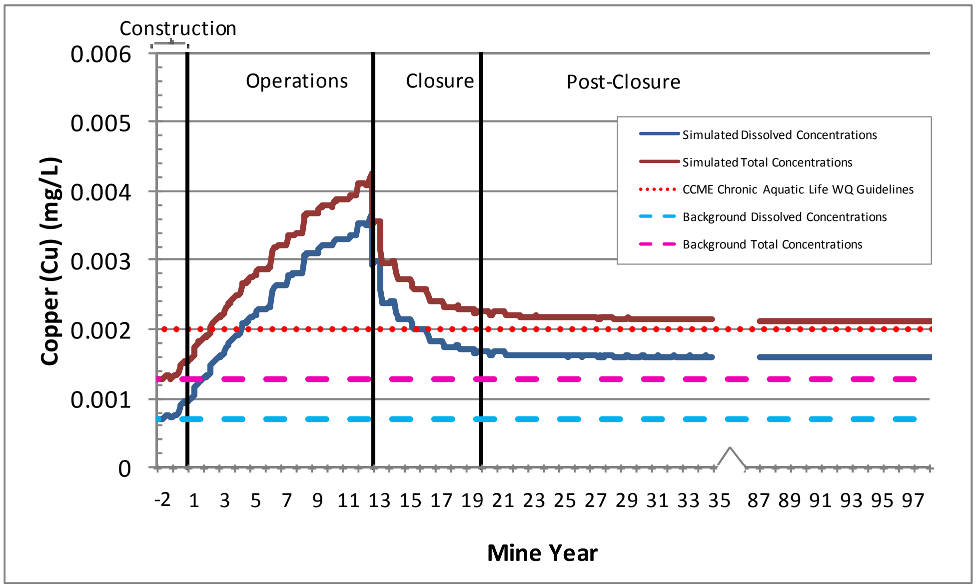
Figure 8.2-10 Trends of Projected Copper Concentrations in Kennady Lake (Areas 3 and 5 – Construction and Operations, and Areas 3 to 7 – Closure and Post-closure)



mg/L = milligrams per litre.

Effects to Water Quality in Area 8 During Post-closure

During operations, Area 8 of Kennady Lake is separated from Areas 3 to 7 by Dyke A, resulting in a reduction in drainage area. Water quality trends as a result of the updated modelling are consistent with the assessment in the 2011 EIS Update (De Beers 2011):

- In construction and operations, following the construction of Dyke A, the concentrations of many of the water quality parameters are projected to increase slightly above background concentrations due to evapo-concentration and lower inflows.
- Following closure, concentrations of all modelled constituents are projected to increase, reaching a peak concentration within five years of the reconnection of Area 8 with Kennady Lake.

The predicted maximum concentrations and long-term steady state concentrations of water quality parameters during post-closure are presented in Table 8.2-13.

Table 8.2-13 Predicted Water Quality in Area 8 during Post-closure

Parameter	Units	CCME Water Quality Guidelines [(a)]	Kennady Lake Baseline Water Quality	Predicted Maximum Post-closure Concentration [(b)]		Long-term Steady State Concentration [(b)]	
				2012	2011	2012	2011
Conventional Parameter							
Total Dissolved Solids	mg/L	-	13	96	94	50	24
Hardness [(c)]	mg/L	-	-	56	54	27	10
Major Ions							
Calcium	mg/L	-	1.2	17	16	8	2.6
Chloride	mg/L	120	0.55	39	35	12	2.7
Fluoride	mg/L	0.12	0.03	0.11	-	0.11	-
Magnesium	mg/L	-	0.52	3.1	3.4	1.9	0.77
Potassium	mg/L	-	0.48	2.0	4.8	1.8	0.9
Sodium	mg/L	-	0.71	9.9	9.7	4.1	1.7
Sulphate	mg/L	-	0.83	13.2	18	9.6	3.2
Nutrients							
Nitrate	mg N /L	13	-	1.1	1.5	0.13	0.05
Ammonia	mg N /L	5.55 [(c)]	0.032	1.03	1.6	0.13	0.05
Total Nitrogen	mg N /L	-	0.35	2.5	5.0	0.48	0.14
Dissolved P	mg/L	-	0.0057	0.01	0.016	0.008	0.015
Total P	mg/L	-	0.033	0.01	0.016	0.008	0.016
Total Metals							
Aluminum	mg/L	0.005 to 0.1 [(e)]	0.0098	0.061	0.06	0.052	0.027
Antimony	mg/L	-	0.0001	0.00058	0.0016	0.00051	0.00027
Arsenic	mg/L	0.005	0.00014	0.0015	0.002	0.0007	0.00049
Barium	mg/L	-	0.0027	0.02	0.15	0.018	0.0183
Beryllium	mg/L	-	0.000041	0.000113	0.00013	0.000111	0.00008
Boron	mg/L	1.5	0.0031	0.079	0.47	0.077	0.05
Cadmium	mg/L	0.000017 [(f)]	**0.00002**	**0.00004**	**0.000039**	**0.000039**	**0.000024**
Chromium	mg/L	0.001	0.0002	0.0007	**0.0025**	0.0005	0.00032
Cobalt	mg/L	-	0.000135	0.00097	0.00034	0.00093	0.00022
Copper	mg/L	0.002-0.004 [(f)]	0.0012	**0.0023**	**0.0026**	0.002	0.0016
Iron	mg/L	0.3	0.065	0.14	0.24	0.11	0.08
Lead	mg/L	0.001-0.007 [(f)]	0.000049	0.00025	0.00022	0.00023	0.00009
Manganese	mg/L	-	0.0122	0.034	0.03	0.032	0.008
Mercury	mg/L	0.000026	0.0000102	0.000012	0.000013	0.000011	0.000006
Molybdenum	mg/L	0.073	0.000074	0.0042	0.0098	0.0031	0.00121
Nickel	mg/L	0.025-0.15 [(f)]	0.00032	0.0032	0.0026	0.0026	0.00079
Selenium	mg/L	0.001	0.00019	0.0002	0.00045	0.0002	0.00007
Silver	mg/L	0.0001	0.00008	0.000095	0.000063	0.000069	0.000017
Strontium	mg/L	0.049	0.0082	0.047	0.15	0.046	0.024
Thallium	mg/L	0.0008	0.000021	0.000042	0.000096	0.000031	0.00002
Uranium	mg/L	-	0.000026	0.0011	0.0011	0.00107	0.00023
Vanadium	mg/L	-	0.00024	0.00213	0.0024	0.00213	0.00038
Zinc	mg/L	0.03	0.0028	0.0066	0.0078	0.0065	0.0029
Dissolved Metals							
Aluminum	mg/L	0.005 to 0.1 [(e)]	0.0055	0.047	0.035	0.047	0.022
Antimony	mg/L	-	0.000082	0.00054	0.0016	0.00047	0.00025
Arsenic	mg/L	0.005	0.00012	0.0015	0.002	0.0007	0.00047
Barium	mg/L	-	0.0027	0.019	0.15	0.018	0.0174
Beryllium	mg/L	-	0.000038	0.000112	0.00013	0.00011	0.00008
Boron	mg/L	-	0.0023	0.079	0.47	0.076	0.05

Table 8.2-13 Predicted Water Quality in Area 8 during Post-closure (continued)

Parameter	Units	CCME Water Quality Guidelines [(a)]	Kennady Lake Baseline Water Quality	Predicted Maximum Post-closure Concentration [(b)]		Long-term Steady State Concentration [(b)]	
				2012	2011	2012	2011
Cadmium	mg/L	0.000017 [(f)]	**0.000022**	**0.000033**	**0.000029**	**0.000032**	**0.000022**
Chromium	mg/L	0.001	0.00016	0.0004	**0.0021**	0.0004	0.00026
Cobalt	mg/L	-	0.000135	0.00094	0.00028	0.00093	0.00021
Copper	mg/L	0.002-0.004 [(f)]	0.00069	0.0017	0.0019	0.0014	0.00124
Iron	mg/L	0.3	0.021	0.08	0.18	0.08	0.053
Lead	mg/L	0.001-0.007 [(f)]	0.00003	0.00023	0.0002	0.000221	0.00006
Manganese	mg/L	-	0.0122	0.033	0.03	0.032	0.0063
Mercury	mg/L	0.000026	0.0000077	0.0000094	0.000011	0.0000087	0.000006
Molybdenum	mg/L	0.073	0.000058	0.0042	0.0098	0.0031	0.0012
Nickel	mg/L	0.025-0.15 [(f)]	0.00032	0.0025	0.0014	0.0025	0.00053
Selenium	mg/L	0.001	0.00004	0.0001	0.00045	0.0001	0.00007
Silver	mg/L	0.0001	0.000051	0.000062	0.000063	0.00006	0.000012
Strontium	mg/L	-	0.0082	0.046	0.15	0.046	0.025
Thallium	mg/L	0.0008	0.000017	0.000037	0.00009	0.000026	0.0000067
Uranium	mg/L	-	0.000019	0.00109	0.0011	0.00106	0.00022
Vanadium	mg/L	-	0.000134	0.00196	0.0022	0.00196	0.00029
Zinc	mg/L	0.03	0.0023	0.0065	0.0077	0.0063	0.0029

[(a)] Chronic Aquatic Health Guidelines from Canadian Environmental Quality Guidelines (CCME 1999).

[(b)] Bold font indicates concentration is higher than the CCME water quality guideline.

[(c)] Theoretical hardness calculated based on observed calcium and magnesium concentrations; measured as mg $CaCO_3$/L.

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

[(e)] Dependent on pH.

[(g)] Dependent on hardness.

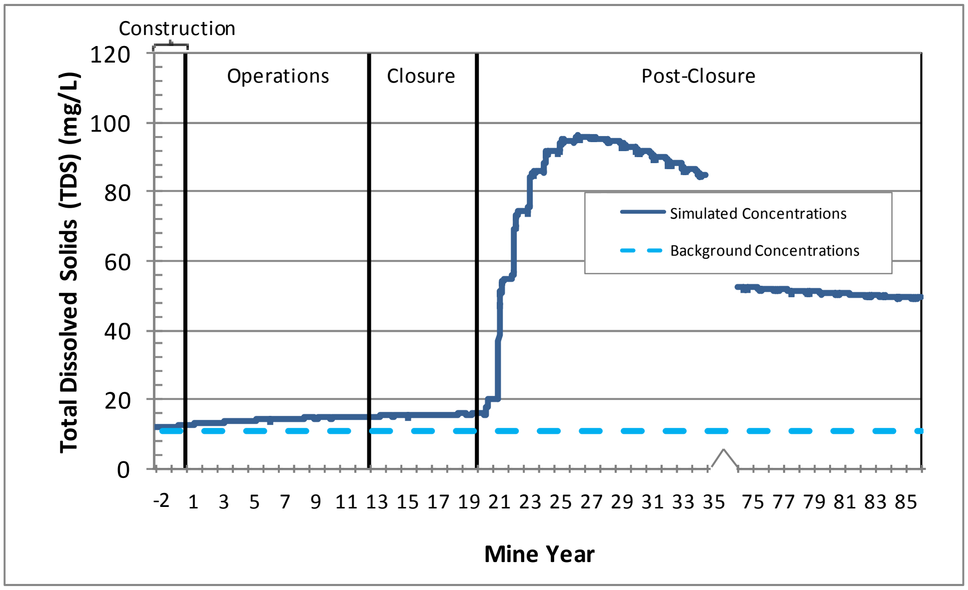
mg/L = milligrams per litre; mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; mg N/L = milligrams nitrogen per litre; - = not available or not applicable.

Total Dissolved Solids and Major Ions

Concentrations of TDS in Area 8 are projected to increase following the reconnection of Kennady Lake with the removal of Dyke A. The maximum TDS concentration of 96 mg/L (Table 8.2-13; Figure 8.2-11) is similar to the maximum concentration presented in the 2011 EIS Update (De Beers 2011). Each of the major ions follow a similar trend to TDS, in that concentrations are similar to those presented in the 2011 EIS Update, except potassium (Figure 8.2-12) and sulphate, which are projected to be lower than presented in the 2011 EIS Update.

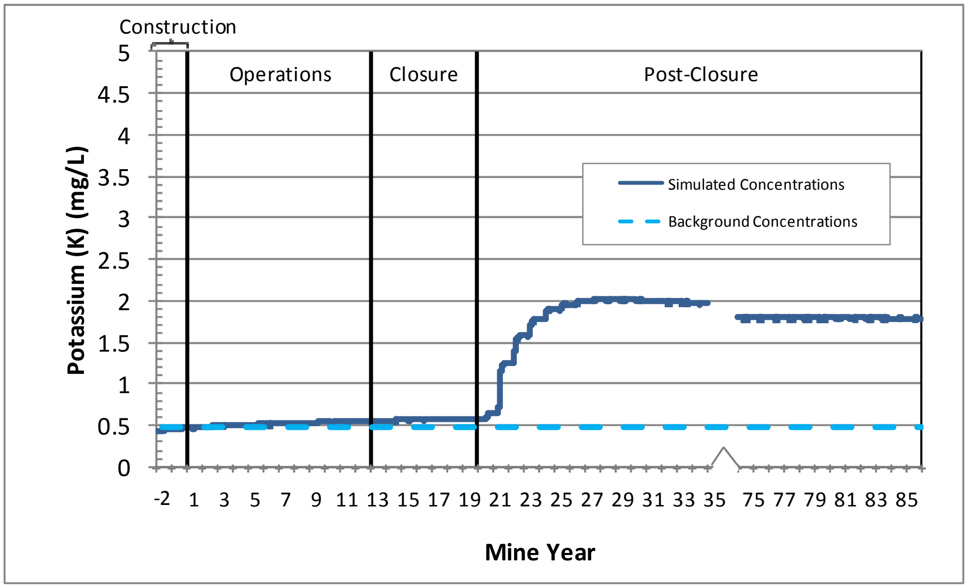
The maximum projected fluoride concentration is 0.11 mg/L (Table 8.2-13; Figure 8.2-13), which is below CCME guidelines. This concentration remains as a steady state concentration, as a result of the predominant geochemical loading of fluoride from the remaining mine rock and PK facilities under the assumption of permafrost-free conditions.

