From: Virtue,Robyn-Lynne [CEAA] **On Behalf Of** DGR Review / Examen DFGP [CEAA]
Sent: March 25, 2013 11:26 AM
To: DGR Review / Examen DFGP [CEAA]
Subject:

Hello Panel Members,

As per your request, I have attached Ontario Power Generation’s technical report titled “ Water Quality Results for the Stormwater Management Pond” which is relevant to the Information Request Response for EIS-08-394.

Thank you,
Robyn

OPG'S DEEP GEOLOGIC REPOSITORY FOR LOW & INTERMEDIATE LEVEL WASTE
WORK PACKAGE 2-12: WATER QUALITY MODELLING RESULTS FOR THE STORMWATER MANAGEMENT POND (SWMP)

Authorization

Prepared by: Date: December 18, 2012
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Approved by: <signature removed> Date: December 18, 2012
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Accepted by: <signature removed> Date: 10 Jan 2013
Richard Heystee
Area Package 2 Lead, NWMO

Title: OPG’s Deep Geologic Repository for Low & Intermediate Level Waste – WP2-12 Water Quality Modelling Results for the Stormwater Management Pond (SWMP)		
Document No.: 1011170042-TM-G2120-0014-01	**Revision:** 01	**Date:** December 18, 2012

Revision Summary		
Revision Number	**Date**	**Description of Changes/Improvements**
00	November 16, 2012	Final Issue
01	December 18, 2012	Correction to pond surface area
		Use of CCME criteria for comparison of chloride results
		Prediction of un-ionized ammonia in the SWMP for 25°C and 30°C (in addition to predictions made at 20°C) during construction and operations
		Clarification of monitoring frequency

TECHNICAL MEMORANDUM

DATE December 18, 2012 **REFERENCE No.** 1011170042-TM-G2120-00014-01

TO Richard Heystee
Nuclear Waste Management Organization (NWMO)

CC Serge Clement (TetraTech); Chuck Steed (Golder)

FROM Che McRae **EMAIL** cmcrae@golder.com

OPG'S DEEP GEOLOGIC REPOSITORY FOR LOW LEVEL AND INTERMEDIATE NUCLEAR WASTE WORK PACKAGE 2-12: WATER QUALITY MODELLING RESULTS FOR THE STORMWATER MANAGEMENT POND (SWMP)

1.0 INTRODUCTION

OPG's Deep Geologic Repository (DGR) for low and intermediate level waste will be constructed and operated in such a manner that there will be no adverse impact to the environment as a result of surface water discharge from the site. A key component of the DGR water management system is the Stormwater Management Pond (SWMP) which receives water pumped from the underground and surface water runoff from various areas on the DGR site. OPG is committed to meeting required discharge limits for the SWMP that will be developed in conjunction with the Ontario Ministry of the Environment as part of the Environmental Compliance Approval (ECA) process and other regulatory processes (e.g. Canadian Nuclear Safety Commission), that will be protective of the environment. This memorandum presents results of water quality modelling for the SWMP and associated discharge water. This memorandum also describes mitigation measures that can be used to ensure SWMP water will meet discharge limits.

This memorandum describes results of water quality modeling to predict concentration of dissolved constituents in the SWMP discharge water. Analysis of total suspended solids (TSS) and settlement within the SWMP involves a different type of modeling and is reported elsewhere (Golder 2012d). The results of the TSS assessment have been used to size the SWMP so that TSS concentrations will not exceed target concentration of 40 mg/L (see Table 6 in NWMO, 2011). For the purpose of water quality modelling it was assumed that the SWMP has an area of approximately 0.6 ha at the expected maximum operating water level.

2.0 WATER BALANCE

Water pumped from underground and surface water runoff from different areas on the DGR site will be conveyed by a system of ditches to SWMP. Figure 1 presents a conceptual diagram of flows due to underground dewatering and surface water runoff that will be sent to the pond. These two types of flows are described in more detail in the following sections.

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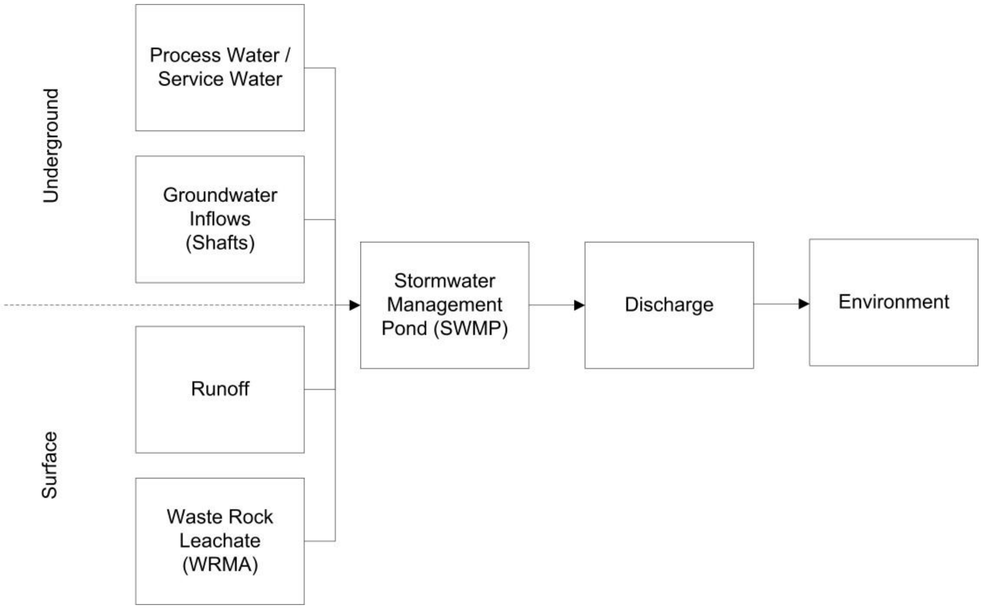

Figure 1: Conceptual Diagram of Flows into the Stormwater Management Pond (SWMP)

A detailed description of the water budget for the project has been provided in (Golder, 2012b). A summary of the flows, under average conditions is provided in Table 1.

Table 1: Summary of Average Annual Inflows to the SWMP

Component	**Construction**	**Operations**
	Flow (L/s)	Flow (L/s)
Process Water	21	—
Service Water	—	0.43
Groundwater Inflows from Shafts and Repository	0.46	0.46
Runoff from Waste Rock Piles	2.2	1.8
Runoff from Other Areas	3.5	3.8
Direct Precipitation	0.2	0.2
Total	**27**	**7**

2.1 Water from the Underground

The following is a summary of flows from the underground.

2.1.1 Groundwater Inflows from the Shafts and Repository

Groundwater, which is the water that seeps from the bedrock and into the shafts and repository, will be collected in a sump and pumped to surface. The total rate of groundwater flow entering the sumps is 0.46 L/s (Golder 2012c). Table 2 presents the expected steady-state flow of groundwater, by geological formation. For the purpose of the water quality model, it was assumed that three main zones would contribute to the groundwater flow as a total. These groupings include:

- Group 1: Overburden, Lucas, Amherstburg, Bois Blanc, Bass Islands, Salina G;
- Group 2: Salina Upper Aquitard, Salina A1 Aquifer, Salina Lower Aquitard, Guelph; and
- Group 3: Goat Island to Cobourg, Repository.

The flow contribution from these three groups is summarized in Table 2.

Table 2: Steady-State Groundwater Inflows

Group	Formation	*Flow (m^3/d)*	*Flow (L/s)*	*Combined Flow (L/s)*
Group 1	Overburden Lucas Amherstburg Bois Blanc Bass Islands Salina G	2.2	0.025	0.025
Group 2	Salina Upper Aquitard	0.02	0.0002	0.41
	Salina A1 Aquifer	29	0.34	
	Salina Lower Aquitard	1.5	0.02	
	Guelph	4.4	0.05	
Group 3	Goat Island to Cobourg	1.3	0.02	0.026
	Repository	0.5	0.006	
Totals		**39**	**0.46**	

Groundwater is expected to seep into the shaft as soon as each of the units has been intersected and will continue for the entire period of operation. For the purpose of water quality modelling, it is assumed this flow is constant for both construction and operation periods.

