APPENDIX D:
COMPUTATION COVER SHEET

Client: Prodigy Gold, Inc

Project: Magino **Project:** ______ **Task No.:** ______

Title of Computations: Magino Mine Pit Water Quality Projection

Computations By:

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SIGNATURE	May 18, 2018 (revised) DATE

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Computations Checked By:

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SIGNATURE	June 1, 2018 DATE

Tom Patterson Ph.D., Managing Principal
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Approved By
(PM or Designate):

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SIGNATURE	June 1, 2018 DATE

Tom Patterson Ph.D., Managing Principal
PRINTED NAME AND TITLE

Written by: Nestor Godinez	Date: 5/18/2018	Reviewed by: Tom Patterson, Ph.D.	Date: 6/1/2018
Client: Prodigy Gold, Inc	Project: Magino	Project No: 117.00950.00006	Task No.: 6300

MAGINO SITE PIT WATER QUALITY PROJECTION

1. PURPOSE AND SCOPE

The purpose of this calculation package is to project the pit water quality for the Magino Mine Project after pit filling occurs. As pit filling occurs, pit water chemistry will subsequently evolve and change. Overall water quality in the pit will be determined by different water inflows, and their specific chemical compositions. The analysis of the pit water chemistry is based on a number of models and data sets which include:

- Water and mass balance calculations;
- Pit filling model including volumes of;
    - Groundwater including seepage from the Tailings Management Facility (TMF) and Mine Rock Management Facility (MRMF)
    - Surface water runoff
    - Plant area runoff
    - Closure decant of TMF pool water and water transfers from the subsurface water collection system under the TMF and MRMF
    - Precipitation
    - Evaporation
    - Pit wall weathering constituents
    - Goudreau Lake inflow (accelerated filling alternative)
- Geologic block model; and
- Leaching rates calculated from humidity cell test data.

2. SCENARIOS

The following scenarios are evaluated:

1. Base Model: (approximately 50 years to fill)
    - Determined for a single point in time after which the pit has filled naturally.
2. Accelerated Model: (approximately 43 years to fill)
    - Increase water influx from Goudreau Lake is accounted for, effectively accelerating the pit filling process by approximately 7 years.

Preliminary mass balance calculations are performed for each scenario. The results of the conservative preliminary calculations are then reviewed to determine if any constituents may exceed water quality criteria. More detailed evaluation/consideration is performed for any constituents that exceed water quality criteria. More detailed analysis would consist of chemical equilibrium modeling and/or biogeochemical process modeling.

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3. PIT WATER FILLING

Once fully developed, the pit will be allowed to fill until it reaches the elevation of nearby Goudreau Lake. Two alternate pit filling scenarios were analyzed, which were natural pit filling and accelerated pit filling. The total inflows to the pit and the length of time required for filling are determined to be used later in the water quality projections.

Assumptions:

- Surface water catchment area at closure consists of the pit top area plus the plant area runoff and runoff collected between the crest of the MRMF and the pit.
- Volume of the pit itself remains stable during the filling process (approximately 185 million cubic metres [m^3]).
- Water influxes not listed contribute negligible amounts of water to the pit.
- Total groundwater inflow into the pit includes seepage from the TMF and MRMF.

Data Sources:

- Magino Mine Project Water Balance found in Appendix A of the Site Water Balance and Quality TSD
- TSD 7 – Hydrogeological Study and Groundwater Modeling

Calculations:

The pit filling analysis in the above spreadsheet has flows of each inflow component (i.e. groundwater, surface runoff, etc.) that are used with the total pit volume to determine the total volume of each component in the full pit lake.

Example Parameters and Calculation:

- Local hydrologic inflow from groundwater = 68.4 million m^3
- Pit volume = 185 million m^3

(68.4) / (185) = 37% of total pit volume is groundwater

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Table D-1: Contributions to Pit Filling (from pit filling analysis)

Component	Natural Filling	Accelerated Filling
Total Groundwater	37%	32%
Direct Net Precipitation	6%	5%
Runoff from Pit catchment, plant area, and area between MRMF and the Pit	50%	42%
Pumping from Goudreau Lake	0%	14%
Dewatering of TMF pool and Subsurface Water Collection System during Closure	7%	7%
Total	100%	100%

Results:

Following the natural model of filling, the pit will fill via water inflow from groundwater seepage, and runoff from rainfall and snowmelt. Analysis of water influxes indicate approximately 49 years needed to completely fill the pit (Figure D-1).

Under the accelerated model, the pit receives water via groundwater seepage, runoff from rainfall and snowmelt, and additionally, water pumped from Goudreau Lake. Assuming a pumping rate of 1,680 m^3 per day, it will take 43 years to completely fill the pit (Figure D-2).