Figure 8.2-11 Projected Trends of Total Dissolved Solids Concentrations in Area 8



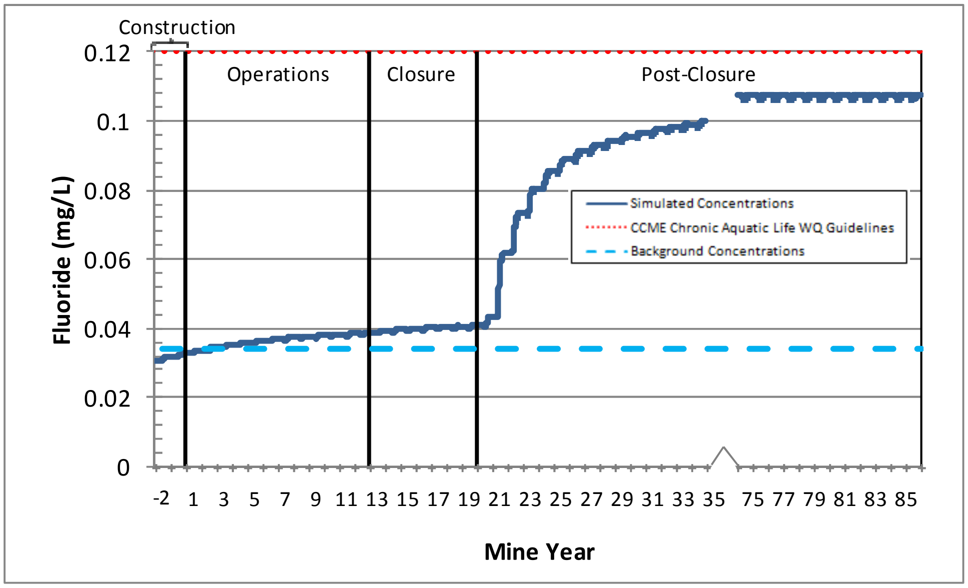
mg/L = milligrams per litre.

Figure 8.2-12 Projected Trends of Potassium Concentrations in Area 8



mg/L = milligrams per litre.

Figure 8.2-13 Projected Trends of Fluoride Concentrations in Area 8



mg/L = milligrams per litre.

Nutrients

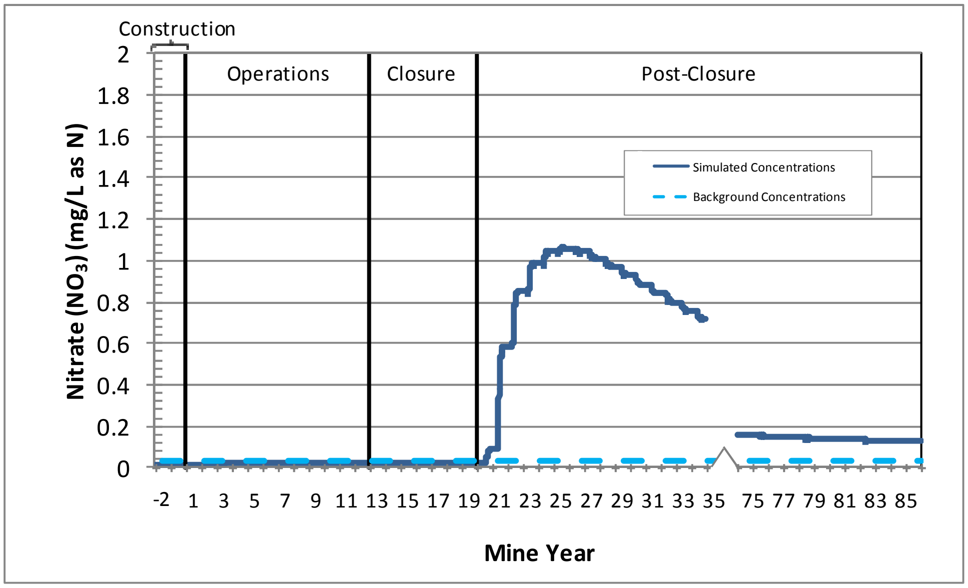
Nitrogen

Concentrations of nutrients are projected to peak within five years of Kennady Lake reconnecting with Area 8. However, for nitrate and ammonia, projected long-term steady state concentrations return to near-background concentrations. These trends are consistent with those presented for nitrate (Figure 8.2-14) and ammonia in the 2011 EIS Update (De Beers 2011). Following closure, nitrate and ammonia concentrations in Area 8 are projected to remain below CCME water quality guidelines (Table 8.2-13).

Phosphorus

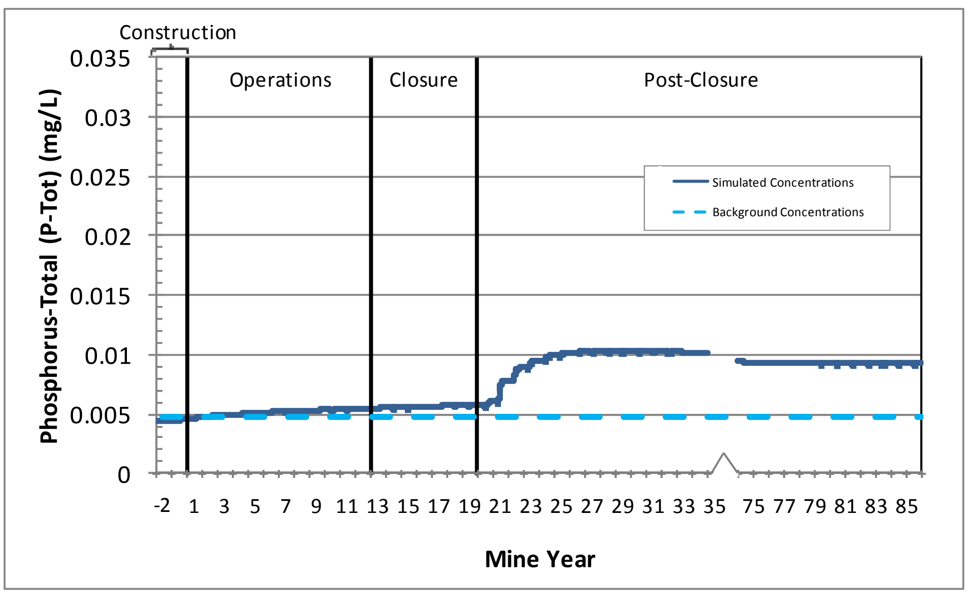
Concentrations of phosphorus in Area 8 following closure are lower than presented in the 2011 EIS Update (De Beers 2011) as a direct result of reduced loading from the smaller Fine PKC Facility (mitigated) (Table 8.2-13). Maximum concentrations peaks following closure are projected to be 0.01 mg/L, compared to 0.016 mg/L in the 2011 EIS Update, with a decrease to a long-term steady state concentration of 0.008 mg/L (Figure 8.2-15). The predominant source of phosphorus is the geochemical loading from the Fine PK facility under the assumption of permafrost-free conditions. The predicted maximum and long-term steady state TP concentration remains within an oligotrophic status (CCME 2004; Environment Canada 2004).

Figure 8.2-14 Projected Trends of Nitrate Concentrations in Area 8



mg/L as N = milligrams per litre as nitrogen.

Figure 8.2-15 Projected Trends of Total Phosphorus Concentrations in Area 8



mg/L = milligrams per litre.

Trace Metals

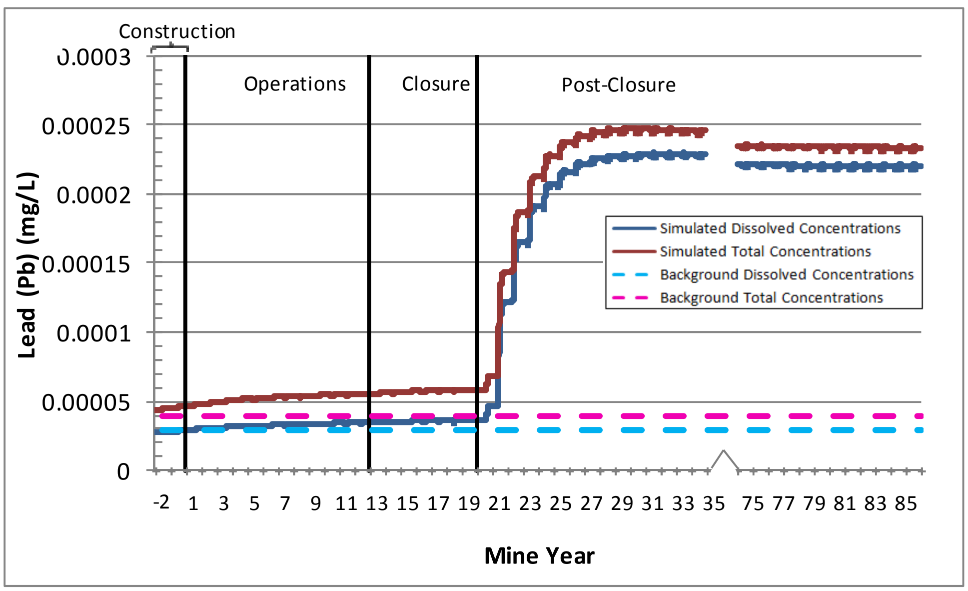
Of the 23 trace metals modelled in Area 8, peak concentrations of aluminum, cadmium, cobalt, lead, manganese, nickel and selenium are projected to be higher than presented in the 2011 EIS Update (De Beers 2011) (Table 8.2-13). These increases are small, with the exception of cobalt, due to the revised geochemical source term input resulting from the updated geochemistry testing (Appendix 8.III); the long-term steady state concentration remains below 0.001 mg/L (there are no CCME water quality guidelines for cobalt). Consistent with the 2011 EIS Update, maximum projected cadmium and copper concentrations are higher than CCME guidelines (Table 8.2-13); in the 2011 EIS Update, the maximum projected chromium concentration was also higher than the CCME guideline.

As noted for Kennady Lake (Areas 3 to 7), two patterns are evident in the time series trends for trace metals following closure in Area 8:

A. Trace Metals that Increase Following Closure, and Slightly Decrease to Reach a Steady State Concentration Soon After Closure

Of 23 metals modelled in Area 8, the metals that follow this pattern include aluminum, antimony, arsenic, chromium, cobalt, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, and thallium. This pattern is reflective of the primary source of these metals, which is loading from the waste material storage facilities within the Kennady Lake watershed under the assumption of permafrost-free conditions. A representative time series plot for lead is presented in Figure 8.2-16.

Figure 8.2-16 Projected Trends of Lead Concentrations in Area 8

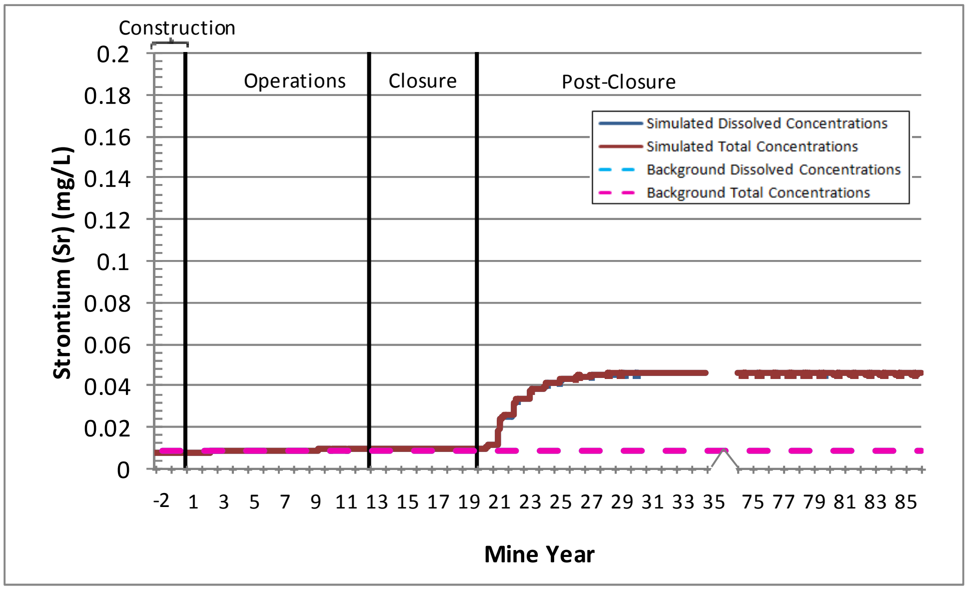


mg/L = milligrams per litre.

B. Trace Metals that are Predicted to Increase and Remain Constant

The metals that follow this pattern include barium, beryllium, boron, cadmium, copper, strontium, uranium, vanadium, and zinc. This pattern is reflective of the primary source of these metals, which is groundwater inflows to the WMP during operations, and loading from the waste material storage facilities within the Kennady Lake watershed that persists into post-closure under the assumption of permafrost-free conditions. A representative time series plot for strontium is presented in Figure 8.2-17.

Figure 8.2-17 Projected Trends of Strontium Concentrations in Area 8



mg/L = milligrams per litre.

8.2.5.2 Stability of Meromictic Conditions in Hearne and Tuzo Pits

In the 2011 EIS Update (De Beers 2011), hydrodynamic modelling of Tuzo Pit was completed, which indicated persistent stable meromictic conditions would be expected to occur once the pit had been flooded during closure. As a result of the updated water quality modelling in Kennady Lake during operations and closure, the hydrodynamic modelling was updated for Tuzo Pit. In addition, a hydrodynamic model was also developed for the Hearne Pit as part of the current assessment, as it was not included in the 2011 EIS Update.

The stability of stratification in Hearne and Tuzo Pits was analyzed using two methods:

- hydrodynamic modelling of the first 100 years after refilling, using CE-QUAL-W2; and
- mass balance calculations over 15,000 years using a vertical slice spreadsheet model.

Details of the hydrodynamic modelling for these pits are provided in Appendix 8.II.

