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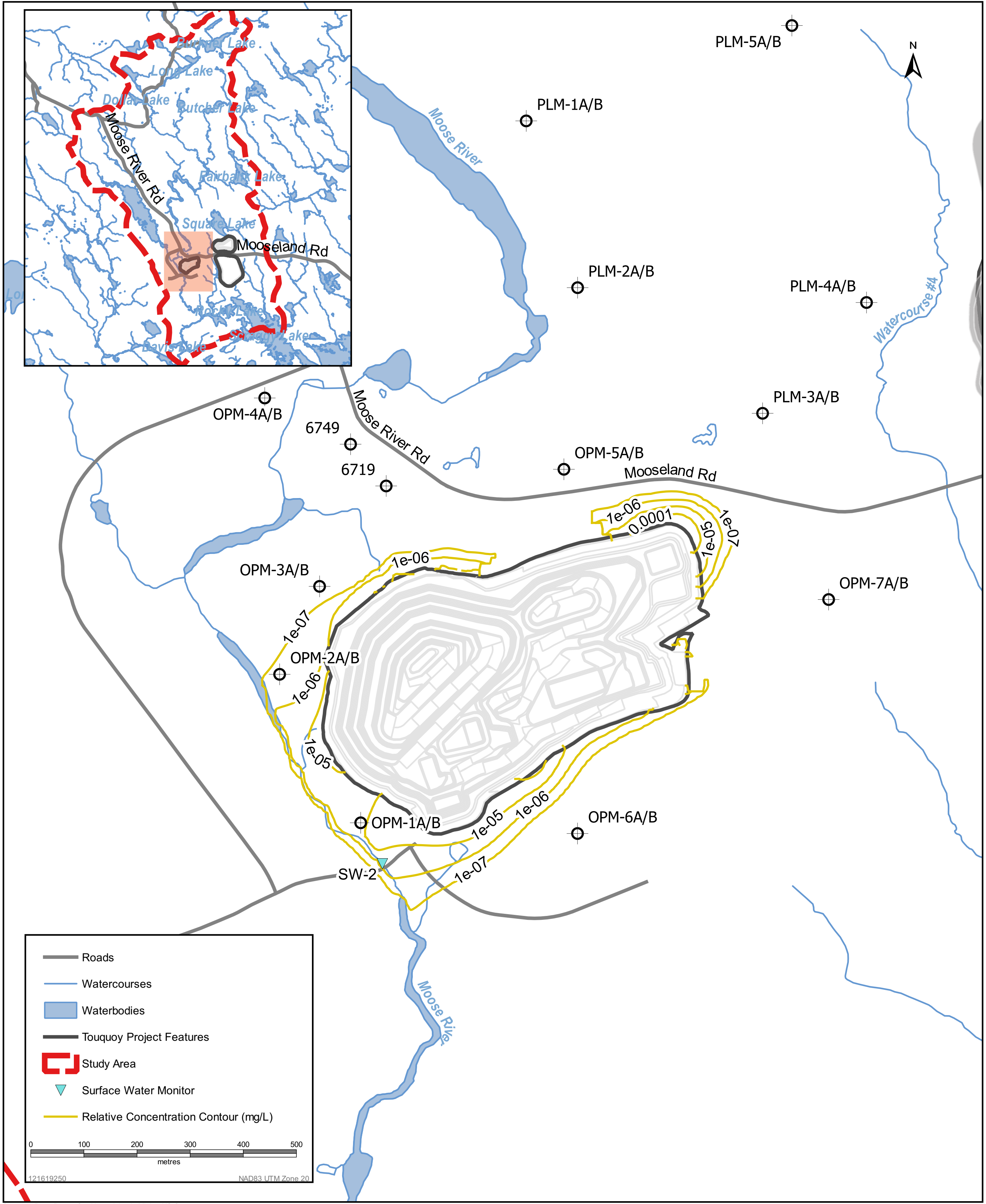

Sources: Base Data - GeoNova, Atlantic Mining NS Corp.

Relative Concentration Contours in Groundwater 100 Years Following Pit Lake at Stage 108 m

Stantec

Fifteen Mile Stream Gold Project

Figure 5.7

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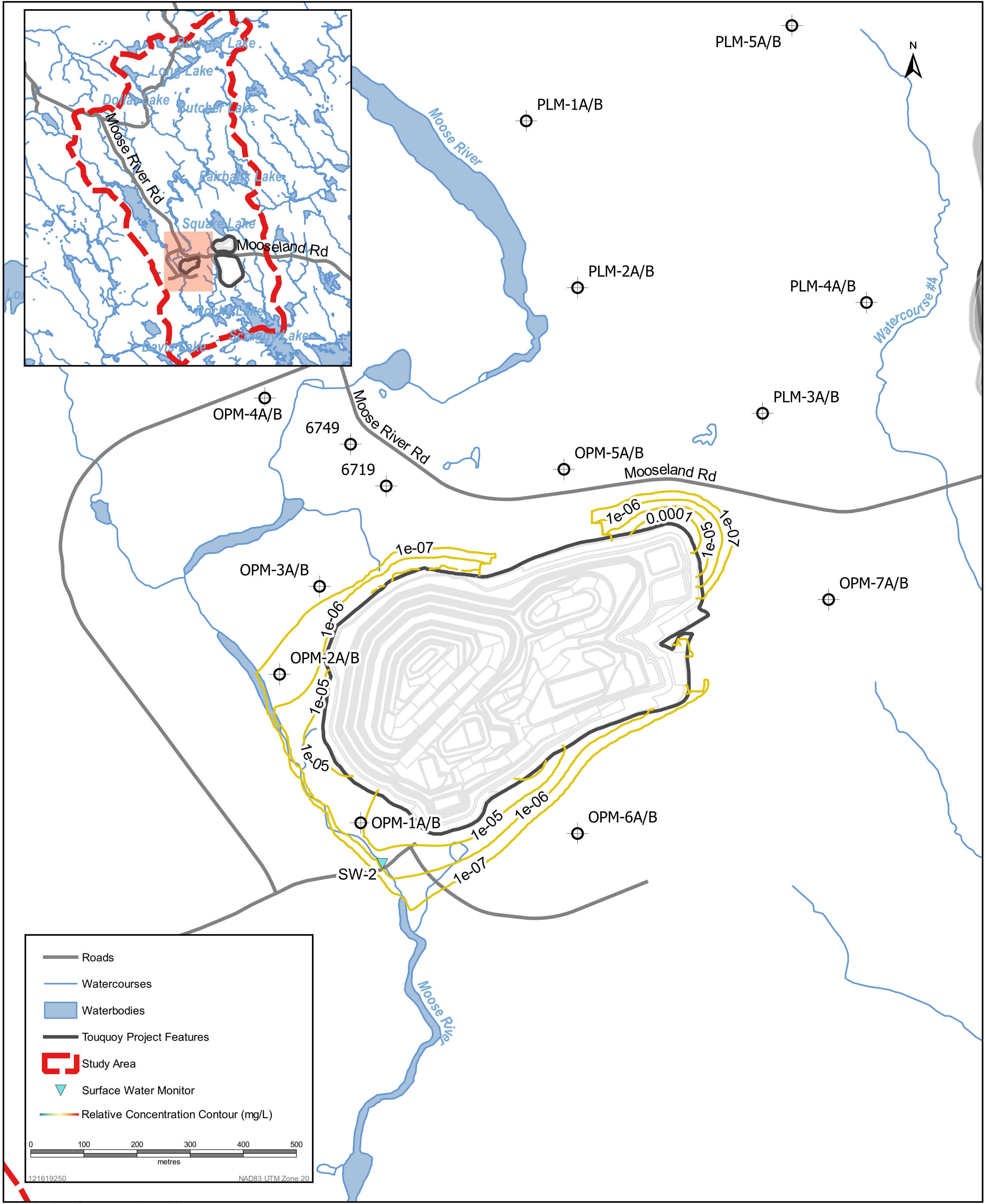

Sources: Base Data - GeoNova, Atlantic Mining NS Corp.

