In post-closure, the upper zone of Kennady Lake (i.e., 1 to 6 m) is expected to maintain sufficient dissolved oxygen concentrations to support cold water aquatic life (greater than 6.5 mg/L). The middle and bottom depths will be exposed to higher WODRs and lower dissolved oxygen concentrations, which are expected to decrease below 6.5 mg/L over winter. The deeper zone is expected to exhibit a higher prevalence of anoxia before the end of winter. There will be some dissolved oxygen variability within the lake, as observed in baseline conditions, and it is expected, for example, that shallow littoral zones of the Kennady Lake with fine organic sediment substrates will have higher oxygen demand than cobbled substrates. Additionally, the Hearne and Tuzo pits in Kennady Lake after closure were not included in the above estimates. These open pits will have a deeper epiliminion and lower WODR (i.e., resulting from negligible sediment oxygen demand) compared to other regions of Kennady Lake. As a result an additional store of dissolved oxygen will be available through the winter.

Under open-water conditions, Kennady Lake is expected to remain well mixed. In most of Kennady Lake, stratification is not expected in summer due to wind-driven circulation, and dissolved oxygen concentrations are likely to be generally uniform throughout the water column in Areas 3 to 8, ranging from 9 to 16.5 mg/L (mirroring current conditions – see Section 8.3.6), which will extend into the deeper pit depths.

Trace Metals

Trace metals can be toxic to aquatic life in high concentrations. The toxicity of some metals (e.g., cadmium, copper, lead, nickel, and zinc) can vary with hardness, with increasing hardness levels resulting in a decrease in the potential toxicity of these metals to aquatic life.

There are several potential loading sources of trace metals to Areas 3 to 7 during the operations phase. Geochemical sources include loadings from mine rock and PK drainage, and pit wall exposure. Groundwater discharge from the active pits will contribute metals during the period when groundwater is discharged to the WMP (see Section 8.4.3.5). Inputs that increase during the operations phase are generally predicted to increase trace metals concentrations during this period, then decline during refilling (i.e., closure), and approach background concentrations as the lake flushes in the post-closure period.

However, some of the geochemical sources are anticipated to continue to contribute loads into post-closure, so trace metals that are elevated in these sources are not predicted to approach background conditions. In addition, it was assumed that 1 mg/L of fine sediments will be re-suspended in perpetuity (see

Appendix 8.I). These sediments were assumed to have the chemical makeup of solid fine PK.

Surface water from Lake N11 and natural runoff from the upper watershed used to refill Kennady Lake will not be a primary source of metals to the refilled Kennady Lake, as concentrations in these sources are not expected to be higher than background levels.

Predicted trace metal concentrations are discussed in more detail below, and are grouped according to predicted long-term trends.

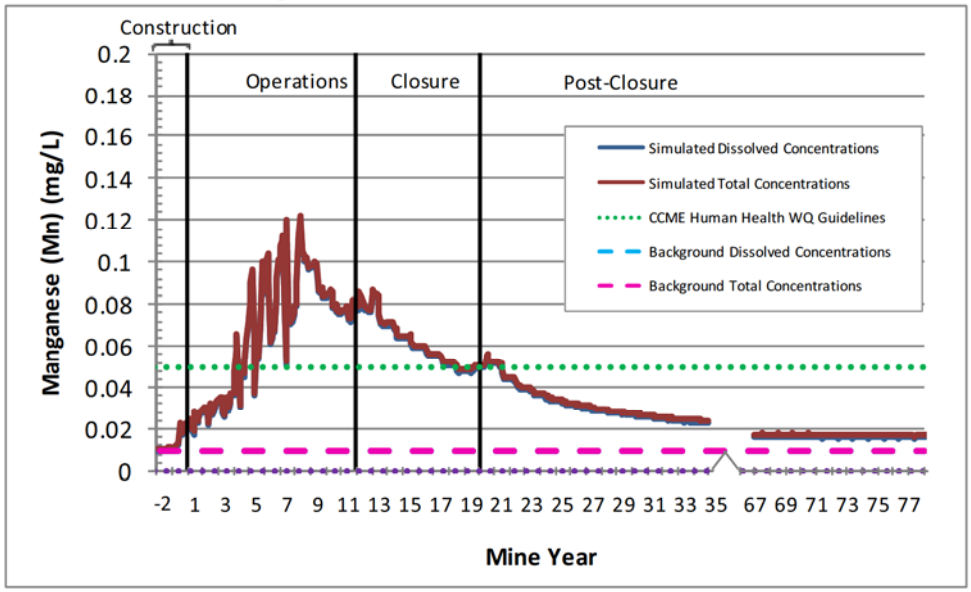
Trace Metals that are Predicted to Decline in Post-Closure