8.2.5.2.1 Results

Vertical profiles of TDS concentrations for Hearne and Tuzo Pits are depicted in Figures 8.2-18 and 8.2-19, respectively. The hydrodynamic results indicate that the elevation of the pycnocline will remain unchanged, for both the Hearne and Tuzo Pit at the initial elevation, but the thickness of the transition layer will increase with time (i.e., the elevation of the transition between high- and low-TDS waters will not change appreciably, but the gradient will become less sharp, reflecting a transfer of mass from the pits to the overlying water). This upward movement is predicted to occur rapidly after refilling, and gradually thereafter.

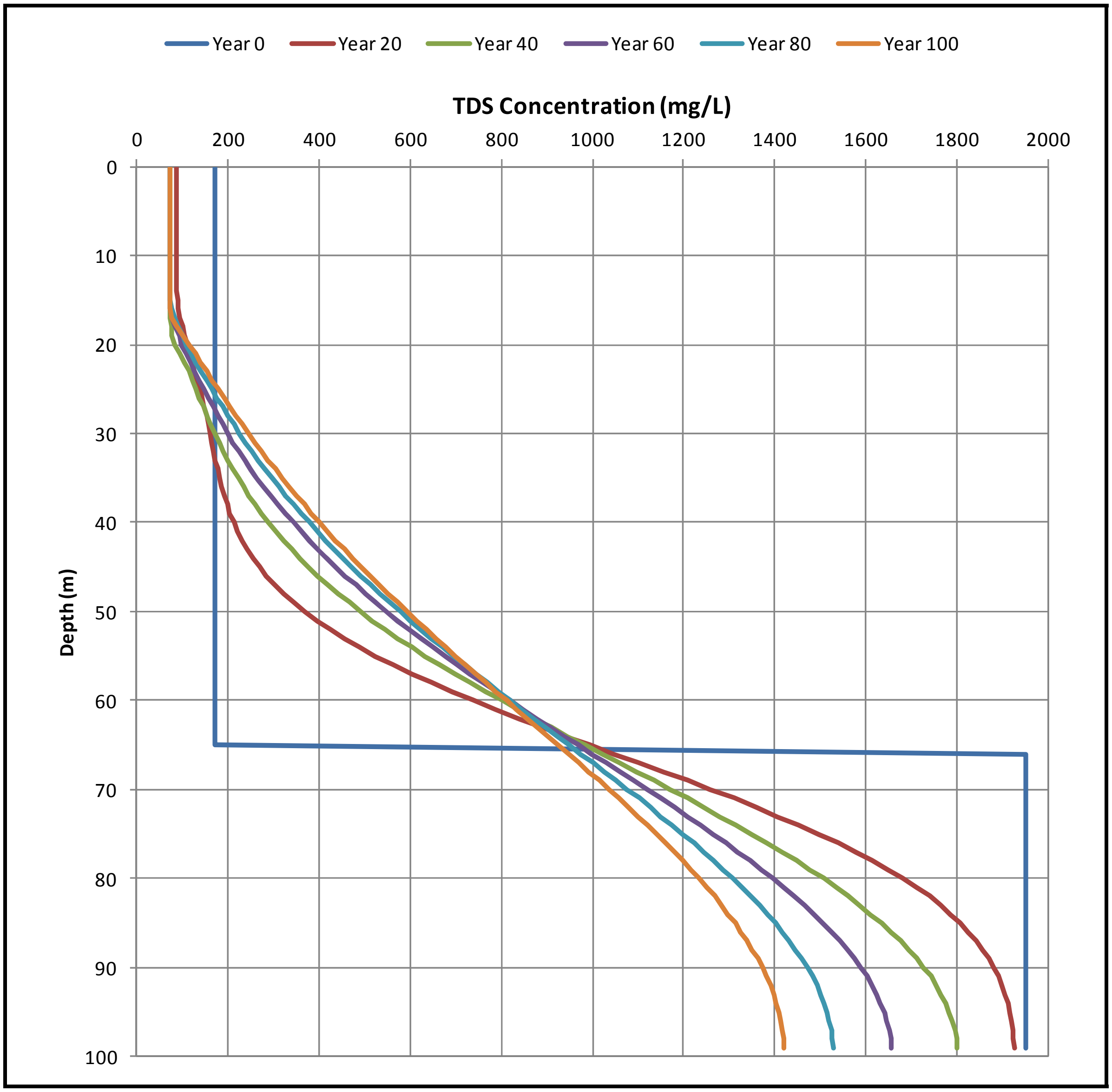
The strength of stratification in Hearne Pit is predicted to weaken with time. Upward diffusive flux will reduce the TDS concentration in the monimolimnion more rapidly than in Tuzo Pit due to its shallower depth and smaller volume. Nevertheless, the upward flux will contribute a relatively small amount of water and mass to the surface layers, and will therefore have a small effect on the water quality of Kennady Lake in the post-closure phase. This upward flux was accounted for in the Kennady Lake water quality predictions, as detailed in Section 8.2.5.1.

The strengthened stratification in Tuzo Pit is predominantly due to two factors:

- firstly, a deeper transition layer is inherently more stable because wind-driven forces are applied at the lake surface, so the energy required to disrupt the two density layers (i.e., the pit lake) increases with depth; and
- secondly, the gradual replacement of Kennady Lake waters with natural runoff will continue to reduce the TDS of the overlying water, thereby strengthening the pycnocline by increasing the density difference between the surface and deep water zones (Figures 8.2-18 and 8.2-19).

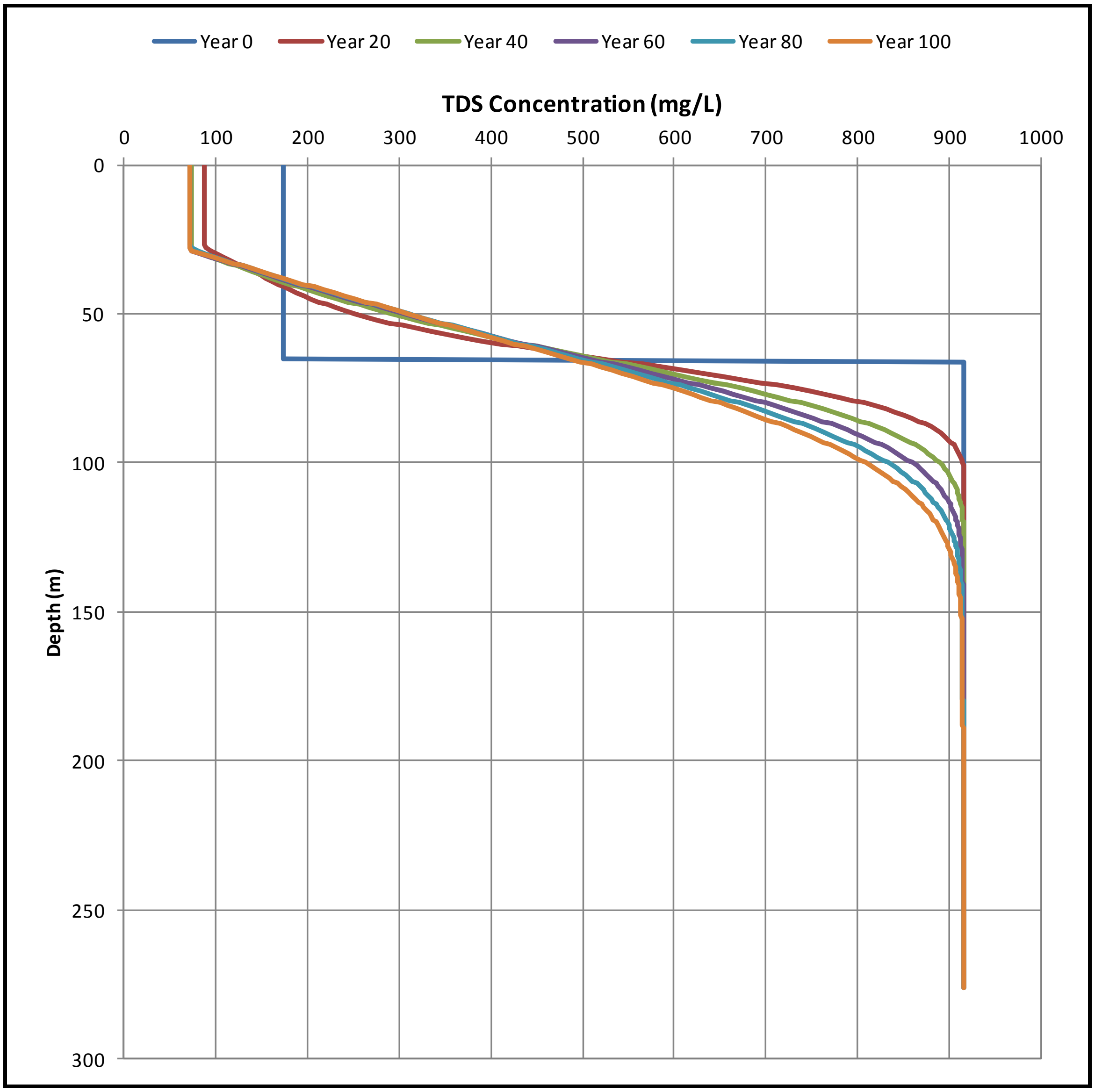
A small influx of groundwater to the pits predicted by the groundwater modelling is not projected to increase TDS at depth over the modelled 100-year timeframe.

Figure 8.2-18 Predicted Pycnoclines over 100-year period after Refilling of Hearne Pit



m = metres; mg/L = milligrams per litre.

Figure 8.2-19 Predicted Pycnoclines over 100-year period after Refilling of Tuzo Pit

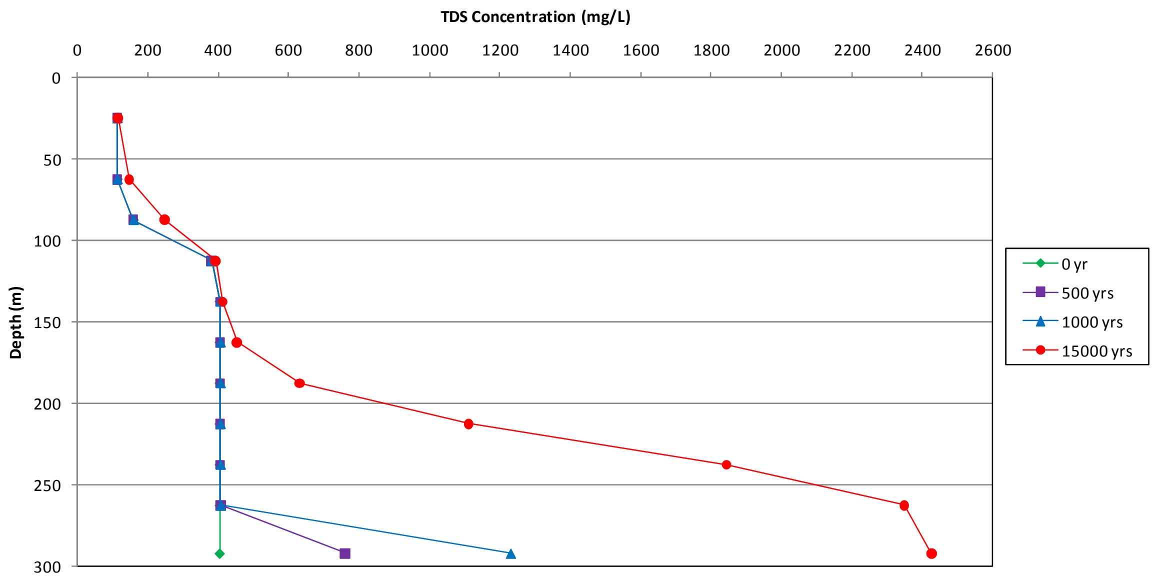


m = metres; mg/L = milligrams per litre.

The vertical slice mass-balance model projected a rising and strengthening stratification in Tuzo Pit in the long term. Although the hydrodynamic simulation indicated very little change in TDS in the monimolimnion (the lower, dense stratum of a meromictic lake that does not mix with the waters above it) in the first hundred years, the mass-balance slice model indicated that groundwater inflows would begin to change TDS at depth in the first thousand years. After 15,000 years, the model indicated that the monimolimnion would increase in TDS and expand upwards due to the slight net inflow (Figure 8.2-20). The deeper pit water will eventually, over the very long-term, take on the characteristics of the surrounding deep, high TDS groundwater.

While the general trend of increased TDS and upward expansion of the pycnocline is likely reliable, this model may over-predict the extent to which these phenomena may occur. The model did not account for upward diffusion due to a concentration gradient, and it extrapolated groundwater inflows beyond the timeframe modelled by hydrogeological modelling. Nevertheless, it may be concluded with some confidence from this modelling, that stratification in Tuzo pit will strengthen with time.

Figure 8.2-20 Modelled Water Column Distribution of Total Dissolved Solids Concentration in the Tuzo Pit Projected Over Time



m = metres; mg/L = milligrams per litre.

8.2.5.3 Under-Ice Dissolved Oxygen Modelling in Kennady Lake During Closure

Empirical dissolved oxygen (DO) modelling was presented in 2011 EIS Update (Appendix 8.V; De Beers 2011) to predict post-closure winter dissolved oxygen concentrations in Kennady Lake based on modelled TP concentrations. The empirical models had the following limitations to the assessment presented in the 2011 EIS Update:

- each model was limited to a single input variable, i.e., total phosphorus; other variables including water chemistry, hydrological and meteorological factors were not considered;
- they did not develop depth profile estimates of dissolved oxygen , but were limited to estimates average dissolved oxygen concentrations for three depth-zones (i.e., under ice to 6 m, 6 to 12 m, and greater than 12 m); and
- they excluded the littoral zones and pit lakes.

For the 2012 EIS Supplement, a comprehensive 3-D model was developed using the Generalized Environmental Modelling System for Surface waters (GEMSS®) to address the limitations of the empirical models and refine or confirm the empirically derived end-of-winter DO concentrations presented in the 2011 EIS Update (De Beers 2011). Additionally, this modelling included the long-term steady state nutrient concentrations provided by the updated water quality modelling for Kennady Lake (Section 8.2.5.1). A “Modified WASP5” module was adapted to fit within the GEMSS® framework to simulate nutrients and oxygen-related constituents. A detailed description of methods and results are presented in Appendix 8.V.

