Denison Mines   Rio Algom

March 24, 2020

Ron Stenson, Senior Project Officer
Uranium Mines and Mills Division
280 Slater Street
P.O. Box 1046, Station B
Ottawa, Ontario
K1P 5S9

Dear Mr. Stenson:

Re: Serpent River Watershed Monitoring Program – Year Five of Cycle 4

Denison Mines Inc. and Rio Algom Limited are pleased to submit one copy of the Serpent River
Watershed Monitoring Program Year Five of Cycle 4 Annual Water Quality Report for 2019.

If you have any questions or comments, please do not hesitate to contact the undersigned.

Yours very truly,

Denison Mines Inc.   Rio Algom Limited
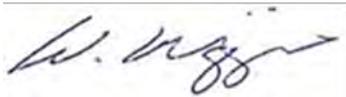
Wade Wiggins,   David Hewitt,
Manager of Environmental Services   Secondment Site Superintendent Elliot Lake
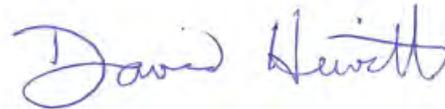
cc: Distribution List

Canadian Nuclear Safety Commission Ron Stenson, Senior Project Officer Uranium Mines and Mills Division ron.stenson@canada.ca Tel: 613-995-2624 cc: cnsc.ummd-dmucu.ccsn@canada.ca Mailing address: Canadian Nuclear Safety Commission 280 Slater Street, P.O. Box 1046, Station B Ottawa, ON K1P 5S9	**Ministry of Energy, Northern Development and Mines** Rob Purdon, Mine Rehabilitation Project Manager rob.h.purdon@ontario.ca Tel: 807-631-8519 Mailing address: Ministry of Energy, Northern Development and Mines 435 James Street South, Suite B002 Thunder Bay, ON P7E 6S7
Environment and Climate Change Canada Catalin Obreja Physical Science Officer, Environmental Stewardship Branch catalin.obreja@canada.ca Tel: 416-739-5973 Mailing address: Environment Canada, Environmental Protection Operations 4905 Dufferin Street, 2nd Floor, Office 2S316 Toronto, Ontario M3H 5T4	**Environment and Climate Change Canada** Duck Kim Physical Science Officer, Environmental Stewardship Branch duck.kim@canada.ca Tel: 416-739-5919 Mailing address: Environment Canada, Environmental Protection Operations 4905 Dufferin Street, 2nd Floor, Office 2S311 Toronto, Ontario M3H 5T4
Ministry of the Environment, Conservation and Parks Kirk Crosson, Senior Environmental Officer, Sault Ste Marie Area Office kirk.crosson@ontario.ca Tel: 705-942-6392 Mailing address: Ministry of the Environment, Conservation and Parks 70 Foster Drive, Suite 110 Sault Ste Marie, ON P6A 6V4	**Ministry of the Environment, Conservation and Parks** Ed Snucins Surface Water Specialist, Northern Region ed.snucins@ontario.ca Tel: 705-698-5546 Mailing address: Ministry of the Environment, Conservation and Parks 199 Larch Street, Suite 1201 Sudbury, Ontario P3E 5P9
Ministry of Natural Resources and Forestry Jim Trottier Management Biologist, Blind River Field Office jim.trottier@ontario.ca Tel: 705-356-3018 Mailing address: Ministry of Natural Resources and Forestry 62 Queen Avenue, P.O. Box 190 Blind River, ON P0R 1B0	**Ministry of Natural Resources and Forestry** Megan Becker Lands & Waters Technical Specialist, Sault Ste Marie District megan.becker@ontario.ca Tel: 705-941-5104 Mailing address: Ministry of Natural Resources and Forestry 64 Church Street, Sault Ste. Marie, ON P6A 3H3
Ministry of Labour, Training and Skills Development Pierre Lefebvre District Manager, Timmins pierre.lefebvre@ontario.ca Tel: 705-235-1907 Mailing address: Ministry of Labour, Training and Skills Development Ontario Government Complex D Wing 5520 Highway 101 East, P.O. Bag 3050 South Porcupine ON P0N 1H0	**Ministry of Labour, Training and Skills Development** Jerry Wedzicha Program Specialist – Electrical Mechanical, Mining Health and Safety Program jerry.wedzicha@ontario.ca Tel: 705-564-4109 Mailing address: Ministry of Labour, Training and Skills Development Ontario Government Bldg 159 Cedar Street, Sudbury, ON P3E 6A5

City of Elliot Lake Mayor Dan Marchisella City of Elliot Lake d.marchisella@city.elliotlake.on.ca Tel: 705-848-2287 ext 2126 Mailing address: City of Elliot Lake 45 Hillside Drive North Elliot Lake, ON P5A 1X5	**Elliot Lake Public Library** Mailing address: Elliot Lake Public Library Pearson Plaza 40 Hillside Drive South Elliot Lake, ON P5A 1M7
Serpent River First Nation Chief Brent Bissaillion chief.srfn@eastlink.ca Tel: 705-844-2418 Mailing address: Serpent River First Nation 195 Village Road, P.O. Box 14 Cutler, ON P0P 1B0	**Township of the North Shore** Mary Lynn Duguay Clerk-Treasurer twpns@ontera.net Tel: 705-849-2213 x 25 Mailing address: Township of the North Shore 1385 Hwy 17, P.O. Box 108 Algoma Mills, ON P0R 1A0
Town of Spanish Pam Lortie CAO/Clerk-Treasurer pamlortie@townofspanish.com Tel: 705-844-2300 Mailing address: Town of Spanish 8 Trunk Road, P.O. Box 70 Spanish, ON P0P 2A0	**Mississauga First Nation** Keith Sayers Land and Natural Resources Manager keith@mississaugi.com Tel: 705-356-1621 Mailing address: Mississauga First Nation 64 Park Road, P.O. Box 1299 Blind River, ON P0R 1B0
BHP (Rio Algom Ltd.) Ben Hoskie Ben.BN.Hoskie@bhp.com Tel: 520-448-5865	**Denison Mines Inc.** David Cates dcates@denisonmines.com Tel: 416-979-1991

Denison Mines

Rio Algom

Serpent River Watershed Monitoring Program
2019 Annual Water Quality Report

Submitted to the
Canadian Nuclear Safety Commission
March 31, 2020

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1   INTRODUCTION

As part of the closure and decommissioning process, Rio Algom Limited (RAL) and Denison Mines Inc. (DMI) developed a focused and integrated performance monitoring network for legacy sites within the Serpent River Watershed (SRW). The comprehensive monitoring and management strategy clearly defined and delineated the purpose for all monitoring activities through three integrated programs; the Tailings Management Area (TMA) Operational Monitoring Program (TOMP), the Source Area Monitoring Program (SAMP), and the Serpent River Watershed Monitoring Program (SRWMP) (Minnow Environmental Inc. (Minnow), 2016). An integrated assessment of the results from all of these programs is prepared every five years in a *State of the Environment Report* (SOE) in compliance with license requirements and in accordance to Canadian Standards Association (CSA) N288.4-10 (2010). The regulatory review draft of the most recent SOE covering data collection and monitoring for the period of January 1, 2010 – December 31, 2014 was issued to the Canadian Nuclear Safety Commission (CNSC) as well as other members of the Joint Regulatory Review Group (JRG) on March 10, 2016 with response to regulatory comments issued September 30, 2016. The final SOE report with regulatory approval was distributed in November 2017.

The SRWMP was initiated in 1999 as a joint initiative of RAL and DMI with the objectives of evaluating the effectiveness of mine decommissioning plans and assessing long-term environmental water quality trends in the watershed (Beak International Incorporated (Beak), 1999). Evolution of the program, key outcomes, program modification decisions, and associated references are summarized in Appendix I. In 2019, the SRWMP followed the 2016 approved program modifications recommendations described in the document submission entitled *Cycle 4 Study Design for the SRWMP, SAMP and TOMP* (Minnow, 2016).

The SRWMP Annual Water Quality Report for 2019 provides water quality data from shared RAL and DMI watershed monitoring locations from January 1, 2019 through December 31, 2019. This report should be read in conjunction with the Annual Operating Care and Maintenance (OCM) reports, prepared independently by each company, that incorporate upstream SAMP and TOMP data, and discuss operational activities of each company (RAL, 2020; DMI, 2020). The objective of the SRWMP annual data review is to identify anomalous data and provide visual evaluation of short-term data trends at key locations. Step changes and anomalies are identified in this report by reviewing and compiling the last five years of annual average data for all SRWMP monitoring locations, and visually reviewing the information for any noticeable changes. Significant changes and unusual results are investigated in accordance with the *Water Quality Assessment and Response Plan*, which is found in Appendix A of the most recent SOE Report (Minnow, 2017).

The SRWMP Annual Water Quality Report for 2019 also provides a summary of the quality management program and water quality results for the period January 1, 2019 through December 31, 2019.

As part of the 2015 SOE review, CNSC instructed RAL and DMI to include annual reporting of a representative radiation dose to the public associated with their closed uranium mine sites in the Serpent River Watershed. Details on this topic are included in Section 4.4 of this report.

2   METHODOLOGY

2.1   2019 Program Requirements

The 2019 SRWMP followed program requirements (sampling locations, frequencies, parameters, and analytical protocols) as recommended and approved in the *Cycle 4 Study Design for the*

SRWMP, SAMP and TOMP (Minnow, 2016). Table 2.1 provides a brief description of each monitoring location, the frequency and parameters monitored, as well as non-regulatory parameters, and Figure 2.1 provides a map of the stations included in the water quality monitoring program.

### *Table 2.1* *2019 SRWMP Water Quality Monitoring Requirements*

Sampling Station	Location / Description	Sample Type	Purpose	Flow (L/s)	Field pH	Sulphate (mg/L)	Radium-226 (Bq/L total)	Uranium (mg/L)	Barium (mg/L)	Cobalt (mg/L)	Iron (mg/L)	Manganese (mg/L)	Hardness[3] (mg/L)
SR-16[2]	Fox Creek at Highway 108	Wetland/stream reference	SAMP		4	4	4	4	4	4	4	4	4
SR-17[2]	Unnamed Creek Drain Lake 3 @ Hwy 108	Wetland/stream reference	SAMP		4	4	4	4	4	4	4	4	4
SR-18	Outlet of Jim Christ Lake	Lake reference	SRWMP		2	2	2	2	2	2	2	2	2
SR-19	Inlet to Elliot Lake	Lake reference	SRWMP		4	4	4	4	4	4	4	4	2
SR-08	Nordic Lk Outlet	far field	SRWMP & MOE		4	4	4	4	4	4	4	4	4
SR-15	May Lake Outlet	far field	SRWMP/ Internal	2	2	2	2	2	2	2	2	2	2
M-01[1]	Sherriff Ck @ Hwy 108	near field	SRWMP		4	4	4	4	4	4	4	4	4
Q-09	Serpent River Below Q Effluent	near field	SRWMP	4	4	4	4	4	4	4	4	4	4
Q-20	Evans Lk Outlet to Dunlop Lk	near field	SRWMP	1	1	1	1	1	1	1	1	1	1
SC-01	Westner Lk Outlet	near field	SRWMP&MOE		1	1	1	1	1	1	1	1	1
SR-06	McCabe Lk Outlet	near field	SRWMP	2	2	2	2	2	2	2	2	2	2
FBR5	Field Blank Rio	QA/QC	SRWMP		2	2	2	2	2	2	2	2	2
BSR5	Blind Sample Rio	QA/QC	SRWMP		2	2	2	2	2	2	2	2	2
Rio Algom total excluding field blanks & blind samples				**9**	**32**	**32**	**32**	**32**	**32**	**32**	**32**	**32**	**30**
D-4	Dunlop Lk Outlet	Lake reference	SRWMP		2	2	2	2	2	2	2	2	2
D-5	Serpent R. between Q and D	near field	SRWMP	4	4	4	4	4	4	4	4	4	4
D-6[1]	Cinder Lk Outlet	near field	SRWMP	4	4	4	4	4	4	4	4	4	4
DS-18	Halfmoon Lk Outlet	near field	SRWMP&MOE	4	4	4	4	4	4	4	4	4	4
SR-01	Quirke Lk Outlet	far field	SRWMP		1	1	1	1	1	1	1	1	1
FBD2	Field Blank Denison	QA/QC	SRWMP		2	2	2	2	2	2	2	2	2
BSD2	Blind Sample Denison	QA/QC	SRWMP		2	2	2	2	2	2	2	2	2
Denison total excluding field blanks & blind samples				**12**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**
Total QA/QC samples				0	8	8	8	8	8	8	8	8	8
TOTAL SAMPLES				**21**	**47**	**47**	**47**	**47**	**47**	**47**	**47**	**47**	**45**
QA/QC Fraction of Total				0%	17%	17%	17%	17%	17%	17%	17%	17%	18%
Denison Fraction of Total				57%	32%	32%	32%	32%	32%	32%	32%	32%	33%

Notes

1. Field QA-QC designated stations.

2. SR-16 and SR-17 are part of SAMP program Cycle 4 but are historically SRWMP locations.

3. Hardness is an ancillary parameter used to assess Mn and SO4 as both parameters are hardness dependent (BCMOE, 2006, 2013)
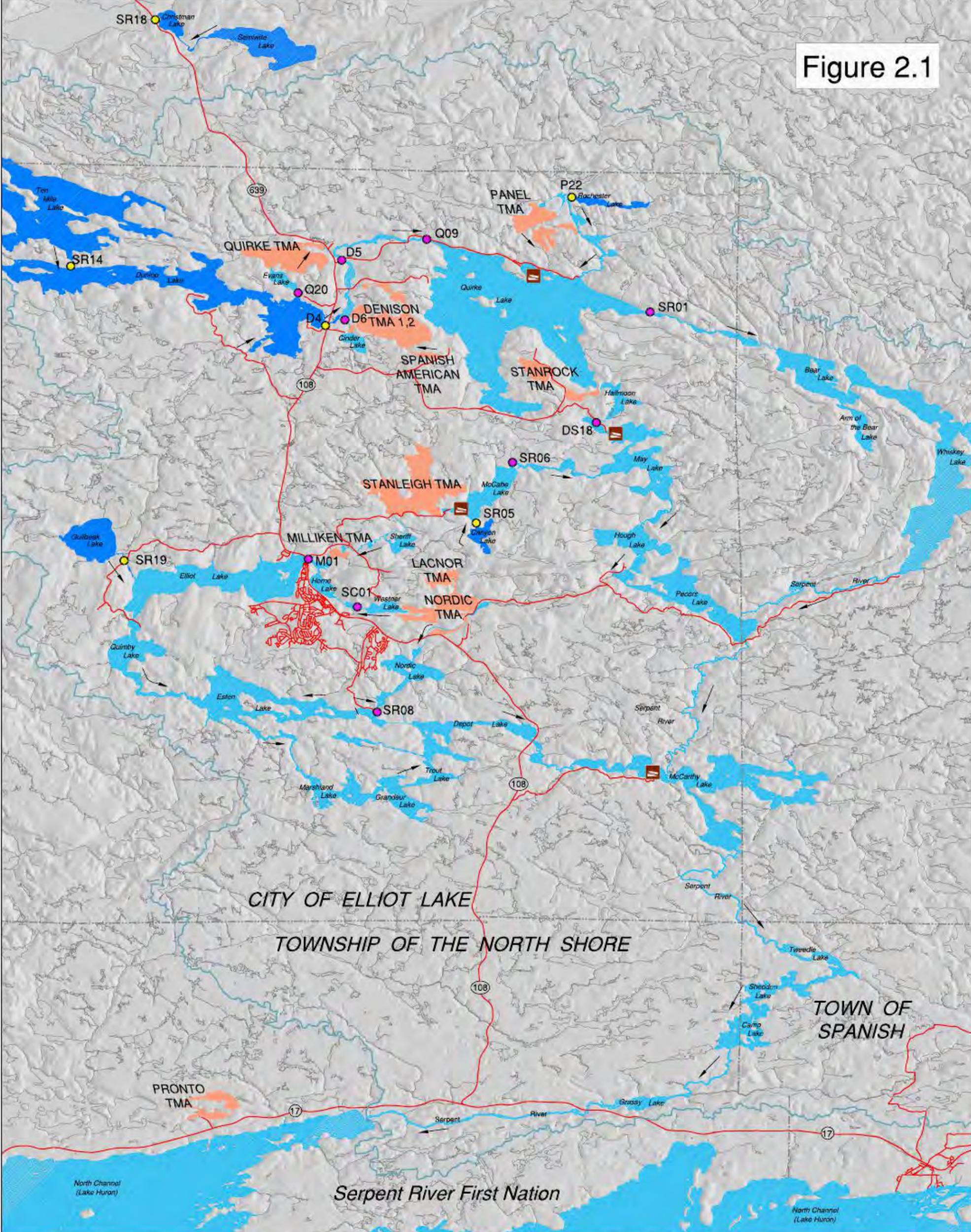
Serpent River Watershed Monitoring Program
Water Sample Collection Locations
March 2011
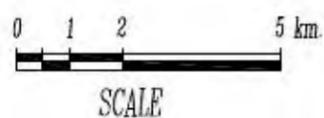
Legend:
- Tailings Management Areas (TMA).
- Exposure Lakes (included in SRWMP).
- Reference Lakes (included in SRWMP).
- Water Sample Location (Exposure).
- Water Sample Location (Reference).
- Direction of flow.
- Exterior limit of the Serpent River Watershed.

Figure 2.1

SCALE
0 1 2 5 km.

DENISON MINES

Rio Algom

2.2   2019 Program Conformance

All Cycle 4 approved sampling, field measurement, and analytical requirements were met during the 2019 reporting period, with the exception of three flow measurements. Although all samples were collected, flow could not be measured at D-6 in February or at DS-18 in February and November due to thick ice build-up across the channels.

Hardness continues to be monitored as an ancillary parameter at all SRWMP stations. According to the Approved Water Quality Guidelines for Aquatic Life, Wildlife & Agriculture from the British Columbia Ministry of Environment & Climate Change Strategy (BC ENV), formerly BCMOE Ambient Water Quality Guidelines, manganese and sulphate are hardness dependent (BC ENV, 2019). Semi-annual response monitoring also continued downstream at the outlet of May Lake (SR-15) effective January 1, 2016. Response monitoring is discussed in further detail in Section 4.1.

2.3   Field Measurements

Field measurement requirements and protocols for the 2019 SRWMP are presented in detail in the *Cycle 4 Study Design for the SRWMP, SAMP and TOMP* (Minnow, 2016). Field Staff have been thoroughly trained and have reviewed procedures associated with the proper calibration and use of field equipment for the measurement of field parameters. The models and accuracy for equipment used in measuring SRWMP field parameters are provided in Table 2.3.

Table 2.3   SRWMP Field Equipment Models and Accuracy

Parameter	Meter	Accuracy	Unit
pH	YSI Pro 10	+/- 0.02	pH units
flow	Global Flow Probe	0.1	feet per second

2.4   Data Quality Objectives

Field and laboratory data quality objectives (DQOs) for the 2019 SRWMP are presented in detail in the *Cycle 4 Study Design for the SRWMP, SAMP and TOMP* (Minnow, 2016). Table 2.4.a. provides a summary of field DQOs and Table 2.4.b. provides a summary of laboratory methods, detection limits and DQOs.

Data quality assessment results are covered in Section 3 of this report.

Table 2.4.a.   2019 SRWMP Field Data Quality Objectives

| Parameter | Units | Assessment Criteria [1] | | Data Quality Objectives [2] | | | |
		PWQO BCMOE	Background	Detection Limit	Minimum [3] Detectable Difference	Field Blank Criteria	Field Precision
Field Parameters[3]							
Flow	L/s	-	-	method	method	-	30%
pH				0.1	0.01 or 0.02	-	10%
Lake Stations		6.5	-				
Wetland/Streams		-	5.2				
Laboratory Parameters							
Barium	mg/L	1.0	-	0.005	-	0.01	20%
Cobalt	mg/L	0.0025	-	0.0005	-	0.001	20%
Iron	mg/L	-	-		-		
Lake Stations		-	0.49	0.02	-	0.04	20%
Wetland/Streams		-	1.69	0.02	-	0.04	20%
Manganese [4]	mg/L	0.8	-	0.002	-	0.004	20%
Radium (total)	Bq/L	1.0	-	0.005	-	0.01	20%
Sulphate [4]	mg/L	128-429	-	0.1	-	0.2	20%
Uranium	mg/L	0.015	-	0.0005	-	0.001	20%
Hardness	mg/L	-	-	0.5	-	1.0	20%

Notes:

1. Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

2. Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

3. Minimum detectable difference as identified in instrument manual

4. Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

Table 2.4.b. 2019 SRWMP Laboratory Methods and Data Quality Objectives

| Parameter | Units | Assessment Criteria [1] | | Method | Laboratory Data Quality Objectives [2] | | | | |
		PWQO BCMOE	Background		Detection Limit	Laboratory Blank	Precision	Spikes	Accuracy (CRM)
Barium	mg/L	1.0	-	ICP-MS	0.005	0.01	10%	20%	20%
Cobalt	mg/L	0.0025	-	ICP-MS	0.0005	0.001	10%	20%	20%
Iron	mg/L	-		ICP-OES					
Lake Stations			0.49		0.02	0.04	10%	20%	20%
Wetland/Streams			1.69		0.02	0.04	10%	20%	20%
Manganese [3]	mg/L	0.8	-	ICP-MS	0.002	0.004	10%	20%	20%
Radium (total)	Bq/L	1.0	-	Alpha Spectroscopy	0.005	0.01	20%	20%	-
Sulphate [3]	mg/L	128-429	-	Ion Chromatography	0.1	0.2	10%	20%	20%
Uranium	mg/L	0.015	-	ICP-MS	0.0005	0.001	10%	20%	20%
Hardness	mg/L	-	-	ICP-OES	0.5	0.1	10%	-	-

Notes:

1. Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

2. Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

3. Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

2.5 Changes in Analytical Methods

There were no changes in analytical methodology in 2019.

2.6 Reporting of Method Detection Limits

Program method detection limits (MDLs) are presented in Tables 2.4.a. and 2.4.b. The target MDL for radium-226 (0.005 Bq/L) was not met on all samples analysed in 2019 due to decreased sample throughput of the analytical laboratory. There was no change in method during this period; however, the laboratory was only able to claim a MDL of 0.007 Bq/L.

2.7 Data Screening and Assessment Conventions

Data validation was conducted on SRWMP water quality data throughout the year. The assessment screening process flags all data points outside a rolling minimum 12 value mean $\pm$ 3 standard deviations.

Flagged data and short-term response plans for the SRWMP are reported quarterly to the regulatory agencies as part of the water quality report. Data validation of "flagged data" for the year 2019 can be found in Appendix II.

Annual water quality reporting is designed to be concise and focused on the presentation of data in a standardized format with limited interpretation, as per Section 14.2 of the Implementation Document (Beak, 1999c). Data validation ensures prompt response to upset conditions or unusual results, as documented in *Data Validation Procedures* in conjunction with *Water Quality Assessment and Response Plan*, which is included in Appendix B of the SOE (Minnow, 2017). Assessment criteria as outlined in Table 2.4.a. and 2.4.b. of this report, are standardized to approved benchmarks selected, rationalized and presented in Tables 4.3 and 4.5 of the *Cycle 4 Study Design for the SRWMP, SAMP and TOMP (*Minnow, 2016*).

Approved program modifications implemented in January of 2015 focused water quality monitoring on lakes located immediately downstream of the decommissioned TMAs. An in-depth and detailed statistical evaluation of water quality trends is included in the SOE every five years (Minnow 2009, 2011, 2017).

A SRWMP location summary of all annual average concentrations is reviewed and compared to assessment criteria in this report in Table 3.2. In addition, the most recent five-year annual concentrations of mine indicator parameters at key downstream locations are reviewed in this report in Figures 3.1.a to 3.1.c.

3 RESULTS

3.1 Data Quality Results and Assessment

Detailed laboratory quality assurance and quality control (QA/QC) results are provided in Appendix III, and detailed field QA/QC results are provided in Appendix IV. Field quality control results are summarized in Table 3.1. Data quality assessments for each type of data quality objective are provided in the following sections.

3.1.1   Laboratory Quality Assurance and Quality Control

In 2019, all analytical requirements for the SRWMP were contracted to laboratories with Canadian Association for Laboratory Accreditation Inc. (CALA) accreditations. It should be noted that in June 2019, the laboratory accreditation from Perdue Central Analytical Facility (PCAF), formerly the Elliot Lake Research Field Station (ELRFS), was withdrawn by CALA due to previous management not filing the "Management Review" document. However, PCAF continued to maintain and pass regular proficiency testing (PT) for radium analysis, conduct analysis following the same Ra226 alpha spectrometer SOP method and incorporate all of the same quality control samples. Since identical procedures to those under the accreditation were still followed, PCAF continued to meet the requirements for regulatory reporting. Accreditation was formerly restored on March 19, 2020 under ISO/IEC:17025-2017 for Ra226 in water and wastewater (Appendix III).

Detailed laboratory QA/QC results are provided in Appendix III. The 10% objective for QA/QC was met by both labs. SGS performed 11183 analyses with 7973 QC checks, which represents 71% QC for sample analysis (Appendix III). PCAF analyzed 104 batches totaling 1206 radium samples with each batch incorporating blank, certified reference material (CRM), duplicate, and spiked samples providing greater than 20% quality control checks. All quality control samples were within control limits (mean +/- 3SD) (Appendix III).

