APPENDIX R1

Seepage and Draindown Evaluation of the 66 MT Eagle Gold Heap Leach Facility

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Technical Memorandum

To:	Steve Wilbur	**From:**	Amy L. Hudson, REM
Company:	Victoria Gold	**Date:**	November 23, 2011
Re:	Seepage and Draindown Evaluation of the 66 Million Tonne Eagle Gold Project Heap Leach Facility	**Doc #:**	
CC:	Bruce Marshall, Troy Meyer (Tetra Tech)		

1.0 Introduction

This technical memorandum presents Tetra Tech's infiltration and seepage modeling of the proposed 66 million tonne heap leach facility at the Eagle Gold Project in the Yukon Territory, Canada. The purpose of this modeling was to assess the seepage conditions that would likely exist during closure and post-closure periods and to estimate draindown rates during this period. The modeling was completed using the VADOSE/W program, a variably saturated (unsaturated and saturated conditions) model from the GeoStudio 2007 software package (GEO-SLOPE, 2007). Modeling was performed on a cross-section through the central portion of the heap and the embankment (see Figure 1).

2.0 Model Construction

The conceptual model provided as Figure 2, shows the system water balance components of the heap. The system water balance components consist of precipitation (rain and snow which can accumulate on the surface of the facility), evaporation (from soil surface), runoff, infiltration, and seepage. Seepage includes continued drain-down of the residual tailings solution, as well as any infiltration of precipitation. Modeling was performed to simulate the conditions during the closure and post closure period of the facility, so the water balance does not include the application of leaching solution or rinse water. The starting point of model is the first day after the completion of rinsing and includes the in-heap pond. It is assumed for the purpose of simulating the draindown conditions that the system is free draining.

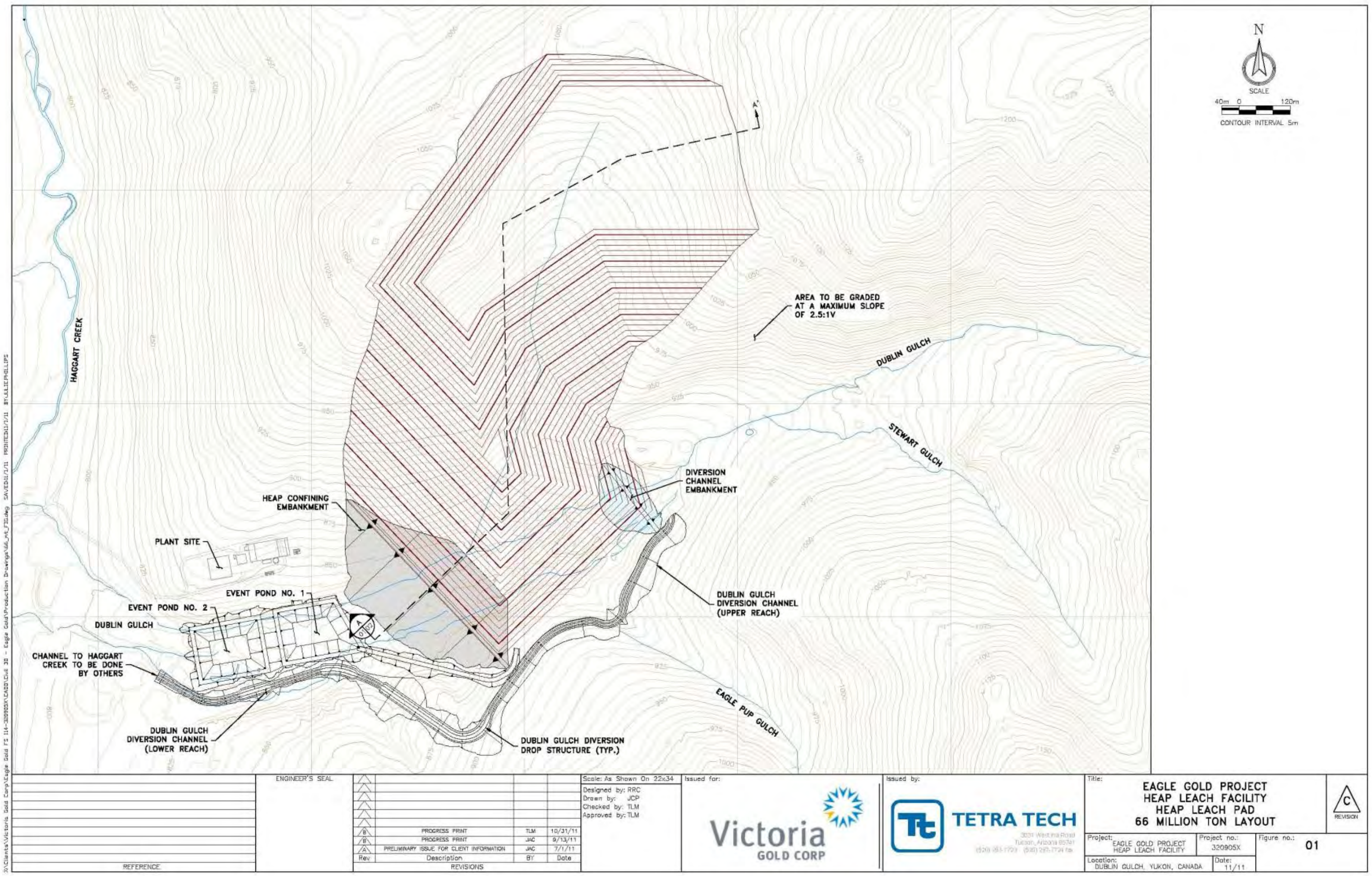


Figure 1 Heap Leach Facility Layout and Model Cross-Section

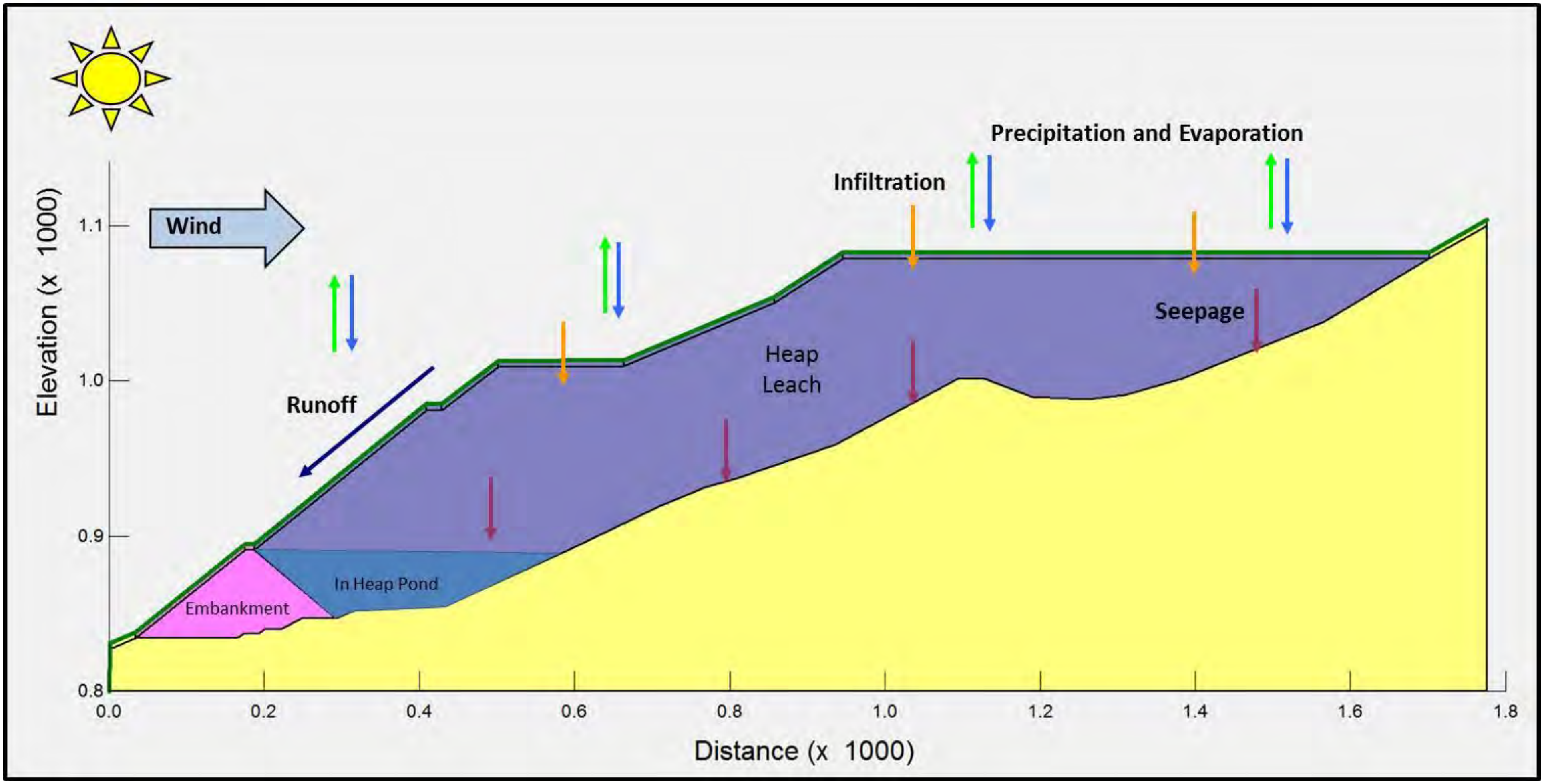


Figure 2 Heap Leach Facility Conceptual Model

2.1 Model Input Parameters

The following sections present the data that was used in the seepage assessment.

2.1.1 Climate Data

The climate data used for this modeling was obtained from the Potato Hills and the Dawson meteorological stations. The parameters in the climate data file included:

- Minimum and maximum daily temperature;
- Daily precipitation;
- Minimum and maximum daily humidity;
- Daily evaporation or net radiation; and
- Average daily wind speed.

The Potato Hills meteorological station is located approximately four kilometers from the heap. The dataset applied to the modeling utilizes the data from period of record for the meteorological station (2007 to 2011). The Dawson meteorological station is located approximately 170 kilometers from the heap and a limited amount of data was utilized to provide information to fill gaps in the precipitation record from the Potato Hills record (no snow measurements collect at this station). The climate data was used as an actual conditions file in the modeling so the daily measured data from the station was used to make a ten year continuous data set that represents the site conditions and would provide a long term scenario to minimize the “noise” in the model results and to allow the draindown to reach a near steady state condition. Each year selected for use in the ten year file had a generally average amount of precipitation. The average site precipitation was determined to be 533 millimeters (mm) from a regression equation presented in the Surface Water Balance Model Report (Stantec, 2011):

$$y = (0.173x + 203) \text{ site adjustment factor}$$

Where: y = average annual precipitation (mm)

x = median basin elevation (m)

site adjustment factor = 1.4

2.1.2 Material Properties

The most significant difference between saturated and unsaturated flow is the hydraulic conductivity. The hydraulic conductivity in saturated media is a function of the material type. In unsaturated flow, the hydraulic conductivity is a function of the material properties and the moisture content of the material. The equation used to calculate water flow within unsaturated media is:

$$q = -K(\theta)\nabla H$$

Where:

- q = water flow velocity (L^2/t)
- K(θ) = hydraulic conductivity as a function of soil (or rock) moisture content (L/t)

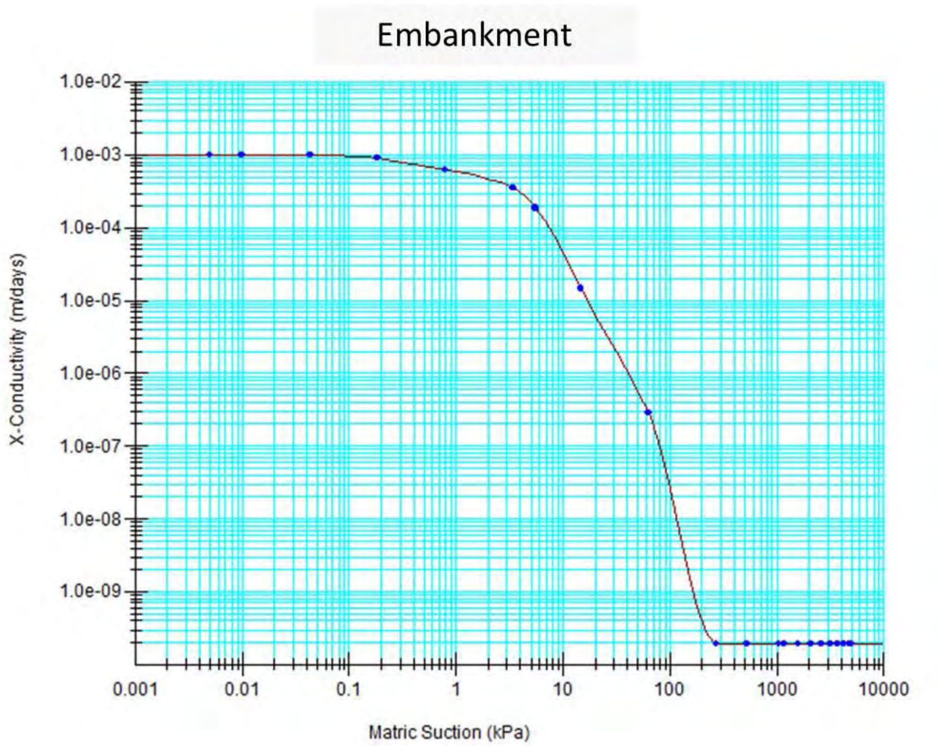
- ∇H = hydraulic head (L)

The relationship between moisture content and hydraulic conductivity is non-linear, which further complicates the flow dynamics. In saturated material, the physics of flow are relatively simple and are driven by Darcy's Law where the flow is proportional to the saturated hydraulic conductivity, gravity, and pressure gradients. In simple terms, water flows downhill (downward pressure gradient) and flows faster through coarse material than fine material. However, in unsaturated flow, additional controlling forces include matric pressure, absorption, and electrostatic forces.

Matric pressure is the suction created by capillary forces and the interaction of water, air, and solid surfaces. Matric pressure can be observed by placing a thin straw into a body of water. Driven by the surface tension forces, the water rises inside the straw, defying the force of gravity. The thinner the straw, the stronger the suction force will be and the higher the column of water will rise in the tube. The same process occurs in the voids between material particles in a heap.

One of the most unusual properties of unsaturated zone flow is that different materials are preferentially conductive with varying moisture contents. Under high moisture conditions, pores are saturated and their suction decreases significantly. In this case, gravity is the strongest force and water will flow downhill from pore space to pore space. At low moisture conditions, the preferential flow changes, and the suction forces become stronger than gravitational forces. In this case, the tight materials are the most conductive with small voids that literally suck water through them. Under low moisture conditions, clay is more conductive than the sandy material.

The material properties used in the VADOSE/W (GEO-SLOPE, 2007) models were based on the design properties of the heap, literature values and previous experience. The embankment material was simulated as low permeability dam material (10^{-6} cm/sec), and the heap material simulated as a generally uniform material with a saturated hydraulic conductivity of approximately 10^{-2} cm/sec (well-sorted sand and gravel [Fetter, 2000]). The ore will be conventionally ground to a P80 of 6.3 mm (fine gravel) and agglomerated with cement. Figure 3 presents the hydraulic conductivity as a function of the matric suction of the heap and embankment materials. Figure 4 presents the water content as a function of the matric suction of the same materials. The units used in these figures are those utilized by the modeling software.



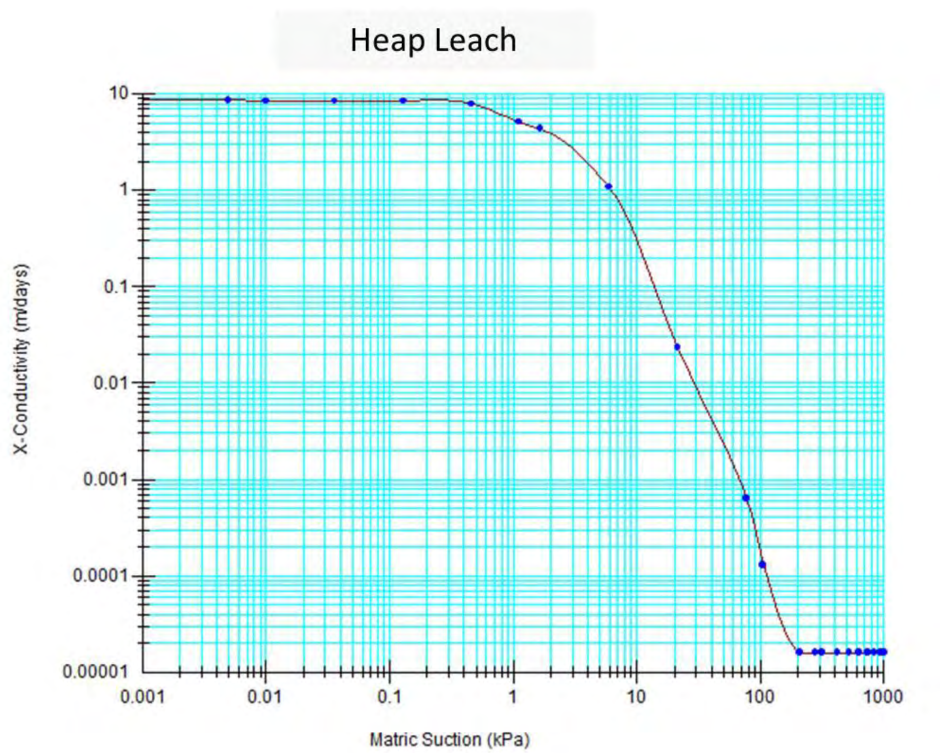
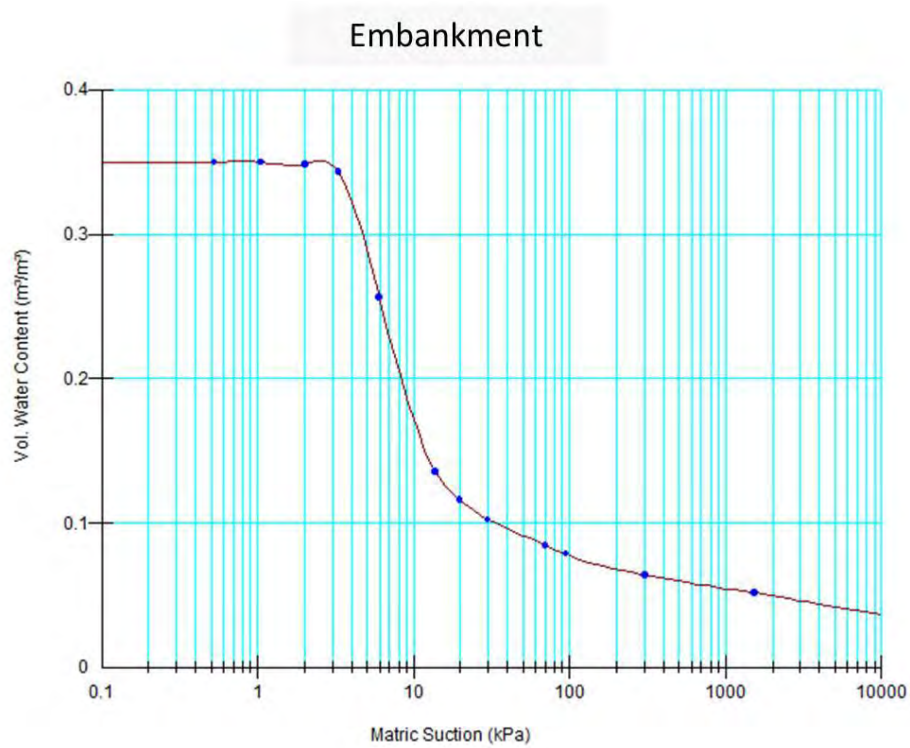


Figure 3 Hydraulic Conductivity Functions



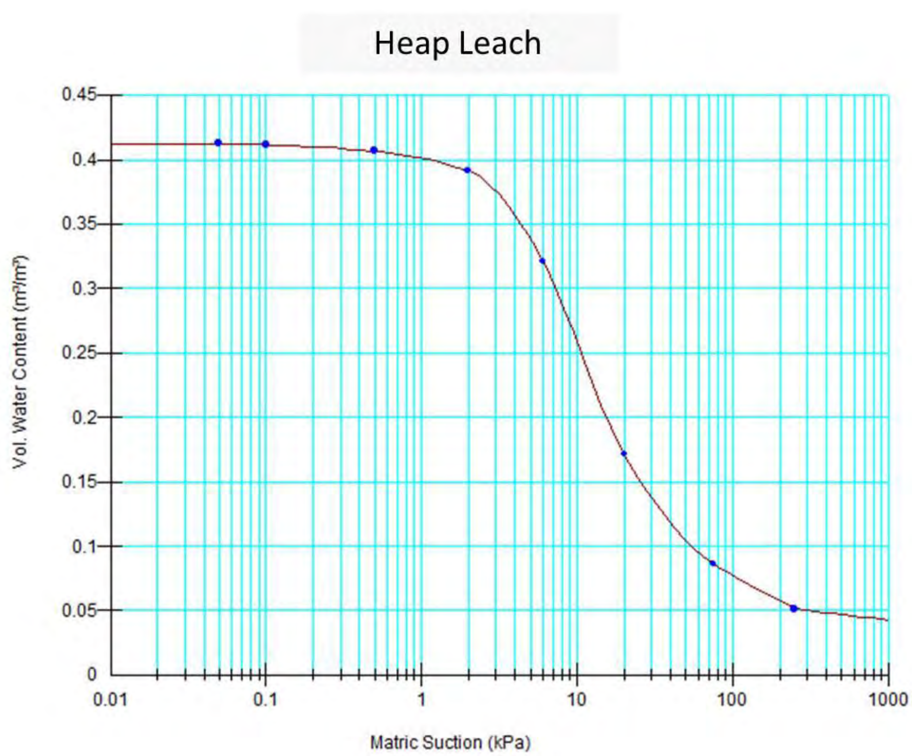


Figure 4 Soil Water Characteristic Curves

2.1.3 Boundary Conditions

The boundary conditions used in this modeling were limited to a zero pressure boundary at the base of the model to ensure the system is free draining, initial moisture addition to simulate moisture applied to the system by the emitters during the operational phase of the heap, and the climate file. The initial moisture content of the heap leach material was defined by applying a very small source of water at the top surface of the model and allowing the model to reach a steady state condition that is representative of the operational moisture content of the heap material, including the in-heap pond. A climate file was used in this modeling to ensure an evaluation of the long term behavior of the heap leach material under actual climatic conditions.

2.2 Modeling Technique

2.2.1 Steady State Modeling

Steady state modeling is challenging when analyzing mining sites because the facilities change quickly. Therefore, one of the objectives of the steady state model was to offer non-zero starting values for the subsequent transient modeling scenario and establish the water level of the in-heap pond.

2.2.2 Transient Modeling

Transient modeling provides a reasonable simulation of flow conditions within the heap material. The uppermost layer of the model is a surface region representing the top surface layer of the facility. It is in this part of the model that atmospheric conditions and heap come in contact, driving the water balance. The water within the facility then moves according to the rules of unsaturated flow physics through the heap material. Finally, and if applicable, the water reaches the base of the modeled region, where it moves to the model discharge point.

2.2.2.1 Surface Layer

VADOSE/W (Geo-Slope, 2007) simulates the dynamics of the facility surface by considering climate and soil interactions. VADOSE/W (Geo-Slope, 2007) simulates precipitation using time increments with a maximum size of two (2) hours. The daily precipitation data is distributed according to a sinusoidal function that peaks at noon (normal distribution). This distribution pattern was compared with the constant averaged and the sloped averaged distribution patterns, and it was determined that the sinusoidal pattern resulted in the most stable calculation of the results. Potential evaporation or net radiation measurements are used to calculate the actual evaporation that is possible based on the conditions provided in the surface layer of the model. Evaporation is calculated from the following climate and soil parameters:

- Air temperature;
- Soil temperature;
- Relative humidity;
- Solar intensity (from latitude);
- Soil temperature;
- Soil moisture content;
- Wind speed; and

- Measured pan/modeled actual evaporation.

The combination of the factors listed above provides a reasonable estimate of water evaporation from the system. Infiltration is based on the unsaturated hydraulic conductivity of the material at a given time. Excess rain that has not evaporated or infiltrated is tabulated as runoff. Excess snow is allowed to accumulate on the surface of the heap, and snow that does not sublimate becomes snow melt and can infiltrate into the heap material.

2.2.2.2 Transient Flow within the Facilities

The transient flow dynamics within the heap material are simulated over time and space. The models account for transitions between material types and produces the following data sets:

- Water flux within the model domain;
- Moisture content;
- Water flow velocity; and
- Seepage discharge, if applicable (out of the model domain).

The following sections present the infiltration and seepage model results.

3.0 Model Results

After leaching and rinsing are complete, the spent ore will be allowed to drain freely. For this modeling effort, it was assumed that all of the draindown flow would be removed from the heap to provide a baseline draindown curve. No optimization scenarios (e.g. recirculation of fluid) were considered in this modeling. This assumption results in a faster draindown of the heap than would be realized if solution is recirculated back to the top of the heap to be draindowned again. Additionally, this modeling assumed that the heap would remain uncovered for the period of modeling. This assumption results in a conservative estimation of the drainage. The simulated draindown curve for the heap is presented in Figure 5.

As shown in Figure 5, the baseline rate of draindown decreases quickly, and can be managed through active or passive treatment techniques. In Year 10, the calculated draindown flow is approximately two to three cubic meters per hour (2 - 3 m^3/hr), which equates to roughly 4 - 5% of average annual precipitation. For an uncovered heap, the draindown rate will not trend toward zero but instead will become asymptotic with the drainage rate due to net infiltration through the top of the heap (approximately 2.8 m^3/hr for this heap). Infiltration during the ten year simulation period is approximately 10% of annual precipitation, with the balance of the water being lost through evaporation/sublimation and runoff.

It is assumed that the draindown rate after the ten year period (2.8 m^3/hr) will be representative of the long term drainage conditions of the heap. The calculated total volume of draindown from the heap during the first ten years of the closure period is 1,296,000 cubic meters (m^3) as determined from the ten year simulation period of this modeling study (Figure 6).