Relative Concentration Contours in Groundwater 500 Years Following Pit Lake at Stage 108 m

Stantec

Fifteen Mile Stream Gold Project

Figure 5.8

Table 5.3 Predicted Mass Loading to Moose River from Groundwater

Parameter	Source Term Concentration (mg/L)	Mass Loading (g/d)			
Elapsed Time (years)		10	50	100	500
Sulphate	897	1.3×10^{-1}	3.3×10^{-1}	3.7×10^{-1}	4.0×10^{-1}
Aluminum	0.0469	6.6×10^{-6}	1.7×10^{-5}	1.9×10^{-5}	2.1×10^{-5}
Silver	0.00001	1.4×10^{-9}	3.7×10^{-9}	4.1×10^{-9}	4.4×10^{-9}
Arsenic	3.07	4.3×10^{-4}	1.1×10^{-3}	1.3×10^{-3}	1.4×10^{-3}
Calcium	86.9	1.2×10^{-2}	3.2×10^{-2}	3.6×10^{-2}	3.8×10^{-2}
Cadmium	0.00002	2.8×10^{-9}	7.3×10^{-9}	8.3×10^{-9}	8.9×10^{-9}
Cobalt	0.0262	3.7×10^{-6}	9.6×10^{-6}	1.1×10^{-5}	1.2×10^{-5}
Chromium	0.0002	2.8×10^{-8}	7.3×10^{-8}	8.3×10^{-8}	8.9×10^{-8}
Copper	0.00937	1.3×10^{-6}	3.4×10^{-6}	3.9×10^{-6}	4.1×10^{-6}
Iron	0.0326	4.6×10^{-6}	1.2×10^{-5}	1.3×10^{-5}	1.4×10^{-5}
Mercury	0.000005	7.0×10^{-10}	1.8×10^{-9}	2.1×10^{-9}	2.2×10^{-9}
Magnesium	14.8	2.1×10^{-3}	5.4×10^{-3}	6.1×10^{-3}	6.6×10^{-3}
Manganese	0.37	5.2×10^{-5}	1.4×10^{-4}	1.5×10^{-4}	1.6×10^{-4}
Molybdenum	0.0603	8.4×10^{-6}	2.2×10^{-5}	2.5×10^{-5}	2.7×10^{-5}
Nickel	0.00685	9.6×10^{-7}	2.5×10^{-6}	2.8×10^{-6}	3.0×10^{-6}
Lead	0.0000248	3.5×10^{-9}	9.1×10^{-9}	1.0×10^{-8}	1.1×10^{-8}
Tin	0.00604	8.4×10^{-7}	2.2×10^{-6}	2.5×10^{-6}	2.7×10^{-6}
Selenium	0.000193	2.7×10^{-8}	7.0×10^{-8}	8.0×10^{-8}	8.5×10^{-8}
Tellurium	0.0000154	2.2×10^{-9}	5.6×10^{-9}	6.4×10^{-9}	6.8×10^{-9}
Uranium	0.00203	2.8×10^{-7}	7.4×10^{-7}	8.4×10^{-7}	9.0×10^{-7}
Zinc	0.0096	1.3×10^{-6}	3.5×10^{-6}	4.0×10^{-6}	4.3×10^{-6}
WAD CN	0.005	7.0×10^{-7}	1.8×10^{-6}	2.1×10^{-6}	2.2×10^{-6}
Total CN	0.087	1.2×10^{-5}	3.2×10^{-5}	3.6×10^{-5}	3.9×10^{-5}
Nitrate (as N)	0.053	7.4×10^{-6}	1.9×10^{-5}	2.2×10^{-5}	2.3×10^{-5}
Nitrite (as N)	0.11	1.5×10^{-5}	4.0×10^{-5}	4.5×10^{-5}	4.9×10^{-5}
Ammonia	34	4.8×10^{-3}	1.2×10^{-2}	1.4×10^{-2}	1.5×10^{-2}

Table 5.4 Predicted Average Groundwater Concentration Discharging to Moose River

Parameter	Source Term Concentration (mg/L)	Average Concentration (mg/L)			
Elapsed Time (years)		5	60	150	500
Sulphate	897	4.9×10^{-4}	1.3×10^{-3}	1.4×10^{-3}	1.5×10^{-3}
Aluminum	0.0469	2.5×10^{-8}	6.6×10^{-8}	7.5×10^{-8}	8.0×10^{-8}
Silver	0.00001	5.4×10^{-12}	1.4×10^{-11}	1.6×10^{-11}	1.7×10^{-11}
Arsenic	3.07	1.7×10^{-6}	4.3×10^{-6}	4.9×10^{-6}	5.3×10^{-6}
Calcium	86.9	4.7×10^{-5}	1.2×10^{-4}	1.4×10^{-4}	1.5×10^{-4}
Cadmium	0.00002	1.1×10^{-11}	2.8×10^{-11}	3.2×10^{-11}	3.4×10^{-11}
Cobalt	0.0262	1.4×10^{-8}	3.7×10^{-8}	4.2×10^{-8}	4.5×10^{-8}
Chromium	0.0002	1.1×10^{-10}	2.8×10^{-10}	3.2×10^{-10}	3.4×10^{-10}
Copper	0.00937	5.1×10^{-9}	1.3×10^{-8}	1.5×10^{-8}	1.6×10^{-8}
Iron	0.0326	1.8×10^{-8}	4.6×10^{-8}	5.2×10^{-8}	5.6×10^{-8}
Mercury	0.000005	2.7×10^{-12}	7.1×10^{-12}	8.0×10^{-12}	8.6×10^{-12}
Magnesium	14.8	8.0×10^{-6}	2.1×10^{-5}	2.4×10^{-5}	2.5×10^{-5}
Manganese	0.37	2.0×10^{-7}	5.2×10^{-7}	5.9×10^{-7}	6.4×10^{-7}
Molybdenum	0.0603	3.3×10^{-8}	8.5×10^{-8}	9.6×10^{-8}	1.0×10^{-7}
Nickel	0.00685	3.7×10^{-9}	9.7×10^{-9}	1.1×10^{-8}	1.2×10^{-8}
Lead	0.0000248	1.3×10^{-11}	3.5×10^{-11}	4.0×10^{-11}	4.3×10^{-11}
Tin	0.00604	3.3×10^{-9}	8.5×10^{-9}	9.7×10^{-9}	1.0×10^{-8}
Selenium	0.000193	1.0×10^{-10}	2.7×10^{-10}	3.1×10^{-10}	3.3×10^{-10}
Tellurium	0.0000154	8.4×10^{-12}	2.2×10^{-11}	2.5×10^{-11}	2.6×10^{-11}
Uranium	0.00203	1.1×10^{-9}	2.9×10^{-9}	3.2×10^{-9}	3.5×10^{-9}
Zinc	0.0096	5.2×10^{-9}	1.4×10^{-8}	1.5×10^{-8}	1.6×10^{-8}
Weak Acid Dissociable Cyanide	0.005	2.7×10^{-9}	7.1×10^{-9}	8.0×10^{-9}	8.6×10^{-9}
Total Cyanide	0.087	4.7×10^{-8}	1.2×10^{-7}	1.4×10^{-7}	1.5×10^{-7}
Nitrate (as N)	0.053	2.9×10^{-8}	7.5×10^{-8}	8.5×10^{-8}	9.1×10^{-8}
Nitrite (as N)	0.11	6.0×10^{-8}	1.6×10^{-7}	1.8×10^{-7}	1.9×10^{-7}
Ammonia (as N)	34	1.8×10^{-5}	4.8×10^{-5}	5.4×10^{-5}	5.8×10^{-5}