Estimates of groundwater inflow in Table 2 have assumed both shafts are lined with a concrete hydrostatic (or water-tight) liner to a depth of approximately 195 metres below ground surface (mBGS) or about 20 m below contact between Group 1 and 2 rock formations. The remainder of each concrete liner down to the repository horizon is assumed to be “leaky” (i.e. drain system that allows water flow through liner where it is collected on the inside shaft wall and directed to the shaft bottom via pipes). The majority (~90%) of groundwater inflow can be attributed to inflow from Salina A1 Aquifer and Guelph formations which, for the purpose of estimating inflows, were conservatively assumed to be ungrouted. Groundwater inflow could be reduced through in-shaft grouting of these formations while sinking the shafts.

2.1.2 Process Water and Service Water

Process water will be used during excavation of tunnels and emplacement rooms for drilling, dust suppression and flushing slicklines. After use, this water will be pumped to surface and discharged into a ditch leading to SWMP. Before discharging into the ditch, oil, grease and grit will be removed from the water. For the purposes of this analysis it has been assumed that process water will be pumped to surface at a constant rate of 21 L/s (Tetra Tech, 2011).

During operations, service water will be delivered underground by a pipe in Main Shaft for use primarily in the Underground Services Area and for road dust control. For the purposes of this analysis it has been assumed that some of this service water will flow back to Main Sump and will then be pumped to surface a constant rate of 0.42 L/s (Tetra Tech 2012).

2.2 Surface Flows

Pertinent to the water quality modelling, the average surface inflows into the SWMP during construction and operations are provided in Tables 3 and 4, respectively.

Table 3: Monthly and Average Annual Surface Water Flows to the Stormwater Management Pond During Construction

Month	Unit	Flow				
		Temporary Shale Stockpile	Temporary Dolostone Stockpile	Permanent Limestone Pile	Direct Precipitation onto SWMP	Runoff from Other Areas(1)
January	m³/month	468	340	4,488	331	7,828
February	m³/month	508	369	4,878	360	8,519
March	m³/month	1,007	731	9,662	893	16,627
April	m³/month	740	537	7,096	655	12,210
May	m³/month	578	419	5,544	511	9,538
June	m³/month	227	165	2,175	481	6,698
July	m³/month	199	145	1,911	424	5,900
August	m³/month	223	162	2,144	476	6,615
September	m³/month	600	435	5,755	638	10,377
October	m³/month	521	378	4,995	553	9,008
November	m³/month	488	354	4,678	518	8,434
December	m³/month	472	343	4,530	335	7,914
Year	**m³/year**	**6,030**	**4,377**	**57,854**	**6,175**	**109,667**
Average Annual	**L/s**	**0.19**	**0.14**	**1.8**	**0.20**	**3.5**

Notes:

(1) Runoff from other areas includes all areas except the stockpiles.

Table 4: Monthly and Average Annual Surface Water Flows to the Stormwater Management Pond during Operations

Month	Unit	Flow		
		Permanent Limestone Pile	Direct Precipitation onto SWMP	Runoff from Other Areas
January	m³/month	4,488	331	8,688
February	m³/month	4,878	360	9,455
March	m³/month	9,662	893	18,364
April	m³/month	7,096	655	13,487
May	m³/month	5,544	511	10,535
June	m³/month	2,175	481	7,322
July	m³/month	1,911	424	6,450
August	m³/month	2,144	476	7,232
September	m³/month	5,755	638	11,412
October	m³/month	4,995	553	9,906
November	m³/month	4,678	518	9,275
December	m³/month	4,530	335	8,784
Year	**m³/year**	**57,854**	**6,175**	**120,911**
Average Annual	**L/s**	**1.8**	**0.20**	**3.8**

Notes:

(1) Runoff from other areas includes all areas except the permanent limestone pile. The temporary shale and dolostone stockpiles that were present during construction are now included in the runoff from other areas.

Shale and dolostone waste rock will be produced during excavation of the two shafts and will be placed into stockpiles on the DGR project site. The shale and dolostone piles are temporary and these materials will likely be used for other purposes on the DGR site within one year of placement; e.g. shales may be used for constructing berms and would have a soil cap, and dolostones could be crushed and used for road bed material. If shales are not used within one year of placement, they will be covered to prevent erosion and to limit water infiltration. However for the purpose of this analysis it is conservatively assumed that the shale and dolostone will remain uncovered for duration of construction period (see Section 3.2.2.1).

The flows into the pond associated with the 25mm – 6 hour storm (the design storm) and the 24 hour storm for 2, 5, 10 and 25 year return periods have been provided in Table 5 for construction and Table 6 during operations (Golder, 2012b). These flow data were used to predict the quality of SWMP water during storm events (see Section 4.1.2)

Table 5: Inputs to the Stormwater Management Pond for Storm Events During Construction

Land Use	Drainage Areas (m²)	Runoff Volume (m³)				
		25 mm 6 hour	24 hour 2 year	24 hour 5 year	24 hour 10 year	24 hour 25 year
Temporary shale stockpile	11,005	13	74	150	209	293
Temporary dolostone stockpile	7,989	9	54	109	152	213
Permanent limestone pile	105,595	125	710	1,435	2,006	2,812
Runoff from Other Areas	165,074	771	2,536	4,350	5,666	7,429
Direct Precipitation onto SWMP	5,850	158	278	375	439	519
Total catchment	**295,513**	**1,076**	**3,652**	**6,419**	**8,472**	**11,266**

Table 6: Inputs to the Stormwater Management Pond for Storm Events During Operations

Land Use	Drainage Areas (m²)	Runoff Volume (m³)				
		25 mm 6 hour	24 hour 2 year	24 hour 5 year	24 hour 10 year	24 hour 25 year
Permanent limestone pile	105,595	125	710	1,435	2,006	2,812
Runoff from Other Areas	184,068	792	2,679	4,643	6,076	8,002
Direct Precipitation onto SWMP	5,850	158	278	375	439	519
Total catchment	**295,513**	**1,075**	**3,667**	**6,453**	**8,521**	**11,333**

3.0 WATER QUALITY INPUTS

Water qualities were assigned for each input into the SWMP. Each of the subsections below describes the assigned qualities in further detail for both underground and surface flows.

3.1 Water from the Underground

The following is a summary of the groundwater inflows from the shafts and repository as well as the process water.

3.1.1 Groundwater Inflows from the Shafts and Repository

Groundwater quality was based on the results from Intera (2010a, b). Groundwater was opportunistically sampled from four boreholes to better understand the hydrogeology and geochemistry at the Project site. Table 7 presents the borehole samples, the depths the samples were collected from and the formation sampled.

These four boreholes are located at the proposed Project site and have been used extensively to understand the subsurface conditions of the Project.

Table 7: Details of Groundwater Samples

Sample Number	Borehole	Sample Interval (mBGS)	Formation
OGW-1	DGR-1	38.72 – 47.50	Amherstburg Dolostone
OGW-2	DGR-1	77.77 – 81.05	Bois Blanc Dolostone
OGW-3	DGR-1	107.81 – 114.63	Bois Blanc Dolostone
OGW-4	DGR-1	133.64 – 142.08	Bass Island Dolostone
OGW-6	DGR-2	841.96 – 847.50	Cambrian Sandstone
OGW-7	DGR-2	843.70 – 860.70	Cambrian Sandstone
OGW-8	DGR-3	337.80 – 341.51	Salina A1 Unit
OGW-9	DGR-3	386.61 – 393.36	Guelph Formation
OWQ-10	DGR-3	851.89 – 869.17	Cambrian Sandstone
OGW-11	DGR-4	324.83 – 329.33	Salina A1
OGW-12	DGR-4	373.66 – 381.18	Guelph Formation
OGW-13	DGR-4	840.01 – 856.98	Cambrian Sandstone

The samples were grouped into the same three main rock types with respect to groundwater flow (Table 2). The 75th percentile of the concentrations for samples corresponding to these groups was calculated and chosen to represent the overall water quality for each group which is assumed to be the same during construction and operations (Tables 8 and 9 respectively). The 75th percentile was used to conservatively represent the leachate water quality from the rock.