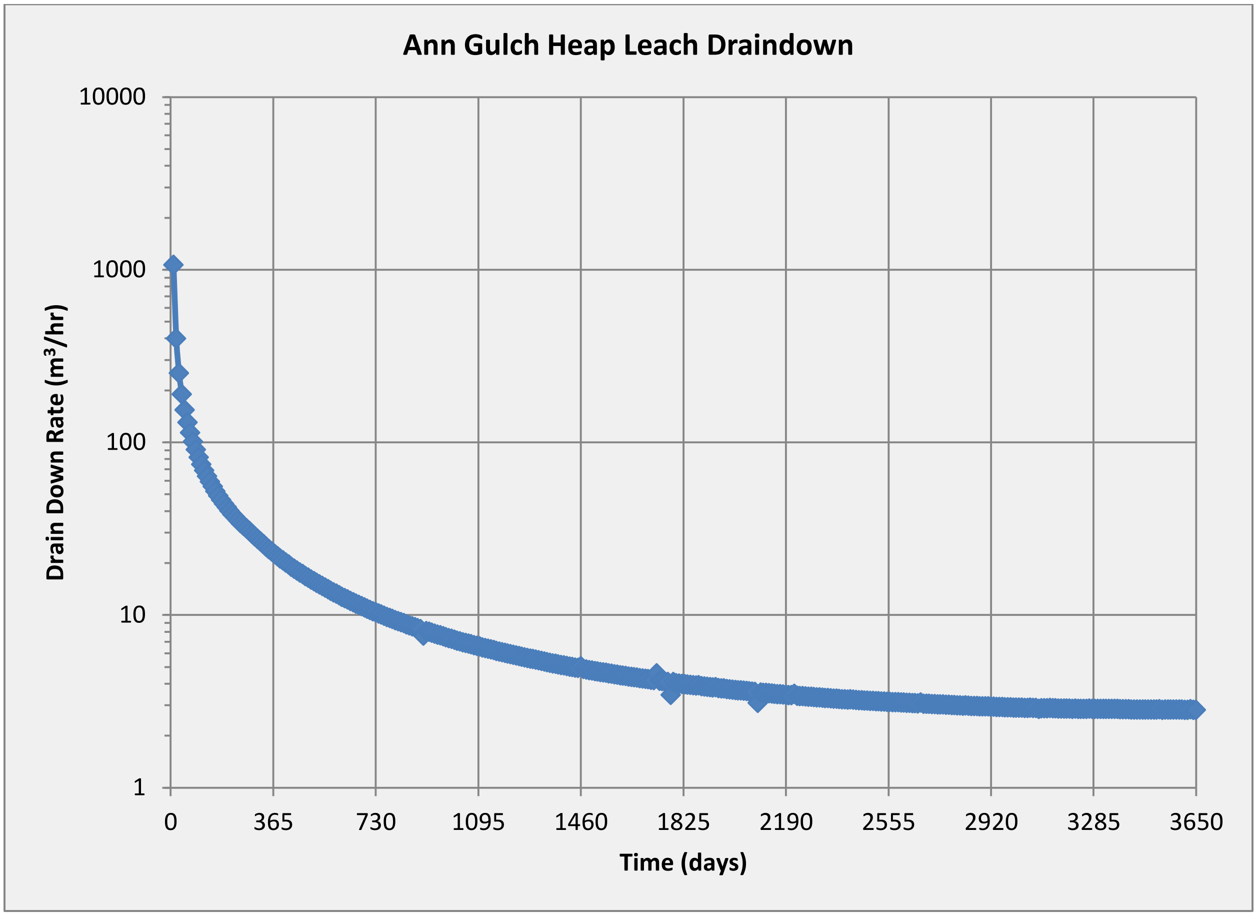


Figure 5 Draindown Curve for Heap Leach Facility

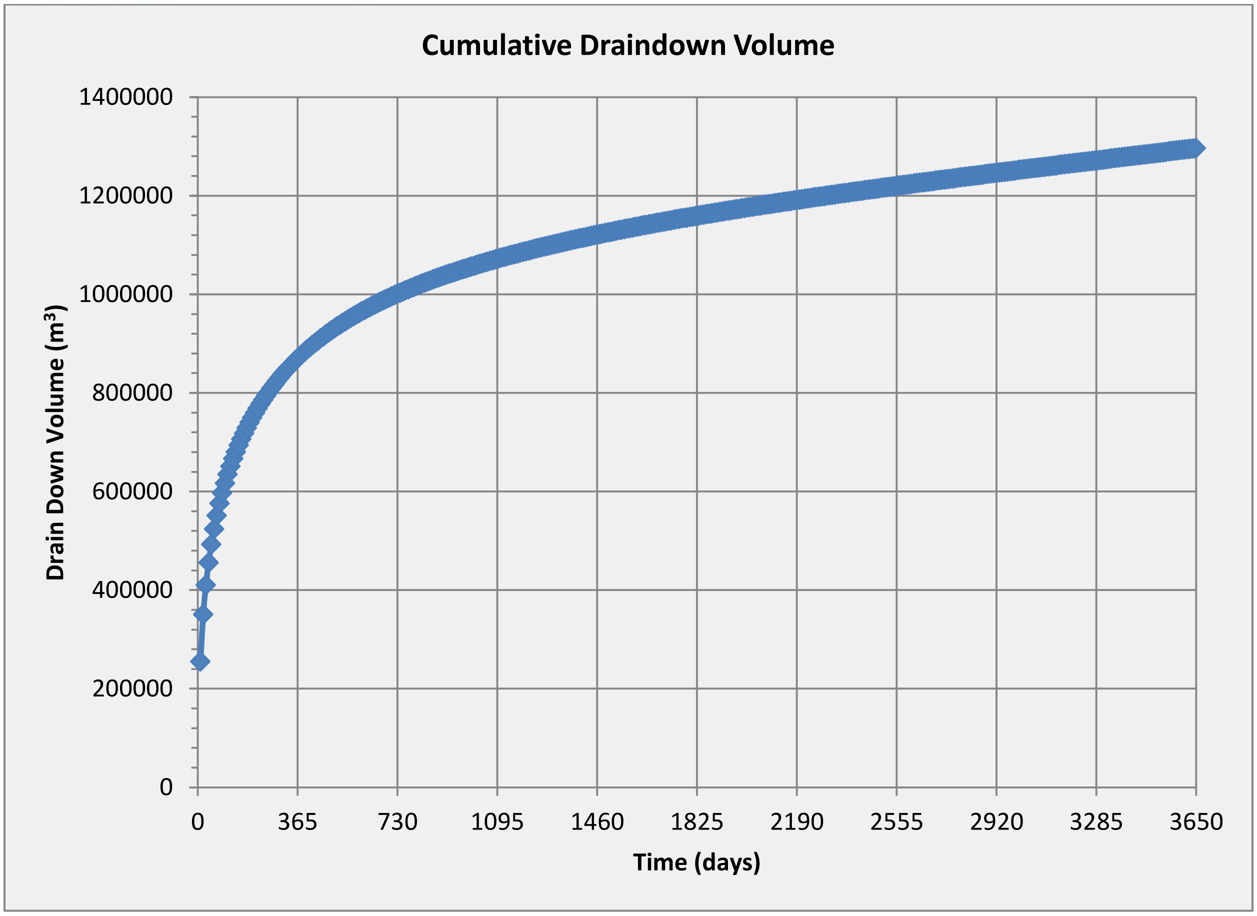


Figure 6 Cumulative Draindown Volume for Heap Leach Facility

4.0 References

Fetter, C.W., 2000. *Applied Hydrogeology*. Prentice Hall: New Jersey.

GEO-SLOPE International, Ltd. (GEO-SLOPE), 2007. *Vadose Zone Modeling with VADOSE/W 2007: An Engineering Methodology*. GEO-SLOPE International Ltd.: Calgary, Alberta, Canada.

Stantec, 2011. Surface Water Balance Model Report

APPENDIX R4

January – April 2011 Water Quality Table

Table R4-1 below presents the data collect January – April 2011 at the sites shown in Figure R4-1. The data presented below were collected after submission of the Eagle Gold Project Proposal (YOR 2110-0267-003-1), and are consequently a supplement to those presented in the Proposal

Table R4-1: Eagle Gold Water Quality Data, January – May 2011

Site	Date	Conductivity	Hardness (as $CaCO_3$)	pH	TSS	TDS	Turbidity	Alkalinity, Total (as $CaCO_3$)	Ammonia (as N)	Bromide	Chloride	Fluoride	Nitrate (as N)	Nitrite (as N)	TKN	Total Nitrogen	Ortho Phosphate (as P)	Total Dissolved Phosphate (as P)	Total Phosphate (as P)	Sulfate
		µS/cm	mg/L		mg/L	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
W1	31-Jan-11	135	66.1	7.58	<5.0	81	1.54	48.6	<0.0050	<0.050	<0.50	0.081	0.103	<0.0010	<0.050	0.103	0.0045	0.0051	0.0098	18.0
W1	24-Feb-11	136	70.1	7.79	<3.0	90	0.43	51.5	<0.0050	<0.050	<0.50	0.084	0.110	<0.0010	0.083	0.192	0.0050	0.0056	0.0085	19.2
W1	30-Mar-11	135	64.1	7.74	<3.0	84	0.21	46.5	<0.0050	<0.050	<0.50	0.078	0.0777	<0.0010	0.074	0.152	0.0023	0.0033	0.0059	18.9
W1	19-Apr-11	138	68.4	7.57	<3.0	99	0.27	53.9	<0.0050	<0.050	<0.50	0.085	0.107	<0.0010	<0.050	0.107	0.0046	0.0039	0.0050	19.1
W4	27-Jan-11	384	212	7.95	<3.0	259	0.40	122	<0.0050	<0.050	<0.50	0.098	0.138	<0.0010	0.057	0.195	<0.0010	<0.0020	<0.0020	86.0
W4	24-Feb-11	397	226	7.95	<3.0	259	0.39	123	<0.0050	<0.050	<0.50	0.093	0.137	<0.0010	0.077	0.214	<0.0020	<0.0010	0.0022	89.2
W4	30-Mar-11	399	211	7.88	<3.0	249	0.73	117	<0.0050	<0.050	<0.50	0.098	0.115	<0.0010	<0.050	0.115	<0.0010	<0.0020	<0.0020	94.3
W4	19-Apr-11	396	220	8.02	3.9	265	0.91	124	<0.0050	<0.050	<0.50	0.106	0.122	<0.0010	<0.050	0.122	<0.0010	<0.0020	<0.0020	92.9
W9	31-Jan-11	442	276	8.12	**23**	233	3.67	192	<0.0050	<0.050	<0.50	0.143	0.295	<0.0010	0.26	0.555	0.0041	0.0045	0.01	60.3
W9	24-Feb-11	Frozen																		
W9	30-Mar-11	Frozen																		
W9	19-Apr-11	454	261	8.16	<3.0	281	0.67	195	<0.0050	<0.050	<0.50	0.144	0.262	<0.0010	<0.050	0.262	0.0047	0.0040	0.0056	64.2
W21	27-Jan-11	242	127	7.91	<3.0	172	0.18	70.9	<0.0050	<0.050	<0.50	0.094	0.131	<0.0010	0.059	0.190	0.0037	0.0039	0.0039	56.4
W21	24-Feb-11	268	143	7.97	<3.0	181	0.34	73.1	<0.0050	<0.050	<0.50	0.096	0.133	<0.0010	0.102	0.235	0.0042	0.0042	0.0050	63.9
W21	30-Mar-11	309	162	8.02	<3.0	209	0.30	87.8	0.0169	<0.050	<0.50	0.082	0.225	<0.0010	0.368	0.593	<0.0010	0.0022	0.0084	70.1
W21	19-Apr-11	249	128	8.03	9.4	161	17.5	75.6	<0.0050	<0.050	2.00	0.077	0.0753	<0.0010	0.104	0.180	0.0027	0.0052	0.0193	52.1
W22	27-Jan-11	391	217	7.90	<3.0	264	0.24	122	<0.0050	<0.050	<0.50	0.102	0.146	<0.0010	<0.050	0.146	<0.0010	<0.0020	<0.0020	89.5
W22	24-Feb-11	407	228	7.92	<3.0	267	0.44	125	<0.0050	<0.050	<0.50	0.094	0.138	<0.0010	0.082	0.220	<0.0020	0.0013	<0.0020	93.3
W22 mean	30-Mar-11	405	221	7.92	2.55	261	0.65	117	<0.0050	<0.050	<0.50	0.098	0.117	0.0010	0.04	0.145	<0.0010	<0.0020	0.00155	96.4
W22	19-Apr-11	400	220	7.99	4.4	253	0.64	120	0.0064	<0.050	<0.50	0.107	0.129	<0.0010	<0.050	0.129	<0.0010	<0.0020	<0.0020	95.2
W23	27-Jan-11	416	236	8.01	<3.0	282	0.39	127	<0.0050	<0.050	<0.50	0.089	0.215	<0.0010	0.074	0.289	0.0024	0.0033	0.0043	93.3
W27	27-Jan-11	368	205	8.18	**22.5**	238	3.83	146	<0.0050	<0.050	<0.50	0.166	0.132	<0.0010	0.057	0.189	0.0080	0.0088	0.0205	58.3
W27	24-Feb-11	Frozen																		
W27	30-Mar-11	290	152	8.08	<3.0	185	1.08	90.2	<0.0050	<0.050	<0.50	0.106	0.137	<0.0010	<0.050	0.137	<0.0010	<0.0020	0.0041	57.0
W27	19-Apr-11	256	138	8.02	**7850**	192	**>4000**	82.5	0.143	<0.050	1.29	0.144	0.132	0.0028	**1.69**	**1.82**	0.0020	0.0056	**1.20**	52.5
W29	27-Jan-11	410	229	8.05	<3.0	276	0.50	133	<0.0050	<0.050	<0.50	0.110	0.133	<0.0010	0.055	0.188	0.0011	<0.0020	<0.0020	92.7
W29	24-Feb-11	427	241	8.02	<3.0	274	0.49	134	<0.0050	<0.050	<0.50	0.101	0.132	<0.0010	0.076	0.208	<0.0020	0.0014	0.0021	96.4
W29	30-Mar-11	425	230	8.03	<3.0	275	0.50	132	<0.0050	<0.050	0.87	0.102	0.111	<0.0010	<0.050	0.111	<0.0010	<0.0020	<0.0020	98.5
W29 mean	19-Apr-12	418	235	8.10	3.4	276	3.27	130	<0.0050	<0.050	1.06	0.113	0.118	<0.0010	<0.050	0.118	0.0012	<0.0020	0.0032	97.2

NOTES:
Bolded values exceed Canadian Council of Ministers for the Environment Water Quality Guidelines for the Protection of Aquatic Life or British Columbia Ministry of Environment Water Quality Guidelines
Shaded samples have elevated TSS, suggestive of sample disturbance during collection under ice
W27, April - elevated TSS related to permafrost disturbance in Suttle Gulch watershed

Site	Date	Conductivity	Hardness (as $CaCO_3$)	pH	TSS	Cyanide, Weak Acid Diss	Cyanide Total	DOC	Aluminum Total	Antimony Total	Arsenic Total	Barium Total	Beryllium Total	Bismuth Total	Boron Total	Cadmium Total	Calcium Total	Chromium Total	Cobalt Total	Copper Total
		µS/cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
W1	31-Jan-11	135	66.1	7.58	<5.0	<0.0050	<0.0050	<0.50	0.0186	0.0011	**0.0293**	0.0518	<0.00050	<0.00050	<0.010	<0.000017	18.9	<0.00050	<0.00010	<0.00050
W1	24-Feb-11	136	70.1	7.79	<3.0	<0.0050	<0.0050	0.83	0.0113	0.00099	**0.0254**	0.0518	<0.00050	<0.00050	<0.010	<0.000017	18.3	<0.00050	<0.00010	<0.00050
W1	30-Mar-11	135	64.1	7.74	<3.0	<0.0050	<0.0050	1.02	<0.012	0.00098	**0.0238**	0.0517	<0.00050	<0.00050	<0.010	0.000019	17.9	<0.00050	<0.00010	<0.00050
W1	19-Apr-11	138	68.4	7.57	<3.0	<0.0050	<0.0050	1.17	0.0088	0.00107	**0.0273**	0.0551	<0.00050	<0.00050	<0.010	<0.000017	18.9	<0.00050	<0.00010	<0.00050
W4	27-Jan-11	384	212	7.95	<3.0	<0.0050	<0.0050	1.00	0.0046	0.00025	0.00149	0.0423	<0.00050	<0.00050	<0.010	<0.000017	48.6	<0.00050	<0.00010	<0.00050
W4	24-Feb-11	397	226	7.95	<3.0	<0.0050	<0.0050	0.83	0.0074	0.00028	0.00126	0.0458	<0.00050	<0.00050	<0.010	<0.000017	51.7	<0.00050	0.00011	**0.00507**
W4	30-Mar-11	399	211	7.88	<3.0	<0.0050	<0.0050	1.06	<0.015	0.00025	0.00110	0.0427	<0.00050	<0.00050	<0.010	<0.000017	52.1	<0.00050	0.00010	<0.00050
W4	19-Apr-11	396	220	8.02	3.9	<0.0050	<0.0050	1.27	0.0321	0.00023	0.00123	0.0418	<0.00050	<0.00050	<0.010	<0.000017	52.6	<0.00050	0.00015	<0.00050
W9	31-Jan-11	442	276	8.12	**23**	<0.0050	**0.0716**	0.51	0.056	0.00056	**0.0179**	0.0785	<0.00050	<0.00050	<0.010	<0.000017	46.6	<0.00050	<0.00010	<0.00050
W9	24-Feb-11	Frozen																		
W9	30-Mar-11	Frozen																		
W9	19-Apr-11	454	261	8.16	<3.0	<0.0050	<0.0050	2.24	0.0280	0.00063	**0.0144**	0.0807	<0.00050	<0.00050	<0.010	<0.000017	52.9	<0.00050	<0.00010	<0.00050
W21	27-Jan-11	242	127	7.91	<3.0	<0.0050	<0.0050	1.24	0.0042	0.00148	**0.0254**	0.0585	<0.00050	<0.00050	<0.010	<0.000017	32.2	<0.00050	<0.00010	<0.00050
W21	24-Feb-11	268	143	7.97	<3.0	<0.0050	<0.0050	1.13	<0.0030	0.00158	**0.0283**	0.0606	<0.00050	<0.00050	<0.010	0.000018	35.4	<0.00050	<0.00010	0.00052
W21	30-Mar-11	309	162	8.02	<3.0	<0.0050	<0.0050	1.83	<0.0090	0.00164	**0.0208**	0.0656	<0.00050	<0.00050	<0.010	0.000023	40.1	<0.00050	<0.00010	0.00073
W21	19-Apr-11	249	128	8.03	9.4	<0.0050	<0.0050	3.46	**0.574**	0.00166	**0.0211**	0.0641	<0.00050	<0.00050	<0.010	**0.000473**	33.7	0.00101	0.00027	0.00195
W22	27-Jan-11	391	217	7.90	<3.0	<0.0050	<0.0050	1.08	0.0058	0.00021	0.00065	0.0439	<0.00050	<0.00050	<0.010	<0.000017	50.9	<0.00050	<0.00010	<0.00050
W22	24-Feb-11	407	228	7.92	<3.0	<0.0050	<0.0050	0.80	0.0043	0.00023	0.00070	0.0461	<0.00050	<0.00050	<0.010	0.000019	53.3	<0.00050	0.00012	0.00232
W22 mean	30-Mar-11	405	221	7.92	2.55	<0.0050	<0.0050	1.07	<0.015	0.00023	0.00077	0.0427	<0.00050	<0.00050	<0.010	0.000020	51.8	<0.00050	0.00009	<0.00050
W22	19-Apr-11	400	220	7.99	4.4	<0.0050	<0.0050	1.27	0.0446	0.00024	0.00082	0.0433	<0.00050	<0.00050	<0.010	0.000018	54.0	<0.00050	0.00018	<0.00050
W23	27-Jan-11	416	236	8.01	<3.0	<0.0050	<0.0050	1.51	0.0375	0.00047	0.00404	0.0577	<0.00050	<0.00050	<0.010	<0.000017	63.6	<0.00050	<0.00010	<0.00050
W27	27-Jan-11	368	205	8.18	**22.5**	<0.0050	<0.0050	1.92	**0.142**	0.00486	**0.0324**	0.0641	<0.00050	<0.00050	<0.010	0.000024	44.5	<0.00050	0.00014	0.00156
W27	24-Feb-11	Frozen																		
W27	30-Mar-11	290	152	8.08	<3.0	<0.0050	<0.0050	1.38	<0.024	0.00258	**0.0180**	0.0470	<0.00050	<0.00050	<0.010	<0.000017	34.8	<0.00050	<0.00010	0.00071
W27	19-Apr-11	256	138	8.02	**7850**	<0.0050	**0.0749**	3.23	**77.2**	0.0147	**0.977**	1.98	<0.0050	0.0060	<0.10	**0.00500**	74.7	**0.168**	**0.117**	**0.327**
W29	27-Jan-11	410	229	8.05	<3.0	<0.0050	<0.0050	1.12	0.0085	0.00065	0.00241	0.0468	<0.00050	<0.00050	<0.010	<0.000017	55.1	<0.00050	<0.00010	<0.00050
W29	24-Feb-11	427	241	8.02	<3.0	<0.0050	<0.0050	0.82	0.0033	0.00062	0.00252	0.0486	<0.00050	<0.00050	<0.010	<0.000017	56.6	<0.00050	<0.00010	<0.00050
W29	30-Mar-11	425	230	8.03	<3.0	<0.0050	<0.0050	1.22	<0.0090	0.00057	0.00241	0.0449	<0.00050	<0.00050	<0.010	<0.000017	56.6	<0.00050	<0.00010	0.00108
W29 mean	19-Apr-12	418	235	8.10	3.4	<0.0050	<0.0050	1.23	**0.134**	0.00064	0.00452	0.0457	<0.00050	<0.00050	<0.010	<0.000017	56.3	<0.00050	0.00012	0.00056

NOTES:
Bolded values exceed Canadian Council of Ministers for the Environment Water Quality Guidelines for the Protection of Aquatic Life or British Columbia Ministry of Environment Water Quality Guidelines
Shaded samples have elevated TSS, suggestive of sample disturbance during collection under ice
W27, April - elevated TSS related to permafrost disturbance in Suttle Gulch watershed

Site	Date	Conductivity	Hardness (as $CaCO_3$)	pH	TSS	Iron Total	Lead Total	Lithium Total	Magnesium Total	Manganese Total	Mercury Total	Molybdenum Total	Nickel Total	Phosphorus Total	Potassium Total	Selenium Total	Silicon Total	Silver Total	Sodium Total
		μS/cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
W1	31-Jan-11	135	66.1	7.58	<5.0	<0.030	<0.000050	<0.0050	4.83	0.000752	<0.000050	0.00200	<0.00050	<0.30	<2.0	<0.0010	6.47	<0.000010	<2.0
W1	24-Feb-11	136	70.1	7.79	<3.0	<0.030	<0.000050	<0.0050	4.99	0.000594	<0.000010	0.00198	<0.00050	<0.30	<2.0	<0.0010	6.36	<0.000010	<2.0
W1	30-Mar-11	135	64.1	7.74	<3.0	<0.030	<0.000050	<0.0050	4.93	0.000769	<0.000010	0.00209	<0.00050	<0.30	<2.0	<0.0010	6.26	0.000019	<2.0
W1	19-Apr-11	138	68.4	7.57	<3.0	<0.030	<0.000050	<0.0050	5.33	0.000540	<0.000010	0.00222	<0.00050	<0.30	<2.0	<0.0010	6.46	<0.000010	<2.0
W4	27-Jan-11	384	212	7.95	<3.0	<0.030	<0.000050	0.0078	19.8	0.0266	<0.000010	0.000132	0.00072	<0.30	<2.0	<0.0010	4.29	<0.000010	2.2
W4	24-Feb-11	397	226	7.95	<3.0	0.041	0.000054	0.0082	21.7	0.0349	<0.000010	0.000117	0.00110	<0.30	<2.0	<0.0010	4.57	<0.000010	2.3
W4	30-Mar-11	399	211	7.88	<3.0	0.054	0.000055	0.0081	22.5	0.0337	<0.000010	0.000080	0.00128	<0.30	<2.0	<0.0010	4.57	0.000012	2.4
W4	19-Apr-11	396	220	8.02	3.9	0.105	0.000085	0.0096	22.3	0.0433	<0.000010	0.000088	0.00138	<0.30	<2.0	<0.0010	4.56	<0.000010	2.4
W9	31-Jan-11	442	276	8.12	**23**	0.085	0.000113	0.0111	33	0.00153	<0.000050	0.00101	<0.00050	<0.30	<2.0	<0.0010	3.95	<0.000010	2.9
W9	24-Feb-11	Frozen																	
W9	30-Mar-11	Frozen																	
W9	19-Apr-11	454	261	8.16	<3.0	0.062	0.000098	0.0113	35.2	0.00180	<0.000010	0.000998	0.00062	<0.30	<2.0	<0.0010	4.29	<0.000010	3.3
W21	27-Jan-11	242	127	7.91	<3.0	<0.030	0.000058	0.0177	10.5	0.00402	<0.000010	0.00150	0.00085	<0.30	<2.0	<0.0010	6.32	<0.000010	2.2
W21	24-Feb-11	268	143	7.97	<3.0	<0.030	<0.000050	0.0192	11.9	0.00289	<0.000010	0.00147	0.00088	<0.30	<2.0	<0.0010	6.70	<0.000010	2.3
W21	30-Mar-11	309	162	8.02	<3.0	<0.030	0.000177	0.0152	14.0	0.00774	<0.000010	0.00119	0.00117	<0.30	2.0	<0.0010	6.63	0.000021	2.7
W21	19-Apr-11	249	128	8.03	9.4	**0.805**	0.00251	0.0138	11.4	0.0197	<0.000010	0.00109	0.00158	<0.30	2.1	<0.0010	6.75	0.000013	3.0
W22	27-Jan-11	391	217	7.90	<3.0	<0.030	<0.000050	0.0078	21.1	0.0306	<0.000010	<0.000050	0.00088	<0.30	<2.0	<0.0010	4.30	<0.000010	2.3
W22	24-Feb-11	407	228	7.92	<3.0	<0.030	0.000201	0.0081	22.9	0.0333	<0.000010	0.000063	0.00107	<0.30	<2.0	<0.0010	4.66	<0.000010	2.3
W22 mean	30-Mar-11	405	221	7.92	2.55	0.058	0.000099	0.0081	22.4	0.0354	<0.000010	0.000060	0.00119	<0.30	<2.0	<0.0010	4.44	0.000008	2.4
W22	19-Apr-11	400	220	7.99	4.4	0.131	0.000116	0.0085	23.1	0.0494	<0.000010	0.000069	0.00141	<0.30	<2.0	<0.0010	4.68	<0.000010	2.4
W23	27-Jan-11	416	236	8.01	<3.0	0.075	0.000110	<0.0050	17.3	0.0295	<0.000010	0.000506	0.00054	<0.30	<2.0	<0.0010	4.58	<0.000010	2.5
W27	27-Jan-11	368	205	8.18	**22.5**	0.255	0.000664	0.0111	23.5	0.0146	<0.000010	0.00109	0.00062	<0.30	2.1	<0.0010	5.33	<0.000010	3.0
W27	24-Feb-11	Frozen																	
W27	30-Mar-11	290	152	8.08	<3.0	0.032	0.000144	0.0117	16.0	0.00970	<0.000010	0.00114	0.00061	<0.30	<2.0	<0.0010	5.47	0.000010	2.4
W27	19-Apr-11	256	138	8.02	**7850**	**163**	**0.364**	0.129	51.4	**5.29**	**0.00108**	0.00279	**0.231**	2.01	19.8	<0.010	87.1	**0.00210**	4.1
W29	27-Jan-11	410	229	8.05	<3.0	<0.030	0.000154	0.0086	22.3	0.0309	<0.000010	0.000132	0.00077	<0.30	<2.0	<0.0010	4.43	<0.000010	2.5
W29	24-Feb-11	427	241	8.02	<3.0	<0.030	0.000056	0.0083	23.8	0.0390	<0.000010	0.000130	0.00095	<0.30	<2.0	<0.0010	4.62	<0.000010	2.4
W29	30-Mar-11	425	230	8.03	<3.0	<0.030	0.000148	0.0092	24.1	0.0332	<0.000010	0.000132	0.00113	<0.30	<2.0	<0.0010	4.58	<0.000010	3.0
W29 mean	19-Apr-12	418	235	8.10	3.4	0.169	0.000275	0.0093	23.5	0.0394	<0.000010	0.000199	0.00146	<0.30	<2.0	<0.0010	4.74	<0.000010	3.3

NOTES:
Bolded values exceed Canadian Council of Ministers for the Environment Water Quality Guidelines for the Protection of Aquatic Life or British Columbia Ministry of Environment Water Quality Guidelines
Shaded samples have elevated TSS, suggestive of sample disturbance during collection under ice
W27, April - elevated TSS related to permafrost disturbance in Suttle Gulch watershed