Table D-2: Pit Water Influx Component Volumes for Each Scenario

Scenario	Water Source (millions m^3)					
	Natural GW	RO	Goudreau Lake	Mine Rock Infiltration	TMF Water	Precipitation
Natural Filling	51.3	91.9	0.0	12.0	18.2	11.2
Accelerated Filling	44.5	77.4	25.2	11.0	17.0	9.6

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Figure D-1: Natural Pit Filling Curve

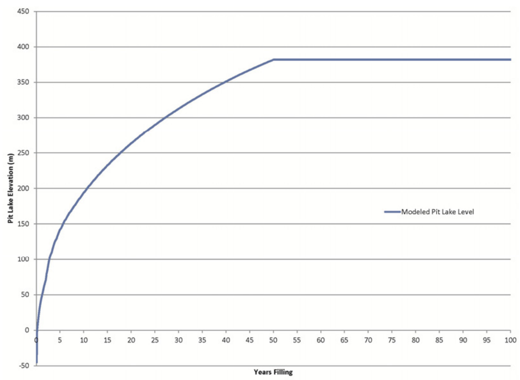
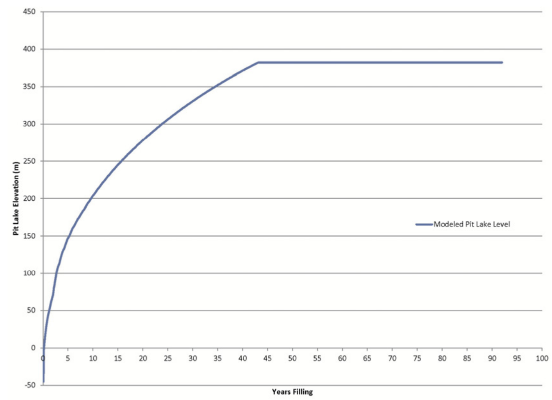


Figure D-2: Accelerated Pit Filling Curve



4. WATER INFLOW CONCENTRATIONS

In this section, the chemistry of each contributing water source provided in milligrams per liter (mg/L) was assigned. The components are groundwater, which include TMF and MRMF seepage into groundwater, surface water runoff including pit catchment and plant area runoff, precipitation directly onto the pit lake, water transfers from the TMF pool and the subsurface water collection system during closure, and surface water from Goudreau Lake for the accelerated case. Pit wall weathering also contributes to the dissolved load of the lake and is calculated in the next section.

Assumptions:

- Groundwater chemistry is constant spatially, vertically or temporally.
- Seepage from the TMF and MRMF represents 25% of the groundwater inflow into the pit.
- The TMF and MRMF represent 53% and 47%, respectively, of the 25% of groundwater that is seepage.
- Precipitation does not contribute any constituent load.
- Evaporation removes only water, not constituents.

Data Sources:

- Magino Mine Project Discharge Water Concentrations (Appendix B and Appendix C).
- Geochemical Assessment TSD; SLR International, November 2016.

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Calculations:

- Groundwater quality is the average concentration of all groundwater monitoring data (all depths and locations) collected at the site to date. Use of all the data is supported by the fact that there are no large differences in groundwater chemistry either spatially or vertically.
- Surface runoff water quality is the average concentration of the surface water monitoring stations in the upper McVeigh Creek watershed. This is the location of former mining facilities and disturbed areas from previous mining (includes the existing tailings pond, polishing pond, and inlet to Lovell Lake).
- Goudreau Lake water quality used in the accelerated filling case is the average concentration derived from baseline monitoring of Goudreau Lake.
- TMF water quality (for the seepage and the pool) is the average concentration of the TMF pool during Years 11 and 12 calculated from the water balance and quality model.
- Seepage water from infiltration through the mine rock of the MRMF and TMF embankment infiltrates in groundwater which flows into the pit and also is collected in the subsurface water collection system. The seepage water quality is the average of the field cell results for each lithology, and mass-weighting the averages by the mass of each lithologic unit that will be in the mine rock used to make the TMF embankment and the MRMF. Unit 5E (the PAG Unit) will be disposed in the tailings pond and so is not included in calculating the average.

Table D-3: Baseline Water Source Concentrations

Constituent	ODWS	PWQO	Ground Water	Surface Runoff	Goudreau Lake	Mine Rock Infiltration	TMF Water
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
pH	-	6.5 - 8.5	7.7	7.9	7.3	7.9	7.6
TDS	-	-	205	146	114	353	6,394
Sulfate	-	-	16.32	28.8	5.9	179.5	5,266
Alkalinity (as CaCO3)	-	-	133	70	73	70	453
Phosphorus (T)	-	0.01	0.01	0.0037	0.009	0.0545	0.45
Nitrate - N	-	-	0.097	0.59	1.04	0.59	1.41
Ammonia N	-	-	0.096	0.268	0.08	0.268	0.18
Organic Carbon (D)	5	-	5.22	11.2	7.55	0	0
Arsenic	0.025	0.005	0.001	0.0035	0.0016	0.0061	0.018
Cadmium	0.005	0.0001	5.6E-5	0	7.00E-06	4.7E-4	8.9E-04