3.1.2   Quality Assurance and Quality Control Resolution of Key Issues

There were no major issues with laboratory analysis requiring resolution in 2019. However, the radium target MDL of 0.005 Bq/L was not achieved by PCAF, but the MDL still remained below the laboratory Data Quality Objective (DQO) of 0.01 Bq/L at <0.007 Bq/L (Appendix III). In addition, SGS was asked to run a quality investigation regarding TSS analysis. During the second half of 2019, there were a number of unusually high TSS results received for various locations, none of which were consistent with expected values (generally <1 to 4 mg/L). The repeated TSS results differed considerably from the original TSS results reported with repeat values generally returning to expected values. As a result of the deviations, a quality investigation was initiated. SGS found that the original and repeated low level TSS sample results (<10mg/L) varied within the range from 1 to 10mg/L. They concluded that it was difficult to determine exactly why there were variations at this level. Some contributing factors for variations at this low level included using less sample volume to perform the reanalysis and sub-sampling from a different sample container for the reanalysis. Another factor they considered was the reanalysis was performed on sample portions that were past the holding time. For samples with TSS concentrations reported above 10mg/L, the investigation found analytical carryover was a contributing factor in the discrepancy of the results. The technicians involved were then provided additional training to eliminate carryover issues during TSS analysis where required (Appendix III). There has been an improvement in original results since the investigation was completed whereby results are consistent with expected values, however, TSS will be closely monitored to ensure the issues have been fully resolved.

3.1.3   Analytical Blank Performance

Laboratory quality control results confirm that blank data quality objectives were met for all parameters in all samples (Appendix III).

3.1.4 Analytical Duplicate Performance

Laboratory quality control results confirm that duplicate data quality objectives of 20% for radium and 10% for all other remaining parameters were achieved in all samples (Appendix III).

3.1.5 Analytical Laboratory Spike Performance

Laboratory quality control results confirm that the spike data quality objective of 20% was achieved for all parameters in all samples (Appendix III).

3.1.6 Analytical Certified Reference Material Performance

Laboratory quality control results confirm that the CRM data quality objective of 20% accuracy was achieved for all parameters in all samples in 2019 (Appendix III).

3.1.7 Field Blank Performance

Field Blank quality control results confirm that SRWMP field blank data quality objectives were achieved in 2019 (Appendix IV).

3.1.8 Field Precision Performance

Field precision quality control results confirm that SRWMP field precision data quality objectives were achieved in 2019 (Appendix IV).

Table 3.1   2019 SRWMP Field Quality Control Results Summary

QA/QC	pH	SO4	Ra(T)	U	Ba	Co	Fe	Mn	Hardness
		(mg/L)	(Bq/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
MDL[1]	-	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
Field Blank Statistics									
Count	-	4	4	4	4	4	4	4	4
Average	-	<0.1	<0.007	<0.0005	<0.005	<0.0005	<0.02	<0.002	<0.5
Max	-	<0.1	<0.007	<0.0005	<0.005	<0.0005	<0.02	<0.002	<0.5
Min	-	<0.1	<0.007	<0.0005	<0.005	<0.0005	<0.02	<0.002	<0.5
Field Blank Exceedances									
Criteria[1]	-	0.2	0.01	0.001	0.01	0.001	0.04	0.004	1.0
Exceedance	0	0	0	0	0	0	0	0	0
Field Precision Statistics									
Count	4	4	4	4	4	4	4	2	2
Average	0.0%	2.2%	3.3%	2.5%	2.0%	0.0%	3.6%	6.8%	4.3%
Max	0.0%	7.7%	13.3%	10.0%	8.0%	0.0%	6.9%	12.5%	6.2%
Min	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.9%	2.0%
Field Precision Exceedances									
Criteria[1]	20%	20%	20%	20%	20%	20%	20%	20%	20%
Exceedance	0	0	0	0	0	0	0	0	0

Notes:

[1] Data Quality Objectives taken from Table 5.2 af the Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

Bold indicates an exceedance in the Data Quality Objectives (DQO's)

3.2   2019 Annual Average Location Results Summary

Annual average concentrations of SRWMP parameters for 2019 in comparison to the *Cycle 4 Study Design* (Minnow, 2016) receiving environment assessment criteria are provided in Table 3.2. Annual detailed results and five-year summaries of annual average concentrations in comparison to assessment criteria are provided in Appendix V.

Water quality throughout the Serpent River Watershed continues to meet and remain well below the assessment criteria established for the protection of aquatic life. Annual average concentrations for all parameters in 2019 were better than assessment criteria at all locations, with the exception of iron at station D-6 (Cinder Lake Outlet), and cobalt concentrations remained close to or below detection levels at all locations (Appendix V).

The annual average iron concentration at D-6 (0.82 mg/L) exceeded the water quality benchmark applied to lake stations (0.49 mg/L). This can be attributed to a seasonal spike (2.76 mg/L) that occurred in August when flow was very low (<1.0 L/s). Iron concentrations are generally influenced by the particulate matter within the sample during periods of very low flow. The remaining concentrations throughout the year were more than an order of magnitude lower (ranging from 0.15 mg/L to 0.19 mg/L) and more typical of expected values when flow is generally higher (Appendix V). In addition, no impact was observed further downstream at D-5, located in the Serpent River between the Denison and Quirke TMAs, where the annual average concentration was 0.05 mg/L.

The annual average manganese concentration, also observed at D-6, appears elevated compared to other SRWMP locations. This again can be attributed to a seasonal spike (1.26 mg/L) that occurred in August when flow was very low (<1.0 L/s). However, water hardness at the time of sampling was 85.1 mg/L, indicating that the elevated manganese concentration was below the BC ENV guideline of 1.4 mg/L for the protection of aquatic biota against acute toxicity. In addition, all remaining results through the year were an order of magnitude lower, ranging from 0.070 mg/L to 0.076 mg/L at a hardness range of 15.2 mg/L to 23.6mg/L (Appendix V), well below the chronic toxicity guideline of 0.6 mg/L at hardness below 25 mg/L (BC ENV, 2019). Furthermore, no impact was observed downstream at D-5 where the manganese annual average concentration was 0.024 mg/L.

Annual average barium concentrations at SR-06 (McCabe Lake Outlet) and further downstream at SR-15 (May Lake Outlet) decreased in 2019 with averages at 0.312 mg/L and 0.146 mg/L, respectively. The previous four years had indicated increasing trends at both locations (Appendix V), likely due to the increased barium chloride addition rates required for radium removal upstream from the Stanleigh final discharge (CL-06). The 2019 decrease in barium concentrations is likely associated with an approved interim alteration in the treatment process for radium removal upstream at the Stanleigh Effluent Treatment Plant (ETP). Due to the elevated radium and barium concentrations at CL-06, a pilot program was initiated in 2018 to replace conventional treatment using barium chloride with pre-formed barite for radium removal. The interim change thus far, indicates an improvement in radium removal and a reduction of residual barium in the CL-06 effluent. Details of the pilot program can be found in the 2018 and 2019 Rio Algom Annual OCM Reports (RAL, 2019, 2020). Although barium concentrations still appear elevated compared to other SRWMP stations, they are well below levels considered to be toxic to the aquatic environment (>8.0 mg/L; WHO 2001).

The annual average sulphate concentration at SR-08 (Nordic Lake Outlet) also appears elevated (130.0 mg/l) compared to other SRWMP stations. However, as initially noted in section 2.2, according to the most recent approved guidelines for aquatic life from BC ENV,

manganese and sulphate are hardness dependent. Toxicity studies for both parameters demonstrated amelioration of toxicity with increasing water hardness and were used to develop new water quality guidelines in the province of British Columbia for these substances. Therefore, based on this information, a specific assessment criterion for sulphate has been established for each station in the SRWMP. In this case, the mean hardness concentration at SR-08 was determined to be 223.9 mg/L (Minnow, 2016) and thus, the resulting criteria for sulphate at this location is 429 mg/L. In 2019, all results at SR-08 fell within BC ENV guidelines for the protection of aquatic life (BC ENV, 2019). A review of the data also indicates that sulphate annual concentrations have continued to decrease over the past five years (Figure 3.1.a.). Sulphate assessment criteria for individual stations is included in Appendix V of this report along with the detailed data, as well as in Table B-1, Appendix B, of the *Cycle 4 Study Design for the SRWMP, SAMP, and TOMP* (Minnow, 2016).

3.3 Five-Year Annual Average Trends at Key Locations 2015-2019

Figures 3.1.a to 3.1.c show five-year trends of annual average concentrations for the mine-related parameters sulphate, radium, and uranium at the following key locations:

- SR-01, Quirke Lake Outlet;
- SR-06, McCabe Lake Outlet;
- SR-08, Nordic Lake Outlet;
- DS-18, Halfmoon Lake Outlet.

Based on a review of 5 years of data, annual sulphate concentrations at all key lake outlets are well below the assessment criterion of between 128-429 mg/L as established for each station. Furthermore, annual concentrations have been gradually decreasing at all locations over the past five years (Figure 3.1.a).

With the exception of DS-18, annual average radium concentrations at three key locations are an order of magnitude below the assessment criterion of 1.0 Bq/L based on review of the data (Figure 3.1.b). At station DS-18, the 2017 annual average radium concentration of 0.193 Bq/L appears elevated compared to other annual concentrations in the last five years (Appendix V). This may have been due to an increase in the annual precipitation in 2017 (highest in five years at 338 L/s), which may have caused flushing through the historic tailings spill upstream in the Halfmoon wetland area. However, all results in the last five years remained well below the assessment criterion of 1.0 Bq/L (ranging from 0.094 Bq/L to 0.203 Bq/L) and well below the Health Canada (2009) drinking water quality standard of 0.5 Bq/L. The annual average concentration in 2019 indicates a return to more typical averages at 0.110 Bq/L.

Annual radium concentrations at SR-06 appeared to be gradually increasing over the previous four years, but decreased significantly in 2019 (Appendix V). Again, this is likely associated with an approved interim alteration in the treatment process for radium removal upstream at the Stanleigh ETP (RAL, 2019, 2020). Based on review of the five-year annual average data, all radium concentrations have consistently remained significantly lower than assessment criterion of 1.0 mg/L and well below Health Canada (2009) drinking water quality standard of 0.5 Bq/L (Figure 3.1.b).

Annual average uranium concentrations at all four key Lake locations appear to be relatively stable and were more than an order of magnitude below the assessment criteria of 0.0150 mg/L (Figure 3.1.c) and appear to be relatively stable.

Table 3.2   2019 SRWMP Location Annual Average Results Summary

Parameters			pH	SO4 [5]	Ra(T)	U	Ba	Co	Fe	Mn [5]	Hardness mg/L as CaCO₃
				(mg/L)	(Bq/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
Assessment Criteria [1]	Wetland and lake benchmarks		**6.5**	**128-429**	**1.000**	**0.0150**	**1.000**	**0.0025**		**0.800**	-
	Wetland/Stream benchmark [2]		**5.2**						**1.69**		
	Lake benchmark [3]								**0.49**		
MDL [4]				0.1	0.005	0.0005	0.005	0.0005	0.02	0.005	0.5
Location		# of samples collected									
Reference	**Type**										
D-4	Lake	2	7.0	3.3	<0.007	<0.0005	0.014	<0.0005	0.04	0.018	8.9
SR-18	Lake	2	6.9	3.6	<0.007	<0.0005	0.051	<0.0005	0.06	0.017	10.1
SR-19	Lake	4	6.8	2.9	<0.007	<0.0005	0.023	<0.0005	0.30	0.039	14.7
SR-16	Wetland/Stream	4	5.8	1.1	<0.007	<0.0005	0.007	0.0006	0.80	0.034	7.7
SR-17	Wetland/Stream	4	6.0	2.5	<0.007	<0.0005	0.021	0.0006	0.59	0.039	9.7
Near Field											
D-5		4	6.9	10.3	0.041	0.0010	0.051	<0.0005	0.05	0.024	19.4
D-6		4	6.8	22.0	0.009	<0.0005	0.018	0.0009	**0.82**	0.370	35.9
DS-18		4	7.1	43.2	0.110	0.0008	0.019	<0.0005	0.26	0.017	78.0
M-01		4	6.7	8.4	0.017	0.0027	0.016	0.0005	0.78	0.110	31.2
Q-09		4	6.9	47.3	0.051	0.0015	0.064	<0.0005	0.14	0.038	43.5
Q-20		1	7.3	19.0	0.008	<0.0005	0.020	<0.0005	0.02	0.017	39.4
SC-01		1	7.3	16.0	<0.007	<0.0005	0.011	<0.0005	0.10	0.037	29.1
SR-06		2	7.2	28.0	0.057	0.0006	0.312	<0.0005	0.02	0.019	36.7
Far Field											
SR-15		2	7.2	27.0	0.049	<0.0005	0.146	<0.0005	0.02	0.008	39.0
SR-01		1	7.0	25.0	0.031	0.0011	0.039	<0.0005	<0.02	0.004	36.6
SR-08		4	6.8	130.0	0.030	0.0006	0.018	<0.0005	0.04	0.042	164.0

Notes:

[1] Assessment criteria as per Table 4.5, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland/stream stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.
Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Figure 3.1.a. **Annual Average Sulphate Concentrations at SR-01, SR-06, SR-08, and DS-18, 2015-2019**
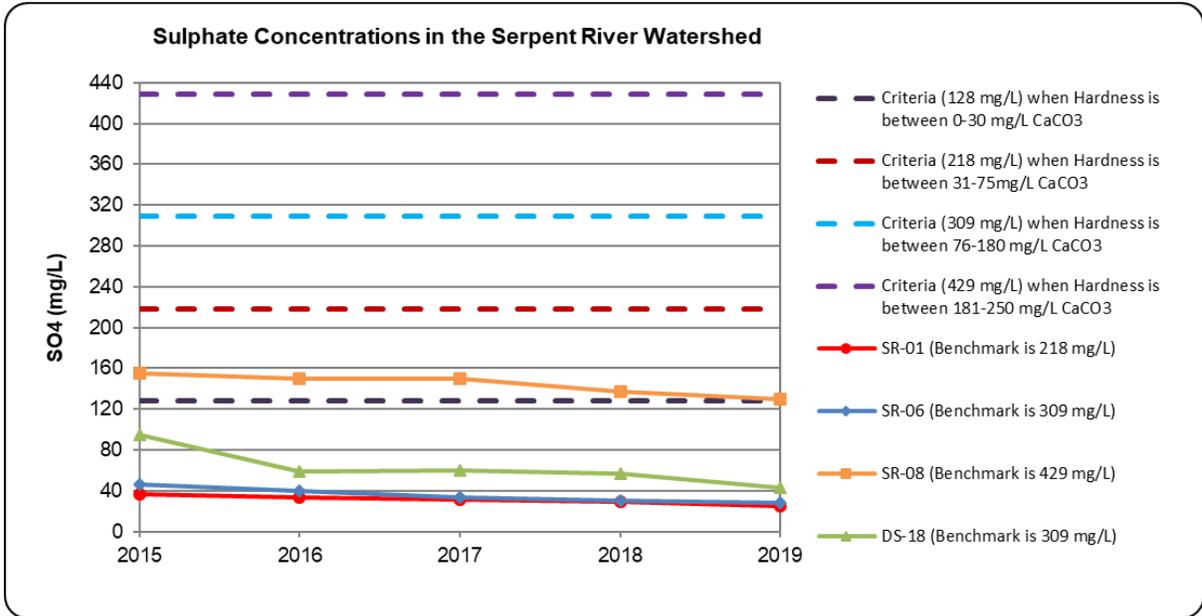

Figure 3.1.b. **Annual Average Radium Concentrations at SR-01, SR-06, SR-08, and DS-18, 2015-2019**
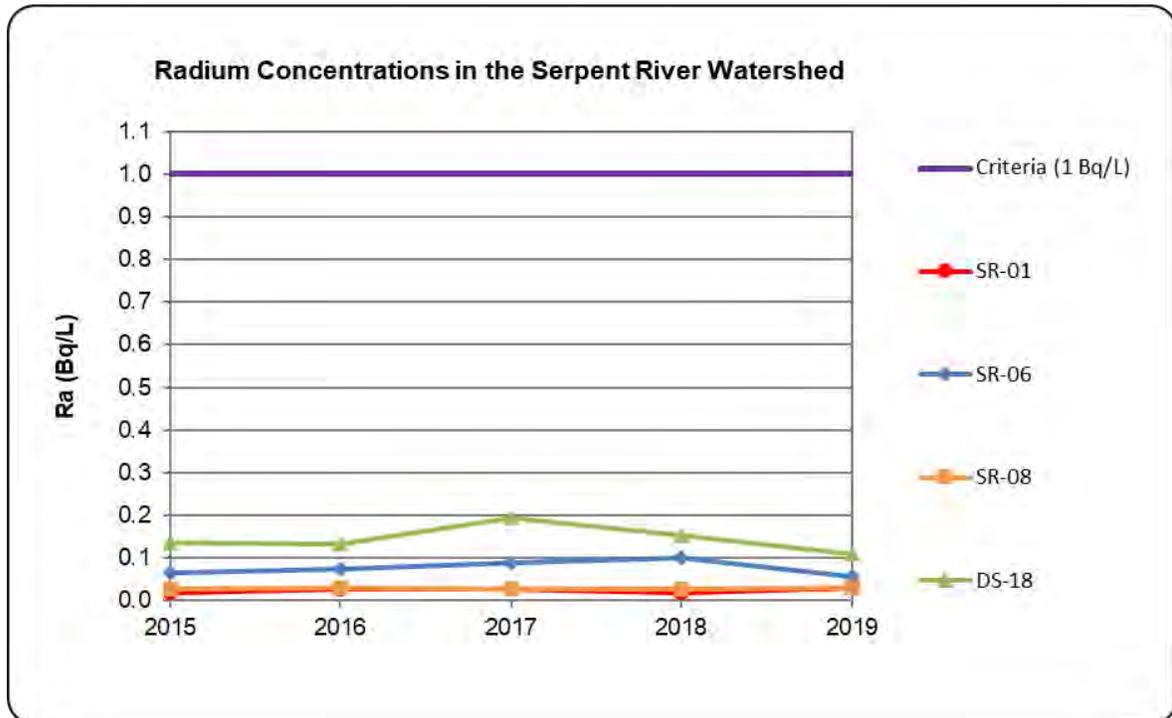
Figure 3.1.c. Annual Average Uranium Concentrations at SR-01, SR-06, SR-08, and DS-18, 2015-2019
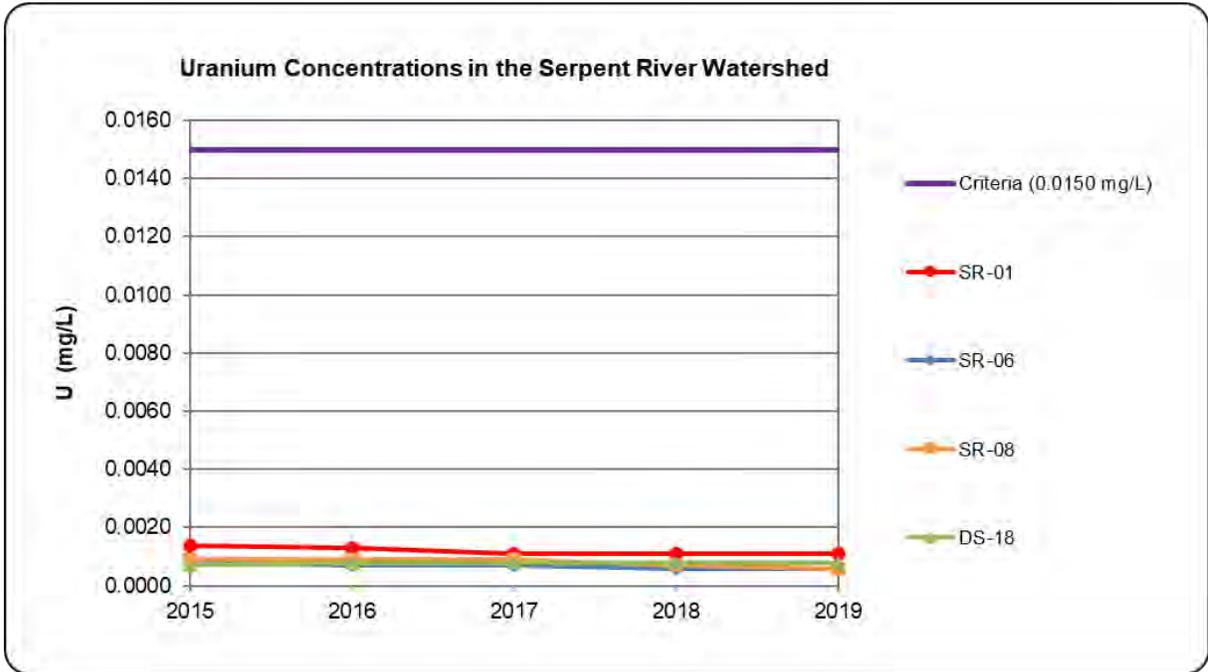
4   DISCUSSION

4.1   Response Monitoring

Beginning in 2016, monitoring at the outlet of May Lake (SR-15) was voluntarily re-established in response to gradually increasing barium and radium concentrations upstream at the outlet of McCabe Lake (SR-06); it was previously removed in the SRWMP Cycle 3 Study Design (Minnow 2009). This station is proposed to be re-established in the monitoring program as per the Cycle 5 study design (beginning 2020) to aid in the assessment of any long-term impacts to the receiving environment as a result of these increasing trends. The Cycle 5 study design is currently under review by CNSC.

4.2   SRWMP Performance Monitoring Program Changes

There were no changes to methodology in 2019.

4.3   Changes to Location Classification and Frequency

Other than the addition of the SRWMP station SR-15 there were no other changes to location classification or frequencies in 2019. Following completion of the 2016 Serpent River Watershed Cycle 4 State of the Environment Report, analysis for cobalt, iron, and manganese were reintroduced at all SRWMP stations to help support future interpretations of the loadings of these substances into the watershed (Minnow, 2016). In addition, hardness was added as an ancillary parameter to all SRWMP stations as it assists in interpretation of water quality concentrations for manganese and sulphate, as discussed in the approved *Cycle 4 Study Design for the SRWMP, SAMP and TOMP* (BC ENV, 2019 and Minnow, 2016). These additions are outlined in Table 2.1.

4.4   Interim Assessment in Support of Representative Public Radiation Dose Estimation

The Canadian Nuclear Safety Commission (CNSC) requested that Rio Algom Limited and Denison Mines Inc. provide annual reporting of the radiation dose to the public associated with the closed uranium mine sites in the Serpent River Watershed. Historically, estimates of the public dose had been based on the use of very conservative values to demonstrate that public dose in the vicinity of Elliot Lake did not exceed the upper dose limit. Measurements of radon and gamma collected during mine operations resulted in dose estimates less than 5% of the annual public dose limit of 1 mSv/a.

However, to determine an updated and more realistic representative annual public dose estimation for a person residing in Elliot Lake, a preliminary design monitoring program to support public dose estimation was prepared in early 2016. Details of the design program were provided in the document entitled *Preliminary Design Monitoring Program to Support Public Dose Estimation* (Ecometrix Incorporated (Ecometrix), 2016), which was included as an appendix in the *SRWMP Annual Water Quality Report 2016* (RAL, DMI, 2017)

In 2016, components of the design monitoring program were completed. This included quarterly site-specific radiation surveys of public walking trails (for radon and direct Gamma specifically), analysis of radionuclides in drinking water, and a community survey. The community survey was conducted to determine the amount of time a representative person spent hiking on the mining properties as well as information about their consumption of fish from local lakes. Based on the interim public dose calculations using the data collected in 2016, it can be concluded that the public dose to the representative person is approximately 0.012 mSv/a, after correction for background exposure. This interim public dose estimation is intended to provide annual interim dose values until 2019. Details of the interim dose are provided in the document entitled *Interim Public Dose Estimation for the Closed Mines of the Serpent River Watershed* (Ecometrix, 2017), which is included in Appendix VI of this report.

The annual dose reporting will be based on periodic updates undertaken as part of the five-year SOE Report. The public dose estimation will be updated as part of the 2020 State of the Environment report. The data used to calculate the interim dose will be updated to reflect results from recent sport fish tissue data collected in 2019.

REFERENCES

Beak International Incorporated 1999. Serpent River Watershed Monitoring Program Framework Document. February 1999.

Ecometrix Incorporated, 2016. Preliminary Design for a Monitoring Program to Support Public Dose Estimation, Prepared for Rio Algom and Denison Mines, September, 2016

Ecometrix Incorporated, 2017. Interim Public Dose Estimation for the Closed Mines of the Serpent River Watershed. February 2018.

Denison Mines Inc., 2019. Annual Operating Care & Maintenance Report. March 2020.

Minnow Environmental Inc., 2009a. Serpent River Watershed State of the Environment. Prepared for Rio Algom Limited and Denison Mines Inc. January 2009.

Minnow Environmental Inc., 2009b. Serpent River Watershed Monitoring Program, Cycle 3 Study Design. Prepared for Rio Algom Limited and Denison Mines Inc. May 2009.

Minnow Environmental Inc., 2009c. Monitoring Framework for Closed Uranium Mines, Near Elliot Lake. Prepared for Rio Algom Limited and Denison Mines Inc. May 2009.

Minnow Environmental Inc., 2011. Serpent River Watershed State of the Environment Report. Prepared for Rio Algom Limited and Denison Mines Inc. July 2011.

Minnow Environmental Inc., 2016a. Cycle 4 Study Design for the SRWMP, SAMP and TOMP. Prepared for Rio Algom Limited and Denison Mines Inc. February 2016.

Minnow Environmental Inc., 2016b. Serpent River Watershed Cycle 4 State of the Environment Report. Prepared for Rio Algom Limited and Denison Mines Inc. November 2017.

Rio Algom Limited, 2019. 2018 Annual Operating Care Maintenance Report. March 2019.

Rio Algom Limited, 2020. 2019 Annual Operating Care Maintenance Report. March 2020.

Rio Algom Limited and Denison Mines Inc., 2017. Serpent River Watershed Monitoring Program 2017 Annual Water Quality Report. March 2018.

World Health Organization (WHO). 2001. Barium and barium compounds. Concise International Chemical Assessment Document 33. Geneva, 2001.