Site	Date	Conductivity	Hardness (as $CaCO_3$)	pH	TSS	Strontium Total	Thallium toTal	Tin Total	Titanium Total	Uranium Total	Vanadium Total	Zinc Total	Aluminum Dissolved	Antimony Dissolved	Arsenic Dissolved	Barium Dissolved	Beryllium Dissolved	Bismuth Dissolved	Boron Dissolved	Cadmium Dissolved
		µS/cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
W1	31-Jan-11	135	66.1	7.58	<5.0	0.0948	<0.00010	<0.00010	<0.010	0.000602	<0.0010	<0.0030	0.0046	0.00107	0.0282	0.0463	<0.00050	<0.00050	<0.010	<0.000017
W1	24-Feb-11	136	70.1	7.79	<3.0	0.0939	<0.00010	<0.00010	<0.010	0.000526	<0.0010	<0.0030	<0.0030	0.00106	0.0282	0.0543	<0.00050	<0.00050	<0.010	<0.000017
W1	30-Mar-11	135	64.1	7.74	<3.0	0.0904	<0.00010	<0.00010	<0.010	0.000434	<0.0010	<0.0030	0.0045	0.00100	0.0286	0.0480	<0.00050	<0.00050	<0.010	0.000018
W1	19-Apr-11	138	68.4	7.57	<3.0	0.0953	<0.00010	<0.00010	<0.010	0.000599	<0.0010	<0.0030	<0.0030	0.00101	0.0282	0.0471	<0.00050	<0.00050	<0.010	<0.000017
W4	27-Jan-11	384	212	7.95	<3.0	0.224	<0.00010	<0.00010	<0.010	0.00151	<0.0010	<0.0030	<0.0030	0.00026	0.00158	0.0416	<0.00050	<0.00050	<0.010	<0.000017
W4	24-Feb-11	397	226	7.95	<3.0	0.242	<0.00010	<0.00010	<0.010	0.00156	<0.0010	0.0042	<0.0030	0.00026	0.00123	0.0465	<0.00050	<0.00050	<0.010	0.000021
W4	30-Mar-11	399	211	7.88	<3.0	0.214	<0.00010	<0.00010	<0.010	0.00143	<0.0010	<0.0030	<0.0030	0.00024	0.00119	0.0391	<0.00050	<0.00050	<0.010	<0.000017
W4	19-Apr-11	396	220	8.02	3.9	0.211	<0.00010	<0.00010	<0.010	0.00156	<0.0010	<0.0030	<0.0030	0.00023	0.00103	0.0377	<0.00050	<0.00050	<0.010	<0.000017
W9	31-Jan-11	442	276	8.12	**23**	0.337	<0.00010	<0.00010	0.01	0.0111	<0.0010	<0.0030	<0.0030	0.00059	0.0181	0.0831	<0.00050	<0.00050	<0.010	<0.000017
W9	24-Feb-11	Frozen																		
W9	30-Mar-11	Frozen																		
W9	19-Apr-11	454	261	8.16	<3.0	0.345	<0.00010	<0.00010	<0.010	0.0105	<0.0010	<0.0030	<0.0030	0.00050	0.0158	0.0726	<0.00050	<0.00050	<0.010	<0.000017
W21	27-Jan-11	242	127	7.91	<3.0	0.168	<0.00010	<0.00010	<0.010	0.000940	<0.0010	<0.0030	<0.0030	0.00148	0.0273	0.0546	<0.00050	<0.00050	<0.010	<0.000017
W21	24-Feb-11	268	143	7.97	<3.0	0.182	<0.00010	<0.00010	<0.010	0.000927	<0.0010	0.0046	<0.0030	0.00165	0.0305	0.0625	<0.00050	<0.00050	<0.010	0.000018
W21	30-Mar-11	309	162	8.02	<3.0	0.193	<0.00010	<0.00010	<0.010	0.000934	<0.0010	0.0051	<0.0030	0.00166	0.0258	0.0631	<0.00050	<0.00050	<0.010	0.000026
W21	19-Apr-11	249	128	8.03	9.4	0.153	<0.00010	<0.00010	0.018	0.000635	<0.0010	**0.196**	0.0055	0.00144	0.0182	0.0510	<0.00050	<0.00050	<0.010	0.000380
W22	27-Jan-11	391	217	7.90	<3.0	0.236	<0.00010	<0.00010	<0.010	0.00141	<0.0010	<0.0030	<0.0030	0.00022	0.00072	0.0415	<0.00050	<0.00050	<0.010	<0.000017
W22	24-Feb-11	407	228	7.92	<3.0	0.247	<0.00010	<0.00010	<0.010	0.00152	<0.0010	0.0039	<0.0030	0.00024	0.00072	0.0462	<0.00050	<0.00050	<0.010	0.000019
W22 mean	30-Mar-11	405	221	7.92	2.55	0.214	<0.00010	<0.00010	<0.010	0.00142	<0.0010	<0.0030	<0.0030	0.00023	0.00086	0.0398	<0.00050	<0.00050	<0.010	0.000020
W22	19-Apr-11	400	220	7.99	4.4	0.213	<0.00010	<0.00010	<0.010	0.00155	<0.0010	0.0030	<0.0030	0.00022	0.00064	0.0384	<0.00050	<0.00050	<0.010	<0.000017
W23	27-Jan-11	416	236	8.01	<3.0	0.270	<0.00010	<0.00010	<0.010	0.00183	<0.0010	<0.0030	<0.0030	0.00044	0.00430	0.0538	<0.00050	<0.00050	<0.010	<0.000017
W27	27-Jan-11	368	205	8.18	**22.5**	0.268	<0.00010	<0.00010	0.013	0.00489	<0.0010	0.0031	<0.0030	0.00484	0.0329	0.0569	<0.00050	<0.00050	<0.010	0.000020
W27	24-Feb-11	Frozen																		
W27	30-Mar-11	290	152	8.08	<3.0	0.175	<0.00010	<0.00010	<0.010	0.00204	<0.0010	<0.0030	0.0047	0.00272	0.0215	0.0444	<0.00050	<0.00050	<0.010	<0.000017
W27	19-Apr-11	256	138	8.02	**7850**	0.405	0.0017	<0.0010	**2.88**	0.0129	**0.205**	**0.702**	0.159	0.0026	0.0079	0.0554	<0.0050	<0.0050	<0.10	<0.00017
W29	27-Jan-11	410	229	8.05	<3.0	0.249	<0.00010	<0.00010	<0.010	0.00197	<0.0010	<0.0030	<0.0030	0.00062	0.00258	0.0437	<0.00050	<0.00050	<0.010	<0.000017
W29	24-Feb-11	427	241	8.02	<3.0	0.262	<0.00010	<0.00010	<0.010	0.00197	<0.0010	<0.0030	<0.0030	0.00062	0.00255	0.0499	<0.00050	<0.00050	<0.010	0.000019
W29	30-Mar-11	425	230	8.03	<3.0	0.232	<0.00010	<0.00010	<0.010	0.00194	<0.0010	<0.0030	<0.0030	0.00058	0.00281	0.0413	<0.00050	<0.00050	<0.010	<0.000017
W29 mean	19-Apr-12	418	235	8.10	3.4	0.230	<0.00010	<0.00010	<0.010	0.00194	<0.0010	<0.0030	<0.0030	0.00060	0.00247	0.0400	<0.00050	<0.00050	<0.010	<0.000017

NOTES:

Bolded values exceed Canadian Council of Ministers for the Environment Water Quality Guidelines for the Protection of Aquatic Life or British Columbia Ministry of Environment Water Quality Guidelines

Shaded samples have elevated TSS, suggestive of sample disturbance during collection under ice

W27, April - elevated TSS related to permafrost disturbance in Suttle Gulch watershed

Site	Date	Conductivity	Hardness (as $CaCO_3$)	pH	TSS	Calcium Dissolved	Chromium Dissolved	Cobalt Dissolved	Copper Dissolved	Iron Dissolved	Lead Dissolved	Lithium Dissolved	Magnesium Dissolved	Manganese Dissolved	Mercury Dissolved	Molybdenum Dissolved	Nickel Dissolved	Phosphorus Dissolved	Potassium Dissolved
		µS/cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
W1	31-Jan-11	135	66.1	7.58	<5.0	18.6	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	<0.0050	4.79	0.000142	<0.000050	0.00184	<0.00050	<0.30	<2.0
W1	24-Feb-11	136	70.1	7.79	<3.0	19.4	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	<0.0050	5.25	0.000278	<0.000010	0.00202	<0.00050	<0.30	<2.0
W1	30-Mar-11	135	64.1	7.74	<3.0	17.7	<0.00050	<0.00010	<0.00050	<0.030	0.000094	<0.0050	4.84	0.000569	<0.000010	0.00186	<0.00050	<0.30	<2.0
W1	19-Apr-11	138	68.4	7.57	<3.0	18.7	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	<0.0050	5.27	0.000287	<0.000010	0.00187	<0.00050	<0.30	<2.0
W4	27-Jan-11	384	212	7.95	<3.0	51.1	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0075	20.5	0.0253	<0.000010	0.000106	0.00074	<0.30	<2.0
W4	24-Feb-11	397	226	7.95	<3.0	53.5	<0.00050	0.00010	<0.00050	<0.030	<0.000050	0.0083	22.4	0.0336	<0.000010	0.000110	0.00096	<0.30	<2.0
W4	30-Mar-11	399	211	7.88	<3.0	49.7	<0.00050	<0.00010	<0.00050	0.035	<0.000050	0.0079	21.2	0.0319	<0.000010	0.000077	0.00117	<0.30	<2.0
W4	19-Apr-11	396	220	8.02	3.9	51.9	<0.00050	0.00012	<0.00050	<0.030	<0.000050	0.0083	21.8	0.0387	<0.000010	0.000076	0.00106	<0.30	<2.0
W9	31-Jan-11	442	276	8.12	**23**	51	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0098	36	0.000124	<0.000050	0.00106	<0.00050	<0.30	<2.0
W9	24-Feb-11	Frozen																	
W9	30-Mar-11	Frozen																	
W9	19-Apr-11	454	261	8.16	<3.0	50.6	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0090	32.8	0.00112	<0.000010	0.000854	<0.00050	<0.30	<2.0
W21	27-Jan-11	242	127	7.91	<3.0	33.1	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0146	10.6	0.00364	<0.000010	0.00135	0.00076	<0.30	<2.0
W21	24-Feb-11	268	143	7.97	<3.0	36.9	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0197	12.3	0.00284	<0.000010	0.00143	0.00089	<0.30	<2.0
W21	30-Mar-11	309	162	8.02	<3.0	41.4	<0.00050	<0.00010	0.00067	<0.030	0.000065	0.0149	14.2	0.00745	<0.000010	0.00107	0.00112	<0.30	2.0
W21	19-Apr-11	249	128	8.03	9.4	32.6	<0.00050	<0.00010	0.00086	<0.030	0.000290	0.0106	11.3	0.00800	<0.000010	0.000967	0.00086	<0.30	2.0
W22	27-Jan-11	391	217	7.90	<3.0	52.3	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0068	21.1	0.0283	<0.000010	<0.000050	0.00086	<0.30	<2.0
W22	24-Feb-11	407	228	7.92	<3.0	53.8	<0.00050	0.00011	<0.00050	<0.030	<0.000050	0.0080	22.8	0.0317	<0.000010	0.000056	0.00105	<0.30	<2.0
W22 mean	30-Mar-11	405	221	7.92	2.55	51.9	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0072	22.2	0.0347	<0.000010	<0.000050	0.00116	<0.30	<2.0
W22	19-Apr-11	400	220	7.99	4.4	51.7	<0.00050	0.00014	<0.00050	<0.030	<0.000050	0.0071	22.0	0.0430	<0.000010	<0.000050	0.00133	<0.30	<2.0
W23	27-Jan-11	416	236	8.01	<3.0	65.8	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	<0.0050	17.3	0.0220	<0.000010	0.000455	<0.00050	<0.30	<2.0
W27	27-Jan-11	368	205	8.18	**22.5**	44.1	<0.00050	<0.00010	0.00101	<0.030	0.000061	0.0100	23.1	0.00201	<0.000010	0.00104	<0.00050	<0.30	2.1
W27	24-Feb-11	Frozen																	
W27	30-Mar-11	290	152	8.08	<3.0	35.0	<0.00050	<0.00010	0.00058	<0.030	0.000057	0.0110	15.8	0.00935	<0.000010	0.00115	0.00055	<0.30	<2.0
W27	19-Apr-11	256	138	8.02	**7850**	36.1	<0.0050	<0.0010	<0.0050	0.054	<0.00050	<0.050	11.6	0.0154	<0.000010	0.00196	<0.0050	<0.30	3.2
W29	27-Jan-11	410	229	8.05	<3.0	55.4	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0069	22.1	0.0272	<0.000010	0.000132	0.00069	<0.30	<2.0
W29	24-Feb-11	427	241	8.02	<3.0	57.3	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0086	23.9	0.0379	<0.000010	0.000142	0.00099	<0.30	<2.0
W29	30-Mar-11	425	230	8.03	<3.0	54.5	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0077	22.9	0.0308	<0.000010	0.000130	0.00099	<0.30	<2.0
W29 mean	19-Apr-12	418	235	8.10	3.4	55.6	<0.00050	<0.00010	<0.00050	<0.030	<0.000050	0.0074	23.3	0.0337	<0.000010	0.000148	0.00101	<0.30	<2.0

NOTES:
Bolded values exceed Canadian Council of Ministers for the Environment Water Quality Guidelines for the Protection of Aquatic Life or British Columbia Ministry of Environment Water Quality Guidelines
Shaded samples have elevated TSS, suggestive of sample disturbance during collection under ice
W27, April - elevated TSS related to permafrost disturbance in Suttle Gulch watershed

Site	Date	Conductivity	Hardness (as $CaCO_3$)	pH	TSS	Selenium Dissolved	Silicon Dissolved	Silver Dissolved	Sodium Dissolved	Strontium Dissolved	Thallium Dissolved	Tin Dissolved	Titanium Dissolved	Uranium Dissolved	Vanadium Dissolved	Zinc Dissolved
		µS/cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
W1	31-Jan-11	135	66.1	7.58	<5.0	<0.0010	6.42	<0.000010	<2.0	0.0849	<0.00010	<0.00010	<0.010	0.000533	<0.0010	<0.0030
W1	24-Feb-11	136	70.1	7.79	<3.0	<0.0010	6.70	<0.000010	<2.0	0.0966	<0.00010	<0.00010	<0.010	0.000538	<0.0010	<0.0030
W1	30-Mar-11	135	64.1	7.74	<3.0	<0.0010	6.16	<0.000010	<2.0	0.0856	<0.00010	0.00650	<0.010	0.000383	<0.0010	<0.0030
W1	19-Apr-11	138	68.4	7.57	<3.0	<0.0010	6.35	<0.000010	<2.0	0.0847	<0.00010	<0.00010	<0.010	0.000543	<0.0010	<0.0030
W4	27-Jan-11	384	212	7.95	<3.0	<0.0010	4.41	<0.000010	2.3	0.217	<0.00010	<0.00010	<0.010	0.00143	<0.0010	<0.0030
W4	24-Feb-11	397	226	7.95	<3.0	<0.0010	4.73	<0.000010	2.4	0.238	<0.00010	<0.00010	<0.010	0.00153	<0.0010	<0.0030
W4	30-Mar-11	399	211	7.88	<3.0	<0.0010	4.29	<0.000010	2.3	0.199	<0.00010	0.00264	<0.010	0.00125	<0.0010	<0.0030
W4	19-Apr-11	396	220	8.02	3.9	<0.0010	4.40	<0.000010	2.3	0.193	<0.00010	<0.00010	<0.010	0.00149	<0.0010	<0.0030
W9	31-Jan-11	442	276	8.12	**23**	<0.0010	4.23	<0.000010	3.2	0.359	<0.00010	<0.00010	<0.010	0.0115	<0.0010	<0.0030
W9	24-Feb-11	Frozen														
W9	30-Mar-11	Frozen														
W9	19-Apr-11	454	261	8.16	<3.0	<0.0010	4.03	<0.000010	3.2	0.313	<0.00010	<0.00010	<0.010	0.0101	<0.0010	<0.0030
W21	27-Jan-11	242	127	7.91	<3.0	<0.0010	6.38	<0.000010	2.2	0.157	<0.00010	<0.00010	<0.010	0.000887	<0.0010	<0.0030
W21	24-Feb-11	268	143	7.97	<3.0	<0.0010	6.96	<0.000010	2.4	0.184	<0.00010	<0.00010	<0.010	0.000940	<0.0010	<0.0030
W21	30-Mar-11	309	162	8.02	<3.0	<0.0010	6.75	<0.000010	2.7	0.189	<0.00010	<0.00010	<0.010	0.000875	<0.0010	0.0044
W21	19-Apr-11	249	128	8.03	9.4	<0.0010	5.59	<0.000010	3.9	0.137	<0.00010	<0.00010	<0.010	0.000564	<0.0010	0.118
W22	27-Jan-11	391	217	7.90	<3.0	<0.0010	4.33	<0.000010	2.3	0.224	<0.00010	<0.00010	<0.010	0.00129	<0.0010	<0.0030
W22	24-Feb-11	407	228	7.92	<3.0	<0.0010	4.62	<0.000010	2.3	0.239	<0.00010	<0.00010	<0.010	0.00148	<0.0010	0.0031
W22 mean	30-Mar-11	405	221	7.92	2.55	<0.0010	4.42	<0.000010	2.3	0.204	<0.00010	0.00013	<0.010	0.00127	<0.0010	<0.0030
W22	19-Apr-11	400	220	7.99	4.4	<0.0010	4.37	<0.000010	2.3	0.193	<0.00010	<0.00010	<0.010	0.00142	<0.0010	<0.0030
W23	27-Jan-11	416	236	8.01	<3.0	<0.0010	4.56	<0.000010	2.4	0.255	<0.00010	<0.00010	<0.010	0.00173	<0.0010	<0.0030
W27	27-Jan-11	368	205	8.18	**22.5**	<0.0010	5.10	<0.000010	3.1	0.249	<0.00010	<0.00010	<0.010	0.00430	<0.0010	0.0035
W27	24-Feb-11	Frozen														
W27	30-Mar-11	290	152	8.08	<3.0	<0.0010	5.40	<0.000010	2.4	0.170	<0.00010	<0.00010	<0.010	0.00189	<0.0010	<0.0030
W27	19-Apr-11	256	138	8.02	**7850**	<0.010	3.92	<0.00010	2.7	0.136	<0.0010	<0.0010	<0.010	0.00208	<0.010	<0.030
W29	27-Jan-11	410	229	8.05	<3.0	<0.0010	4.42	<0.000010	2.4	0.230	<0.00010	<0.00010	<0.010	0.00181	<0.0010	<0.0030
W29	24-Feb-11	427	241	8.02	<3.0	<0.0010	4.65	<0.000010	2.5	0.262	<0.00010	<0.00010	<0.010	0.00197	<0.0010	0.0042
W29	30-Mar-11	425	230	8.03	<3.0	<0.0010	4.36	<0.000010	2.8	0.214	<0.00010	<0.00010	<0.010	0.00168	<0.0010	<0.0030
W29 mean	19-Apr-12	418	235	8.10	3.4	<0.0010	4.44	<0.000010	3.1	0.208	<0.00010	<0.00010	<0.010	0.00181	<0.0010	<0.0030

NOTES:
Bolded values exceed Canadian Council of Ministers for the Environment Water Quality Guidelines for the Protection of Aquatic Life or British Columbia Ministry of Environment Water Quality Guidelines
Shaded samples have elevated TSS, suggestive of sample disturbance during collection under ice
W27, April - elevated TSS related to permafrost disturbance in Suttle Gulch watershed

APPENDIX R7

Supporting Information for Derivation of a Site-specific Water Quality Objective for Arsenic in the Haggart Creek Watershed

Victoria GOLD CORP

Stantec

1. INTRODUCTION

A site-specific water quality objective (SSWQO) for arsenic has been proposed for the Eagle Gold Project to recognize the baseline condition of concentrations higher than the Canadian Council of Ministers of Environment (CCME) water quality guideline (WQG) for protection of aquatic life. This appendix to Supplementary Information Request 7 provides supporting information for the use of the Background Concentration Procedure in deriving the SSWQO, to address comments made by Environment Canada (YOR 2010-0267-192-1), Yukon Government (YOR 2010-0267-197-1), and NND (YOR 2010-0267-200-1) in their review of the Eagle Gold Project.

> R7 request: Rationale for choosing the Background Concentration Procedure rather than other methods outlined in CCME (2003) (e.g., Recalculation Procedure or Water Effect Ratio Procedure) for deriving Site Specific Water Quality Objectives.

Two separate arsenic SSWQOs are proposed, one for Haggart Creek (0.014 mg/L) and one for Dublin Gulch and Eagle Creek (0.070 mg/L), to reflect the differing baseline concentrations in the watercourses. Dublin Gulch and Eagle Creek have the same SSWQO, given that baseline arsenic levels are similar and that Dublin Gulch will be diverted into Eagle Creek. The SSWQO were derived using the Background Concentration Procedure (95th percentile, using data from 2007—2010).

The rationale for choosing the Background Concentration Procedure for derivation of an arsenic SSWQO, and the 95th percentile, rather than other methods outlined in CCME (2003), such as Recalculation Procedure or Water Effect Ratio Procedure, was discussed in the Project Proposal (Section 6.5.1.11, pages 6-17 to 6-20) and in the response to R7.

There are challenges in identifying suitable arsenic SSWQO that recognizes the naturally elevated and highly variable levels in soil, surface water and groundwater. Further, due to the intrinsic high natural variability, it is difficult to quantify the effect of disturbance from historical placer mining in Haggart Creek and a number of its tributaries, including Dublin Gulch. The current (albeit not pristine) conditions should be considered when developing a SSWQO, along with other factors that may affect the ability of Dublin Gulch and Haggart Creek to support a healthy stream ecosystem. The Background Concentration Procedure, although ideally used in pristine situations, continues to be the most supportable approach for developing an arsenic SSWQO for watercourses in the Haggart Creek watershed. The benefits and limitations of the Water Effect Ratio Procedure and Recalculation Procedure are discussed in this appendix, and it is concluded that the concepts are best used in a supporting, rather than leading role in development of the SSWQO.

The following sections provide technical information in support of this conclusion. The appendix is organized into the following sections:

Section 2: Summary of Relevant Baseline Conditions in the Haggart Watershed

Section 3: Factors Affecting Arsenic Bioavailability (potential use of Water Effects Ratio Procedure)

Section 4: Toxicity Data used to Derive CCME WQG (potential for use of Recalculation Procedure).

Section 5: Summary and Conclusions

2. SUMMARY OF RELEVANT BASELINE CONDITIONS IN THE HAGGART WATERSHED

2,1 Baseline Arsenic Levels

2.1.1 Surface Water

Baseline water chemistry data were collected in 1993 – 1996 and 2007 – 2010. As discussed in the Project Proposal and Appendix 16 (Environmental Baseline Report: Water Quality and Aquatic Biota), baseline arsenic concentrations are typically higher than the CCME WQG for arsenic (0.005 mg/L) in Dublin Gulch and its tributaries, Eagle Creek, Lynx Creek and in Haggart Creek downstream of the Dublin Gulch confluence. Arsenic data collected from 1993 – 1996 and 2007 – 2010 are listed in Table 2.1. The data were examined for outliers and data quality.

As noted in the Project Proposal (Section 6.5, page 6-17 to 6-20), levels of total suspended solids and several metals were higher in the data from 1993 – 1996 than in the data from 2007 – 2010. This suggests an anthropogenic influence of placer mining, which occurred extensively in Dublin Gulch during the 1990s, as well as natural arsenic sources.

Arsenic levels in Haggart Creek were higher during freshet than during the rest of the year, as indicated in data from 1995, 1996 and 2010, and consisted of lower percentage of dissolved arsenic than other times of year (30 to 70% dissolved, compared to a more typical >90% dissolved), indicating an influence of silt (total suspended solids) as would be expected during freshet. The consistently high levels of arsenic among the Haggart Creek sites during freshet indicate these values are not outliers, and that they reflect the range of variability to be expected.

Figure 2.1 shows the spatial trends in arsenic concentrations for 2007 – 2010. There are low levels on Haggart upstream of Dublin (W22) and inputs from Dublin Gulch (W21) upstream of W4, Eagle Creek (W27) upstream of W29, and Lynx (W6) between W5 and W23.

