

IN THE MATTER

of the Resource Management Act 1991

AND

IN THE MATTER

of applications by Oceana Gold (New Zealand)
Limited for the Coronation North Project

**STATEMENT OF EVIDENCE OF CHRISTOPHER WAYNE HICKEY
FOR OTAGO REGIONAL COUNCIL**

QUALIFICATIONS AND EXPERIENCE

1. My full name is Christopher Wayne Hickey.
2. I hold the degree of Doctor of Philosophy in biochemistry/microbiology from the University of Waikato which I received in 1985. I have worked for over 30 years in environmental research and consulting in the area of contaminant impacts in fresh and marine waters. My specialist areas are in water quality guidelines and environmental toxicology.
3. I am a research scientist with the National Institute of Water and Atmospheric Research Limited ("NIWA") based in Hamilton. I am a Principal Scientist – Ecotoxicology and Environmental Chemistry with NIWA. I have been employed in this role since 2008. Prior to this I was employed by NIWA and its predecessors as a research scientist since 1979.
4. My research experience includes: characterisation of wastewater treatment systems; environmental impact of wastewater discharges; determining species sensitivity to chemical contaminants; biomonitoring for chemical contaminants and their effects on native fish and invertebrate species; derivation of water and sediment quality guidelines and remediation of environmental contamination.
5. I was a contributing author to the ANZECC (2000) water quality guidelines¹; the New Zealand Municipal Wastewater Monitoring Guidelines²; and Guidelines for Drinking-water Quality Management for New Zealand³. I am currently on a technical committee undertaking a review and derivation of new and revised ANZECC guidelines for marine and freshwaters. This project includes both numeric water and sediment guidelines and guidance on deriving site-specific guidelines. The project is on-going and would not be expected to produce any revised guidelines in a timescale that they can be considered for this hearing. I am also on the Technical Experts Committee for toxicants and sediments for the Ministry for the Environment for derivation and implementation of national environmental standards for freshwaters. I was responsible for the recently derived national standards for nitrate and ammonia, while contributing to reports providing the basis for future standards.
6. I was a Regional Associate Editor of Environmental Toxicology, an International Wiley Journal (1999-2005). I am a member of the Society

¹ ANZECC, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, October 2000 ed. (Canberra, Australia: National Water Quality Management Strategy Paper No. 4, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, 2000).

² NZWERF, *New Zealand Municipal Wastewater Monitoring Guidelines*, ed. D.E. Ray (Wellington: New Zealand Water and Waste Association, 2002).

³ MoH, *Drinking Water Standards for New Zealand 2005 (Revised 2008)* (<http://www.health.govt.nz/publication/drinking-water-standards-new-zealand-2005-revised-2008>) (Wellington, New Zealand: Ministry of Health, 2005).

of Environmental Toxicology and Chemistry (SETAC). I was President of SETAC Global (over 5000 members) in 2004 and served on the Board of Directors for SETAC Asia/Pacific (2001-2010). I was made a SETAC Fellow in 2016. Through my close involvement with national and international societies, I have been involved with the organisation of and have participated in numerous workshops and conferences covering a wide range of environmental issues. This experience is invaluable in undertaking site-specific evaluations of environmental contaminant risks in various geographic locations.

7. Acting as a consultant I have been involved with the design and implementation of aquatic toxicity assessment and biomonitoring programmes, monitoring of pollution impacts, environmental impact reports and discharge consenting applications; site-specific guideline derivations and government policy advice.
8. I have authored or co-authored over 100 published scientific papers on a range of freshwater and marine environmental toxicology topics, including toxicity of chemicals to organisms, pollution impacts on benthic communities, the use of freshwater and marine organisms for biomonitoring, and the chemical contamination of freshwater and marine sediments.

Experience with site

9. I am familiar with the Oceana Gold (New Zealand) Ltd site at Macraes from a site visit undertaken on 22 September 2016.