GEMSS® is in the public domain and has been used for similar studies throughout North America and worldwide including a 3-D water quality model that was developed for the De Beers Canada Inc. Snap Lake Mine (Golder 2011).

8.2.5.3.1 Results

The detailed results of the dissolved oxygen modelling in Kennady Lake are presented in Appendix 8.V. The following section summarizes the results for a number of areas of Kennady Lake that represent different depths for a range of winter oxygen demand conditions. Three modelling scenarios, using sediment oxygen demand (SOD) as the primary factor, were applied to provide a range of potential winter dissolved oxygen concentrations for Kennady Lake. SOD was the only factor of 17 rates and coefficients tested in a sensitivity analysis to show a significant effect on dissolved oxygen concentrations.

Three SOD scenarios were used to predict potential overwintering dissolved oxygen concentrations:

1. Scenario 1: a SOD rate of -0.25 grams of dissolved oxygen per square metre per day (g DO/m^2/d).
2. Scenario 2: a 50% increase in SOD (-0.375 g DO/m^2/d); and
3. Scenario 3: a 100% increase in SOD (-0.5 g DO/m^2/d).

The SOD rates used in the sensitivity analyses (i.e., -0.25 to -0.50 g DO/m^2/d) are very conservative compared to reported literature values. Mathias and Barica (1980) reported SOD levels of -0.23 g DO/m^2/d in eutrophic lakes estimated from four sets of Canadian lakes: prairie, southeastern Ontario, Arctic, and the Experimental Lakes Area (ELA). In addition, White et al. (2008) reported an SOD level of -0.10 g DO/m^2/d in a small arctic gravel pit lake (depth 10.7 metres [m], area 13,355 m^2), and Matisoff and Neeson (2005) reported a summer SOD level in central Lake Erie of -0.164 g DO/m^2/d.

Scenario 1

- The littoral zone of Kennady Lake (to 4 m depth) will have dissolved oxygen concentrations greater than 6.5 mg/L at the end of the ice-covered season (refer to Figure 8.V-14a of Appendix 8.V).
- The pelagic zone of Kennady Lake (excluding Tuzo and Hearne pits) will have dissolved oxygen concentrations greater than 5 mg/L at depths above 8 m and dissolved oxygen concentrations greater than 6.5 mg/L at depths above 7 m at the end of the ice-covered season (refer to Figure 8.V-14b of Appendix 8.V).
- The pit lakes in Kennady Lake (to a depth of 40 m depth) will have dissolved oxygen concentrations greater than 5 mg/L at depths above 38 m and dissolved oxygen concentrations greater than 6.5 mg/L at depths above 36 m at the end of the ice-covered season (refer to Figure 8.V-14a of Appendix 8.V).

The post-closure water volume of Kennady Lake including the Tuzo and Hearne pits to a depth of 40 m is 55.6 million cubic metres (Mm^3). The average volume of Kennady Lake with a dissolved oxygen concentration greater than 5 mg/L and 6.5 mg/L at the end of ice-covered season (i.e. just prior to ice melt) is projected to be approximately 51.4 Mm^3 (or 92% of the total volume) and 49.2 Mm^3 (or 89% of the total volume), respectively.

Scenario 2

- The littoral zone of Kennady Lake will have dissolved oxygen concentrations greater than 6.5 mg/L at the end of the ice-covered season (refer to Figure 8.V-13a of Appendix 8.V).
- The pelagic zone of Kennady Lake will have dissolved oxygen concentrations greater than 5 mg/L at depths above 7 m and dissolved oxygen concentrations greater than 6.5 mg/L at depths above 6 m at the end of the ice-covered season (refer to Figure 8.V-13b of Appendix 8.V).
- The pit lakes in Kennady Lake will have dissolved oxygen concentrations greater than 5 mg/L at depths above 35 m and dissolved oxygen concentrations greater than 6.5 mg/L at depths above 27 m at the end of the ice-covered season (refer to Figure 8.V-13c of Appendix 8.V).

For this scenario, the average volume of Kennady Lake with a dissolved oxygen concentration greater than 5 mg/L and 6.5 mg/L at late winter is projected to be approximately 47.2 Mm^3 (or 85% of the total volume) and 44.5 Mm^3 (or 80% of the total volume), respectively. Therefore, 20% of the post-closure volume of Kennady Lake is projected to have a dissolved oxygen concentration less than the CCME water quality guideline of 6.5 mg/L. The volume of Kennady Lake with a projected dissolved oxygen concentration higher than 6.5 mg/L is 17% higher than the volume of Kennady Lake in pre-development condition (i.e., 38 Mm^3).

Scenario 3

- The littoral zone of Kennady Lake will have dissolved oxygen concentrations greater than 6.5 mg/L at the end of the ice-covered season (refer to Figure 8.V-15a of Appendix 8.V).
- The pelagic zone of Kennady Lake will have dissolved oxygen concentrations greater than 5 mg/L at depths above 6 m and dissolved oxygen concentrations greater than 6.5 mg/L at depths above 5 m at the end of the ice-covered season (refer to Figure 8.V-15b of Appendix 8.V).
- The pit lakes in Kennady Lake will have dissolved oxygen concentrations greater than 5 mg/L at depths above 19 m and dissolved oxygen concentrations greater than 6.5 mg/L at depths above 17 m at the end of the ice-covered season (refer to Figure 8.V-15c of Appendix 8.V).

For this scenario, the average volume of Kennady Lake with a dissolved oxygen concentration greater than 5 mg/L and 6.5 mg/L just prior to ice melt is predicted to be approximately 41.2 Mm^3 (or 74% of the total volume) and 28.6 Mm^3 (or 51% of the total volume), respectively.

The results of the updated GEMSS® dissolved oxygen modelling are consistent with the conclusions outlined in the 2011 EIS Update (De Beers 2011) for the broad range of empirical approaches (i.e., Babin and Prepas 1985, Mathias and Barica 1980, Vollenweider 1979) and based on a total phosphorus concentration of 0.018 mg/L, which concluded that the surface zone of Kennady Lake (i.e., under ice to 6 m) was expected to maintain sufficient DO concentrations to support cold-water aquatic life (greater than 6.5 mg/L). However, the empirical modelling did not separate shallow littoral zones and or include the volume of water available in the pit lakes, which have been included in the GEMSS® model.

With the updated predictions of TP in Kennady Lake in post-closure, and the supplemental DO modelling using GEMSS®, it is anticipated that 74 to 92% of the total volume of Kennady Lake will have a DO concentration above 5 mg/L, which represents the acute guideline for the protection of cold water species excluding the larval stages (AENV 1999), and 51 to 89% of the total volume of Kennady Lake possessing a DO concentration above 6.5 mg/L, which represents the chronic guideline for the protection of aquatic life for cold water species excluding the larval stages (CCME 1999). Even the shallow littoral zones are anticipated to have sufficient DO concentrations which might be related to the considerable portion of cobble/boulder substrate in the littoral zone. Follow-up monitoring will be undertaken to assess this evaluation. Therefore, it is anticipated that the more productive Kennady Lake during the post-closure phase of the Project will be habitable by the fish assemblage that currently exists in the lake.

8.2.6 Effects to Aquatic Health

8.2.6.1 Introduction

Section 8.9 of the 2011 EIS Update (De Beers 2011) assessed the potential for effects to the health of aquatic life (referred to herein as aquatic health) in the Kennady Lake watershed resulting from modelled changes in water quality as presented in Section 8.8 of the 2011 EIS Update. The aquatic health assessment evaluated two exposure pathways by which the predicted changes to water quality could affect aquatic health:

- direct exposure to substances in the water column; and
- indirect effects related to possible accumulation of substances within fish tissue via uptake from both water and diet.

The water quality model was revised based on the supplemental mitigation associated with the Fine PKC Facility. The results of the revised water quality modelling were used to update the aquatic health assessment. The same pathways and scenarios assessed in the 2011 EIS Update (De Beers 2011) were assessed in this revised aquatic health assessment, namely:

- initial closure discharge water quality in Kennady Lake. This scenario summarizes the maximum concentrations in Kennady Lake at the end of the closure period; that is, after refilling is complete and just after breaching of Dyke A, which is the dyke between Area 7 and Area 8.
- long-term water quality in Kennady Lake. This scenario summarizes the maximum concentrations in Kennady Lake 100 years into the post-closure period.
- post-closure water quality in Area 8. This scenario summarizes the maximum concentrations in Area 8 during the post-closure period; that is, after refilling of Kennady Lake is complete and full flow is possible between Kennady Lake and Area 8 up to 100 years into the post-closure period.

The methods for the revised aquatic health assessment were the same as those outlined in the 2011 EIS Update in Section 8.9.2 (De Beers 2011).

The 2011 EIS Update (De Beers 2011) also evaluated potential changes in water quality resulting from deposition of dust and metals during construction and operations (Section 8.8.3.1). Effects of dust and metals deposition do not apply to closure, because mining activities that generate dust will cease after operations end and closure and reclamation activities are complete. The potential effects of dust and metal deposition are not expected to change, and therefore, were not reassessed in this 2012 EIS Supplement.

8.2.6.2 Direct Waterborne Exposure

For the direct waterborne exposure pathway, substances of potential concern (SOPCs) were selected based on the three-step screening process described in Section 8.9.2.2.1 in the 2011 EIS Update (De Beers 2011). This screening process identified SOPCs as parameters that had the potential to detrimentally affect aquatic health, and whose predicted concentrations were more than 10% greater than baseline concentrations and greater than water quality guidelines (WQG) for the protection of aquatic life (i.e., CCME 1999). Parameters without WQGs were identified as SOPCs if the other two SOPC selection criteria were met. Based on this screening process, a minimum of 10 and a maximum of 12 SOPCs were identified in each scenario (Table 8.2-14; screening process summarized in Appendix 8.VI, Tables 8.VI.2-1 to 8.VI.2-3).

Table 8.2-14 Summary of Substances of Potential Concern Identified in Kennady Lake and Area 8 during Modelled Closure

Parameter	Kennady Lake		Area 8
	Initial Closure Discharge Water Quality	Long-term Water Quality	Post-closure Water Quality
Conventional Parameters			
Total Dissolved Solids	√	√	√
Total Suspended Solids	-	-	-
Major Ions			
Chloride	-	-	-
Fluoride	√	-	-
Nutrients			
Ammonia	-	-	-
Nitrate	-	-	-
Total Metals			
Aluminum	-	-	-
Antimony	√	√	√
Arsenic	-	-	-
Barium	√	√	√
Beryllium	√	√	√
Boron			
Cadmium	√	√	√
Chromium	√	-	-
Cobalt	√	√	√
Copper	√	√	√
Iron	-	-	-
Lead	-	-	-
Manganese	√	√	√
Mercury	-	-	-
Molybdenum	-	-	-
Nickel	-	-	-
Selenium	-	-	-
Silver	-	-	-
Strontium	√	√	√
Thallium	-	-	-
Uranium	-	-	-
Vanadium	√	√	√
Zinc	-	-	-

Source: Adapted from Table 8.9-8 in De Beers (2011).

Checkmark (√) indicates that the substance in question was identified as a substance of potential concern (SOPC); "-" indicates that the substance was not identified as an SOPC.

Chronic effects benchmarks (CEBs) were derived for the SOPCs identified in the direct waterborne exposure pathway. The CEBs represent water concentrations above which changes to aquatic health could occur on the scale of individual organisms. The CEBs are less conservative (i.e., more realistic) than water quality guidelines, but retain a level of conservatism for the evaluation of population-level effects, which would require concentrations to be higher than the CEBs described herein. Consequently, the CEBs are considered to be conservative thresholds by which potential effects to aquatic health can be assessed.

For TDS, the CEB took the form of a range of concentrations, which were derived based on a review of the applicable literature. For the remaining SOPCs, single point benchmarks were identified, following the approach outlined in Appendix 8.IV of the 2011 EIS Update (De Beers 2011). The revised assessment identified fluoride, which was not an SOPC in the 2011 EIS Update, as an SOPC for one of the scenarios; the approach and derivation of a CEB for fluoride is described in Appendix 8.VI of this document. Appendix 8.VI also describes new scenario-specific CEBs for copper, which were derived using the Biotic Ligand Model (BLM). The predicted water concentrations were compared to the CEBs to conservatively evaluate the potential for adverse effects to aquatic health. The results of these comparisons are discussed below, beginning with TDS.

Total Dissolved Solids

Using the revised water quality model, predicted maximum concentrations of TDS and constituent ions decreased by 19% on average in Kennady Lake during initial closure discharge, by 61% on average in Kennady Lake during long-term conditions, and by 13% in Area 8 during post-closure conditions compared to the 2011 EIS Update (De Beers 2011) predictions (Table 8.2-15). The new predicted maximum TDS concentrations remain below concentrations associated with adverse effects to freshwater aquatic life. Thus, the prediction that increases in TDS and major ion concentrations will have negligible residual effects on aquatic health has not changed.

Remaining Parameters

The predicted maximum concentrations of the remaining SOPCs decreased by 18% on average in Kennady Lake during initial closure discharge and by 10% in Area 8 during post-closure conditions compared to the 2011 EIS Update (De Beers 2011) predictions (Table 8.2-16). Predicted maximum concentrations increased by 8% on average, compared to background conditions, in Kennady Lake during long-term conditions. With the exception of copper, maximum concentrations are predicted to remain below the CEB identified for each substance. As a result, the predicted increases in the concentrations of these SOPCs are expected to have a negligible residual effect on the aquatic health in Kennady Lake and Area 8 under the assessed conditions.