Table 2.1: Baseline Arsenic Concentrations in Haggart Creek Watershed

Date	Haggart Creek					Lynx Creek		Dublin Gulch				Eagle Pup	Eagle Creek
								Bawn Boy	Dublin	Dublin	Stewart		
	W22	W4	W29	W5	W23	W6	W13	W20	W1	W21	W26	W9	W27
1993—1996													
11-Jun-93		**0.0077**		0.0275		0.0049			**0.0324**			**0.0146**	
7-Jul-93		**0.0203**		**0.0080**		0.0008			**0.0348**			**0.0212**	
5-Aug-93		0.0023		**0.0060**		0.0011			**0.0372**			**0.0183**	
4-Sep-93		0.0040		**0.0062**		0.0009			**0.0338**			**0.0143**	
10-Mar-94		0.0015		0.0030					**0.0578**				
15-Jul-94		0.0014		**0.0636**		**0.0079**			**0.0321**			**0.0134**	
1-May-95		**0.0306**		**0.0865**					**0.0290**			**0.0778**	
3-Jul-95		0.0015		**0.0054**		0.0048			**0.0332**		**0.0203**	**0.0190**	
2-Aug-95		0.0018		**0.0051**		**0.0056**	**0.0075**		**0.0338**			**0.0556**	
13-Sep-95		0.0022		0.0049					**0.0399**				
14-Sep-95		0.0020		0.0049					**0.0369**				
15-Sep-95		0.0020		**0.0058**					**0.0333**				
16-Sep-95		0.0018		0.0049					**0.0357**				
17-Sep-95		0.0024		**0.0054**					**0.0433**				
18-Sep-95		0.0018		**0.0093**					**0.0390**				
19-Sep-95		0.0025		0.0046					**0.0371**				
1-Oct-95		0.0019		0.0050		**0.0070**			**0.0340**			**0.0220**	
23-May-96		**0.0282**		**0.0223**		**0.0069**			**0.0447**			**0.0477**	
20-Jun-96		**0.0060**		**0.0058**					**0.0288**				
21-Jun-96		**0.0055**		**0.0062**					**0.0290**				
22-Jun-96		**0.0061**		**0.0055**					**0.0256**				
23-Jun-96		0.0039		**0.0052**					**0.0259**				

Date	Haggart Creek					Lynx Creek		Dublin Gulch				Eagle Pup	Eagle Creek
								Bawn Boy	Dublin	Dublin	Stewart		
	W22	W4	W29	W5	W23	W6	W13	W20	W1	W21	W26	W9	W27
24-Jun-96		0.0048		**0.0063**					**0.0273**				
25-Jun-96		0.0039		0.0046					**0.0222**				
26-Jun-96		0.0040		0.0050					**0.0287**				
27-Jun-96		0.0042		**0.0052**		0.0013			**0.0265**	**0.0332**		**0.0155**	
22-Jul-96	0.0015	0.0022		**0.0077**	**0.0052**	0.0048	**0.0542**		**0.0303**			**0.0149**	
13-Aug-96	0.0009	0.0019		**0.0069**	**0.0058**	0.0049			**0.0345**			**0.0144**	
20-Sep-96	0.0010	0.0037		**0.0063**	**0.0069**	**0.0051**			**0.0440**			**0.0558**	
2007—2010													
12-Aug-07	0.0007	0.0032		0.0041	**0.0054**	**0.0068**	**0.0088**	**0.0760**	**0.0402**	**0.0352**	**0.0193**		**0.0429**
28-Aug-07	0.0008	0.0037		0.0040	**0.0055**	**0.0069**		**0.0713**	**0.0382**	**0.0370**	**0.0191**		**0.0502**
11-Sep-07	0.0008	0.0036		0.0048	**0.0058**	**0.0067**	**0.0086**	**0.0731**	**0.0385**	**0.0370**	**0.0193**		**0.0470**
25-Sep-07	0.0007	0.0041		0.0040	**0.0056**	**0.0063**	**0.0088**		**0.0375**	**0.0343**	**0.0198**		**0.0473**
20-Oct-07	0.0007	0.0035		0.0035	0.0049	**0.0060**			**0.0364**	**0.0346**	**0.0166**		**0.0385**
21-Nov-07	0.0007	0.0021		0.0028	0.0045	**0.0057**			**0.0388**	**0.0320**			**0.0292**
25-Apr-08	0.0011	0.0012		0.0031	0.0044	**0.0058**			**0.0365**	**0.0313**			**0.0359**
10-Jun-08	0.0010	0.0011		0.0024	**0.0323**	**0.0054**		**0.0513**	**0.0293**	**0.0301**	**0.0143**		**0.0323**
20-Jul-09	0.0008	0.0017		0.0036	0.0048	**0.0058**		**0.0666**	**0.0362**	**0.0383**	**0.0225**	**0.0199**	**0.0398**
6-Aug-09	0.0010		0.0039	0.0036	**0.0051**			**0.0763**	**0.0326**	**0.0412**		**0.0208**	**0.0354**
20-Aug-09	0.0009		**0.0116**	0.0033	**0.0050**			**0.0688**	**0.0354**	**0.0371**	**0.0253**	**0.0199**	**0.0388**
2-Sep-09	0.0008	0.0026		0.0029	0.0049	**0.0062**			**0.0389**	**0.0378**	**0.0221**	**0.0187**	**0.0386**
16-Sep-09	0.0008		0.0032	0.0034	**0.0052**			**0.0690**	**0.0350**	**0.0359**	**0.0234**	**0.0210**	**0.0401**
7-Oct-09	0.0007		**0.0054**	0.0036	0.0049			**0.0711**	**0.0378**	**0.0339**	**0.0214**	**0.0200**	**0.0387**
20-Oct-09	0.0007		0.0042	0.0033	0.0047			**0.0686**	**0.0349**	**0.0342**	**0.0179**	**0.0184**	**0.0364**
31-Mar-10	0.0007	0.0014							**0.0307**				**0.0419**
06-May10	0.0012	**0.0070**	**0.0091**	0.0046	**0.0055**	**0.0062**			**0.0288**	**0.0246**		**0.0175**	**0.0836**

Date	Haggart Creek					Lynx Creek		Dublin Gulch				Eagle Pup	Eagle Creek
								Bawn Boy	Dublin	Dublin	Stewart		
	W22	W4	W29	W5	W23	W6	W13	W20	W1	W21	W26	W9	W27
22-May-10	0.0011	**0.0228**	**0.0206**	**0.0094**	**0.0070**	**0.0090**			**0.0317**	**0.0319**		**0.0154**	**0.0676**
02-Jun-10	0.0008	0.0039	**0.0053**	0.0041	0.0046	**0.0056**			**0.0351**	**0.0310**		**0.0167**	**0.0413**
11-Jul-10	0.0007	0.0049	**0.0070**	0.0048	**0.0054**	**0.0060**			**0.0420**	**0.0373**		**0.0189**	**0.0498**
18-Aug-10	0.0007	**0.0052**	0.0050	0.0047	**0.0055**	**0.0068**			**0.0405**	**0.0387**		**0.0201**	**0.0662**
16-Sep-10	0.0008	**0.0051**	**0.0068**	**0.0050**	**0.0056**	**0.0068**			**0.0388**	**0.0383**		**0.0216**	**0.0516**

NOTE: shaded and bold numbers indicate exceedance of WQG (0.005 mg/L)

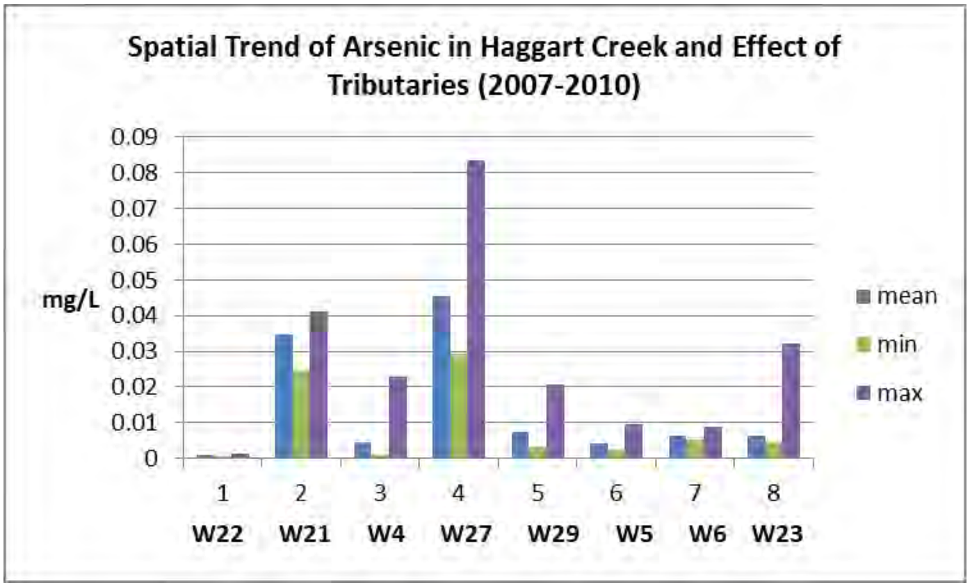


Figure 2.1: Mean Arsenic Concentrations in Haggart Creek and Tributaries, 2007 – 2010

Table 2.2 lists values that could be used to derive a SSWQO using the 95th percentile of the 2007 – 2010 data for each site. The mean and 95th percentile values show the influence of Dublin Gulch, Eagle Creek and Lynx Creek on arsenic levels in Haggart Creek. Examples include the following 95th percentiles:

- For Haggart Creek at W4, 0.014 mg/L arsenic, increasing to 0.018 mg/L at W23, downstream of Lynx Creek
- For Dublin Gulch at W21, 0.042 mg/L arsenic
- For Eagle Creek at W27, 0.071 mg/L arsenic
- For Lynx Creek at W6, 0.008 mg/L arsenic.

Lynx Creek has not been disturbed by placer mining or other activities and has elevated arsenic levels in surface water, indicating there are natural sources of arsenic in surface water. Two sites have been monitored in Lynx Creek (W6 near Haggart and W13 in the upper watershed). W6 was sampled 16 times during 2007—2010, with arsenic levels above CCME WQG in all samples (Table 2.1). Levels ranged from 0.0054 to 0.0090 mg/L, with a mean of 0.0064 mg/L. A SSWQO derived using these data and the background concentration procedure (95th percentile) would be 0.008 mg/L (higher than CCME WQG). W13 was sampled three times, and arsenic levels were 30% higher than at W6. This indicates that locations higher up an undisturbed watershed can show a greater influence of localized arsenic sources, and may help support an explanation of similar conditions in Dublin Gulch.

Table 2.2: Summary Statistics for Total Arsenic Levels in Area Watercourses, 2007—2010

Date	Haggart Creek					Lynx Creek		Dublin Gulch				Eagle Pup	Eagle Creek
								Bawn Boy	Dublin	Dublin	Stewart		
	W22	W4	W29	W5	W23	W6	W13	W20	W1	W21	W26	W9	W27
mean	0.0008	0.0045	0.0075	0.0041	0.0065	0.0064	NA	0.0692	0.0361	0.0348	0.0201	0.0191	0.0454
sd	0.0002	0.0050	0.0050	0.0014	0.0059	0.0008	NA	0.0071	0.0036	0.0038	0.0031	0.0018	0.0128
min	0.0007	0.0011	0.0032	0.0024	0.0044	0.0054	NA	0.0513	0.0288	0.0246	0.0143	0.0154	0.0292
max	0.0012	0.0228	0.0206	0.0094	0.0323	0.0090	NA	0.0763	0.0420	0.0412	0.0253	0.0216	0.0836
mean+2SD (95th percentile)	0.0011	0.0145	0.0175	0.0069	0.0184	0.0080	NA	0.0833	0.0433	0.0424	0.0262	0.0277	0.0711

Haggart Creek and its tributaries have been directly disturbed by placer mining upstream and downstream of Dublin Gulch, although there is less overall historical activity and lower arsenic concentrations upstream of Dublin Gulch (W22). This suggests a non-random distribution of arsenic sources in the Haggart Creek watershed, adding to the challenges distinguishing between natural arsenic loading rates and those affected by anthropogenic activities.

Dublin Gulch and its tributaries contain elevated levels of arsenic, as indicated in the following data collected from 2007 – 2010:

- There are elevated arsenic levels in surface water data for Dublin Gulch (W1 and W21), its headwater Bawn Boy Gulch (W20, where substantial exploration activity dating to the late 1980's has occurred), Stewart Gulch (W26), Eagle Pup (W9) and Eagle Creek (W27, a channel created during placer mining that collects water from Eagle Pup and Suttle Gulch).
- For data collected in 2007—2010, all values at these sites are higher than the CCME WQG, indicating ongoing sources of arsenic. Values range from 0.0143 (Stewart, June 2008) to 0.0836 (Eagle Creek, May 2010). For a given site, there is low variability in the data, indicated by the narrow range of values and low standard deviation of the mean, suggesting that the systems are in equilibrium.
- While disturbance from placer mining may be an obvious contributor to arsenic into surface waters, the underlying cause for elevated arsenic concentrations is due to natural factors that include rock composition and soil types, which have significant variability in their spatial distribution (non-random). This natural variability, which is expressed by the variability of arsenic concentrations in streams throughout the area, is also affected by basin size (less opportunity for dilution with surface runoff, greater contribution of groundwater), hydrogeologic conditions and groundwater-surface water interactions.
- The background concentration method (95^{th} percentile) for individual watercourses would result in SSQGO values of about 0.026 mg/L (Stewart Gulch, Eagle Pup), 0.043 mg/L (Dublin W1 and W21) and 0.071 mg/L (Eagle Creek), as indicated in Table 2.2. These values are 5, 9 and 14 times higher than the CCME WQG, respectively.

Figure 2-1 shows the relationship of total arsenic to turbidity. Both the CCME WQG of 0.005 mg/L and SSWQO for Haggart Creek of 0.014 mg/L are shown on Figure 2.2 (the SSWQO for Eagle Creek and Dublin Gulch of 0.070 mg/L is not shown). Haggart sites (W22, W4, W29, W5 and W23, moving downstream) are indicated as circles (most of which lie below the WQG line of 0.005 mg/L) and tributaries are indicated as squares (most of which are above the WQG and SSWQO line). This figure helps to distinguish the sites spatially:

- Higher arsenic concentrations are associated with higher turbidity (and total suspended solids).
- Upstream concentrations at W22 on Haggart Creek (representing a less disturbed basin) are the lowest

- All other sites on Haggart Creek (W4, W29, W5 and W23) have concentrations in the range between background (W22) and the smaller more disturbed basins (W21 in Dublin Gulch and W27 in Eagle Creek).
- Concentrations for the undisturbed Lynx Creek lie at the upper end of the range for the larger streams (above the WQG but below the proposed SSWQO), suggesting that this undisturbed basin is receiving high inputs of arsenic from an upstream tributary(ies).

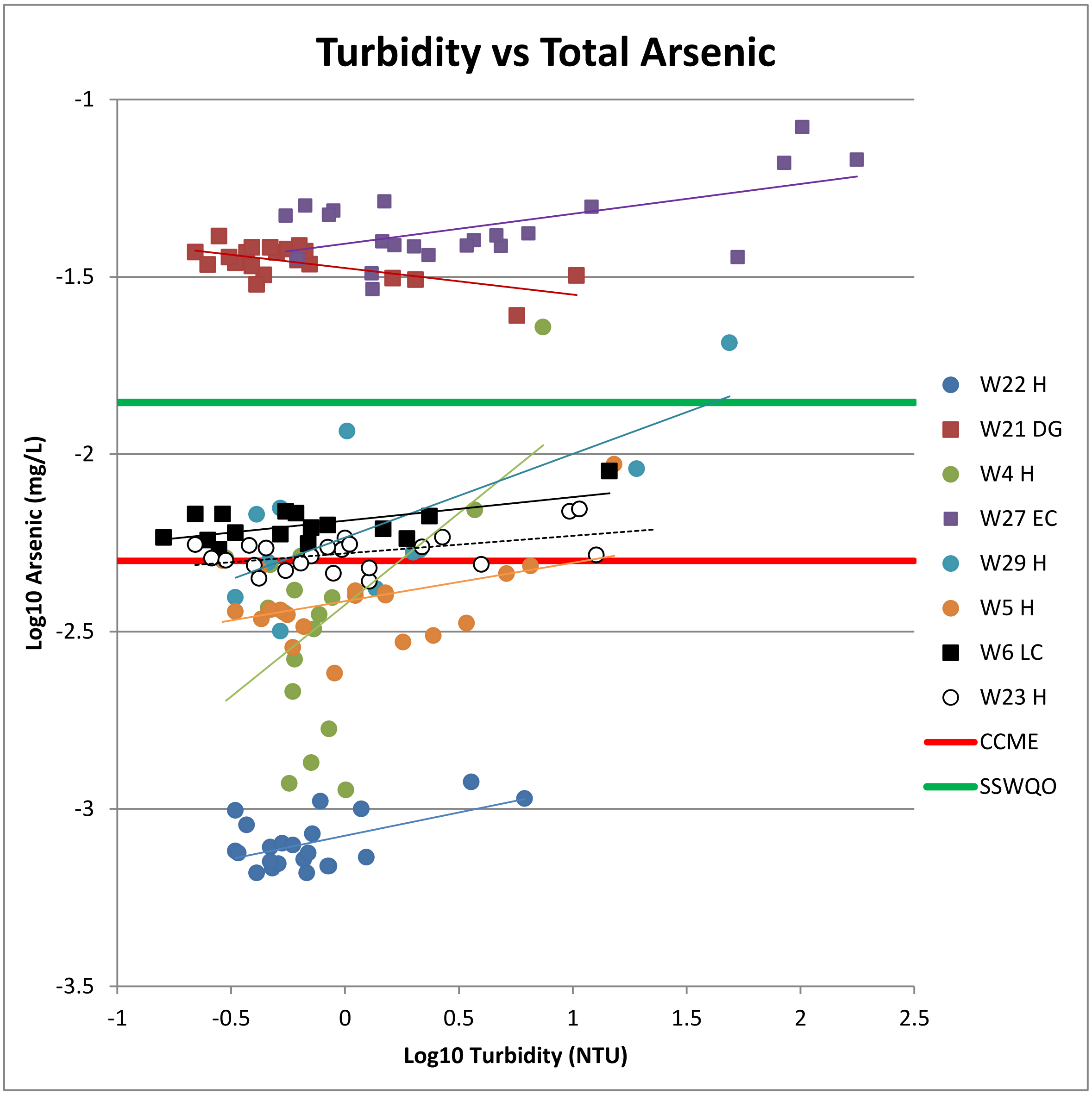


Figure 2-2: Total Arsenic and Turbidity Concentrations at Project Area Sampling Sites

Relationships between total arsenic and other water chemistry parameters were explored by calculating simple correlations (Table 2-3). High positive values indicate a strong positive relationship (as arsenic concentrations increase, concentrations of the other parameter increases). High negative values indicate a strong negative relationship (arsenic concentrations decrease as concentrations of the other parameter increase). While a strong correlation does not necessarily indicate a cause and effect relationship, the statistically significant correlations do suggest areas for further investigation, such as similarities in controlling factors or sources of arsenic in the watercourses. The following trends were identified:

- In Haggart Creek (all sites), total arsenic typically has significant and positive correlations with TSS, turbidity, total phosphate, dissolved organic carbon (DOC), aluminum, copper, iron, and nickel and negative correlations with conductivity, hardness, pH, TDS, sulphate, barium, and calcium
- In Lynx Creek (W6, undisturbed), the relationship of arsenic to other parameters is similar to that for Haggart Creek (W22, undisturbed)
- In Dublin Gulch (W21), relationships between arsenic and many parameters are the opposite of those for sites in Haggart, Lynx and Eagle creeks. For example, turbidity, total phosphate, DOC, copper and nickel are positively correlated with arsenic in Haggart Creek, but negatively correlated in Dublin Gulch. This suggests a different set of controlling factors for Dublin Gulch (e.g., different factors that control sorption of arsenic to sediments, reflecting a different set of sinks or a lack of particular sinks present in other watersheds) or a different source of arsenic.
- In Eagle Creek, there are strong positive correlations between arsenic and TSS, total Kjeldahl nitrogen (TKN), total nitrogen, total phosphate, DOC, copper iron, manganese, nickel and silicon. These relationships may represent natural/soil arsenic sources or controlling factors (since the relationships are similar to those observed at undisturbed stations W22 and W6). However, they may be exacerbated due to additional arsenic releases to the aquatic environment through soil disturbance (e.g., placer mining). High turbidity in W27 Eagle Creek compared to Haggart Creek sites and the strong positive relationship between turbidity and arsenic (Figure 2-2) also suggest that the high arsenic concentrations may be related to higher levels of soil disturbance associated with placer mining in Eagle compared to Haggart Creek.

Table 2.3: Correlations Between Total Arsenic and Other Parameters at Various Water Quality Monitoring Sites

Parameter	Haggart and Inputs from Tributaries Moving Downstream							
	Haggart	Dublin Gulch	Haggart	Eagle Ck	Haggart		Lynx Ck	Haggart
	W22	W21	W4	W27	W29	W5	W6	W23
Conductivity								
Hardness (as CaCO3)								
pH								
TSS	na	na						
TDS								
Turbidity								
Alkalinity, Total (as CaCO3)								
Fluoride								
Nitrate (as N)								
TKN								
Total Nitrogen								
Total Phosphate as P								
Sulfate								
DOC								
Aluminum								
Antimony								
Barium								
Calcium								
Copper								
Iron								
Magnesium								
Manganese								
Molybdenum								
Nickel								
Silicon								
Strontium								
Uranium								

	significant negative correlation at $p<0.05$
	significant negative correlation at $p<0.002$ (Bonferroni Corrected)
	significant positive correlation at $p<0.05$
	significant positive correlation at $p<0.002$ (Bonferroni Corrected)
	no significant correlation detected
na	not enough data or detectable concentrations to run correlation analysis

Given that the current baseline conditions in Dublin Gulch indicate natural arsenic sources and may indicate the influence of historic disturbances that contribute arsenic, it is not possible to identify arsenic concentrations that represent undisturbed conditions in Dublin Gulch (due to its basin-wide disturbance). The current concentrations and low variability suggest that arsenic loadings have stabilized, compared to the 1990s. It is difficult to rationalize that effluent releases from the Project into already disturbed areas would need to meet WQG set for pristine conditions (CCME WQG or a SSWQO set using data from Haggart Creek upstream of Dublin Gulch). For these reasons, the Project Proposal has developed a SSWQO for Haggart Creek between Dublin Gulch and Lynx Creek using data collected from 2007 (0.014 mg/L). This SSWQO does not recognize the influence of arsenic inputs from undisturbed Lynx Creek; including data from downstream of Lynx Creek would result in a SSWQO of 0.018 mg/L. A separate WWQGO for Dublin Gulch and Eagle Creek (0.070 mg/L) is also appropriate, given that baseline arsenic concentrations are higher in these watercourses than in Haggart Creek.

2.1.2 Soil and Groundwater

Baseline arsenic levels are naturally elevated in groundwater and soil in some of the basins of the Haggart Creek watershed, providing useful information about natural sources of arsenic.

Baseline levels of arsenic in soil (< 1 m depth) and overburden (1 to 5 m depth) of the Project area are elevated compared to CCME(1999) and Yukon Contaminated Sites Regulation guidelines for Agriculture and Parkland soils (CSR, 2002), reflecting natural mineralization (Project Proposal Section 4.1.2.4). Nearly all soil and overburden samples collected for the baseline study exceeded arsenic guidelines. When compared to the receptor-specific Yukon CSR guidelines, the natural arsenic levels are above a value considered to pose a risk to livestock, soil invertebrates, plants, and humans. More than half the soil samples collected were above the 50 mg/kg guideline recommended to prevent toxicity to soil invertebrates and plants, and all but one were above the limit recommended to prevent illness in livestock ingesting soil while grazing.

Arsenic concentrations in groundwater are generally elevated and are higher than in surface water (Environmental Data Summary Report, Hydrogeology, Tables 13 and 14 of Appendix B of that report). In Dublin Gulch, one monitoring well installed in bedrock at the mouth of the Ann Gulch basin reported relatively elevated arsenic concentrations (1.5 to 3.9 mg/L total As, mostly dissolved phase) compared to concentrations reported for samples obtained from five wells installed in sediments overlying bedrock (0.001 to 0.46 mg/L total As, about 50% dissolved). Four monitoring wells installed in bedrock in the Ann Gulch basin (location of proposed heap leach facility) also reported elevated arsenic concentrations (0.02 to 0.52 mg/L, total arsenic, variable dissolved phase concentrations). These data, and data from Suttle Gulch and Eagle Pup, indicate the presence of relatively high dissolved arsenic concentrations in localized bedrock areas or zones. This arsenic is natural, not anthropogenic, in origin, and its localized distribution contributes to the variability in arsenic levels reported for the various surface water monitoring sites.

2.1.2 Benthic Communities

Baseline data indicate the presence of viable benthic communities in all the watercourses, including Dublin Gulch and Eagle Creek (Appendix 16, Environmental Baseline Report: Water Quality and Aquatic Biota). The watercourses, including those affected by placer mining and elevated arsenic levels, support a diverse assemblage of periphyton and benthic invertebrates.

Although periphyton are considered among the most sensitive organisms to arsenic, results of baseline monitoring in 2007 did not indicate any adverse effect of arsenic on periphyton. Arsenic levels are higher in Eagle Pup and Dublin Gulch than Haggart Creek and Lynx Creek. This is related to drainage basin size, which provides more opportunity for dilution from non-arsenic bearing areas. In fact, the undisturbed Lynx Creek basin has higher concentrations than the disturbed Haggart Creek system. Periphyton biomass levels (chlorophyll *a*) were higher in Eagle Pup (1.12 mg/m^2) and Dublin Gulch (0.85 mg/m^2) than in Haggart Creek (0.012 to 0.057 mg/m^2) or Lynx Creek (0.18 mg/m^2) in 2007. Taxon richness (number of taxa) was higher in Haggart than in Dublin, Lynx or Eagle Creeks in 2007, although as with biomass levels, this could be related to watershed characteristics other than arsenic. The most obvious difference between low arsenic (Haggart Creek) and high arsenic (Dublin, Lynx and Eagle creeks) systems was the predominance of diatoms in Haggart Creek and predominance of blue-green algae in the other systems; it is possible that this is related to arsenic levels. While overall community characteristics indicated oligotrophic conditions in all these watercourses, there were no particular indicators of toxicological stresses related to arsenic exposure, particularly given the other differences in water chemistry relevant to periphyton growth (e.g., phosphate and nitrogen). The higher chlorophyll *a* levels in 2007 compared to 1995 for all sites except Lynx may suggest possible effects related to active placer mining in 1995.

The abundance in all systems of pollution sensitive benthic invertebrate taxa that provide common food for fish and the presence of a wide variety of feeding types suggests no adverse effects related to arsenic exposure in any of the watercourses studied. Overall, differences in taxon abundance and community composition among sites and years were noted, and were related to the range of habitat characteristics, water quality and fish presence (predators) in the watercourses studied. Benthic invertebrate communities were sampled in 1995, 2007, 2008 and 2009; W1 (Dublin) and W5 (Haggart upstream of Lynx) were sampled in all four years. There was high variability in total abundance from year to year within a given site; however, in general, total abundance was lower in Haggart Creek than in Dublin, Eagle or Lynx Creeks. Some of the sites in the smaller tributaries had lower taxon richness (Dublin and its tributaries, 11 to 27 taxa, and Eagle Creek, 15 to 22 taxa) than sites from the larger watercourses (Haggart Creek, 21 to 27 taxa and Lynx Creek, 22 to 24 taxa), which is commonly noted when comparing larger and smaller streams. A high EPT index (number of taxa of Ephemeroptera, Plecoptera and Trichoptera, or mayflies, stoneflies and caddisflies) is generally considered an indicator of good water quality. Sites in Haggart Creek tended to have a higher EPT index (13 to 19 taxa) than did sites in Eagle Creek and tributaries (6 to 13 taxa), Lynx Creek (13 to 14 taxa) and some sites in Dublin Gulch and tributaries (7 to 20 taxa). At all sites, the predominant taxa included pollution sensitive organisms (Ephemeroptera in all systems except Eagle; Plecoptera in all systems), as well as pollution tolerant organisms (Chironomidae or midges and Oligochaeta or aquatic worms in all systems).

3. FACTORS AFFECTING ARSENIC BIOAVAILABILITY (POTENTIAL USE OF WATER EFFECTS RATIO PROCEDURE)

The presence of viable and diverse periphyton and benthic invertebrate communities in Dublin Gulch, Eagle Creek and Lynx Creek, in areas where arsenic concentrations are higher than WQG, suggests that: arsenic toxicity is reduced by mitigating factors, or that the WQG is highly conservative. This section discusses the potential role of factors that likely reduce arsenic toxicity and the suitability of using a Water Effects Ratio (WER) Procedure to formalize this role. WER Procedure involves performing a series of standard laboratory toxicity tests using site water and laboratory water, comparing the resulting toxicity results, and adjusting the WQG on the basis of the test results.

As discussed in the Project Proposal (page 6-19), the WER Procedure is most useful when there is an identifiable ameliorating characteristic (e.g., hardness, organic carbon, pH, nutrients) that affects bio-availability of the parameter in question. For arsenic, the WQG does not identify ameliorating factors and preliminary discussions with a toxicology lab indicated that such an approach would likely not be helpful in defining a SSWQO for arsenic (James Elphick, Nautilus, pers. comm.). Further review of the literature suggests that aluminum, iron, manganese, phosphorus and dissolved organic carbon can play a role in decreasing arsenic toxicity for a number of aquatic organisms, although it may be challenging to create these conditions in a toxicity test.

Dissolved arsenic may become complexed to aluminum, iron, manganese, phosphorus and dissolved organic carbon, making it less bioavailable. These interactions may provide a protective mechanism for aquatic communities in the Haggart Creek watershed. A greater understanding of the relationship of aluminum, iron, and organic matter to the currently measured arsenic concentrations will help assess the potential for modifying baseline and Project-related arsenic levels.

Further review of baseline data for Haggart Creek indicates that typically TSS, turbidity, TKN, total nitrogen, total phosphorous, DOC, aluminum, copper, iron, manganese and nickel are negatively correlated with the proportion of dissolved arsenic in the water (Table 3.1). As these parameters increase in concentration, the amount of dissolved arsenic in the water decreases. While not all these parameters and their effects on arsenic bioavailability have been examined, the literature suggests arsenic in aquatic systems can adsorb to iron (Bednar et al. 2005; Ciardelli et al. 2008), aluminum (O'day 2006), manganese (O'day 2006), phosphate, silicate, and carbonate (Han *et al*. 2007; Ciardelli et al. 2008) and organic matter (Redman et al. 2002), essentially removing bioavailable arsenic from the system. In fact, ferric iron has been used in arsenic remediation (Sharma and Sohn 2009) and water treatment.

As noted for Table 2.3, a strong positive or negative correlation may indicate similar relationships rather than a cause and effect relationship.