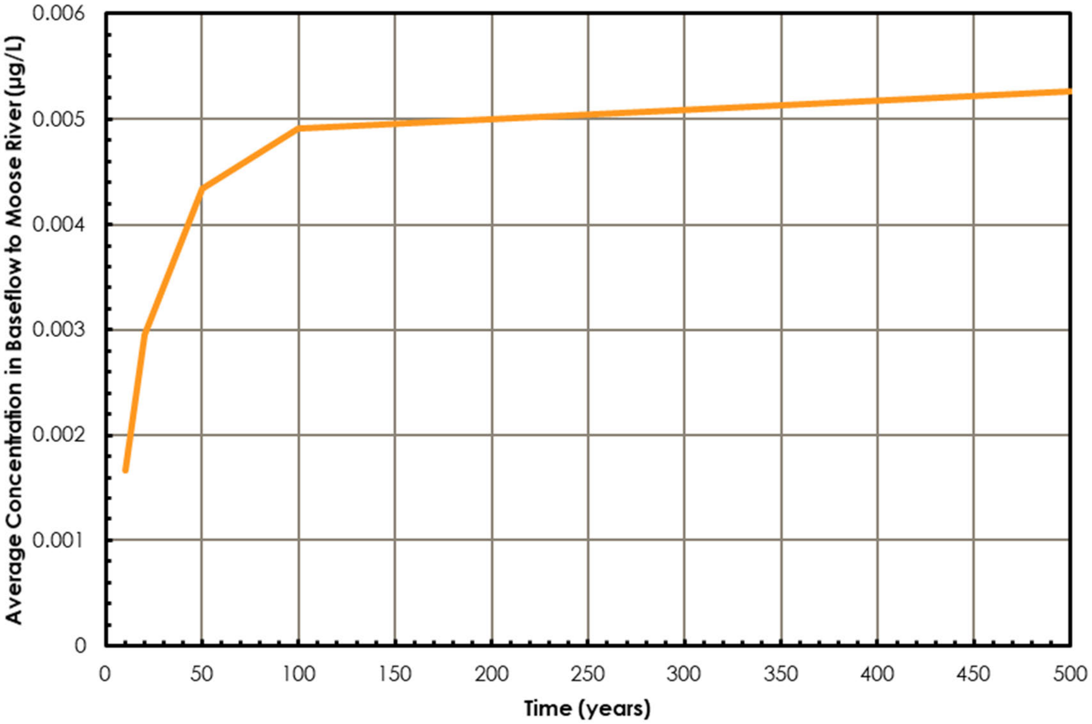

Figure 5.9 **Simulated Average Concentrations of Arsenic Discharged to Moose River in Groundwater Seepage**

The mass loading and average concentration of the parameters of concern listed in Tables 5.3 and 5.4 are combined with surface water concentrations and discharges from the open pit to predict the water quality in Moose River, as detailed in Stantec (2021).

5.4.2.1 Sensitivity of Solute Transport to Mapped Faults

The sensitivity of the solute transport model to the potential hydraulic conductivity of the mapped faults was assessed by conducting scenarios that considered the faults to be ten times more permeable and ten time less permeable than the calibrated values. The predicted relative concentrations in groundwater originating from the filled open pit are presented on Figure 5.10. As shown on Figure 5.10, lowering the permeability of the faults increases the mass loading slightly compared to the values presented in Figure 5.9. This results in more flow (and mass) flowing through the rock matrix than was previously predicted through the faults. However, increasing the hydraulic conductivity of the faults by an order of magnitude significantly increases the predicted concentrations in Moose River. The predicted relative concentrations for the higher permeability faults are presented on Figure 5.11 and Figure 5.12 for 50 and 500 years following the filling of the open pit, respectively. As shown on Figure 5.10, the addition of higher permeability faults indicates that solute transport may proceed more quickly to Moose River than simulated in the case without higher permeability faults (i.e., Figure 5.6).