Intera (2010a,b) and Golder (2011b) show that the connate porewater of the Group 2 and Group 3 rocks that would be encountered during shaft and repository construction is highly saline. As a result, it is expected that groundwater flowing into the shafts below approximately 175 mBGS will have an elevated total dissolved solids (TDS) concentration. Figure 2 (Golder, 2011b) presents measured TDS concentrations for samples collected from boreholes at the Project site. In Group 2 rock formations, Salina A1 and Guelph units are the primary sources of groundwater (Table 2) with an expected combined flow of 0.41 L/s. The associated TDS in groundwater for this group is expected to be approximately 370,000 mg/L. The estimated TDS concentration for Group 3 (the other units below Salina A1 and Guelph) is expected to be lower (230,000 mg/L) but little to no inflow is anticipated from this group of rocks (0.026 L/s). The TDS values for the Group 1 rock formations above the Salina A1 and Guelph units is comparatively lower with a value of 2,100 mg/L.

A combined groundwater quality comprised of the three formation groups was calculated based on the flows expected from each Group (Table 2) and the associated chemistry (Tables 8 and 9) using the formula as follows:

$$\mathrm{C}_{Combined} = \frac{(\mathrm{C}_1 \times \mathrm{F}_1) + (\mathrm{C}_2 \times \mathrm{F}_2) + (\mathrm{C}_3 \times \mathrm{F}_3)}{(\mathrm{F}_1 + \mathrm{F}_2 + \mathrm{F}_3)}$$

Where:

- $C_{combined}$ = Concentration of combined groundwater from Groups 1, 2 and 3;
- C_1 = Concentration of Group 1;

- C_2 = Concentration of Group 2;
- C_3 = Concentration of Group 3;
- F_1 = Groundwater inflow from Group 1;
- F_2 = Groundwater inflow from Group 2; and
- F_3 = Groundwater inflow from Group 3.

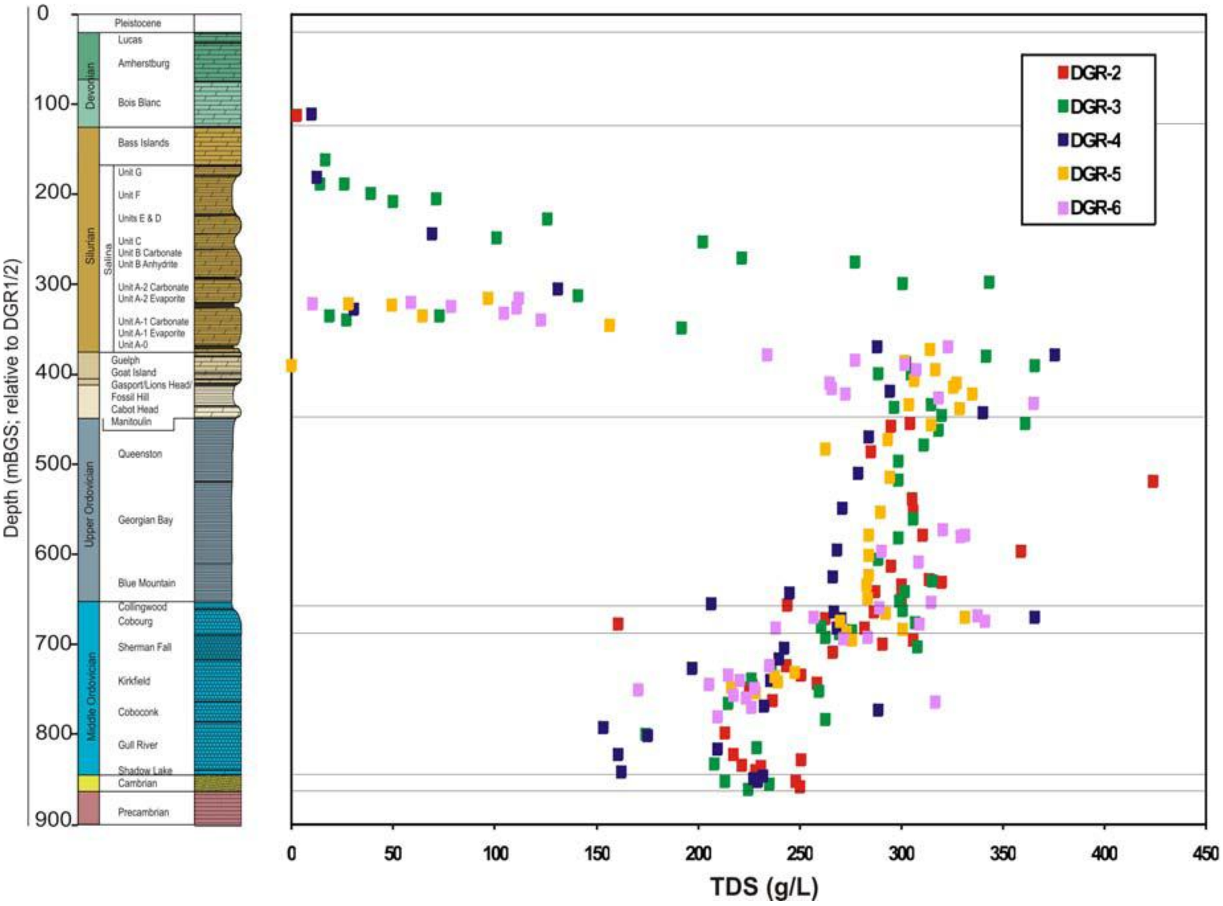

Figure 2: Total Dissolved Solids (TDS) Concentrations with Depth (from Golder 2011b).

3.1.2 Process Water and Service Water

Water from the surface will be pumped below ground and used for various purposes during construction and operations. Process and service water used during construction and operations, respectively, will be pumped to surface and discharged into an on-site ditch as described in Section 2.1.2. For the purposes of this analysis it has been assumed that process and service water will have the same quality as surface water runoff from “other areas” (see Section 3.2.1, and Tables 8 and 9) as it will be passed through a Stormceptor for treatment of grit, oil and grease. While this water will ultimately mix with the groundwater inflows from the shafts and repository, they are kept separate in the water quality model and mixed within the SWMP to be able to identify the behaviour of source terms with respect to the overall water quality.

Table 8: Input Water Quality and Associated Flows for Construction

Parameter	Unit	Surface Water Input				Underground Inputs				
		Surface Runoff from Other Areas	Waste Rock			Process Water	Groundwater			
			Temporary Dolostone Stockpile	Temporary Shale Stockpile	Permanent Limestone Pile		Group 1 (Surface to Salina G)	Group 2 (Salina A1 and Guelph)	Group 3 (Guelph and Below)	Combined Groundwater Quality (Group 1,2, 3)
Flows	L/s	3.5(1)	0.14(1)	0.19(1)	1.8(1)	21	0.025	0.41	0.026	0.46
Total Dissolved Solids	mg/L	540	2,300	3,000	580	540	2,100	370,000	230,000	340,000
Sodium	mg/L	80	240	420	90	80	50	94,000	36,000	85,000
Calcium	mg/L	80	530	440	60	80	360	32,000	40,000	31,000
Magnesium	mg/L	20	70	68	15	20	110	8,000	6,500	7,500
Potassium	mg/L	2	30	190	41	2	6	3,700	920	3,300
Strontium	mg/L	0.8	20	9.4	1.7	0.8	12	610	950	600
Iron	mg/L	0.4	0.002	0.002	0.002	0.4	0.8	50	30	40
Manganese	mg/L	0.06	0.009	0.08	0.002	0.06	—	5	15	5
Chloride	mg/L	—	790	1,700	330	—	23	230,000	150,000	210,000
Bromide	mg/L	—	—	—	—	—	3	1,800	1,500	1,700
Fluoride	mg/L	—	—	—	—	—	1	2	1	2
Sulphate	mg/L	—	600	130	26	—	1,400	3,600	400	3,300
Nitrate (as nitrogen)	mg/L	—	25	25	25	—	1	6	5	5
Ammonia (as nitrogen)	mg/L	0.06	25	25	25	0.06	—	—	—	—
Aluminum	mg/L	0.06	0.05	0.01	0.08	0.06	0.02	50	0.6	45
Arsenic	mg/L	0.001	0.004	0.01	0.002	0.001	0.002	1	0.7	1
Boron	mg/L	0.02	0.6	1	0.5	0.02	—	20	4	20
Cadmium	mg/L	0.0001	0.000003	0.000003	0.000003	0.0001	0.00009	0.004	0.003	0.004
Cobalt	mg/L	0.0005	0.0007	0.001	0.0001	0.0005	0.0006	0.04	0.03	0.03
Chromium	mg/L	0.005	0.0005	0.0005	0.0005	0.005	0.0006	0.7	0.05	0.6
Copper	mg/L	0.002	0.001	0.001	0.0005	0.002	0.0006	7	0.1	6
Molybdenum	mg/L	0.001	0.003	0.003	0.005	0.001	0.02	0.06	0.02	0.06
Nickel	mg/L	0.001	0.005	0.004	0.0009	0.001	0.02	0.2	0.3	0.2
Lead	mg/L	0.0005	0.00002	0.00002	0.00002	0.0005	0.0004	0.07	0.02	0.07
Thallium	mg/L	0.00005	0.0001	0.0004	0.00007	0.00005	0.00003	0.003	0.002	0.002
Vanadium	mg/L	0.001	0.005	0.0003	0.0009	0.001	0.007	0.003	0.003	0.003
Zinc	mg/L	0.03	0.001	0.002	0.001	0.03	0.1	3	0.5	3

Notes:

See 1011170042-CAL-G2120-0011-00 for details on how inputs were calculated from source data.