APPENDIX I
Performance Monitoring Changes 2015 - 2019
Evolution of Programs

March 9, 2016
via e-mail

Karina Lange
Project Officer for Wastes and Decommissioning Division
Canadian Nuclear Safety Commission
280 Slater Street
P.O. Box 1046, Station B
Ottawa, ON, K1P 5S9

Dear Ms. Lange:

Re: Serpent River Watershed Cycle 4 State of the Environment Report

Denison Mines Inc. (DMI) and Rio Algom Limited (RAL) are pleased to submit the Serpent River Cycle 4 State of the Environment (SOE) Report (2010 to 2014). The report presents and integrates the monitoring data obtained through the Elliot Lake closed mines monitoring programs, namely the Serpent River Watershed Monitoring Program (SRWMP), the Source Area Monitoring Program (SAMP) and the TMA Operational Monitoring Program (TOMP). The report covers the period of January 1, 2010 to December 31, 2014 although historical data has been considered for trend analysis.

This report represents the completion of the fourth cycle of the SRWMP. A complete list of all study design and interpretive reports prepared since the start of Cycle 1 is provided in Table 5.1. This table also summarizes the time frame covered for each cycle and the key changes to each of the monitoring programs over time.

We are also distributing this Cycle 4 State of the Environment Report to the members of the Joint Regulatory Review Group (JRG; distribution attached). We look forward to your review of the report and the opportunity to address and any questions or comments you may have.

Yours very truly,

Denison Mines Inc.   Rio Algom Limited

Ian Ludgate,   Debbie Berthelot,
Manager   Reclamation Manager

cc: Distribution List

Table 5.1: Summary of the Elliot Lake monitoring programs; documents produced and changes to the programs during each cycle.

Cycle	Report Title	Year	Period Covered	Description Of Changes To The Monitoring Programs Within Each Cycle
Cycle 1	Serpent River Watershed Monitoring Program Framework Document.	1999	historical monitoring data	SRWMP, IBMP, SAMP and TOMP were developed based on program objectives and existing monitoring data collected over the period of operations and decommissioning.
	In-Basin Monitoring Program Report	1999		
	Serpent River Watershed and In-Basin Monitoring Program – Implementation Document.	1999		
	Serpent River Watershed Monitoring Program -1999 Study	2001	1999 - 2000	
	In-Basin Monitoring Program for the Uranium Tailings Areas - 1999 Study.	2001		
Cycle 2	Overview of Elliot Lake Monitoring Programs and Source Area Monitoring Program Design.	2002	2000 -2004	**Changes only SRWMP** most associated with optimization after first cycle of program was complete: - monitoring substances reduced to mine indicator parameters (barium, cobalt, DOC, iron, manganese, Ra-226, selenium, silver, sulphate and uranium), - addition of two lake reference stations (Summers and Semiwite lakes) and 3 stream reference areas (SR-16, SR-17 and SR-18); - removal of shallow lakes for sediment and benthic sampling (Westner, Grassy, Halfmoom, Upper Cinder and Horne lakes); - removal of some stream sediment and benthic stations (D-15, SC-03 and SR-07); - removal of Depot Lake and Serpent Harbour; addition of May Lake; - the transfer of some SRWMP stations to SAMP or TOMP (N-12, ECA-131, P-11, MPE and Q-23); - fish health assessment eliminated based on performance, fish community assessment added for McCabe Lake and fish tissue monitoring reduced in scope based on performance.
	TMA Operational Monitoring Program Design (TOMP).	2002		
	Cycle 2 Study Design – Serpent River Watershed and In-Basin Monitoring Programs.	2004		
	Serpent River Watershed Monitoring Program: Cycle 2 Interpreative Report	2005		
	Serpent River In-Basin Monitoring Program: Cycle 2 Interpretive Report - 2004 Study.	2005		
	Serpent River Watershed State of the Environment	2009		
Cycle 3	Monitoring Framework For Closed Uranium Mines Near Elliot Lake	2009	2005- 2009	**IBMP** eliminated based on objectives of program being achieved. **SAMP and TOMP:** - removal of silver, selenium based on performance and removal of conductivity based on redundancy with sulphate; - DOC, hardness and flow added at selected stations. **SRWMP:** - removal of selenium and sliver based on performance, - removal of station SR-12, ELO, SR-09, SR-15, SR-02, SR-03, SR-11, P-01, QL-01 and SR-16 and SR-17 based on performance; - monthly monitoring frequency reduced to quarterly; - sediment and benthic monitoring removed from Whiskey, Evans and Cinder Lakes based on redundancy, - depositional streams (Q-20, D-6, SR-06, M-01 and SR-08) based on very high natural variability masking results; - fishing in McCabe Lake and fish tissue monitoring eliminated based on performance.
	In Basin Monitoring Program, Cycle 3 Study Design	2009		
	Serpent River Watershed Monitoring Program: Cycle 3 Study Design	2009		
	Source Area Monitoring Program Revised Study Design.	2009		
	Tailing Management Area Monitoring Program (TOMP) Revised Study Design	2009		
	Serpent River Watershed State of the Environment Report.	2011		
Cycle 4	Cycle 4 Study Design For the SRWMP, SAMP and TOMP.	2014[a]	2010 - 2014	Minor changes to SAMP and TOMP. **SRWMP:** - elimination of reference stations SR-05, P-222 and SR-14; - removal of cobalt as substance for monitoring, addition of DOC; - far-field lakes removed from the program (Hough, Pecors and McCarthy); - removal of Rochester Lake as a sediment and benthic reference area; - reduction in benthic and sediment sampling to 1/10 years based on measured deposition rates.
	Serpent River Watershed Cycle 4 State of the Environment	2016		

[a] Study Design was submitted to CNSC and JRG in 2014 but reissued with agency comments in 2016.

APPENDIX II
Flagged Data Results

Denison Mines

Rio Algom

Report Form: **RC8.7.3.01**

Location	Analyte	Date	Low	Hi	Result	Comment
D-4	Ba	2019-05-23	0.012	0.012	0.013 mg/L	Result is slightly above the high flag limit, but still consistent with previous values in the last two years.
	SO4	2019-05-23	3.4	3.4	3.2 mg/L	Result is slightly below the low flag limit, but consistent with a gradually decreasing trend.
D-5	FLOW	2019-05-23	0	6715.8	8370.0 L/s	Result is above the high flag limit, but consistent with seasonal values in the last five years during spring melt.
Q-09	FLOW	2019-05-23	0	6887.7	8530.0 L/s	Result is above the high flag limit, but consistent with seasonal values in the last five years during spring melt.
SR-06	Mn	2019-05-30	0.001	0.021	0.022 mg/L	Result is a 10-year high, but consistent with historic values (2009 and earlier) and only slightly above the high flag limit. Will continue to monitor at the current semi-annual frequency.
M-01	Fe	2019-08-27	0	1.81	1.94 mg/L	Results are above the high flag limits, but consistent with concentrations observed in similar wetland stations when water levels are low. Results are also influenced by persistent upstream beaver activity.
	Mn	2019-08-27	0	0.238	0.332 mg/L	

Environmental Manager, Denison Environmental Services
All electronic or printed copies other than pdf in controlled file are uncontrolled

Issued on: June 30, 2015
Expires: June 30, 2020

Denison Mines

Rio Algom

Report Form: RC8.7.3.01

Location	Analyte	Date	Low	Hi	Result	Comment
D-4	Fe	2019-11-12	0.02	0.04	0.05 mg/L	Results are slightly above the high flag limits, but consistent with previous values in the last year.
	Mn	2019-11-12	0.012	0.017	0.022 mg/L	

Environmental Manager, Denison Environmental Services
All electronic or printed copies other than pdf in controlled file are uncontrolled

Issued on: June 30, 2015
Expires: June 30, 2020

APPENDIX III
Laboratory QA/QC Results

SGS

REPORT CODE: *DEN-ANN19*

REPORT TITLE: *Annual 2019 Denison Data Quality Report*

REVISION: *1.0*

ISSUED BY:

Quality Coordinator,
SGS Environment, Health & Safety

AUTHORIZED BY:

Technical Manager,
SGS Environment, Health & Safety

DATE: *26 Feb. 2020*

Table of Contents

1. BACKGROUND

SGS Laboratory entered into an agreement with Denison Environmental Services for the analytical lab to provide analysis according to RFT #05-016. Please find below a summary of the laboratory quality management system, key actions taken by the laboratory, as well as a summary of numbers of samples analyzed.

2. QUALITY MANAGEMENT SYSTEM

SGS Environment, Health & Safety is accredited to ISO/IEC 17025 by the Canadian Association for Laboratory Accreditation (CALA), for specific tests listed in the scope of accreditation. ISO/IEC 17025 addresses both quality management and the technical aspects of operating a testing laboratory.

The quality management system at SGS Environment, Health & Safety consists of a documented quality system, which is directed by the Quality Coordinator who is independent of the production area. All appropriate documentation (quality manual, methods, written instructions, standard operating procedures, and data approval criteria) is in place and includes both general and method specific quality control requirements.

The quality control procedures include duplicate samples, spiked blanks, spiked replicates, reagent/instrument blanks, preparation control samples, certified reference material analysis, and instrument control samples, as appropriate for the individual methods. Matrix matching of reference materials to samples is always attempted. Frequency of insertion of control samples is method specific and follows legislated guidelines. A summary of the quality control recoveries is presented in the tables following.

3. QUALITY CONTROL PARAMETERS

All QC parameters are taken directly from SGS LIMS. Denison Environmental Services samples are processed as part of our "worksheet" batch system. A compilation of all QC data appropriate to the parameters tested has been compiled below.

4. NOTABLE OCCURANCES/ACTIONS

- SGS Environment, Health & Safety Lakefield laboratory performed 11183 analyses with 7973 QC checks, which represents 71% QC for sample analysis. **Corrective Action**: N/A

- All blank data results were within the data quality objectives. **Corrective Action**: N/A

- All CRM data results were within the data quality objectives. **Corrective Action**: N/A

- No duplicate value exceeded the data quality objectives. **Corrective Action:** N/A

- No spike blanks exceeded the data quality objectives. **Corrective Action**: N/A

- No spike duplicates fell outside of the data quality objectives. **Corrective Action**: N/A

- During the second half of 2019 Denison requested TSS reanalysis on some of their samples. The repeated TSS results differed from the original TSS results reported in varying degrees. A quality investigation was initiated and documented in SGS NCR 51839.

  Original and repeated low level TSS sample results (<10mg/L) varied within the range from 1 to 10mg/L. It is difficult to determine exactly why there are variations at this level. Some contributing factors for variations at this low level include using less sample volume to perform the reanalysis and sub-sampling from a different sample container for the reanalysis. Another factor to consider is the reanalysis was performed on sample portions that were past the holding time.

  For samples with TSS concentrations reported above 10mg/L, the investigation found analytical carryover was a contributing factor in the discrepancy of the results. The technicians involved have been provided additional training to eliminate carryover issues during TSS analysis where required.

5.   QC DATA SUMMARY

5.1. *Blank Data*

Parameter	Unit	Required Limit	Number of Blanks	Mean Blank Result
Acidity	mg/L as CaCO3	1	143	2
Silver	mg/L	0.0001	44	<0.0001
Alkalinity	mg/L as CaCO3	1	24	<1
Arsenic	mg/L	0.0005	4	<0.0005
Barium	mg/L	0.005	264	<0.005
Cobalt	mg/L	0.0005	188	<0.0005
Copper	mg/L	0.0005	44	<0.0005
DOC	mg/L	0.5	0	
Iron	mg/L	0.02	228	<0.02
Hardness	mg/L as CaCO3	0.5	157	<0.5
Manganese	mg/L	0.002	192	<0.002
Nickel	mg/L	0.002	40	<0.002
Lead	mg/L	0.00002	44	<0.00002
Selenium	mg/L	0.0005	38	<0.0005
Sulphate	mg/L	0.2	282	<0.2
Total Dissolved Solids	mg/L	10	3	<30
Total Suspended Solids	mg/L	1	400	<1
Uranium	mg/L	0.0005	185	<0.0005

| Zinc | mg/L | 0.001 | 44 | <0.002 |

5.2. Reference Material/Spiked Blank Data

Parameter	Unit	Number of RM or SB	% Recovery
Acidity	mg/L as CaCO3	143	100
Silver	mg/L	44	99
Alkalinity	mg/L as CaCO3	18	102
Arsenic	mg/L	4	101
Barium	mg/L	262	100
Cobalt	mg/L	188	99
Copper	mg/L	44	99
DOC	mg/L	0	
Iron	mg/L	228	100
Hardness	mg/L as CaCO3	135	100
Manganese	mg/L	192	101
Nickel	mg/L	44	100
Lead	mg/L	45	98
Selenium	mg/L	45	101
Sulphate	mg/L	282	96
Total Suspended Solids	mg/L	NV*	
Uranium	mg/L	185	98
Zinc	mg/L	44	100

*NV – No value, certified reference materials unavailable for this test

5.3. Duplicate Data

Parameter	Unit	RPD* Limit	Number of Duplicates	RPD*
Acidity	mg/L as CaCO3	20	142	2.6
Silver	mg/L	20	40	4.8
Alkalinity	mg/L as CaCO3	20	19	3.3
Arsenic	mg/L	20	4	4.2
Barium	mg/L	20	264	3.7
Cobalt	mg/L	20	188	5.6
Copper	mg/L	20	40	4.3
DOC	mg/L	20	0	

Iron	mg/L	20	228	4.5
Hardness	mg/L as CaCO3	20	158	2.3
Manganese	mg/L	20	181	3.1
Nickel	mg/L	20	43	5.0
Lead	mg/L	20	45	4.6
pH	units	20	3	1.0
Selenium	mg/L	20	45	6.5
Sulphate	mg/L	20	282	1.7
Total Dissolved Solids	mg/L	20	3	ND
Total Suspended Solids	mg/L	20	400	1.4
Uranium	mg/L	20	185	3.3
Zinc	mg/L	20	44	6.6

*RPD – Relative Percent Difference

5.4. Spike Duplicate Data

Parameter	Unit	Number of Spike Dups	Mean % Recovery
Silver	mg/L	40	92
Arsenic	mg/L	4	111
Barium	mg/L	256	103
Cobalt	mg/L	188	99
Copper	mg/L	37	100
DOC	mg/L	0	
Iron	mg/L	0	
Hardness	mg/L as CaCO3	142	99
Manganese	mg/L	167	103
Nickel	mg/L	24	98
Lead	mg/L	45	98
Selenium	mg/L	45	103
Sulphate	mg/L	262	97
Uranium	mg/L	185	95
Zinc	mg/L	37	107

5.5. QC Frequency

Total Number of Blanks:	2324
Total Number of Reference Materials/Spiked Blanks:	1903
Total Number of Duplicate Samples:	2314
Total Number of Spiked Duplicate Samples:	1432
Sum of QC Insertion:	**7973**
Total Analysis:	**11183**

^{226}Ra DATA QUALITY REPORT

2019 Annual

Prepared by:

Troy Maki

Troy Maki - Chemical Technologist

Reviewed by:

Alan Lock

Dr. Alan Lock – PCAF Laboratory Manager

Elliot Lake Research Field Station of Laurentian University
Date: January 7, 2020

Table of Contents

Contents

1 Background

The Perdue Central Analytical Facility (PCAF), previously Elliot Lake Research Field Station (ELRFS), entered into an agreement with Denison Environmental Services (DES) for the analytical laboratory to provide ^{226}Ra analysis according to the ELFRS Offer of Services document submitted to DES on December 3, 2010. Please find below the summaries of the monthly Quality Control (QC) results for blanks, duplicates, certified reference material (CRM), and spiked sample analysis.

The Analytical Services Laboratory of the Elliot Lake Research Field Station (ELRFS) was established in 1992. In July 2019, ELRFS analytical services was incorporated as part of the new Perdue Central Analytical Facility (PCAF) at Laurentian University to support improved operations through new purposed space and additional, dedicated technical and management staff. The initial (1992) work of the laboratory was to support research into the effects of low-level radioactivity on the environment resulting from regional uranium mining activities.

From this base, the laboratory has provided analytical services in support of local decommissioning and environmental monitoring programs, and in support of academic research. While the laboratory specializes in **radionuclide** analysis, it also provides a wide range of inorganic and organic services for environmental samples, including solid wastes, effluents, receiving waters, ground waters, soils, sediments, geological materials, plant tissues and animal and fish tissues. The PCAF analytical team will also complete specialty analyses outside of the scope of accreditation, following good laboratory practice procedures, using similar QA/QC protocols.

2 Quality Management System

ELRFS maintained ISO/IEC 17025 accreditation by the Canadian Association of Laboratory Accreditation (CALA) for specific environmental tests listed in the Scope of Accreditation since 2001. Shortly before the transition of ELRFS to PCAF, the laboratory accreditation was withdrawn by CALA due to previous management not submitting the Management Review document as required under the standard. Accreditation is the formal recognition of the competence of a laboratory to achieve and demonstrate the highest levels of scientific and management excellence through the combined principles of Competence, Consistency, Credibility and Communication. PCAF takes this very seriously and is currently completing the application process with CALA to obtain laboratory accreditation again. Until formally accredited again, PCAF is committed to operate using Good Laboratory Practice (GLP) and incorporate the same quality control data, impartiality, document control, and client confidentiality that has been used under the ISO: 17025 standard.

The quality management system at PCAF consists of a documented quality system stating the quality policy, quality system and quality practices designed to demonstrate quality control operations are being carried out, to ensure accountability of data, to assure traceability of reported data, and to show that reasonable precautions are being taken against the possibility of falsification of data. Within this manual, Quality Assurance Procedures and Standard Operation Procedures define the laboratory operational duties that guide the analytical QC data. This includes a minimum target of 20% of the samples analysed being distributed as blanks, duplicate analysis, CRMs, and spiked samples. The sample and QC results are logged into excel spread sheets with monthly and annual QC reports generated from the data sets.

3 Quality Control Parameters

All QC parameters are taken directly from the Excel spread sheets and Envista. DES samples are processed as part of the worksheet batch system. A compilation of all QC data appropriate to the parameters tested has been compiled below.

The QC summary reports are presented as control charts with the mean +/- 1 standard deviation illustrated as the SD Level, the mean +/- 2 standard deviations illustrated as the Warning Level and the mean +/- 3 standard deviations illustrated as the Control Level.

Control Level - If the Control Level is exceeded, the analysis of standards and samples must be repeated and if the repeat analysis exceeds the Control Level again, corrective action is required.

Warning Level – If 2 or more consecutive points exceed the Warning Level, another standard must be analyzed and if this analysis exceeds the Warning Level again, corrective action is required.

SD Level – If 4 consecutive results exceed the SD Level, analyse the next sample and if the SD Level is exceeded again, corrective action is required.

4 Notable Occurrences /Actions

Through the year of 2019, ELRFS analyzed 104 batches totaling 1206 samples for ^{226}Ra. Each batch incorporated blank, CRM, duplicate, and spiked samples providing greater than 20% quality control samples. All quality control samples are within control limits (mean +/- 3SD).

Sixteen quality control samples exceeded the warning (mean +/- 2SD) levels. This included five QC Duplicate (Figure 2) samples and eleven QC Spike (Figure 4a) samples. All samples exceeding the warning level were not consecutive, with the next consecutive QC sample falling within the warning level (mean +/- 2SD) limit, thus no corrective actions were required. No QC samples exceeded objectives.

5 QC Data Summary

Table 1. Summary of QC results for January - December 2019.

Quality Element	Unit	Objective	Total Number of QC Samples	Expected Value	Mean	Number Outside Warning Limit	Number Outside Control Limit	Number Exceeding Objective
Blank	Bq/L	0.01	104	0	0.00063	0	0	0
Duplicate % error	%	20	104	0	6.48	5	0	0
CRM	Bq/L	20	104	0.050	0.045	0	0	0
Spike	Bq/L	20	104	0.250	0.234	11	0	0

1 Blanks

The blank sample is composed of ultra pure water and is treated in an identical manner, including all of the added reagents, as normal samples. The criterion of the blank sample is 0.01 Bq/L which is equal to 6 counts per 100 min (0.06 cpm). The 2019 mean blank value is 1.02 counts per 100min (0.00063 Bq/L). PCAF uses counts to monitor the blank quality control data.
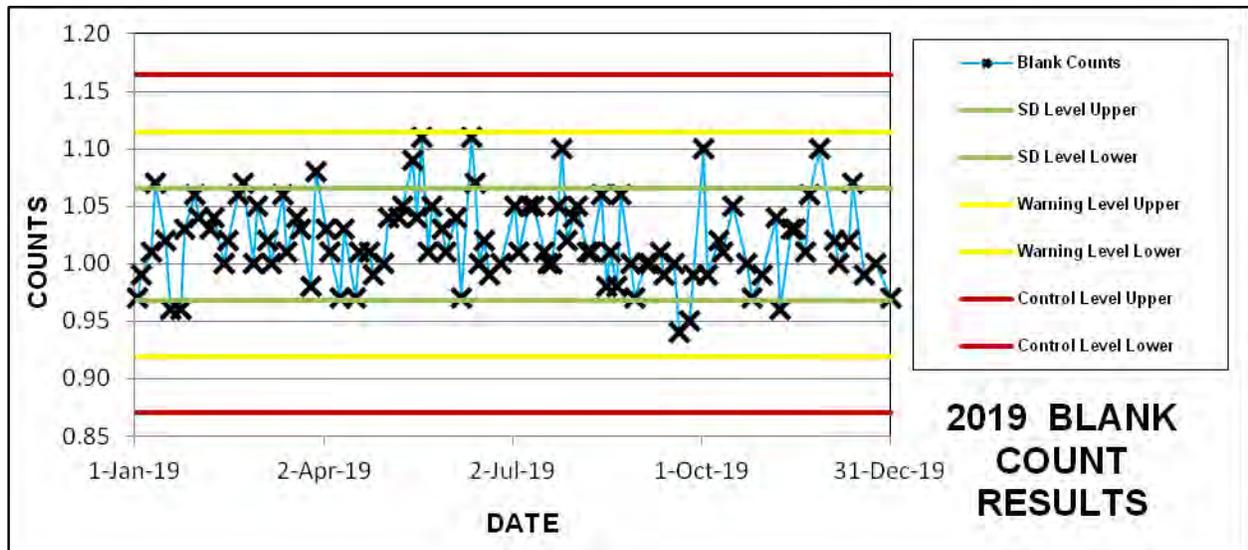
Figure 1a: Blank quality control results for the 2019 year.
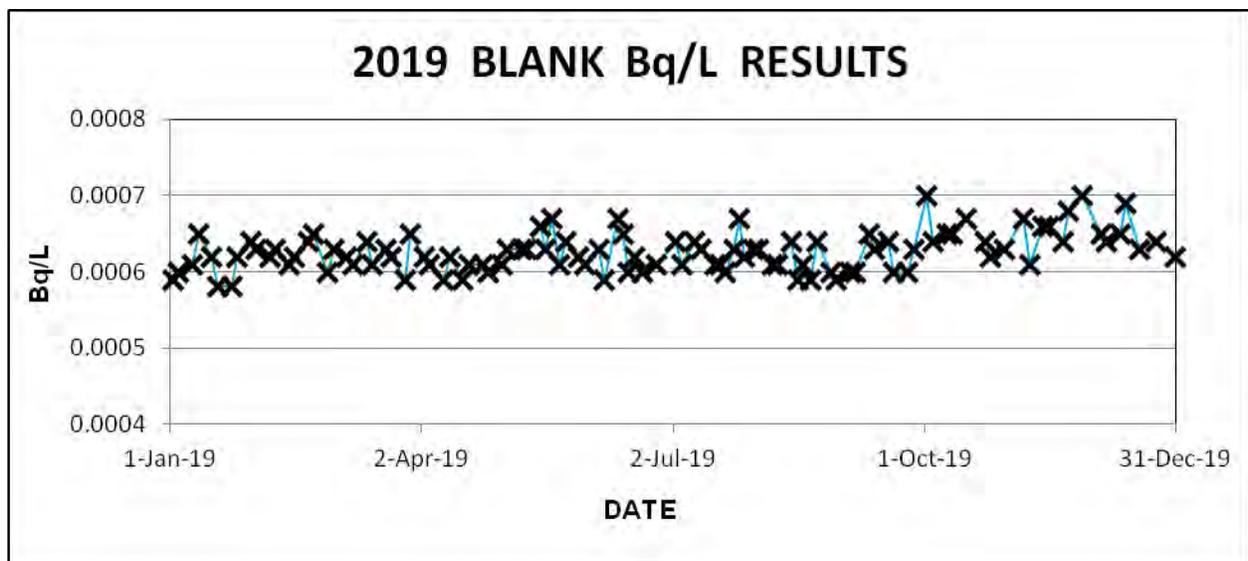
Figure 1b: Blank quality control concentrations for the 2019 year. Note maximum concentrations are 10 times lower than the 0.01 Bq/L criteria.

Central Analytical Facility
PCAF AT LAURENTIAN UNIVERSITY
Centre d'analyse
CAP À L'UNIVERSITÉ LAURENTIENNE

PERDUE

LaurentianUniversity
UniversitéLaurentienne
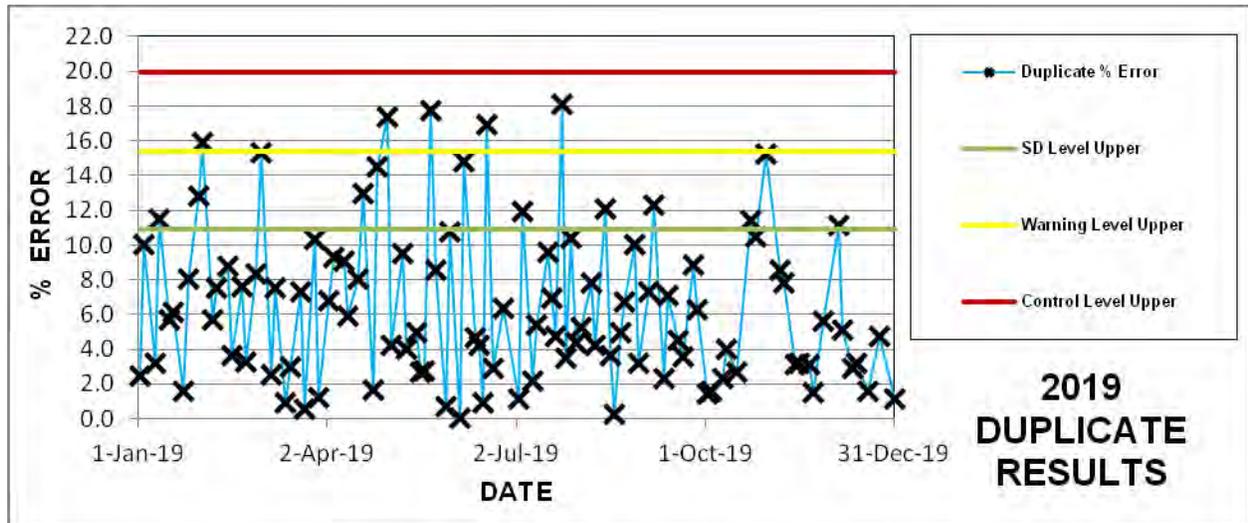
2 Duplicates

Figure 2: Duplicate quality control results for the 2019 year.