Table 3.1: Correlations Between Proportion of Dissolved Arsenic and Other Parameters at Various Water Quality Sites

Parameter	Haggart and Inputs from Tributaries Moving Downstream →							
	Haggart	Dublin Gulch	Haggart	Eagle Ck	Haggart		Lynx Ck	Haggart
	W22	W21	W4	W27	W29	W5	W6	W23
Conductivity								
Hardness (as CaCO3)								
pH								
TSS								
TDS								
Turbidity								
Alkalinity, Total (as CaCO3)								
Fluoride								
Nitrate (as N)								
TKN								
Total Nitrogen								
Total Phosphate as P								
Sulfate								
DOC								
Aluminum								
Antimony								
Barium								
Calcium								
Copper								
Iron								
Magnesium								
Manganese								
Molybdenum								
Nickel								
Silicon								
Strontium								
Uranium								

	significant negative correlation at p<0.05
	significant negative correlation at p<0.002 (Bonferroni Corrected)
	significant positive correlation at p<0.05
	significant positive correlation at p<0.002 (Bonferroni Corrected)
	no significant correlation detected
na	not enough data or detectable concentrations to run correlation analysis

The relationship of total iron and dissolved arsenic is shown in Figure 3.1, and indicates the decrease in proportion of dissolved arsenic with increasing total iron levels, suggesting an absorbent role for iron.

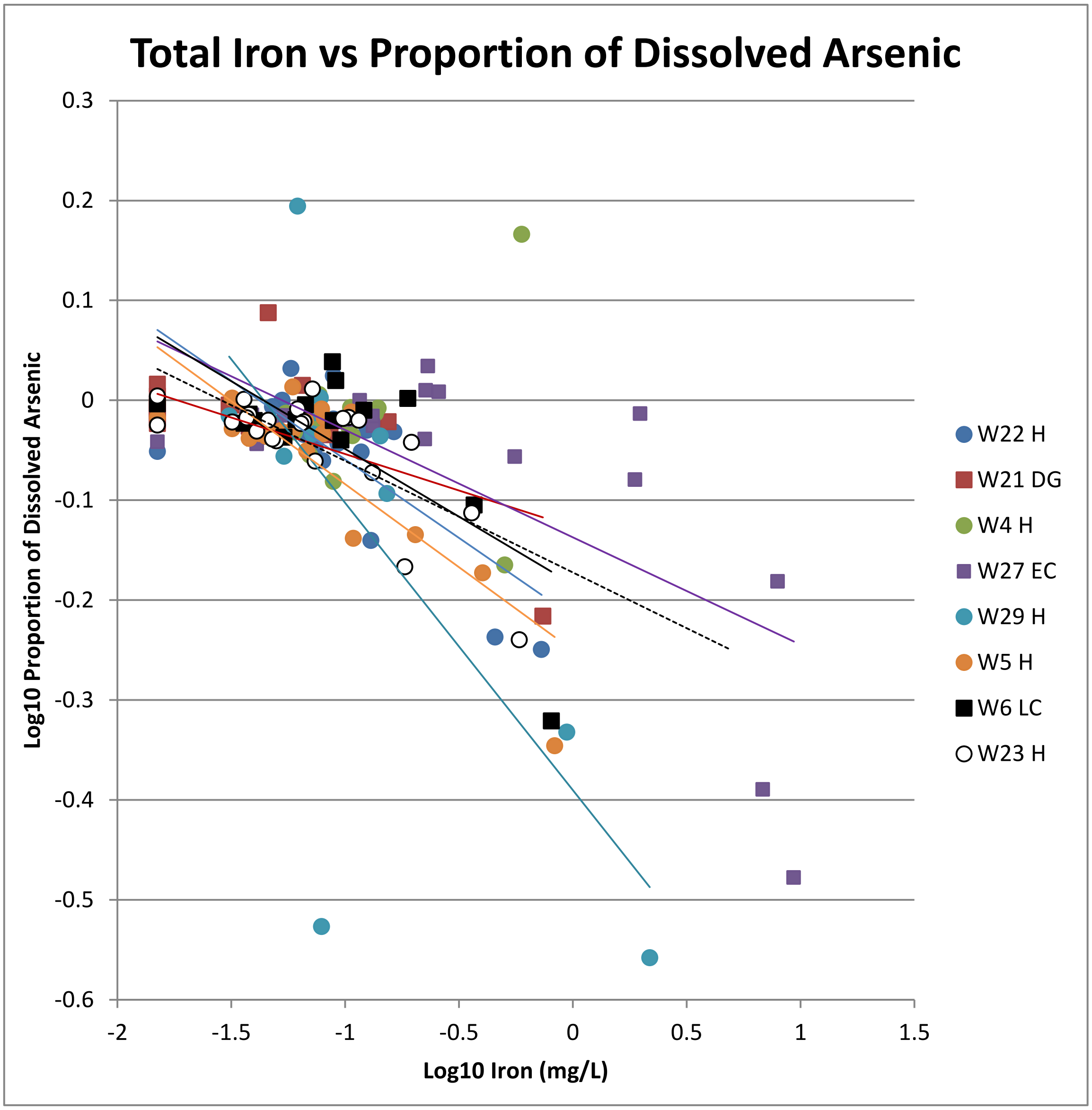


Figure 3.1: Total Iron vs. Proportion of Dissolved Arsenic at Project Area Sampling Sites

Conversely, the baseline water quality data indicates that conductivity, hardness, pH, TDS, alkalinity, sulfate, calcium, magnesium, silicon, and strontium and the proportion of dissolved arsenic, are positively correlated (Table 3.1). Positive relationships suggest that increased concentrations of these parameters increase with, and may cause an increase in, the dissolved fraction of arsenic in the water. For example, anthropogenically enhanced sulfate deposition can enhance the release of dissolved arsenic during sediment diagenesis (Bright *et al.* 1994). Diagenesis is the process of chemical and physical change in deposited sediment during its conversion to rock. Additionally, pH can influence arsenic adsorption, usually indirectly, by influencing the oxidation/reduction of iron and by affecting the surface charge of iron or other potentially sorptive minerals (Wang and Mulligan 2006a, 2006b; Sharma and Sohn 2009).

Of particular interest is the lack of significant relationships between any parameter and the proportion of dissolved arsenic in Haggart Creek at W4, and very few relationships at W29, compared to the other Haggart Creek sites (Table 3.1), indicating different conditions, and perhaps different controlling factors, at these sites immediately downstream of Dublin Gulch and Eagle Creek. Also, the correlations are weaker for Dublin Creek (W21) than for the other sites. The lack of correlations at W4 suggests a perturbation introduced by the Dublin Creek water, with its different chemical composition (e.g., high arsenic, low sulphate) and correlations, for example, a lack of chemical equilibrium downstream of the mixing zone. W4 is located 200 m downstream of Dublin Gulch, in a mixed area. The combination of very few adsorbents (weakly positive correlation between dissolved arsenic and TSS, aluminum, iron, and manganese in Dublin Gulch) entering Haggart Creek, and the mixing of waters (breaking weak chemical bonds between adsorbents and arsenic) can create an aquatic system that is not in chemical equilibrium. Thus, relationships between the various parameters and arsenic dissolution are blurred. Similarly for W29, 500 m downstream of the Eagle Creek confluence, there are only a few factors that show weak correlation with dissolved arsenic; in this instance, Haggart Creek, may be beginning to enter equilibrium downstream of the Eagle Creek confluence.

These analyses clearly indicate that many parameters can influence arsenic availability to aquatic organisms. The strongest arsenic adsorbers in this system appear to be TSS, DOC, aluminum, iron, and manganese. These factors may provide a protective mechanism for the aquatic communities in terms of natural sources of and anthropogenic effects on arsenic concentration. Copper and total phosphate concentrations are also negatively correlated with dissolved arsenic concentrations; however, the relationship with arsenic is more likely to be correlative rather than causative (i.e., these constituents also are affected by the sorbents).

The WER Procedure may provide a useful tool for deriving a SSWQO, and would be able to take into account both adsorbents (e.g., iron) removing bioavailable arsenic and other parameters that may release dissolved arsenic back into the water column (e.g., sulfate). However, there are a number of reasons why the WER Procedure is not suitable as the primary method for SSWQO derivation for this Project:

- The Water Effects Ratio Procedure is associated with complex implementation guidance and the current SSWQO guidance document states "The procedure needs to be simplified before it can be effectively implemented in British Columbia and Yukon" (BC MoE 1997).
- There are many sources of uncertainty relating the results of a WER test to site conditions. Acute and/or chronic toxicity tests must be completed using site water typically on rainbow trout, fathead minnows, water flea and a green alga (BC MoE 1997). These organisms are not typical of the Haggart Creek watershed, so interpreting results in relation to site conditions will be problematic. Native organisms in the Haggart Creek watershed are likely adapted to site conditions. The role of natural adsorbents in controlling arsenic may be too subtle distinguish in the laboratory, or to show cause and effect relationships.
- Multiple toxicity tests would likely be required to account for temporal and seasonal variability in arsenic concentrations, adsorbent concentrations and environmental conditions (e.g., flow, turbidity).

4. TOXICITY DATA USED TO DERIVE THE CCME WQG (POTENTIAL FOR USE OF THE RECALCULATION PROCEDURE)

The Recalculation Procedure involves review of the database used to establish the CCME WQG, removing toxicity endpoints for species (or types of species) that do not occur in the watercourses in question, and recalculating the endpoints using the original safety factor. There would be limited value to using a Recalculation Procedure to derive a SSWQO for arsenic for the Project. As discussed in the Project Proposal, recalculating the CCME WQG by removing species not present in the Project area would remove most of the toxicity endpoints, including all the algae, and most of the invertebrate and fish data.

Using the Recalculation Procedure for the toxicity studies used to derive the CCME WQG for arsenic (CCME 2001), augmented with studies listed in the World Health Organization database for arsenic (WHO 2011, accessed online 2011), indicates the following: remaining species would include one invertebrate (*Chironomus tentans*, a pollution tolerant chironomid) and one fish (arctic grayling) species. Using this method, the lowest toxicity test endpoint (Table 4.1) would be 0.68 mg/L As [III] (effect concentration for mobility of *Chironomus tentans*, Khangarot and Ray 1989) and the SSWQG would be 0.068 mg/L (ten-fold safety factor). This would not account for the lower toxicity of As [V], which is more likely to be the prevalent form of arsenic in the Haggart Creek watershed, and would not address arsenic toxicity to blue-green algae or the many diatom species that are predominant in the Project area.

The CCME WQG for arsenic (0.005 mg/L) was derived in 1991 using the Lowest Threshold Method that was in common use in the 1990s, and is still used in British Columbia. For this method, test results for the most sensitive organism were used. The effect concentration, an $(EC)_{50}$ (growth) of 0.05 mg As/L for the alga *Scenedesmus obliquus* (Vocke et al. 1980) was multiplied by a safety factor of 0.1 (CCME 1991). The study by Vocke et al. (1980) is considered reliable; however it was conducted using a now obsolete test protocol with 14 days of exposure. This is a common weakness with historical toxicological studies that used either arsenate (As[V]) or arsenite (As[III]), and a variety of test procedures, some of which are no longer useful in deriving WQG. In addition, some of the species commonly used in laboratory toxicity tests and derivation of the WQG are not necessarily relevant to the fish, invertebrate and algae species present in the Haggart Creek watershed. For example, algae are typically the most sensitive species to arsenic toxicity, but *S. obliquus,* the alga used to establish the generic CCME WQG, is a planktonic green alga that would rarely occur in watercourses located in northern systems, making the application of the CCME WQG less relevant for this Project. As noted above, using the Recalculation Procedure for the Project would result in a SSWQO for arsenic of 0.068 mg/L which is higher than the proposed SSWQO derived using the Background Procedure for Haggart Creek (0.014 mg/L) and similar to the SSWQO for Dublin Gulch and Eagle Creek (0.070 mg/L). However, it is not scientifically sound to base a WQG or SSWQO on results for two species. Using the Background Procedure to derive a SSWQO for arsenic is appropriate and conservative for the protection of aquatic life in the Haggart Creek watershed.

A brief discussion on arsenic fate in aquatic environments and its toxicity to aquatic biota including algae, invertebrates and fish is provided below.

4.1 Arsenic Toxicity to Aquatic Biota

Arsenic can be found in aquatic environments as a consequence of natural (e.g., soil erosion) and anthropogenic (e.g., metal mining) releases. Generally, inorganic arsenic species (e.g., As [V], arsenate, and As [III], arsenite) are more toxic than organo-arsenic forms and, among the inorganic forms, trivalent arsenic (As [III]) is more toxic than pentavalent forms (As[V]). In aquatic environments, As [V] generally predominates in oxidizing conditions such as surface waters, while As [III] dominates under reducing conditions such as in sediments (De Capitani 2011). Although arsenic may readily accumulate in aquatic organisms, biomagnification between trophic levels appears to be negligible. The speciation of arsenic in aquatic environments is of major importance when considering the toxicity of this element to aquatic biota. Redox potential, pH, organic matter, and inorganic substances such as iron and manganese hydroxides, sulfide, carbonate and phosphate oxyanions have a great influence on arsenic speciation and can consequently modify its toxicity (Sharma and Sohn 2009).

The toxicity of arsenic to aquatic organisms has been extensively studied (Table 4.1). In general, aquatic plants are among the most sensitive organisms to arsenic, whereas invertebrates and fish are less sensitive. Given that phosphate is an essential nutrient for aquatic plants and is chemically similar to arsenate, transport mechanisms in the plant may not be able to differentiate between the two for uptake, which may explain the sensitivity of aquatic plants to arsenic exposure (Meharg and Hartley-Whitaker 2002).

The levels at which adverse effects of arsenic were observed in algae generally ranged from 0.05 to 3.5 mg As/L, as As[V]. These include a range of species, test durations and toxicity endpoints, as noted in Table 4.1, but did not include the diatom or blue-green algal species present in the Haggart Creek watershed:

- 0.05 to 3.5 mg/L As [V] for green algae. This includes 0.05 mg/L for *Scenedesmus obliquus* and *S. denticulatus*) in 2 to 14 day exposures (Vocke et al. 1980, Hörnström 1990), 2 mg/L for *Chlorella vulgaris* (Maeda et al 1985); and 3.5 mg/L for *Scenedesmus quadriculata* after 8 days exposure (Bringmann and Kuhn 1977)
- 0.05 mg/L As [V] reported for unidentified diatoms (Bacillariophyceae) in 2 to 4 day tests (Hörnström 1990); 0.075 mg/L for the diatom *Melosira granulata* (unspecified test conditions, Planas and Healey 1978) and 0.16 mg/L for the diatom *Asterionella formosa* in a 23 day test (Conway 1978)
- 0.075 mg/L for the Chrysophyceae *Ochromonas vallesiaca* (Planas and Healey 1978) in unspecified test conditions and >0.5 mg/L for unidentified Chrysophyceae (Hörnström 1990)
- 0.05 mg/L As [V] reported for unidentified flagellates (Cryptophyceae) in 2 to 4 day tests (Hörnström 1990)

Adverse effects have been reported to occur in aquatic invertebrates exposed to arsenic concentrations greater than 0.3 mg/L (Table 4.1) Most of the tests were conducted using As [V] and some were conducted using As [III], and include a range of test durations and toxicity endpoints, mainly for planktonic, not benthic species:

- 0.32 to 5.8 mg/L As [V] for various planktonic cladocerans and copepoda (Crustacea), including 0.87 mg/L for *Bosmina longirostris*, 0.32 mg/L for *Cyclops*, 1.42 for *Ceriodaphnia dubia*, and 1.0 to 5.8 mg/L for *Daphnia magna* (Passino and Novak 1984, Borgmann et al. 1988, Naddy et al. 1995, Spehar 1980, Biesinger and Christensen 1972, Enserik et al 1991)
- 1.3 mg/L As [III] for *Daphnia* sp. (Lima et al 1984) and 4 mg/L As [III] for several species of unidentified zooplankton species (Cowell 1965)
- 20.74 mg/L As [III] for the freshwater clam *Corbicula fluminea* (Liao et al 2008)
- 0.68 mg/L As [III] for the midge *Chironomus tentans* (Khangarot and Ray 1989)

Table 4.1: Summary of Arsenic Toxicity to Algae, Invertebrates and Fish

Common name	Species	Arsenic Form	Test Duration (days)	Endpoint	Concentration (mg/L)	Reference
Algae						
Green alga	*Scenedesmus obliquus*	As (V)	14	EC50 (growth)	0.05	Vocke et al. (1980)
Green alga	*Scenedesmus quadriculata*	As (V)	8	IC (reproduction)	3.5	Bringmann and Kuhn (1977)
Green alga	*Scenedesmus denticulatus*	As (V)	2 to 4	LOEC	0.05	Hörnström (1990)
Diatom	Unidentified Bacillariophyceae	As (V)	2 to 4	LOEC	0.05	Hörnström (1990)
Cryptophyte	Unidentified Cryptophyceae	As (V)	2 to 4	LOEC	0.05	Hörnström (1990)
Golden alga	Unidentified Chrysophyceae	As (V)	2 to 4	NOEC	> 0.5	Hörnström (1990)
Green alga	*Chlorella vulgaris*	As (V)	N/A	N/A	2	Maeda et al. (1985)
Golden alga	*Ochromonas vallesiaca*	As (V)	N/A	EC50 (growth)	0.075	Planas and Healey (1978)
Diatom	*Melosira granulata*	As (V)	N/A	EC50 (growth)	0.075	Planas and Healey (1978)
Diatom	*Asterionalle Formosa*	As (V)	23	Growth	0.16	Conway (1978)
Invertebrates						
Cladoceran	*Bosmina longirostris*	As (V)	4	LC50	0.87	Passino and Novak (1984)
Cyclops copepods	*Cyclops vernalis*	AS (V)	14	EC20 (Growth)	0.32	Borgmann et al. (1988)
Freshwater clam	*Corbicula fluminea*	As (III)	7	LC50	20.74	Liao et al. (2008)
Midge	*Chironomus tentans*	As (III)	2	EC50 (immobilization)	0.68	Khangarot and Ray (1989)
Water flea	*Ceriodaphnia dubia*	AS (V)	7	NOEC (Reproduction)	1.42	Naddy et al. (1995)
		As (III)	7	LOEC	1	Spehar and Fiant (1986).
Water flea	*Daphnia magna*	As (III); As (V)	14	NOEC(Reproduction;Mortality)	1	Spehar (1980)
		As (V)	21	EC50 (Reproduction)	1.9	Biesinger and Christensen (1972)
		As (V)	21	EC50 (Mortality)	2.9	Biesinger and Christensen (1972)
		As (V)	21	LC50	5.8	Enserik et al. (1991)
		As (V)	21	EC50	3.2	Enserik et al. (1991)

Common name	Species	Arsenic Form	Test Duration (days)	Endpoint	Concentration (mg/L)	Reference
Water flea	*Daphnia sp*	As (III)	28	Mortality and Reproduction	1.3	Lima et al. (1984)
Zooplankton	Several species	As (III)	N/A	N/A	4	Cowell (1965)
Fish						
Arctic grayling	*Thymallus arcticus*	As (III)	4	LC50 (juvenile)	13.7	Buhl and Hamilton (1991)
		As (III)	4	LC50 (alevin)	27.7	Buhl and Hamilton (1991)
Coho salmon	*Oncorhynchus kisutch*	As (III)	4	LC50 (juvenile)	18.5	Buhl and Hamilton (1991)
		As (III)	4	LC50 (alevin)	49.4	Buhl and Hamilton (1991)
		As (III)	N/A	Migration	0.3	Nichols et al. (1984)
Fathead minnow	*Pimephales promelas*	As (III)	29	Growth	4.3	Lima et al. (1984)
		As (III)	32	Growth	3.3	Spehar and Fiant (1986)
Goldfish	*Carassius auratus*	As (V)	N/A	Avoidance Behavior	0.1	Weir and Hine (1970)
		As (III)	7	LC50 (eggs)	0.49	Birge (1978)
Golden shiner	*Notemigonus crysoleucas*	As (III)	N/A	Avoidance Behavior	0.028	Hartwell et al. (1989)
Rainbow trout	*Oncorhynchus mykiss*	As (III)	21	LC50 (eggs)	0.58	Birge (1978)
		As (III)	4	LC50 (juvenile)	16	Buhl and Hamilton (1991)
		As (III); As (V)	28	Survival	0.96	Spehar et al. (1980)
		As (III)	4	LC50 (alevin)	91	Buhl and Hamilton (1991)

Notes

Source: CCME (2001), World Health Organization (2011)

> Greater than; N/A not available

LC-Lethal concentration; EC-Effect concentration; IC-Inhibition concentration; LOEC-Lowest observed effect concentration; NOEC-Non observed effect concentration

Similar to invertebrates, adverse effects have been reported to occur in fish exposed to concentrations of arsenic > 0.3 mg/L (Table 4.1). The endpoints include behaviour, reproduction, growth and survival endpoints in a variety of test conditions:

- A significant decrease in migration of coho salmon smolts (*Oncorhynchus kisutch*) at concentrations greater than 0.3 mg L As [III] (Nichols et al. 1984)
- Impairment of avoidance behaviour in goldfish (*Carassius auratus*) at 0.1 mg/L As [V] (Weir and Hine 1970)
- Altered behaviour in golden shiner (*Notemigonus crysoleucas*) at 0.028 mg/L (As [III]) (Hartwell et al. 1989)
- 7 day LC_{50} for goldfish eggs of 0.49 mg/L As [III] and 0.54 mg/L As [III] for rainbow trout eggs *(Oncorhynchus mykiss)* after 21d of exposure to arsenite (Birge 1978)
- Differences in sensitivity to lethal concentrations for juvenile arctic grayling (*Thymallus arcticus*), coho salmon, and rainbow trout exposed to arsenic [III], with 96 hr LC_{50} of 13.7, 18.5 and 16 mg/L respectively (Buhl and Hamilton 1991). The authors also reported that juvenile stages of these fish species appeared to be more sensitive than alevin stages with 96 hr LC_{50} of 27.7, 49.4 and 91 mg/L reported for alevin arctic grayling, coho salmon and rainbow trout respectively
- No significant effects on survival of rainbow trout exposed to either As [III] or As [V] concentrations of 0.96 mg/L in a 28 day test (Spehar et al. 1980)
- Effects on growth of fathead minnow (*Pimephales promelas)* after 32 day exposure to As [III] at concentrations greater than 3.3 mg (Spehar and Fiant 1986); similar effect of reduced growth for a 29 day bioassay of fathead minnows exposed to As [III] levels of 4.3 mg/L (Lima et al. 1984).

5. SUMMARY AND CONCLUSIONS

Based on existing baseline conditions at some sites in the Haggart Creek watershed (i.e., higher than 0.05 mg As/L) described in Section 2 and the toxicology studies described in Section 4, it is not feasible to rule out the possibility that adverse effects result from arsenic exposure in algae, invertebrates and fish that currently inhabit Dublin Gulch, Eagle Creek and their tributaries. For example, it is possible that the absence of green algae and low abundance of diatoms in Dublin Gulch and Eagle and Lynx creeks is related to elevated arsenic levels. However, the watercourses continue to support diverse and abundant periphyton and benthic invertebrate assemblages, which are adapted to conditions in these watercourses. Any site-specific assessment of arsenic toxicity and derivation of a SSWQO should be based on aquatic species known to occur in the Project area.

In principal, the Recalculation Procedure is a useful approach to derive a SSWQO that will protect the aquatic species that occur in the Project area, without being excessively conservative. However, removing species that do not occur in the Project area from the toxicity database used to derive the

CCME WQG would result in too few remaining species (one invertebrate and one fish species) for derivation of a meaningful SSWQO. An alternative would be to use the Statistical Extrapolation Method recommended by CCME (2007), which uses data from multiple species and a Species Sensitivity Distribution curve to derive the WQG. For the generic CCME WQG, the Lowest Threshold Method was used to derive the WQG of 0.005 mg/L (the lowest toxicity value from a high quality toxicity study, with an safety factor for uncertainty applied). Although the Lowest Threshold and the Statistical Extrapolation Methods were recommended in the past, CCME now prefers to set the generic WQG using the Statistical Extrapolation Method (CCME 2007), as it considers results over a spectrum of species and effect endpoints. To use the Statistical Extrapolation Method, all available studies obtained by querying the US EPA ECOTOX database should be screened for inclusion or exclusion based on rules specified by CCME (2007) for developing site-specific water quality objectives.

The final point to consider when establishing SSWQO is that toxicity of arsenic to aquatic organisms can be highly modified by other parameters, as discussed in Section 3, so the derivation of a SSWQO for arsenic should also take into consideration (when possible) the existing physical and chemical characteristics of watercourses located in the project area. Background Concentration Method implicitly considers all the factors that influence arsenic availability, as it is based on the measured baseline arsenic concentrations (i.e., the absorbent processes have already influenced the arsenic concentrations).

In conclusion, the Background Concentration approach described in the Project Proposal, revised to include data from 2007—2010 and not from the 1990s, remains the most reasonable approach in deriving the arsenic SSWQO in the Haggart Creek watershed. Information reviewed from the perspective of the Water Effects Ratio and Recalculation Procedures are useful in supporting the SSWQO derived using the Background Concentration Procedure, as they describe the role of toxicity modifying factors and adaptation of local communities to baseline conditions. As calculated the arsenic SSWQO is designed to be protective of organisms exposed to existing conditions, and is not proposed to accommodate further discharges of arsenic to Haggart Creek, given that the mine water treatment plant will treat arsenic to levels that meet the SSWQO.

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7. CLOSURE

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APPENDIX R9

Aquatic Toxicological Evaluation of Sulphate

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AN AQUATIC TOXICOLOGICAL EVALUATION OF SULFATE: THE CASE FOR CONSIDERING HARDNESS AS A MODIFYING FACTOR IN SETTING WATER QUALITY GUIDELINES

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Abstract—Elevated concentrations of sulfate occur commonly in anthropogenically impacted and natural waters. However, water quality guidelines (WQG) have not been developed in many jurisdictions, and chronic toxicity data are scarce for this anion. A variety of test organisms, including species of invertebrate, fish, algae, moss, and an amphibian, were tested for chronic toxicity to develop a robust dataset that could be used to develop WQGs. As an example of how these data might be used to establish guidelines, calculations were performed using two standard procedures: a species sensitivity distribution (SSD) approach, following methods employed in developing Canadian WQGs, and a safety factor approach, according to procedures typically used in the development of provincial WQGs in British Columbia. The interaction of sulfate toxicity and water hardness was evaluated and incorporated into the calculations, resulting in separate values for soft (10–40 mg/L), moderately hard (80–100 mg/L) and hard water (160–250 mg/L). The resulting values were 129, 644, and 725 mg/L sulfate, respectively, following the SSD approach, and 75, 625, and 675 mg/L sulfate, following the safety factor approach. Environ. Toxicol. Chem. 2011;30:247–253. © 2010 SETAC

Keywords—Sulfate Chronic toxicity Species sensitivity distribution Hardness

INTRODUCTION

Sulfate commonly occurs at elevated concentrations in wastewaters from industrial processes, in runoff from agricultural areas, and in natural waters draining areas of significant mineralization. Federal water quality guidelines (WQGs) have not been developed in Canada or the United States for this anion. However, the province of British Columbia (BC) established a WQG for sulfate of 100 mg/L for the protection of aquatic life in freshwater [1]. The absence of widely applied WQGs, and the presence of sulfate at elevated concentrations in some discharges, suggests a need for establishing a science-based threshold for adverse effects associated with this anion.