Of the 23 trace metals that were modelled for this assessment, 11 are predicted to increase in concentration during the operations phase, and then steadily decline in concentration as the lake is flushed during post-closure. These metals are chromium, cobalt, iron, lead, manganese, mercury, selenium, silver, thallium, uranium and zinc. A time series plot of manganese (Figure 8.8-10) illustrates the general trend predicted for these metals.

With the exception of thallium, the primary loading source of these metals to Kennady Lake is groundwater from the active mine pits, hence the decline once pit dewatering is finished. Thallium has two primary loading sources, namely, groundwater and mine rock runoff. Because the concentrations of these metals will be mainly groundwater-driven, the dissolved fraction of these metals is predicted to comprise the majority of the total concentrations. Of these 11 trace metals, chromium and iron are predicted to exceed guidelines in the post-closure phase (Figures 8.8-11 and 8.8-12, respectively).

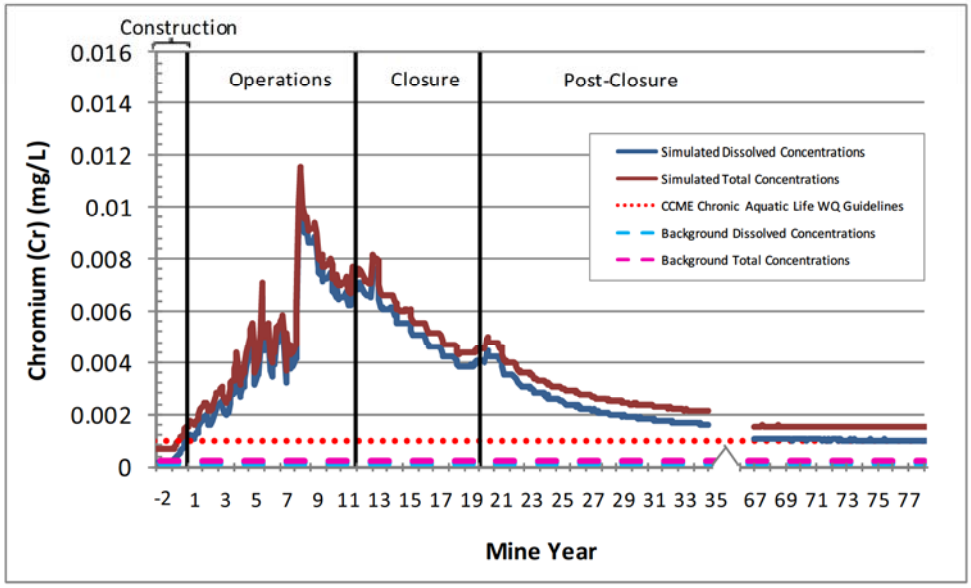
In the case of chromium, it should be noted that the guideline for chromium (VI) was conservatively applied to total and dissolved chromium predictions, although it is anticipated that most chromium will be present as chromium (III). The basis for this assumption is that the dominant sources of chromium to Kennady Lake are groundwater and seepage from fine PK and waste rock, and these are not highly oxidative systems that would generate chromium (VI). Predicted concentrations of total and dissolved chromium are below the CCME guideline of 0.0089 mg/L for chromium (III).