3 CRM

The CRM material used is from Eckert & Ziegler (0.050Bq/L).

.
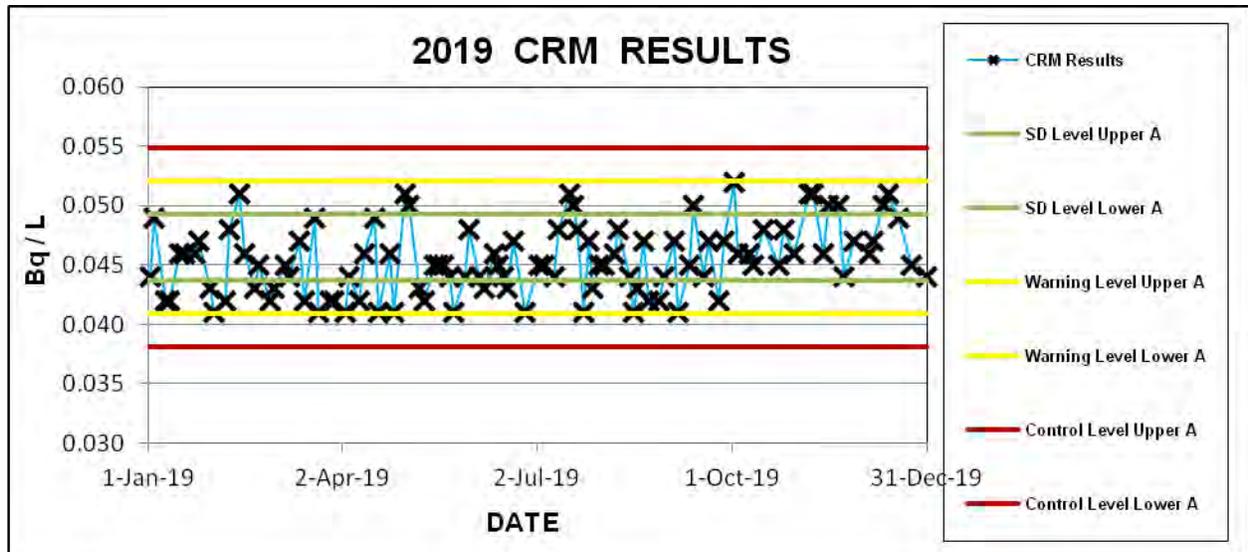
Figure 3a: CRM quality control results for the 2019 year.
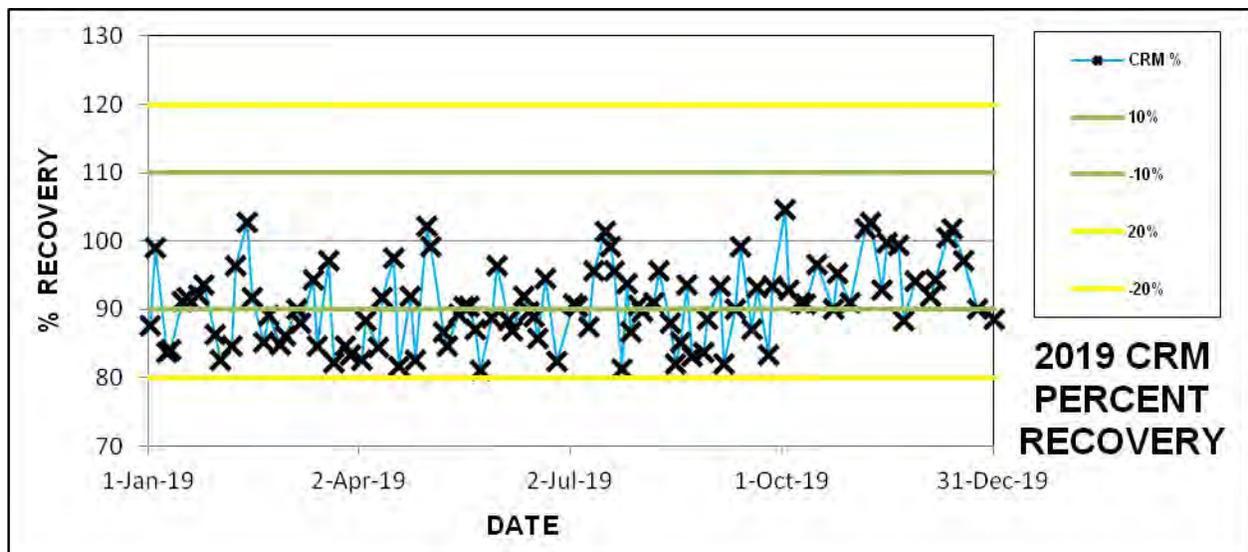
Figure 3b: CRM percent recovery quality control results for the 2019 year.

4 Spikes

The spike standard used is from Eckert & Ziegler (0.250Bq/L) .
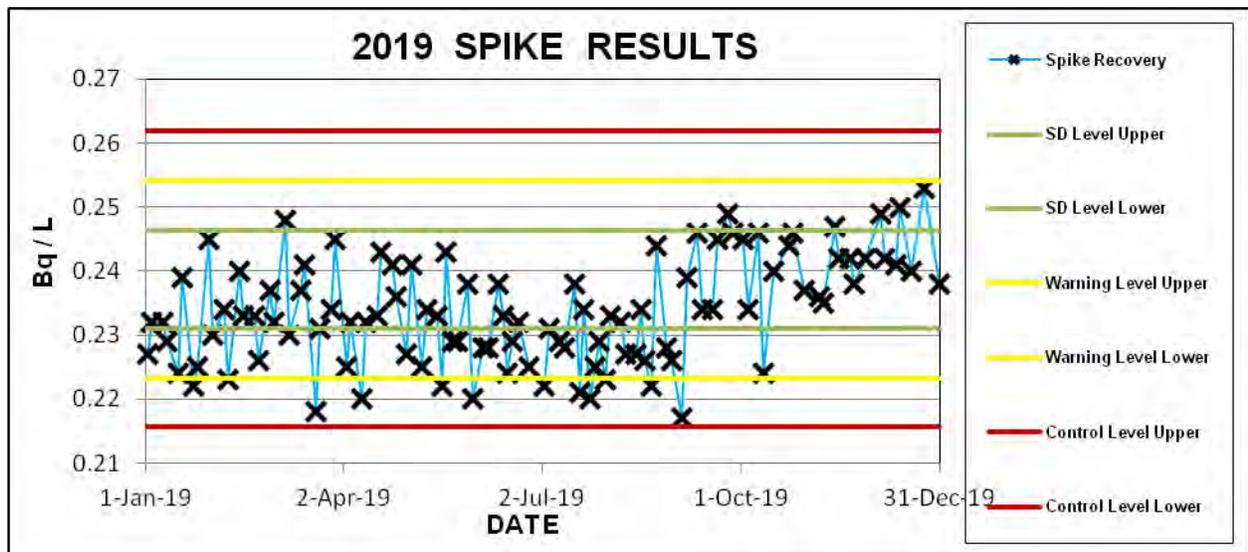
Figure 4a: Spike recovery quality control results for the 2019 year
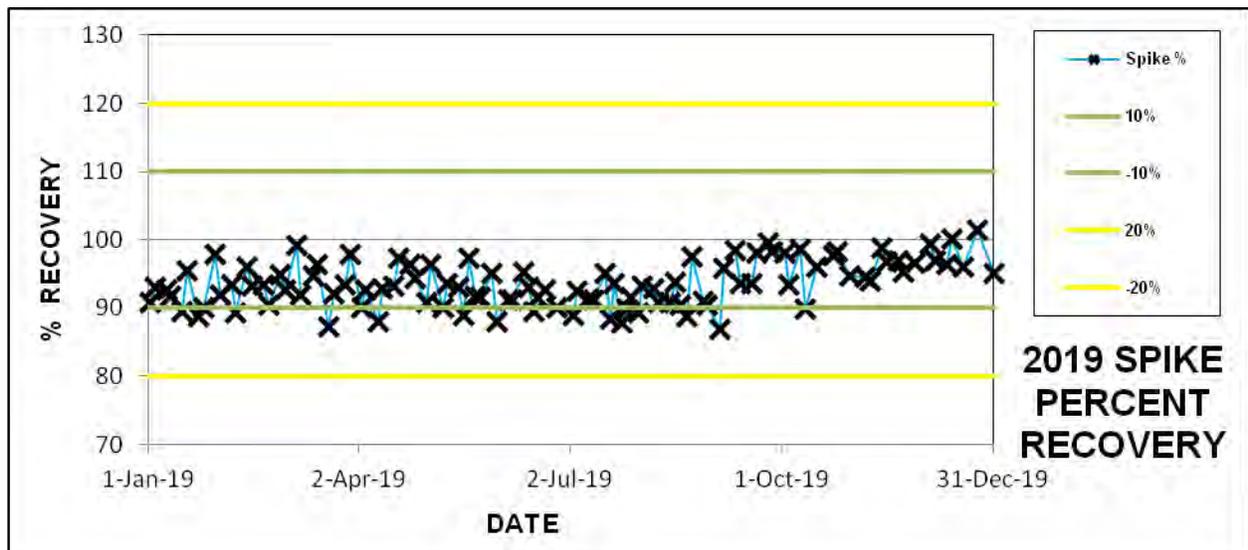
Figure 4b: Percent spike recovery quality control results for the 2019 year.

QC Frequency

Through the 2019 year, ELRFS analyzed 104 batches totaling 1206 samples for ^{226}Ra. Each batch incorporated blank, CRM, duplicate, and spiked samples providing greater than 20% quality control samples.

APPENDIX IV
Field QA/QC Results

SRWMP DATA QUALITY REPORTING
2019 Field Precision
Revision: 2016.01

Month	Sample	pH	Sulphate mg/L	Radium (T) Bq/L	Uranium mg/L	Barium mg/L	Cobalt mg/L	Iron mg/L	Manganese mg/L	Hardness mg/L
2019-05	BSR5	6.9	8.8	0.017	0.0021	0.0130	< 0.0005	0.22	0.031	26.8
	M-01	6.9	8.8	0.017	0.0019	0.0120	< 0.0005	0.22	0.029	25.2
	variance	0.0%	0.0%	0.0%	10.0%	8.0%	0.0%	0.0%	6.7%	6.2%
2019-05	BSD2	7.0	8.7	< 0.007	< 0.0005	0.0120	< 0.0005	0.14	0.068	15.1
	D-6	7.0	9.4	< 0.007	< 0.0005	0.0120	< 0.0005	0.15	0.070	15.4
	variance	0.0%	7.7%	0.0%	0.0%	0.0%	0.0%	6.9%	2.9%	2.0%
2019-11	BSD2	6.8	16.0	< 0.007	< 0.0005	0.0130	< 0.0005	0.20	0.080	25.0
	D-6	6.8	16.0	< 0.007	< 0.0005	0.0130	< 0.0005	0.19	0.076	23.6
	variance	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.1%	5.1%	5.8%
2019-11	BSR5	7.0	9.0	0.014	0.0025	0.0140	< 0.0005	0.43	0.034	35.2
	M-01	7.0	8.9	0.016	0.0025	0.0140	< 0.0005	0.42	0.030	34.0
	variance	0.0%	1.1%	13.3%	0.0%	0.0%	0.0%	2.4%	12.5%	3.5%
Count		4	4	4	4	4	4	4	4	4
Average		0.0%	2.2%	3.3%	2.5%	2.0%	0.0%	3.6%	6.8%	4.3%
Max		0.0%	7.7%	13.3%	10.0%	8.0%	0.0%	6.9%	12.5%	6.2%
Min		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.9%	2.0%
SRWMP[1] Target		20%	20%	20%	20%	20%	20%	20%	20%	20%
# Exceedances		0	0	0	0	0	0	0	0	0

[1] Field Precision criteria as per Table 5.2 in the Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

Bold indicates an exceedance in the field precision criteria

Issued by: Environmental Manager, Denison Environmental Services
All electronic or printed copies other than pdf in contolled file are uncontrolled

Issued on: April 29, 2016
Expires on: April 29, 2020

Denison Mines

Rio Algom

Report Form: RC8.5.4.01b

Date		pH	Sulphate	Radium (total)	Uranium	Barium	Cobalt	Iron	Manganese
			mg/L	Bq/L	mg/L	mg/L	mg/L	mg/L	mg/L
SRWMP [1]		1	0.2	0.01	0.0010	0.010	0.0010	0.04	0.004
2019.05	FBR5	5.9	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002
2019.05	FBD2	5.8	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002
2019.11	FBD2	5.8	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002
2019.11	FBR5	6.0	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002
Count		4	4	4	4	4	4	4	4
# Exceedances		4	0	0	0	0	0	0	0
Average		5.9	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002
Max		6.0	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002
Min		5.8	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002

[1] [1] Field Precision criteria as per Table 5.2 in the Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016).

Bold indicates an exceedance in the Field Blank criteria

Issued by: Environmental Manager, Denison Environmental Services
All electronic or printed copies other than pdf in contolled file are uncontrolled

Issued on: April 29, 2016
Expires on: April 29, 2020

APPENDIX V
Location Results

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

BSD2

Month	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L	Mn mg/L
2019-05	15.1	7.0	8.7	<0.007	0.012	<0.0005	0.14	0.068
2019-11	25.0	6.8	16.0	<0.007	0.013	<0.0005	0.20	0.080
Count	2	2	2	2	2	2	2	2
High	25.0	7.0	16.0	<0.007	0.013	<0.0005	0.20	0.080
Low	15.1	6.8	8.7	<0.007	0.012	<0.0005	0.14	0.068
Mean	20.1	6.9	12.4	<0.007	0.013	<0.0005	0.17	0.074
High Limit		8.5	309.0	1.000	1.000	0.0025	0.49	0.800
Low Limit		6.5						
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U mg/L
2019-05	<0.0005
2019-11	<0.0005
Count	2
High	<0.0005
Low	<0.0005
Mean	<0.0005
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

BSR5

Month	hard	pHF	SO4	Ra	Ba	Co	Fe	Mn
	mg/L		mg/L	Bq/L	mg/L	mg/L	mg/L	mg/L
2019-05	26.8	6.9	8.8	0.017	0.013	<0.0005	0.22	0.031
2019-11	35.2	7.0	9.0	0.014	0.014	<0.0005	0.42	0.034
Count	2	2	2	2	2	2	2	2
High	35.2	7.0	9.0	0.017	0.014	<0.0005	0.42	0.034
Low	26.8	6.9	8.8	0.014	0.013	<0.0005	0.22	0.031
Mean	31.0	7.0	8.9	0.016	0.014	<0.0005	0.32	0.033
High Limit		8.5	218.0	1.000	1.000	0.0025	1.69	0.800
Low Limit		5.2						
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U
	mg/L
2019-05	0.0021
2019-11	0.0025
Count	2
High	0.0025
Low	0.0021
Mean	0.0023
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

D-4 Dunlop Lake Outlet

Month	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L	Mn mg/L
2019-05	8.8	7.1	3.2	<0.007	0.013	<0.0005	0.03	0.014
2019-11	9.1	6.9	3.3	<0.007	0.014	<0.0005	0.05	0.022
Count	2	2	2	2	2	2	2	2
High	9.1	7.1	3.3	<0.007	0.014	<0.0005	0.05	0.022
Low	8.8	6.9	3.2	<0.007	0.013	<0.0005	0.03	0.014
Mean	8.9	7.0	3.3	<0.007	0.014	<0.0005	0.04	0.018
High Limit		8.5	128.0	1.000	1.000	0.0025	0.49	0.800
Low Limit		6.5						
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U mg/L
2019-05	<0.0005
2019-11	<0.0005
Count	2
High	<0.0005
Low	<0.0005
Mean	<0.0005
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

D-5 Serpent R. between Denison and Quirke TMAs

Month	FLOW	hard	pHF	SO4	Ra	Ba	Co	Fe
	L/s	mg/L		mg/L	Bq/L	mg/L	mg/L	mg/L
2019-02	2000.00	21.5	7.0	11.0	0.017	0.026	<0.0005	0.04
2019-05	8370.00	14.8	7.0	7.2	0.016	0.038	<0.0005	0.05
2019-08	692.00	21.9	6.9	12.0	0.108	0.106	<0.0005	0.07
2019-11	2930.00	19.2	6.8	11.0	0.021	0.033	<0.0005	0.07
Count	4	4	4	4	4	4	4	4
High	8370.00	21.9	7.0	12.0	0.108	0.106	<0.0005	0.07
Low	692.00	14.8	6.8	7.2	0.016	0.026	<0.0005	0.04
Mean	3498.00	19.4	6.9	10.3	0.041	0.051	<0.0005	0.05
High Limit			8.5	128.0	1.000	1.000	0.0025	0.49
Low Limit			6.5					
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	Mn	U
	mg/L	mg/L
2019-02	0.020	0.0010
2019-05	0.020	0.0008
2019-08	0.027	0.0012
2019-11	0.028	0.0012
Count	4	4
High	0.028	0.0012
Low	0.020	0.0008
Mean	0.024	0.0010
High Limit	0.800	0.0150
Low Limit		
Lim Ex	0	0
Frequency	0%	0%
10x Lim Ex	0	0
Frequency	0%	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

D-6 Cinder Lake Outlet

Month	FLOW	hard	pHF	SO4	Ra	Ba	Co	Fe
	L/s	mg/L		mg/L	Bq/L	mg/L	mg/L	mg/L
2019-02		19.6	6.8	11.0	<0.007	0.012	<0.0005	0.18
2019-05	425.00	15.4	7.0	9.4	<0.007	0.012	<0.0005	0.15
2019-08	1.00	85.1	6.6	55.0	0.014	0.035	0.0021	2.76
2019-11	68.00	23.6	6.8	16.0	<0.007	0.013	<0.0005	0.19
Count	4	4	4	4	4	4	4	4
High	425.00	85.1	7.0	55.0	0.014	0.035	0.0021	2.76
Low	1.00	15.4	6.6	9.4	<0.007	0.012	<0.0005	0.15
Mean	164.67	35.9	6.8	22.9	0.009	0.018	0.0009	0.82
High Limit			8.5	309.0	1.000	1.000	0.0025	0.49
Low Limit			6.5					
Lim Ex	0	0	0	0	0	0	0	1
Frequency	0%	0%	0%	0%	0%	0%	0%	25%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	Mn	U
	mg/L	mg/L
2019-02	0.073	<0.0005
2019-05	0.070	<0.0005
2019-08	1.260	<0.0005
2019-11	0.076	<0.0005
Count	4	4
High	1.260	<0.0005
Low	0.070	<0.0005
Mean	0.370	<0.0005
High Limit	0.800	0.0150
Low Limit		
Lim Ex	1	0
Frequency	25%	0%
10x Lim Ex	0	0
Frequency	0%	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

DS-18 Halfmoon Lake Outlet

Month	FLOW L/s	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L
2019-02		90.4	7.1	9.8	0.132	0.019	<0.0005	0.27
2019-05	224.00	58.7	7.3	51.0	0.102	0.022	<0.0005	0.18
2019-08	272.00	47.7	6.9	24.0	0.094	0.014	<0.0005	0.37
2019-11		115.0	7.3	88.0	0.114	0.022	<0.0005	0.22
Count	4	4	4	4	4	4	4	4
High	272.00	115.0	7.3	88.0	0.132	0.022	<0.0005	0.37
Low	224.00	47.7	6.9	9.8	0.094	0.014	<0.0005	0.18
Mean	248.00	77.9	7.2	43.2	0.111	0.019	<0.0005	0.26
High Limit				309.0	1.000	1.000	0.0025	1.69
Low Limit			5.2					
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	Mn mg/L	U mg/L
2019-02	0.027	0.0008
2019-05	0.011	0.0005
2019-08	0.018	0.0008
2019-11	0.014	0.0013
Count	4	4
High	0.027	0.0013
Low	0.011	0.0005
Mean	0.017	0.0008
High Limit	0.800	0.0150
Low Limit		
Lim Ex	0	0
Frequency	0%	0%
10x Lim Ex	0	0
Frequency	0%	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

FBD2

Month	hard	pHF	SO4	Ra	Ba	Co	Fe	Mn
	mg/L		mg/L	Bq/L	mg/L	mg/L	mg/L	mg/L
2019-05	<0.5	5.8	<0.1	<0.007	<0.005	<0.0005	<0.02	<0.002
2019-11	<0.5	5.8	<0.1	<0.007	<0.005	<0.0005	<0.02	<0.002
Count	2	2	2	2	2	2	2	2
High	<0.5	5.8	<0.1	<0.007	<0.005	<0.0005	<0.02	<0.002
Low	<0.5	5.8	<0.1	<0.007	<0.005	<0.0005	<0.02	<0.002
Mean	<0.5	5.8	<0.1	<0.007	<0.005	<0.0005	<0.02	<0.002

Month	U
	mg/L
2019-05	<0.0005
2019-11	<0.0005
Count	2
High	<0.0005
Low	<0.0005
Mean	<0.0005

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

FBR5

Month	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L	Mn mg/L
2019-05	<0.5	5.9	<0.1	<0.007	<0.005	<0.0005	<0.02	<0.002
2019-11	<0.5	6.0	<0.1	<0.007	<0.005	<0.0005	<0.02	<0.002
Count	2	2	2	2	2	2	2	2
High	<0.5	6.0	<0.1	<0.007	<0.005	<0.0005	<0.02	<0.002
Low	<0.5	5.9	<0.1	<0.007	<0.005	<0.0005	<0.02	<0.002
Mean	<0.5	6.0	<0.1	<0.007	<0.005	<0.0005	<0.02	<0.002

Month	U mg/L
2019-05	<0.0005
2019-11	<0.0005
Count	2
High	<0.0005
Low	<0.0005
Mean	<0.0005

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

M-01 Sherriff Creek @ Hwy 108

Month	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L	Mn mg/L
2019-02	33.7	6.5	11.0	0.011	0.017	<0.0005	0.54	0.050
2019-05	25.2	6.9	8.8	0.017	0.012	<0.0005	0.22	0.029
2019-08	31.7	6.5	4.9	0.023	0.019	0.0006	1.94	0.332
2019-11	34.0	7.0	8.9	0.016	0.014	<0.0005	0.42	0.030
Count	4	4	4	4	4	4	4	4
High	34.0	7.0	11.0	0.023	0.019	0.0006	1.94	0.332
Low	25.2	6.5	4.9	0.011	0.012	<0.0005	0.22	0.029
Mean	31.2	6.7	8.4	0.017	0.016	0.0005	0.78	0.110
High Limit			218.0	1.000	1.000	0.0025	1.69	0.800
Low Limit		5.2						
Lim Ex	0	0	0	0	0	0	2	0
Frequency	0%	0%	0%	0%	0%	0%	50%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U mg/L
2019-02	0.0039
2019-05	0.0019
2019-08	0.0025
2019-11	0.0025
Count	4
High	0.0039
Low	0.0019
Mean	0.0027
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

Q-09 Serpent R. below Quirke TMA Effluent

Month	FLOW	hard	pHF	SO4	Ra	Ba	Co	Fe
	L/s	mg/L		mg/L	Bq/L	mg/L	mg/L	mg/L
2019-02	2150.00	58.7	7.0	48.0	0.030	0.029	<0.0005	0.13
2019-05	8530.00	22.1	7.0	14.0	0.029	0.038	<0.0005	0.10
2019-08	772.00	53.4	6.8	97.0	0.114	0.150	<0.0005	0.19
2019-11	3030.00	39.6	6.7	30.0	0.030	0.037	<0.0005	0.16
Count	4	4	4	4	4	4	4	4
High	8530.00	58.7	7.0	97.0	0.114	0.150	<0.0005	0.19
Low	772.00	22.1	6.7	14.0	0.029	0.029	<0.0005	0.10
Mean	3620.50	43.4	6.9	47.3	0.051	0.064	<0.0005	0.14
High Limit			8.5	218.0	1.000	1.000	0.0025	0.49
Low Limit			6.5					
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	Mn	U
	mg/L	mg/L
2019-02	0.052	0.0016
2019-05	0.029	0.0011
2019-08	0.031	0.0019
2019-11	0.041	0.0014
Count	4	4
High	0.052	0.0019
Low	0.029	0.0011
Mean	0.038	0.0015
High Limit	0.800	0.0150
Low Limit		
Lim Ex	0	0
Frequency	0%	0%
10x Lim Ex	0	0
Frequency	0%	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

Q-20 Evans Lake Outlet to Dunlop Lake

Month	FLOW L/s	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L
2019-11	4.00	39.4	7.3	19.0	0.008	0.020	<0.0005	0.02
Count	1	1	1	1	1	1	1	1
High	4.00	39.4	7.3	19.0	0.008	0.020	<0.0005	0.02
Low	4.00	39.4	7.3	19.0	0.008	0.020	<0.0005	0.02
Mean	4.00	39.4	7.3	19.0	0.008	0.020	<0.0005	0.02
High Limit			8.5	218.0	1.000	1.000	0.0025	0.49
Low Limit			6.5					
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	Mn mg/L	U mg/L
2019-11	0.017	<0.0005
Count	1	1
High	0.017	<0.0005
Low	0.017	<0.0005
Mean	0.017	<0.0005
High Limit	0.800	0.0150
LowLimit		
Lim Ex	0	0
Frequency	0%	0%
10x Lim Ex	0	0
Frequency	0%	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

