4	16.49	45.45	47.84
Dissolved Metals												
Aluminum (Al)	0.0002	0.005-0.1[b]	0.0869	12.67	3.479	0.0476	0.0703	60.19	127	0.766	0.939	0.0958
Antimony (Sb)	0.000005		0.000116	0.000026	0.000052	0.000247	0.000233	0.000083	0.000165	0.000035	0.00006	0.000072
Arsenic (As)	0.0001	0.005	0.0003	0.0011	< 0.0001	0.0002	0.0012	0.0079	0.0367	< 0.0001	0.0002	< 0.0001
Barium (Ba)	0.00002		0.0324	0.02	0.0209	0.0523	0.0364	0.02685	0.00672	0.0218	0.0319	0.0356
Berylium (Be)	0.000002		0.000005	0.000651	0.00032	0.000003	0.000002	0.001815	0.00695	0.000304	0.000287	0.000079
Bismuth (Bi)	0.00002		< 0.00002	< 0.00002	0.00007	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002	< 0.00002
Boron (B)	0.002		0.002	0.003	0.002	0.002	0.002	0.008	0.026	0.003	0.002	0.002
Cadmium (Cd)	0.00001	0.000017	0.00127	0.0327	0.0149	0.00512	0.00066	0.25	0.167	0.00215	0.0115	0.00281
Chromium (Cr)	0.0002	0.001	< 0.0002	0.0085	0.0004	< 0.0002	< 0.0002	0.0504	0.184	< 0.0002	< 0.0002	< 0.0002
Cobalt (Co)	0.000005		0.00222	0.0372	0.0249	0.00759	0.00267	0.1115	0.155	0.00645	0.0266	0.00398
Copper (Cu)	0.00005	0.002-0.004[c]	0.00058	0.138	0.0537	0.00057	0.0007	0.318	0.511	0.00699	0.00689	0.00182
Lead (Pb)	0.00001	0.001-0.007[d]	< 0.00001	0.00011	0.00029	0.00002	< 0.00001	0.02455	0.00018	0.00002	< 0.00001	0.00013
Lithium (Li)	0.00005		0.003	0.018	0.0138	0.00411	0.00562	0.0299	0.0958	0.00569	0.0284	0.00758
Magnesium (Mg)	0.00005		17.872	4.59	20.842	23.9	0.0703	11.0175	17.9	-	17.7	3.75
Manganese (Mn)	0.000005		0.0152	0.393	0.767	0.0515	0.0524	1.149	0.902	0.0645	0.798	0.0735
Molybdenum (Mo)	0.00005	0.073	0.00197	0.00019	0.00024	0.00196	0.00302	0.000385	0.00153	0.00006	< 0.00005	0.00012
Nickel (Ni)	0.00005	0.025-0.15[e]	0.0288	0.228	0.157	0.104	0.0498	1.031	1.838	0.0415	1.11	0.034
Selenium (Se)	0.0002	0.001	0.0023	0.0015	0.0016	0.0042	0.002	0.0054	0.0222	0.0008	0.0044	0.0006
Silver (Ag)	0.00002	0.0001	< 0.00002	0.0001	0.00007	< 0.00002	< 0.00002	0.000135	0.00017	< 0.00002	< 0.00002	< 0.00002
Strontium (Sr)	0.000005		0.117	0.0323	0.146	0.186	0.112	0.07275	0.0551	0.0309	0.0933	0.0376
Thallium (Tl)	0.000002	0.0008	0.000052	0.000249	0.000061	0.000032	0.000024	0.001495	0.00161	0.000038	0.000007	0.00007
Tin (Sn)	0.00001		< 0.00001	< 0.00001	0.00007	< 0.00001	0.00008	< 0.00001	< 0.00001	< 0.00001	< 0.00001	< 0.00001
Uranium (U)	0.000002		0.0019	0.00411	0.000036	0.0035	0.0026	0.0128	0.0407	0.000055	0.000014	0.000031
Vanadium (V)	0.00005		0.00022	0.0118	0.00007	0.00011	0.00038	0.173	0.644	0.00015	0.00006	0.00008
Zinc (Zn)	0.0001	0.03	0.0306	1.193	0.53	0.184	0.0662	8.613	5.367	0.181	0.613	0.225

All units mg/l and tested using ICPMS analysis unless otherwise noted

a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2005

b) 0.005mg/L at pH < 6.5, [Ca2+] < 4 mg/L, DOC < 2 mg/L: 0.1 mg/L at pH ≥ 6.5, [Ca2+] ≥ 4 mg/L, DOC ≥ 2 mg/L

c) 0.002 mg/L at [CaCO3] = 0 - 120 mg/L; 0.003 mg/L at [CaCO3] =120 - 180 mg/L; 0.004 mg/L at [CaCO3] >180mg/L

d) 0.001 mg/L at [CaCO3] = 0 - 60 mg/L; 0.002 mg/L at [CaCO3] =60 - 120 mg/L; 0.004 mg/L at [CaCO3] =120 -180mg/L; 0.007 mg/L at [CaCO3] > 180mg/L

e) 0.025 mg/L at [CaCO3] = 0 - 60 mg/L; 0.065 mg/L at [CaCO3] =60 - 120 mg/L; 0.110 mg/L at [CaCO3] =120 -180mg/L; 0.150 mg/L at [CaCO3] > 180mg/L