Figure 8.8-10 Predicted Manganese Concentrations in Areas 3 to 7



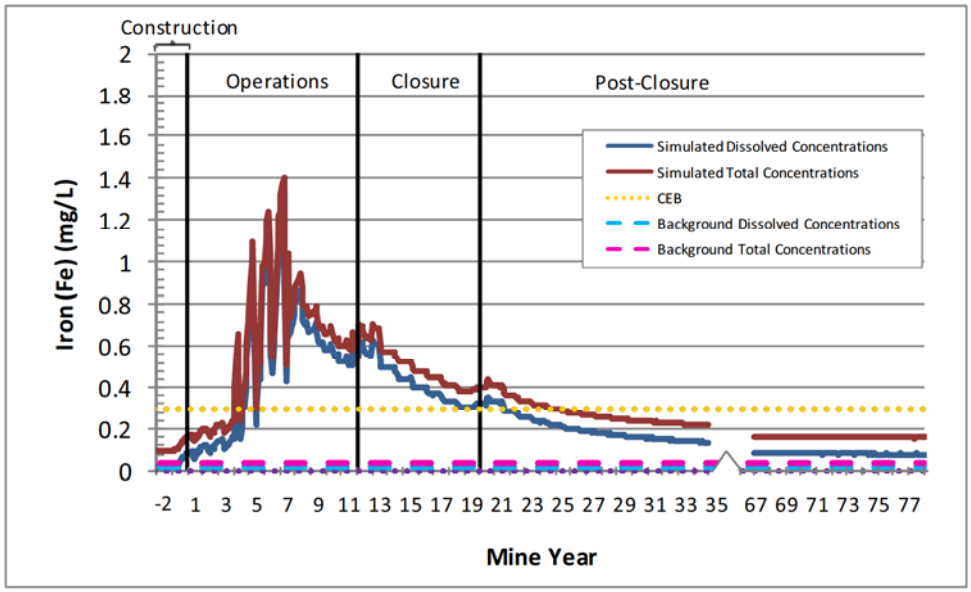
mg/L = milligrams per litre

Figure 8.8-11 Predicted Chromium Concentrations in Areas 3 to 7



mg/L = milligrams per litre

Figure 8.8-12 Predicted Iron Concentrations in Areas 3 to 7



mg/L = milligrams per litre

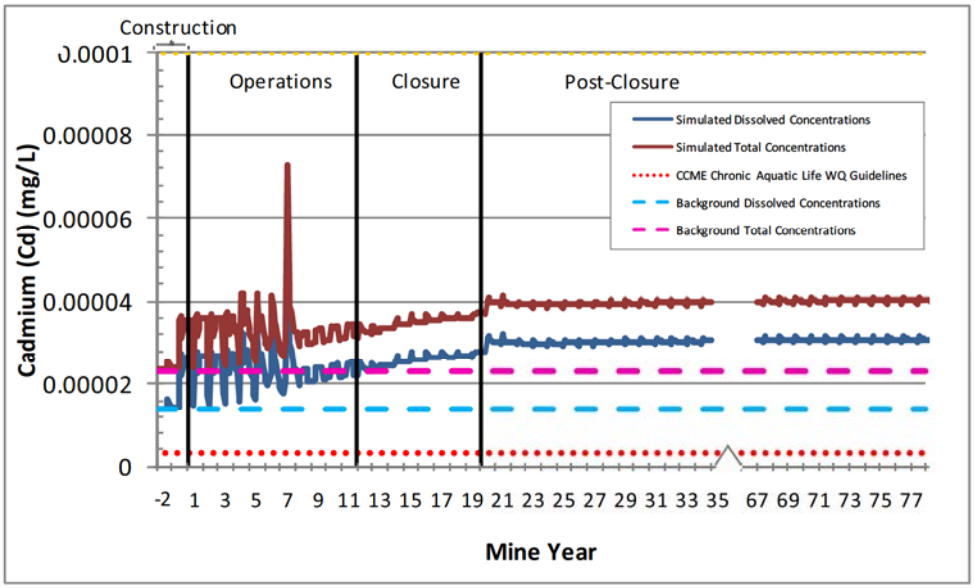
Trace Metals that are Predicted to Remain Constant in the Post-Closure Phase

A second group of metals will be influenced by a combination of sources throughout the operations phase. These metals are predicted to increase mainly due to inputs from groundwater and mine rock runoff, with secondary loading sources from fine PK and process water. They are predicted to increase in concentration steadily throughout the operations phase, rise or fall during closure, then remain fairly constant throughout post-closure. The lack of decline in post-closure concentrations of these metals is due to the geochemical loading that will occur from the remaining mine rock and fine PK in and near Kennady Lake.