Code of Conduct

10. I confirm that I have read the Environment Court's Code of Conduct for expert witnesses and I agree to comply with it. I confirm that I have considered all the material facts that I am aware of that might alter or detract from the opinions that I express, and that this evidence is within my area of expertise, except where I state that I am relying on the evidence of another person.

SCOPE OF WORK UNDERTAKEN

11. I have been engaged by Otago Regional Council to address specific matters relating to components of a resource consent application from Oceana Gold to Otago Regional Council (ORC) for an extension of Macraes mine (Oceana Gold Application RM16.138). The brief specified (P. Christophers email of 090616):

11.1. Review of "Surface Water Modelling", "Arsenic and Iron Mobility" and "Water Quality Mitigation – Fresh Water Dam Scenario", "Erosion and Sediment Control", which can be found in objective links Oceana Gold - Consent Application Appendices 4a; Oceana

Gold - Consent Application Appendices 4b and Oceana Gold – Consent Application Appendices 14 & 15⁴.

11.2. Review relates to surface water quality and not aquatic ecological values.

12. All assessments are based on the information supplied in the supplied Appendix information. Additional information was obtained from Charles Horrell (ORC) in relation to existing consent conditions, fauna present at stream sites and information on the proposed water storage dam.
13. I provided a Technical Assessment to ORC in response to this review brief⁵, and a subsequent report responding to the s92 response received from Oceana Gold⁶. In my Technical Assessment I raised 19 issues where I considered that further information was required. In my response to the s92 I summarised the adequacy of the response in relation to the issues I had raised. Overall, I considered that *"...the responses to the s92 information request is insufficient to address the issues raised in relation to future water quality issues in Mare Burn as a result of the proposed Macraes Mine expansion."* I address these outstanding issues in my evidence below.
14. At the time of writing (20 September 2016) I had not received any further information from Oceana Gold on water quality monitoring or proposed consent compliance conditions.
15. No submissions relating to this application nor the ORC Officer's Report were available for comment at the time of writing.
16. Specifically, in this evidence I address:
 - 16.1. Contaminants of concern;
 - 16.2. Overview of issues raised in my assessment; and
 - 16.3. Proposed consent conditions.

⁴ Golder Associates, "Coronation North Project. Surface Water Modelling," (Golder Associates report to Oceana Gold (New Zealand) Ltd, 2016).; Engineering Geology, "Oceana Gold (New Zealand) Ltd. Macraes Gold Project: Coronation North Project. Erosion and Sediment Control," (Engineering Geology Ltd report to Oceana Gold (New Zealand) Ltd, 2016).

⁵ C.W. Hickey, "Technical Assessment - Oceana Gold," (NIWA report to Otago Regional Council (ORC). 27 June 2016, 2016a).

⁶ "Oceana Gold - Comments on S92 Response," (NIWA report to Otago Regional Council (ORC). 14 July 2016, 2016b).

Additional material considered

17. In preparing this evidence I only refer to the addition material provided by J. Bywater (Oceana Gold) as a s92 response dated 11 July 2016 ⁷.

Contaminants of potential concern

18. In undertaking this review I used a check list of issues which I consider should be addressed in relation to management of water quality downstream of the various discharge sites in order to provide for adequate levels of ecological protection for the receiving waters. In applying this approach I have assumed that at some point downstream there will be ecological values which should be protected.
19. The contaminants and stressors of potential concern and their potential effects on freshwater streams are summarised in **Attachment 1**. The contaminants of potential concern include both stimulants (e.g., nutrients), sediments and toxicants, which together can result in a range of enhancement and stressor effects. The extent of the actual impact is dependent on the species and the relative concentrations of the contaminant in the receiving environment following discharge treatment and available dilution in the receiving water.
20. The most important stressors in the receiving environment are as follows:
- Direct toxic effects and potential food chain uptake of heavy metals and metalloids (e.g., arsenic)
 - Toxic effects attributable to elevated total dissolved solids (TDS) (measured as electrical conductivity, EC)
 - Sediments and colour affecting aesthetics
 - Sediments settling and affecting streambed communities (including precipitating iron and manganese flocs)
 - Nutrients resulting in excessive algal growths on the streambed
21. While some common contaminants may be assessed on the basis of water quality guidelines (e.g., heavy metals, arsenic), the availability of guidelines for other ecological stressors (e.g., sediments, TDS, nutrients) is limited. This assessment is further complicated by the complex mixtures of toxicants which may occur in the mining operation's wastewater.