**Average of sample and replicate*

Italic *results exceed CCME Aquatic Life Guidelines*

Gartner Lee

Table 5 Sediment Samples from South MacMillan Watershed, July 2006

Total Metals Analysis (ug/g)

South MacMillan Sites

Station	Detection Limits	BC ME Sediment Quality Guidelines		M7	M22	M23	M4	M26	M24	M25	M15
Date	ICP-MS	ISQG[1]	PEL[2]	10-Jul-06	10-Jul-06	10-Jul-06	10-Jul-06	12-Jul-06	11-Jul-06	11-Jul-06	11-Jul-06
Distances DS (km)				1	3.56	7.24	9.63	11.78	14.16	15.31	23.38
Antimony (Sb)	0.005	N/A	N/A	0.865	0.951	0.932	0.973	1.27	1.73	1.5	1.23
Arsenic (As)	0.1	5.9	17	**26.1**	**48.8**	**41.4**	**32.1**	**55.5**	**61.1**	**60.1**	**46.7**
Barium (Ba)	0.02	N/A	N/A	224	196	148	518	1028	793	737	1084
Berylium (Be)	0.002	N/A	N/A	0.276	0.799	0.809	0.652	1	0.665	0.706	0.767
Bismuth (Bi)	0.02	N/A	N/A	0.08	0.13	0.12	0.12	0.17	0.15	0.13	0.12
Cadmium (Cd)	0.01	0.6	3.5	0.12	**5.45**	*1.56*	*1.83*	**8.01**	*2.86*	*2.65*	*2.56*
Chromium (Cr)	0.2	37.3	90	15.4	9.8	28.3	12.7	15.5	17.8	17.2	14
Cobalt (Co)	0.005	N/A	N/A	0.927	24.4	19.9	16	31.9	11.4	12.7	10.8
Copper (Cu)	0.08	35.7	197	*80.5*	*129*	*126*	*101*	*163*	*101*	*114*	*93.3*
Lead (Pb)	0.01	35	91	7.38	13.6	13.1	15.4	19.9	33.4	*46.5*	23.1
Lithium (Li)	0.05	N/A	N/A	4.77	7.37	8.44	8.76	8.63	7.48	5.94	8.78
Manganese (Mn)	0.005	N/A	N/A	22.5	318	226	220	480	156	176	168
Molybdenum (Mo)	0.05	N/A	N/A	8.78	9.38	12.5	10.5	12.8	13.5	16.5	10.4
Nickel (Ni)	0.05	16	75	6.68	**99.2**	*63.7*	*56.9*	**118**	*64*	*69.7*	*57.6*
Selenium (Se)	0.2	5	N/A	*6.9*	3.2	3.5	3.3	3.9	3.6	4.7	2.8
Silver (Ag)	0.02	0.5	N/A	0.63	0.45	*0.78*	0.49	*0.66*	*0.55*	*0.59*	0.36
Strontium (Sr)	0.005	N/A	N/A	29.9	42.8	26.2	32.2	55.6	60.1	46.2	59.7
Thallium (Tl)	0.002	N/A	N/A	0.182	0.33	0.371	0.258	0.434	0.406	0.451	0.285
Tin (Sn)	0.05	N/A	N/A	0.07	0.1	0.1	0.18	0.13	0.13	0.1	0.11
Uranium (U)	0.002	N/A	N/A	2.65	6.2	9.09	4.84	8.6	7.31	8.3	7.57
Vanadium (V)	0.05	N/A	N/A	56.1	37.4	119	51	76.9	153	138	80.8
Zinc (Zn)	0.1	123	315	59	**439**	*233*	*284*	**630**	**350**	**374**	**349**