Because the primary loading sources of these metals is groundwater and geochemical reactions, the majority of these metals will be in the dissolved form.

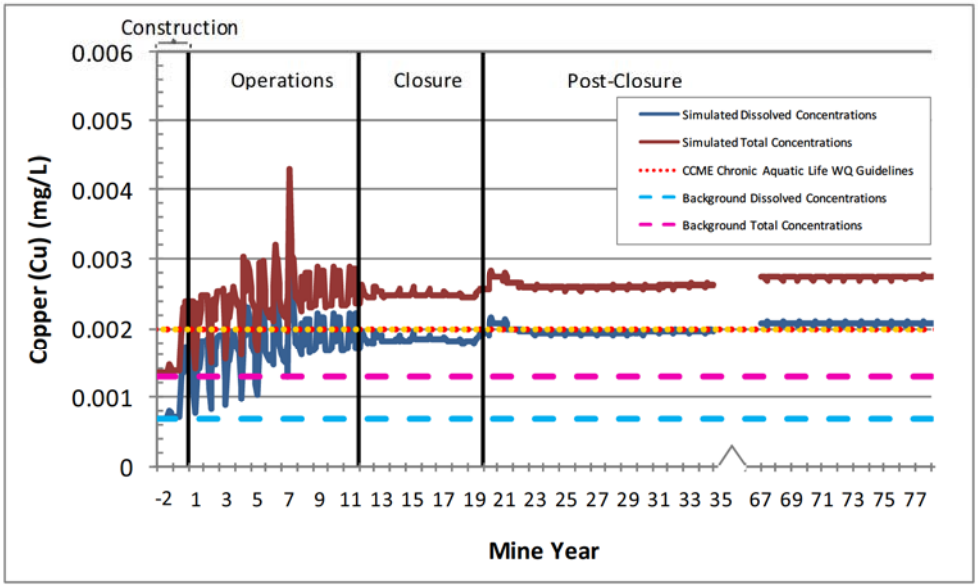
The metals that follow this trend are aluminum, antimony, arsenic, cadmium, copper, nickel, and vanadium. Of these seven metals, cadmium and copper are predicted to exceed guidelines in post-closure. Representative time series plots are shown for cadmium (Figure 8.8-13), copper (Figure 8.8-14), and vanadium (Figure 8.8-15) to illustrate the general trends of this group of metals.