The current BC WQG of 100 mg/L is based largely on results from toxicity tests using three test species, representing an invertebrate, a plant, and a fish. In particular, the tests were a 96-h survival test using *Hyalella azteca*, which resulted in a median lethal concentration (LC50) of 205 mg/L sulfate under hardness conditions of 25 mg/L (as $CaCO_3$); a 21-d growth test using the aquatic moss *Fontinalis antipyretica*, which indicated that adverse effects may occur at 100 mg/L sulfate; and a 96-h survival test using larval striped bass (*Morone saxatilis*), which yielded an LC50 of 250 mg/L [1].

Results of these tests have been questioned in the literature, in part because of the inability of researchers to replicate them. For example, Davies [2] reported statistically detectable effects on growth and chlorophyll content of *F. antipyretica* at 400 mg/L, but not at 200 mg/L sulfate. These authors suggested that the higher degree of toxicity observed by Frahm [3], and incorporated in the BC WQG [1], likely related to the use of potassium sulfate in that study, rather than sodium sulfate. Potassium exhibits a greater degree of toxicity as compared with Na [4] and, consequently, is not suitable as a counter-ion in any evaluations of the toxicity of anions.

The sensitive LC50 value of 205 mg/L sulfate for *H. azteca* in very soft water, which was taken from an unpublished study conducted by Environment Canada (Pacific Environmental Science Centre, North Vancouver, BC, Canada) [1], was questioned by Davies et al. [5], who obtained an LC50 value of 491 mg/L sulfate in a test with this species under similar hardness conditions (25 mg/L). Davies et al. also observed poor survival in control exposures from a number of tests conducted at this hardness, suggesting that the water quality conditions associated with the low-hardness water may have caused stress to the test organisms.

Finally, data characterizing sulfate toxicity to larval striped bass reported by Hughes [6], and incorporated into the BC guideline [1], have also been questioned [5]. This species is anadromous, spawning in the lower reaches of rivers, including estuaries. The optimal salinity for larval development in this species is 10 ppt seawater, which would contain approximately 775 mg/L sulfate. Thus, the LC50 value of 250 mg/L reported for sulfate is not supported; this result suggests an effect of ionic composition of the test water, rather than of sulfate toxicity. Indeed, Davies et al. [5] reported improved survival of this species with increasing sulfate concentrations, with the highest rate of survival at the highest sulfate concentration tested (4,000 mg/L);

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these authors postulated that the high degree of sensitivity observed by Hughes [6] was related to osmotic stress associated with use of a low-ionic-strength dilution water in that study.

A growing body of evidence suggests that the toxicity of sulfate decreases with increasing hardness. This effect has been demonstrated in acute toxicity studies using rainbow trout, coho salmon, *H. azteca,* and *Daphnia magna* [1,7,8], as well as in sublethal tests, including embryo-development tests with rainbow trout and survival and reproduction tests using *D. magna* [1]. The mechanism by which ions constituting water hardness influence the toxicity of sulfate has not yet been established; however, this phenomenon likely relates to either competition from other ions at ionic uptake sites in the gill, or an effect on membrane permeability, as suggested by Penttinen et al. [9]. Reduced toxicity of a major anion caused by higher water hardness also has been reported for another major anion, chloride, in sublethal toxicity tests using *Ceriodaphnia dubia* [10].

Based on the apparent importance of water hardness for sulfate toxicity and the concern over the robustness of key data employed to derive the BC WQG for protection of aquatic life, additional effort appears warranted to establish safe, scientifically defensible levels for sulfate in the aquatic environment. Consequently, the present study was conducted to provide a comprehensive set of toxicological data, generated using standardized test methods, which can be used to establish safe limits for sulfate under varying conditions of hardness.

Test species and types were selected to meet Canadian Council of Ministers of the Environment requirements for establishing Type A Canadian WQGs for the protection of aquatic life, using a Species Sensitivity Distribution (SSD) approach [11]. This process requires toxicity test data of suitable quality for three fish species (including at least one salmonid and one non-salmonid); three aquatic invertebrates (including at least one planktonic crustacean); at least one vascular plant or freshwater alga; and aquatic life stages of an amphibian (considered highly desirable, although not required).

MATERIALS AND METHODS

Test species, durations, and endpoints were chosen on the basis of providing a suitable representation of species to meet Canadian Council of Ministers of the Environment requirements [11] for which chronic exposures could be conducted in the laboratory following standardized published procedures. Species selection also accommodated selection of species that have previously been demonstrated to be sensitive to sulfate (*H. azteca, F. antipyretica* [1]).

Test organisms included three species of invertebrates (a cladoceran [*C. dubia*], a rotifer [*Brachionus calyciflorus*], and an amphipod [*H. azteca*]), three species of fish (rainbow trout [*Oncorhynchus mykiss*], coho salmon [*Oncorhynchus kisutch*], and fathead minnow [*Pimephales promelas*]), one amphibian species (Pacific tree frog [*Pseudacris regilla*]), and two plant species (a green alga [*Pseudokirchneriella subcapitata*] and an aquatic moss [*F. antipyretica*]). All tests were conducted according to standardized biological test methods, with the exception of the tests using *F. antipyretica*, which were based on procedures described by Davies [2], and methods for tests using Pacific tree frogs, which were adapted from the Organisation for Economic Co-operation and Development (OECD) guidance for measuring effects of thyroid-active substances on amphibians [12]. Test durations and endpoints are provided in Table 1.

Exposures were conducted in constant environment rooms that maintained temperature within 1°C of the target temperature. Water used in the tests was dechlorinated municipal tap water (hardness of approximately 15 mg/L), or was prepared by supplementing de-ionized or dechlorinated municipal water with reagent-grade salts according to procedures specified in U.S. Environmental Protection Agency guidance documents to obtain soft, moderately hard, hard, or very hard water [13], with the exception of tests using *H. azteca*, which used a recipe for salt addition that resulted in a higher chloride concentration [14]. The dilution water for the *C. dubia*, *B. calyciflorus,* and *P. subcapitata* tests was deionized water prepared with added salts, and for the remaining species was dechlorinated municipal tap water, with or without the addition of salts. Hardness values of test exposure solutions used for each species are provided in Table 1.

Exposure solutions incorporated five to eight test concentrations, in addition to the control, and followed a 0.5- or a 0.67-fold dilution series, and were prepared by addition of sodium sulfate to achieve the target sulfate concentrations. Sodium sulfate was used rather than the sulfate salts of other cations (Ca, Mg, or K) because Na is expected to contribute the least to toxicity relative to the other cations [4]. Subsamples were collected from the test solutions at the beginning and end of each of the tests, and sulfate concentrations were confirmed analytically using automated colorimetry. Quality assurance/quality control procedures for analytical confirmations included evaluation of sulfate in laboratory duplicate samples and blanks, as well as in sulfate-spiked laboratory water and sample matrix. Quality control limits were 20% relative percent difference for duplicates, 75 to 125% recovery for matrix spikes, and 80 to 120% for laboratory water spikes. The mean measured concentration of sulfate was used to calculate the test endpoints.

Cladocerans

Chronic toxicity tests using *C. dubia* were conducted according to Environment Canada procedures [15] in 20-ml volumes in 25-ml glass test tubes. Exposures of each concentration

Table 1. Summary of toxicity tests used in the aquatic toxicological evaluation of sulfate

Test species	Test duration	Test endpoint(s)	Hardnesses tested (mg/L)
Ceriodaphnia dubia	7 ± 1 d	Survival, reproduction	40, 80, 160, 320
Brachionus calyciflorus	48 h	Population growth	40, 80, 160, 320
Hyalella azteca	96 h	Survival	25, 80
	14 d	Survival, growth	80
Oncorhynchus kisutch	10 d	Embryo development	15
Oncorhynchus mykiss	31 d	Embryo/alevin development	15
Pimephales promelas	7 d	Survival, growth	40, 80, 160, 320
Pseudacris regilla	21 d	Survival, growth	15, 80
Pseudokirchneriella subcapitata	72 h	Population growth	10, 80, 320
Fontinalis antipyretica	21 d	Growth, chlorophyll	15

comprised 10 replicates, each initiated with a single less-than-24-h-old daphnid obtained from in-house cultures. The organisms were cultured at the corresponding test hardness for at least two generations before initiation of the tests. Solutions were renewed with freshly prepared solutions daily, at which time they were fed a mixture of *P. subcapitata* cells and digested yeast, Cerophyl, and trout chow. Exposures were conducted at 25°C under a 16:8 h light:dark photoperiod. Survival and reproductive output were recorded daily for the 7 ± 1-d duration of the tests. Exposures were terminated on the day that at least 60% of the control organisms produced their third brood. Acceptable limits for control performance were 80% or higher survival and production of at least 15 offspring by surviving control organisms producing three broods.

Rotifers

Brachionus calyciflorus tests were conducted under static conditions for 48 h in a culture plate using a 0.5-ml exposure volume and eight replicates per concentration, each containing one rotifer [16]. The test was initiated with organisms that were less than 4 h old, and solutions were supplemented with *P. subcapitata* as food at test initiation. Exposures were conducted at 25°C in the dark. Despite its relatively short duration, this test is considered a chronic test because of the short life history of this organism, and the fact that the method incorporated a reproductive endpoint within this timeframe. The acceptable limit for control performance was a mean intrinsic rate of population increase of $\geq$0.7

Amphipods

Acute (96-h) and chronic (14-d) toxicity tests using *H. azteca* were conducted using amphipods obtained from Aquatic Biosystems (Fort Collins, CO). Chronic toxicity tests with this species were conducted using clean sediment comprising beach-collected sand, rinsed with laboratory control water, and supplemented with peat at a rate of 2% by weight. Test methods were modified from Environment Canada procedures that are typically employed to evaluate sediment toxicity [17], by incorporating test solution renewal three times per week throughout exposure with freshly prepared, sulfate-spiked water, at which time yeast, Cerophyl, and trout chow were added as food. These tests were conducted using four replicates per concentration in glass jars containing 100 ml control sediment and filled to 275 ml with the test solutions. The exposures were conducted at 23°C with a 16:8 h light:dark photoperiod. Surviving amphipods were dried at the end of the test on preweighed aluminum weighboats, and dry weight was determined. Acute exposures using this species were conducted in 200-ml volumes in glass jars with no solution renewal and feeding at test initiation and after 48 h exposure [17]. Both acute and chronic exposures were conducted using 10 test organisms per replicate. Acceptable limits for control performance were 90% or higher survival in the acute exposures, 90% or higher survival, and at least 0.1 mg average dry weight per organism in chronic exposures.

Fish (salmonid)

Toxicity tests with rainbow trout and coho salmon were conducted according to procedures described by Environment Canada for early life stages of salmonids [18]. Tests were initiated less than 30 min after dry fertilization of the eggs; gametes for these tests were obtained from the Fraser Valley Trout Hatchery (Abbottsford, BC, Canada) and the Capilano Hatchery (North Vancouver, BC, Canada), respectively. Rainbow trout and coho salmon were each exposed using four replicates of 30 embryos in 2-L volumes; coho embryos were exposed at 11°C for 10 d, and rainbow trout were exposed at 14°C for 31 d. Solutions were renewed daily and gently aerated throughout exposure. The endpoint for the coho salmon test (embryo development) was normal embryonic development and for the rainbow trout test (embryo-alevin development) was normal, hatched fish. Acceptable limits for control performance were at least 65% viable alevins in the rainbow trout test and at least 70% normally developed embryos in the coho test.

Fish (non-salmonid)

Fathead minnow tests were conducted according to procedures described by Environment Canada [19], involving a 7-d exposure initiated with less than 24 h post-hatch fish. Larval fish were obtained from Aquatic Biosystems. Tests were conducted using three replicates in 300-ml glass jars containing 250 ml solution and 10 fish per replicate and were exposed at 25°C and under a 16:8 h light:dark photoperiod. Fish were fed with *Artemia salina* nauplii, and solutions were renewed daily throughout the exposure period. At the end of the test, surviving larvae were dried overnight on preweighed aluminum pans, and then weighed. Endpoints from the test were survival and biomass, and acceptable control performance limits were at least 80% normal surviving fish and at least 0.25 mg dry weight per surviving fish.

Amphibian

Tests using *Pseudacris regilla* were conducted according to methods adapted from the Organisation for Economic Co-operation and Development guidance for tests using the frog species *Xenopus laevis* [12]. Tests were initiated with tadpoles (Gosner stage 29) hatched from eggs that were field-collected from a pond near Squamish, BC, Canada. The tests were conducted using three replicates with five tadpoles in each replicate. Test containers were glass jars containing 1 L test solution, which was aerated throughout the test. Exposures were conducted at 23°C under a 16:8 h light:dark photoperiod. The test organisms were fed daily with Sera Micron. Test endpoints included survival and wet weight, and criteria for acceptable control performance included survival of at least 90%.

Algae

Toxicity tests using *P. subcapitata* were conducted according to procedures described by Environment Canada [20]. Tests were conducted at 24°C under continuous light with intensity of $4{,}000 \pm 400$ lux. Exposures were performed in 96-well U-shaped microplates and were initiated with a density of 10,000 cells/ml, obtained from an in-house culture in exponential growth phase. Four replicates were used for the test solutions. Density of algal cells of the end of the 72-h exposure period was measured, using a hemacytometer, and the endpoint from the test was calculated on the basis of cell yield (increase in cell density). Acceptable control performance was based on achieving at least a 16-fold increase in cell density, with a coefficient of variation of 20% or less.

Moss

Toxicity testing using *F. antipyretica* followed procedures described by Davies [2]. Tests were conducted in 300-ml glass jars containing 150 ml test solution and five 2-cm apical tips in each of four replicates. Test solutions were renewed at 7-d intervals throughout the exposure period. The exposures were conducted at 14°C under continuous light of 1,300 to 1,800 lux.

Test endpoints were length, dry weight, and chlorophyll content. Dry weight was measured on three tips at test termination, after drying for 24 h on preweighed aluminum pans; two tips (the longest and shortest from each replicate) were pooled and used for the measurement of chlorophylls A and B. Chlorophyll measurements were conducted using spectrophotometry after digestion in acetone. Tests using this species were conducted on two occasions, using moss collected from Hazeltine and Musqueam Creeks (BC, Canada). Quantitative criteria for acceptable control performance have not been established for this test; consequently, the test was considered acceptable if the moss tips in the control exposures appeared to be healthy.

Statistical analyses

Statistical analyses were conducted using CETIS (Tidepool Software) and according to procedures described by Environment Canada [21] for calculating point estimates and hypothesis tests. Survival and normality data were analyzed using probit or logit multiple linear estimation, where possible, and quantitative data for reproduction and growth were analyzed using nonlinear regression in cases in which model assumptions were met. Linear interpolation of log-transformed data was used in cases in which the assumptions of the models described were not met. Species sensitivity distributions were calculated using CETIS by multiple linear estimation regression. Log-logit, lognormal (Probit), log-Gompertz, and log-angle models were tested, and the best fit was selected on the basis of the lowest Akaike information criterion value, which provides a relative measure of goodness of fit of various models.

RESULTS AND DISCUSSION

The results of all toxicity tests reported herein met requirements specified in each of the test methods for control performance, and water quality parameters remained within the ranges specified in the corresponding test methods. Quality control limits for analytical chemistry were achieved for duplicate measurements, spikes, and blanks. Measured concentrations of sulfate were consistent with nominal values (Table 2) and showed minimal departure between test initiation and termination; final values were $101 \pm 0.9\%$ of initial values in the tests. Presence of sediment in the test using *H. azteca* did not appear to influence the water column concentration of sulfate.

The geometric means of LC50 values for *H. azteca* were 619 and 2,099 mg/L sulfate for tests at 25 mg/L ($n = 5$) and 80 to 100 mg/L hardness ($n = 6$), respectively, demonstrating a 3.4-fold change in toxicity associated with a similar degree change in hardness. These values are similar to those reported by Davies and Hall [7], who reported LC50 values of 569 and 1,580 mg/L sulfate at hardness of 25 and 75 mg/L, respectively. The LC50 values for water with a hardness of 25 mg/L were more than twofold higher than the 205-mg/L value used in the derivation of the current BC WQG for sulfate [1]. This difference may be related to differences in dilution water used in the tests; for example, chloride has been noted to affect the toxicity of sulfate to *H. azteca* [8].

Table 2. Measured concentrations of sulfate as a percentage of nominal in test solutions[a]

Species	Measured sulfate as a percentage of nominal (mean ± SD)
Ceriodaphnia dubia	104 ± 22
Brachionus calyciflorus	87 ± 7
Hyalella azteca	99 ± 22
Oncorhynchus kisutch	91 ± 6
Oncorhynchus mykiss	93 ± 9
Pimephales promelas	97 ± 14
Pseudacris regilla	97 ± 3
Pseudokirchneriella subcapitata	97 ± 3
Fontinalis antipyretica	102 ± 10

[a] Values are presented as a mean and standard deviation for measurements conducted in tests with each species.

Results of sublethal toxicity tests conducted during the current study are summarized in Table 3; point estimates are provided for a 10%, 25%, and 50% effect relative to the control. Procedures for developing Canadian WQGs indicate that the most appropriate effect concentration or inhibition concentration values reflecting the toxicological threshold from the test should be used for calculating SSDs, where available [11]. Ideally, tenth percentile effect levels are preferred; however, interpreting the significance of tenth percentile data requires caution in some cases, because the uncertainty of statistical calculation increases substantially in the tails of the distribution, and long-term laboratory toxicity tests rarely have the statistical sensitivity to detect a 10% departure from control performance. The approach taken here involves the use of the 10% inhibition concentration or 10% effect concentration values as the toxicological threshold in cases in which this value exceeded the no observed effect concentration from the test. In cases in which the tenth percentile point estimate was lower than the no observed effect concentration, the toxicological threshold was considered to be the 25th percentile effect levels (25% inhibition concentration [IC25] or 25% effect concentration) from the test, because the dataset was not considered to be sufficiently robust to derive a 10% inhibition concentration value with a suitable degree of confidence.

As observed in acute tests using *H. azteca*, sublethal tests conducted at differing hardnesses also indicated decreasing sulfate toxicity with increasing water hardness for most of the species tested in the current study. For example, biomass of fathead minnows and reproduction of *C. dubia* exhibited an approximate fourfold change in sensitivity to sulfate across a fourfold change in hardness (from 40–160 mg/L hardness) (Fig. 1).

Exceptions to this general pattern were *P. subcapitata* (algae), *B. calyciflorus* (rotifer), and *P. regilla* (amphibian), which exhibited minimal changes in sensitivity to sulfate with increasing hardness. This difference may reflect physiological differences among organisms. For example, algae accumulate sulfate into their cells by active transport, given that sulfate is required by the cells to produce sulfur-containing amino acids, such as methionine and cysteine [22]. Thus, uptake of sulfate by these cells is governed by Michaelis-Menten kinetics, in which the number of active uptake sites limits the maximal uptake rate, and relative concentrations of other ions would not be expected to interfere with uptake kinetics unless they compete for binding sites. Conversely, freshwater fish apparently have no active mechanism for sulfate uptake or regulation at the gill, and sulfate uptake likely occurs by passive diffusion through ion channels. Decreased toxicity of sulfate to these organisms with increasing ionic strength therefore may occur as a result of competitive exclusion by other ions in these channels, or effects of calcium on cell membrane permeability [9].

Whether amphibians have active uptake sites for sulfate is not known, but that may explain why *P. regilla* was not substantially more sensitive to sulfate under soft water conditions. Interestingly, growth of *P. regilla* tadpoles was significantly enhanced in nonlethal concentrations of sulfate; exposure to 1,000 mg/L sulfate produced tadpoles that were approximately 30% heavier than control tadpoles under both

Table 3. Responses of various aquatic organisms to waterborne sulfate, at different hardness levels[a]

Species	Endpoint	Hardness	EC10 or IC10[b]	EC25 or IC25	EC50 or IC50	NOEC	LOEC
Ceriodaphnia dubia	Survival	40	NC[c]	NC	914 (809–1,030)	610	1,300
		80	NC	NC	1,267 (1,026–1,566)	1,250	2,000
		160	NC	NC	1,551 (1,297–1,855)	1,300	2,600
		320	NC	NC	1,619 (1,364–1,920)	1,450	2,700
	Reproduction	40	137 (71–204)	246 (172–326)	465 (358–592)	<150	150
		80	622 (NC–813)	855 (601–1,036)	1,129 (990–1,269)	645	1,250
		160	1,174 (1,153–1,188)	1,212 (1,206–1,219)	1,257 (1,248–1,267)	775	1,300
		320	402 (331–481)	542 (455–640)	843 (710–1,003)	420	480
Brachionus calyciflorus	Reproduction	40	703 (158–1,013)	997 (739–1,115)	1,214 (1,083–1,308)	950	1,800
		80	245 (148–744)	1,824 (721–1,921)	2,200 (2,089–2,277)	510	960
		160	678 (258–1,059)	1,292 (1,078–1,766)	>1,800	560	1,100
		320	844 (795–1,174)	1,027 (900–NC)	>1,800	1,800	>1,800
Hyalella azteca	Survival	80	2069 (NC)	2,246 (NC)	2461 (NC)	1,637	2,412
	Reproduction	80	380 (NC–626)	1,056 (NC)	>2,412	1,637	2,412
Oncorhynchus kisutch	Embryo	15	941 (803–1,062)	1,264 (1,128–1,391)	1,755 (1,607–1,921)	825	1,450
Oncorhynchus mykiss	Embryo-alevin	15	356 (256–433)	501 (407–582)	734 (640–823)	205	340
Pimephales promelas	Survival	40	559 (293–805)	933 (601–1,230)	1,649 (1,255–2,097)	595	1,250
		80	1,555 (869–2,032)	2,183 (1,499–2,634)	2,938 (2,359–3,385)	1,300	2,850
		160	3,231 (2,084–3,840)	3,801 (2,817–4,356)	4,553 (3,827–5,157)	2,850	5,500
		320	2,451 (1,129– > 5,250)	>5,250	>5,250	2,900	5,250
	Biomass	40	388 (187–553)	752 (537–943)	1,244 (1,047–1,449)	595	1,250
		80	1,342 (NC–1,926)	1,950 (915–2,485)	2,591 (2,211–2,975)	760	1,300
		160	2,491 (NC–2,934)	3,077 (2,525–3,541)	3,892 (3445–4397)	1,300	2,850
		320	1,323 (297–2,656)	3,463 (1,953–5,473)	>5,250	820	1,400
Pseudacris regilla	Survival	15	719 (234–1,041)	1,190 (750–2,002)	>1,850	978	1,850
		80	985 (146–1,302)	1,205 (363–1,510)	1,507 (907–1,963)	1,075	1,925
	Growth	15	1,342 (NC–1,905)	1,560 (NC–2,079)	1,853 (1,646–2,082)	978	1,950
		80	1,252 (NC–1,492)	1,348 (NC–1,649)	1,510 (1,217–2,167)	1,075	1,925
Pseudokirchneriella subcapitata	Cell yield	10	700 (NC–1,256)	1,112 (262–1,325)	1,430 (1,206–1,637)	1,100	2,000
		80	1,345 (NC–1,532)	1,763 (936–2,170)	2,742 (1,871–3,221)	1,200	2,700
		320	1,377 (NC–1,582)	1,727 (1,371–1,983)	2,518 (2,093–3,007)	1,300	2,800
Fontinalis antipyretica	Chlorophyll	15 (test 1)	53 (NC–261)	176 (NC–320)	298 (158–1,014)	145	300
		15 (test 2)	716 (680–750)	820 (777–920)	1,029 (931–1,288)	654	1,240
	Growth	15 (test 1)	531 (243–818)	849 (600–1,034)	>2,575	603	1,250
		15 (test 2)	297 (NC–1,025)	828 (335–1,040)	>2,522	654	1,240

[a] Responses are presented on the basis of 10th, 25th and 50th percentile effect concentration (ECx) or inhibition concentration (ICx), as well as no observed effect concentration (NOEC) and lowest observed effect eoncentration (LOEC).
[b] IC10 and EC10 values were not considered sufficiently robust for use in guideline calculation in cases in which they were lower than the NOEC.
[c] NC = Not calculable.

hardness regimens tested. Thus, tadpoles of this species may have an active uptake mechanism for sulfate, and this anion may be utilized beneficially in metabolic processes.

At the highest hardness tested (320 mg/L), a continued reduction in sulfate toxicity to fathead minnows was observed relative to tests conducted at lower hardness values. However, *C. dubia* exhibited increased sensitivity to sulfate in this water relative to tests at a hardness of 160 mg/L. Likely the overall ionic strength of the test solutions in this very hard water type resulted in an osmotic challenge to this species that, combined with elevated sulfate concentrations, resulted in the adverse effect. This relationship also has been reported for chloride [10],

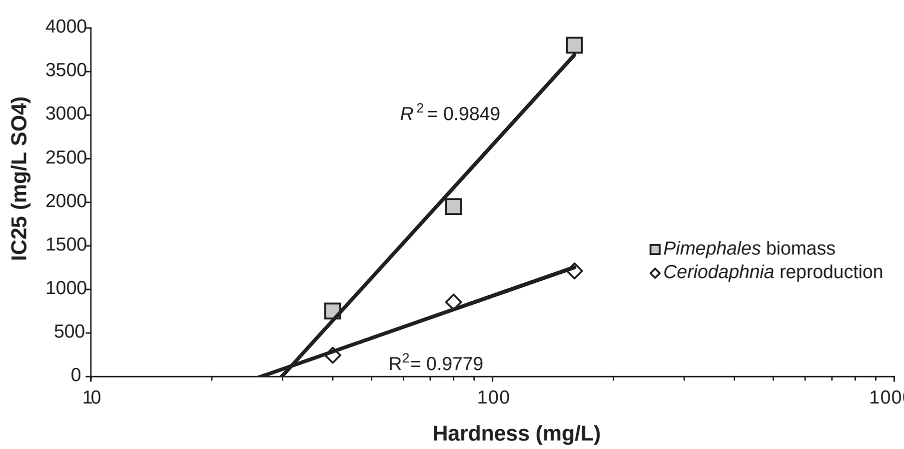

Fig. 1. Relationship between sulfate toxicity, presented as the 25th percentile inhibition concentration (IC25), and water hardness for toxicity tests with fathead minnows (*Pimephales promelas*) and *Ceriodaphnia dubia* across a range of hardnesses from 40 to 160 mg/L.

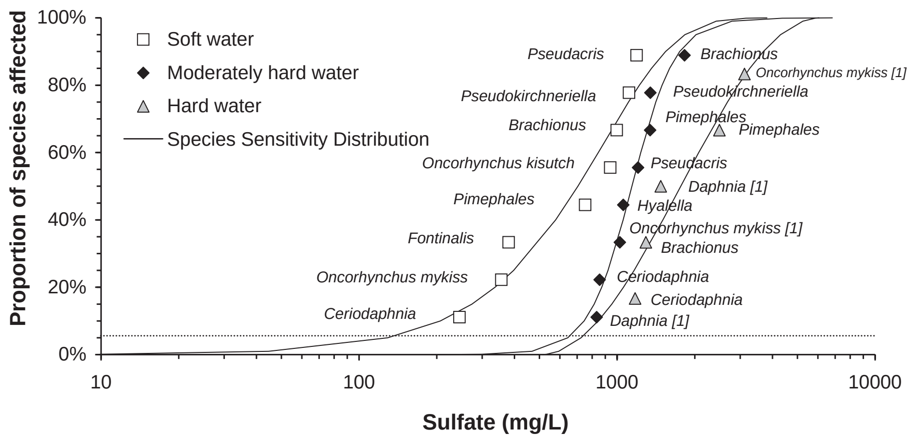

Fig. 2. Species sensitivity distributions for sulfate under soft (10–40 mg/L), moderately hard (80–100 mg/L), and hard water (150–250 mg/L) conditions.

where a strong log-linear relationship was observed between hardness and toxicity of this anion across a range of hardness values up to 160 mg/L, with increased sensitivity observed at 320 mg/L hardness.