(1) Average annual values converted to L/s are presented. See Table 5 for storm events.

Table 9: Input Water Quality and Associated Flows for Operations

Parameter (mg/L)	Unit	Surface Water		Underground Inputs				
			Waste Rock		Groundwater			
		Surface Runoff from Other Areas	Permanent Limestone Pile	Service Water	Group 1 (Surface to Salina G)	Group 2 (Salina A1 and Guelph)	Group 3 (Guelph and Below)	Combined Groundwater Quality (Group 1,2, 3)
Flow	L/s	3.8(1)	1.8(1)	0.43	0.025	0.41	0.026	0.46
Total Dissolved Solids	mg/L	540	580	540	2,100	370,000	230,000	340,000
Sodium	mg/L	80	90	80	50	94,000	36,000	85,000
Calcium	mg/L	80	60	80	360	32,000	40,000	31,000
Magnesium	mg/L	20	15	20	110	8,000	6,500	7,500
Potassium	mg/L	2	41	2	6	3,700	920	3,300
Strontium	mg/L	0.8	1.7	0.8	12	610	950	600
Iron	mg/L	0.4	0.002	0.4	0.8	50	30	40
Manganese	mg/L	0.06	0.002	0.06	—	5	15	5
Chloride	mg/L	—	330	—	23	230,000	150,000	210,000
Bromide	mg/L	—	—	—	3	1,800	1,500	1,700
Fluoride	mg/L	—	—	—	1	2	1	2
Sulphate	mg/L	—	26	—	1,400	3,600	400	3,300
Nitrate (as nitrogen)	mg/L	—	25	—	1	6	5	5
Ammonia (as nitrogen)	mg/L	0.06	25	0.06	—	—	—	—
Aluminum	mg/L	0.06	0.08	0.06	0.02	50	0.6	45
Arsenic	mg/L	0.001	0.002	0.001	0.002	1	0.7	1
Boron	mg/L	0.02	0.5	0.02	—	20	4	20
Cadmium	mg/L	0.0001	0.000003	0.0001	0.00009	0.004	0.003	0.004
Cobalt	mg/L	0.0005	0.0001	0.0005	0.0006	0.04	0.03	0.03
Chromium	mg/L	0.005	0.0005	0.005	0.0006	0.7	0.05	0.6
Copper	mg/L	0.002	0.0005	0.002	0.0006	7	0.1	6
Molybdenum	mg/L	0.001	0.005	0.001	0.02	0.06	0.02	0.06
Nickel	mg/L	0.001	0.0009	0.001	0.02	0.2	0.3	0.2
Lead	mg/L	0.0005	0.00002	0.0005	0.0004	0.07	0.02	0.07
Thallium	mg/L	0.00005	0.00007	0.00005	0.00003	0.003	0.002	0.002
Vanadium	mg/L	0.001	0.0009	0.001	0.007	0.003	0.003	0.003
Zinc	mg/L	0.03	0.001	0.03	0.1	3	0.5	3

Notes:

See 1011170042-CAL-G2120-0011-00 for details on how inputs were calculated from source data.

(1) Average annual values converted to L/s are presented. See Table 6 for storm events.

3.2 Surface Water

3.2.1 Surface Runoff From Other Areas

Surface water runoff will enter the SWMP from areas that are not affected by the Waste Rock Management Area (WRMA) or other site activities. Essentially, the quality of this water would be the same as the existing water quality. The average water quality from samples collected at locations SW1, SW2, SW3, SW4 and SW5 during baseline data collection was used to represent site runoff from other areas. The average quality is provided in Tables 8 and 9 for construction and operations respectively. The data and sample locations were obtained from Golder (2011c). Note that the quality of runoff from other areas, for these two phases, remains constant and is not expected change between the construction and operations phases.

3.2.2 Runoff from Waste Rock Piles

Precipitation that falls on the waste rock will interact with the waste rock in two ways. Minerals in the rock will dissolve into the water as will nitrogen compounds from residual explosives. Both processes and a description of the assumed input water qualities are discussed below.

3.2.2.1 Metal Leaching

Geochemical testing was performed on rock samples collected from drill core (Golder 2011a). The rock is not expected to generate acidity. Short-term leach testing was also performed to characterize the quality of water that would come into contact with the rocks that will be brought to surface during the construction. The three main groups of rock expected to be brought to and stored on surface and their associated tonnages (Golder, 2012a) are as follows:

- Dolostones – 92,500 tonnes;
- Shales – 57,500 tonnes; and
- Limestone – 1,735,050 tonnes.

The results of short-term leach testing are commonly used as a qualitative screening tool to identify elements that may be soluble. However, the results of these leachates will not directly correlate to operational site conditions because the laboratory tests are characterized by a high degree of contact between the liquid and solid test charge, which may not exist under site specific conditions. As such, the concentrations observed from the laboratory testing are expected to be higher than those observed in the field. In addition, as the rock is not dominated by sulphide minerals, the concentrations are not expected to change appreciably over time, resulting in relatively constant leaching rates from the waste rock pile.

Tables 8 and 9 provide the water quality used to represent the leaching of the waste rock piles during construction and operations. The 75th percentile of the short-term leachate concentrations for each rock type was used to represent the quality of water draining from the temporary and permanent stockpiles in the WRMA. The 75th percentile was used to conservatively represent the leachate water quality from the rock. The short-term leach results are provided in Golder (2011a).

During construction, it is assumed that all three waste rock piles are stored at surface. However, during operations, it is assumed that the dolostones and shales will have been used elsewhere on site and removed from the WRMA or covered, leaving only the limestones contributing to potential metal leaching.

3.2.2.2 Explosives

During construction of the shafts and repository, explosives will be used. An ammonium nitrate fuel-oil (ANFO) and emulsion blend will used and both contain nitrogen compounds. Blasting residues will remain on the waste rock and will dissolve into water. The amount of nitrogen compounds (i.e., nitrate and ammonia) that will dissolve in water is highly dependant on the type of explosive used, the rate of usage and handling practices. A proportion of ammonia will be converted to un-ionized ammonia, depending on the pH and temperature. High concentrations of un-ionized ammonia are particularly toxic to aquatic life. Given all of the uncertainties, the following assumptions were used to predict the concentration of nitrate, ammonia and un-ionized ammonia in the SWMP:

- Powder factor conservatively chosen as 2.0 kg/m^3, which is the highest value of the range given (1.4 to 2.0 kg/m^3) (OPG, 2012);
- ANFO / Emulsion ratio of 30% / 70%;
- Amount of residual explosive (i.e., not consumed in the blast) that dissolves completely into water is 5%; and
- Assumed conditions in the pond include a pH of 8 and a temperature range of 20°C, 25°C and 30°C to span the expected conditions in the pond during summer (higher pond temperatures would result in higher un-ionized ammonia concentrations).

An estimate of the cumulative tonnages of rock expected during construction is provided in Figure 3. During the first 3 years of construction, relatively small amounts of waste rock will be placed at surface. Not until year 4, when lateral excavation begins in the repository, are large tonnages brought to and stored at surface. The estimated tonnages from years 4 to 7 are presented in Golder (2012a). Tonnages from years 1 to 3 are based on estimated volumes of the dolostones and shales (Hatch 2010), an assumed specific gravity of 2.69 (Golder 2012a) and a constant rate of excavation over the 3 years.