Table 8.2-15 Maximum Concentrations of Total Dissolved Solids and Constituent Ions in Kennady Lake and Area 8 during Closure

Parameter	Background Concentration (mg/L)[(a)]	Kennady Lake Initial Closure Discharge Predicted Maximum Concentrations (mg/L)			Kennady Lake Long-term Predicted Maximum Concentrations (mg/L)			Area 8 Post-closure Predicted Maximum Concentrations (mg/L)		
		2011 EIS Update[(a)]	2012 EIS Supplement	Change (%)	2011 EIS Update[(a)]	2012 EIS Supplement	Change (%)	2011 EIS Update[(a)]	2012 EIS Supplement	Change (%)
Total Dissolved Solids	13	162	145	-11	83	37	-56	94	96	2
Calcium	1.2	30	27	-10	13	5	-62	16	17	6
Chloride	0.55	69	64	-8	21	3	-84	35	39	12
Fluoride	0.03	-	0.13	-	-	0.12	-	-	0.11	-
Magnesium	0.52	5.6	4.6	-17	3.4	1.6	-53	3.4	3.1	-7
Potassium	0.48	5.8	2.8	-53	5.7	1.9	-67	4.8	2.0	-58
Sodium	0.71	17	15	-8	9.5	2.4	-74	9.7	9.9	1
Sulphate	0.83	22	20	-11	22	10	-55	18	13.2	-27
Nitrate as N	<0.007[(c)]	2.9	2.0	-32	0.037	0.024	-36	1.5	1.1	-31

(a) Kennady Lake Background Concentrations (Long-term Average).

(b) From De Beers (2011).

(c) Median detection limit.

mg/L = milligrams per litre; "-" no predicted concentrations for that parameter; < = less than; N = nitrogen

Table 8.2-16 Maximum Concentrations for Selected Substances of Potential Concern in Kennady Lake and Area 8 during Closure

Parameter	Chronic Effect Benchmark (mg/L) [(a)]	Kennady Lake Initial Closure Discharge Predicted Maximum Concentrations (mg/L)			Kennady Lake Long-term Predicted Maximum Concentrations (mg/L)			Area 8 Post-closure Predicted Maximum Concentrations (mg/L)		
		2011 EIS Update [(a)]	2012 EIS Supplement	Change (%)	2011 EIS Update [(a)]	2012 EIS Supplement	Change (%)	2011 EIS Update [(a)]	2012 EIS Supplement	Change (%)
Antimony	0.157	0.0021	0.0008	-62	0.0019	0.0005	-74	0.0016	0.00058	-64
Barium	5.8	0.19	0.03	-84	0.19	0.02	-89	0.15	0.02	-87
Beryllium	0.0053	0.00014	0.00014	-1	0.00014	0.00012	-14	0.00013	0.00011	-12
Cadmium	0.000132 [(b)]	0.000042	0.000045	8	0.00004	0.000041	2	0.000039	0.000040	2
Chromium	0.0083 [(c)]	0.005	0.00103	-79	0.0013	- [(d)]	-	0.0025	- [(d)]	-
Cobalt	0.0093	0.00048	0.00136	182	0.00027	0.00105	290	0.00034	0.00097	184
Copper, Total [(f)]	0.0019 [(e)]	0.0028	**0.0023**	-18	0.0027	**0.0020**	-27	0.0026	0.0020	-22
Copper, Dissolved [(f)]	0.0018 [(e)]	0.0022	0.0017	-21	0.0021	0.0015	-28	0.0019	0.0014	-26
Fluoride	0.4	-	0.13	-	-	- [(d)]	-	-	- [(d)]	-
Manganese	1.455	0.056	0.043	-23	0.015	0.033	122	0.03	0.034	12
Strontium	0.049 [(f)]	0.19	0.028	-86	0.19	0.020	-90	0.15	0.047	-70
Vanadium	0.0338	0.003	0.0027	-9	0.0029	0.0024	-16	0.0024	0.0021	-13

Bolded concentrations are greater than corresponding chronic effects benchmark.

(a) Developed as outlined in Appendix 8.IV of the 2011 EIS Update (DeBeers 2011) and Appendix 8.VI (for copper and fluoride). Note that CEBs were based on total concentrations with the exception of copper, which was based on total and dissolved concentrations.

(b) The CEB for cadmium varies with hardness; the reported value is based on a hardness of 19 mg/L, which is the lowest predicted hardness in the 2012 water quality predictions and thus results in a conservative cadmium CEB.

(c) The CEB for chromium varies with speciation; the CEB for chromium (VI) is 0.0083 mg/L whereas the CEB for chromium (III) is 0.089 mg/L. Although it is anticipated that most chromium will be present as chromium (III) (Section 8.8.4.1.1; De Beers [2011]), the more conservative CEB for chromium (VI) was used in the current assessment.

(d) The parameter was no longer identified as a substance of potential concern (SOPC).

(e) Scenario-specific CEBs for copper were developed using the BLM (Appendix 8.VI). The CEB is dependent on the water chemistry in each scenario. The CEBs for total and dissolved copper in Kennady Lake for the long-term water quality scenario are presented in the table, as they were the lowest of the three scenarios shown. The CEBs for total and dissolved copper were 0.0022 and 0.0021 mg/L, respectively, in Kennady Lake Initial Closure and 0.0021 and 0.0020 mg/L, respectively, in Area 8 Post-closure.

(f) The BLM yielded CEBs for dissolved copper, which were converted to total copper values using an Acute-to-Chronic Ratio as recommended by USEPA 2007. Given that CEBs for total and dissolved copper were available, both sets of predicted concentrations were presented in the table.

mg/L = milligrams per litre.

Copper is a component of Kennady Lake bed sediment. Another source of copper to Kennady Lake is from the PK, which will either be deposited in the Fine PKC Facility, or be placed in the mined-out Hearne open pit. The exceedences of the CEBs are based on predicted maximum copper concentrations, which are expected to decrease over time, but remain above CEBs in Kennady Lake into the post-closure period. Time series plots of predicted copper concentrations in Kennady Lake are presented in Appendix 8.IV.

Maximum concentrations of total copper are predicted to be above CEBs in Kennady Lake during closure conditions (Table 8.2-16). However, the predicted concentrations only marginally exceeded the CEBs: maximum total copper concentration was predicted to be 0.0023 mg/L during initial closure discharge, which is slightly higher than the corresponding CEB of 0.0022 mg/L, and was predicted to be 0.0020 mg/L during long-term conditions, which is slightly higher than the corresponding CEB of 0.0019 mg/L. Predicted maximum dissolved copper concentrations do not exceed the CEBs. Maximum total and dissolved copper concentrations in Area 8 during post-closure conditions are predicted to be below CEBs.

Despite the predicted exceedances of the CEBs, the potential for copper to cause adverse residual effects to aquatic life in Kennady Lake is considered to be low. The CEBs for copper were derived using the BLM, which takes exposure and toxicity modifying factors, such as dissolved organic carbon (DOC), pH, and sulphide into account. In this assessment, the BLM was most sensitive to pH and DOC (Appendix 8.VI). Although these parameters were not predicted by modelling, increases in DOC are expected due to the expected increases in productivity (Section 8.2.5). Baseline DOC concentrations were used to run the BLM (Appendix 8.VI), which yielded conservative estimates of the CEBs. Given the small magnitude by which predicted maximum concentrations exceed the CEBs, and the potential for DOC concentrations discussed above to increase, the potential for adverse effects from copper is considered to be low. Follow-up monitoring will be undertaken to assess this evaluation. The BLM will be used to update the CEBs for copper, when monitoring data are available, and parameters not predicted by water quality modelling will be measured (i.e., pH, DOC, and sulphide). Adaptive management strategies will be adopted, if necessary.

8.2.6.2.1 Indirect Exposure - Changes to Fish Tissue Quality

To assess potential effects due to changes in fish tissue quality, potential changes to fish tissue concentrations in Kennady Lake and Area 8 were estimated by multiplying predicted maximum concentrations in water by parameter-specific bioaccumulation factors (BAFs; Appendix 8.VI, Tables 8.VI.2-4 and 8.VI.2-5). Only those parameters for which toxicological benchmarks could be defined were considered. These parameters, hereafter called substances of interest (SOI), were:

- aluminum
- antimony
- arsenic
- cadmium
- chromium
- copper
- lead
- mercury
- nickel
- selenium
- silver
- vanadium
- zinc

Predicted fish tissue concentrations were then compared to toxicological benchmarks that have been shown in laboratory studies to be associated with sublethal effects in fish.

The predicted fish tissue concentrations decreased on average by 20% in Kennady Lake during initial closure discharge and long-term conditions, and on average by 14% in Area 8 during post-closure conditions (Table 8.2-17). Predicted fish tissue concentrations in Kennady Lake and Area 8 remained below toxicological benchmarks for all SOIs with the exception of aluminum, nickel, and silver. Predicted fish tissue concentrations of aluminum and nickel exceeded the toxicological benchmarks in Kennady Lake during initial discharge closure conditions, whereas predicted concentrations of silver exceeded the benchmark in all three scenarios.

The predicted aluminum and nickel fish tissue concentrations in Kennady Lake during the initial closure discharge increased by 29% and 56%, respectively compared to the 2011 EIS Update (De Beers 2011). These increases were due to increases in the model source terms based on supplemental geochemical testing conducted since 2010 (see Appendix 8.III).

The predicted aluminum concentration in fish was 25.5 milligrams per kilogram wet weight (mg/kg ww), which exceeds the toxicological benchmark of 20 mg/kg ww. Accumulation of aluminum in fish tissue and organs via uptake from the water occurs slowly, whereas aluminum accumulation and toxicity via the diet are thought to be unlikely, based on toxicity studies and the absence of biomagnification in freshwater invertebrates (Wilson 2012). Wilson (2012) further documented that aluminum may undergo trophic dilution, where accumulation of aluminum would be lower in fish than in phytoplankton and zooplankton. As such, effects to aquatic health from aluminum accumulating in fish tissue via the diet are not expected.

Table 8.2-17 Predicted Metal Concentrations in Fish Tissues in Kennady Lake and Area 8 during Closure

Substance of Interest	Toxicological Benchmark (mg/kg ww) [(a)]	Kennady Lake Initial Closure Discharge Predicted Fish Tissue Concentrations (mg/kg ww)			Kennady Lake Long-term Predicted Fish Tissue Concentrations (mg/kg ww)			Area 8 Post-closure Predicted Fish Tissue Concentrations (mg/kg ww)		
		2011 EIS Update [(b)]	2012 EIS Supplement	Change (%)	2011 EIS Update [(b)]	2012 EIS Supplement	Change (%)	2011 EIS Update [(b)]	2012 EIS Supplement	Change (%)
Aluminum	20	19.7	**25.5**	29	19.6	15.9	-19	17	17.0	0
Antimony	9	5.8	2.09	-64	5.2	1.41	-73	4.4	1.58	-64
Arsenic	3.1	1.0	1.011	1	1.0	0.271	-73	0.83	0.611	-26
Cadmium	0.6	0.0098	0.0106	8	0.0096	0.0097	1	0.0093	0.0094	1
Chromium	0.58	0.39	0.080	-79	0.10	0.042	-58	0.19	0.055	-71
Copper	3.4	2.4	1.9	-21	2.3	1.7	-26	2.2	1.7	-23
Lead	4.0	0.030	0.027	-10	0.018	0.021	17	0.018	0.020	11
Mercury	0.8	0.16	0.097 [(c)]	-39	0.10	0.091 [(c)]	-9	0.12	0.116 [(c)]	-3
Nickel	0.82	0.72	**1.12**	56	0.71	0.68	-4	0.61	0.73	20
Selenium	2.58	2.5	0.502	-80	0.75	0.421	-44	1.4	0.673	-52
Silver	0.06	**0.15**	**0.12**	-20	**0.12**	**0.11**	-8	**0.13**	**0.19**	46
Vanadium	0.41	0.28	0.258	-8	0.27	0.227	-16	0.23	0.203	-12
Zinc	60	4.6	3.1	-33	1.7	2.5	47	2.9	2.5	-14

Source: Adapted from Tables 8.9-10 to 8.9-12 in De Beers (2011).

Bolded estimated fish tissue concentrations are greater than corresponding toxicological benchmark.

[(a)] Developed as outlined in Section 8.9.2.2.2 of the 2011 EIS Update (De Beers 2011). Benchmarks originate from Jarvinen and Ankley (1999), with the exception of selenium; the selenium benchmark is based on data contained in US EPA (2004) expressed as wet weight assuming a moisture content of 76%.

[(b)] From De Beers (2011).

[(c)] Mercury concentration in tissue increases with fish size. The largest lake trout captured during the baseline (789 mm) had a measured mercury concentration in muscle tissue that was about three times higher than the median concentration. A predicted tissue concentration that is three times higher than that reported here would not exceed the toxicological benchmark, indicating that there is negligible risk of the predicted mercury water concentrations even to the largest fish.

mg/kg ww = milligrams per kilogram wet weight.

The predicted nickel concentration in fish was 1.12 mg/kg ww, which exceeds the toxicological benchmark of 0.82 mg/kg ww. The nickel benchmark was based on a 180-day (d) no observed effect concentration (NOEC) for survival of rainbow trout (*Oncorhynchus mykiss*). Other tissue thresholds found for nickel were higher, including a 15-d NOEC and a 4-d lethal concentration 50% (LC50) for freshwater carp of 118.1 and 58 mg/kg ww, respectively (Jarvinen and Ankley 1999). However, recent studies have not been able to establish tissue benchmarks; Couture and Pyle (2008) could not identify a threshold value to differentiate between yellow perch from clean and nickel-contaminated environments (unlike the case for cadmium and copper). No evidence of biomagnification or bioconcentration of nickel has been found in aquatic ecosystems (Pyle and Couture 2012). Nickel is likely essential to fish; fish tissue concentrations remain constant despite wide fluctuations in water concentrations, suggesting that fish actively regulate uptake and elimination of nickel (Pyle and Couture 2012). As such, the predicted tissue concentrations of nickel may be biased high, and not representative of future conditions. Therefore, adverse residual effects to aquatic health from nickel accumulating in fish tissue are considered to be low. Follow-up monitoring will be undertaken to assess this evaluation.