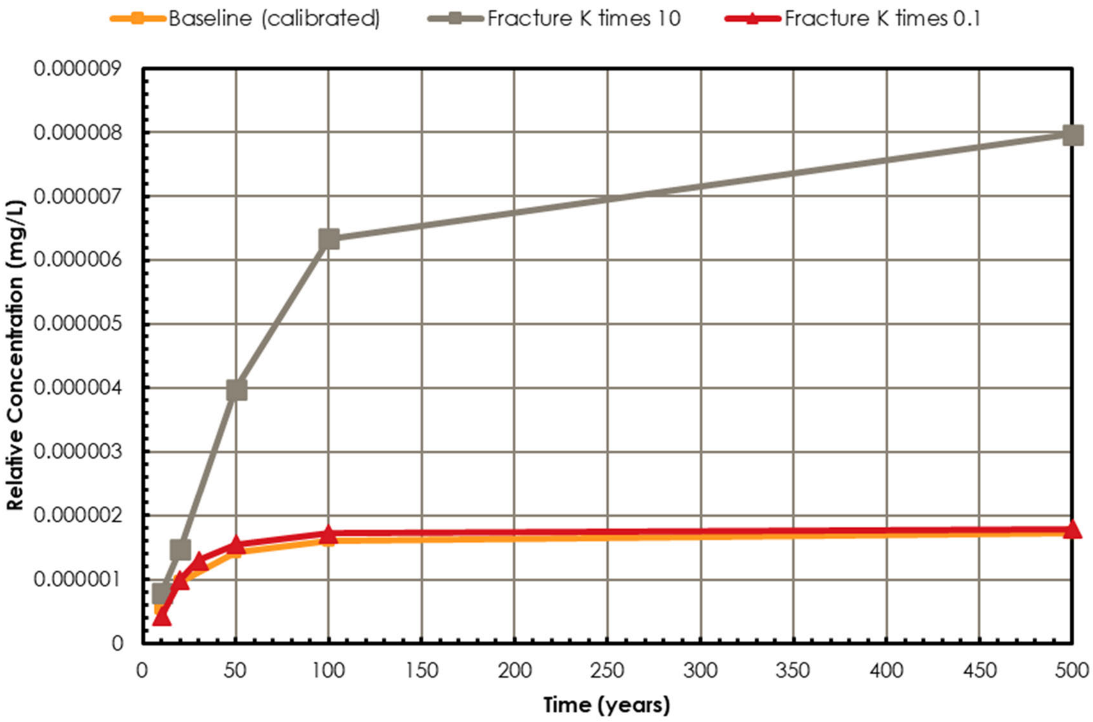

Figure 5.10 **Sensitivity of Fracture Hydraulic Conductivity on Relative Concentrations in Moose River**

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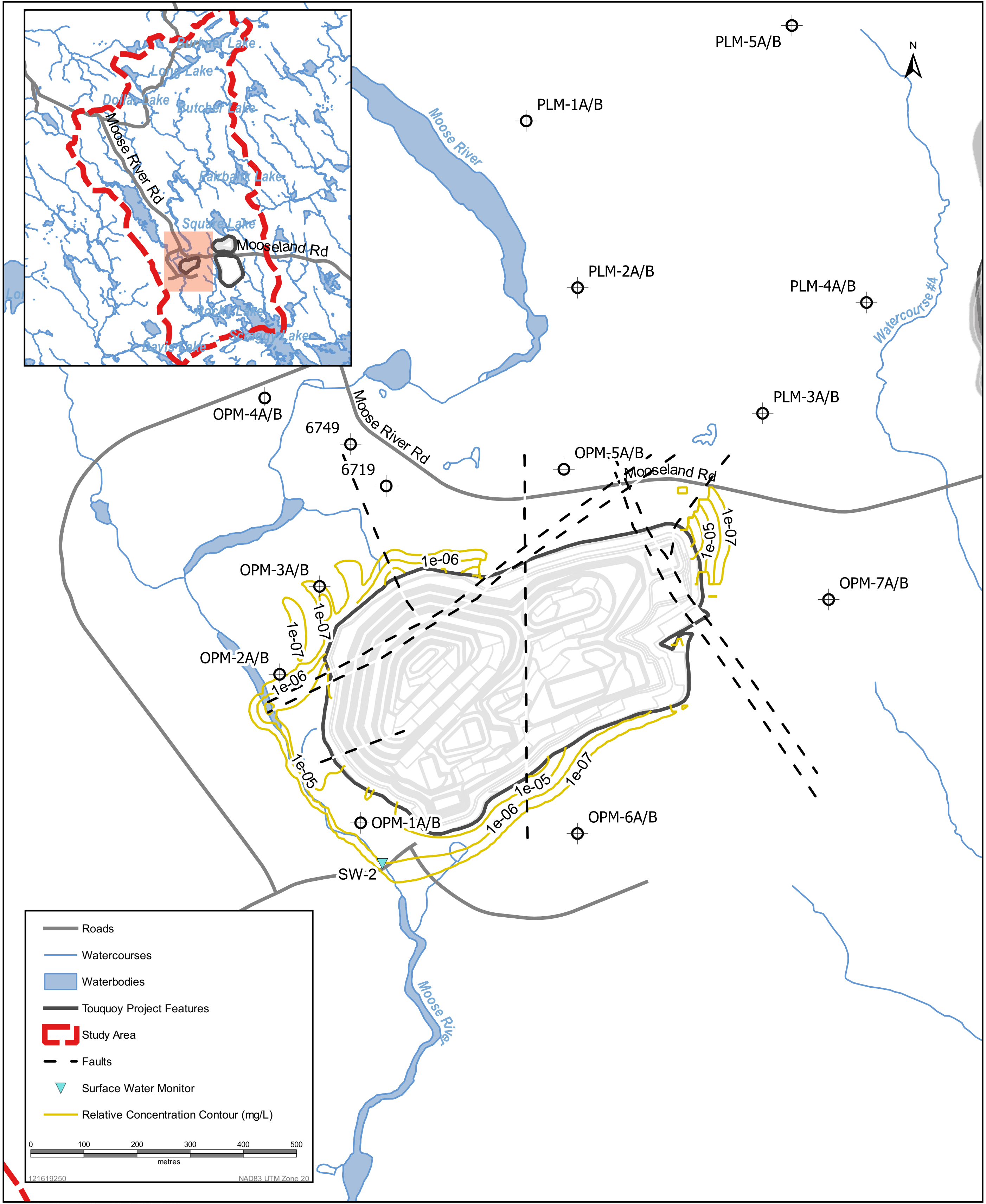

Sources: Base Data - GeoNova, Atlantic Mining NS Corp.

Relative Concentration Contours in Groundwater with High Permeability Faults 50 Years Following Pit Lake at Stage 108 m