Figure 8.8-13 Predicted Cadmium Concentrations in Areas 3 to 7



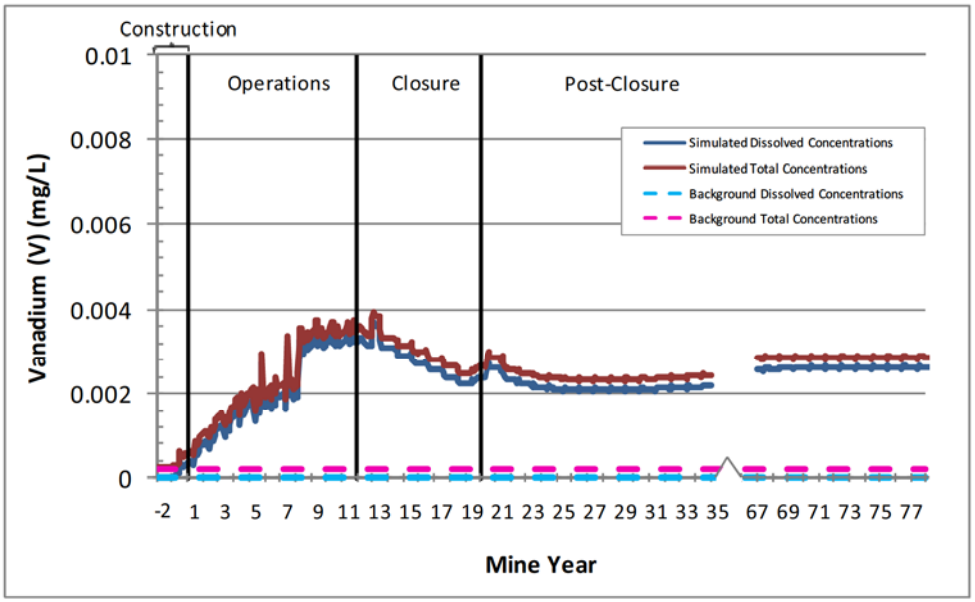
mg/L = milligrams per litre

Figure 8.8-14 Predicted Copper Concentrations in Areas 3 to 7



mg/L = milligrams per litre

Figure 8.8-15 Predicted Vanadium Concentrations in Areas 3 to 7



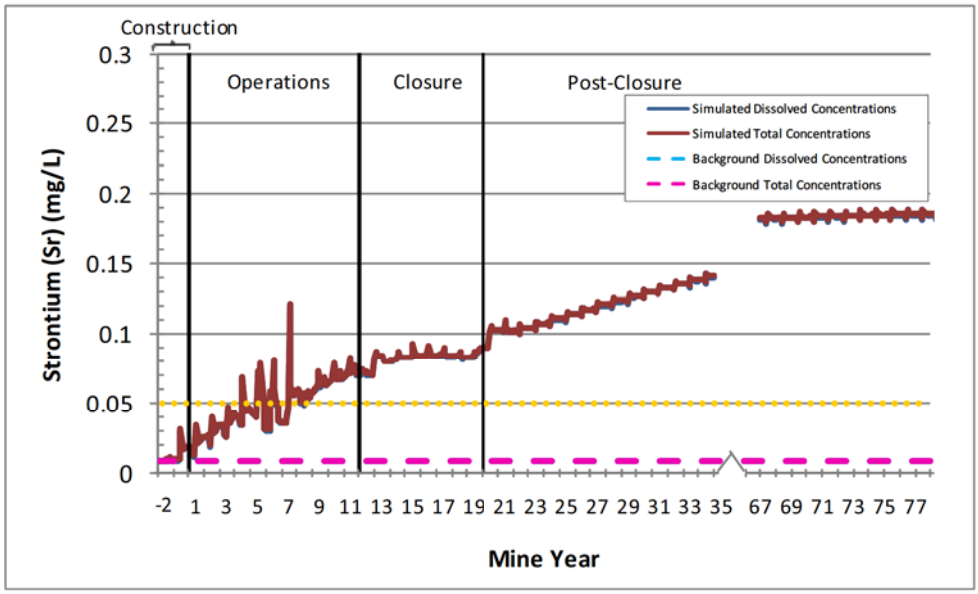
mg/L = milligrams per litre

Trace Metals that are Predicted to Increase in the Post-Closure Phase

The five remaining trace metals that were modelled are predicted to increase in post-closure. Concentrations of these metals, which include barium, beryllium, boron, molybdenum, and strontium, will mainly be driven by loadings from geochemical sources. Mine rock, coarse PK and fine PK will contribute loadings of these metals. Because these materials will be present in post-closure, concentrations of these metals are predicted to increase after closure, reaching steady state conditions in Kennady Lake within about 40 years.

Because geochemical sources are the primary contributors of these metals, the majority of total concentrations will be in the dissolved form. None of these five metals are predicted to exceed water quality guidelines in the post-closure phase. A time series plot of strontium concentrations is shown to illustrate the general trends of these five metals (Figure 8.8-16).

Figure 8.8-16 Predicted Strontium Concentrations in Areas 3 to 7



mg/L = milligrams per litre

The potential health effects of all trace metals on aquatic life, including the four metals that are projected to have maximum concentrations above guideline concentrations (i.e., cadmium, chromium, copper and iron), are assessed in Section 8.9. These metals have been measured in Kennady Lake above guideline concentrations under existing environment conditions (Section 8.3.6).

8.8.4.1.2 Effects to Water Quality in Area 8 after Refilling Activities

Water quality in Area 8 during the post-closure phase will be driven by the water flowing from Kennady Lake after Dyke A is breached, with additional dilution from the Area 8 sub-watershed. A general trend for all modelled water quality constituents is described below.