It was assumed that each year, all nitrogen compounds are flushed from the mass of rock placed in the WRMA To be conservative, the year with the highest tonnage of rock was chosen to reflect the largest nitrogen loadings to the SWMP. This is predicted to occur in year 6 when 650,000 tonnes of rock will be placed in the WRMA area (Golder, 2012a). To calculate an annual average loading rate, the Year 6 tonnage of rock was assumed to come into contact with the total annual average precipitation of 68,261 m^3 (Table 3) expected in the WRMA during construction (i.e., total annual average flows from the temporary shale and dolostone stockpile as well as the permanent limestone pile). It is assumed that the residual explosives will have been flushed from the waste rock piles early in the operations phase.

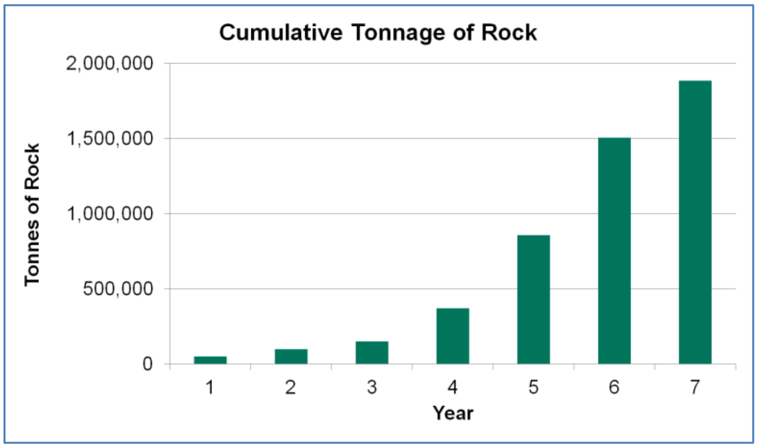

Figure 3: Cumulative Tonnages of rock Excavated During Construction

4.0 RESULTS

Modelling results are provided in the following sections for construction and operations phases. The results were calculated by the following formula:

$$C_x = \frac{\sum_{i=n}^{n} c_1 q_1 + c_{i+1} q_{i+1} + \ldots + c_n q_n}{\sum_{i=n}^{n} q_1 + q_{i+1} + \ldots + q_n}$$

where:

C_x = predicted concentration (mg/L) in the SWMP;

c_i = concentration of input source "i" (mg/L);

q_i = flow rate of input source '*i*' (L/s); and

n = number of input sources.

Detailed calculations can be found in 1011170042-CAL-G2120-0011-00 (Golder 2012f) and the results are summarized in Tables 10, 11 and 12.

The results are compared to the Provincial Water Quality Objectives (PWQOs) (MOEE, 1994), with the exception of chloride and nitrate. There are no PWQO criteria for chloride or nitrate. As such a criterion of 120 mg/L for chloride and 13 mg/L for nitrate was selected from the Canadian Water Quality Guidelines for the Protection of Aquatic Life (CCME 2012). This comparison to criteria is meant to provide context with respect to the predicated water quality and is not meant to be reflective of values that would be used as compliance standards for effluent quality.

Salinity and elevated metal concentrations from groundwater inflow to two shafts and nitrogen compounds due to leaching of blasting residues on waste rock have been identified as potential contaminants of concern in SWMP discharge water. To help ensure salinity and nitrogen compound concentrations are below discharge limits for SWMP, in-design mitigation measures are proposed (Section 4.3.1). In the remote event that in-design mitigation measures are not effective, then contingency water treatment options have been identified (Section 4.3.2). Section 4.3.3 provides new water quality estimates assuming successful mitigation measures are in place.

Given that the receiving ditches can be dry for periods of time, it was conservatively assumed that the quality of the SWMP water was the same expected in the downstream ditches (i.e., receiving environment).

4.1 Construction

The results of predicted water quality during construction for average flow and storm flow conditions are presented in Table 10. The sections below describe the results for these two conditions.

4.1.1 Average Flow Conditions

The concentrations of the aluminum, arsenic, boron, chloride, chromium, cobalt, copper, iron, and zinc are greater than the criteria (Table 10). It should be noted that for the metals iron, chromium and zinc the baseline concentrations are already greater than the criteria (Table 8). The TDS concentration is estimated at 6,500 mg/L

Table 10: Predicted Construction Water Quality in the SWMP and Assumed Discharge Quality – Without Mitigation

Parameter	Unit	Criteria	Average Conditions	25mm 6 hour storm	24 hour 2 year storm	24 hour 5 year storm	24 hour 10 year storm	24 hour 25 year storm
Total Dissolved Solids	mg/L	—	6,500	2,700	3,100	2,200	1,900	1,600
Sodium	mg/L	—	1,600	640	700	500	420	350
Calcium	mg/L	—	620	280	300	230	200	180
Magnesium	mg/L	—	150	70	80	60	50	40
Potassium	mg/L	—	70	30	30	30	30	25
Strontium	mg/L	—	10	5	6	4	4	3
Iron	mg/L	0.3	**1**	**0.6**	**0.6**	**0.5**	**0.5**	**0.4**
Manganese	mg/L	—	0.1	0.08	0.08	0.07	0.06	0.06
Chloride	mg/L	120(1)	**3,700**	**1,400**	**1,600**	**1,100**	**930**	**760**
Bromide	mg/L	—	30	10	10	8	6	5
Fluoride	mg/L	—	0.03	0.01	0.01	0.008	0.006	0.005
Sulphate	mg/L	—	60	30	40	30	30	30
Nitrate (as nitrogen)	mg/L	13(1)	2	3	4	5	6	6
Ammonia (as nitrogen)	mg/L	—	2	3	4	5	6	6
Un-ionized ammonia(2a)	mg/L	0.02	**0.08**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**
Un-ionized ammonia(2b)	mg/L	0.02	**0.1**	**0.1**	**0.2**	**0.3**	**0.3**	**0.3**
Un-ionized ammonia(2c)	mg/L	0.02	**0.2**	**0.2**	**0.3**	**0.4**	**0.4**	**0.5**
Aluminum	mg/L	0.075(3)	**0.9**	**0.4**	**0.4**	**0.3**	**0.2**	**0.2**
Arsenic	mg/L	0.005	**0.02**	**0.007**	**0.008**	**0.006**	0.005	0.004
Boron	mg/L	0.2	**0.4**	0.2	0.2	0.2	0.2	0.2
Cadmium	mg/L	0.0005(4)	0.0002	0.0001	0.0001	0.00009	0.00009	0.00008
Cobalt	mg/L	0.0009	**0.001**	0.0006	0.0007	0.0006	0.0005	0.0005
Chromium	mg/L	0.001(5)	**0.02**	**0.008**	**0.008**	**0.007**	**0.006**	**0.005**
Copper	mg/L	0.005(5)	**0.1**	**0.04**	**0.05**	**0.03**	**0.03**	**0.02**
Molybdenum	mg/L	0.04	0.002	0.002	0.002	0.002	0.002	0.002
Nickel	mg/L	0.025	0.004	0.002	0.003	0.002	0.002	0.002
Lead	mg/L	0.005(7)	0.002	0.0009	0.0009	0.0007	0.0007	0.0006
Thallium	mg/L	—	0.0001	0.00007	0.00007	0.00007	0.00007	0.00007
Vanadium	mg/L	0.006	0.001	0.001	0.001	0.001	0.001	0.001
Zinc	mg/L	0.02	**0.08**	**0.04**	**0.05**	**0.04**	**0.03**	**0.03**

Notes:

Detailed calculations can be found in 1011170042-CAL-G2120-0011-00 (Golder 2012f)

Bolded values are greater than the criteria.

(1) CCME criteria for chloride and nitrate have been used as no PWQO exists.

(2a) Un-ionized ammonia concentrations calculated based on assumed pH of 8.0 and assumed temperature of 20°C.

(2b) Un-ionized ammonia concentrations calculated based on assumed pH of 8.0 and assumed temperature of 25°C.

(2c) Un-ionized ammonia concentrations calculated based on assumed pH of 8.0 and assumed temperature of 30°C.

(3) PWQO for aluminum of 0.075 mg/L based on observed pH between 6.5 and 9.0.

(4) PWQO for cadmium depends on hardness. PWQO = 0.0005 mg/L based on predicted hardness values > 100 mg/L as $CaCO_3$.