Using the revised water quality model, the predicted silver concentrations in fish decreased in Kennady Lake by 20% during the initial closure discharge and by 8% during long-term conditions compared to the 2011 EIS Update (De Beers 2011) (Table 8.2-4). Predicted silver concentration in fish increased 46% from 0.13 to 0.19 mg/kg ww in Area 8 during post-closure conditions. Overall, the revised predicted silver concentrations in fish from all three scenarios are still higher than the toxicological benchmark of 0.06 mg/kg ww. The benchmark was based on a 180-d NOEC for survival and growth of bluegill (*Lepomis macrochirus*). A low-effect tissue threshold could not be found for silver, either in Jarvinen and Ankley (1999) or during a literature search for concentrations of silver in muscle or whole body. Therefore, the selected tissue benchmark, which is based on a no-effect threshold, is likely a highly conservative basis for assessing the potential for predicted silver concentrations to cause adverse residual effects to fish.

The predicted silver concentrations are similar to the maximum baseline tissue concentration in the dataset used to derive the silver BAF. The maximum baseline tissue concentration was 0.09 mg/kg ww. Therefore, fish tissue silver concentrations are predicted to increase only marginally above baseline conditions as a result of the Project. Given the modest predicted increase, and given that both baseline and predicted tissue concentrations only marginally exceed the available benchmark which is based on a no-effect threshold, the potential for the predicted silver concentration to cause adverse residual effects to fish is concluded to be low.

Based on the above results from the direct waterborne exposure and indirect exposure pathways, changes to concentrations of all substances considered in this assessment are predicted to result in negligible residual effects to aquatic communities.

8.2.7 Effects to Fish and Fish Habitat

The Effects Analysis Methods sections of the 2011 EIS Update (De Beers 2011) for Fish and Fish Habitat have not changed (i.e., Section 8.10.1 for Construction and Operation, and Section 8.10.2 for Closure and Post-Closure).

The effects analysis results sections remain unchanged with the exception of the following six pathways:

Construction and Operations

- Effects of Changes to Fish Habitat from Project Footprint (Section 8.10.3.1 of the 2011 EIS Update)
- Effects of Dewatering on Fish and Fish Habitat (Section 8.10.3.2 of the 2011 EIS Update)
- Effects of Watershed Diversions on Fish and Fish Habitat (Section 8.10.3.3 of the 2011 EIS Update)

Closure and Post-Closure

- Effects of Development of Fish Habitat Compensation Works on Fish and Fish Habitat (Section 8.10.4.1 of the 2011 EIS Update)
- Effects of Re-diverting B, D, and E Watersheds to Kennady Lake (Section 8.10.4.2 of the 2011 EIS Update)
- Effects to Fish and Fish Habitat in Kennady Lake during Post-Closure (Section 8.10.4.4 of the 2011 EIS Update).

A discussion on how the supplemental mitigation associated with the Fine PKC Facility (mitigated) has changed the results for each of these pathways is provided below.

8.2.7.1 Effects Analysis Results – Construction and Operations

8.2.7.1.1 Effects of Changes to Fish Habitat from Project Footprint

Due to supplemental mitigation associated with the Fine PKC Facility, there have been changes to the footprint of the facility. The footprint of the Fine PKC Facility (mitigated) has been confined to Area 2 of Kennady Lake. The calculations of the habitat areas affected by the revised Project footprint will be included as part of the development of the detailed fish habitat compensation plan.

As described in Section 8.10.3.1 and the CCP (Appendix 3.II of the 2010 EIS [De Beers 2010]), the affected habitat areas include the following:

- portions of Kennady Lake and adjacent lakes within the Kennady Lake watershed that will be permanently lost;
- portions of Kennady Lake that will be physically altered after dewatering and later submerged in the refilled Kennady Lake; and
- portions of Kennady Lake that will be dewatered (or partially dewatered) but not otherwise physically altered before being submerged in the refilled Kennady Lake.

Permanently Lost Areas

The areas of permanent losses associated with the Project will be reduced compared to the losses presented in the 2010 EIS (De Beers 2010) and 2011 EIS Update (De Beers 2011). As the footprint of the Fine PKC Facility (mitigated) will be confined to Area 2 of Kennady Lake, Lake A1 (34.5 ha), Lake A2 (3.07 ha), Lake A5 (0.14 ha), Lake A6 (0.07 ha), and Lake A7 (0.12 ha) will no longer be permanently lost due to the Project. There also will no longer be permanent losses in watercourse area associated with the tributaries from these lakes.

Within Kennady Lake itself, there will be a small (i.e., less than 5 ha) increase in the permanently lost area due to the increase in the size of the Fine PKC Facility (mitigated) in Area 2; however, the permanently lost area within Kennady Lake will continue to represent about 20% of the total pre-development Kennady Lake area of 813.57 ha.

Physically Altered and Re-submerged Areas

The supplemental mitigation associated with the Project will not change to a large extent the lake area being physically altered and re-submerged at closure. However, the areas of pits, dykes, roads, and water collection pond berms that are classified as physically altered and re-submerged will be recalculated during the development of the detailed compensation plan. It is expected that the area being physically altered and re-submerged at closure within Kennady Lake will continue to be about 10% of the total pre-mine Kennady Lake area of 813.57 ha.

Dewatered and Re-submerged Areas

As the footprint of the Fine PKC Facility (mitigated) is slightly increased, there will be a small corresponding decrease in lake area within Kennady Lake that is being dewatered and re-submerged at closure but that will remain otherwise unaltered (i.e., less than 5 ha). This will continue to represent about 53% of the total pre-mine Kennady Lake area. The areas of Lake D1 and streams D1, D2, and E1 will not be changed by the Fine PKC Facility.

Compensation Plan

The small changes to the habitat areas affected by the footprint do not change the conclusions of the assessment, as the detailed fish habitat compensation plan will still be developed to achieve no net loss of fish habitat according to DFO's Fish Habitat Management Policy (DFO 1986, 1998, 2006). More information on proposed compensation options is included in Section 8.2.7.2.

8.2.7.1.2 Effects of Dewatering on Fish and Fish Habitat

The assessment of this pathway is unchanged from the 2011 EIS Update (De Beers 2011) except that with the revised footprint of the Fine PKC Facility (mitigated) to avoid Area 1, Lakes A1 and A2 will not be dewatered. As a result, fish salvage will not be completed in these lakes.

Under the *Temporary Habitat Loss* subsection, due to the revised footprint of the Fine PKC Facility, the area of Kennady Lake that will be dewatered and re-submerged at closure but will remain otherwise unaltered is about 5 ha less than that presented in the 2011 EIS Update (De Beers 2011). The conclusions of the pathway remain unchanged.

8.2.7.1.3 Effects of Watershed Diversions on Fish and Fish Habitat

The effects related to the diversions for the B, D, and E watersheds are as presented in the 2011 EIS Update (De Beers 2011). Follow-up monitoring will be undertaken to assess this evaluation. However, due to the supplemental mitigation associated with the Fine PKC Facility, the diversion of the A watershed differs from what was described in the 2011 EIS Update. The footprint of the Fine PKC Facility (mitigated) is confined to Area 2 of Kennady Lake and no longer covers Lakes A1 and A2; as a result, the diversion in the A watershed has been redesigned.

During mine operations, the A watershed will be isolated from Kennady Lake and the Fine PKC Facility (mitigated) through the construction of three low, till berms and a permanent saddle dam (Dyke A1) between the A watershed and Area 2 of Kennady Lake. During operations, flow from Lake A1 will be pumped via a discharge pipeline to Lake J1b, which flows to Area 8.

Lake areas, maximum depths, and known fish species in the A watershed lakes are shown in Table 8.2-18. Channel lengths, fish passage potential, and fish species recorded in streams in the A watershed are shown in Table 8.2-19.

Table 8.2-18 Lake Areas, Depths and Fish Species Recorded in the Diverted Lakes of the A Watershed

Lake	Lake Area (ha)	Maximum Depth (m)	Fish Species Recorded
A1	34.5	8.0	ARGR, BURB, RNWH
A2	3.07	1.1	-
A3	23.8	12.4	ARGR, BURB, LKTR, NRPK

ha = hectare; m = metre: ARGR = Arctic grayling; BURB = burbot; LKTR = lake trout; NRPK = northern pike; RNWH = round whitefish; - = not sampled.

Table 8.2-19 Channel Length, Fish Passage Potential and Fish Species Recorded in the Streams between Diverted Lakes of the A Watershed

Stream	Channel Length (m)	Fish Passage Potential[a]	Fish Species Recorded
A1	100	spring to fall	ARGR, BURB, LKCH, NNST, NRPK, SLSC
A2	20	spring to fall	ARGR, BURB, NRPK
A3	294	spring to fall	ARGR, BURB, LKTR, NNST, NRPK

[a] Seasons of potential fish passage estimated during habitat assessments.

m = metre: ARGR = Arctic grayling; BURB = burbot: LKCH = lake chub; LKTR = lake trout; NRPK = northern pike; NNST = ninespine stickleback; SLSC = slimy sculpin

Loss of Stream Habitat Downstream of Dykes

As discussed in the 2011 EIS Update (De Beers 2011), habitat downstream of the dykes will be dewatered and lost to fish residing in upstream lakes. With the redesign of the diversion in the A watershed, Stream A1 is affected by the placement of the dyke (instead of Stream A3 as presented in the 2011 EIS Update). The loss of fish habitat resulting from the placement of the dykes and the dewatering of downstream stream segments is described in Section 8.2.7.1.1, and will be included in the compensation plan to ensure that no net loss in fish habitat is achieved for the Project. Fish species and habitat use in the A watershed is summarized below.

A Watershed

Arctic grayling, northern pike, burbot, lake chub, slimy sculpin, and ninespine stickleback have been recorded in Stream A1. Lake trout and round whitefish have also been recorded in the A watershed.

Loss of Stream A1 downstream of Dyke A1 is likely to affect Arctic grayling and northern pike. Arctic grayling and northern pike use Stream A1 as a movement corridor between Kennady Lake and the A watershed. The spawning habitat in Stream A1 has been assessed as moderate quality for Arctic grayling and high for northern pike. However, Arctic grayling in Kennady Lake may use streams within the A watershed for spawning, but the numbers of fish using these streams is small in comparison to the numbers of Arctic grayling using streams downstream of Kennady Lake. Limited northern pike spawning may occur in the lakes of the A watershed; studies indicate that lakes in the D watershed are the primary spawning location for Kennady Lake northern pike.

The persistence of Arctic grayling and northern pike in the A watershed will depend on these species using habitat in the upper tributaries of the A watershed for spawning (primarily Stream A3). Stream A3 is a permanent stream, 294 m in length, with overall moderate quality habitat for fish. Potential Arctic grayling and northern pike spawning habitat is present, but considered to be low quality. Other tributary streams (e.g., streams A6 and A9) are ephemeral, with limited potential spawning habitat for these species, if any. Stream A2 is a short (20 m) channel linking lakes A1 and A2.

Changes to Lake Levels and Lake Areas Upstream of Dykes

During operations, there may be an increase in water level and lake area in spring and into summer in Lake A1 compared to baseline, as pumping from the discharge pipeline from Lake A1 to Lake J1b may be less than the freshet inflows. It is expected that the water levels will remain at near spring freshet levels longer into the summer compared to baseline conditions. The increases in lake level are projected to be small (i.e., maximum of 50 cm) in Lake A1; as a result, the increases in water levels are unlikely to have a substantive effect on fish habitat or benthic invertebrate communities in the lake, although the additional flooded vegetation may provide additional northern pike spawning habitat in the spring.

Towards the end of operations, lake levels will gradually be raised in Lake A1 to allow for the flow to Area 3 of Kennady Lake at closure. Lakes A1 and A2 will become one raised lake, Lake A1-A2.

Shoreline Erosion, Resuspension of Sediments and Sedimentation

No effects to fish and fish habitat would be expected from shoreline erosion in Lake A1 from the increased water levels compared to baseline conditions. The shoreline habitats in Lake A1 are dominated by boulders and large cobble substrates, with some areas of bedrock. The presence of these large substrates will promote long-term stability of the shoreline. The effects are as described in the 2011 EIS Update (De Beers 2011); negligible effects on fish and fish habitat in the diverted lakes are expected from shoreline erosion, resuspension of sediments, and sedimentation.

Changes to Fish Migrations

With the redesign of the diversion in the A watershed, Stream A1 is affected by the placement of the dyke (instead of Stream A3 as presented in the 2011 EIS Update [De Beers 2011]). Unlike the B, D, and E watershed diversions, the A watershed will not be connected to the N watershed during operations through designed stream channels; water from the A watershed will be pumped via a discharge pipeline to Lake J1b, which flows into Area 8, effectively isolating the A watershed during operations.

For the A watershed diversion, Dyke A1 in Stream A1 will interrupt the movements of fish between Kennady Lake and waterbodies upstream of the dyke. This effect will be limited to the period of mine operations, as Lake A1 will be connected with Area 3 of Kennady Lake during the closure period. Loss of access to the lowermost streams in the A watershed is likely to affect Arctic grayling, which currently use this stream habitat for spawning and rearing. Persistence of this species will depend on whether Arctic grayling use habitat in upper tributary streams; however, natural spawning habitats for Arctic grayling may be limited in this watershed upstream of the dyke.

Northern pike have been documented to use lake and stream habitat in the A watershed and suitable spawning, rearing, and overwintering habitats exist in this watershed upstream of Dyke A1. The dyke will preclude the annual spring spawning migrations of adults from Kennady Lake and prevent potential recruitment from this system. Although the dyke will in effect isolate the northern pike population within this watershed for the duration of mine operations, it is likely that the isolated population will be self-sustaining.

Small populations of burbot, slimy sculpin, and ninespine stickleback will likely continue to spawn in the diverted watershed. These species are not known to undergo extensive migrations between waterbodies and the loss of connectivity to Kennady Lake is not likely to affect their abundance. Lakes A1 and A3 are deep (i.e., greater than 8 m) relative to other lakes in the A watershed, and, thus, would provide suitable overwintering habitat. Nearshore habitats in the A watershed lakes include clean boulder/cobble substrates, which could be used by slimy sculpin and burbot for spawning and rearing, as well as submerged and emergent aquatic vegetation used by northern pike and ninespine stickleback for spawning, rearing, and foraging. As such, all life history requirements for these species can be fulfilled in the diverted watershed, without the need to access Kennady Lake.