During the operations phase, water quality constituent concentrations are predicted to increase slightly in Area 8 due to evapo-concentration. The construction of Dyke A will result in a reduction in drainage area reporting to Area 8, thereby increasing the residence time and the rate of evaporation relative to recharge. Consequently, all constituents are predicted to increase to slightly above background conditions by the time Dyke A is breached in Year 21. Because concentrations were not corrected for the background rate of evapo-concentration, the predicted increases are conservative estimates.

Concentrations of all modelled constituents are predicted to increase when Dyke A is breached. In nearly all cases, concentrations are predicted to peak within

five years of Dyke A being breached, as water in Area 8 is replaced with water from the refilled Kennady Lake. Concentrations are generally predicted to decline with time, mirroring those discussed for Kennady Lake in Section 8.8.4.1. In a few cases, discussed in more detail below, concentrations are predicted to increase during post-closure and reach a long-term steady state concentration within a few decades.

Regardless of time to reach peak concentrations, both the concentration peaks and steady state concentrations attained in Area 8 are generally predicted to be about 20% lower than peaks in Kennady Lake due to the additional dilution afforded by runoff from the Area 8 catchment. The amount of dilution (on a concentration basis) in Area 8 varies by constituent; those with high concentrations relative to background will receive more than 20% dilution, and those with concentrations closer to background will receive less.

Predicted concentrations in Area 8 during the post-closure phase are listed in Table 8.8-15. Results for phosphorus, following the application of supplemental mitigation strategies, are provided in Table 8.8-16.

Table 8.8-15 Predicted Water Quality in Area 8 for Post-Closure

Regulated Parameter	Units	Water Quality Guidelines [a]	Kennady Lake Baseline WQ	Predicted Values / Concentrations in Area 8
				Long-term Steady State Post-closure Concentration [b]
Conventional				
pH	pH units	6.5 - 9.0	6.7	6.7 [c]
Total Dissolved Solids	mg/L	-	11	94
Total Suspended Solids	mg/L	-	1.0	2.0
Hardness [d]	mg/L as $CaCO_3$	-	6.0	54
Major Ions				
Calcium	mg/L	-	1.3	16
Chloride	mg/L	-	0.64	35
Magnesium	mg/L	-	0.54	3.4
Potassium	mg/L	-	0.47	4.8
Sodium	mg/L	-	0.75	9.7
Sulphate	mg/L	-	0.89	18
Nitrogen - Nutrients				
Ammonia	mg/L as N	11 [e]	0.018	1.6
Nitrate	mg/L as N	2.9	0.035	1.5
Total Nitrogen	mg/L as N	-	0.33	3.5

Table 8.8-15 Predicted Water Quality in Area 8 for Post-closure (continued)

Regulated Parameter	Units	Water Quality Guidelines [a]	Kennady Lake Baseline WQ	Predicted Values / Concentrations in Area 8
				Long-term Steady State Post-closure Concentration [b]
Dissolved Metals				
Aluminum	mg/L	0.1 [f]	0.0057	0.035
Antimony	mg/L	-	0.000093	0.0016
Arsenic	mg/L	0.005	0.00013	0.002
Barium	mg/L	-	0.0024	0.15
Beryllium	mg/L	-	0.000048	0.00013
Boron	mg/L	1.5	0.002	0.47
Cadmium	mg/L	0.000003 [g]	0.000014	**0.000029**
Chromium	mg/L	0.001	0.00012	**0.0021**
Cobalt	mg/L	-	0.000083	0.00028
Copper	mg/L	0.002 [g]	0.00069	0.0019
Iron	mg/L	0.3	0.018	0.18
Lead	mg/L	0.001 [g]	0.000029	0.0002
Manganese	mg/L	-	0.0091	0.03
Mercury	mg/L	0.000026	0.0000051	0.000011
Molybdenum	mg/L	0.073	0.000059	0.0098
Nickel	mg/L	0.025 [g]	0.00033	0.0014
Selenium	mg/L	0.001	0.00003	0.00045
Silver	mg/L	0.0001	0.000043	0.000063
Strontium	mg/L	-	0.0082	0.15
Thallium	mg/L	0.0008	0.000017	0.00009
Uranium	mg/L	-	0.000024	0.0011
Vanadium	mg/L	-	0.000025	0.0022
Zinc	mg/L	0.03	0.0028	0.0077
Total Metals				
Aluminum	mg/L	0.1 [f]	0.0094	0.06
Antimony	mg/L	-	0.00014	0.0016
Arsenic	mg/L	0.005	0.00013	0.002
Barium	mg/L	-	0.0026	0.15
Beryllium	mg/L	-	0.000048	0.00013
Boron	mg/L	1.5	0.002	0.47
Cadmium	mg/L	0.000003 [g]	0.000023	**0.000039**
Chromium	mg/L	0.001	0.00021	**0.0025**
Cobalt	mg/L	-	0.000085	0.00034
Copper	mg/L	0.002 [g]	0.0013	**0.0026**
Iron	mg/L	0.3	0.042	0.24
Lead	mg/L	0.001 [g]	0.000039	0.00022
Manganese	mg/L	-	0.0091	0.03
Mercury	mg/L	0.000026	0.0000066	0.000013