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Constituent	ODWS	PWQO	Ground Water	Surface Runoff	Goudreau Lake	Mine Rock Infiltration	TMF Water
Chromium	0.05	-	0.00034	0	0.0005	0.00282	0.0045
Cobalt	-	0.0009	0.00105	0.0015	0.0005	0.00092	0.036
Copper	-	0.001	0.001	0.0017	0.002	0.0050	0.45
Iron	-	0.3	0.564	0.057	0.08	0.066	0.18
Magnesium	-	-	5.1	3.6	4.1	3.6	60
Manganese	0.05	-	0.348	0.01	0.026	0.095	0.018
Nickel	-	0.025	0.00144	0.001	0.0006	0.0031	0.0089
Silver	-	0.0001	0.000056	0	0.00005	0.00019	0.0071
Vanadium	-	0.006	0.00058	0	0.00005	0.0018	0.048
Zinc	-	0.02	0.0061	0	0.004	0.0052	0.0089
Mercury	-	0.0002	0.000012	0	5.65E-06	0	0.00054
Lead	-	0.025	0	0	0.0003	0.00066	0.00179
Total Cyanide	-	0.005	0.0012	0	0	0	0(1)
Aluminum	-	-	0.032	0.021	0.021	0.062	0.21
Boron	-	-	0.028	0.03	0.02	0.073	0.089
Molybdenum	-	-	0.0062	0.001	0.0008	0.047	0.0089
Selenium	-	-	0.0002	0.0002	0.0002	0.00274	0.004
Chloride	-	-	1.85	2.82	0	14.1	38.4
Calcium	-	-	42.8	29	29	84.3	571
Thallium	-	-	0.00015	0	0.0002	0.00066	0.00045
Hardness	-	-	128	87	89	87	228

In order to get the mass of each constituent contributing to the filled pit, the source water concentrations in Table D-3 are multiplied by the total volume of each specific water source in Table D-2 and the sum of all the contributions and divided by the total volume of the pit lake. Table D-4 and Table D-5 present the contributions for the natural filling and accelerated filling cases, respectively.

Example Parameters and Calculation:

- Baseline sulfate concentration from groundwater = 16.3 mg/L
- Total Groundwater Volume = 57.4 million m^3

(16.3 mg/L Sulfate) x (51,300,000 m^3 GW) = 837E+8 total g of Sulfate contributed to pit components

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For pH, the contribution was calculated by converting the pH to the concentration of H^+ (=10^(-pH), performing the mass balance concentration on H^+, and then converting back to pH (= -log(H^+).

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Table D-4: Total Contributed Constituents to Filled Pit (Natural Fill)

Constituent	Ground Water	Surface Water	Goudreau Lake	Mine Rock Infiltration	TMF Water
	kg	kg	kg	kg	kg
TDS	10,541,284	13,453,555	0	4,250,625	116,217,753
Sulfate	837,211	2,646,447	0	2,162,094	95,749,009
Alkalinity (as CaCO3)	6,822,858	6,432,335	0	843,314	8,236,803
Phosphorus (T)	513	340	0	657	8,114
Nitrate - N	4,976	54,215	0	7,1078	25,565
Ammonia N	4,925	24,627	0	3,229	3,232
Organic Carbon (D)	267,784	1,029,174	0	0	0
Arsenic	51.3	322	0	73.0	325
Cadmium	2.9	0	0	5.7	16.2
Chromium	17.4	0	0	34.0	81.1
Cobalt	53.9	138	0	11.1	649
Copper	51.3	152	0	60.4	8,114
Iron	28,933	5,238	0	791	3,246
Magnesium	261,628	330,806	0	43,370	1,090,967
Manganese	17,852	919	0	1,146	325
Nickel	73.9	92.0	0	37.9	162
Silver	2.9	0	0	2.3	130
Vanadium	29.8	0	0	22.0	876
Zinc	313	0	0	62.2	162
Mercury	0.6	0	0	0	9.7
Lead	0	0	0	8.0	32.5
Total Cyanide	61.6	0	0	0	0
Aluminum	1,642	1,930	0	754	3,895
Boron	1,436	2,757	0	880	1,623
Molybdenum	318	91.9	0	568	162
Selenium	10.3	18.4	0	33.1	81.1
Chloride	94,904	259,131	0	170,426	697,832
Calcium	2,195,627	2,664,825	0	1,015,930	10,386,333
Thallium	7.7	0	0	8.0	8.1
Hardness	6,566,975	8,024,981	0	1,048,119	4,154,533

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Table D-5: Total Contributed Constituents to Filled Pit (Accelerated Fill)