SC-01 Westner Lake Outlet

Month	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L	Mn mg/L
2019-11	29.1	7.3	16.0	<0.007	0.011	<0.0005	0.10	0.037
Count	1	1	1	1	1	1	1	1
High	29.1	7.3	16.0	<0.007	0.011	<0.0005	0.10	0.037
Low	29.1	7.3	16.0	<0.007	0.011	<0.0005	0.10	0.037
Mean	29.1	7.3	16.0	<0.007	0.011	<0.0005	0.10	0.037
High Limit			218.0	1.000	1.000	0.0025	1.69	0.800
Low Limit		5.2						
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U mg/L
2019-11	<0.0005
Count	1
High	<0.0005
Low	<0.0005
Mean	<0.0005
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

SR-01 Quirke Lake Outlet

Month	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L	Mn mg/L
2019-10	36.6	7.0	25.0	0.031	0.039	<0.0005	<0.02	0.004
Count	1	1	1	1	1	1	1	1
High	36.6	7.0	25.0	0.031	0.039	<0.0005	<0.02	0.004
Low	36.6	7.0	25.0	0.031	0.039	<0.0005	<0.02	0.004
Mean	36.6	7.0	25.0	0.031	0.039	<0.0005	<0.02	0.004
High Limit		8.5	218.0	1.000	1.000	0.0025	0.49	0.800
Low Limit		6.5						
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U mg/L
2019-10	0.0011
Count	1
High	0.0011
Low	0.0011
Mean	0.0011
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

SR-06 McCabe Lake Outlet

Month	FLOW L/s	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L
2019-05	952.00	37.3	7.3	29.0	0.062	0.343	<0.0005	0.02
2019-10	655.00	36.1	7.1	27.0	0.052	0.281	<0.0005	<0.02
Count	2	2	2	2	2	2	2	2
High	952.00	37.3	7.3	29.0	0.062	0.343	<0.0005	0.02
Low	655.00	36.1	7.1	27.0	0.052	0.281	<0.0005	<0.02
Mean	803.50	36.7	7.2	28.0	0.057	0.312	<0.0005	0.02
High Limit			8.5	128.0	1.000	1.000	0.0025	0.49
Low Limit			6.5					
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	Mn mg/L	U mg/L
2019-05	0.022	0.0007
2019-10	0.016	0.0006
Count	2	2
High	0.022	0.0007
Low	0.016	0.0006
Mean	0.019	0.0006
High Limit	0.800	0.0150
Low Limit		
Lim Ex	0	0
Frequency	0%	0%
10x Lim Ex	0	0
Frequency	0%	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

SR-08 Nordic Lake Outlet

Month	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L	Mn mg/L
2019-02	198.0	6.7	150.0	0.036	0.020	<0.0005	0.02	0.063
2019-05	111.0	6.8	100.0	0.030	0.016	<0.0005	0.05	0.025
2019-08	157.0	6.9	120.0	0.025	0.016	<0.0005	0.03	0.027
2019-11	190.0	7.0	150.0	0.030	0.020	<0.0005	0.05	0.054
Count	4	4	4	4	4	4	4	4
High	198.0	7.0	150.0	0.036	0.020	<0.0005	0.05	0.063
Low	111.0	6.7	100.0	0.025	0.016	<0.0005	0.02	0.025
Mean	164.0	6.8	130.0	0.030	0.018	<0.0005	0.04	0.042
High Limit		8.5	429.0	1.000	1.000	0.0025	0.49	0.800
Low Limit		6.5						
Lim Ex	0	0	2	0	0	0	0	0
Frequency	0%	0%	50%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U mg/L
2019-02	0.0007
2019-05	0.0006
2019-08	0.0006
2019-11	0.0007
Count	4
High	0.0007
Low	0.0006
Mean	0.0006
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

SR-15 May Lake

Month	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L	Mn mg/L
2019-05	40.2	7.3	28.0	0.052	0.151	<0.0005	0.03	0.009
2019-10	37.9	7.1	26.0	0.045	0.140	<0.0005	<0.02	0.007
Count	2	2	2	2	2	2	2	2
High	40.2	7.3	28.0	0.052	0.151	<0.0005	0.03	0.009
Low	37.9	7.1	26.0	0.045	0.140	<0.0005	<0.02	0.007
Mean	39.0	7.2	27.0	0.049	0.146	<0.0005	0.02	0.008
High Limit		8.5	218.0	1.000	1.000	0.0025	0.49	0.800
Low Limit		6.5						
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U mg/L
2019-05	<0.0005
2019-10	<0.0005
Count	2
High	<0.0005
Low	<0.0005
Mean	<0.0005
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

SR-16 Fox Creek @ Hwy 108

Month	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L	Mn mg/L
2019-03	8.8	5.8	1.3	<0.007	0.008	0.0005	1.00	0.040
2019-05	4.7	5.9	1.1	<0.007	<0.005	<0.0005	0.27	0.013
2019-08	10.2	5.3	0.7	<0.007	0.008	0.0008	1.48	0.056
2019-11	6.9	6.0	1.1	<0.007	0.006	<0.0005	0.45	0.026
Count	4	4	4	4	4	4	4	4
High	10.2	6.0	1.3	<0.007	0.008	0.0008	1.48	0.056
Low	4.7	5.3	0.7	<0.007	<0.005	<0.0005	0.27	0.013
Mean	7.7	5.8	1.1	<0.007	0.007	0.0006	0.80	0.034
High Limit			128.0	1.000	1.000	0.0025	1.69	0.800
Low Limit		5.2						
Lim Ex	0	0	0	0	0	0	2	0
Frequency	0%	0%	0%	0%	0%	0%	50%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U mg/L
2019-03	<0.0005
2019-05	<0.0005
2019-08	<0.0005
2019-11	<0.0005
Count	4
High	<0.0005
Low	<0.0005
Mean	<0.0005
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

SR-17 Unnamed Creek Drain Lake 3 @ Hwy 108

Month	hard	pHF	SO4	Ra	Ba	Co	Fe	Mn
	mg/L		mg/L	Bq/L	mg/L	mg/L	mg/L	mg/L
2019-02	13.6	6.3	3.4	<0.007	0.039	0.0008	0.57	0.055
2019-05	6.2	6.3	2.6	<0.007	0.015	<0.0005	0.25	0.020
2019-08	10.9	5.5	1.4	<0.007	0.018	0.0008	1.06	0.046
2019-11	7.9	5.8	2.6	<0.007	0.013	0.0005	0.48	0.036
Count	4	4	4	4	4	4	4	4
High	13.6	6.3	3.4	<0.007	0.039	0.0008	1.06	0.055
Low	6.2	5.5	1.4	<0.007	0.013	<0.0005	0.25	0.020
Mean	9.7	6.0	2.5	<0.007	0.021	0.0006	0.59	0.039
High Limit			128.0	1.000	1.000	0.0025	1.69	0.800
Low Limit		5.2						
Lim Ex	0	0	0	0	0	0	2	0
Frequency	0%	0%	0%	0%	0%	0%	50%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U
	mg/L
2019-02	<0.0005
2019-05	<0.0005
2019-08	<0.0005
2019-11	<0.0005
Count	4
High	<0.0005
Low	<0.0005
Mean	<0.0005
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

SR-18 Jim Christ Lake Outlet

Month	hard mg/L	pHF	SO4 mg/L	Ra Bq/L	Ba mg/L	Co mg/L	Fe mg/L	Mn mg/L
2019-05	8.4	7.1	3.4	<0.007	0.050	<0.0005	0.04	0.007
2019-11	11.7	6.7	3.8	<0.007	0.051	<0.0005	0.08	0.027
Count	2	2	2	2	2	2	2	2
High	11.7	7.1	3.8	<0.007	0.051	<0.0005	0.08	0.027
Low	8.4	6.7	3.4	<0.007	0.050	<0.0005	0.04	0.007
Mean	10.1	6.9	3.6	<0.007	0.051	<0.0005	0.06	0.017
High Limit		8.5	128.0	1.000	1.000	0.0025	0.49	0.800
Low Limit		6.5						
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U mg/L
2019-05	<0.0005
2019-11	<0.0005
Count	2
High	<0.0005
Low	<0.0005
Mean	<0.0005
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

SRWMP ANNUAL WATER QUALITY REPORT 2019
Performance Monitoring Monthly Average Results 2019

SR-19 Inlet to Elliot Lake

Month	hard	pHF	SO4	Ra	Ba	Co	Fe	Mn
	mg/L		mg/L	Bq/L	mg/L	mg/L	mg/L	mg/L
2019-02	15.6	6.6	3.3	<0.007	0.024	<0.0005	0.21	0.017
2019-05	11.8	7.0	2.6	<0.007	0.019	<0.0005	0.23	0.023
2019-08	17.4	6.8	3.1	<0.007	0.028	<0.0005	0.49	0.082
2019-11	14.0	7.0	2.7	<0.007	0.019	<0.0005	0.27	0.033
Count	4	4	4	4	4	4	4	4
High	17.4	7.0	3.3	<0.007	0.028	<0.0005	0.49	0.082
Low	11.8	6.6	2.6	<0.007	0.019	<0.0005	0.21	0.017
Mean	14.7	6.8	2.9	<0.007	0.022	<0.0005	0.30	0.039
High Limit		8.5	128.0	1.000	1.000	0.0025	0.49	0.800
Low Limit		6.5						
Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%
10x Lim Ex	0	0	0	0	0	0	0	0
Frequency	0%	0%	0%	0%	0%	0%	0%	0%

Month	U
	mg/L
2019-02	<0.0005
2019-05	<0.0005
2019-08	<0.0005
2019-11	<0.0005
Count	4
High	<0.0005
Low	<0.0005
Mean	<0.0005
High Limit	0.0150
Low Limit	
Lim Ex	0
Frequency	0%
10x Lim Ex	0
Frequency	0%

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station D-4

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	128.0	1.000	0.0150	1.000	0.0025		0.800	-
	Wetland benchmark [2]	5.2						1.69		
	Lake benchmark [3]							0.49		
MDL [4]		0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.05
2015		6.9	3.9	< 0.007	< 0.0005	0.013	< 0.0005	0.03	0.017	9.3
2016		6.8	3.8	< 0.008	< 0.0005	0.013	< 0.0005	0.04	0.016	10.8
2017		6.8	3.5	< 0.007	< 0.0005	0.013	< 0.0005	0.04	0.021	9.6
2018		6.7	3.4	< 0.007	< 0.0005	0.012	< 0.0005	0.04	0.014	9.3
2019		7.0	3.3	< 0.007	< 0.0005	0.014	< 0.0005	0.04	0.018	8.9

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.
Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station SR-18

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	128.0	1.000	0.0150	1.000	0.0025		0.800	-
	Wetland benchmark [2]	5.2						1.69		
	Lake benchmark [3]							0.49		
MDL [4]		0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.50
2015		6.9	4.6	< 0.007	< 0.0005	0.048	< 0.0005	0.07	0.030	10.4
2016		7.0	4.5	< 0.008	< 0.0005	0.048	< 0.0005	0.05	0.015	11.5
2017		6.8	4.0	< 0.007	< 0.0005	0.043	< 0.0005	0.07	0.025	10.4
2018		6.8	4.5	< 0.007	< 0.0005	0.045	< 0.0005	0.04	0.011	9.9
2019		6.9	3.6	< 0.007	< 0.0005	0.051	< 0.0005	0.06	0.017	10.1

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 202016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station SR-19

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)		U (mg/L)	Ba (mg/L)	Co (mg/L)		Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	128.0		1.000	0.0150	1.000	0.0025			0.800	-
	Wetland benchmark [2]	5.2								1.69		
	Lake benchmark [3]									0.49		
MDL [4]		0.1	0.1		0.005	0.0005	0.005	0.0005		0.02	0.002	0.50
2015		7.1	4.0	<	0.007	< 0.0005	0.025	< 0.0005		0.40	0.050	18.2
2016		6.8	4.0	<	0.008	< 0.0005	0.026	< 0.0005		0.35	0.054	16.0
2017		7.0	3.0		0.008	< 0.0005	0.019	< 0.0005		0.36	0.031	14.4
2018		6.7	3.2		0.009	< 0.0005	0.025	0.0006		0.35	0.060	17.9
2019		6.8	2.9	<	0.007	< 0.0005	0.023	< 0.0005		0.30	0.039	14.7

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent. Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station SR-16

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	128.0	1.000	0.0150	1.000	0.0025		0.800	-
	Wetland benchmark [2]	5.2						1.69		
	Lake benchmark [3]							0.49		
MDL [4]		0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2015		5.6	1.1	< 0.007	< 0.0005	0.006	0.0007	0.97	0.044	7.2
2016		5.8	1.3	< 0.008	< 0.0005	0.007	0.0006	0.67	0.032	8.0
2017		5.7	1.1	< 0.007	< 0.0005	0.007	0.0007	0.94	0.038	7.4
2018		5.4	1.2	< 0.007	< 0.0005	0.008	< 0.0005	0.66	0.043	9.0
2019		5.8	1.1	< 0.007	< 0.0005	0.007	0.0006	0.80	0.034	7.7

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland/stream stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station SR-17

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	128.0	1.000	0.0150	1.000	0.0025		0.800	-
	Wetland benchmark [2]	5.2						1.69		
	Lake benchmark [3]							0.49		
MDL [4]		0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2015		5.6	2.6	< 0.007	< 0.0005	0.017	0.0010	1.11	0.061	10.2
2016		5.8	2.5	0.009	< 0.0005	0.022	0.0010	1.32	0.064	12.8
2017		5.8	2.8	0.007	< 0.0005	0.022	0.0008	0.73	0.048	11.8
2018		5.5	2.4	0.007	< 0.0005	0.027	0.0013	1.08	0.081	14.2
2019		6.0	2.5	< 0.007	< 0.0005	0.021	0.0006	0.59	0.039	9.7

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland/stream stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station D-5

YEAR		FLOW (L/s)	pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks		6.5	128.0	1.000	0.0150	1.000	0.0025		0.800	
	Wetland benchmark [2]		5.2						1.69		
	Lake benchmark [3]								0.49		
MDL [4]			0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2015		2144.3	6.9	13.8	0.057	0.0015	0.068	< 0.0005			
2016		1884.0	6.8	14.1	0.069	0.0015	0.047	< 0.0005	0.08	0.047	26.6
2017		4843.0	6.8	11.3	0.040	0.0013	0.045	< 0.0005	0.07	0.026	20.5
2018		2065.0	6.7	13.8	0.073	0.0015	0.106	< 0.0005	0.07	0.039	26.6
2019		3498.0	6.9	10.3	0.041	0.0010	0.051	< 0.0005	0.05	0.024	19.4

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and Manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station D-6

YEAR		FLOW (L/s)	pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks		6.5	309.0	1.000	0.0150	1.000	0.0025		0.800	-
	Wetland benchmark [2]		5.2						1.69		
	Lake benchmark [3]								0.49		
MDL [4]			0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2015		167.9	6.7	22.8	0.007	< 0.0005	0.017	0.0007	0.45	0.267	53.3
2016		95.3	6.6	88.8	0.011	< 0.0005	0.022	0.0013	0.54	0.458	100.9
2017		151.9	6.7	18.8 <	0.007	< 0.0005	0.013	< 0.0005	0.19	0.102	28.7
2018		129.3	6.6	34.8	0.015	< 0.0005	0.017	0.0020	**0.82**	0.481	49.0
2019		164.7	6.8	22.9	0.009	< 0.0005	0.018	0.0009	**0.82**	0.370	35.9

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland/stream stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station BSD2

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	309.0	1.000	0.0150	1.000	0.0025		0.800	-
	Wetland benchmark [2]	5.2						1.69		
	Lake benchmark [3]							0.49		
MDL [4]		0.1	0.1	0.005	0.0005	0.005		0.02	0.002	0.5
2015		6.8	21.0	< 0.007	< 0.0005	0.012	< 0.0005	0.13	0.066	26.1
2016		6.6	54.0	0.010	< 0.0005	0.017	0.0006	0.28	0.160	64.6
2017		6.7	18.0	< 0.007	< 0.0005	0.013	< 0.0005	0.17	0.099	27.2
2018		6.5	15.0	0.007	< 0.0005	0.012	< 0.0005	0.17	0.088	22.8
2019		6.9	12.4	< 0.007	< 0.0005	0.013	< 0.0005	0.17	0.074	20.1

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station FBD2

YEAR		pHF	SO4 [5] (mg/L)		Ra (Bq/L)		U (mg/L)		Ba (mg/L)		Co (mg/L)		Fe (mg/L)		Mn [5] (mg/L)		Hardness mg/L
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	309.0		1.000		0.0150		1.000		0.0025				0.800		-
	Wetland benchmark [2]	5.2												1.69			
	Lake benchmark [3]													0.49			
MDL [4]		0.1	0.1		0.005		0.0005		0.005		0.0005		0.02		0.002		0.5
2015		5.4	0.3	<	0.007	<	0.0005	<	0.005	<	0.0005	<	0.02	<	0.002		< 0.5
2016		5.7	< 0.1	<	0.008	<	0.0005	<	0.005	<	0.0005	<	0.02	<	0.002		< 0.5
2017		5.2	< 0.1	<	0.007	<	0.0005	<	0.005	<	0.0005	<	0.02	<	0.002		< 0.5
2018		5.6	< 0.1	<	0.007	<	0.0005	<	0.005	<	0.0005	<	0.02	<	0.002		< 0.5
2019		5.8	< 0.1	<	0.007	<	0.0005	<	0.005	<	0.0005	<	0.02	<	0.002		< 0.5

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station DS-18

YEAR		FLOW (L/s)	pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks		6.5	309.0	1.000	0.0150	1.000	0.0025		0.80	-
	Wetland benchmark [2]		5.2						1.69		
	Lake benchmark [3]								0.49		
MDL [4]			0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2015		126.9	7.0	94.8	0.135	0.0007	0.020	< 0.0005	0.39		93.0
2016		118.5	7.0	58.8	0.131	0.0006	0.018	< 0.0005	0.34	0.020	80.6
2017		338.7	6.8	59.8	0.193	0.0008	0.017	< 0.0005	0.60	0.037	83.5
2018		240.9	7.1	56.8	0.152	0.0008	0.021	< 0.0005	0.28	0.022	80.2
2019		248.0	7.1	43.2	0.110	0.0008	0.019	< 0.0005	0.26	0.017	78.0

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and Manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station M-01

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)		Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	218.0	1.000	0.0150	1.000	0.0025			0.800	-
	Wetland benchmark [2]	5.2							1.69		
	Lake benchmark [3]								0.49		
MDL [4]		0.1	0.1	0.005	0.0005	0.005	0.0005		0.02	0.002	0.5
2015		6.8	11.1	0.013	0.0025	0.015	<	0.0005	0.50		
2016		6.7	11.4	0.021	0.0026	0.017	<	0.0005	0.43	0.017	44.4
2017		6.8	10.0	0.016	0.0034	0.015	<	0.0005	0.58	0.070	36.3
2018		6.7	8.9	0.015	0.0020	0.015		0.0006	0.78	0.079	30.0
2019		6.7	8.4	0.017	0.0027	0.016		0.0005	0.78	0.110	31.2

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and Manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station BSR5

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	218.0	1.000	0.0050	1.000	0.0025		0.8	-
	Wetland benchmark [2]	5.2						1.69		
	Lake benchmark [3]							0.49		
MDL [4]		0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2015		6.9	11.0	0.014	0.0026	0.014	< 0.0005	0.33		
2016		6.7	13.0	0.026	0.0021	0.018	< 0.0005	0.41	0.136	38.8
2017		6.8	9.1	0.014	0.0031	0.014	< 0.0005	0.32	0.064	34.5
2018		6.8	10.1	0.018	0.0024	0.015	< 0.0005	0.43	0.084	33.1
2019		7.0	8.9	0.016	0.0023	0.014	< 0.0005	0.32	0.033	31.0

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and Manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station FBR5

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	218.0	1.000	0.0150	1.000	0.0025		0.800	-
	Wetland benchmark [2]	5.2						1.69		
	Lake benchmark [3]							0.49		
MDL [4]		0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2015		5.6	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02		
2016		5.3	< 0.1	< 0.008	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002	< 0.5
2017		5.3	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002	< 0.5
2018		5.8	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002	< 0.5
2019		6.0	< 0.1	< 0.007	< 0.0005	< 0.005	< 0.0005	< 0.02	< 0.002	< 0.5

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and Manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station Q-09

YEAR		FLOW (L/s)	pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks		6.5	218.0	1.000	0.0150	1.000			0.800	-
	Wetland benchmark [2]		5.2						1.69		
	Lake benchmark [3]								0.49		
MDL [4]			0.1	0.1	0.005	0.0005	0.005		0.02	0.002	0.5
2015		2187.75	6.8	47.8	0.069	0.0027	0.095	< 0.0005			59.0
2016		1956.25	6.6	82.3	0.077	0.0027	0.097	< 0.0005	0.08	0.034	92.8
2017		2531.30	6.7	44.8	0.052	0.0015	0.055	< 0.0005	0.17	0.036	55.6
2018		2160.00	6.7	50.5	0.100	0.0022	0.119	< 0.0005	0.37	0.102	66.6
2019		3620.00	6.9	47.3	0.051	0.0015	0.064	< 0.0005	0.14	0.038	43.5

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and Manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpr (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station Q-20

YEAR		FLOW (L/s)	pHF	SO4 [5] (mg/L)	Ra (Bq/L)		U (mg/L)		Ba (mg/L)	Co (mg/L)		Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks		6.5	218.0		1.000		0.0150	1.000				0.800	
	Wetland benchmark [2]		5.2									1.69		
	Lake benchmark [3]											0.49		
MDL [4]			0.1	0.1		0.005		0.0005	0.005			0.02	0.002	
2015		4.0	7.0	21.0	<	0.008	<	0.0005	0.018	<	0.0005			
2016		2.0	6.8	22.0	<	0.008	<	0.0005	0.020	<	0.0005	< 0.02	0.014	40.0
2017		45.0	6.9	19.0	<	0.007	<	0.0005	0.018	<	0.0005	0.04	0.030	37.1
2018		10.0	6.6	19.0	<	0.007	<	0.0005	0.019	<	0.0005	<0.02	0.025	38.2
2019		4.0	7.3	19.0		0.008	<	0.0005	0.020	<	0.0005	0.02	0.017	39.4

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and Manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station SC-01

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)		U (mg/L)		Ba (mg/L)	Co (mg/L)		Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	218.0		1.000		0.0150	1.000	0.0025			0.800	
	Wetland benchmark [2]	5.2									1.69		
	Lake benchmark [3]										0.49		
MDL [4]		0.1	0.1		0.005		0.0005	0.005	0.0005		0.02	0.002	0.5
2015		7.0	21.0	<	0.008	<	0.0005	0.010	<	0.0005	0.07		
2016		6.9	20.0	<	0.008	<	0.0005	0.010	<	0.0005	0.06	0.008	31.0
2017		6.9	16.0	<	0.007	<	0.0005	0.009	<	0.0005	0.07	0.010	26.1
2018		6.6	18.0		0.009	<	0.0005	0.011	<	0.0005	0.14	0.015	31.5
2019		7.3	16.0	<	0.007	<	0.0005	0.011	<	0.0005	0.10	0.037	29.1

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station SR-06

YEAR		FLOW (L/s)	pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks		6.5	309.0	1.000	0.0150	1.000	0.0025		0.8	
	Wetland benchmark [2]		5.2						1.69		
	Lake benchmark [3]								0.49		
MDL [4]			0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2015		276.0	7.2	46.5	0.064	0.0008	0.450	< 0.0005			
2016		494.5	6.9	39.3	0.074	0.0007	0.512	< 0.0005	0.03	0.014	53.2
2017		842.1	7.0	35.5	0.089	0.0007	0.606	< 0.0005	0.03	0.011	52.6
2018		515.8	7.0	30.2	0.100	0.0006	0.682	< 0.0005	0.05	0.011	44.7
2019		803.5	7.2	28.0	0.057	0.0006	0.312	< 0.0005	0.02	0.019	36.7

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and Manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness
Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station SR-15

YEAR		pHF	SO4[5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn[5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	128.0	1.000	0.0050	1.000	0.0025		0.8	
	Wetland benchmark [2]	5.2						1.69		
	Lake benchmark [3]							0.49		
MDL [4]		0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2016		7.0	36.5	0.049	< 0.0005	0.139	< 0.0005	< 0.02	0.005	51.8
2017		6.9	32.0	0.069	< 0.0005	0.149	< 0.0005	<0.02	0.005	52.3
2018		7.1	30.3	0.058	< 0.0005	0.213	< 0.0005	0.02	0.006	44.5
2019		7.2	27.0	0.049	< 0.0005	0.146	< 0.0005	0.02	0.008	39.0

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow,2016). Parameters are hardness dependent. Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station SR-01

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn [5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	218.0	1.000	0.0150	1.000	0.0025		0.800	-
	Wetland benchmark [2]	5.2						1.69		
	Lake benchmark [3]							0.49		
MDL [4]		0.1	0.1	0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2015		6.9	36.0	0.019	0.0014	0.039	< 0.0005			
2016		6.8	33.0	0.026	0.0013	0.036	< 0.0005	< 0.02	0.003	40.0
2017		6.9	31.0	0.028	0.0011	0.035	< 0.0005	< 0.02	0.003	38.3
2018		6.7	29.0	0.017	0.0011	0.034	< 0.0005	< 0.02	0.004	35.4
2019		7.0	25.0	0.031	0.0011	0.039	< 0.0005	< 0.02	0.004	36.6

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and Manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

Rio Algom Limited and Denison Mines Inc.
2019 Serpent River Watershed Water Quality Monitoring Results
Five Year Annual Average Station SR-08

YEAR		pHF	SO4 [5] (mg/L)	Ra (Bq/L)	U (mg/L)	Ba (mg/L)	Co (mg/L)	Fe (mg/L)	Mn[5] (mg/L)	Hardness (mg/L)
Assessment Criteria [1]	Wetland and lake benchmarks	6.5	429	1.000	0.0150	1.000	0.0025		0.800	-
	Wetland benchmark [2]	5.2						1.69		
	Lake benchmark [3]							0.49		
MDL [4]		0.1		0.005	0.0005	0.005	0.0005	0.02	0.002	0.5
2015		7.1	155.0	0.028	0.0009	0.018	< 0.0005			170.0
2016		6.8	150.0	0.029	0.0009	0.017	< 0.0005	0.05	0.033	178.5
2017		7.1	150.0	0.026	0.0009	0.017	< 0.0005	0.05	0.036	186.3
2018		6.8	137.5	0.028	0.0007	0.019	< 0.0005	0.07	0.065	184.0
2019		6.8	130.0	0.030	0.0006	0.018	< 0.0005	0.04	0.042	164.0

Notes:

[1] Assessment criteria as per Table 4.5 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[2] Benchmark applies to wetland stations: M-01, DS-18, SC-01.