Stantec

Fifteen Mile Stream Gold Project

Figure 5.11

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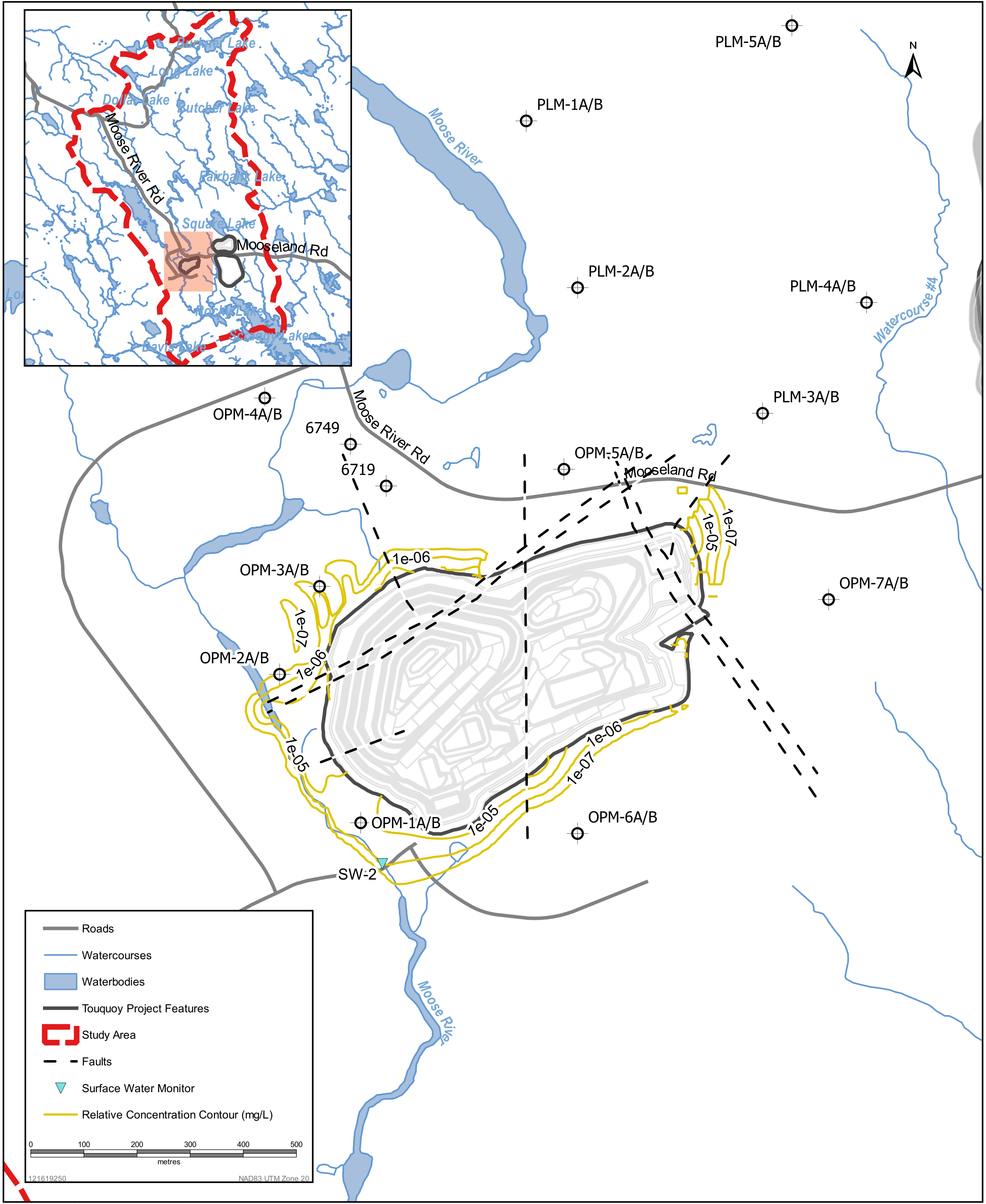

Sources: Base Data - GeoNova, Atlantic Mining NS Corp.

Relative Concentration Contours in Groundwater with High Permeability Faults 500 Years Following Pit Lake at Stage 108 m

Stantec

Fifteen Mile Stream Gold Project

Figure 5.12

Based on the sensitivity of the mapped faults to the predicted water quality in Moose River, there is the potential for additional mass to migrate toward Moose River. However, because the predicted concentrations shown on Figures 5.11 and 5.12 remain low (i.e., below detection limits), this transport is not expected to significantly alter the water quality in Moose River. The development of management, mitigation and contingency plans should consider the potential for higher permeability faulting, such as the grouting of high permeability faults, should observed concentrations exceed predictions during the post-closure period.

5.4.2.2 Sensitivity of Solute Transport to Bedrock Porosity

The sensitivity of the solute transport model to the potential porosity of the bedrock was assessed by conducting scenarios as shown on Figure 5.13. The porosity assigned to the shallow bedrock was varied between the baseline value of 10% to 1%, which is a reasonable lower bound to the weathered bedrock observed at the site. The porosity assigned to the deeper, more competent bedrock, was varied from the baseline value of 5% to 0.01%. The transport model was re-run to estimate the mass loading and predicted relative concentrations in groundwater discharge to Moose River.

As shown on Figure 5.13, the timing of the solute transport from the pit to Moose River is sensitivity to the bedrock porosity. However, the magnitude of the final concentrations in Moose River are not significantly different between the scenarios, with slightly lower relative concentrations predicted in the lower porosity scenarios.

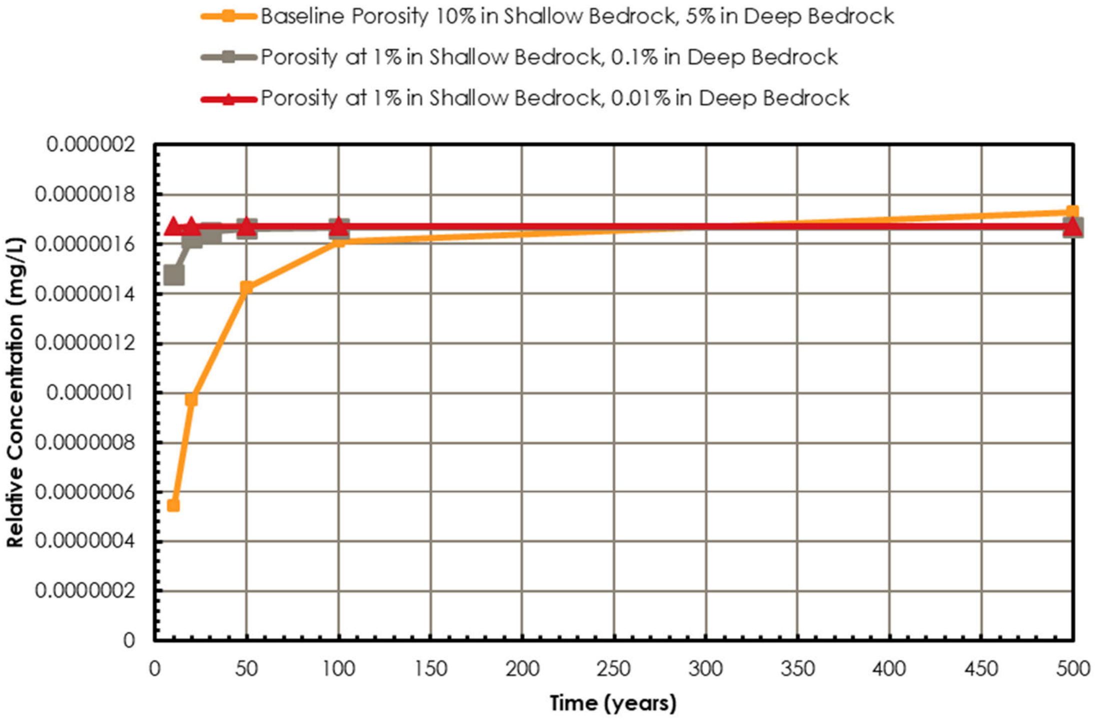

Figure 5.13 Sensitivity of Bedrock Porosity on Relative Concentrations in Moose River

5.5 PREDICTION CONFIDENCE

The approach used in model simulations completed for this Project was to incorporate conservative assumptions for predicting effects that may result from the Project. This report presents the assumptions made in developing these conservative predictions and discusses the high-level confidence of these predictions.

The modelling was conducted using an EPM approach., This is appropriate based on the regional scale of the modelling, and considering that flow was predicted to occur primarily through the shallow weathered bedrock, which is highly fractured, and therefore behaves like a porous medium.