⁷ J. Bywater, "Section 92 Response. 11 July 2016," (Oceana Gold, 2016).

22. I have specifically addressed the contaminants of potential concern (COPCs) in **Attachment 1** for the various activities which are operating or are proposed to operate in the catchment. Notably, amongst those are major ecological stressors which are not addressed, including: total dissolved solids (TDS, measured by electrical conductivity (EC) as a proxy for salinity), suspended sediments / turbidity and various other metals which may be present (e.g., manganese, nickel, chromium).
23. I consider that the proposed increase in TDS concentrations from the mining operation may pose the highest risk to ecological communities in the receiving waters.
24. The consent conditions proposed for receiving waters in Mare Burn are at two monitoring sites (designated MB01 and MB02, shown in **Attachment 2**). The proposed receiving water compliance conditions for these sites are based on stock water quality guidelines (i.e., not ecological protection guidelines) as shown in **Attachment 3**. The proposed sulfate concentration alone under these consents is 1000 g/m³ (equivalent to mg/L), and salt addition for TDS will be markedly higher when the calcium or magnesium ions are also included.
25. This proposed level of TDS alone of 1000 g/m³ from sulfate equates to an EC value of 156 mS/m or 1,560 µS/cm⁸.
26. In my Technical Assessment review I noted that the median and 95th percentile EC values for New Zealand rivers based on the "100 rivers" study were 86 µS/cm and 225 µS/cm⁹. Thus the proposed EC from sulfate alone is 7x greater than the 95th percentile value for NZ rivers.

Salinization guidelines for freshwaters

27. Scientific understanding of mechanisms by which increasing salinization damages freshwater ecosystems is in its infancy, which makes it challenging to develop and implement standards protective of freshwater life¹⁰. Technical challenges exist in that the thresholds for different salts appear dependent on the concentrations of specific ions (e.g., chloride, magnesium or bicarbonate)¹¹, making generalised standards more difficult to develop.

⁸ Conversions: 100 microS/cm = 0.1 mS/cm; 10 mS/m = 64 ppm TDS. This TDS conversion is based on NaCl and will differ with other salt compositions.
(http://www.lennotech.com/calculators/conductivity/tds_engels.htm).

⁹ J.M. Quinn and C.W. Hickey, "Characterisation and Classification of Benthic Invertebrate Communities in 88 New Zealand Rivers in Relation to Environmental Factors," *New Zealand Journal of Marine and Freshwater Research* 24, no. 3 (1990).

¹⁰ M. Canedo-Arguelles et al., "Saving Freshwater from Salts," *Science* 351, no. 6276 (2016).

¹¹ David R. Mount et al., "The Acute Toxicity of Major Ion Salts to *Ceriodaphnia Dubia*: I. Influence of Background Water Chemistry," *Environmental Toxicology and Chemistry* (2016); William H. Clements and Chris Kotalik, "Effects of Major Ions on Natural Benthic Communities: An Experimental Assessment of the US Environmental Protection Agency Aquatic Life Benchmark for Conductivity," *Freshwater Science* 35, no. 1 (2016).

28. No water quality guidelines for EC or TDS have been developed for NZ freshwaters. Therefore no linkage has been established for NZ freshwater species with EC as an ecological stressor.
29. In my Technical Review I identified the US EPA have derived a “field-based benchmark” for EC in central Appalachian streams areas where mountain top mining is occurring, and in which EC changes are dominated by salts of calcium, magnesium, sulphate and bicarbonate ¹². The 95% percentile protection EC criterion for these streams was determined to be 295 µS/cm.
30. The Canadian province of British Columbia has recently compiled a review of mining-related increases in sulphate concentrations in freshwaters ¹³. The toxicological approach taken for this guideline derivation is broadly consistent with the ANZECC derivation approach and establishes a range of sulphate guideline values (GVs) for ecological protection which are related to water hardness – with the GV increasing as water hardness increases.
31. The British Columbia GV is summarized in **Attachment 4**. Assuming the Mare Burn waters are in the ‘very soft’ category the sulphate guideline would be 128 mg/L.
32. This GV is 7.8x lower than the existing (MB01) and proposed (MB02) guidelines based on stock watering (**Attachment 3**). Water hardness information for Mare Burn would be required to refine the application of these GV to the local receiving waters.