[3] Benchmark applies to lake stations: D-5, D-6, Q-09, Q-20, SR-01, SR-06, SR-08.

[4] Method Detection Limits as per Table 5.2 Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016)

[5] Sulphate and Manganese criteria taken from Table B.1, Appendix B, Cycle 4 Study Design for the SRWMP, SAMP and TOMP (Minnow, 2016). Parameters are hardness dependent.

Variation in number of significant figures reflect MDL's at the time of reporting. In 2006, laboratory reported MDL's were standardized to achieve consistency and meet program requirements, as per Cycle 2 Interpretive Report (Minnow 2005).

Bold indicates exceedance of evaluation criteria value

APPENDIX VI
Interim Public Dose Estimation for the Closed
Mines of the Serpent River Watershed

INTERIM PUBLIC DOSE ESTIMATION FOR THE CLOSED MINES OF THE SERPENT RIVER WATERSHED

Report prepared for:

Rio Algom Limited
PO Box 38
Elliot Lake, Ontario
P5A 2J6

and

Denison Mines Inc.
1 Horne Walk, Suite 200
Elliot Lake, Ontario
P5A 2A5

Report prepared by:

EcoMetrix Incorporated
6800 Campobello Road
Mississauga, Ontario
L5N 2L8

16-2226
February 2018

INTERIM PUBLIC DOSE ESTIMATION FOR THE CLOSED MINES OF THE SERPENT RIVER WATERSHED

Janeen Tang, B.A.Sc.,M.E.S., P.Eng.
Project Manager and Principal Investigator

Don Hart, Ph.D.
Project Principal and Reviewer

EXECUTIVE SUMMARY

The Canadian Nuclear Safety Commission (CNSC) has asked Rio Algom Limited and Denison Mines Inc. to undertake annual reporting of radiation dose to the public associated with their closed uranium mine sites in the Serpent River Watershed. The annual dose reporting will be based on periodic updates undertaken as part of the five-year State of the Environment (SOE) reports.

This interim public dose estimation is intended to provide interim dose values for the period 2017 – 2020 when the next SOE is scheduled for completion. The intention is to estimate realistic doses for a representative person residing in the City of Elliot Lake to be included in annual Serpent River Watershed Monitoring reports effective 2017. Elliot Lake is the only lake in the watershed with an urban community. The residents of the City are potentially exposed to radioactive substances via both Elliot Lake water and recreational use of mine properties, and are considered to be the population with the greatest potential for exposure to radiation and radioactive materials from the closed mine sites.

Ingestion of drinking water from Elliot Lake, and ingestion of fish caught in this and other lakes downstream of the Tailings Management Areas (TMAs) were identified as key ingestion pathways based on upper bound public dose estimates prepared for SOE reports for the Serpent River Watershed. Radon and direct gamma pathways were identified as key pathways based on upper bound dose estimates for people walking near TMAs prepared by the CNSC.

Site-specific surveys of residents were undertaken by Rio Algom in 2016 to characterize resident exposure pathways and habits relevant to exposure, and monitoring was undertaken to characterize mine site gamma and radon fields, as well as drinking water radionuclide concentrations, to update the characterization of the levels of public exposure. This report includes the results of the 2016 site-specific surveys and monitoring programs, as well as an interim public dose estimation, based on current understanding of human receptors and key exposure pathways.

The interim monitoring program to support public dose estimation for a representative Elliot Lake resident included:

- Surveys of City of Elliot Lake residents to refine estimates of time spent on roads and trails near the TMAs and estimates of fish consumption from different lakes in the Serpent River watershed;

- Monitoring of radon and gamma on roads and trails near TMAs often used by walkers and hikers; and

- Monitoring of appropriate U-238 series radionuclides in drinking water from the City of Elliot Lake Water Treatment Plant, after treatment.

The 2016 data from these surveys and monitoring programs were used in the interim public dose estimation. Available data for radionuclides in sport fish from 2005 were also used. The sport fish data pertain to the lakes most used for fishing but should be updated.

Based on the interim public dose calculations, it may be concluded that:

- Public dose to the representative person is approximately 0.012 mSv/a, after correction for background exposure.

- This value is based on available measurements of radon and direct gamma near TMAs, and U-238 series radionuclides in treated drinking water and sport fish, as well as survey information and several assumptions for exposure factors.

The public dose estimation will next be updated as part of the 2020 State of the Environment report. Changes to the monitoring data are projected to include updated sport fish tissue analysis.

TABLE OF CONTENTS

LIST OF TABLES

1.0   INTRODUCTION

1.1   Background

The Canadian Nuclear Safety Commission (CNSC) has asked Rio Algom Limited and Denison Mines Inc. to undertake annual reporting of radiation dose to the public associated with their closed uranium mine sites in the Serpent River Watershed.

State of the Environment (SOE) reports for the watershed have focused on demonstrating upper bounds of public dose, using rather conservative assumptions for hypothetical human residents on lakes downstream of the Tailings Management Areas (TMAs). The CNSC (2002) also estimated upper bound doses from recreational use of TMAs in and around Elliot Lake, based on conservative use assumptions. Neither of these dose estimates are considered to be realistic estimates of public dose.

The intention of this report is to present a more realistic public dose for a representative person exposed to radioactivity from the closed mine properties. This will be included in annual Serpent River Watershed Monitoring reports effective 2017. The value reported in the 2017 annual report will be interim, based on the radon and gamma survey data along with two rounds of drinking water quality data collected in 2016. In the 2017, 2018 and 2019 annual reports, the interim public dose value from 2017 will continue to be reported. Updates to the public dose estimation will be included in the next State of the Environment report whose field program is scheduled for the fall of 2019.

Elliot Lake is the only lake in the watershed with an urban community. The residents of the city are potentially exposed to radioactive substances via consumption of Elliot Lake water and recreational use of mine properties, and are considered to be the population with the greatest potential for exposure to radiation and radioactive materials from the closed mine sites.

A preliminary design for a monitoring program to support public dose estimation was prepared in early 2016 (EcoMetrix, 2016). Based on this plan, site-specific surveys of residents were completed in 2016 to characterize their exposure pathways and habits relevant to exposure. Additional radiological monitoring in 2016 included radon and gamma monitoring on roads and trails near TMAs often used by walkers and hikers and radionuclide monitoring of drinking water. This information has been used in conjunction with historic fish tissue data to estimate an interim public dose for a representative resident of the City of Elliot Lake.

1.2   Objectives

The objective of this report is to document interim survey and monitoring data relevant to public exposure, and use it to derive an interim realistic public dose estimate for a representative person in the population group living near the closed mine properties in the

Serpent River watershed. It is recognized that some revisions to the estimated public dose may be appropriate once additional data become available, and these will be addressed as part of the updates to the representative public dose in the 2020 State of the Environment Report.

2.0 THE REPRESENTATIVE PERSON AND MAIN EXPOSURE PATHWAYS

2.1 The Representative Person

In estimating public dose for comparison to a dose constraint, the dose is estimated for a "representative person" with characteristics that reflect those of the group that receives the highest dose (ICRP, 2007). The representative person is equivalent to, and replaces, the "average member of the critical group" which was previously used for determining compliance with a public dose constraint (ICRP, 1986).

The critical group within which the representative person is defined must be large enough to support reliable characterization of typical habits relevant to exposure, and should be relatively homogeneous. ICRP (1986) has defined homogeneity to mean that the individual doses within the group lie substantially within a range of a factor of ten, provided that the mean is less than one-tenth of the dose limit. The preliminary survey of 300 Elliot Lake residents indicates that, of those using TMAs for walking and hiking, the use rates vary within a factor of ten. Since this is the dominant exposure pathway of dose, the Elliot Lake group was considered to be homogeneous.

The group size and homogeneity conditions imply that the representative person should not be characterized based on single individuals or households with extreme behaviors. Rather, the representative person can reflect an average across distinct practices within the group. Site-specific surveys on habits relevant to exposure should be conducted to characterize the representative person. Surveys should address the use of local food and water resources, as appropriate. The Elliot Lake survey addressed local fish consumption, as well as TMA use for walking and hiking.

In characterizing the representative person, averaging should not occur across age classes. The ICRP (2007) considers three age classes, for which intake rates and dose coefficients have been defined. Nominal ages are 1 year (age 0 to 5), 10 years (age 6-15) and adult (age 16 to 70). These age classes may be designated infant, child and adult (CSA, 2014). Since Elliot Lake is a retirement community, the adult age class is dominant, with only 10% of the population in the 0-14 age group according to the 2011 census. The preliminary survey of 300 residents indicated that only 6 out of 300 respondents had children under the age of 16 who walk or hike around the closed mine properties, and only 7 had children who eat locally caught fish. The small sample sizes make it difficult to reliably characterize TMA or local fish use rates for child or infant age groups. Therefore, only adult doses were estimated.

2.2 Main Exposure Pathways

Upper bound ingestion doses to hypothetical human residents on lakes downstream of the TMAs were estimated by EcoMetrix (2011) and included in Appendix F of the 2011 SOE

report (Minnow, 2011). While these estimates are conservative, and are not considered suitable as public dose estimates, they provide a preliminary indication of key ingestion pathways. The dose estimate for a hypothetical resident on Elliot Lake, after correction for background, was 0.0244 mSv/a. The ingestion dose estimates were based on 1.5 L/day of lake water intake, 2.92 kg/year of local fish consumption, 1 kg/year of local waterfowl (mallard) consumption and 1 kg/year of local moose meat consumption. Of the pathways considered, intake of drinking water and fish accounted for almost 99% of the incremental dose (73% from drinking water, 26% from fish). These two main exposure pathways have been included in the interim public dose calculations.

Upper bound doses arising from exposure to radon and gamma radiation while walking near TMAs were estimated by the CNSC (2002) as 0.04 and 0.06 mSv/a (incremental), respectively, based on an assumed 200 hours each year at the location of highest measured radon and gamma radiation (Lacnor and Nordic TMAs). The gamma dose estimate makes no allowance for the cover that was placed on the tailings after the gamma survey. The incremental dose from radon was estimated as 0.016 mSv/a for a person at Nordic Lake. The radon dose estimates assume full progeny ingrowth. While these estimates are overly conservative, and not suitable as public dose estimates, they suggest that radon and direct gamma pathways should be included in the public dose calculations.

The assumed water ingestion rate of 1.5 L/day (Health Canada, 1995) is an average value for adults in the general population. The water supply for Elliot Lake residents comes from Elliot Lake. Water consumption rates are physiologically driven, thus it is reasonable to apply this rate to the Elliot Lake water supply for Elliot Lake residents.

The assumed fish ingestion rate of 2.92 kg/year (8 g/day, U.S. EPA, 1997) is a value for freshwater anglers. The U.S. EPA (2011) also cites a value of 5 g/day for anglers around Lake Ontario. The assumption that all fish are taken from Elliot Lake is probably overly conservative. While Elliot Lake and other local lakes may be used, it is likely that much of the fish consumption is not of local origin. The 2016 site-specific survey has been used in the present assessment to clarify local amounts of fish consumption.

The concentrations of radionuclides in water that have been used in historical dose calculations are either measured values in Elliot Lake water, or values estimated from sediments and partition coefficients. The water quality monitoring data are often reported as "non-detects", which are values below the reporting limit. The use of water quality monitoring data for Elliot Lake means that there has been no accounting for water treatment. 2016 treated water monitoring results have been used in the present assessment for the calculation of dose from municipal drinking water.

The concentrations of radionuclides in sport fish that have been used in the dose calculations are either measured values in sport fish from Elliot Lake, or values estimated from water and bioaccumulation factors. The fish chemistry data are often reported as non-detects. Only Unat and Ra-226 have actually been measured in sport fish. Some of the bioaccumulation factors used for sport fish were estimated from forage fish values.

Measured activities in sport fish should be considered for the calculation of dose from fish ingestion.

3.0 SURVEYS AND MONITORING TO CHARACTERIZE EXPOSURE

The site-specific surveys and monitoring programs support the estimation of realistic public dose to a representative person residing in the City of Elliot Lake. Based on the main exposure pathways identified in Section 2.2, the surveys and monitoring program included the following components: surveys to refine estimates of time spent hiking at TMAs, surveys to refine estimates of fish consumed from lakes downstream of TMAs, monitoring of radon and gamma where people walk, hike or otherwise use trails and roads at TMAs, and monitoring of radionuclides in drinking water. Historic data have been used for sport fish tissue concentrations, though measured activities in sport fish will be collected as part of the 2019 biological component of the Cycle 5 State of the Environment study and a revised public dose included in the 2020 Cycle 5 State of the Environment report. The design of surveys and monitoring programs is discussed in the following sections.

3.1 Survey of Habits Relevant to Exposure

The intent of the site-specific surveys of residents is to characterize exposure pathways and habits relevant to exposure. The survey form for trail users and fishers was designed to address the following questions:

- How many hours do residents use trails and roads at the TMAs?

- How do people divide their trail use time among the TMAs?

- Where do people fish and how much fish do they consume from each lake?

- Which fish species are consumed?

The answers provided in the survey informed the estimation of public dose and the design of the monitoring programs for radon, gamma and sport fish. The survey was administered to residents of the Elliot Lake area as part of a larger community survey conducted on behalf of Rio Algom Limited by Globescan. A screening question was included at the beginning of the survey to determine whether the respondent is a resident of Elliot Lake. Data were collected from one respondent per household who responded on behalf of the entire household.

The survey questions and results are provided in Appendix A.

It is expected that most people in Elliot Lake will be on municipal water, which is drawn from Elliot Lake and treated prior to distribution. There are some homeowners and cottage owners on the lakefront, who take water directly from the lake, and Quirke Lake is the main area for development. There may also be some people who drink bottled water. In characterizing the representative Elliot Lake resident, it would be reasonable to assume

that this person drinks water from the municipal system. Surveys to investigate the frequency of use of drinking water sources other than the municipal water supply could be considered at a later date, based on information about these sources.

3.2   Measurements of Radon and Direct Gamma

The intent of the radon and direct gamma monitoring program is to characterize levels of exposure to radon and direct gamma for trail users at the TMAs.

Denison Environmental Services (DES, 2016a,b) conducted an initial monitoring program in December 2015 to measure radon and direct gamma radiation during walking surveys at the Lacnor, Milliken, Stanleigh, Quirke, Panel, Nordic, Pronto, Denison and Stanrock TMAs. In 2016, the surveys were repeated quarterly and extended to include the Buckles tailings and the Spanish American TMA. DES provided the data. The surveys were conducted quarterly to assess seasonal variability. Figures showing the location of the walking surveys are provided in **Appendix B**. The Esten Lake boat launch trail was surveyed to estimate background radiation in areas uninfluenced by TMAs. Radon decay products were collected on filter paper with an air sampling pump and then alpha radiation was measured using a scintillometer. Gamma radiation was measured using an SEI Inspector USB multi-radiation detector.

Radon was typically highest in October or December and lowest in April or July, with a maximum/minimum ratio ranging between 8 and 28. The gamma field was typically highest in July or October, but was much less variable, and was the dominant component of exposure for a walker near any TMA. The maximum/minimum ratio for the total exposure ranged between 1.1 and 1.9, and averaged 1.4. Since there was little seasonality in total exposure, it was considered acceptable to characterize TMA use on an annual basis.

3.3   Monitoring of Concentrations in Drinking Water and Fish

The intent of the monitoring program for drinking water and sport fish is to characterize levels of exposure to radionuclides through the ingestion pathway.

The water treatment plant for the City of Elliot Lake provides annual reporting on concentrations of uranium in treated water. Recent annual reports indicate that uranium concentrations in municipal drinking water were 0.172 µg/L on 31 January 2014 and 0.149 µg/L on 22 July 2015 (City of Elliot Lake, 2014, 2015). Uranium concentrations in municipal drinking water are approximately one tenth of uranium concentrations in untreated water from Elliot Lake, based on 2010 lake water quality used in the previous dose assessment for Elliot Lake (EcoMetrix, 2011).

Health Canada (2009) has suggested that the measured levels of radionuclides in the Elliot Lake water supply likely represent natural background. Although drinking water in Elliot Lake may not be different from background, monitoring of radionuclides in municipal

drinking water was completed in August 2016 and November 2016 to confirm this and provide data to support the estimation of annual public dose.

Detection limits for radionuclides in drinking water were 0.1 µg/L for U, 0.01 Bq/L for Th-230, 0.005 Bq/L for Ra-226, 0.02 Bq/L for Pb-210, and 0.005 Bq/L for Po-210. Certificates of Analysis for drinking water are provided in **Appendix C**.

Radionuclides in the Th-232 series were not detected in lake waters during the special investigation study (EcoMetrix, 2011). They were elevated in sediments relative to background only in Quirke and May lakes. Using partitioning estimates of concentrations in water, the drinking water dose from the Th-232 series contributed less than 5% of the total ingestion dose for the representative human at Elliot Lake. The analysis of Th-232 radionuclides in drinking water was not considered to be warranted because of its small contribution to total dose.

Concentrations of uranium and Ra-226 were measured in 2004 in northern pike, smallmouth bass and lake trout from lakes downstream of the TMAs (Elliot Lake, Quirke Lake and McCarthy Lake) and in reference lakes (Minnow, 2005).

As part of the 2019 update, the following radionuclides should be analyzed in sport fish: Unat, Th-230, Ra-226, Pb-210 and Po-210. Based on the results of the survey of Elliot Lake residents, fish should be collected from Elliot, Quirke and McCarthy lakes, as these were the lakes in the Serpent River watershed most used by sport fishers. Lake trout and walleye should be targeted as they were identified as the species most consumed by Elliot Lake residents; smallmouth bass and northern pike were next in order of preference, and may also be considered. Radionuclide concentrations in fish are likely to change slowly, following the gradual improvement of water quality in the lakes.

Low detection limits will be needed to obtain quantitative results for radionuclides in fish tissue. Suggested detection limits for fish tissue are: 0.001µg/g for U, 0.0001 Bq/g for Th-230, 0.0006 Bq/g for Ra-226, 0.001 Bq/g for Pb-210, and 0.0002 Bq/g for Po-210.   Prior to collecting fish tissue samples, the analytical laboratory should be consulted regarding detection limits, sample size and other sampling requirements. It may be possible to achieve lower detection limits by increasing the sample volume.

Radionuclides in the Th-232 series were not measured in sport fish during the special investigation study (EcoMetrix, 2011). They were elevated in sediments relative to background only in Quirke and May lakes. Using bioaccumulation estimates of concentrations in sport fish, the sport fish dose from the Th-232 series contributed less than 1% of the total ingestion dose for the representative human at Quirke Lake and 3% of the total ingestion dose for the representative human at May Lake. The analysis of Th-232 radionuclides in sport fish is not considered to be warranted because of its small contribution to total dose.

4.0   INTERIM ESTIMATION OF PUBLIC DOSE

4.1   Overview of Approach

The approach to public dose estimation is intended to capture the main exposure pathways for Elliot Lake residents, as discussed in Section 2.2. Those pathways are exposure to radon and direct gamma radiation while walking near TMAs, ingestion of drinking water from Elliot Lake, and ingestion of fish caught in lakes downstream of the TMAs. The approach is intended to produce a realistic dose estimate, and uses 2016 survey and monitoring data to improve the estimate. An interim dose estimation for adult residents is presented here to illustrate the approach. The adult age class is dominant in Elliot Lake, as noted in Section 2.1; therefore, only adult dose was calculated.   The use of survey and monitoring data and the assumptions made in this initial dose estimation are discussed by pathway in the following sections.

4.2   Radon and Direct Gamma Measurements

Measurements of dose from radon progeny in air and from direct gamma radiation while walking on roads and trails near the TMAs were obtained by Denison Environmental Services during four surveys in 2016 (April, July, October, December) (data provided by DES). Radon decay products were collected on filter paper with an air sampling pump and then alpha radiation was measured using a scintillometer. Gamma radiation was measured using an SEI Inspector USB multi-radiation detector. **Table 4-1** summarizes the results.

Measurements at the Esten Lake boat launch trail provide an estimate of background dose while walking in areas uninfluenced by TMAs. The Esten Lake area was chosen because it has similar environmental characteristics to the TMAs, but has no tailings nearby.

A survey of Elliot Lake residents conducted by Rio Algom Limited in 2016 (Appendix A) provides an estimate of the actual number of hours per year spent walking near TMAs for the representative person, and the proportion of that time spent at each TMA. The measured doses recorded for a nominal 200 hours per year at each TMA were adjusted for actual hours, and a weighted average dose across TMAs was calculated using the proportion of time at each TMA. The average number of hours per year walking at TMAs was 110.76 hours (2.13 hours per week) for a typical Elliot Lake resident.

The survey of Elliot Lake residents indicated that Milliken/Sheriff Creek Park was most used for walking and hiking, followed by the Quirke TMA. The use proportions for the TMAs, as reported in the survey, were adjusted up to account for the people who did not know the TMA used. The resulting proportions (45.3% Milliken, 12.6% Quirke, 9.5% Stanleigh, 9.5% Nordic, 8.4% Panel, 7.4% Denison, and 7.4% Stanrock) were used to allot the time spent walking among TMAs, making a weighted average dose from casual access at TMAs for the typical Elliot Lake resident.

Table 4.1: Radon and Direct Gamma Doses from Walking Near TMAs (2016)

Site	Route	Radon Dose (mSv/a*)	Gamma Mean Dose (mSv/a*)	Total Annual Dose (mSv/a*)	Annual Dose for TMA (mSv/a*)
Denison	William's Lake ETP to Settling Pond Berm	0.003818	0.058728	0.062545	0.04687
	TMA 1 Treatment Plant to Dam 10	0.001430	0.029773	0.031203	
Stanrock	Main Gate to Rooster Rock	0.004158	0.043343	0.047501	0.04657
	Main Gate to Dam A Gate	0.003121	0.042525	0.045646	
Lacnor	Dumbell Lake gate to Dam A	0.001476	0.060696	0.062172	0.062172
Milliken	Tailing Management Area (Sheriff Creek Sanctuary)	0.001902	0.028084	0.029986	0.029986
Stanleigh	Gate 1 to Gate 2	0.002274	0.032206	0.034480	0.053916
	Tailing Management Area	0.001935	0.071417	0.073353	
Quirke	Gate to gate	0.006848	0.041048	0.047896	0.047896
Panel	Gate 1 to peninsula	0.004803	0.066627	0.071430	0.063754
	Tailing Management Area	0.003384	0.052695	0.056079	
Nordic	Gate to past Treatment Plant	0.001451	0.063308	0.064759	0.064759
Buckles		0.001883	0.046327	0.048210	0.048210
Pronto	Gate to Treatment Plant	0.002134	0.040689	0.042822	0.04005
	Tailing Management Area	0.003638	0.03363	0.037268	
Spanish American	Tailing Management Area	0.00169	0.036063	0.037753	0.037753
Esten Lake	Esten Boat Launch trail	0.001866	0.024304	0.026170	0.026170

*Based on a radiation exposure period of 200 hours.

The casual access dose from measured radon and direct gamma radiation includes a background component. In order to calculate an incremental dose from walking near the TMAs, the dose as measured at Esten Lake must be subtracted from the dose measured at each TMA.

4.3   Radionuclides in Drinking Water and Fish

Measurements are available for some radionuclides in Elliot Lake drinking water (City of Elliot Lake, 2014, 2015), and in flesh samples from sport fish collected in lakes downstream

of the TMAs (Elliot Lake, Quirke Lake and McCarthy Lake) and in reference lakes (Minnow, 2005). Additional samples of treated drinking water were obtained by DES in August and November of 2016 and analyzed by SRC Environmental Analytical Laboratories for U-238 series radionuclides.

Based on the City of Elliot Lake measurements of uranium in treated drinking water (0.149 and 0.172 µg/L), and the two DES measurements (both <0.1 µg/L), the average uranium concentration in the treated water was 0.13 µg/L, or approximately one thirteenth of the lake water concentrations used in previous dose assessments for Elliot Lake (EcoMetrix, 2011), where uranium was 1.7 µg/L. Those concentrations included measured values for uranium and Pb-210, and detection limit values (<0.01 Bq/L) for Th-230, Ra-226 and Po-210. For the interim public dose assessment, the treated water concentration of uranium was 0.13 µg/L and the concentrations of Th-234 and Th-230 were assumed to have the same ratios to U as reported for lake water by EcoMetrix (2011). Ra-226 in treated drinking water was estimated from the uranium concentration, based on the Ra/U ratio reported by Health Canada (2009) for the Elliot Lake water supply (0.015 Bq/L Ra per µg/L U). Pb-210 and Po-210 were estimated from the Ra-226, based on the ratios for Elliot Lake water reported by EcoMetrix (2011). All the estimated radionuclide concentrations were below their limits of detection.

Health Canada (2009) has reported historical data for the Elliot Lake water supply (before treatment). The data show that concentrations of uranium and Ra-226 were relatively constant in 1995-96 when the record ends, at about 0.6 µg/L and 0.007 Bq/L respectively. The concentrations for treated water, at present, are about one third of this level.

The treated drinking water concentrations include a background component. It is unclear what the background levels are in treated water. However, Health Canada (2009) reports that concentrations in Canadian water supplies range from <0.1 to 1 µg/L for uranium, and from <0.005 to 0.02 Bq/L for Ra-226. In order to calculate an incremental dose from treated drinking water at Elliot Lake, a background uranium concentration of 0.1 µg/L was assumed, and background concentrations of other radionuclides were estimated using ratios as described above. This implies a background concentration of 0.0015 Bq/L for Ra-226, which is unlikely to be detectable. Incremental dose can be calculated by subtracting the dose based on background concentrations from the dose based on Elliot Lake concentrations.