The groundwater flow modelling was conducted using a model calibrated to water levels, and baseflow targets to establish baseline conditions. Predictions made using the model are based on several conservative assumptions to reduce the influence of uncertainty in the predictions. Therefore, the confidence in the predictions made using the model is considered high.

6.0 CONCLUSIONS

A three-dimensional steady-state groundwater flow model and solute transport model was constructed using MODFLOW to simulate groundwater conditions prior to the development of the Touquoy Pit, baseline conditions (i.e., when Touquoy Pit has been fully dewatered), changes to groundwater inflows during operations (i.e., when the FMS tailings are filling the open pit), and to evaluate potential changes to water quality in the receiving environment due to the subaqueous disposal of tailings in the Touquoy pit post-closure (i.e., when the pit is full). The model was prepared using a conceptual model and hydrostratigraphic framework developed from regional and site-specific data, and assumed homogeneous properties within the units. A good calibration of model parameters was obtained, as evaluated by comparing simulated and observed groundwater levels and estimated baseflow. The parameter values for hydraulic conductivity are similar to those obtained from other analyses of field observations.

At baseline, the open pit will be fully dewatered, and is simulated to intercept groundwater seepage at a rate of 768 m^3/d. The extent of the corresponding drawdown cone, as delineated by the 0.5 m drawdown contour, extends approximately 600 m south of the open pit and about 50 m west of the site toward Moose River. The inflow to the open pit decreases as it is filled with tailings and water during FMS operations, until the open pit stage reaches the maximum level of 108 m CGVD2013. At this stage, the groundwater seepage decreases to 373 m^3/d, and the corresponding drawdown cone is about the same as the baseline condition. Groundwater baseflow to Moose River is reduced by less than 1% in all cases.

Upon the filling of the open pit to its ultimate lake stage at 108 m CGVD2013, groundwater flow is dominated by flow from the pit to Moose River through the glacial till and weathered fractured bedrock. Solute transport in this case is dominated by advection (movement with the flow of groundwater). Solute transport modelling using the calibrated model simulates a slow migration of solutes to Moose River, with concentrations approaching a steady state after about 100 years of travel. Mass loadings for various parameters of concern are simulated by the model for inclusion in a surface water mixing model of Moose River (Stantec 2021).

The presence of preferential pathways, such as fractures and faults not characterized in previous field assessment, were assessed with sensitivity analyses in the model to predict the potential migration of solutes from pit into the receiving environment. The results of the sensitivity analyses indicated that should the faults have higher hydraulic conductivity, solute transport to Moose River would occur more quickly. Therefore, the potential for higher permeability faults should be considered in the development of management, mitigation and contingency plans.

The groundwater flow and solute transport modelling was conducted with the best available information on the hydrogeologic conditions at the Touquoy site. However, it is recommended that the following data gaps be addressed to improve the reliability of the predictions made with the model:

- Update the FMS tailings geochemical characterization assessment to refine the current tailings source term estimates.
- Perform geochemical testing of water quality in the Touquoy Pit lake to predict the concentrations of potential compounds of concern in the open pit lake. These data could then be simulated to predict actual concentrations to the receiving environment.

7.0 REFERENCES

Anderson, M.P., and W.W. Woessner. 1991. Applied Groundwater Modeling. Academic Press, 381 pp.

Arnold, J.G., P.M. Allen, R. Muttiah, and G. Bernhardt. 1995. “Automated Base Flow Separation and Recession Analysis Techniques.” Ground Water 33 (6): 1010–18.

Ausenco Engineering Canada Inc. 2015. NI 43-101 Technical Report, Feasibility Study for Moose River Consolidated Project, Nova Scotia. Report 100880–01. Prepared for Atlantic Gold Corporation.

Bedekar, V., Morway, E.D., Langevin, C.D., and Tonkin, M., 2016, MT3D-USGS version 1: A U.S. Geological Survey release of MT3DMS updated with new and expanded transport capabilities for use with MODFLOW: U.S. Geological Survey Techniques and Methods 6-A53, 69 p., http://dx.doi.org/10.3133/tm6A53Conestoga-Rovers & Associates. 2007a. Environmental Assessment Registration Document for the Touquoy Gold Project, Ref. No. 820933 (3).

Conestoga-Rovers & Associates (CRA). 2007a. “Environmental Assessment Registration Document, Touquoy Gold Project, Moose River, Nova Scotia.” Consultant Report. Prepared for DDV Gold Limited.

Conestoga-Rovers & Associates. 2007b. Focus Report, Touquoy Gold Project, Moose River Gold Mines, Nova Scotia.

Doherty, J. 2018. PEST: Model-Independent Parameter Estimation, User Manual (7th Edition). Watermark Numerical Consulting.

Environment Canada. 2015a. Climate, Canadian Climate Normals, 1981-2010 Canadian Climate Normals & Averages. Middle Musquodoboit, Nova Scotia. Website: http://climate.weather.gc.ca/climate_normals/index_e.html. Reviewed on January 6, 2016.

Environment Canada. 2015b. Climate, Canadian Climate Normals, 1981-2010 Canadian Climate Normals & Averages. Truro, Nova Scotia. Website: http://climate.weather.gc.ca/climate_normals/index_e.html. Reviewed on December 5, 2015.

Environment Canada. Undated. Ecoregions of Canada. Webiste: http://ecozones.ca/english/zone/AtlanticMaritime/ecoregions.html

Environmental Simulations International. 2018. Groundwater Vistas Version 7.20 Build 14.

GeoNova. 2020. Nova Scotia DataLocator – Elevation Explorer. Website: https://nsgi.novascotia.ca/datalocator/elevation/

GHD Limited. 2016a. “Monitor Well Drilling, Installation and Associated Groundwater Monitoring Program (Phase 1) Touquoy Gold Project, Moose River, Nova Scotia.” Letter 820933-H-05. Prepared for Atlantic Gold Corporation.

GHD Limited. 2016b. “Monitor Well Drilling, Installation and Associated Groundwater Monitoring Program (Phase 2) Touquoy Gold Project, Moose River, Nova Scotia.” Letter 820933-H-07. Prepared for Atlantic Gold Corporation.

Lorax Environmental Services Ltd. 2018. “Beaver Dam Project Geochemical Source Term Predictions for Waste Rock, Low-Grade Ore, Tailings and Overburden.” Consultant Report A458-1. Prepared for Atlantic Gold Corporation.

Niswonger, R. G., S. Panday and M. Ibaraki. 2012. MODFLOW-NWT, A Newton Formulation for MODFLOW-2005. U.S. Geological Survey Techniques and Methods 6-A37.

Nova Scotia Department of Natural Resources. 2016. Nova Scotia Drillhole Database, DP ME 3, Version 5, compiled by Mick O’Neill and Jeff Poole.

Peter Clifton & Associates. 2007. Hydrogeological Investigation and Assessment, Touquoy Gold Project, Nova Scotia.