Table 8.8-15 Predicted Water Quality in Area 8 for Post-closure (continued)

Regulated Parameter	Units	Water Quality Guidelines [a]	Kennady Lake Baseline WQ	Predicted Values / Concentrations in Area 8
				Long-term Steady State Post-closure Concentration [b]
Molybdenum	mg/L	0.073	0.000059	0.0098
Nickel	mg/L	0.025 [g]	0.00048	0.0026
Selenium	mg/L	0.001	0.00003	0.00045
Silver	mg/L	0.0001	0.000043	0.000063
Strontium	mg/L	-	0.0082	0.15
Thallium	mg/L	0.0008	0.000022	0.000096
Uranium	mg/L	-	0.000024	0.0011
Vanadium	mg/L	-	0.00021	0.0024
Zinc	mg/L	0.03	0.0028	0.0078

a) Chronic Aquatic Health Guidelines from Canadian Environmental Quality Guidelines, Update 7.0 (CCME 2007).

b) Bold font indicates concentration exceeds guideline.

c) Assumed no change in pH based on geochemical characteristics and acidification assessment of local waterbodies.

d) Theoretical hardness calculated based on observed calcium and magnesium concentrations.

e) Dependent on pH and temperature (assumed 15ºC, to give most conservative guideline).

f) Dependent on pH.

g) Dependent on hardness.

N/A - these values are still currently being assessed and are not available at this time. They will be provided later in a supplemental filing.

WQ = water quality; mg/L = milligrams per litre; mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; mg/L as N = milligrams per litre as nitrogen.

Table 8.8-16 Projected Long-term Phosphorus Concentrations in Area 8 for Post-closure with Supplemental Mitigation Strategies

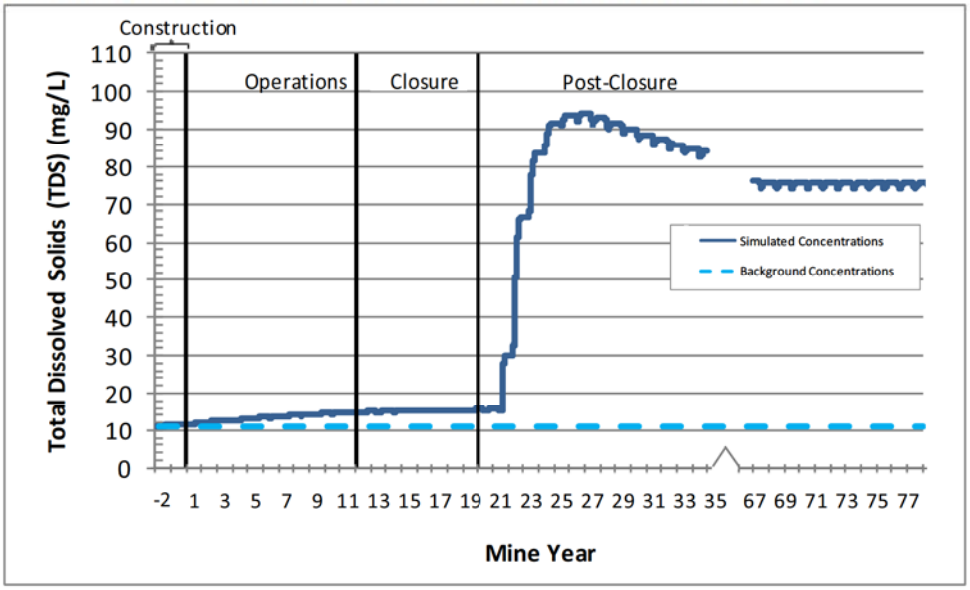
Regulated Parameter	Units	Water Quality Guidelines	Kennady Lake Baseline WQ	Predicted Values / Concentrations in Area 8
				Long-term Steady State Post-closure Concentration
Phosphorus - Nutrients				
Dissolved Phosphorus	mg/L	-	0.005	0.015
Total Phosphorus	mg/L	-	0.005	0.016