Constituent	Ground Water	Surface Water	Goudreau Lake	Mine Rock Infiltration	TMF Water
	kg	kg	kg	kg	kg
TDS	9,146,573	11,334,053	2,877,748	3,875,441	108,553,459
Sulfate	726,440	2,229,520	148,936	1,971,256	89,434,581
Alkalinity (as CaCO3)	5,920,130	5,418,971	1,842,768	768,879	7,693,604
Phosphorus (T)	445	286	227	599	7,579
Nitrate - N	4,318	45,674	26,253	6,481	23,879
Ammonia N	4,273	20,747	2,019	2,944	3,019
Organic Carbon (D)	232,354	867,035	190,588	0	0
Arsenic	44.5	271	40.4	66.6	303
Cadmium	2.5	0	0.2	5.2	15.2
Chromium	15.1	0	12.6	31.0	75.8
Cobalt	46.7	116	12.6	10.1	606
Copper	44.5	128	50.5	55.1	7,579
Iron	25,105	4,413	2,019	721	3,032
Magnesium	227,012	278,690	103,498	39,542	1,019,020
Manganese	15,490	774	656	1,045	303
Nickel	64.1	77.4	15.1	34.5	152
Silver	2.5	0	1.3	2.1	121
Vanadium	25.8	0	1.3	20.1	819
Zinc	272	0	101	56.7	152
Mercury	0.5	0	0.1	0	9.1
Lead	0	0	7.6	7.2	30.3
Total Cyanide	53.4	0	0	0	0
Aluminum	1,424	1,626	530	687	3,638
Boron	1,246	2,322	505	803	1,516
Molybdenum	276	77.4	20.2	518	152
Selenium	8.9	15.5	5.0	30.1	75.8
Chloride	82,348	218,307	0	155,384	651,811
Calcium	1,905,124	2,245,002	732,059	926,258	9,701,378
Thallium	6.7	0	5.0	7.2	7.6
Hardness	5,698,103	6,760,709	2,256,558	955,606	3,880,551

5. SURFACE AREA OF PIT WALL UNITS

The final pit wall will have the various lithological units covering portions of its surface; each unit contributing differently to the overall chemical composition of the filled lake via oxidation and weathering. In order to calculate each lithology's contribution to the pit lake, the surface area of the entire pit and the percentage of each unit on the wall was established. The presence of fractures in the wall results in a non-smooth surface, which in turn increases the surface area from which metals can leach into the lake.

Assumptions:

- Pit wall is a non-smooth surface.
- Fractures exist throughout pit walls.

Data Sources:

- Fractional area of each lithology in the pit wall and total pit wall surface area provided by JDS.
- Humidity cell data used for sulfate, calcium, alkalinity, and metals loading presented in Geochemical Assessment TSD.

Results:

Argonaut Geologists used a pit model with the geologic block model to map seven major lithologic units spanning the walls. The resultant measured surface areas are presented in Table D-6.

Table D-6: Surface Area of Lithologic Units

Lithologic Unit	Surface Area (metres^2)
6C	671,360
7C	3,248
9G	881
11A	21,584
5C	19,993
5E	9,088
MV	1,201,089
Total	1,927,243

6. SULFATE, CALCIUM, AND BICARBONATE (TDS) FROM PIT WALLS

Contribution from the pit walls to overall pit water chemistry is simulated as a mass of constituent added to the water in the pit lake. These constituents become added to the pit lake through weathering (oxidation) during the fill period of the pit. As weathering occurs, each lithologic unit reacts differently due to its unique chemical composition. Sulfate, calcium and bicarbonate from weathering are calculated based on the sulfide in the rock oxidizing to sulfuring acid and then neutralization of the sulfuric acid by naturally occurring calcium carbonate in the rock.

Data Sources:

- Geochemical Assessment TSD; SLR International, November 2016.

Assumptions:

- Constituents dissolve out of the pit wall and into the lake during the filling process
- Weathering only occurs to a specified depth within pit walls of all units (0.1 metres)
- Account for fractures and roughness in pit wall using a conservative factor (100)

Calculations:

Two methods were used in calculating the total amount of SO_4, Ca, and HCO_3 being added to the pit lake to calibrate assumptions.

The first method focuses on the use of humidity cell test results. Humidity cell testing of the various lithologic units provides data on sulfate release. The weight of each sample in each humidity cell was on the order of 1.5 kg. The total surface area of the particles in the cell was estimated by assuming uniform spherical particles of 0.3 cm radius. The release rate per unit mass of sample (from the humidity cell results) can thus be converted to a release rate per unit surface area.

Example Parameters and Calculation for sulfate from Unit 5E:

- (SA) Pit Wall Surface Area = 9,088 m^2
- (HCLA) Humidity Cell Leaching Average = 80.905 mg/kg of solid/week
- (HCW) Humidity Cell Sample Weight = 1.5 kg
- (SAHC) Surface Area of Particles in Humidity Cell = 0.005172 m^2 (includes conservative factor of 100 in calculation)
- (PFD) Pit Filling Duration: 46 years x 52 weeks = 2,392 weeks

SA x HCLA x (HCW / SAHC) x PFD / 1000000000 = 510 Tonnes of Sulfate

The second method to find the amount of constituents being contributed by pit wall weathering is based on assuming that all sulfides in the wall rock to a specified depth in the wall (0.1 m) are oxidized and released to the pit lake. The amount of sulfate released is calculated using the average sulfide content of each lithologic unit from static testing results presented in the Geochemical Assessment TSD, the specific gravity of each rock type, and the estimated surface area of each rock type.