Using this low level of background is conservative, resulting in calculation of a small incremental exposure. Health Canada (2009) has suggested that the measured levels of radionuclides in the Elliot Lake water supply likely represent natural background rather than effects from uranium mining operations.

Average measured concentrations of uranium and Ra-226 in sport fish collected in 2004 from Elliot Lake (Minnow, 2005) were used in the interim public dose assessment. These concentrations, on a fresh weight basis, were, respectively, 0.0132 mg/kg and 0.20 Bq/kg for Elliot Lake fish, 0.0144 mg/kg and 0.238 Bq/kg for Quirke Lake fish, and 0.0148 mg/kg

and 0.32 Bq/kg for McCarthy Lake fish. Concentrations of Th-230 were estimated from uranium, and concentrations of Pb-210 and Po-210 were estimated from Ra-226, using the isotope ratios that were previously found in forage fish (EcoMetrix, 2011).

The survey of Elliot Lake residents by Rio Algom Limited in 2016 indicates that Elliot Lake, Quirke Lake and McCarthy Lake are the lakes most used for local fish consumption. The use proportions for these lakes from the survey were adjusted up to account for the people who did not know the lake fished, and to include the small fraction of people who used May Lake or Nordic Lake (collectively only 4% of users who knew the lake fished). The resulting proportions (50.4% Elliot, 28.3% Quirke, and 21.2% McCarthy) were used to weight the fish flesh concentrations across lakes, making a set of average concentrations for fish taken from exposed lakes, i.e. those downstream of TMAs.

The survey information also provided an estimate of the number of meals per year of fish from lakes downstream of TMAs (Elliot, Quirke, Nordic, McCabe, May and McCarthy), and this was converted to an intake rate for the representative person.   The survey indicated an average of 7 meals per year for the typical Elliot Lake resident. For the interim dose estimate, using a meal size of 0.227 kg (fresh weight) (OMOECC, 2015), the intake rate of local fish was estimated at 1.59 kg/a.

The sport fish concentrations include a background component. Background levels were taken from sport fish collected in Dunlop Lake in 2004 (Minnow, 2005). For uranium and Ra-226, these levels were 0.01 mg/kg and 0.1 Bq/kg, respectively, on a fresh weight basis. Background concentrations for other radionuclides were estimated as described above. Incremental dose can be calculated by subtracting the dose based on background concentrations from the dose based on exposed lake concentrations in fish flesh.

4.4   Interim Public Dose Estimate

The interim public dose estimate for a representative person (adult) at Elliot Lake was calculated using radon and direct gamma measurements near TMAs, and radionuclide concentrations in treated drinking water and in sport fish flesh, as described above in Sections 4.2 and 4.3.

The casual access dose was calculated assuming 110.76 hours per year spent walking near the TMAs. The adult water intake of 1.5 L/d (Health Canada, 1995) was assumed to occur 365 days per year. This intake rate was applied to treated Elliot Lake drinking water. The adult intake of sport fish flesh from affected lakes was assumed to be 1.59 kg/year on a fresh weight basis.

Using these access and ingestion rates, the dose to human receptors was calculated as follows:

$$D_h \; = \; D_{r+g} + (C_w \bullet I_w + C_f \bullet I_f) \bullet DCF_i$$

where: D_h = human radiation dose (Sv/a)

D_{r+g} = dose from radon and gamma, with TMA-specific values weighted by proportion of local walking time spent at each TMA (Sv/a)

C_w = activity concentration in drinking water (Bq/L)

I_w = drinking water intake rate (L/a)

C_f = concentration in sport fish flesh, with lake-specific values weighted by proportion of local intake arising from each lake (Bq/kg fw)

I_f = intake of sport fish flesh from affected lakes (kg fw / a)

DCF_i = ingestion dose coefficient (Sv/Bq)

Ingestion dose coefficients were taken from ICRP Publication 72 (ICRP, 1996). The values provided by ICRP include dose contributions from progeny that may grow in over a lifetime following radionuclide ingestion. In addition, the values listed for parents and short-lived progeny have been combined to account for environmental ingrowth of progeny.

The dose limit for people (members of the public) is 1 mSv/a, as recommended in ICRP Publication 60 (ICRP, 1991). This is an incremental dose. Background radiation exposure, including natural and anthropogenic sources, is typically about 2 mSv/a (Health Canada, 2014). In addition, Health Canada (2014) has defined a dose constraint of 0.3 mSv/a as an incremental value above which dose management may be needed for naturally occurring radioactive materials. This is a conservative value which allows for exposure from other sources while still ensuring that incremental dose to a member of the public does not exceed the public dose limit.

The human doses calculated from measured radon, direct gamma, and radionuclide concentrations in affected areas include a natural background component. Therefore, the background component must be removed before comparison to the public dose limit, or to a dose constraint. The background component was estimated as described above, but using background values for radon, direct gamma and radionuclide concentrations, as described in **Sections 4.2** and **4.3.**

The interim total dose estimate, including background, as outlined in **Table 4-2**, is 0.030 mSv/a. The interim background dose estimate, as outlined in **Table 4-3**, is 0.018 mSv/a, and the incremental dose is 0.012 mSv/a. This is well below the public dose limit of 1 mSv/a, and also well below the dose constraint of 0.3 mSv/a.

Table 4.2: Estimation of Background-Inclusive Dose for a Representative Adult in Elliot Lake

Parameter	Units	U238/234	Th234+	Th230	Ra226	Rn222+	Pb210+	Po210	TOTAL
Water concentration	Bq/L	0.0032*	0.0026	0.0008	0.0020	0.0020	0.0059	0.0020	
Sport fish tissue conc.	Bq/kg (fw)	0.342#	0.169	0.099	0.237	0.024	0.430	0.624	
Ingestion rate water	L/a	547.5	547.5	547.5	547.5	547.5	547.5	547.5	
Ingestion rate fish	kg/a	1.59	1.59	1.59	1.59	1.59	1.59	1.59	
Exposure via water	Bq/a	1.75	1.41	0.42	1.07	1.07	3.20	1.07	
Exposure via fish	Bq/a	0.54	0.27	0.16	0.38	0.04	0.68	0.99	
Ingestion DCF adult	Sv/Bq	4.70E-08	3.40E-09	2.10E-07	2.80E-07	2.50E-10	6.91E-07	1.20E-06	
Dose via water	mSv/a	8.23E-05	4.80E-06	8.79E-05	2.99E-04	2.67E-07	2.21E-03	1.28E-03	3.97E-03
Dose via fish	mSv/a	2.56E-05	9.11E-07	3.31E-05	1.05E-04	9.41E-09	4.73E-04	1.19E-03	1.83E-03
Total ingestion dose	mSv/a	1.08E-04	5.72E-06	1.21E-04	4.04E-04	2.76E-07	2.69E-03	2.47E-03	5.80E-03
Casual access dose	mSv/a								2.39E-02
Total dose	mSv/a								2.97E-02

* mg/L U x 24.6 Bq/mg   # mg/kg x 24.6 Bq/mg
+ indicates that progeny contributions are included in the DCF

Table 4.3: Estimation of Background Dose for a Representative Adult

Parameter	Units	U238/234	Th234+	Th230	Ra226	Rn222+	Pb210+	Po210	TOTAL
Water concentration	Bq/L	0.0025*	0.0020	0.0006	0.0015	0.0015	0.0045	0.0015	
Sport fish tissue conc.	Bq/kg (fw)	0.246#	0.121	0.071	0.100	0.010	0.182	0.264	
Ingestion rate water	L/a	547.5	547.5	547.5	547.5	547.5	547.5	547.5	
Ingestion rate fish	kg/a	1.59	1.59	1.59	1.59	1.59	1.59	1.59	
Exposure via water	Bq/a	1.35	1.09	0.32	0.82	0.82	2.46	0.82	
Exposure via fish	Bq/a	0.39	0.19	0.11	0.16	0.02	0.29	0.42	
Ingestion DCF adult	Sv/Bq	4.70E-08	3.40E-09	2.10E-07	2.80E-07	2.50E-10	6.91E-07	1.20E-06	
Dose via water	mSv/a	6.33E-05	3.70E-06	6.76E-05	2.30E-04	2.05E-07	1.70E-03	9.86E-04	3.05E-03
Dose via fish	mSv/a	1.84E-05	6.56E-07	2.38E-05	4.45E-05	3.98E-09	2.00E-04	5.03E-04	7.90E-04
Total ingestion dose	mSv/a	8.17E-05	4.35E-06	9.15E-05	2.74E-04	2.09E-07	1.90E-03	1.49E-03	3.84E-03
Casual access dose	mSv/a								1.45E-02
Total dose	mSv/a								1.83E-02

* mg/L U x 24.6 Bq/mg   # mg/kg x 24.6 Bq/mg
+ indicates that progeny contributions are included in the DCF

5.0   CONCLUSIONS AND RECOMMENDATIONS

Based on the interim public dose calculations, it may be concluded that:

- Public dose to the representative person is approximately 0.012 mSv/a, after correction for background exposure.

- This value is based on available measurements of radon and direct gamma near TMAs, and U-238 series radionuclides in treated drinking water and sport fish, as well as critical group survey information and several assumptions for exposure factors.

The public dose estimation may be refined in the future based on information from critical group surveys and from the monitoring program.

Preliminary recommendations for the monitoring program to support future public dose estimates include:

- Prior to the next reporting cycle, update the sampling and analysis of U-238 series radionuclides in sport fish collected from lakes of the Serpent River watershed most used by sport fishers (Elliot, Quirke and McCarthy lakes); target lake trout and walleye, which were the species most consumed according to the survey of Elliot Lake residents. Smallmouth bass and northern pike were next in order of preference, and may also be used.

- In subsequent cycles, consider whether the resident survey or components of the monitoring program may need to be updated, based on possible demographic changes in the community, changes in waste management operations, or trends observed in the watershed monitoring program.

The information from the resident survey and monitoring programs is expected to be used in public dose estimation as described in Section 4.4. Public dose estimates may be revised in the future as the relevant information is updated.

6.0 REFERENCES

CNSC (Canadian Nuclear Safety Commission). 2002. Environmental Assessment Screening Report: Possession and Management of Waste Nuclear Substances Situated at Spanish American, Milliken, Lacnor, Nordic/Buckles, and Pronto Historical Properties in the Elliot Lake Area, Ontario. SENES Consultants Ltd.

CSA (Canadian Standards Association). 2014. Guidelines for Calculating Derived Release Limits for Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities. N288.1-14.

City of Elliot Lake. 2014. City of Elliot Lake Water Treatment Plant 2014 Annual Report.

City of Elliot Lake. 2015. City of Elliot Lake Water Treatment Plant 2015 Annual Report.

DES (Denison Environmental Services Inc.). 2016a. Public Radiation Dose on RAL Sites. Survey Results. Memo to File. 22 January 2016.

DES. 2016b. Public Radiation Dose on Denison Sites. Survey Results. Memo to File. 22 February 2016.

EcoMetrix (EcoMetrix Incorporated). 2011. Special Investigations 2009 – Implications for Radiological Dose and Risk Calculations. Report to Denison Mines Inc. and Rio Algom Limited.

EcoMetrix (EcoMetrix Incorporated). 2016. Preliminary Design for a Monitoring Program to Support Public Dose Estimation. Report to Rio Algom Limited and Denison Mines Inc.

Health Canada. 1995. Investigating Human Exposure to Contaminants in the Environment: A Handbook for Exposure Calculations.

Health Canada. 2009. Guidelines for Canadian Drinking Water Quality. Guideline Technical Document. Radiological Parameters. Federal-Provincial-Territorial Committee on Drinking Water. Ottawa, Ontario.

Health Canada. 2014. Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM). NORM Working Group of the Federal-Provincial Territorial radiation Protection Committee. Revise 2011.

ICRP (International Commission on Radiological Protection). 1986. Radiation Protection Principles for the Disposal of Solid Radioactive Waste. ICRP Publication 46.

ICRP. 1991. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60.

ICRP. 1996. Age-dependent Doses to Members of the Public from Intake of Radionuclides: Part 5, Compilation of Ingestion and Inhalation Coefficients. ICRP Publication 72.

ICRP. 2007. Assessing the Dose of the Representative Person for the Purpose of Radiation Protection of the Public and the Optimisation of Radiological Protection. ICRP Publication 101.

Minnow (Minnow Environmental Inc.). 2005. Serpent River Watershed Monitoring Program – 2004 Study. Prepared for Rio Algom Limited and Denison Mines Inc., Elliot Lake, Ontario.

Minnow. 2011. Serpent River Watershed State of the Environment.

Ontario Ministry of the Environment and Climate Change (OMOECC). 2015. Guide to Eating Ontario Fish. 2015-2016. 28th Edition, revised. Queen's Printer for Ontario.

U.S. EPA (U.S. Environmental Protection Agency). 1997. Exposure Factors Handbook, Vol. II, Food Ingestion Factors.

U.S. EPA. 2011. Exposure Factors Handbook: 2011 Edition. Food Ingestion Factors.

Appendix A   Questionnaire and Results for Survey of Elliot Lake Residents

q5.1t recode. How many years have you lived in the area around Elliot Lake?

Sample Size	300
Less than 1	
Column %	1
1 - 5	
Column %	8
6 - 10	
Column %	9
11 - 15	
Column %	9
16 - 20	
Column %	14
21 - 25	
Column %	8
26 - 30	
Column %	6
31 - 35	
Column %	6
36+	
Column %	37
DK/NA	
Column %	1

q5.1t_mean. How many years have you lived in the area around Elliot Lake?

Sample Size	296
Mean	29
Std. Dev.	18

Q5.2. Do you ever eat fish that was caught in local lakes - in other words, from either Elliot Lake, McCarthy Lake, May Lake, Nordic Lake or Quirke Lake?

		Meals/Year	Weighted Average Meals per Year
Sample Size	300		
Yes - at least three times a week or more			
Column %	1	156	7
Yes - around once a week on average over the year			
Column %	8	52	
Yes - about once a month on average over the year			
Column %	14	12	
Yes - a few times a year			
Column %	41	3	
No, never			
Column %	31	0	
DK/NA			
Column %	5	0	

Q5.3. Of the lakes I just mentioned, where would you say most of the local fish that you eat comes from?

		% of those that know	
Sample Size	192		
Elliot Lake			
Column %	30	48.3	50.4
McCarthy Lake			
Column %	13	20.3	21.2
McCabe Lake			
Column %	0	0.0	
May Lake			
Column %	2	3.4	omit
Nordic Lake			
Column %	1	0.8	omit
Quirke Lake			
Column %	17	27.1	28.3
DK/NA			
Column %	39		

Q5.4. What species of fish caught from local lakes would you say you eat most often?

Sample Size	192
Lake trout	
Column %	43
Brook/Speckle trout	
Column %	2
Rainbow trout	
Column %	4
Northern pike	
Column %	6
Smallmouth bass	
Column %	7
Walleye/Pickerel	
Column %	21
Splake	
Column %	1
Perch	
Column %	3
Whitefish	
Column %	1
Sturgeon	
Column %	1
Other	
Column %	13

Q5.5. Do you have any children under the age of 16 in your household that eat fish that was caught in local lakes - in other words, from either Elliot Lake, McCarthy Lake, McCabe Lake, May Lake, Nordic Lake or Quirke Lake?

Sample Size	300
Yes	
Column %	7
No	
Column %	92
DK/NA	
Column %	2

q5.7_recode. How many hours per week would you say you spend walking or hiking around the closed mine properties in the area? (this would include Quirke, Panel, Spanish American, Stanleigh, Milliken and Sheriff Creek Park, Lacnor, Nordic, Buckles, Pronto, Denison and Stanrock)

Sample Size	300
Zero	
Column %	59
1 - 5	
Column %	18
6 - 10	
Column %	7
11 - 15	
Column %	3
16 - 20	
Column %	1
21+	
Column %	1
DK/NA	
Column %	12

q5.7_mean. How many hours per week would you say you spend walking or hiking around the closed mine properties in the area...?

		Hours per Year
Sample Size	264	
Mean	2.13	110.76
Std. Dev.	5.39	

Q5.8. Considering the mine properties I just mentioned, on which one would you say you walk or hike the most?

		% of those that know
Sample Size	124	
Quirke		
Column %	10	12.6
Panel		
Column %	6	8.4
Spanish American		
Column %	0	0.0
Stanleigh		
Column %	7	9.5
Milliken / Sheriff Creek Park		
Column %	35	45.3
Lacnor		
Column %	0	0.0
Nordic		
Column %	7	9.5
Buckles		
Column %	0	0.0
Pronto		
Column %	0	0.0
Denison		
Column %	6	7.4
Stanrock		
Column %	6	7.4
DK/NA		
Column %	23	

Q5.9. Do you have any children under age 16 who spend time walking or hiking around the closed mine properties in the area...?

Sample Size	300
Yes	
Column %	6
No	
Column %	92
DK/NA	
Column %	2

Appendix B   Site Maps with Walking Surveys for Radon and Gamma

Rio Algom — Milliken Site Map

Map labels:

- 5142500 N
- 373000 E
- 376500 E
- Lake No. 10
- Strouth Lake
- DAM E
- STANLEIGH TMA
- DAM 8
- DAM A
- DAM A1
- Gate
- Penelope Lake
- GUNTERMAN TOWNSHIP
- Gate
- BERM
- Gate
- Sheriff Creek
- Sheriff Lake
- TILL PIT
- DAM
- BEAVER MOUNTAIN
- Milliken Mine Road
- Sheriff
- Parking Lot
- MILLIKEN TMA
- Sheriff Creek
- SHERIFF CREEK BERM
- Communication Tower
- Lacnor Creek
- Gate
- Dumbell Lake
- 373000 E
- 5139000 N
- MOUNT DUFOUR
- Horne Lake
- 376500 E
- 5139000 N
- Gate

SCALE

0   0.5   1.0 kms

N (compass rose) W — E / S

Legend

- vegetated tailings.
- water covered tailings.
- treatment solids.
- flow direction.
- limits of CNSC licence.
- limits of unlicenced property.
- public road.
- main access.
- secondary access.
- seasonal access.
- trail.
- public motorized trail.
- public non motorized trail.
- power line.
- dams.
- swamp.

Notes

- Produced by Torrance Surveying Ltd. under licence with the Ontario Ministry of Northern Development and Mines as well as the Ontario Ministry of Natural Resources © Queens Printer for Ontario, 2005. No endorsement by these Ministries or the Ontario Government is implied by the use of their mapping products.

- Mine structures, property limits and mapping details were derived from Rio Algom records, MNDM digital data, MNR OBM and GeoEye-1 Satelite Imagery (summer 2011).

- GeoEye-1 Satelite Imagery (2011-08-01), provided by GeoEye International.

- Mapping export parameters = NAD83 WGS_1984_ UTM_Zone_17N (Central Meridian = 81°W).

- File-Milliken OCM (Site Map).

- March 2013.

Rio Algom **Stanleigh**
Site Map

SCALE

| 0 | 0.5 | 1.0 | 2.0 kms |

N
W E
S

Legend
- vegetated tailings.
- water covered tailings.
- treatment solids.
- flow direction.
- limits of CNSC licence.
- limits of unlicenced property.
- public road.
- main access.
- secondary access.
- seasonal access.
- trail.
- public motorized trail.
- public non motorized trail.
- power line.
- dams.
- swamp.

Notes

- Produced by Torrance Surveying Ltd. under licence with the Ontario Ministry of Northern Development and Mines as well as the Ontario Ministry of Natural Resources © Queens Printer for Ontario, 2005. No endorsement by these Ministries or the Ontario Government is implied by the use of their mapping products.

- Mine structures, property limits and mapping details were derived from Rio Algom records, MNDM digital data, MNR OBM and GeoEye-1 Satelite Imagery (summer 2011).

- GeoEye-1 Satelite Imagery (2011-08-01), provided by GeoEye International.

- Mapping export parameters = NAD83 WGS_1984_ UTM_Zone_17N (Central Meridian = 81°W).

- File-Stanleigh OCM (Site Map).

- March 2013.

BOOCK TOWNSHIP
GUNTERMAN TOWNSHIP
JOUBIN TOWNSHIP

STANROCK ROAD
HWY 108
MILLIKEN MINE ROAD

STANLEIGH TMA
MILLIKEN TMA
LACNOR TMA

Mellon Lake
Rye Lake
Quirke Lake
Lake No. 3
Lake No. 4
Lake No. 5
Lake No. 6
Lake No. 7
Lake No. 8
Lake No. 9
Lake No. 10
Strouth Lake
Penelope Lake
McCabe Lake
Canyon Lake
Sheriff Lake
Wise Lake
Dumbell Lake
Elliot Lake
Home Lake

DAM 10
DAM R5
DAM R3
DAM E
DAM A
DAM A1
DAM B
DAM C
DAM 8
TMA SPILLWAY
TREATMENT PLANT
QUARRY
SETTLING POND DAM
SETTLING POND
Ditch
Gate
BERM
TILL PIT
Tower
Sheriff Creek
SHERIFF CREEK BERM

BEAVER MOUNTAIN
MOUNT DUFOUR

372000 E
379000 E
5146000 N
5139000 N

Rio Algom Quirke Site Map

BOUCK TOWNSHIP

TOWNSHIP

BEANGE

Little Quirke Lake

Duthorne Lake

Quirke Creek

OFSC Trail

HWY 639

DAM M — Gate

Johnson Creek

Boulder Barricade

River

Screen

Gate

MAIN DAM — DAM D

Cell 16N

Pond 3

Pond 2

Pond 4

DAM E

TREATMENT PLANT

SPILLWAY

DAM G

DECANT

Gravelpit Lake

DAM L

QUARRY

Cell 14

DAM K1

DAM K2

QUIRKE TMA

Cell 15

EMERGENCY SPILLWAY MAIN SPILLWAY

Cell 17

DYKE 17

DAM G2

PANEL MINE RD.

Gate

Q-23 DYKE

WEIR SPILLWAY

DYKE 14

DYKE 15

Cell 16S

DYKE 16

Cell 18

DAM J

Gate Substation

DAM I

DAM H

HWY 108

DENISON

MINE ROAD

DENISON TMA 2

Quirke Lake

Evens Lake

Lake G

SPILLWAYS

OFSC TRAIL

EVERGREEN LANE

Dunlop Lake

DUNLOP LAKE RD.

Stollery Lake

DENISON TMA 1

Dunlop Lake

BOYCHUK RD.

CINDER LAKE RD.

Cinder Lake

Marsh Lake

DUNLOP SHORES RD.

PINE POND ROAD

ROAD

SOUTH BAY

Summers

SPANISH AMERICAN TMA

STANROCK ROAD

Eye Lake

5154000 N

5147000 N

369000 E

378000 E

SCALE

0   0.5   1.0   2.0 kms

N
W — E
S

Legend

- vegetated tailings.
- water covered tailings.
- treatment sludge.
- flow direction.
- limits of licenced area.
- limits of unlicenced property.
- public road.
- main access.
- secondary access.
- seasonal access.
- trail.
- public motorized trail.
- public non motorized trail.
- other roads.
- power line.
- dams.
- swamp.

Notes

- Produced by Torrance Surveying Ltd. under Licence with the Ontario Ministry of Northern Development and Mines as well as the Ontario Ministry of Natural Resources © Queens Printer for Ontario, 2005. No endorsement by these Ministries or the Ontario Government is implied by the use of their mapping products.

- Mine structures, property limits and mapping details were derived from Rio Algom records, MNDM digital data, MNR OBM and GeoEye-1 Satelite Imagery (summer 2011).

- GeoEye-1 Satelite Imagery (2011-08-01), provided by GeoEye International.

- Mapping export parameters = NAD83 WGS_1984_ UTM_Zone_17N (Central Meridian = 81°W).

- File-Quirke OCM (Site Map).

- March 2013.

Rio Algom **Panel**
Site Map

CHANNEL Y
BERMS W1 W2
DAM K
BERM W3
DAM E
DAM B

MAIN BASIN

5153000 N
379000 E
5153000 N
384000 E

Rochester Lake
Rochester Creek

POND C

SPILLWAY
Inlet Weir
DAM D
Culvert
DAM A
POND C BERM

DAM H
CHANNEL Z

SOUTH BASIN

TREATMENT PLANT
DAM F
SPILLWAY

Gate
Panel Mine Road
BOUCK TOWNSHIP

PUHKY ISLAND
QUIRKE LAKE SENIORS PARK
Gate
Panel Creek
Gate

BUCKLES

TOWNSHIP

Rochester Creek

KNOWLES ISLAND

Quirke Lake

ROMAN ISLAND

CONECHO POINT

Teasdale Lake

5149000 N
379000 E
5149000 N
384000 E

Quirke Lake

SCALE
0   0.5   1.0   1.5 kms

N
W   E
S

Legend
- vegetated tailings.
- water covered tailings.
- treatment solids.
- flow direction.
- limits of CNSC licence.
- limits of unlicenced property.
- public road.
- main access.
- secondary access.
- seasonal access.
- trail.
- public motorized trail.
- public non motorized trail.
- power line.
- dams.
- swamp.

Notes

- Produced by Torrance Surveying Ltd. under licence with the Ontario Ministry of Northern Development and Mines as well as the Ontario Ministry of Natural Resources © Queens Printer for Ontario, 2005. No endorsement by these Ministries or the Ontario Government is implied by the use of their mapping products.

- Mine structures, property limits and mapping details were derived from Rio Algom records, MNDM digital data, MNR OBM and GeoEye-1 Satelite Imagery (summer 2011).

- GeoEye-1 Satelite Imagery (2011-08-01), provided by GeoEye International.

- Mapping export parameters = NAD83 WGS_1984_ UTM_Zone_17N (Central Meridian = 81°W).

- File-Panel OCM (Site Map).