Aquatic toxicity data generated in the current study, and those already published by Singleton [1], can be used to calculate a water quality benchmark for sulfate that reflects sublethal test endpoints and incorporates hardness as a toxicity-modifying factor. Various WQGs for metals, such as Cu and Zn, have incorporated an equation for hardness to provide a mechanism to adjust the generic guideline based on site-specific hardness conditions. This approach assumes that the relationship between toxicity and hardness is generally similar among organisms. In the case of sulfate, the data presented here and elsewhere [1,2,5,7,8] demonstrate that most organisms exhibit reduced sensitivity to sulfate with increasing hardness. However, the slopes of this relationship were not consistent among species. Consequently, the approach taken in this study was to calculate a guideline based on data available for soft water (10–40 mg/L hardness), moderately hard water (80–100 mg/L), and hard water conditions (150–250 mg/L). At higher hardness values, total dissolved solids may contribute to adverse effects, and, consequently, using site-specific approaches to establish a guideline under these conditions would be more appropriate.

The current BC WQG for protection of aquatic life [1] was calculated based largely on the application of a twofold safety margin to results from an unpublished acute toxicity test result for *H. azteca* of 205 mg/L, resulting in a guideline of 100 mg/L [1]. This value also took into consideration data for an aquatic moss (*F. antipyretica*) and larval striped bass (*M. saxatilis*). Conversely, the results presented in this study demonstrate that *H. azteca* is not the most sensitive species; daphnids were the most sensitive species tested in each of the hardness ranges, with IC25 values of 245 mg/L (*C. dubia*), 833 mg/L (*D. magna*; data from Singleton [1]), and 1,213 mg/L (*C. dubia*) at hardnesses of 25, 80, and 160 mg/L, respectively. In developing WQGs, the BC Ministry of Environment typically applies between a twofold and 10-fold safety margin below the lowest available lowest observed effect concentration; selection of a safety margin depends on the quality and quantity of available data, severity of adverse effects, and the potential for bioaccumulation [23]. In the case of this dataset, in which sublethal toxicity data are available for a number of sensitive species, a twofold safety margin appears to be appropriate; this approach is consistent with the current BC water quality guideline for this anion, which uses a safety factor of 2. This approach would result in guidelines for soft, moderately hard, and hard water conditions of 75, 625, and 650 mg/L sulfate, respectively.

An alternative approach to deriving WQGs involves the use of SSDs. This approach is currently employed in calculating federal WQGs in Canada [11] and elsewhere [24,25]. Canadian WQGs are established as the hazard coefficient associated with the 5th percentile of the SSD [11]. The distributions of available toxicological threshold data under soft, moderately hard, and hard water conditions are provided in Fig. 2 and are discussed further in later paragraphs.

Soft water guideline

Data available for soft-water conditions included test results for an aquatic moss, a unicellular green alga, two planktonic invertebrates, three fish (including two salmonids), and an amphibian. The hazard coefficient associated with the 5th percentile of the SSD calculated from this dataset was 129 mg/L sulfate (log-Gompertz model). This value provides a suitable degree of protection for the most sensitive species represented in this dataset (*C. dubia*), which yielded a toxicity threshold of 245 mg/L. This value is almost twofold higher than the guideline calculated using the BC approach.

Moderately hard water guideline

Results of tests conducted at between 80 and 100 mg/L hardness (moderately hard-water conditions) were available for two cladocerans, a rotifer, an amphipod, a green alga, two fish, and an amphibian. The hazard coefficient associated with the 5th percentile of the SSD calculated from the SSD of the dataset was 644 mg/L sulfate (log-logit model), which provides a suitable level of protection below the most sensitive test result, which was an IC25 of 833 mg/L for *D. magna*. Furthermore, this value was similar to the guideline of 625 mg/L sulfate calculated by using the BC approach.

Hard water guideline

Tests conducted in hard water, arbitrarily grouped as tests conducted in waters of between 160 and 250 mg/L, were available for two cladocerans, a rotifer, and two species of fish. The hazard coefficient associated with the 5th percentile of the SSD calculated from this dataset (log-angle model) was 725 mg/L sulfate, which provides a suitable level of protection below the most sensitive IC25 of 1,213 mg/L for *C. dubia*, and is similar to the guideline of 650 mg/L calculated using the BC approach.

CONCLUSION

Development of WQGs requires a robust dataset of toxicological thresholds representing a broad range of sensitive test organisms representing those that occur in receiving water bodies. The battery of tests needs to include sublethal exposures to ensure that resulting guidelines are suitably protective. Data should be of primary quality, which requires that the tests be conducted according to standardized procedures; analytical confirmation of actual concentrations to which test organisms are exposed; and the tests meet quality control requirements for health and sensitivity.

The data presented herein provide a dataset that, we propose, meet these requirements. Furthermore, the data demonstrate that sulfate toxicity is dependent on concentrations of other major ions, with a general reduction in toxicity associated with an increase in water hardness. Thus, accommodating hardness as a toxicity-modifying factor appears to be appropriate in establishing water quality guidelines for this anion. Calculation of guidelines for soft, moderately hard, and hard water conditions using the BC and Canadian Council of Ministers of the Environment approaches for development of WQGs resulted in generally similar results, although under soft water conditions, the BC approach provided a guideline that was approximately twofold more conservative than the Canadian Council of Ministers of the Environment approach.

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APPENDIX 10

Post-Closure Passive Treatment Systems

Victoria GOLD CORP

Stantec

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File No.:VA101-290/4-A.01
Cont. No.:VA11-01586

November 30, 2011

Mr. Todd Goodsell
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Whitehorse YT, Y1A 1J1

Dear Todd,

Re: Eagle Gold Project – Post-Closure Passive Treatment Systems

Executive Summary

The proposed Eagle Gold Project, located in the central Yukon Territory, is a 66 million tonne open pit gold mine. The mine will operate for approximately 7.3 years, plus an additional year or so for supplemental gold recovery, in which time ore will be mined, crushed, and placed on a heap leach pad where conventional cyanidation, adsorption, and desorption will be used to recover gold.

During mining operations, uneconomic ore (waste rock) will be placed in one of two waste rock storage facilities located adjacent to the open pit. Upon mine closure the heap leach facility and waste rock storage areas will be decommissioned and reclaimed. After reclamation, the geochemical characterization of the waste rock and spent ore indicates that metal leaching will occur under neutral pH conditions for tens of years, and leachate concentrations of a number of metals are expected to exceed Canadian Council of Ministers of the Environment (CCME) water quality guidelines, most notably with aluminum, antimony, arsenic, mercury, selenium, and silver in post-closure mine-influenced water (MIW).

Active mine water treatment will address these metal exceedances throughout operations; however, in time during reclamation and closure activities, on site infrastructure (buildings, roads, process and treatment plants and other site works) will be decommissioned when environmental monitoring indicates that post post-closure conditions can be adequately addressed by *passive* mine water treatment systems.

Passive treatment systems (PTS) employ aerobic and anaerobic processes to sequentially remove metals in a man-made system that operates using natural ecological and geochemical processes, requiring no power or chemical addition once constructed (Gusek, 2009).

Appendix 28 (Passive Techniques for the Treatment of Mine Effluent (C. Aurala - Knight Piésold, 2011)) of the Eagle Gold Project Proposal (Stantec, 2011a) provided an initial discussion of the viability and context for passive mine water treatment as a post-closure "walk-away" solution.

The following report reflects advances in the understanding of the site characterization and design improvements developed following the Project Proposal (June 2011). This includes a discussion of the rationale and development of PTS based on performance objectives (meeting water quality guidelines) and criteria (hydraulic, treatment and sustainability). Design parameters involve environmental factors (climate), seepage flow rates and water quality objectives, while considering site-specific hydrogeologic controls and seepage water chemistry which typically limit particular solutions.

Various design considerations include the selection of appropriate technologies, sequencing of these technologies, required residence time and built-in safety factors to ensure the viability of the process. For the Eagle Gold Project, passive treatment system options proposed include permeable reactive barriers (PRB), biochemical reactors (BCR), aerobic wetlands (AW) and aerobic cascades (AC) constructed in a sequence optimized for treatment success. A discussion of the limitations of and techniques for implementing the chosen system in cold climates follows. The proposed design will likely be one of two process treatment trains:

1. Mine water stream → [PRB] →[optional limestone unit]→ [AC] → environment, and
2. Mine water stream → [BCR] → [AW] → [AC] → environment.

Proof of concept will be based on a tiered approach that involves laboratory-scale testing, bench-scale testing and then pilot-scale testing. The final design will be optimized to ensure water quality closure objectives are achieved while ongoing performance monitoring and maintenance will sustain operation. The proposed PTS will achieve the long-term "passive care" implementation that is required by the Yukon Government via the *Quartz Mining Act*. For these purposes, long-term period is defined as 20-40 years following the detoxification of the heap.

Objectives

The purpose of this technical letter is to provide additional rationale for the use and selection of PTS to support the long-term closure objectives of the proposed Eagle Gold Project, including the following:

- Achieve "walk away" status – The executive committee representing the Yukon Environment and Socio-economic Advisory Board has defined "walk away" as a state requiring no further monitoring or maintenance once a period of "active care" has been satisfactorily demonstrated from the results of site monitoring that reclamation measures have achieved the required outcomes and are self-sustaining – particularly with respect to the spent ore heap. An initial "active care" system is proposed to rinse and neutralize the heap until heap effluent quality is demonstrated (i.e., meets MMER standards), at which time a "passive care" system will be implemented (Supreme Court of Yukon, 2011).
- Ensure that long-term effluent from the heap and waste dump areas will meet acceptable discharge criteria for metals, metalloids, and pH such that the effluent streams are not likely to adversely affect local groundwater or surface water.

The proposed PTS will achieve the long-term "passive care" implementation that is required by the Yukon Government. This long-term period is anticipated to be in the order of 20-40 years following the detoxification of the heap (SRK, 2011).

Background

Mining operations will create a single open pit and two waste rock storage areas (WRSAs) located south of Dublin Gulch. Gold-bearing ore will be mechanically processed (crushed) and conveyed to the Ann Gulch Heap Leach Facility (HLF). Uneconomic ore (waste rock) will be placed in either the Platinum Gulch WRSA or the Eagle Pup WRSA.

Following the cessation of mining, the HLF will continue to operate until gold recovery ceases to be economic while the WRSAs will be decommissioned, covered and reclaimed. Once the final lift of ore has been placed on the heap, preparations for closure of the heap will commence. These operations include cyanide detoxification and supplemental rinsing to remove cyanide, its' by-products and any additional residual chemicals introduced during the heap leaching operations. During this period, an active mine water treatment plant will operate to ensure that any excess mine water will be treated to comply with environmental discharge requirements to meet water quality guidelines and regulated standards to be determined by the Water License. Once the heap has been detoxified and rinsed, water stored in the heap will be drawn down in preparation for final closure.

Closure operations may also include the construction of passive treatment systems (PTS) located downstream from each of the three mine water streams (the two WRSAs and the HLF) as required. The design of these systems will be based on the results of a series of test programs that will provide operational guidance and proof of concept for the selection, design, and usage of a specific (or series of) PTS.

PTS in the context of mine-influenced water (MIW) are defined as any method or process that can be used to improve the quality of given water sources without the continual or active addition of chemical or biological reagents. PTS take advantage of controlled environmental conditions and an engineered mix of hydraulic characteristics, chemical reagents, and microbial ecologies to emulate and enhance natural attenuation processes. PTS may involve physical, chemical, or biological processes to achieve water quality improvements. The mechanisms of metal removal or retention include the following:

- Oxidation
- Precipitation as hydroxides and carbonates under aerobic conditions
- Precipitation as sulfides and hydroxy-sulphate under anaerobic conditions
- Complexation and adsorption onto organic matter
- Ion exchange with organic matter, and
- Uptake by plants (phyto-remediation).

The dominant metal removal processes are dependent on the conditions of the environment in which the PTS operate.

PTS can provide a means of ensuring long-term mine water treatment with minimal intervention (periodic monitoring and general scheduled maintenance) when appropriately designed, constructed, operated and maintained. When combined with source control measures (such as engineered cover systems, seepage controls and in situ measures) and monitored natural attenuation PTS can be feasible, reliable and effective.

This technical letter describes the rationale and development of the proposed approach to PTS in the following sections:

- Performance objectives and functional requirements for PTS operations
- PTS design parameters
- PTS design methodology;
- A discussion of potential PTS components
- Proposed design concepts
- Anticipated performance, and
- Recommendations for future work.

<u>Performance Objective, Criteria and Functional Requirements</u>

It is important to identify the performance criteria and functional requirements to have clear direction from performance closure objectives on how the passive treatment should operate. PTS performance objectives must be consistent with overall mine site closure objectives of protecting human health and the environment. The primary performance objective of the proposed PTS(s) is to substantially reduce metal loadings delivered into receiving waters while meeting closure objectives for water quality.

Functional requirements are defined by the performance objectives. Proper definition of these requirements will dictate the appropriate design for the site. Within the functional requirements there are three basic performance criteria that need to be considered to satisfy the greater performance objectives of the system:

1. Hydraulic performance
2. Treatment performance, and
3. Sustainability performance.

In terms of hydraulic performance, the PTS must:

- Sustain an optimal range of flow rates entering the PTS
- Maintain appropriate hydraulic gradient conditions to operate by gravity
- Maintain appropriate surface-water recharge controls
- Prevent system bypass
- Ensure permeability of reactive media for the life span of the PTS, and
- Maintain desired water level requirements for operations.

For treatment performance, the PTS must:

- Treat MIW to meet specific water quality objectives for target parameters
- Provide a means to evaluate water quality and chemical analyte data for trends in treatment efficiency, and
- Provide a means to sample and measure secondary analytes to provide guidance on system aging and performance.

For sustainability performance, the PTS must:

- Operate for a number of years (20-40 years) with little or no maintenance
- Operate within the context of water conservation (inflows = outflows with minor losses due to evaporation and other natural processes)
- Utilize locally-sourced materials (organic matter for anaerobic systems), recycled materials (zero valent iron) or waste byproducts (blast furnace slag) in its construction and operation, and
- Operate without the need to add energy or mechanical means to promote flux of MIW through the system.

Design Parameters for the proposed PTS at Eagle Gold

General Environmental Parameters

- Annual maximum temperature: 27 ºC (Potato Hills), 29 ºC (Camp)
- Mean annual temperature: -3.6 ºC
- Annual minimum temperature: -36.5 ºC
- Average annual precipitation: 534 mm
- Average annual evaporation: 439 mm, and
- Average annual snowpack: 143 mm snow water equivalent.

Temperature data are based on short-term record of collection by Stantec between 2007-2011 (Stantec, 2011b), while precipitation is based on long-term regional data that have been adjusted for the site based on comparisons of concurrent site and regional data. Average annual precipitation, evaporation and snowpack were then adjusted for a median basin elevation of 1,029 m above sea-level (corresponding to the median elevation of Ann Gulch at the Project site, which is a representative elevation for sites that may be considered for passive treatment systems).

Flow Parameters

The anticipated inflow rates for each MIW stream are listed in Table 1. These values were derived from Stantec (2010b and 2011e) based upon the assumption that engineered cover systems have been constructed on each of the WRSAs and the HLF.

Table 1: Inflow Rates Reporting to Passive Treatment Systems (Stantec, 2011c; Munro, 2011)

Mine Water Stream	Average Conditions [m^3/s]	Wet Conditions [m^3/s]	Dry Conditions [m^3/s]
Eagle Pup WRSA	0.028	0.050	0.010
Platinum Gulch WRSA	0.045	0.093	0.014
Heap Leach Facility	0.005	0.009	0.002

These inflow rates are predicted results based on robust modeling. In actuality, inflow rates will vary on a seasonal basis as hydrologic, hydrogeological and cold regions processes alter the interflow of water throughout each system. Optimization of these variables will be the focus of continuing studies as the project advances.

For the purposes of design, the average condition is assumed as the design flow for each PTS; however, the proposed PTS will be capable of operating over a range of flow rates. Provisions for upset dry and wet conditions will also be considered as the PTS design evolves from concept to detailed design.

Discharge Objectives

The design discharge objectives are based on CCME and site-specific effluent criteria derived by Stantec. In general, CCME guidelines dictate effluent criteria; however, site-specific criteria have been developed for arsenic due to high background concentrations throughout the Project area. Tables 2-4, attached, list predicted untreated effluent concentrations, target treated concentrations and receiving water quality objectives set for the Post-Closure stage of the Eagle Gold Project under average, wet and dry conditions as provided in the Eagle Gold Water Quality Model (Stantec, 2011c, Responses 7 and 8).

Hydrogeological Controls

The baseline hydrogeological parameters are an important consideration for any in situ or subsurface passive treatment techniques. The hydraulic conductivities of the hydrostratigraphic units underlying the various facilities could potential reinforce or inhibit the ability of an in situ PTS to contain and convey MIW.

Field work conducted at the Project site suggests that overburden (loose soil, sand, or gravel overlying bedrock) experiences average hydraulic conductivities ranging between $k = 10^{-3}$ m/s to 10^{-7} m/s while bedrock units experience average hydraulic conductivities ranging between $k = 10^{-5}$ m/s to 10^{-8} m/s. The following table provides a summary of the relevant hydraulic testing beneath and downstream from the proposed WRSAs and HLF. A summary of the ranges of hydraulic conductivity observed in specific hydrostratigraphic units within the Project footprint where PTS may be developed are provided in Table 5. Refinements to these estimates in specific areas are currently underway based on an extensive drilling and testing program conducted during the summer and fall 2011.

Table 5: Summary of Hydrogeological Characterization, (Stantec, 2011d)

Baseline Location	Affected System	Test Method	Ranges of Hydraulic Conductivity (m/s)	Hydrostratigraphic Unit
Ann Gulch	HLF	Recovery tests	9.2 x10^{-7} to 1.7 x10^{-6}	Meta-sediments
Platinum Gulch	Platinum Gulch WRSA	Packer tests (1995)	9.9 x10^{-8} to 8.4 x10^{-7}	Granodiorite
		Recovery tests (2010)	4.1 x10^{-8}	Granodiorite
Eagle Pup	Eagle Pup WRSA	Packer tests (1995)	2.4 x10^{-7}	Meta-sediments
		Recovery tests (1996)	8.6 x10^{-7}	Granodiorite
			3.8 x10^{-6} to 5.1 x10^{-7}	Meta-sediments
		(2009)	7.3 x10^{-6} to 7.4 x10^{-5}	Meta-sediments
			7.3 x10^{-6} to 7.4 x10^{-5}	Surficial deposits
Stuttle Gulch	Downstream area	Packer tests (1995)	1.0 x10^{-8} to 7.6 x10^{-8}	Granodiorite
			7.6 x10^{-7}	Granodiorite/Meta-sediments
		Recovery tests (1996)	5.0 x10^{-7}	Granodiorite
			1.0 x10^{-7}	Meta-sediments
		(2009)	3.2 x10^{-5}	Surficial deposits
		Aquifer test (1996)	2.9 x10^{-7}	Granodiorite
Dublin Gulch	Downstream area	Packer tests (2009)	1.2 x10^{-6}	Meta-sediments
		Recovery tests (2009)	3.1 x10^{-5} to 3.9 x10^{-3}	Surficial deposits
			1.8 x10^{-5}	Meta-sediments
		(2010)	4.0 x10^{-7}	Meta-sediments

Predicted Seepage Geochemistry

The baseline geochemical characterization (SRK, 2010) identified arsenic, cadmium, aluminum, selenium and antimony as they key water quality parameters of concern anticipated to be present in the post-closure MIW. Baseline source term determinations were derived by assuming the percentage of each basic rock type that is anticipated in each MIW source. In each case, neutral pH is expected. The breakdown of the various rock types as well as the anticipated dissolved parameters of concern are shown in Table 6.

Table 6: Waste Rock Source Characterization (SRK, 2011)

MIW Source	Meta-sediments	Unaltered Granodiorite	Oxidized Granodiorite	Altered Granodiorite	Dissolved Constituents of Concern
Platinum Gulch WRSA	60%	29%	11%	0%	SO_4, As, Cd, Mn, Sb, Se, U
Eagle Pup WRSA	49%	35%	14%	2%	SO_4, As, Cd, Mn, Sb, Se, U
Ann Gulch HLF	45%	28%	17%	10%	SO_4, As, Cd, Mn, Sb, Se, U
Open Pit Walls	26%	32%	37%	5%	As, Sb, Se, U

Design Considerations

The following items have been considered in the development of the proposed PTS for the Eagle Gold Project:

- Selection of passive treatment techniques
- Special considerations regarding arsenic
- Sequencing of PTS components
- Residence times required for metal removal
- Design safety factors, and
- Proposed passive treatment technologies and processes.

Overview

It is of critical importance to be well-informed with respect to regulations, site characterization, and performance objectives (as described above) to determine the applicability of specific PTSs and to select appropriate mechanisms and processes for treatment.

PTSs are viable options for post-closure MIW treatment at the Eagle Gold Project. As a natural course of developing a PTS, each stage of the design process will require proof of site-specific concepts and applications followed by design optimization. The proof of concept process will occur through a series of site-specific testing regimes, ultimately leading to the appropriate design.

Selection of Passive Treatment Techniques

Engineered PTSs have been in operation for decades, and a wide range of options and configurations have emerged to operate in nearly all conceivable mine operating conditions (climate and geological settings), mine water characterizations, and types of mines. Industry, academia, and government have collaborated to develop tools to consolidate and simplify the process of selecting appropriate passive treatment systems.

The PIRAMID Consortium (Passive In-situ Remediation of Acid Mine / Industrial Drainage, a research project of the European Commission) developed a decision tree (see Figure 1) to assist in the selection of appropriate passive treatment technologies given a general understanding about the characterization of mine water. The decision tree was primarily developed from the perspective of coal mining operations prior the middle 1990s.

Recognizing that the field of passive treatment technologies has grown significantly in recent years and additional technologies specific to metal mines have emerged, Gusek (2009) has suggested an alternative decision support tool for the selection of passive treatment approaches. The Periodic Table of Passive Treatment (as depicted on Figure 2) recognizes that certain elements in MIW can be treated optimally using specific types of passive treatment technologies based upon the prevailing oxidation-reduction potential (ORP) of a given system.

Gusek acknowledges that this approach is not without limitations as there is limited information regarding the passive treatment of some elements (such as selenium and other recently recognized elements of concern). Gusek suggests that this approach should be “living” – updated to reflect the current state of practice and level of understanding in the industry.

Performance objectives may not always be achieved with a single type of passive treatment system, a single treatment cell, or to a level of redundancy that provides an appropriate level of comfort for long term passive treatment; thus, in some cases, it is worth considering sequences of multiple passive treatment units or cells that utilize the same or different approaches to mine water treatment.

Formulae and additional rationale that support the design of passive treatment systems are provided in Appendix A.

Sequencing of Passive Treatment Components

As suggested above, the effectiveness of a specific passive treatment technology may be limited to a narrow range of conditions, specific metals, and/or specific nutrients. To counteract these limitations it may be possible to sequence multiple cells of the same type of passive treatment units or provide a series of different passive treatment technologies to customize the treatment scheme and best address the parameters of a specific MIW stream.

When considering a sequence of passive treatment units or cells it is important to consider how the individual units will work as a system to achieve the ultimate performance objectives. Gusek (2008) offers the following practical considerations for sequencing:

- Oxidation lowers pH, reduction raises pH
- $Fe(OH)_3$ has a tendency to clog system plumbing in aerobic systems
- FeS does not foul system plumbing anaerobic systems
- Aluminum precipitates as a dense aluminum hydroxyl-sulfate and can foul anaerobic systems, and
- Biochemical reactors cells can efficiently remove most metals common in mine effluent such as iron, cobalt, copper, molybdenum, and zinc with the exception of manganese.

PTS have also been shown to be effective at removing trace metals, metalloids and radioactive elements and such as arsenic, selenium, and uranium.

Aerobic cells are a component of the PTS proposed for the Eagle Gold Project. In general, it is common practice to include an aerobic cell downstream of any anaerobic cells to allow for additional settling capacity and aeration (addition of dissolved oxygen) prior to discharge into the environment. This is typically required as anaerobic treatment units tend to discharge relatively oxygen-starved water.

In general, aerobic systems use free oxygen for oxidation of organic and inorganic matter to produce innocuous end products while anaerobic systems bring about analogous oxidation through the reduction of inorganic salts such as sulfate.

Residence Times for Metal Removal

Residence times within PTS's are dependent on the reaction rates for inorganic species. These rates vary widely and depend on the site-specific characteristics of the aquifer, the groundwater chemistry, and the reactive material (EPA, 1998). The required residence time is best assessed using a battery of scale tests to identify the limiting factors that will impact the rate at which metal removal will occur. Scale tests will be conducted during operations to determine the ultimate design of the PTS to ensure required influent residence time is achieved.

As arsenic is particularly prevalent in site baseline water chemistry and will be present in MIW at concentrations greater than the CCME Standards, an additional brief discussion on the chemical speciation and removal mechanisms is provided in Appendix B.

Design Safety Factors

It is standard practice to apply a factor of safety to the size of the PTS component. It is common to build a system two to three times larger than the minimum design specifications to account for factors that can affect the performance of the systems (IRTC, 2011). These factors include changes in the influent concentrations of metals and nutrients of concern, the hydraulic gradient, flow direction and velocity, and hydraulic conductivity.

Safety factors may be reduced by realistically assessing the downstream risks of partial treatment, careful modeling of the full-range of anticipated conditions. A probabilistic approach (using stochastic simulation) applied to the design of the systems can also reduce the safety factor by attaching probability distributions to uncertain parameters and assessing the risk of failure (not being able to achieve the desired results).

In addition to this, utilizing multiple treatment cells can be installed to ensure that a sufficient reactive media, pore volume, and system redundancy is in place to account for uncertainty in design, degradation in performance, and the ability to handle the full range of anticipated conditions.

Passive Treatment Technologies and Processes

Overview

There are a number of different passive treatment technologies and processes; however, within the context of the anticipated mine water conditions at the Eagle Gold Project three primary techniques will be applied:

- Permeable Reactive Barriers (in situ technique)
- Biochemical Reactors (anaerobic treatment cells), and
- Aerobic Wetlands / Aeration Cascades (aerobic treatment).

As mentioned earlier, these systems may operate in isolation or in sequence with one another depending on the needs of the Project. To provide a better understanding of how these systems operate, each system is discussed briefly in the following sections.

Permeable Reactive Barriers (PRBs)

PRBs are a form of in situ passive treatment. They rely on gravity to convey MIW through a zone of engineered reactive media (reactive barrier). As the MIW pass through the PRBs the metals and nutrients are degraded, transformed, or immobilized as they interact with the reactive media (Li *et al*, 2005).

There are two general configurations for PRBs:

1. Continuous PRBs, and
2. Funnel-and-Gate PRBs.

Continuous PRBs are constructed to fully encompass the vertical and horizontal extents of the aquifer that is transmitting the MIW; whereas funnel-and-gate designs utilize impermeable barriers such as slurry walls or sheet piles to funnel the plume into a concentrated space that discharges through the “gate” – a PRB constructed at the nape of the funnel. In each case it is essential that the PRBs key into impermeable ground or reach a depth keyed into the aquitard (a bed of low permeability that restricts flow from one aquifer into another) such that there is very little risk of bypassing the PRB.

PRBs have been shown to effectively remove both metals (including Cr, Ni, Pb, U, Tc, Fe, Mn, Se, Cu, Co, Cd, Zn), As and anion complexes (PO_4, NO_3, SO_4).