Example Parameters and Calculation for sulfate from Unit 5E:

- (SA) Pit Wall Surface Area = 9,088 m^2
- (SG) Specific Gravity of Lithology = 3.47
- (PWD) Pit Wall Weathering Depth = 0.1 m
- (EBA/FRAC) Average Static Test Sulfide Content = 11.5%

SA x SG x PWD x (EBA / FRAC) = 363 Tonnes of Sulfide

363 Tonnes of Sulfide (M.W. = 32 g/mol) oxidized to sulfate (MW = 96 g/mol) →

$$363 \text{ Tonnes } \left(\frac{96\ tonnes\ SO4}{32\ tonnes}\right) = 1{,}088 \text{ tonnes sulfate}$$

The wall rock weathering contribution to TDS was estimated by assuming that the sulfate released by oxidation of the sulfide to produce sulfuric acid. This acid is then neutralized by reaction with calcite in the pit wall surfaces. The reactions produce one mole of sulfate per mole of sulfide oxidized in the pit wall, as well as two moles of dissolved calcium and two moles of dissolved bicarbonate. The sum of the masses of sulfate, calcium, and bicarbonate that result from these reactions was used to represent the TDS dissolved load to the pit lake from the pit wall. Using the mass balance equation, the other amounts of constituents that wall weathering will produce can be determined. The same mass balance equation was used regardless of the method utilized in finding the initial tonnes of constituent.

$$O_2 + H_20 + S^{2-} \rightarrow H_2SO_4$$

$$H_20 + 2CaCO_3 + H_2SO_4 \rightarrow SO_4^{2-} + 2Ca^{2+} + 2HCO_3^{-}$$

Example: Tonnes of Bicarbonate (HCO_3^-), from Tonnes of Sulfide (S^{2-})

- (MMS) Molar Mass of Sulfide = 32 g/mol^{1-}
- (MMB) Molar Mass of Bicarbonate = 61 g/mol^{1-}

(363 Tonnes of Sulfide / MMS) x (2 x MMB) = 1,383 Tonnes of Bicarbonate

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Results:

As shown in the calculations section, both methods produce very similar results for the total added from the pit wall weathering (within a factor of 2). Results of acid-base accounting indicate an overwhelming neutralization potential relative to the acid generation potential. Therefore, there is no risk of exhausting the alkalinity or an acidic pit lake. [Tables D-7 and D-8 both show the findings of these separate methods.]

Table D-7: Method 1 Constituent Contributions to Pit Lake

Lithologic Unit	Tonnes of SO4	Tonnes of Ca	Tonnes of HCO3
6C	275	115	349
7C	3	1	4
9G	0.6	0.2	0.7
11A	14	6	17
5C	197	82	250
5E	510	213	648
MV	1,895	792	2,409
Total	2,894	1,209	3,678

Table D-8: Method 2 Constituent Contributions to Pit Lake

METHOD 2						
Lithologic Unit	**Surface Area**	**Tonnage**	**Tonnes of S**	**Tonnes of SO4**	**Tonnes of Ca**	**Tonnes of HCO3**
6C	671,360	182,610	310	931	389	1,184
7C	3,248	952	3	9	4	12
9G	881	239	1	2	1	2
11A	21,584	6,497	10	31	13	40
5C	19,993	5,662	89	268	112	341
5E	9,088	3,153	363	1,088	454	1,383
MV	1,201,089	340,509	1,243	3,729	1,557	4,738
Total	1,927,243	539,621	2,019	6,058	2,531	7,699

7. METAL LOADING CALCULATIONS

Metal leaching from the various lithologic units was also measured in humidity cell tests. The results showed that the only significant metal leaching took place within the first five or six weeks of the test. The metal loading to the pit lake due to pit wall weathering was estimated the same way as Method 1 for the sulfate, calcium and bicarbonate.

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Assumptions:

- Cumulative amounts of metal released during the entire humidity cell test duration represents total amount of metal released per unit mass of pit wall
- The mass of rock that could release metal corresponds to the pit wall surface area of each unit multiplied by a depth of 0.1 m and the specific gravity of the unit.
- Units 9 and 11 were not tested in the humidity cell program and are assumed to be the average of the other metasedimentary units (6 and 7)

Data Sources:

- Analytical Results from Geochemical Assessment TSD (SLR, November 2016)

Calculations:

To calculate the leaching rate for each specific lithology, similar lithologic units' constituent measurements were averaged and then multiplied by the weight of the humidity cell divided by the total surface area of particles in the humidity cell. Non-similar lithologic units didn't need to be averaged with other units, and instead just multiplied their humidity cell results with the humidity cell weight divided by the total surface area of particles in the humidity cell. The results were converted to amounts per unit area, which are listed in Table D-9.