Province of Nova Scotia. 2020. Nova Scotia Geographic Data Directory – Nova Scotia Hydrographic Network. Website: https://nsgi.novascotia.ca/gdd/

Stea, R.R., H. Conley and Y. Brown. 1992. Digital Version of Nova Scotia Department of Natural Resources Map ME 1992-3, Surficial Geology Map of the Province of Nova Scotia, scale 1:500 000.

Spitz, K. and J. Moreno. 1996. A Practical Guide to Groundwater and Solute Transport Modeling. John Wiley & Sons Inc. New York.

Stantec Consulting Ltd. 2018. 2017 Annual Report - Surface Water and Groundwater Monitoring. Prepared for Altantic Mining Nova Scotia Corp.

Stantec Consulting Ltd. 2021. Fifteen Mile Stream Gold Project Assimilative Capacity Study of Moose River – Touquoy Open Pit Discharge. Prepared for Atlantic Mining Nova Scotia Corporation.

Wels, C., D. Mackie and J. Scibek. 2012. Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities. Prepared for the British Columbia Ministry of Environment, Water Protection & Sustainability Branch.

APPENDIX A

Concordance Table

Response to Regulator Comments Regarding Groundwater Modelling Update to Address November 5, 2020 Information Request from IAAC for the Beaver Dam and Fifteen Mile Stream Projects.

Item	Comment	Response
Nova Scotia Environment (Email from Bridget Tutty 9/12/2020)		
NSE-1	Provide representation in the document of the new model discretization. Include a figure showing the overall site modelling grid and domain.	See Section 4.1
NSE-2	Provide information and a cross-section figure from the Moose River to the open pit which shows the hydrogeological conceptual model (including details of actual stratigraphy) for groundwater interactions as well as the model layers and parameters that are representative of this.	See Section 4.1
NSE-3	Update the revised model groundwater calibration analysis based on changes to the model grid, include stream baseflow target for both average annual and yearly minimum flow conditions.	See Section 4.4.3
NSE-4	Update the uncertainty/sensitivity analysis to include the variable effects of streambed conductivity on observed streamflows and groundwater influx to the open pit.	See Section 4.4.6
NSE-5	General question – will long-term ambient hydrogeochemical quality (e.g. observations of elevated pH in the pit water and some monitoring wells) have any effect on the stability and solubility of any parameters found in the proposed tailings? Some parameters such as Arsenic may be more soluble at higher pH levels. If so, are such mixing interaction effects included in the long term transport modelling predictions?	This is beyond the scope of the groundwater flow modelling, and will be addressed under separate cover.
Fisheries and Oceans Canada – Email from Chris Burbidge (11/12/2020)		
DFO-1	DFO needs to understand the plausible worst-case scenario regarding changes in flow in Moose River from the projects and the associated effects to fish and fish habitat to verify compliance with the Fisheries Act. It is not immediately clear how the use of averages in the model will give an indication of the worst-case scenario.	Groundwater fluctuations to baseflow are longer-term processes and vary less frequently than precipitation and runoff processes that are observed in surface water. The groundwater modelling approach can be used to estimate the “worst-case” by reducing the “lowest flows” in the streams by the average summer baseflow reductions calculated using the model.
DFO-2	Actual low flows in Moose River during summer are often much lower than the monthly average. For example, the average flows in the river in August have been estimated to be 0.39 m3/s at SW-2. In August 2019, the lowest flow measured was 0.055 m3/s at SW-2. Flow data from Moose River in summer 2020 have not been provided, but data from a nearby hydrometric station [Middle River of Pictou at	As described in response to DFO-1, groundwater fluctuations in baseflow are longer-term processes that vary less frequently than precipitation and runoff processes. The baseflow reductions for the summer months calculated using this approach are expected to be representative throughout the summer, even if specific

Item	Comment	Response
	Rocklin (01DP004)] shows that the lowest flow in August 2020 was likely less than 1% of the Mean Annual Discharge.	flows in the stream may be reduced due to lack of precipitation.
DFO-3	It is not clear what is meant by the statement "The average summer conditions will be based on the lowest flows available for the Moose River." on page 1.	This was intended to mean the summer with the lowest flows observed in Moose River (i.e., 2019).
DFO-4	The "lowest observed flow conditions from 2019, and 2020" (page 2) may not represent the potential lowest summer flow conditions (i.e., historical minimum flow).	Our stated goal was to reproduce the lowest observed flows, as we do not have sufficient information to confirm the water levels for potential historical minimum flows in Moose River.
DFO-5	Previous comments: The September 2020 tech memo shows that the measured drawdown at well pairs OPM-1A/B and OPM-2A/B located in between the current open pit and Moose River are 28% to 793% greater than predicted by the groundwater model. The tech memo states that this difference is likely due to local variations in hydraulic connectivity near the wells not represented in the model. The location of these wells mean that they are particularly relevant to the assessment of potential effects to Moose River. Please provide a description of the factors related to hydraulic connectivity at this location that could explain this variation and consider this information in the revised groundwater model.	See Section 4.4.3
DFO-6	The April 2019 groundwater model describes how watercourses are considered in the model using the River package. For Moose River, the model assumed a uniform river width of 8 m and depth of 1 m. A comparison of the estimated mean monthly flows and the stage-discharge curves provided in the tech memo for the water stations in Moose River in the vicinity of the open pit suggest that water depths of 1 m in Moose River in vicinity of the open pit would be relatively rare and would be expected to occur only during temporary high flow events and that an average depth of approximately 0.6 m is more representative of mean annual flows, if only one depth value is to be used in the model. Furthermore, the average channel width estimated in the September 2019 tech memo from the habitat surveys in the vicinity of the open pit was approximately 12 m. Please update the model's river package with the best available information about Moose River.	See Section 4.3.3
DFO-7	The April 2019 groundwater model uses an estimated mean annual discharge (MAD) in Moose River at SW-2 of 1.23 m3/s. The analysis in the 2020 tech memo estimated MAD to be 1.15 m3/s using flow measurements from surface water stations in Moose River in the vicinity of the open pit and a regression analysis of	See Section 4.3.3

Response to Regulator Comments Regarding Groundwater Modelling Update to Address November 5, 2020 Information Request from IAAC for the Beaver Dam and Fifteen Mile Stream Projects.