(5) PWQO for chromium is 0.001 mg/L, which assumes all chromium is present as hexavalent chromium [Cr(VI)].

(6) PWQO for copper depends on hardness. PWQO = 0.005 mg/ based on predicted hardness values > 20 mg/L as $CaCO_3$

(7) PWQO for lead depends on hardness. PWQO = 0.005 mg/L based on predicted hardness values > 80 mg/L as $CaCO_3$.

during construction. There is no criterion for TDS. The elevated TDS and metal concentrations are a result of the inflow of groundwater. The influence of metal leaching from the waste rock is negligible and is not the cause of the elevated concentrations of TDS and metals in the SWMP.

Nitrate and total ammonia concentrations in the SWMP are estimated to be 2 mg/L each, for average conditions. These concentrations are a result of dissolution of residual explosives during blasting of the shafts. Using the formula provided in MOEE (1994) results in un-ionized ammonia concentrations that range between 0.08 mg/L and 0.2 mg/L (for temperatures between 20°C and 30°C), greater than the criterion (0.02 mg/L). Table 11 provides an indication of un-ionized ammonia concentrations for different years during construction, under average conditions. These results demonstrate that un-ionized concentrations do not increase appreciably until after year 4 of construction.

Table 11: Predicted Nitrate, Ammonia and Un-Ionized Ammonia Concentrations During Construction for Average Flow Conditions.

Year	Expected Annual Tonnage (tonnes)	Predicted Concentration (mg/L)				
		Nitrate	Ammonia	Un-Ionized Ammonia (pH = 8.0)		
				T=20°C	T=25°C	T=30°C
1	50,000	0.3	0.2	0.008	0.01	0.01
2	50,000	0.3	0.2	0.008	0.01	0.01
3	50,000	0.3	0.2	0.008	0.01	0.01
4	220,530	0.8	0.8	**0.03**	**0.04**	**0.06**
5	486,810	2	2	**0.08**	**0.1**	**0.1**
6	649,085	2	2	**0.08**	**0.1**	**0.1**
7	378,625	1	1	**0.04**	**0.05**	**0.07**
			PWQO	0.02		

Notes:
Bolded values are greater than the criteria.
For predicted nitrate, ammonia and un-ionized ammonia concentrations during operations, see Table 12.

4.1.2 Storm Flow Conditions

During storm events, there is a larger contribution of runoff from the site which serves to dilute the water in the SWMP. Hence, as the size of the storm events increase, the TDS and metal concentrations decrease. However, the concentrations of aluminum, arsenic, chloride, chromium, copper, iron and zinc are still predicted to be greater than the criteria. TDS concentrations range from 1,600 to 3,100 mg/L during construction storm events.

Conversely, nitrate and ammonia concentrations increase with storm events as more water will serve to dissolve and flush residual explosives form the pile. Predicted nitrate and total ammonia concentrations during storm conditions ranged from 3 to 6 mg/L. Corresponding un-ionized ammonia concentrations range form 0.1 to 0.5 mg/L, greater than the criterion of 0.02 mg/L.

4.2 Operations

The results of predicted water quality during operations for average and storm conditions are presented in Table 12. The sections below describe the results for these two conditions.

Table 12: Predicted Operations Water Quality in the SWMP and Assumed Discharge Quality – Without Mitigation

Parameter	Unit	Criteria	Average Conditions	25mm 6 hour storm	24 hour 2 year storm	24 hour 5 year storm	24 hour 10 year storm	24 hour 25 year storm
Total Dissolved Solids	mg/L	—	24,000	3,600	4,100	2,600	2,100	1,700
Sodium	mg/L	—	5,900	850	990	600	480	380
Calcium	mg/L	—	2,200	300	400	260	210	180
Magnesium	mg/L	—	530	90	100	60	50	50
Potassium	mg/L	—	240	40	45	30	30	20
Strontium	mg/L	—	40	6	7	5	4	3
Iron	mg/L	0.3	**3**	**0.7**	**0.7**	**0.5**	**0.5**	**0.4**
Manganese	mg/L	—	0.4	0.09	0.1	0.07	0.07	0.06
Chloride	mg/L	120(1)	**14,000**	**1,900**	**2,300**	**1,400**	**1,000**	**810**
Bromide	mg/L	—	110	15	18	10	8	6
Fluoride	mg/L	—	0.1	0.02	0.02	0.01	0.008	0.006
Sulphate	mg/L	—	230	30	40	30	20	20
Nitrate (as nitrogen)	mg/L	13(1)	0.4	0.05	0.06	0.03	0.03	0.02
Ammonia (as nitrogen)	mg/L	—	0.04	0.05	0.05	0.05	0.05	0.05
Un-ionized ammonia(2a)	mg/L	0.02	0.002	0.002	0.007	0.002	0.002	0.002
Un-ionized ammonia(2b)	mg/L	0.02	0.002	0.003	0.002	0.002	0.002	0.002
Un-ionized ammonia(2c)	mg/L	0.02	0.003	0.003	0.003	0.009	0.009	0.008
Aluminum	mg/L	0.075(3)	**3**	**0.5**	**0.5**	**0.4**	**0.3**	**0.2**
Arsenic	mg/L	0.005	**0.06**	**0.009**	**0.01**	**0.007**	**0.005**	0.004
Boron	mg/L	0.2	**1**	**0.2**	**0.3**	**0.2**	**0.2**	**0.2**
Cadmium	mg/L	0.0005(4)	0.0003	0.0001	0.0001	0.00009	0.00009	0.00008
Cobalt	mg/L	0.0009	**0.003**	0.0007	0.0007	0.0006	0.0005	0.0005
Chromium	mg/L	0.001(5)	**0.04**	**0.009**	**0.01**	**0.007**	**0.006**	**0.006**
Copper	mg/L	0.005(5)	**0.4**	**0.06**	**0.07**	**0.04**	**0.03**	**0.02**
Molybdenum	mg/L	0.04	0.006	0.002	0.002	0.002	0.002	0.002
Nickel	mg/L	0.025	0.01	0.003	0.003	0.002	0.002	0.002
Lead	mg/L	0.005(7)	0.005	0.001	0.001	0.0008	0.0007	0.0006
Thallium	mg/L	—	0.0002	0.00007	0.00008	0.00006	0.00006	0.00006
Vanadium	mg/L	0.006	0.001	0.001	0.001	0.001	0.001	0.001
Zinc	mg/L	0.02	**0.2**	**0.05**	**0.05**	**0.04**	**0.04**	**0.03**

Notes:

Detailed calculations can be found in 1011170042-CAL-G2120-0011-00 (Golder 2012f).

Bolded values are greater than the criteria.

(1) CCME criteria for chloride and nitrate have been used as no PWQO exists.

(2a) Un-ionized ammonia concentrations calculated based on assumed pH of 8.0 and assumed temperature of 20°C.

(2b) Un-ionized ammonia concentrations calculated based on assumed pH of 8.0 and assumed temperature of 25°C.

(2c) Un-ionized ammonia concentrations calculated based on assumed pH of 8.0 and assumed temperature of 30°C.

(3) PWQO for aluminum of 0.075 mg/L based on observed pH between 6.5 and 9.0.

(4) PWQO for cadmium depends on hardness. PWQO = 0.0005 mg/L based on predicted hardness values > 100 mg/L as $CaCO_3$.

(5) PWQO for chromium is 0.001 mg/L, which assumes all chromium is present as hexavalent chromium [Cr(VI)].

(6) PWQO for copper depends on hardness. PWQO = 0.005 mg/ based on predicted hardness values > 20 mg/L as $CaCO_3$

(7) PWQO for lead depends on hardness. PWQO = 0.005 mg/L based on predicted hardness values > 80 mg/L as $CaCO_3$.

4.2.1 Average Flow Conditions

During operations, the effect of salinity in the groundwater is more pronounced compared to construction. This is due to the lower expected flow of service water during operations (0.42 L/s) as compared to the higher flows of process water expected during operations (21 L/s). Hence metal, chloride and TDS concentrations during average operational conditions are higher than during construction. Specifically the concentrations of aluminum, arsenic, boron, chloride. chromium, cobalt, copper, iron and zinc are greater than the criteria for average conditions. The TDS concentration is estimated at 24,000 mg/L.