Other guidelines suitable for ecological protection of freshwaters

33. In my Technical Review I identified a range of water quality guidelines which would be suitable to provide ecological protection for the receiving communities. These guidelines are summarised in **Attachment 5** and are based largely on the ANZECC (2000) water quality guidelines ¹⁴ and the MfE National Policy Statement – Freshwater (NPS-FW) ¹⁵ standards.
34. Further information on the background water quality conditions and the concentrations of contaminants in pond and seepage discharges will be required before a suite of ecologically protective compliance conditions can be finalised.

Issues remaining after s92 response

¹² US EPA, “A Field-Based Aquatic Life Benchmark for Conductivity in Central Appalachian Streams (Final Report),” (Washington, DC: U.S. Environmental Protection Agency, 2011).

¹³ British Columbia Ministry of Environment, “Ambient Water Quality Guidelines for Sulphate. Technical Appendix,” (Report by C. Meays and R. Nordin, Water Protection & Sustainability Branch, Environmental Sustainability and Strategic Policy Division, BC Ministry of Environment, 2013).

¹⁴ ANZECC, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.

¹⁵ MfE, “National Policy Statement for Freshwater Management 2014.

(<http://www.mfe.govt.nz/publications/Rma/Nps-Freshwater-Management-2014/Nps-Freshwater-Management-Jul-14.Pdf>),” (Wellington: Ministry for the Environment, 2014).

35. I provided a memo to ORC in response to the s92 responses received from Oceana Gold ¹⁶. I provided specific comments on: sediment conditions; ecological monitoring; sediment monitoring data; dissolved oxygen; nutrients; electrical conductivity; and alternate discharge methods. Additionally, I provided a detailed response and comments to the 19 issues raised in my initial Technical Assessment.
36. Overall, I considered that “...the responses to the s92 information request is insufficient to address the issues raised in relation to future water quality issues in Mare Burn as a result of the proposed Macraes Mine expansion.”
37. As one of the proposed mitigation measures Oceana Gold have proposed building a high dam to provide additional dilution at sites downstream of the wastewater seepage inputs. I consider that various issues relating to downstream water quality and the dilution flows which are potentially available over summer low flows are still to be resolved, should this reservoir proposal go ahead.
38. My comments relating to alternate discharge methods address the need for a more detailed assessment of the potential for irrigation of salinized wastewaters to land or to discharge to other receiving waters with higher available dilutions. This assessment was not available at the time of this evidence writing.
39. The presence of the locally important flathead galaxiid fish populations and their sensitivity to salinization of their habitat is a major site-specific issue relating to the proposed discharges to the small streams.
40. I consider that, because of the proposed marked elevation in receiving water sulfate (i.e., TDS) concentrations, site-specific criteria will need to be developed to provide long-term (i.e., chronic) protection for the flathead galaxiid populations.

RESPONSES TO SUBMISSIONS

41. I am unable to provide a response to submissions at the time of writing since they were not available.

Officer's Report

42. I am unable to provide comments on the Officer's Report as it is not available at the time of evidence writing.

RECOMMENDED MONITORING CONDITIONS

43. I recommend the following mitigation and monitoring measures:

¹⁶ Hickey, "Oceana Gold - Comments on S92 Response."