Example Parameters and Calculation:

Calculate Aluminum Leaching Rate for Lithologic Unit 6

- (L6) Lithologic Unit 6 Aluminum Concentration Humidity Cell Average = 1.43 mg/week
- (HCW) Humidity Cell Weight = 1.5 kg
- (SAHC) Surface Area of Particles in Humidity Cell = 0.005172 m^2

$$L6 \times (HCW / SAHC) = 415\ mg/m^2/t^*$$

* t = per week for TDS, sulfate, calcium and alkalinity; t = time to pit being full for all other constituents.

The resulting total metal mass leaching from the various lithologic units and the total metal mass loading to the pit lake due to pit wall weathering are presented in Table D-10.

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Table D-9: Leaching Rates from Pit Walls (mg/m²/t)

	Lithologic Unit						
	MV (1&2)	5C	5E	6	7	9	11
	Percent of Wall Surface Area						
Constituent	**62%**	**1.04%**	**0.47%**	**35%**	**0.17%**	**0.05%**	**1.12%**
TDS	4,019	19,604	113,370	1,759	1,073	1,416	1,416
Sulfate	663	3,232	18,691	290	177	233	233
Alkalinity (as CaCO3)	2,526	12,322	71,258	1,106	674	890	890
Phosphorus (T)	0	0	0	0	0	0	0
Nitrate - N	0	0	0	0	0	0	0
Ammonia N	0	0	0	0	0	0	0
Organic Carbon (D)	0	0	0	0	0	0	0
Arsenic	1.90	0.97	0.39	5.63	1.36	3.49	3.49
Cadmium	0	0.046	0.587	0	0	0	0
Chromium	0	0	0	0	0	0	0
Cobalt	0	0	1.44	0.41	0	0.20	0.20
Copper	5.52	4.69	10.71	15.76	3.38	9.57	9.57
Iron	67.1	4.4	21.6	1.2	2.9	2.0	2.0
Manganese	30.6	551	3,600	28.3	33.1	30.7	30.7
Nickel	0	0	51.6	1.88	0	0.94	0.94
Silver	0	0	0	0.136	0	0.068	0.068
Vanadium	7.7	0	0	0	9.8	4.9	4.9
Zinc	10.6	11.7	84.4	9.3	5.2	7.2	7.2
Mercury	0	0	0	0	0	0	0
Lead	1.21	0.31	1.03	0.35	0.58	0.47	0.47
Total Cyanide	0	0	0	0	0	0	0
Aluminum	1,463	191	23	415	1,154	785	785
Boron	0	52.2	68.6	0	0	0	0
Molybdenum	1.87	1.96	0.22	2.71	1.60	2.15	2.15
Selenium	0.44	0.21	3.67	0	1.08	0.54	0.54
Chloride	0	0	0	0	0	0	0
Calcium	830	4,050	23,422	363	222	293	293
Magnesium	-	-	-	-	-	-	-
Thallium	0	0.063	0.062	0.039	0.100	0.069	0.069

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Results:

Table D-10: Resulting Metal Mass Contributions (kg)

	Lithologic Unit							Totals
	MV (1&2)	5C	5E	6	7	9	11	
Arsenic	2.79	0.043	0.005	5.23	0.007	0.004	0.004	8.08
Cadmium	0.008	0.004	0.011	0	0	0	0	0.02
Chromium	0.069	0	0.0003	0	0	0	0	0.07
Cobalt	0	0.001	0.023	0.138	0.0001	0.0001	0.0001	0.16
Copper	9.44	0.79	0.15	17.39	0.022	0.014	0.014	27.8
Iron	0	0.096	0.183	0	0	0	0	0.28
Magnesium	14,153	446	563	1,141	28.1	4.3	4.3	16,340
Manganese	49.9	70.1	54.4	29.1	0.144	0.037	0.037	204
Nickel	0.311	0.033	0.683	0.706	0.001	0.001	0.001	1.73
Silver	0.007	0.002	0.002	0.282	0.00003	0.0002	0.0002	0.29
Vanadium	10.4	0	0	0	0.045	0.006	0.006	10.5
Zinc	11.21	0.69	1.41	9.82	0.034	0.011	0.011	23.2
Mercury	0	0.0001	0	0	0	0	0	0
Lead	1.85	0.017	0.014	0.370	0.002	0.0005	0.0005	2.25
Aluminum	2,021	9.8	0.26	380	4.3	0.78	0.78	2,418
Boron	186	9.9	2.2	137	0.67	0.17	0.17	336
Molybdenum	2.27	0.091	0.002	1.79	0.006	0.002	0.002	4.17
Selenium	0.568	0.013	0.061	0.039	0.005	0.001	0.001	0.69
Calcium	61,523	7,043	4,568	23,731	232	44.6	44.6	97,187
Thallium	0.018	0.004	0.001	0.016	0.001	0.000	0.000	0.04
Antimony	3.31	0.187	0.033	1.26	0.008	0.002	0.002	4.81
Barium	11.2	0.296	0.155	4.69	0.037	0.008	0.008	16.4
Beryllium	0	0	0	0	0	0	0	0
Bismuth	0	0	0	0	0	0	0	0
Lithium	3.56	0.236	0.061	1.48	0.014	0.003	0.003	5.35
Magnesium	14,153	446	563	1,141	28.1	4.3	4.3	16,340
Potassium	4,024	110	33.37	1,860	11.6	2.7	2.7	6,044
Silicon	7,880	199	24.0	3,083	22.8	4.9	4.9	11,219
Sodium	6,021	242	19.4	2,684	13.6	3.5	3.5	8,986
Strontium	201	7.0	5.9	31.3	0.49	0.08	0.08	246
Sulfur	12,862	4,487	5,900	4,068	27.8	6.1	6.1	27,358
Tin	0.892	0.051	0.005	0.485	0.005	0.001	0.001	1.44
Titanium	0	0	0.015	0	0	0	0	0.02
Uranium	1.79	0.034	0.002	1.76	0.001	0.001	0.001	3.59