WQ = water quality; mg/L = milligrams per litre.

Total Dissolved Solids and Major Ions

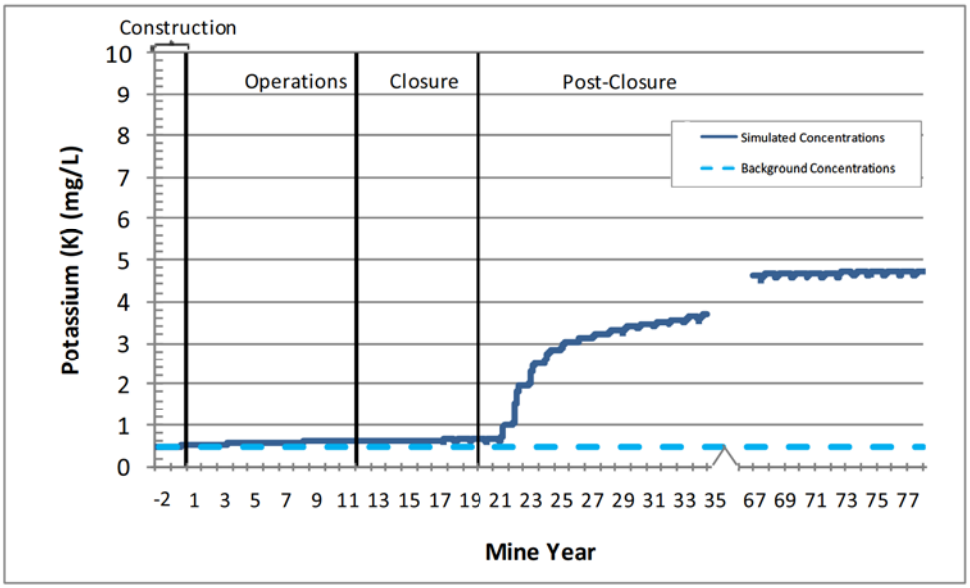
Concentrations of TDS and major ions in Area 8 are predicted to follow the general trends described above. A representative time series plot of TDS concentrations is shown in Figure 8.8-17. All ions follow this trend, except potassium (Figure 8.8-18) and sulphate, which are predicted to increase following closure. The increases in these two ions are consistent with the increases described in Kennady Lake (see Section 8.8.4.1) and due to continued loading from geochemical sources. There are no CCME aquatic life water quality guidelines for TDS and the modelled major ions.

Figure 8.8-17 Predicted Total Dissolved Solids Concentrations in Area 8



mg/L = milligrams per litre

Figure 8.8-18 Predicted Potassium Concentrations in Area 8



mg/L = milligrams per litre

Nutrients

Nitrogen

All forms of nitrogen are predicted to peak in concentration in Area 8 within five years of breaching Dyke A, then return to near-background concentrations, for the reasons described for Kennady Lake in Section 8.8.4.1. A representative time series plot is shown for total nitrogen in Figure 8.8-19. Both nitrate and ammonia concentrations are predicted to remain below CCME guidelines for the protection of aquatic health in Area 8.

Based on the total nitrogen concentrations predicted for post-closure, nitrogen is not anticipated to be a limiting nutrient.