It is assumed that all blasting residuals will have been flushed from the waste rock piles early in the operations phase (Bailey *et. al.*, 2012; Davis *et. al.*, 1996; Forsyth *et.al.*, 1995). Hence, nitrate and ammonia concentrations are similar to the input values (which are largely baseline values) and the expected un-ionized ammonia concentration (0.002 mg/L) is lower than the criterion of 0.02 mg/L.

4.2.2 Storm Flow Conditions

While there is still some dilution during storm events, TDS and the associated parameters continue to be elevated in the pond during operations. Concentrations of aluminum, arsenic, boron, chloride, chromium, copper, iron and zinc are greater than the criteria. TDS concentrations range from 1,700 to 4,100 mg/L. Nitrate, ammonia and un-ionized ammonia concentration are all similar to input values and lower than criteria.

4.3 Mitigation and Improved Water Quality

The following sections outline the proposed mitigation (section 4.3.1) and treatment (section 4.3.2) measures that can be performed during the construction of the Project, if necessary. Regular monitoring will be performed to determine the need for mitigation. Section 4.3.3 presents the predicted water quality considering the successful implementation of either the mitigation measures outlined or treatment.

4.3.1 Proposed In-Design Mitigation Measures

Several options, largely related to source reduction or elimination, have been identified to lower the concentrations of metals, TDS, nitrate and ammonia in the SWMP.

It will be possible to reduce salinity in SWMP discharge water if groundwater inflow from the Salina A1 and Guelph formations are reduced or eliminated by grouting. Table 13 provides the changes in TDS concentration that could be achieved for various reductions in groundwater inflow during both construction and operations.

Table 13: Predicted TDS Concentrations in the SWMP for Decreasing Groundwater Flows

Percentage Decrease of Groundwater Inflow from Group 2 Formation	TDS (mg/L)	
	Construction	Operations
0	6,500	24,000
25	5,000	18,000
50	3,600	13,000
75	2,200	7,300
85	1,600	5,000
90	1,300	3,800
95	1,000	2,700
100	500	1,500

While a specific criterion for TDS in the effluent from the SWMP will be determined as part of the ECA process, for reference, freshwater typically has TDS concentrations of 1,500mg/L or lower. However, the trend shown in Table 13 indicates that TDS concentrations in the SWMP can be decreased as the groundwater contribution from the Group 2 formation decreases.

To decrease nitrogen compound concentrations in SWMP discharge, blasting practices would be modified, as required, to reduce the amount of blast residue on waste rock; for example, by greater use of emulsions and/or improvements to handling of explosives. It should be noted that the potential for elevated nitrogen compounds from blasting will be a concern during construction and perhaps in the early stages of operations. These compounds are typically flushed from the waste rock piles quickly (Bailey *et. al.*, 2012; Davis *et. al.*, 1996; Forsyth *et.al.*, 1995), making this a temporary water quality issue, if at all. By following best management practices (Forsyth et. al., 1995; Cameron et. al., 2007) the loss of nitrogen species to water can be greatly reduced. Best management practices can include:

- Cleanup of spilled explosives;
- Use of the appropriate formulation (i.e. increased use emulsion blends decreases the dissolution of nitrogen species compare to ANFO);
- Ensure complete detonation; and
- Visual observations and audits.

Given that when these best management practices are followed appropriately they allow for mine sites to meet regulatory criteria, they should be sufficient for the Project considering the tonnages expected at the Project are orders of magnitude lower than mine sites.

With respect to monitoring, the issues of higher TDS and metals as well as increased blasting residuals would be observed early in the construction phase when the tonnage of rock is still relatively small (Figure 2). As the shafts are advanced, monitoring of water from the rock formations can be observed and measured, allowing for the opportunity for additional grouting, or if necessary, the implementation of treatment. Water quality predictions during average conditions indicate appreciable increases in un-ionized ammonia concentrations are not expected until year 4 of construction (Table 11), allowing for time to improve blasting and explosive handling practices.

More frequent monitoring is required to accurately characterize the water quality in the initialization period (i.e. period of time immediately following start of pond operations). If regular monitoring indicates the data are consistently below the criteria in the first week, sampling may be reduced to weekly frequency. If data are consistently below the criteria for the first month, the sampling may be reduced to quarterly. If exceedances are detected, the mitigation measures can be implemented, and the verification sampling schedule would follow the same schedule as the initialization period. A detailed sampling plan will be developed prior to the site preparation and construction phase as described in Section 12 of the EA Follow-up Monitoring Program, and that sample frequency can be adjusted based on the data quality objectives of the quality of the SWMP discharge water.

It should be noted that un-ionized ammonia concentrations are expected to be lowest during the first three years of construction (see Table 11). If a significant upward trend in un-ionized ammonia concentrations is detected in the first three years of the construction phase or if concentrations are higher than predicted in the model, there would be adequate time to evaluate and (if necessary) implement mitigative measures before the expected peak concentrations of unionized ammonia in years four to seven. Additionally, the EA Follow-up Program is assessed on an annual basis for completeness. The annual assessment will identify the effectiveness of the existing follow-up monitoring program design and identify any problems and gaps (NWMO 2011, Section 16). Therefore, if there is a change to the scheduled construction activities, if concentrations of the parameters of concern are trending toward the regulatory discharge criteria, or if sudden/anomalous changes in the monitoring trends are detected, the frequency of the surface water monitoring could be adjusted in order to capture these changes.

Note that if an exceedance of the regulatory discharge criteria is detected, the SWMP outlet will be closed (NWMO 2011, Section 13.1) and mitigation will be applied as appropriate. SWMP water will be tested prior to release to confirm that the mitigation is effective and that the discharge criteria are achieved and then daily samples will be collected and analyzed for the first week. Provided there are no exceedances, sampling will revert to the normal frequency.

4.3.2 Proposed Water Treatment Options

In the event that source reduction or elimination cannot reduce concentrations to within acceptable levels in SWMP discharge, then a final option of treatment has been identified. The need for treatment would depend on the effectiveness of any measures implemented to reduce or eliminate the sources and will be confirmed through the results of a monitoring program.

Should treatment be required, water from areas that contain high salinity (i.e., groundwater inflow from the shafts) and nitrogen compounds (runoff and leachate from the waste rock in the waste rock management area) could be collected and treated prior to entering the SWMP as follows:

- Saline groundwater collected at the bottom of the shafts could be taken to ground surface and treated, with an evaporator for example, and the treated water would then be directed to the SWMP. Effluent from an evaporator will be close to that of de-ionized water.
- Water from the waste rock pile could be routed to a separate pond and treated, by aeration for example (or other suitable technology), in a separate intermediate pond before being directed into the SWMP. For the assumed pH (8.0) and temperature (20°C) in the SWMP, a total ammonia concentration of 0.6 mg/L or less would result in an un-ionized ammonia concentration that would be at or lower than the PWQO criterion (0.02 mg/L). Considering the maximum predicted total ammonia concentration during construction is 6 mg/L, a 10-fold decrease in concentrations is required, which is technically feasible for a range of treatment technologies.

4.3.3 Results of Successful Mitigation

For the purpose of modelling, it is assumed that the inflows have been successfully mitigated and/or treated before reaching the SWMP, allowing for the gate at the discharge point to be left open. It was assumed that these measures will be sufficient to treat high TDS groundwater and potentially elevated concentrations of nitrogen species in surface water run-off from waste rock piles. It was assumed that the resultant treated water will have same quality as baseline: for surface water runoff from the waste rock piles an input quality from column 3 from Table 8 was used and for groundwater, an input quality from Column 7 Table 8 was used.

The results for average conditions during construction and operations are presented in Table 14. Modelling results indicate that for a fully mitigated option, the water quality in the SWMP does not exceed the criteria for any parameter that does not currently exceed the criteria in the natural runoff. Natural runoff quality already includes concentrations of chromium and zinc that are greater than the PWQOs. This indicates that if mitigation and/or treatment scenario are implemented appropriately, a significant improvement in the SWMP water quality can be achieved.