Tributaries of the South MacMillan

Station	Detection Limits	BC ME Sediment Quality Guidelines		M1	M2	M3	M9	M11	M13	M18	M20
Date	ICP-MS	ISQG[1]	PEL[2]	10-Jul-06	10-Jul-06	10-Jul-06	11-Jul-06	11-Jul-06	11-Jul-06	12-Jul-06	12-Jul-06
Distances DS (km)				2.14	4.7	7.14	12.13	13.4	16.49	45.45	47.84
Antimony (Sb)	0.005	N/A	N/A	1.38	0.969	1.12	2.31	2.55	0.546	0.533	0.777
Arsenic (As)	0.1	5.9	17	**75.3**	**36.8**	**57.6**	**79.9**	**281**	**50.5**	**77.5**	**45.1**
Barium (Ba)	0.02	N/A	N/A	185	72.8	692	74.7	106	98.4	216	727
Berylium (Be)	0.002	N/A	N/A	0.872	0.162	0.343	0.099	0.041	0.55	0.866	0.812
Bismuth (Bi)	0.02	N/A	N/A	0.34	0.11	0.15	0.05	0.02	0.13	0.14	0.12
Cadmium (Cd)	0.01	0.6	3.5	**10.9**	0.13	0.47	*1.25*	0.39	0.21	**18.1**	*1.55*
Chromium (Cr)	0.2	37.3	90	7.8	18.6	11.6	*40.1*	**313**	14	20.9	12.7
Cobalt (Co)	0.005	N/A	N/A	32.2	1.33	7.32	0.702	0.536	3.36	139	13.3
Copper (Cu)	0.08	35.7	197	*128*	34.6	*102*	32.2	8.46	29.1	*86.6*	*48.3*
Lead (Pb)	0.01	35	91	22.4	10.5	26.1	**306**	6.77	14.2	15.4	10.7
Lithium (Li)	0.05	N/A	N/A	5.96	12.3	4.23	0.68	0.26	15.5	45.9	18.2
Manganese (Mn)	0.005	N/A	N/A	423	58.6	185	19.6	7.31	78.7	3986	264
Molybdenum (Mo)	0.05	N/A	N/A	12.3	12	7.15	15.5	16.7	6.11	3.34	8.6
Nickel (Ni)	0.05	16	75	**120**	7.66	*20.8*	5.52	5.32	*21.4*	**124**	*50.7*
Selenium (Se)	0.2	5	N/A	2.8	5	*5.5*	*8.2*	0.2	2.9	2.9	3.4
Silver (Ag)	0.02	0.5	N/A	*0.64*	0.48	*0.73*	*1.11*	*0.61*	0.25	0.2	0.44
Strontium (Sr)	0.005	N/A	N/A	49.3	7.42	15.1	13.9	3.68	13	24.2	19.7
Thallium (Tl)	0.002	N/A	N/A	0.564	0.165	0.099	0.314	0.322	0.226	0.118	0.388
Tin (Sn)	0.05	N/A	N/A	0.15	0.08	0.1	0.15	1.02	0.13	0.05	0.06
Uranium (U)	0.002	N/A	N/A	5.34	2.47	2.09	2.46	2.6	10.9	1.78	5.26
Vanadium (V)	0.05	N/A	N/A	36	115	40.4	891	7087	66.3	24.4	36.2
Zinc (Zn)	0.1	123	315	**510**	60.8	111	*227*	72.3	94.1	**583**	**353**

All units ug/g unless otherwise noted

a) Working Guidelines for the Sediments, A compendium of working water quality guidelines for British Columbia, 2006

1)Interim sediment quality guidelines from "A compendium of working water quality guidelines for British Columbia "(2006)

2)Probable effects level from "A compendium of working water quality guidelines for British Columbia"(2006)

N/A indicates no current working Guidelines.

Italic	*Results Exceed ISQG*
BOLD	*Results Exceed PEL*

Appendix A

Photo Log

- PHOTOGRAPHS -

PHOTOGRAPH 1

Doug Davidge of Environment Canada Sampling macro invertebrates at sample location M1. Photo is looking up stream on a tributary of the South MacMillan River.

PHOTOGRAPH 2

Looking down stream on site stream flow and water quality site M7 on the South MacMillan River.

- PHOTOGRAPHS -

PHOTOGRAPH 3

Stream flow and water quality site M22 looking upstream on the South MacMillan River.

PHOTOGRAPH 4

Water quality and flow measurement site M2 looking down stream on tributary of South MacMillan River.

- PHOTOGRAPHS -

PHOTOGRAPH 5

Water quality and flow measurement site M3, looking at confluence with south MacMillan River.

PHOTOGRAPH 6

Water quality and flow measurement site M23, looking downstream on South MacMillan River 20m upstream of sample site/tributary M3.

- PHOTOGRAPHS -

PHOTOGRAPH 7

Water quality and flow measurement site M4, looking downstream on the South MacMillan River.

PHOTOGRAPH 8

Water quality and flow measurement site M5 at confluence with South MacMillan River looking upstream.

- PHOTOGRAPHS -

PHOTOGRAPH 9

Water quality and flow measurement site M13, looking down stream on Sekie Creek # 1.

PHOTOGRAPH 10

Water quality and flow measurement site M6 looking down stream at confluence with South MacMillan River.

- PHOTOGRAPHS -

PHOTOGRAPH 11

Water quality and flow measurement site M26 looking upstream on the South MacMillan River

PHOTOGRAPH 12

Water quality and flow measurement site M9, looking downstream on Sekie Creek #2 towards the North Canol Highway.

- PHOTOGRAPHS -

PHOTOGRAPH 13

Water quality and flow measurement site M11, looking downstream on Macintosh Creek.

PHOTOGRAPH 14

Water quality and flow measurement site M24 on South MacMillan River looking down stream.

- PHOTOGRAPHS -

PHOTOGRAPH 15

Water quality and flow measurement site M25 on South MacMillan River looking upstream at impassable bridge leading to Jason property.

PHOTOGRAPH 16

Water quality and flow measurement site M20 looking down stream (under bridge) on Hess Creek.

PHOTOGRAPH 17

Water quality site M21 looking upstream on the South MacMillan River.

PHOTOGRAPH 18

Water quality and flow measurement site M15, looking upstream on the South MacMillan River.

PHOTOGRAPH 19

Water quality and flow measurement site M18, looking downstream on a Dewhurst Creek.