As described in the 2011 EIS Update (De Beers 2011), a second effect of the dyke on fish migrations is the prevention of out-migrations of juvenile and young-of-the-year fish to Kennady Lake during operations. Prevention of downstream emigration to Kennady Lake is expected to have a minor effect on fish populations in lakes in the A watershed upstream of the dyke. These lakes have a carrying capacity which, like all lakes in the Kennady Lake area, is limited by low nutrient availability. The lakes can be assumed to be at their natural carrying capacity and will remain at or near this carrying capacity during mine operations, regardless of whether fish can emigrate to Kennady Lake.

Changes to Fish Communities

Similar to the other diverted watersheds, water quality is expected to remain suitable for aquatic life in the A watershed during the operational diversion. Populations of small-bodied fish, such as lake chub, ninespine stickleback, and slimy sculpin, are likely to persist in the diverted A watershed during mine operations because suitable spawning, rearing, and foraging habitat for each species will be available and there is no critical habitat in Kennady Lake that any of these species require to complete their life histories. Aquatic vegetation exists in lakes in the A watershed, and these lakes will continue to provide suitable habitat for northern pike and ninespine stickleback throughout mine operations.

Few lake trout have been captured in the A watershed. Although lakes A1 and A3 are among the deeper of the small lakes in the Kennady Lake watershed, lake trout generally prefer large, deep lakes that have low water temperatures in summer and high levels of dissolved oxygen year round. There may be some lake trout that live year-round in Lake A3; however, most lake trout in the A watershed are likely using the lakes seasonally for rearing and feeding (e.g., juvenile lake trout that move out of Kennady Lake in the summer to feed and escape predation from adults). The lakes in the A watershed upstream of Dyke A1 will likely continue to provide the same amount of habitat for lake trout that currently exists.

Small numbers of burbot have been captured in lakes A1 and A3. Lakes A1 and A3 will likely continue to provide the same amount of habitat for burbot that currently exists.

Most available spawning and rearing areas used by Arctic grayling in the A watershed are located under the footprint or downstream of Dyke A1. As such, the construction of the dyke will negatively affect Arctic grayling reproduction. The persistence of Arctic grayling in the diverted A watershed, therefore, will be dependent on the suitability of spawning and rearing habitat in the upper tributary streams and the use of this habitat by Arctic grayling. As the amount of high quality Arctic grayling spawning habitat in streams A2 and A3 is limited, the population of Arctic grayling in these lakes persisting through operations is expected to be small.

8.2.7.2 Effects Analysis Results – Closure and Post-Closure

8.2.7.2.1 Effects of Development of Fish Habitat Compensation Works on Fish and Fish Habitat

As described in Section 8.2.7.1, De Beers will compensate for habitat permanently lost or altered due to proposed mine development. The Project includes a habitat compensation plan designed to create new fish habitat to offset predicted habitat losses so that there is no net loss of fish habitat according to DFO's Fish Habitat Management Policy (DFO 1986, 1998, 2006). Compensation options were identified in Section 8.10.4.1 and the Conceptual Compensation Plan (CCP, Appendix 3.II) of the 2010 EIS (De Beers 2010). With the change in the footprint of the Fine PKC Facility, Option 2 (raising Lake A3 to a greater elevation than would be only for development of the Project) is no longer under consideration.

The remaining potential compensation options include the following: Options 1b and 1c (raising the water level in lakes to the west of Kennady Lake); Option 10 (widening the top bench of mine pits where they extend onto land); Options 3 and 4 (construction of habitat enhancement features in Areas 6, 7, and 8); and Option 8 (the Dyke B habitat structure). More details on the options are provided in Appendix 3.II of the 2010 EIS (De Beers 2010).

Quantification of habitat gains in terms of Habitat Units (HUs), and determination of compensation ratios based on HUs, will be completed as part of the development of a detailed compensation plan to be completed in 2012. The detailed compensation plan will be developed in consultation with DFO, and with input from communities.

8.2.7.2.2 Effects of Re-diverting A, B, D, and E Watersheds to Kennady Lake

The effects of re-diverting the B, D, and E watersheds to Kennady Lake are as described in the Section 8.10.4.2 of the 2011 EIS Update (De Beers 2011). The A watershed will be reconnected at closure to Area 3 of Kennady Lake.

Changes to Lake Levels and Lake Areas

Towards the end of operations, lake levels will gradually be raised in Lake A1 to allow for the flow to Area 3 of Kennady Lake at closure. The water level will be raised by approximately 1.7 m, relatively to baseline conditions, creating one raised lake (Lake A1-A2) with a surface area approximately 43% larger than the combined pre-Project area of the two lakes.

Raised water levels may create a benefit to fish residing in these lakes. These benefits will be manifested largely from the additional space and increased amount of overwintering habitat for all resident species. Populations of northern pike and ninespine stickleback may also benefit initially from the increased spawning and rearing habitat in areas with flooded vegetation.

Changes to Lower Trophic Levels

Changes in water levels and lake areas in Lake A1-A2 are expected to increase habitat area available for plankton and benthic invertebrates, once new lake areas are fully colonized. This will result in overall increased total biomass of plankton and benthic invertebrates in these lakes, after a period of adjustment to the new water levels. In addition, the increased water level in Lake A2, which currently freezes to the bottom, would allow for greater year-round production of benthic invertebrates.

Changes to Fish Migrations

Changes to fish migrations in the B, D, and E watersheds at closure are as described in Section 8.10.4.2 of the 2011 EIS Update (De Beers 2011). Prior to, and during the refilling process, De Beers will track the water quality within Kennady Lake and use adaptive management to make decisions with respect to dyke removal, in consultation with regulatory agencies.

As described in Section 8.11.1.3.3 of the 2011 EIS Update (De Beers 2011), during refilling, exclusion measures may be used to limit the initial migration of fish from the upper sub-watersheds into Kennady Lake. These exclusion measures would target large-bodied fish, including sensitive fish species, such as lake trout. Small-bodied forage fish species, such as lake chub, slimy sculpin, and ninespine stickleback, would potentially pass through the exclusion structures; these fish species are less sensitive to water quality changes including increased TSS, and would form a forage fish base for the lake recovery. The exclusion measures have not yet been selected, but would be based on structures that have been used for fish exclusion or screening for other projects. It is anticipated that these structures will be selected during the detailed design for the closure stage of the Project, which will include consultation with the regulatory agencies, including DFO. Once the dykes have been breached and the exclusion measures removed, fish from the reconnected upper watersheds would be able to move back into and out of Kennady Lake.

Similar to the B, D, and E watershed diversions, the A watershed will also be reconnected to Kennady Lake at closure. The A watershed will be allowed to flow into Area 3 of Kennady Lake through a natural, low saddle after a section of the low berm between Area 3 and Lake A1 is removed. The connected channel will be designed to allow fish passage between the refilled Kennady Lake and the A watershed.

8.2.7.2.3 Effects to Fish and Fish Habitat in Kennady Lake during Post-Closure

Effects of Changes in Nutrient Levels

As discussed in the Effects to Water Quality section (Section 8.2.5), taking into account the supplemental mitigation associated with the Fine PKC Facility, the long-term maximum steady state total phosphorus concentration in Kennady Lake is projected to be 0.009 mg/L (i.e., half of the concentration projected in the 2011 EIS Update [De Beers 2011]). A long-term total phosphorus concentration of 0.009 mg/L is also predicted in Area 8. Based on the supplemental mitigation, the post-closure trophic status of Kennady Lake is expected to remain oligotrophic, rather than mesotrophic, as predicted in the 2011 EIS Update.

Because nutrient levels during closure and post-closure are expected to increase from baseline levels, an increase in lake productivity is expected. However, as the post-closure trophic status of Kennady Lake is predicted to remain oligotrophic, the effects to lower trophic levels, and fish and fish habitat, will be lower than those predicted in the 2011 EIS Update (De Beers 2011).

A summary of the predicted changes in Kennady Lake based on the predicted long-term maximum steady-state total phosphorus concentration of 0.009 mg/L is provided below. A literature review and additional supporting information are provided in Section 8.10.4.4.1 of the 2011 EIS Update (De Beers 2011).

Changes to Lower Trophic Communities

Nutrient concentrations in Kennady Lake will increase within the oligotrophic range, with corresponding changes in productivity and lower trophic communities. Increased productivity is expected at all lower trophic levels, reflected in increases in biomass of phytoplankton, zooplankton, and benthic invertebrates. In addition, some shifts in relative abundances of different plankton and invertebrate groups will likely occur, as communities adjust to the greater nutrient and food supply.

The types of changes expected in Kennady Lake lower trophic communities are anticipated to be similar to those observed in Snap Lake, a small, oligotrophic sub-Arctic lake that receives inputs of nutrients and dissolved salts from an underground diamond mine. Effects on Snap Lake water quality differ from those predicted for Kennady Lake, in that concentrations of dissolved salts have increased to higher levels in Snap Lake (De Beers 2012) than predicted for Kennady Lake. In Snap Lake, changes observed to date in lower trophic communities include increased but highly variable biomass of phytoplankton, but no appreciable change in zooplankton biomass. An increase in zooplankton biomass is expected to follow as enrichment proceeds. Changes in composition of phytoplankton consist of increased relative biomass of diatoms, and decreased relative biomass of cyanobacteria and chrysophytes. Changes in zooplankton composition include a decrease in calanoid copepod relative biomass, balanced by an increased biomass of rotifers. Compared to a nearby reference lake, year-to-year variation in phytoplankton and zooplankton community structure has been greater in Snap Lake in recent years. Changes have also been observed in benthic invertebrate community structure, consisting of generally increased and highly variable total density, and increases in densities of some taxa (fingernail clams and some midge genera), without substantial changes in richness or community structure.

The changes observed in Snap Lake represent the early stage of nutrient enrichment, with trophic status remaining in the oligotrophic range. Similar, or slightly greater changes, with increased biomass at all trophic levels, are expected in Kennady Lake during post-closure, mostly in the form of mild nutrient enrichment.

Changes to Fish and Fish Habitat

As a result of the increased nutrients in Kennady Lake during post-closure, it is expected that there will be increases in the food base for fish (e.g., zooplankton and benthic invertebrates), as well as potentially increased production in the small-bodied fish community (e.g., lake chub, slimy sculpin, and ninespine stickleback). Because of the increased food base, there may also be increased growth and production in the large-bodied fish species of Kennady Lake (e.g., northern pike, burbot, round whitefish, lake trout, Arctic grayling); however, this is more difficult to predict, as other factors associated with the change in trophic status will also play a role in the response of the fish population.

Studies have shown that increased phosphorus in lakes may affect fish habitat through increased algal growth on spawning shoals and declines in dissolved oxygen levels. However, as the increase in nutrients in the refilled Kennady Lake is not expected to result in a change in the trophic status of the lake, changes to spawning shoals are not expected to occur. Wind and wave action within the lake would continue to keep spawning areas clean and minimize the accumulation of silt and attached algae; suitable spawning habitat would continue to be available.

Summer dissolved oxygen levels would not be affected as Kennady Lake is expected to remain cool and generally well-mixed in summer, due to its climate and northern location; summer dissolved oxygen depletion in a hypolimnion would, therefore, not be an issue.

Due to the increased nutrient levels, the refilled Kennady Lake may be subject to a higher winter oxygen demand than under baseline conditions. With the updated predictions of total phosphorus in Kennady Lake in post-closure (i.e., long-term steady state concentration of 0.009 mg/L), and the supplemental dissolved oxygen modelling using GEMSS® (Section 8.2.5 and Appendix 8.V), it is anticipated that 74 to 92% of the total volume of Kennady Lake will have a dissolved oxygen concentration above 5 mg/L, which represents the acute guideline for the protection of cold water species excluding the larval stages (AENV 1999), and 51 to 89% of the total volume of Kennady Lake possessing a dissolved oxygen concentration above 6.5 mg/L, which represents the chronic guideline for the protection of aquatic life for cold water species excluding the larval stages (CCME 1999). Even the littoral zones are anticipated to have sufficient dissolved oxygen concentrations due to the considerable portion of cobble/boulder substrate in the littoral zone.

The conclusions of the 2011 EIS Update (De Beers 2011) remain unchanged in that Kennady Lake during the post-closure phase of the Project is expected to retain sufficient levels of dissolved oxygen during winter to support fish, including sensitive species, such as lake trout. However, limitations on fall spawning and overwintering habitat would be less than described in the 2011 EIS Update. As the shallow littoral zone is expected to remain well oxygenated through the period of egg incubation, it is expected that there will continue to be suitable spawning and egg incubation habitat for lake trout and round whitefish in the refilled Kennady Lake, and that natural recruitment will occur.

Based on the availability of large volumes of water with under-ice dissolved oxygen levels greater than 5 mg/L, overwintering habitat in Kennady Lake at post-closure is expected to suitable for all fish species currently in the lake, including lake trout. Based on published literature for lake trout, the optimal (or preferred) range of dissolved oxygen levels for this sensitive species is greater than 5 to 6 mg/L, with 4 mg/L being the avoidance threshold, and less than 3 mg/L approximating the incipient lethal threshold (Evans 2006).

Change in Fish Community

In the 2011 EIS Update (De Beers 2011), Kennady Lake was predicted to change in trophic status to mesotrophic; habitat conditions potentially were considered to be more suitable for top predatory species like northern pike and burbot, rather than lake trout. However, based on the revised nutrient levels, the lake will remain oligotrophic and potential limitations on spawning and overwintering habitat are expected to be less than presented in the 2011 EIS Update. As described above, habitat conditions in the refilled lake will be suitable for all species currently within the lake to return and re-establish.

As per Section 8.10.4.4.1 of the 2011 EIS Update (De Beers 2011), the final fish community of Kennady Lake will likely be characterized by a small-bodied forage fish community (e.g., lake chub, slimy sculpin, ninespine stickleback) and large-bodied species, such as Arctic grayling, northern pike, burbot, round whitefish, lake trout, and possibly longnose sucker. It is expected that the fish species assemblage within Kennady Lake will be similar to pre-Project conditions. However, due to factors such as predation and inter-species competition during the succession process, as well as the slight increase in productivity, the community structure may be different than what exists currently.