- March 2013.
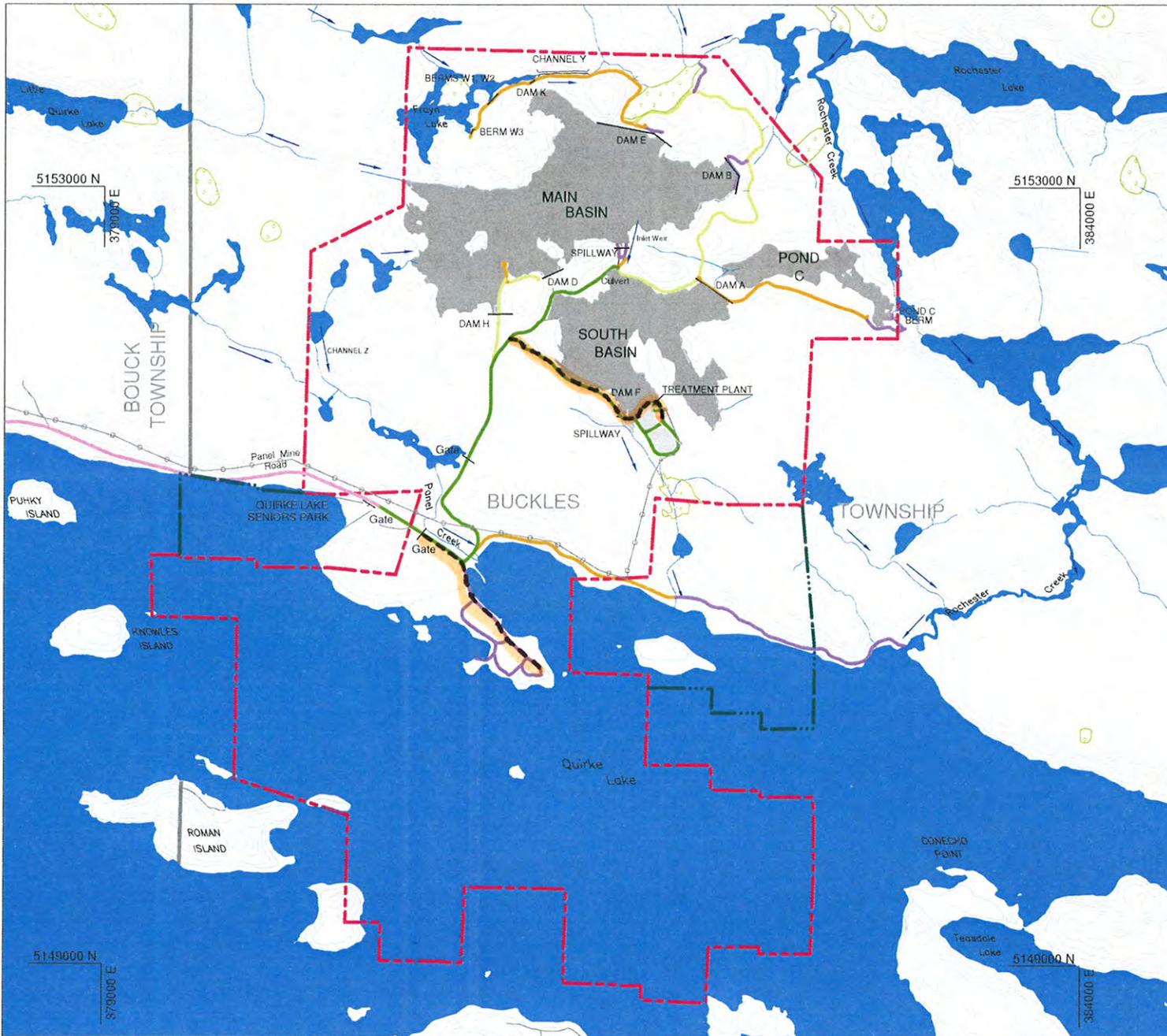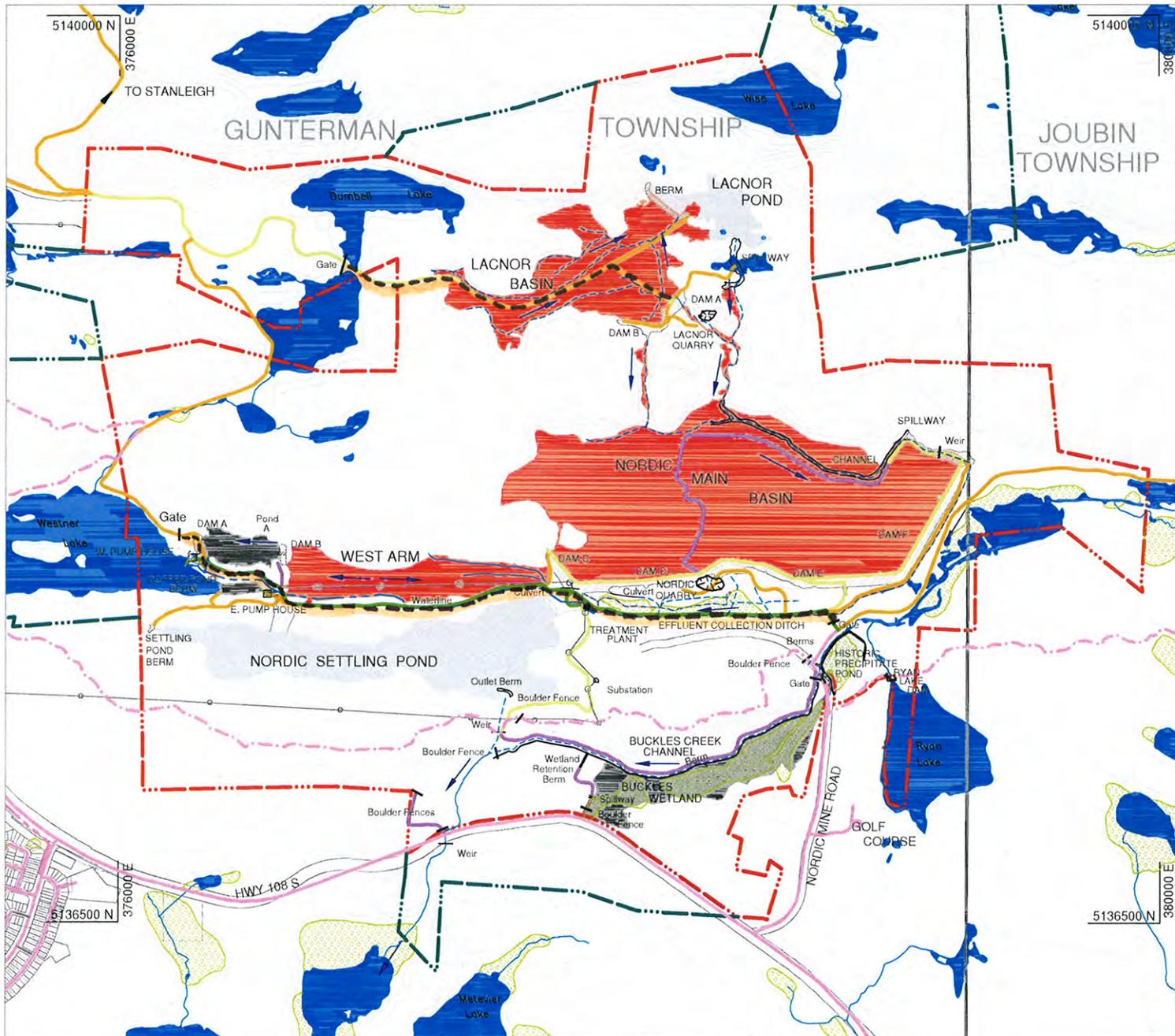
Rio Algom

Lacnor, Nordic and Buckles Site Map
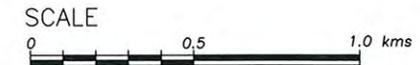
SCALE

```
0          0.5          1.0  kms
```

Legend

- vegetated tailings.
- water covered tailings.
- treatment sludge.
- flow direction.
- limits of licenced area.
- limits of unlicenced property.
- public road.
- main access.
- secondary access.
- seasonal access.
- trail.
- public motorized trail.
- public non motorized trail.
- power line.
- collection ditch or channel.
- diversion berm.
- wetlands.
- dams.

Notes

- Produced by Torrance Surveying Ltd. under Licence with the Ontario Ministry of Northern Development and Mines as well as the Ontario Ministry of Natural Resources © Queens Printer for Ontario, 2005. No endorsement by these Ministries or the Ontario Government is implied by the use of their mapping products.

- Mine structures, property limits and mapping details were derived from Rio Algom records, MNDM digital data, MNR OBM and GeoEye-1 Satelite Imagery (summer 2011).

- GeoEye-1 Satelite Imagery (2011-08-01), provided by GeoEye International.

- Mapping export parameters = NAD83 WGS_1984_ UTM_Zone_17N (Central Meridian = 81°W).

- File-LNB OCM (Site Map).

- March 2013.

Map labels:
5140000 N, 376000 E, 380000 E, 5136500 N
TO STANLEIGH
GUNTERMAN TOWNSHIP
JOUBIN TOWNSHIP
Dumbell Lake
Wise Lake
LACNOR POND
BERM
LACNOR BASIN
Gate
SPILLWAY
DAM A
DAM B
LACNOR QUARRY
NORDIC MAIN BASIN
CHANNEL
SPILLWAY
Weir
Westner Lake
Gate
DAM A
Pond A
DAM B
WEST ARM
W. PUMP HOUSE
E. PUMP HOUSE
Waterline
DAM C
DAM D
DAM E
DAM F
Culvert
Culvert
NORDIC QUARRY
TREATMENT PLANT
EFFLUENT COLLECTION DITCH
Berms
SETTLING POND BERM
NORDIC SETTLING POND
Outlet Berm
Boulder Fence
Substation
Boulder Fence
Gate
HISTORIC PRECIPITATE POND
RYAN LAKE DAM
Weir
Boulder Fence
BUCKLES CREEK CHANNEL
Berm
Wetland Retention Berm
BUCKLES WETLAND
Spillway
Boulder Fence
Boulder Fences
Ryan Lake
GOLF COURSE
NORDIC MINE ROAD
HWY 108 S
Metevier Lake
Weir

Rio Algom Pronto Site Map

SCALE

0   0.5   1.0 kms

N
W — E
S

Legend

- vegetated tailings.
- water covered tailings.
- treatment solids.
- flow direction.
- limits of CNSC licence.
- limits of unlicenced property.
- public road.
- main access.
- secondary access.
- seasonal access.
- trail.
- public motorized trail.
- public non motorized trail.
- power line.
- dams.
- swamp.

Notes

- Produced by Torrance Surveying Ltd. under Licence with the Ontario Ministry of Northern Development and Mines as well as the Ontario Ministry of Natural Resources © Queens Printer for Ontario, 2005. No endorsement by these Ministries or the Ontario Government is implied by the use of their mapping products.

- Mine structures, property limits and mapping details were derived from Rio Algom records, MNDM digital data, MNR OBM and Image-GeoEye-1 Imagery (summer 2011).

- Image-GeoEye-1 Imagery (2011-08-01), provided by GeoEye International.

- Mapping export parameters = NAD83 WGS_1984_ UTM_Zone_17N (Central Meridian = 81°W).

- File-Pronto OCM (Site Map).

- March 2013.

Map labels

5120500 N
5120500 N
LONG TOWNSHIP
SPRAGGE TOWNSHIP
Long Lake
Sploose Creek
PRONTO TMA
FRESH WATER DIVERSION DAM
LOT 4
LOT 3
LOT 2
LOT 1
SECTION 30
Lake Lauzon
WEST SPILLWAY
Gate
DAM A
QUARRY
EAST SPILLWAY
DIVERSION BERM
TP
TREATMENT PLANT
SETTLING POND
CAUSEWAY DAM
HOLDING POND
DAM D
Gate
OFSC TRAIL
CPR
CONCESSION 2
Wetkoufer Bay (Lake Lauzon)
DAM E
DAM F
OFSC TRAIL
HWY 17
McFERSON
CARMEUSSE LIME
HOSPITAL POINT
METEOR ROCK
STRONG ISLAND
FOURNIER ISLANDS
North Channel (Lake Huron)
5117000 N
5117000 N
306500 E
370500 E

QUIRKE TMA

PANEL MINE RD.

373500 E
5151000 N

378000 E
5151000 N

Benner Lake

Roman Lake

Denison House Gate

Snowmobile Gate

Fence

Mill Gate 2   Mill Gate 1   YARD #8

WILLIAMS LAKE TREATMENT PLANT

Lower Williams Lake Gate

Dam 1 Gate

SETTLING POND BERM
Spillway
D-3 Flume
D-3

LOWER WILLIAMS LAKE SETTLING POND

D-22

91-D9A

DAM 1
(UPPER WILLIAMS LAKE)

DENISON MINE

Barricade

DENISON MINE RD.

(SMITH LAKE)
Weir

Quirke Lake

TMA 2

Boulder Barricade

River

TMA2 Primary Spillway
Weir

(BARREN POND)

DAM 5 Spillway

(POND A)

(DROP BOX POND)
Weir
DIVERSION BERM

D-2 Flume
D-2

Spillway

TMA1 Spillway

TMA 2 OUTLET BERM

BOUCK TOWNSHIP

(CITY OF ELLIOT LAKE)

Stollery Lake

STOLLERY LAKE SETTLING POND

D-25 Flow Station
D-25

D-12 Flow Station
D-16

91-D1-A,B

HWY 108

Boulder Barricade

DYKE 8

TMA 1 TREATMENT PLANT
Weir
D-1

Boulder Barricade

Old Stollery Culverts

Flow Stations

91-DG4-A,B

DAM 18   SEE DETAIL

DAM 9

91-D3-A,B

Serpent

Cinder Lake Gate

DAM 10

TMA 1

DAM 17

D-9
D-9 Flow Station

Dunlop Lake

LITTLE CINDER LAKE BERM

D-6 Flow Station

Little Cinder Lake

DAM 16

Dam 17 Gate

378000 E
5148000 N

Cinder Lake

Upper Cinder Lake

373500 E
5148000 N

DETAIL
Propane Tank
Chemical Offload
Mixing Area
Stilling Well
ETP
Reagent Addition Point
V-Notch Weir
D-1 Weir
D-1
Emergency Spillway
Berm
TMA1 Main Spillway

SCALE
0   0.5   1.0 kms

SPANISH AMERICAN TMA

DENISON MINES D

Denison Mines Inc.

Denison

SAMPLE
LOCATION MAP

Rev. 2015-01
November 2015

Legend

- water covered tailings.
- settling ponds.
- surface water sample location.
- groundwater sample location.
- flow direction.
- roads or trails.
- power line.
- flow station or weir.
- pipeline.
- gate.
- wetlands.

Notes

- OBM© Queens Printer for Ontario, 2008.
- Mine structures and property limits were derived from Denison Mines records.
- Mapping export parameters = NAD83 WGS_1984_UTM Zone_17N (Central Meridian = 81°W).
- Contour Interval = 10 metres.
- File 9.3.2 (Sample Location Map).

N
W   E
S

Issued on: _____
Issued by: _____
Denison Responsible Authority

SCALE

0   0.5   1.0 kms

N
W — E
S

Notes

- OBM© Queens Printer for Ontario, 2007.

- Mine structures and property limits were derived from Denison Mines records.

- Mapping export parameters = NAD83 WGS_1984_UTM Zone_17N (Central Meridian = 81°W).

DENISON MINES

Denison Mines Inc.

Stanrock

General Site Map
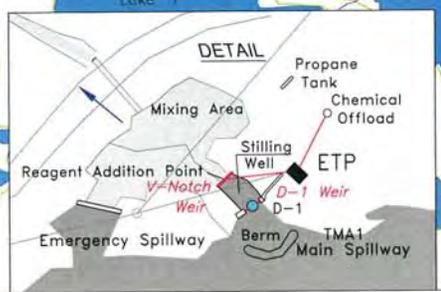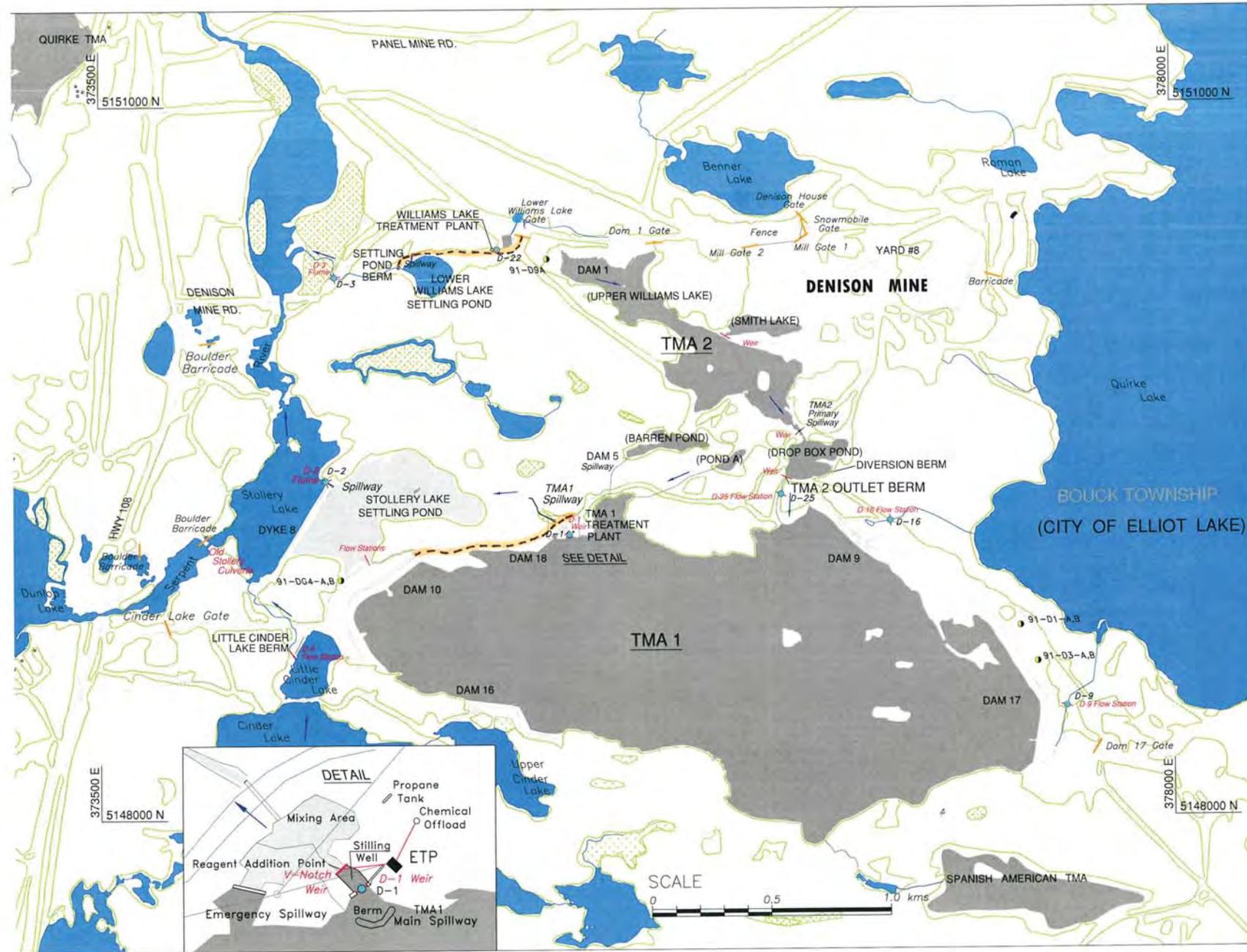
Figure 3.2.1

Rev. 2007-01
File 3.2.1

Legend

- vegetated tailings.
- collection or settling ponds.
- sealed former mine openings.
- decommissioned facilities.
- flow direction.
- limits of licenced area.
- roads or trails.
- power line.
- siphon line.
- pipeline.
- gate.
- wetlands.
- bedrock.

Issued on: _____

Issued by: _____

Denison Responsible Authority

Map labels

5149000 N
380000 E
5146000 N
380000 E
385000 E
5146000 N

#1 SHAFT
#2 SHAFT
VENT FINGER
CANMET MINE

Teasdale Lake
Quirke Lake
Ouellette Lake

VENT ADIT
#2 SHAFT
NORTH ADIT
SERVICE RAISE
VENT RAISE
#1 SHAFT
ROOSTER ROCK
STANROCK MINE
SOUTH ADIT

NELSON LAKE QUARRY
Nelson Lake
Main Gate
Canmet Gate

DAM 'B'
TMA
DAM 'C'
Dam A Gate
DAM 'A'

COLLECTION POND PUMP HOUSE
DS-12 Weir
DS-13 Weir
ST-3A Weir
DAM 'G'
DAM 'D'
HEADPOND
DS-13 Weir
Spillway

SETTLING POND
TEMPORARY TREATMENT PLANT
DS-4B Weir
ST-5 Weir
Beaver Lake Siphon Line
Dam G Pumping Line
Spillway Weir
DS-11 Weir

Quirke Lake
ST-1A Weir
Beaver Lake
DAM 'J'

HOLDING POND
TREATMENT PLANT
DAM 'L'
Spillway
Halfmoon Wetland
PROPOSED BERMS
DS-4 Weir

MOOSE LAKE SETTLING POND
DS-1 Weir
Spillway
DAM 'F'
ORIENT LAKE POLISHING POND
OUTLET BERM
Halfmoon Lake

STANROCK ROAD
DS-5 Flume
DAM 'K'
Moose Lake Gate

Moose Lake Gate
Little May Lake

BUCKLES TOWNSHIP
JOUBIN TOWNSHIP

Appendix C   Certificates of Analysis for Drinking Water

Environmental Analytical Laboratories
102 - 422 Downey Road, Saskatoon, SK Canada S7N 4N1

T: 306-933-6932 **F:** 306-933-7922
Toll-free: 1-800-240-8808
E: analytical@src.sk.ca

www.src.sk.ca/analytical

SRC Group # 2016-10582

Sep 21, 2016

Denison Environmental Services
1 Horne Walk, Suite 200
Elliot Lake, ON   P5A 2A5
 Attn: Valerie Kilp

Date Samples Received: Sep-06-2016   Client P.O.: 107732

This is a final report.

Lab Section 1 results have been authorized by Keith Gipman, Supervisor

Lab Section 2 results have been authorized by Melissa Tackaberry-Syed, Supervisor

Lab Section 3 results have been authorized by Pat Moser, Supervisor

Lab Sections 4 and 5 results have been authorized by Vicky Snook, Supervisor

Lab Section 6 results have been authorized by Marion McConnell, Supervisor

* Test methods and data are validated by the laboratory's Quality Assurance Program.

* Routine methods follow recognized procedures from sources such as

* Standard Methods for the Examination of Water and Wastewater APHA AWWA WEF
* Environment Canada
* US EPA
* CANMET

* The results reported relate only to the test samples as provided by the client.

* Samples will be kept for 30 days after the final report is sent. Please contact the lab if you have any special requirements.

* Additional information is available upon request.

Environmental Analytical Laboratories
102 - 422 Downey Road, Saskatoon, SK Canada S7N 4N1

T: 306-933-6932 **F:** 306-933-7922
Toll-free: 1-800-240-8808
E: analytical@src.sk.ca

www.src.sk.ca/analytical

SRC Group # 2016-10582

Sep 21, 2016

Denison Environmental Services

1 Horne Walk, Suite 200
Elliot Lake, ON   P5A 2A5
 Attn: Valerie Kilp

Date Samples Received: Sep-06-2016   Client P.O.: 107732

27799   08/31/2016 DWW *WATER*

Analyte	Units	27799
Lab Section 2 (ICP)		
Uranium	ug/L	<0.1
Lab Section 4 (Radiochemistry)		
Lead-210	Bq/L	<0.02
Polonium-210	Bq/L	<0.005
Radium-226	Bq/L	<0.005
Thorium-230	Bq/L	<0.01

Symbol of "<" means "less than". This indicates that it was not detected at level stated above.

Environmental Analytical Laboratories
102 - 422 Downey Road, Saskatoon, SK Canada S7N 4N1

T: 306-933-6932 **F:** 306-933-7922
Toll-free: 1-800-240-8808
E: analytical@src.sk.ca

www.src.sk.ca/analytical

SRC Group # 2016-14713

Dec 14, 2016

Denison Environmental Services
1 Horne Walk, Suite 200
Elliot Lake, ON   P5A 2A5
  Attn: Valerie Kilp

Date Samples Received: Dec-01-2016   Client P.O.: 107732

This is a final report.

Lab Section 1 results have been authorized by Keith Gipman QP, Supervisor
Lab Section 2 results have been authorized by Melissa Tackaberry-Syed QP, Supervisor
Lab Section 3 results have been authorized by Pat Moser QP, Supervisor
Lab Sections 4 and 5 results have been authorized by Vicky Snook QP, Supervisor
Lab Section 6 results have been authorized by Marion McConnell QP, Supervisor

QP: Qualified Person in accordance with the Saskatchewan Environmental Code, Corrective Action Plan Chapter, for the purposes of certifying a laboratory analysis

* Test methods and data are validated by the laboratory's Quality Assurance Program.

* Routine methods follow recognized procedures from sources such as
        * Standard Methods for the Examination of Water and Wastewater APHA AWWA WEF
        * Environment Canada
        * US EPA
        * CANMET

* The results reported relate only to the test samples as provided by the client.

* Samples will be kept for 30 days after the final report is sent. Please contact the lab if you have any special requirements.

* Additional information is available upon request.

SRC Group # 2016-14713

Dec 14, 2016

Denison Environmental Services

1 Horne Walk, Suite 200
Elliot Lake, ON   P5A 2A5
  Attn: Valerie Kilp

Date Samples Received: Dec-01-2016

Client P.O.: 107732

40387   11/29/2016 DWW *WATER*

Analyte	Units	40387
Lab Section 2 (ICP)		
Uranium	ug/L	<0.1
Lab Section 4 (Radiochemistry)		
Lead-210	Bq/L	<0.02
Polonium-210	Bq/L	<0.005
Radium-226	Bq/L	<0.005
Thorium-230	Bq/L	<0.01

Symbol of "<" means "less than". This indicates that it was not detected at level stated above.