Item	Comment	Response
	long-term data from eight (or possibly ten) WSC stations. Please update the model with the best estimate of MAD for Moose River.	
NRCan – D. Paradis (email from Kathryn MacCarthy 14/12/2020)		
NRCan-1	Given my review of I4, I summarize my main concerns using the scope of work proposed here. I also provide additional concerns reviewing I4. Main points in the Memo (see comments below in the text): 1. Baseflow calibration. 2. Streambed conductance. 3. Numerical dispersion. 4. Effective porosity. 5. Faults impact. Additional points from I4 that need clarifications:	See responses below.
NRCan-2	1. Fig. 4.1: This figure shows the model layer with corresponding stratigraphy. The thickness of each layer and their spatial relations with the pit and the Moose River is however not well illustrated. **Information Request:** A few cross-sections should be presented to better illustrate the conceptual and numerical models. In particular, deep of the pit with respect to the bottom of the numerical model, and the stratigraphy between Moose River and the pit.	See Section 4.1
NRCan-3	2.Table 5.1: Dispersivity is expected to be much higher in the weathered bedrock than competent bedrock. Why is the proponent using the same dispersivity values for weathered and competent bedrock? **Information Request:** Please explain the rationale for using the same dispersivity value for weathered bedrock and the competent bedrock.	As presented by Gelhar (1992), dispersivity is a scale dependent parameter that can be estimated based as 10% of the representative length of the expected plume. The longitudinal dispersivity of 5 m was selected based on the representative distance between the open pit and Moose River (i.e., 50 m).
NRCan-4	3a. Fig 5.4: This figure showing drawdowns may falsely suggest that the pit is gaining water from the Moose River. A map of the hydraulic heads with main groundwater flow direction would be more illustrative of the situation. **Information Request:** Provide a map of the hydraulic heads for comment # 3a above.	See Figure 5.5.
NRCan-5	3b. Fig. 5.5: Also, given the very small relative concentrations predicted away from the pit, and the relatively coarse cells (spatially and vertically) of the model grid with	The grid Peclet number was in the original modelling varied between 5 and 10, and varies between 1 and 10

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	respect to the distance between Moose River and the pit, has the Peclet number been verified to avoid numerical artifacts (e.g., numerical dispersion and numerical oscillations) to ensure realistic transport simulations? **Information Request:** a clarification is required for comment #3b wrt. Peclet number.	for the current modelling (depending on whether the grid cell is 5 m or 50 m long). Although it is usually suggested to select the grid spacing so that the Peclet number does not exceed 2, in many cases acceptable solutions with mild oscillation are achieved with grid Peclet numbers as high as 10 (Huyakorn and Pinder 1983). The predicted concentration results were reviewed to confirm that oscillatory behaviour did not adversely affect the results (i.e., by checking for negative concentrations in the modelling results).
NRCan-6	3c. Fig. 5.10: This figure seems to show numerical oscillations. To be verified. **Information Request:** confirm whether Figure 5.10 shows numerical oscillations.	The interpreted numerical oscillations are due to flow through the high conductivity faults. The maximum length of timesteps was adjusted in the modelling to avoid numerical oscillations in the updated modelling results. The sensitivity runs presented in Section 5.
NRCan-7	Section 6.0 Conclusions: "Upon the filling of the open pit to its ultimate lake stage at 108 m asl, groundwater flow is anticipated to flow from the pit to Moose River through the glacial till and weathered fractured bedrock.". This is an interesting analysis, but this should be illustrated and discussed in the main body of the report. Should present cross-sections with heads simulated in each layer of the model. **Information Request:** Illustrate and discuss the groundwater flow from the pit to the Moose River, present cross sections with heads simulated in each layer of the model.	The conclusions have been updated based on the updated modelling text.
NRCan-8	Table 5.3: Should tell if those concentrations exceed the authorized concentrations in receiving environments. **Information Request:** confirm whether the concentrations exceed the authorized concentrations in the receiving environments (Table 5.3).	The concentrations in the previous modelling were below the MDMER limits in the receiving environment. The updated modelling results will be compared to MDMER limits in the receiving environment in the updated modelling report.
NRCan-9	Section 1.0: Drawdowns at Moose River are restricted by the modelling approach. In this approach river stage is fixed by the model using constant head boundary condition. This is a limitation of fully-saturated models where rivers cannot be let free. **Baseflow calibration:** However, what matters is the amount of water exchanged between the river and the aquifer. To know the impact of pumping on the river, a	See Section 4.4

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	mass balance around the river should be done. An important piece of information to get meaningful mass balance is the calibration of the model with baseflow estimated from field measurements. If the model can reproduce field baseflow, we can be more confident in the impact assessment.	
NRCan-10	Section 2.0 Task 1 – re: “streambed sediments”: **Streambed conductance**: To be conservative, the streambed conductance should be kept the same as the underlying sediments/bedrock. Using very low conductance value may isolate the river from the main aquifer, and then underestimate the amount of water withdrawn from pumping. Calibration with field-based baseflow estimates will thus be very important to assess the hydraulic connection between Moose River and the aquifer. **Baseflow calibration:** Also, an additional sensitivity analysis showing the sensitivity of baseflow to parameters should be conducted. Parameters of interest are hydraulic conductivity, recharge and streambed conductance. **Effective porosity:** Finally, it would be also useful to see a sensitivity analysis for contaminant concentrations reaching Moose River. In addition to the previous parameters used for baseflow sensitivity analysis, effective porosity should also be tested.	See Section 4.4.6
NRCan-11	Section 2.0 Task 1 – re: “summer low-flow condition.”: **Numerical dispersion:** Likely with no recharge?	As indicated in Section 4.3.2, both recharge and evapotranspiration (ET) have be included as separate processes in the modelling update. Therefore recharge will be reduced in the summer, but ET will be increased. The net result is an effective recharge of 22 mm/yr, as calculated using the recharge and ET rates presented in Table 4.6.
NRCan-12	Section 2.0 Task 1 – re: “…flow conditions from 2019 and 2020. These years represent the most complete datasets available…”: **Baseflow calibration:** How those 2019 and 2020 year compare to historical conditions. Are they wet, dry or average years ? For annual and low-flow period.	Below average precipitation were observed in the summers of 2019 and 2020.
NRCan-13	Section 2.0 Task 1 – re: “Refining the grid cell size in the existing modell…”: **Numerical dispersion:** Refining the grid at the vertical layer should between the Moose River and the pit also be considered. Horizontal and vertical resolutions are particularly important for transport simulations where numerical dispersion (too large Peclet number) seems to be an issue in I4.	The vertical discretization in the vicinity of the open pit was reviewed, and was not updated as part of this update. The relatively fine vertical discretization in the vicinity of the open pit and Moose River does not warrant additional refinement in the shallow model layers.

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NRCan-14	Section 2.0 Task 2 – re: "transport simulations": **Numerical dispersion:** Appropriate cell size in the region between Moose River and the pit should be used to avoid numerical artifact in the transport simulations. See previous comment. **Effective porosity:** Porosity is also important for transport simulations. Large porosities will accumulate mass in the aquifer and delay migration times. The opposite for low porosity values. What is the supporting information for porosity? Porosity should be also included in the sensitivity simulations. **Effective porosity:** Moreover, porosity values reported in I4 seems to reflect total porosity. For transport simulation, effective porosity should instead be used. Effective porosity is generally much lower than total porosity. Especially in bedrock formations where much of the pores are not interconnected and an important proportion of water is not contributing to flow (stagnant water). To be conservative, without field/lab support, effective porosity values on the lower-end range of reported values in the literature should be used.	A sensitivity analysis for the effects of porosity on transport runs is provided in Section 5.4.2.2.
NRCan-15	Section 2.0 Task 2 – re: "Additional model runs…": **Faults impact:** Given that no field work can support the role of the faults, a conservative scenario with high permeability faults should be used.	This was the approach used in the previous modelling, and has been updated in Section 5.4.2.1 of the current report.