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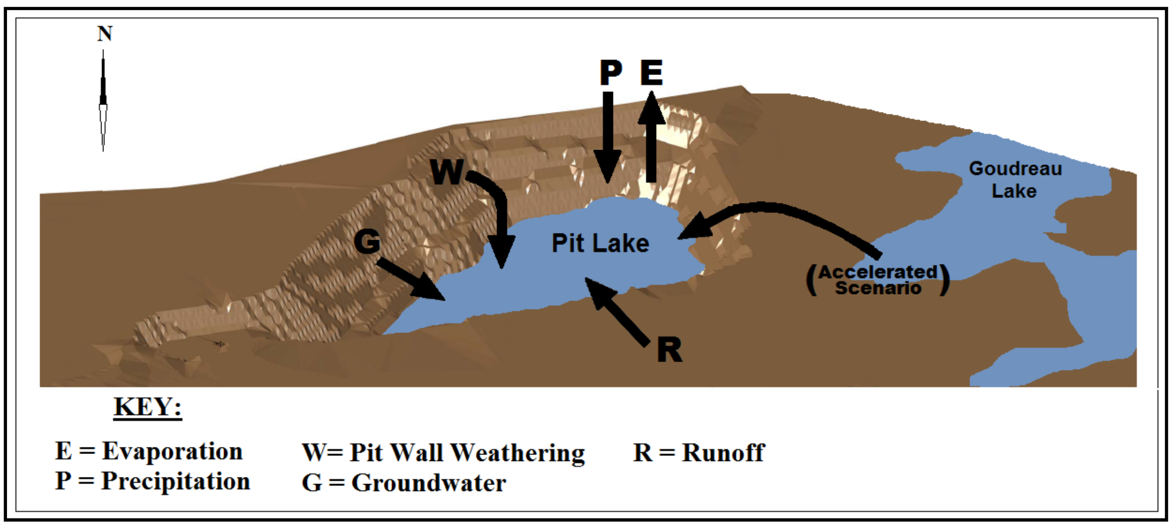
8. MASS BALANCE CALCULATIONS

Given the two filling time scenarios and each constituent contributing source concentrations, mass balance calculations to find the projected pit lake concentrations at the end of each scenario were prepared. The results of these projections were reviewed to determine if there are any constituents which could represent an environmental or human health hazard. If such a hazard was revealed, more detailed analyses (such as long-term evolution of the pit water quality after filling or geochemical modeling to adjust for saturation and thermodynamic stability) could be warranted.

Calculations:

To calculate the pit lake concentrations at the completion of filling, each constituent contributing source volume is multiplied by its concentration. The sum of those values is then divided by the sum of the volumes of seepage, TMF water, groundwater, runoff, and precipitation minus evaporation.

Figure E-3: Mass Calculation Components in Final Pit Lake Composition



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Example Parameters and Calculation for TDS (Accelerated):

- (C_{GW}) Concentration of groundwater constituents = 205 mg/L (Table D-3)
- (V_{GW}) Volume of groundwater in pit = 44.5 million m^3 (Table D-2)
- (C_{TMF}) Concentration of TMF water constituents = 6,394 mg/L (Table D-3)
- (V_{TMF}) Volume of TMF water in pit = 17.0 million m^3 (Table D-2)
- (C_{RO}) Concentration of runoff constituents = 146 mg/L (Table D-3)
- (V_{RO}) Volume of runoff in pit = 77.4 million m^3 (Table D-2)
- (C_{MR}) Concentration of mine rock constituents = 353 mg/L (Table D-3)
- (V_{MR}) Volume of mine rock water in pit = 11.0 million m^3 (Table D-2)
- (M_{PW}) Mass from pit wall = 7.8 billion mg (Table D-10)
- (P) Net Precipitation = 9.6 million m^3 (Table D-2)
- (C_{GL}) Concentration of Goudreau Lake constituents = 114 mg/L (Table D-3)
- (V_{GL}) Volume of Goudreau Lake = 25.2 million m^3 (Table D-2)