- 43.1. That the water quality guidelines provided in **Attachment 5** should be used to provide receiving water compliance conditions for relevant contaminants.
- 43.2. That the sulphate water quality guidelines developed by Canadian province of British Columbia (**Attachment 4**) should be used as an interim guideline for salinity until appropriate site-specific guidelines can be developed. Assuming the Mare Burn waters are in the 'very soft' category the sulphate guideline would be 128 mg/L as a maximum concentration.
- 43.3. That suitable long-term (i.e., chronic) guidelines for salinity tolerance for flathead galaxiids should be developed and then applied as site-specific compliance standards for these local receiving waters.
44. *Monitoring.* I recommend that consideration be given to the implementation of a suitable continuous and discrete monitoring programme to adequately characterise key water quality parameters at the proposed receiving water sites.
45. This monitoring programme should be designed to provide the required background water quality data necessary to develop a robust receiving water compliance monitoring design which is suitable for both annual and long-term implementation.

CONCLUSIONS

46. I consider that:
- 46.1. the Mare Burn receiving waters require compliance conditions based on suitable ecological protection guidelines.
- 46.2. the receiving water compliance conditions must include conditions to provide suitable ecological protection for sulphate and general salinization effects.
- 46.3. the site-specific guidelines should be development to provide long-term protection thresholds for flathead galaxiids from sulphate and total dissolved solids discharged from the site.
- 46.4. issues relating to the potential for alternative disposal options for high salinity wastewaters should be thoroughly evaluated. Avoidance of discharge to the receiving waters is highly desirable so as to remove the potential for marked reductions in water quality – particularly over summer low flow periods.

Christopher W. Hickey.

Dr C.W. Hickey

Date: 20 September 2016

REFERENCES

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- Mount, David R., Russell J. Erickson, Terry L. Highland, J. Russell Hockett, Dale J. Hoff, Correne T. Jenson, Teresa J. Norberg-King, *et al.* "The Acute Toxicity of Major Ion Salts to *Ceriodaphnia Dubia*: I. Influence of Background Water Chemistry." *Environmental Toxicology and Chemistry* (2016): n/a-n/a.
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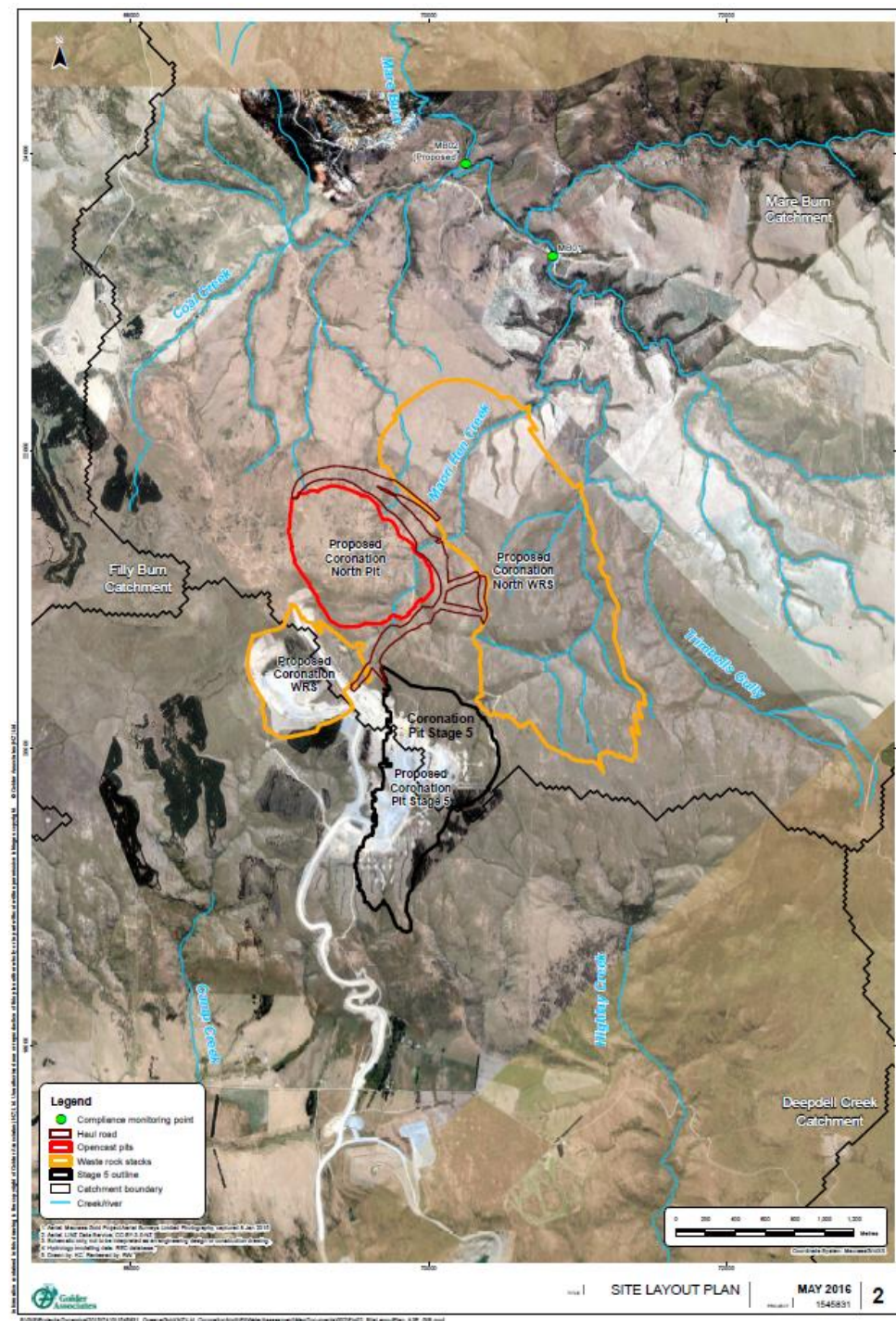
Attachment 1:

Overview of contaminants of potential concern (COPCs) for Mare Burn downstream of proposed pit and waste rock discharges (from ¹⁷)

Discharge	Contaminant / stressor of concern	Sources	Potential effects
Waste rock	Heavy metals (copper, zinc, nickel, chromium, silver)	Leaching	Toxicity
	Reduced metals (iron, manganese)	Reduced metals occur under anoxic conditions	Toxicity by smothering
	Metaloids (arsenic, antimony)		Toxicity
	Sulphate/conductivity		Toxicity
	pH	Sulphide oxidation; addition of flocculents (e.g., alum); pH control	
	Sediment / turbidity	Mining operations	Aesthetics / toxicity
Pit operations	As above		
	Chemicals for suspended sediment management	Various chemical potentially used for SS management	Toxicity
	Nutrients (nitrogen and phosphorus)		Aesthetics / periphyton growths
	Cyanide	Gold extraction processing	Toxicity
Reservoir	Low dissolved oxygen	Generated under stratified conditions in hypolimnion	Toxicity
	Hydrogen sulphide	as above	Toxicity
	Ammonia	as above	Toxicity
	Iron & Manganese	as above	Toxicity
	Nutrients	from run-off	Aesthetics / periphyton growths
Other	Residual flows	Abstractions of water	Habitat loss in streams
Roading	Sediment	Roading	Aesthetics / toxicity
	Dust control chemicals		Toxicity
Run-off			
	Hydrocarbon spillages	Transort activities on site	Toxic and aesthetic effects

¹⁷ "Technical Assessment - Oceana Gold."

Attachment 2: Map of proposed Coronation North development showing location of receiving waters, including Mare Burn and the proposed monitoring sites MB01 and MB02.



Attachment 3: Proposed receiving water compliance conditions (Golder Associates 2016 ¹⁸)

Table 21: MB01 and MB02 compliance criteria.