Table 14: Predicted Water Quality During Construction and Operations in the SWMP Considering Mitigation

Parameter	Unit	Criteria	Average Conditions	
			Construction	Operations
Total Dissolved Solids	mg/L	—	350	340
Sodium	mg/L	—	80	80
Calcium	mg/L	—	80	70
Magnesium	mg/L	—	20	20
Potassium	mg/L	—	6	7
Strontium	mg/L	—	1	0.9
Iron	mg/L	0.3	0.3	0.3
Manganese	mg/L	—	0.05	0.05
Chloride	mg/L	—	40	50
Bromide	mg/L	—	—	—
Fluoride	mg/L	—	—	—
Sulphate	mg/L	—	6	4
Nitrate (as nitrogen)	mg/L	13(1)	0.1	0.3
Ammonia (as nitrogen)	mg/L	—	0.1	0.1
Un-ionized ammonia(2)	mg/L	0.02	0.004	0.004
Aluminum	mg/L	0.075(3)	0.07	0.07
Arsenic	mg/L	0.005	0.001	0.001
Boron	mg/L	0.2	0.07	0.1
Cadmium	mg/L	0.0005(4)	0.00009	0.00009
Cobalt	mg/L	0.0009	0.0005	0.0004
Chromium	mg/L	0.001(5)	**0.005**	**0.004**
Copper	mg/L	0.005(5)	0.002	0.002
Molybdenum	mg/L	0.04	0.001	0.002
Nickel	mg/L	0.025	0.001	0.001
Lead	mg/L	0.005(7)	0.0005	0.0005
Thallium	mg/L	—	0.00005	0.00005
Vanadium	mg/L	0.006	0.001	0.001
Zinc	mg/L	0.02	**0.03**	**0.02**

Notes:
Detailed calculations can be found in 1011170042-CAL-G2120-0011-00 (Golder 2012f).
(1) CCME Criteria for nitrate used as no PWQO exists.
(2) Un-ionized ammonia concentrations calculated based on assumed pH of 8.5 and assumed temperature of 25°C.
(3) PWQO for aluminum of 0.075 mg/L based on observed pH between 6.5 and 9.0.
(4) PWQO for cadmium depends on hardness. PWQO = 0.0005 mg/L based on predicted hardness values > 100 mg/L as $CaCO_3$.
(5) PWQO for chromium is 0.001 mg/L, which assumes all chromium is present as hexavalent chromium [Cr(VI)].
(6) PWQO for copper depends on hardness. PWQO = 0.005 mg/ based on predicted hardness values > 20 mg/L as $CaCO_3$
(7) PWQO for lead depends on hardness. PWQO = 0.005 mg/L based on predicted hardness values > 80 mg/L as $CaCO_3$

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5.0 MODEL LIMITATIONS AND CONSERVATISM

The prediction of water quality is based on several inputs (surface flows, groundwater flows, baseline water quality and geochemical characterization), all of which have inherent variability. The water quality model has attempted to predict process for a facility that has not yet been constructed. To address uncertainties, different levels of conservatism were used. They include:

- Short term leachate concentrations from the test results from the waste rock are likely higher than what is actually expected in the field;
- The model assumes no grouting of the shafts;
- The model assumes the dolomite and shale piles will be present for all five years of construction, when in reality they will only be present and/or exposed for 1 year;
- Highest range of powder factor provided was used in the model for explosives; and
- Assumed that all residual explosives will dissolve.

The results of the water quality model should be used as a tool to aid in the design of monitoring programs and develop mitigations strategies rather than to provide absolute concentrations. Ultimately, even the best of models cannot compare with operational monitoring data. Once the Project is operational, monitoring of water quality and periodic re-assessment of predicted effects and/or mitigation measures will be required.

The prediction confidence is also dependent on the success of the effective mitigations proposed. The proposed mitigation methods are commonly used, are based on standard practices and are known to be effective. Nevertheless, even if all of these proposed mitigation options fail, water treatment can and will be designed to prevent impacted water from affecting the receiving environment.

6.0 REFERENCES

Bailey, B.L., L. J. D. Smith, D. W. Blowes, C. J. Ptacek, L. Smith and D.C. Sego (2012). The Diavik Waste Rock Project: Persistence of contaminants from blasting agents in waste rock effluent. Applied Geochemistry (in press).

Cameron, A., D. Corkery, MacDonald, G., Forsyth, B. and T. Gong (2007). An Investigation of Ammonium Nitrate Loss to Mine Discharge Water at Diavik Diamond Mines. EXPLO Conference Wollongong, NSW, 3-4 September 2007

Canadian Council of Ministers of the Environment (CCME). 2012. Canadian water quality guidelines for the protection of aquatic life: Nitrate. In: Canadian Environmental Quality Guidelines, Canadian Council of Ministers of the Environment, Winnipeg.

Davis, A. D., A. Heriba, C.J. Webb. (1999). Prediction Of Nitrate Concentrations In Effluent From Spent Ore. International Journal of Rock Mechanics and Mining Sciences and Geomechanics Abstracts, Volume 33, Number 8, December 1996 , pp. 377A-377A(1).

Forsyth, B., A. Cameron, S. Miller (1995). Explosives and water quality, in Proceedings of Sudbury `95 Mining and the Environment. Montreal, Quebec, Canada, MEND (Mine Environment Neutral Drainage), p. 795-803.

Golder Associates Ltd. (Golder), 2011a, “Results of Geochemical Testing of Rock Samples from the Deep Geologic Repository (DGR)”, Golder Project No. 06-1112-037(9000), Technical Memorandum dated February 7, 2011.

Golder Associates Ltd. (Golder), 2011b, “Geology Technical Support Document March 2011”, NWMO DGR-TR-2011-03, March2011.

Golder Associates Ltd. (Golder), 2011c, “Hydrology and Surface Water Quality Technical Support Document”, NWMO DGR-TR-2011-04, March 2011.

Golder Associates Ltd. (Golder), 2012a, “Geotechnical Design Criteria for the Permanent Waste Rock Pile”, Golder Document No. 1011170042-TM-G2120-0002-01, Technical Memorandum dated September 19, 2012.

Golder Associates Ltd. (Golder), 2012b, “Monthly Water Budgets for Ontario Power Generation’s Deep Geologic Repository Site”, Golder Document No. 1011170042-TM-G2120-00015-A, Technical Memorandum dated October 2012.

Golder Associates Ltd. (Golder), 2012c, “Preliminary Estimates of Groundwater Inflow Under Normal Operating Conditions”, Golder Document No. 1011170042-TM-G2100-0002-02, Technical Memorandum dated March 23, 2012.

Golder Associates Ltd. (Golder), 2012d. “Analysis of Stormwater Runoff Quantity and Total Suspended Solids Concentrations from the DGR Project Site”. Golder Document No. 1011170042-TM-G2120-0005-B.

Golder Associates Ltd. (Golder), 2012f. Calculation Worksheet 1011170042-CAL-G2120-0011-00, November 1, 2012.

Hatch, 2010. Deep Geological Repository Project. Functional Description Waste Rock Management Area. Document No. H33300-WP404-10-109-0001, Rev 01.

Intera Engineering (Intera), 2010a, “Opportunistic Groundwater Sampling in DGR-1 & DGR-2”, Document ID. TR-07-11, Technical Report dated May 19, 2010.

Intera Engineering (Intera), 2010b, “Opportunistic Groundwater Sampling in DGR-3 and DGR-4”, Document ID. TR-08-18, Technical Report dated June 18, 2010.

NWMO (2011), OPG’s Deep Geologic Repository for Low and Intermediate Level Waste, DGR EA Follow-up Monitoring Program, Report No DGR-TR-2011-10, March 2011

Ontario Ministry Environment and Energy (MOEE). 1994. Policies Guidelines and Provincial Water Quality Objectives of the Ministry of Environment and Energy. Queen’s Printer for Ontario. Toronto, ON.

Ontario Power Generation (OPG). 2012. Deep Geological Repository for Low and Intermediate Level Wastes – Submission of Responses to Information Request (IR) Package #3: EIS-03-96. (CEAA Registry Doc# 608).

Tetra Tech (2011), WP2-10: Underground Process Water and Dewatering Requirements, Document No 1088240200-MEM-M0002-00, Technical Memorandum dated July 11, 2011

Tetra Tech (2012). Calculation Worksheet 1088240200-CAL-M0005-01 Aug 12, 2012.

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Subject: Golder Reports
Attachments: 1011170042-TM-G2030-0008-00 Pavement Design Recommendations_Final.pdf; 1011170042-TM-G2120-0014-01 SWMP Water Quality_Final Signed.pdf

Hi Maria,

Please find attached reports for Record. Both follow the same filing codes:

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