Effects of Changes to Aquatic Health

The results of the revised water quality modelling associated with the supplemental mitigation for the Fine PKC Facility (mitigated) were used to update the aquatic health assessment (Section 8.2.6). For the direct waterborne exposure assessment, the prediction has not changed that adverse residual effects to fish and aquatic invertebrates are not expected at the predicted total dissolved solids (TDS) concentrations in Kennady Lake and Area 8. At closure, predicted maximum concentrations of substances of potential concern (SOPCs) in Kennady Lake and Area 8 are below chronic effects benchmarks (CEBs), with the exception of total copper. Similar to the 2011 EIS Update (De Beers 2011), the potential for copper to cause adverse residual effects to aquatic life in Kennady Lake and Area 8 was considered to be low (Section 8.2.6).

For the indirect exposure pathway, predicted fish tissue concentrations in Kennady Lake and Area 8 were projected to be above toxicological benchmarks for three substances of interest (SOIs): aluminum, nickel, and silver. However, as described in Section 8.2.6, the potential for adverse effects to aquatic health in Kennady Lake and Area 8 from aluminum, nickel, and silver was considered to be low, and residual effects to aquatic communities were considered to be negligible.

Based on the aquatic health assessment, predicted changes to concentrations of all substances considered were projected to result in negligible effects to fish tissue quality and, by association, aquatic health in Kennady Lake. As a result, the conclusion from the 2011 EIS Update (De Beers 2011) has not changed, in that no adverse residual effects to fish populations or communities are expected from changes in aquatic health.

8.2.8 Recovery of Kennady Lake and its Watershed

The establishment of the aquatic community and timeline for the recovery of Kennady Lake is as outlined in the 2010 EIS (De Beers 2010). However, in Section 8.11.1.3.2 of the 2011 EIS Update (Applicability of Literature Review Findings to Kennady Lake; De Beers 2011) under the *Increased Nutrient Levels* subheading, it is indicated that the long-term increase in nutrient levels in the refilled lake was expected to increase lake trophic status to mesotrophic. However, due to the supplemental mitigation associated with the Fine PKC Facility, the nutrient status of Kennady Lake is now expected to remain oligotrophic.

Although the refilled Kennady Lake is expected to remain oligotrophic, there will still be increased nutrient levels compared to baseline. Although increased productivity would still be expected, changes would be less than presented in the 2011 EIS Update (De Beers 2011), which predicted mesotrophic conditions. However, the time for the lower trophic communities and fish populations to develop and stabilize is expected to be similar under both scenarios (i.e., as described in Section 8.11.1.3.3 of the 2011 EIS Update).

Lower trophic communities are expected to be more productive, but to remain reflective of oligotrophic systems. In general, biomass of plankton and benthic invertebrates is expected to be higher in the refilled Kennady Lake compared to the baseline period. This may result in increased growth and production of the small-bodied forage fish species community (e.g., lake chub, slimy sculpin, ninespine stickleback), as well as increased survival of larvae of the large-bodied fish species due to the increased zooplankton production. Due to the increased food base, there may also be increased growth and production in large-bodied fish species. The fish species assemblage (i.e., fish species present) within Kennady Lake is expected to be similar to pre-development conditions, including the re-establishment of large-bodied fish populations, such as, northern pike, Arctic grayling, burbot, round whitefish, lake trout, and possibly longnose sucker. As described in Section 8.2.5.3, the dissolved oxygen modelling indicates that the overwintering habitat conditions in the refilled Kennady Lake will be less limiting than presented in the 2011 EIS Update (De Beers 2011). Kennady Lake will remain suitable for cold-water fish species, such as lake trout.

Although all large-bodied fish species, including lake trout, are expected to return to Kennady Lake, the relative abundances of the large-bodied fish species may change from baseline conditions. During the succession process, both abiotic and biotic factors may affect the final community structure (i.e., relative abundances of the species).

8.2.9 Related Effects to Wildlife and Human Use

One of the potential pathways for effects to wildlife identified in the 2010 EIS (De Beers 2010) was effects to wildlife from a decrease in lake area due to the dewatering of Areas 2 to 7 of Kennady Lake, isolation of Area 8, and changes to small lakes in the watershed. Because the mitigation presented in this supplement represents an overall reduction in the disturbance to open-water lake area, this pathway is updated in this subsection. The reduction in the disturbance to open water area will be 22.4 ha during operations and 24.3 ha during closure (Table 11.7-3). This reduction is due primarily to changes in the A watershed when Area 1 is no longer used for fine processed kimberlite storage.

The 2010 EIS (De Beers 2010) predicted that the overall decrease in the surface area of open water in the Kennady Lake watershed through operations and closure will primarily affect habitat for water birds (e.g., waterfowl, loons, and grebes) and shore birds. Since the Project was expected to affect less than 1.4% of highly suitable habitat in the wildlife baseline regional study area (RSA), the direct effect of the Project on the population size and distribution of water birds and shore birds was predicted to be low in magnitude in the 2010 EIS. Although less open water habitat will now be disturbed, the increase in habitat available for water birds is small and unlikely to affect the population size and distribution of water birds and shore birds (i.e., there is no anticipated change to impact predictions).

8.2.10 Uncertainty

The discussion regarding uncertainty remains as described in Section 8.15 of the 2011 EIS Update (De Beers 2011), with the following exceptions. The discussion regarding the water quality model assumptions and limitations was updated in

Section 8.II.4 of Appendix 8.II (Water Quality Model Report). The discussion regarding the limitations of the geochemical characterization for the Project was updated in Section 8.III.6 of the Appendix 8.III (Metal Leaching and Acid Rock Drainage Report). Additional geochemical testing was completed to reduce the uncertainty related to the geochemical source terms for mine rock and PK material used in the water quality model.

The model uncertainty for the 3-D hydrodynamic model developed to predict post-closure concentrations of nutrients and dissolved oxygen in Kennady Lake is provided in Section 8.V.4 of Appendix 8.V (Dissolved Oxygen and Nutrient Model Report). This hydrodynamic model was developed to reduce the uncertainty regarding the under-ice dissolved oxygen predictions in the refilled Kennady Lake, and replaces the empirical relationships used to estimate winter oxygen depletion rates in the 2011 EIS Update (De Beers 2011).

8.2.11 Monitoring and Follow-up

Although the scope of the potential monitoring programs and the potential monitoring activities have not changed from the 2011 EIS Update (De Beers 2011), the text contains references to site facilities and locations (e.g., Area 1) that have been affected by the supplemental mitigation. The following changes should be noted:

- The monitoring effort mentioned in Section 8.16.2 of the 2011 EIS Update will be adjusted accordingly based on the change to the footprint of the Fine PKC Facility (mitigated) and the diversion of the A watershed.
- Fine PKC facility and West Mine Rock Pile are now Fine PKC facility (mitigated) and West Mine Rock Pile (mitigated).

8.2.12 Conclusions

To mitigate phosphorus loadings to Kennady Lake, De Beers updated the mine plan to reduce the footprint of the Fine PKC Facility (mitigated) by approximately one half and use the 5034 and Hearne pits for the deposit of additional fine PK. As a result of the change in footprint and redesign of the A watershed diversion, the water balance and water quality model for the Project were updated.

An evaluation of the water quality in Kennady Lake for this supplemental mitigation, incorporating the most recent results from ongoing and supplemental geochemical testing, indicates total phosphorus concentrations will be less than presented in the 2011 EIS Update (De Beers 2011) following refilling of Kennady

Lake (long-term maximum steady state concentration of 0.009 mg/L, with the lake remaining oligotrophic). Updated dissolved oxygen modelling also was conducted to better evaluate potential changes to under-ice dissolved oxygen as a result of the revised water quality projections. Similar to the 2011 aquatic health assessment, changes to water quality are predicted to have negligible residual effects to aquatic communities in the Kennady Lake in post-closure under the assessed conditions.

The supplemental mitigation associated with the Fine PKC Facility (mitigated) will not change the impact classification for the first time period (i.e., initiation of the Project to 100 years later), as the rating for this time period is based primarily on the dewatering and subsequent loss of the aquatic ecosystem in Kennady Lake during mining operations. However, as the second time period (after 100 years from Project initiation) is focused on future, steady state conditions, the impact classification for this time period has changed from the 2011 EIS Update (De Beers 2011). The classification for both time periods is provided in Table 8.2-20.

Table 8.2-20 Residual Impact Classification of Projected Impacts to Water Quality and Fish in Kennady Lake

Assessment Endpoint	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Likelihood
Suitability of water within the Kennady Lake watershed to support a viable and self-sustaining aquatic ecosystem							
Construction to 100 years from Project start	negative	moderate	local	long-term	continuous	reversible	likely
Beyond 100 years from Project start	negative	negligible	-	-	-	-	-
Abundance and persistence of Arctic grayling within the Kennady Lake watershed							
Construction to 100 years from Project start	negative	high	local	long-term	continuous	reversible	likely
Beyond 100 years from Project start	neutral - positive	negligible	-	-	-	-	-
Abundance and persistence of lake trout within the Kennady Lake watershed							
Construction to 100 years from Project start	negative	high	local	long-term	continuous	reversible	likely
Beyond 100 years from Project start	negative	negligible	-	-	-	-	-
Abundance and persistence of northern pike within the Kennady Lake watershed							
Construction to 100 years from Project start	negative	high	local	long-term	continuous	reversible	likely
Beyond 100 years from Project start	neutral - positive	negligible	-	-	-	-	-

- = not applicable.

As a result of the increased phosphorus in the long-term, it is expected that overall biological productivity in the refilled lake will increase in comparison to the nutrient-limited pre-development conditions. However, taking into account the revised phosphorus predictions and the updated modelling, the potential effects on fish overwintering habitat are less than what was predicted in the 2011 EIS Update (De Beers 2011).

As a result, it is expected that the water within the Kennady Lake watershed will support a viable and self-sustaining aquatic ecosystem, with the refilled lake being somewhat more productive than pre-development conditions. There are both positive and negative effects to aquatic life within Kennady Lake from the increased productivity during the second time period. The increased nutrients will be reflected in increased biomass of lower trophic communities, which may also increase the growth and production of fish species. However, there may be some small changes to under-ice dissolved oxygen levels in Kennady Lake and Area 8 at post-closure compared to pre-development conditions. Therefore, projected impacts on the suitability of water within the Kennady Lake watershed to support a viable and self-sustaining aquatic ecosystem are rated as negative in direction and negligible (Table 8.2-20).

Self-sustaining populations of the three highly valued fish species (i.e., Arctic grayling, lake trout, and northern pike) are expected to establish in the refilled Kennady Lake. As described above, limitations on overwintering are expected to be less than predicted in the 2011 EIS Update (De Beers 2011). Therefore, projected impacts on the abundance and persistence of Arctic grayling for the second time period are rated as neutral to positive in direction and negligible, as a result of the increased planktonic and benthic food base. For lake trout, the projected impacts are rated as negative in direction and negligible. Lake trout will also benefit from the increased productivity within the refilled lake due to the increased food base (lower trophic levels and forage fish base). The refilled Kennady Lake will remain oligotrophic and thus, the overwintering habitat conditions are expected to be suitable for lake trout; however, there may be some small reductions in under-ice dissolved oxygen levels compared to baseline. For northern pike, the projected impacts during the second time period have not changed from the 2011 EIS Update: neutral to positive in direction and negligible (Table 8.2.-20).

There are no changes to the evaluation of environmental significance. Similar to the 2011 EIS Update (De Beers 2011), the projected impacts on the suitability of water within the Kennady Lake watershed to support a viable and self-sustaining aquatic ecosystem, and on the abundance and persistence of Arctic grayling, lake trout, and northern pike are considered to be not environmentally significant for both time periods.

8.3 UPDATES TO SECTION 8 APPENDICES

Appendices associated with Section 8 of the 2011 EIS Update (De Beers 2011) are summarized in Table 8.3-1, together with cross-references to those Section 8 appendices revised and presented within this submission.

Table 8.3-1 Revisions to Appendices Associated with Section 8

Appendix Name	Appendix Number from the 2011 EIS Update	Updated/ New in 2012?	Reason for Update	Appendix Number within the 2012 EIS Supplement
Water Quality Modelling Report	Appendix 8.I	updated	Updated water quality modelling associated with supplemental mitigation	Appendix 8.II
Metal Leaching and Acid/Alkalinity Rock Drainage	Appendix 8.II	updated	Updated results from supplemental geochemical characterization; takes into account supplemental mitigation	Appendix 8.III
Water Quality Time Series Plots	Appendix 8.III	updated	Updated water quality modelling results associated with supplemental mitigation	Appendix 8.IV
Aquatic Health: Derivation of Chronic Effects Benchmarks	Appendix 8.IV	updated	Updated derivation of benchmarks, plus updated tables of new results based on revised water quality modelling	Appendix 8.VI
Dissolved Oxygen Modelling	Appendix 8.V	updated	Water quality model developed to predict post-closure nutrients and dissolved oxygen in Kennady Lake	Appendix 8.V
Hydrology Update	n/a	new	Updated hydrology tables and figures resulting from changes in footprint and diversion of A watershed	Appendix 8.I

Notes: EIS = Environmental Impact Statement; n/a=not applicable.

Appendix 8.I, Hydrology Update, is a new appendix added to the 2012 EIS Supplement; it includes updated tables and figures that are referred to in Section 8.2.4, Effects to Water Quantity. Appendices 8.II, 8.III, and 8.IV are updates to appendices from the 2011 EIS Update (De Beers 2011). Appendix 8.V is a revised appendix. In the 2011 EIS Update, this appendix described methods and results for the empirical dissolved oxygen modelling; Appendix 8.V currently describes the new hydrodynamic model developed to predict post-closure nutrients and dissolved oxygen in Kennady Lake. Appendix 8.VI contains the updated derivation of Chronic Effects Benchmarks, and also includes tables of new results that are referred to in Section 8.2.6, Effects to Aquatic Health.