Pit Lake Concentration:

$$\frac{((C_{GW} \times V_{GW}) + (C_{RO} \times V_{RO}) + (C_{TMF} \times V_{TMF}) + (C_{MR} \times V_{MR}) + M_{PW} + (C_{GL} \times V_{GL}))}{\sum (V_{GW} + V_{RO} + V_{TMF} + V_{MR} + P + V_{GL})}$$

= 777 TDS mg/L

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Table D-11: Final Pit Filling Constituent Concentrations

Constituent	ODWS	PWQO	Base Case	Alternative
	mg/L	mg/L	mg/L	mg/L
pH	-	6.5 - 8.5	7.82	7.70
TDS	-	-	825	777
Sulfate	-	-	596	559
Alkalinity (as CaCO3)	-	-	137	133
Phosphorus (T)	-	0.01	0.05	0.05
Nitrate - N	-	-	0.50	0.58
Ammonia N	-	-	0.20	0.18
Organic Carbon (D)	5	-	7.0	7.0
Arsenic	0.025	0.005	0.004	0.004
Cadmium	0.005	0.0001	0.00013	0.00012
Chromium	0.05	-	0.0007	0.0007
Cobalt	-	0.0009	0.005	0.004
Copper	-	0.001	0.046	0.043
Iron	-	0.3	0.21	0.19
Magnesium	-	-	9.4	9.1
Manganese	0.05	-	0.11	0.10
Nickel	-	0.025	0.0020	0.0019
Silver	-	0.0001	0.0007	0.0007
Vanadium	-	0.006	0.0051	0.0047
Zinc	-	0.02	0.0030	0.0033
Mercury	-	0.0002	0.00006	0.00005
Lead	-	0.025	0.0002	0.0003
Total Cyanide	-	0.005	0.0003	0.0003
Aluminum	-	-	0.058	0.056
Boron	-	-	0.038	0.036
Molybdenum	-	-	0.006	0.006
Selenium	-	-	0.0008	0.0007
Chloride	-	-	7	6
Calcium	-	-	102	98
Thallium	-	-	0.00013	0.00014
Hardness	-	-	296	282

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Discussion:

As shown in Table D-11, the projected pit water concentrations are low in comparison to water quality criteria (i.e., provincial water quality objectives [PWQOs] and Ontario Drinking Water Standards [ODWS]). Further, the concentrations are generally not much different from current baseline water quality (Table D-3) except for TDS, sulfate, and alkalinity.

The base case results indicate concentrations are low enough that more detailed analysis is not necessary. However, based on experience with such modeling and the results of the preliminary mass balance calculations, there are likely some differences in results that would occur. In particular, bicarbonate concentrations would likely drop due to equilibration with the atmosphere resulting in a very slight (probably unmeasurable) change in pH. Also, dissolved manganese and iron (which come primarily from groundwater inflow into the pit) are stable in reducing conditions that typically occur in groundwater but are unstable in the oxidizing conditions that are expected in the pit lake. Therefore, these two metals are expected to precipitate in the sediments at the bottom of the lake. Also, organic carbon, nitrate and phosphate are consumed in surface water by natural biological activity so the estimated organic carbon, nitrate and phosphate concentrations in Table D-11 are higher than what will actually be present in the pit water. Similarly, ammonia is expected to rapidly transform into nitrate and be consumed by biological activity.

Cadmium, cobalt, copper and silver are all predicted by conserved-mass balance modeling to be above applicable water quality criteria (Table D-11). The source of these constituents in the pit lake is the TMF water transferred early in closure and with groundwater seepage. As mentioned with regard to the TMF water predictions in the Water Balance and Quality TSD, these constituents are among several metals that are present in the TMF water because they form soluble complexes with cyanide. For the predictions presented herein, the cyanide is predicted to degrade in the TMF and it is assumed to completely degrade in the pit lake during the 40 to 50 years of pit lake filling. When the cyanide is degraded, the soluble complexes with cadmium, cobalt, copper and silver have broken down and these metals are released for other natural reactions in the pit lake water. None of these metals are naturally stable in dissolved form in oxygenated, neutral pH water such as what will be present in the pit lake. Copper forms precipitates with carbonate and hydroxides; silver forms insoluble hydroxide and chloride salts; and cobalt coprecipitates with iron and manganese hydroxyoxides and will adsorb to mineral and clay surfaces. Cadmium is removed with biological activity. Therefore, it is expected that the concentrations of these constituents are over-predicted in the pit lake mass balance model.

The results for the accelerated filling approach (using Goudreau Lake Water) are also shown in Table D-11. The results are very similar to those of the base case. Because the results are similar, there is no need for more detailed evaluation for the accelerated filling case.