Parameter ⁽¹⁾	Existing at MB01 and proposed for MB02	ANZECC 2000 (stock water)	NZDWS 2008 ⁽²⁾
pH (unitless)	6.0 – 9.5	-	7.0 – 8.5
Sulfate	1,000	1,000	250
Cyanide _{WAD}	0.1	-	0.08
Arsenic	0.15	0.5	0.01
Copper ⁽³⁾	0.009	0.5	2
Iron	1.0	N/A	0.2
Lead ⁽³⁾	0.0025	0.1	0.01
Zinc ⁽³⁾	0.12	20	-

Notes: 1) All units g/m³ unless stated.
 2) Some of these values are maximum acceptable values while others are guideline values for aesthetic determinands.
 3) Copper, lead and zinc compliance criteria for MB01 are hardness related.

¹⁸ Golder Associates, "Coronation North Project. Surface Water Modelling."

Attachment 4: British Columbia Ministry of Environment sulphate toxicity guidelines (British Columbia Ministry of Environment 2013¹⁹) (Table 4 from²⁰).

Table 6. Sulphate water quality guidelines (mg/L) based on water hardness (mg/L) categories.

Water hardness* (mg/L)	Sulphate guideline (mg/L)
Very Soft (0-30)	128
Soft to moderately soft (31-75)	218
Moderately soft/hard to hard (76-180)	309
Very hard (181-250)	429
>250	Need to determine based on site water**

*Water hardness categories adapted from the CCME.

** Toxicity tests on the early stage rainbow trout were only conducted up to a water hardness of 250 mg/L. Natural background concentrations of water hardness in BC are generally much lower than 250 mg/L. It is recommended that additional toxicity testing on several species is required if natural background water hardness is greater than 250 mg/L. Organisms exposed to higher concentrations of water hardness in combination with sulphate may experience osmotic stress.

¹⁹ British Columbia Ministry of Environment, "Ambient Water Quality Guidelines for Sulphate. Technical Appendix."

²⁰ Hickey, "Technical Assessment - Oceana Gold."

Attachment 5: Comparison of existing compliance criteria at site MB01 with potential ecologically relevant criteria suitable for MB02 (Table 3 from ²¹).

Parameter	Existing compliance criteria at MB01	Potential ecological protection criteria for MB02	Reference for proposed criteria
pH (unitless)	6.0-9.5	6.5-9.0	(ANZECC 2000)
Dissolved copper	0.009	0.0014	ANZECC (2000)
Dissolved zinc	0.12	0.008	ANZECC (2000)
Dissolved nickel		0.011	ANZECC (2000)
Dissolved lead	0.0025	0.0034	ANZECC (2000)
Dissolved silver		0.00005	ANZECC (2000)
Arsenic	0.15	0.013, 0.024	ANZECC (2000)
Iron	1	1	US EPA (1976)
Manganese		0.5	
Cyanide	0.1	0.007	ANZECC (2000)
Sulphate	1000	128	MFE-BC (2013)
Dissolved oxygen	~	>7.0 (>5.0)	NPS-FM (MfE 2014)
Nitrate		<2.4 (<3.5)	NPS-FM
Ammonia		<0.24 (<0.40)	NPS-FM
Turbidity		30-50% change in clarity	(MfE 1994)
Suspended solids		30-50% change in clarity	MfE (1994)

Notes:

All units g/m³ (i.e., mg/L) unless stated.

1. pH range from ANZECC. Aluminium becomes markedly more toxic at pH 6 so range should be limited. Ammonia toxicity increases at high pH.

2. Default metal guideline for a hardness of 30 g CaCO₃ m³.

3. Guideline dependent on arsenic speciation (AsIII or AsV)

4. Manganese flocc precipitates like iron flocc. Estimated guideline value for initial evaluation.

5. Guideline is hardness-dependent. Value is for 'very soft' waters and may be higher in high hardness waters.

6. Values for 7 day mean minimum (1 day minimum) in summer period for 'B' attribute waters.

7. Values for median (95th percentile bracketed) for 'B' attribute waters.

8. Values for median (maximum bracketed) for 'B' attribute waters for total ammoniacal-N at pH 8. Note that pH adjustment for other pH values.

9. Turbidity and SS change relative to background water clarity as aesthetic measure. No values available for ecological protection.

²¹ Ibid.