PRBs require a reactive media to facilitate the removal and transformation of contaminants in mine water streams. The selection of an appropriate media depends on the elements and ionic complexes of concern present in the water. For the treatment of arsenic and cationic metals (i.e. Ni, Cu, Zn) as anticipated in the Eagle Gold MIW, iron-based reactive media has been shown to be most effective. In addition, the removal of redox-sensitive oxyanions such as selenium, technetium, and uranium has also been demonstrated using iron-based reactive media (IRTC, 2011).

Typical iron-based reactive mediums include the following:

- Zero Valent Iron (ZVI): material with a high fraction of iron (>90%), low carbon content (<3%), and non-hazardous levels of leachable trace metal impurities (IRTC, 2011). ZVI is typically sourced from either recycled scrap iron from the automotive manufacturing industry or molten iron that is later granulated using high-pressure water jets.
- Basic Oxygen Furnace Slag (BOFS): BOFS is a waste byproduct of iron and steel production. It has been demonstrated that BOFS can contribute to the effective removal of metals and metalloids from MIW; albeit, somewhat less effectively than ZVI.
- ZVI-Carbon combinations. Test work referenced by the IRTC indicates that the reducing environments established in carbon-ZVI systems are also conducive to the precipitation of trace metals including chromium and arsenic (IRTC, 2011).

Each of these mediums has been shown to be effective at full-scale installations. In addition, zeolite-based reactive media also shows promise based on laboratory evaluation; however, no full-scale applications have been implemented as of June 2011 (IRTC, 2011).

As a sub-surface, in situ treatment technique, PRBs tend to be relatively immune to cold climate malfunctions, provided that suitable cover is provided at the ground surface. At Eagle Gold, a 2-3 meter thick cover will be sufficient to prevent malfunction due to cold temperatures.

Biochemical Reactors

Biochemical Reactors (BCRs) are in-line passive treatment units that can be used to improve water quality through the use of biogeochemical processes. BCRs typically consist of in-ground cells composed of multi-layer units of substrates containing horizontal layers of rock, sand and gravel (to improve permeability), limestone (to adjust pH), and a carbon-based active source material. The carbon source may be any carbonaceous material including waste materials such as sawdust, wood chips or manure. The carbon source is saturated in the contaminated mine water, carbon-based liquid (such as methanol), and microbially-available inoculant (such as compost or bio solids), and is maintained under anaerobic conditions.

The microbial activity within the BCR produces sulfide and bicarbonate through the sulfate reduction process. The bicarbonate raises pH which promotes the removal of some metals as carbonates under some conditions whereas target metals precipitate as metal sulfides at pH values of 5.0 and above (IRTC, 2010).

Thomas (2002) characterizes solid-phase BCRs by the following treatment processes:

- Biological reduction of sulphate to sulphide and subsequent precipitation of metal sulphides
- Alkalinity increase due to dissolution of limestone contained within the substrate and reduction of sulphate
- Precipitation of metal hydroxides, and
- Sorption of trace metals to metal hydroxides and organic media.

BCRs are relatively simple to build and operate; in addition, survivability of temporary upset conditions is generally good with a well-designed system. BCRs have been shown to operate for decades without much intervention and there is the potential that a well-designed BCR could operate indefinitely provided that a self-sustaining microbial ecology and nutrient stream can be applied. Cold region's performance is also favourable provided that appropriate insulation is installed. This is discussed in detail with examples provided in Appendix 28 of the Project Proposal (Knight Piésold, 2011).

BCRs sustain the biogeochemical processes required to remove entrained metals while also providing the retention to prevent the precipitated metals from re-mobilizing and discharging into the downstream environment.

An aerobic treatment unit (or wetland) is often required downstream from a BCR to re-oxygenate the treated water exiting the BCR. MIW that passes through an anaerobic reactor tends to contain increased levels of nutrients and biochemical oxygen demand (BOD). The aerobic unit allows for re-aeration and allows an additional opportunity for metals to precipitate and settle out of suspension (as a redundant measure).

Arsenic removal is generally facilitated by the formation of solid arsenate (AsO_4^{3-}). If additional arsenic removal is required the aerobic cells may be seeded with iron filings as arsenic has a high affinity for adsorption onto ferric oxides.

One of the key advantages of BCR is that the organic matter used to seed the reactor can typically be sourced locally and once the substrate is activated, the design life typically ranges from 20 to 30 years before the substrate requires replacement; however, a self-sustaining microbial ecology may be established in a shorter time period provided that stable inflows and environmental conditions within the BCR are well-controlled.

Over time, the system will equilibrate into an effectively natural passive wetland. Once this occurs, maintenance will no longer be required as the system becomes self-regulating. Prior to equilibrating, the system may require periodic maintenance that may include replacement of the substrate, flushing the drains to remove excess precipitates, or servicing the insulation cover.

Aerobic Wetlands and Aeration Cascades

Aerobic wetlands (AW) and aeration cascades (AC) provide environmental conditions that are conducive to the removal of suspended solids and selected metals. In addition, they often function as polishing ponds to recondition treated mine water prior to discharge into the environment.

Typical aerobic wetlands consist of the following features (GARD, 2011):
Relatively shallow water depths to allow aeration of the mine drainage
Cascades to further enhance aeration
Configuration and layout to promote favourable hydrodynamic flow conditions (prevent short circuiting)
Wetlands vegetation to assist in aeration of the substrate (wetlands vegetation has the capability to maintain aerobic conditions around the root/rhyzome area and can also promote favourable flow conditions)
Sufficient residence time to allow the treatment reactions to take place
Space for the settling and accumulation of the metal precipitates and solids
Layout and screening against wind mixing and re-suspension of settled solids
Promote algal growth to further increase the pH and facilitate manganese oxidation and precipitation, and
Piping and hydraulic controls to manage the water levels in individual wetlands cells.
Aeration can also be facilitated passively by cascading mine water down a rock-lined channel or a cascade of step pools that encourage turbulence and splashing.

During periods of extended cold weather, it is anticipated that the channels will freeze over. It is expected that seasonal low flows will occur through the winter months and system throughput will be reduced accordingly. Hyporheic flow or underflow (flow which occurs in the zone immediately beneath a stream channel) in a zone of surface water-groundwater mixing will likely continue unabated. If additional winter flow conveyance is desired, the channel can be constructed using a notched cross-sectional geometry (i.e. a small channel is cut along the invert of the channel) where low flow conditions can continue to flow under an ice cover in the channel.

As enhanced iron oxidation and hydrolysis are essential to most passive treatment systems, turbulence steps are routinely added between wetland cells. For sites where the iron loading is particularly high, or where the change in elevation is minimal, supplemental aeration may be necessary.

Aerobic wetlands promote metal oxidation and hydrolysis, causing precipitation and physical retention of Fe, Al, and Mn oxyhydroxides, much like sedimentation structures. Successful metal removal depends principally on the dissolved metal concentrations, dissolved oxygen (DO) content, pH, net acidity/alkalinity of the mine water, and the retention time of the water in the wetland. The pH and net acidity/alkalinity of the water are particularly important because they influence both the solubility of metal hydroxide precipitates and the kinetics of metal oxidation and hydrolysis.

With this in mind, aerobic wetlands are best utilized in net alkaline mine water streams. Vegetation enhances physical filtration of suspended metal particles and colloids; direct uptake by the plants is usually only a significant factor when the metal concentrations are already very low.

Ponds constructed within the aerobic wetland system are usually sized to allow an 8 to 24 hour retention time (often encompassing as much surface area as the wetland cells that follow it). Depths typically range between 1.5 to 2.5 m. It is recommended that a dead storage allowance of 1 m be included to provide capacity to contain sediment and metal precipitates. In addition to this, one meter of freeboard (above 1 in 10 year ponded water level) should be provided to allow for upset storm conditions.

Often, several wetland cells and/or ponds are connected by flow through a v-notch weir or through a ditch. Use of multiple cell/ponds can limit the amount of short-circuiting and aerate the water at each connection. If there are elevation differences between the cells (as discussed above, to increase dissolved oxygen), the interconnection should be designed to dissipate kinetic energy and avoid erosion and/or the mobilization of precipitates in the next cell.

The layout and slope of aerobic wetlands should be designed to minimize disruption of the natural conditions when the wetland sludge is removed and substrate is replaced, while maintaining the above engineering considerations. Sludge removal may be required periodically during the initial start-up of the aerobic wetlands as coarse-fraction materials and sludge are flushed through the passive treatment modules located upstream. This would occur during the semi-passive period of post-closure activity. Any habitat value should reflect and provide mitigation for the potential uptake of toxic metals to birds, riparian mammals, and amphibians while enhancing the aesthetic quality of the project.

In general, wetland ponds should be designed with a length-to-width aspect ratio between 3:1 to 5:1 to prevent short circuiting and inadequate retention time. Typical depths range from 100 mm to 600 mm for surface flow wetlands and 500 mm to 800 mm for subsurface flow wetlands (IRTC, 2003).

Proposed Design

The following section provides conceptual designs for two possible passive treatment system configurations for the Eagle Gold Project. The selection and sequencing are based on the decision support tools (PIRAMID decision tree and Gusek's Periodic Table) presented above in conjunction with an understanding of the conditions specific to the site. The conceptual designs presented below are based upon the design criteria, and input parameters, and well as the effluent targets presented in Tables 2-4.

Two passive treatment process trains have been evaluated for Eagle Gold:

1. Mine water stream → [PRB] →[optional limestone unit]→ [AC] → environment, and
2. Mine water stream → [BCR] → [AW] → [AC] → environment.

Where [PRB] refers to an in situ permeable reactive barrier, [BCR] refers to a biochemical reactor cells (generally two operate in parallel to provide operational flexibility) while [AC] and [AW] refer to aerobic cascade and aerobic wetland respectively. An inline limestone unit or PRB component may be required as a pH buffer as iron reduction may result in increased acidity.

The ultimate sequencing will depend on the post-closure mine water characterization for each of the MIW streams. At the current time, it is anticipated that Option 1, presented above, will provided the best outcome in terms of functionality and performance; however, new technologies and treatment techniques that have not been evaluated could also be of benefit when applied to the Project.

A single sequence may be applicable to each of the mine water streams; however, site specific conditions will dictate the ultimate configuration required for each stream. For the purposes of this conceptual assessment, both sequences have been evaluated using the environmental conditions and mine water characterizations presented above.

The BCRs will be designed as vertical flow reactors with MIW entering above the media, flowing through the media, and exiting via perforated pipes contained within an inert granular drainage layer. Inflows to the BCRs will be distributed evenly using a flow splitter. External insulation will be provided by a combination of wood chip fill or another suitable insulating material) and a geomembrane cover. The BCRs will discharge into an aerobic wetland.

Assumptions

The design of the PRB components is based upon the test work conducted at the University of Waterloo (McRae, et al, 1999). The test work demonstrated the effectiveness of using zero-valent iron (ZVI), blast iron furnace slag and activated alumina to treat arsenic-laden groundwater. Given the prevalence of arsenic in the groundwater at the Eagle Gold Project – this provides a reasonable analog from which design may be based upon.

In line with the aforementioned analog, zero-valent iron was selected as the reactive media of choice for this analysis. The ZVI is assumed to have grain size diameters ranging from 1-5 mm. It is also assumed that agricultural-grade limestone will be utilized as a source of calcium (alkalinity) and as a pH buffer. The remaining solid volume of the reactive barriers will consist of non-reactive rock, sand, and gravel.

The PRBs are assumed to have the following breakdown by weight:

- 10% zero-valent iron
- 40% agricultural-grade limestone, and
- 50% inert rock, sand and gravel.

A factor of safety of 1.3 has been applied to the median annual discharges reporting to the PTS for each MIW stream. This provides an allowance for seepage rates that may exceed the median annual flow and is in line with the design safety factors for most general hydraulic structures.

Component Sizing

In general, the size of the passive treatment components is dependent on the inflow rates and the required residence time to achieve the treatment performance objectives.

Using the design guides and input parameters provided above, the design flows, anticipated residence times and design volumes (wet storage only) are summarized in Table 7, below.

Table 7: Conceptual System Design

PTS Unit	System	Design Flow Rate	Residence Time (PRB)	Residence Time (BCR)	Residence Time (AW)	Minimum Design Volume (treatment unit)
		L/s	days	days	days	m^3
Conceptual Sequence 1	EP	85	1.0	-	-	7,300 (PRB)
	PG	36	1.0	-	-	3,100 (PRB)
	HLF	120	1.0	-	-	10,300 (PRB)
Conceptual Sequence 2	EP	85	-	4.0	1.0	18,400 x4 BCR 7,300 AW
	PG	36	-	4.0	1.0	16,000 x2 BCR 3,100 AW
	HLF	120	-	4.0	1.0	27,300 x4 BCR 10,300 AW

Additional 'dead' storage will be required in the aerobic wetland unit downstream from the biochemical reactors to accommodate the sludge and sediment accumulation. The amount of dead storage allocated will depend on the loading conditions and the frequency of clean out following initial start-up.

Anticipated Performance

Reduction of Toxicity, Mobility or Volume

By removing metals from the MIW streams at Eagle Gold, the toxicity of the treated effluent discharging to the environment will be significantly reduced. In addition, the mobility of metals will be reduced. It is anticipated that greater than 98% of cationic metals will be removed (IRTC, 2011) while 92-96% of arsenic will be removed (Wilkens, et al. 2009) using conventional PRB technology with ZVI. Using a mix ZVI-compost PRB, an arsenic removal of >99.9% has been demonstrated in pilot scale testing (Ludwig, et al., 2008). The subject of removal rates for biochemical reactors is discussed in greater detail in Appendix 28 of the Project Proposal (Knight Piésold, 2011). Briefly, the analytical results for samples from PRB mine water treatment systems confirmed arsenic removal rates ranged from 78% to 99+%. Actual metal removal rates will be assessed using pilot testing procedures (discussed below).

Recommendations

Testing for Proof of Concept

As noted above, a number of assumptions were required to develop reasonable, conceptual designs for the proposed passive treatment systems. Test work will be required to confirm, refine, and/or modify these assumptions in addition to proving the performance and longevity of the systems. Three levels of testing are proposed:

1. Laboratory-scale testing: the initial round of concept test work includes controlled laboratory testing with limited samples of each ore type or analog. This work is complementary to ongoing metallurgical

and geochemical test work and will last approximately 12 months. Under laboratory conditions, it is often possible to control the environment to accelerate the testing and evaluation of processes.

2. Bench-scale testing: bench testing is effectively laboratory testing in an uncontrolled, site-specific environment. This battery of test work allows the processes developed in the laboratory to be subjected to on-site climatic conditions. Bench testing will run for a period of time not less than 6 months to a year depending on results and climate.
3. Pilot-scale testing: once the metal removal processes have been confirmed through laboratory and bench-scale testing, pilot-scale passive treatment systems will be constructed. These systems are scaled down equivalents of the ultimate designs that will be constructed to operate in the closed mine environment. These test works will be established as soon as practicable based on the findings of the bench studies. Ideally, the pilot systems will operate for a number of years throughout mining operations to provide feedback on the effectiveness of the design.

The tiered testing process should lead to proof of concept and allow for the ultimate design of full-scale passive treatment systems to achieve the long-term post-closure objectives of the Project.

Opportunity for Co-Mixing

It is often advantageous to split the MIW streams when the seepage (or inflow) water quality is only marginally above water quality criteria, allowing a portion of the water to be treated while the remainder is co-mixed with the treated effluent – producing a blended stream of MIW. Provided that the target objectives are achieved, there could be a substantial reduction in the scale of PTS required and thus the costs involved in constructing, operating and maintaining the system.

This opportunity should be investigated as the Project advances to more developed stages.

Monitoring, Operations, Maintenance, and System Longevity

Following the closure and reclamation of the mine, periodic monitoring will be required to ensure that closure objectives are being met (reclamation, re-vegetation, and water quality). It is envisioned that monitoring and the potential for operator intervention will be more frequent during the early years following closure, when more monitoring is required to establish the rate of treatment effectiveness, gradually reducing in frequency over time as the closed mine site approaches a state of ecological equilibrium.

During this period, mine site operators will be required to monitor and maintain the PTS components to ensure that the performance objectives are being met. Once successful passive operation has been achieved, monitoring and maintenance visits reduce in frequency (to annually or semi-annually).

Based on experience with existing systems the longevity of the PTS components are anticipated to be as follows:

- PRB: 15-20 years (IRTC, 2011)
- BCR: 10-20 years (Gusek and Schuek, 2004), and
- Aerobic Wetlands: varies, estimated at 5-10 years – depends on sediment loading in groundwater GARD Guide, 2011).

It is recognized that PTS *age* as metal precipitates accumulate in the systems, altering the hydraulic efficiencies, throughput, and treatment capacity of the PTS. The post-closure operations protocols for the PTS will include provisions for the following:

- Removal of spent reactive media and replacement with fresh material.
- Repairs and/or replacement of damaged or fouled pipe works or drainage systems.

- Removal and proper disposal of accumulated sludge.
- Decommissioning of passive systems if metal loadings have decreased below water quality criteria via natural attenuation or depletion of the metal loading within the source materials.

It is important to recognize that the frequency of events that trigger maintenance is likely to decrease as metal concentrations in the MIW declines over time. This time period likely coincides with the early years of passive treatment immediately following mine closure.

Based upon existing data (geochemical characterization), it is envisioned that passive treatment will be required for a period of time ranging from 20-40 years following the complete rinsing of the heap facility. The passive treatment systems proposed for Eagle Gold are likely to require minor maintenance during the short-term period (<20 years) following closure, after which it is anticipated that loading rates (metals and nutrients from the waste streams) will have attenuated to levels where maintenance is no longer required. A better estimate of the long-term performance and maintenance requirements will be evaluated through on-site bench and pilot testing through the operating years of the mine.

Cold Climate Considerations
As the Project is located in a sub-arctic situation, cold regions considerations will dictate much of the efficacy of the proposed PTS. Prolonged periods of cold weather and freezing conditions may impact the operation of the treatment systems depending on the design and system sensitivities or insulation to environmental conditions. The primary effects of operating in cold regions include the following:

- Snow cover – delays surface runoff and provides insulation to subsurface flow
- Ground freezing – impedes flow through coarse permeable soils and rock; inhibits infiltration
- Temperature sensitivity of chemical kinetics – noting that in some cases cold weather favours precipitation reactions; slow sorption kinetics at low temperatures
- Reduced capacity at low temperatures (BCRs)
- Effect of diurnal freeze-thaw cycles
- Potential reduction in throughflow – effects on metal concentrations and media saturation, and
- Surplus melt water loading – potential to overload the systems volumetrically.

These considerations will be assessed using field testing procedures to ensure that the concepts are proved under site specific conditions. Design criteria will be developed to minimize these effects.

Conclusion
Properly implemented PTS that are designed to specifically address post-closure conditions for the Project will achieve the primary closure objective of meeting water quality guidelines (end-of-pipe water quality solution). This will be achieved by first reducing metal concentrations in the MIW to levels that can be managed by PTS (i.e., use of source controls), and configuring the PTS such that they are best able to treat influent. Once a stable system wide equilibrium is reached, the PTS will operate sustainably as a walk-away solution without the need for human intervention.

As more modern cold regions mines come on line and evolve from concept to post-closure, knowledge, application, and viability of PTS will undoubtedly proliferate. There are numerous applications where PTS have been demonstrated successfully in cold regions (refer to Appendix 28 of the Project Proposal). These successes are the leading edge of a significant paradigm shift in the mining industry to provide better long term stewardship beyond the active mine life.

The prudent approach is to utilize the best passive treatment practices, proven in temperate regions and applied with a thorough understanding of cold regions processes and phenomena, in pilot-scale facilities.

This will allow adaptation of final designs into functional, site-specific PTS that may be scaled-up to fully address the water treatment objectives at the end of the mine's active life.

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Closure

We trust that this document provides the guidance necessary to support the assessment of Victoria Gold Corporation's Eagle Gold Project.

Yours truly,
KNIGHT PIESOLD LTD.

Signed:
Corey Aurala, P.Eng.
Project Engineer

Reviewed:
Jessica Mackie
Senior Environmental Scientist

Approved:
for: Ken Brouwer, P.Eng.
Managing Director

Attachments:

Table 1 Rev 0	Inflow Rates Reporting to Passive Treatment Systems (Stantec, 2011c; Munro, 2011) [In text, p. 5]
Table 2 Rev 0	Post-Closure Water Quality Estimates – Eagle Pup WRSA to Mixing Point A
Table 3 Rev 0	Post-Closure Water Quality Estimates – Platinum Gulch WRSA to Mixing Point C
Table 4 Rev 0	Post-Closure Water Quality Estimates – HLF to Mixing Point B
Table 5 Rev 0	Summary of Hydrogeological Characterization, (Stantec, 2011d) [In text, p. 6]
Table 6 Rev 0	Waste Rock Source Characterization (SRK, 2011) [In text, p. 6]
Table 7 Rev 0	Conceptual System Design [In text, p. 14]
Figure 1 Rev 0	Decision Tree for the Selection of Passive Treatment Systems
Figure 2 Rev 0	Periodic Table of Passive Treatment Systems

Appendices:

Appendix A	Passive Treatment Design Formulae
Appendix B	A Brief Discussion on Arsenic

Copy To: Todd Goodsell (VIT), Steve Wilbur (VIT), Jeff Brokaw (Stantec), Ben Byrd (Stantec)

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TABLE 2

VICTORIA GOLD CORPORATION
EAGLE GOLD PROJECT

POST-CLOSURE WATER QUALITY ESTIMATES
EAGLE PUP WRSA TO MIXING POINT A

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Parameter	Receiving Water WQO	WQO Basis	EP WRSA to Mixing Point A - Dry Scenario			EP WRSA to Mixing Point A - Average Scenario			EP WRSA to Mixing Point A - Wet Scenario		
			Concentration of Raw Effluent from Source	Concentration of Mixed Water (Raw + Receiving)	% Exceedance (Mixed Water / WQO)	Concentration of Raw Effluent from Source	Concentration of Mixed Water (Raw + Receiving)	% Exceedance (Mixed Water / WQO)	Concentration of Raw Effluent from Source	Concentration of Mixed Water (Raw + Receiving)	% Exceedance (Mixed Water / WQO)
	mg/L		mg/L	mg/L		mg/L	mg/L		mg/L	mg/L	
Sulphate	100	BC	180	29	in compliance	177	46	in compliance	188	60	in compliance
Fluoride	0.3	BC	0.346	0.102	in compliance	0.342	0.130	in compliance	0.357	0.152	in compliance
Nitrate			0.370	0.075		0.371	0.111		0.366	0.131	
Ammonia			0.004	0.003		0.004	0.003		0.004	0.003	
Phosphate			0.143	0.025		0.140	0.039		0.150	0.050	
Aluminum	0.1	BC – dis	0.156	0.092	in compliance	0.156	0.100	in compliance	0.154	0.103	**3%**
Antimony	0.02	BC	0.220	0.025	**26%**	0.215	0.047	**136%**	0.232	0.066	**228%**
Arsenic	**0.07**	**SSWQO**	0.233	0.052	in compliance	0.228	0.072	**3%**	0.244	0.089	**27%**
Boron	1.2	BC	0.037	0.040	in compliance	0.037	0.040	in compliance	0.037	0.040	in compliance
Cadmium	0.0003	Dr CCME	0.00111	0.00013	in compliance	0.001	0.000	in compliance	0.00117	0.00034	**12%**
Chromium	0.0089	CCME	0.00523	0.00092	in compliance	0.005	0.001	in compliance	0.00550	0.00182	in compliance
Copper	0.003	CCME	0.012	0.002	in compliance	0.011	0.003	**1%**	0.012	0.004	**32%**
Iron	1	BC –tot	0.267	0.104	in compliance	0.264	0.122	in compliance	0.264	0.133	in compliance
Lead	0.004	CCME	0.008	0.001	in compliance	0.008	0.002	in compliance	0.008	0.002	in compliance
Manganese	0.05	BC - dw	0.143	0.019	in compliance	0.140	0.033	in compliance	0.140	0.041	in compliance
Mercury	0.00003	CCME	0.00002	0.00001	in compliance	0.000	0.000	in compliance	0.00002	0.00001	in compliance
Molybdenum	0.073	CCME	0.016	0.003	in compliance	0.015	0.005	in compliance	0.015	0.006	in compliance
Nickel	0.11	CCME	0.095	0.011	in compliance	0.093	0.020	in compliance	0.100	0.028	in compliance
Selenium	0.002	BC	0.0084	0.0013	in compliance	0.0082	0.0021	**5%**	0.0088	0.0028	**38%**
Silver	0.0001	CCME	0.00032	0.00004	in compliance	0.00031	0.00007	in compliance	0.00033	0.00010	in compliance
Thallium	0.0008	BC	0.00029	0.00010	in compliance	0.00029	0.00012	in compliance	0.00031	0.00014	in compliance
Uranium	0.015	dr CCME	0.072	0.008	in compliance	0.071	0.016	**5%**	0.076	0.022	**45%**
Zinc	0.03	CCME	0.038	0.007	in compliance	0.037	0.010	in compliance	0.040	0.013	in compliance

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NOTES:

1. ALL VALUES PROVIDED BY STANTEC (NOV. 21, 2011); REFERRING TO SHORT-TERM POST-CLOSURE (10-30 YEARS) ASSUMING NO TREATMENT IN PLACE, 10% INFILTRATION IN BASIN

2. WQO = WATER QUALITY OBJECTIVES
BC = BC WATER QUALITY GUIDELINES
SSWQO = SITE-SPECIFIC WATER QUALITY OBJECTIVE
CCME = CANADIAN COUNCIL OF THE MINISTERS OF THE ENVIRONMENT GUIDELINES

3. NOTE SITE SPECIFIC WATER QUALITY OBJECTIVE FOR ARSENIC

0	28NOV'2011	ISSUED WITH LETTER VA11-01586	STANTEC	CA	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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TABLE 3

VICTORIA GOLD CORPORATION
EAGLE GOLD PROJECT

POST-CLOSURE WATER QUALITY ESTIMATES
PLATINUM GULCH WRSA TO MIXING POINT C

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Parameter	Receiving Water WQO	WQO Basis	PG to Mixing Point C - Dry Scenario			PG to Mixing Point C - Average Scenario			PG to Mixing Point C - Wet Scenario		
			Concentration of Raw Effluent from Source	Concentration of Mixed Water (Raw + Receiving)	% Exceedance (Mixed Raw / WQO)	Concentration of Raw Effluent from Source	Concentration of Mixed Water (Raw + Receiving)	% Exceedance (Mixed Raw / WQO)	Concentration of Raw Effluent from Source	Concentration of Mixed Water (Raw + Receiving)	% Exceedance (Mixed Raw / WQO)
	mg/L		mg/L	mg/L		mg/L	mg/L		mg/L	mg/L	
Sulphate	100	BC	103	35	in compliance	109	35	in compliance	110	35	in compliance
Fluoride	0.3	BC	0.699	0.098	in compliance	0.759	0.103	in compliance	0.772	0.103	in compliance
Nitrate			0.040	0.154		0.034	0.146		0.033	0.143	
Ammonia			0.004	0.007		0.003	0.007		0.003	0.006	
Phosphate			0.489	0.043		0.521	0.046		0.529	0.045	
Aluminum	0.1	BC – dis	0.518	0.419	**319%**	0.446	0.404	**304%**	0.442	0.396	**296%**
Antimony	0.02	BC	0.090	0.009	in compliance	0.097	0.009	in compliance	0.099	0.009	in compliance
Arsenic	**0.014**	**SSWQO**	0.179	0.032	**128%**	0.187	0.031	**124%**	0.188	0.031	**118%**
Boron	1.2	BC	0.040	0.011	in compliance	0.041	0.011	in compliance	0.042	0.011	in compliance
Cadmium	0.0003	Dr CCME	0.00051	0.00006	in compliance	0.00053	0.00006	in compliance	0.00054	0.00006	in compliance
Chromium	0.0089	CCME	0.01461	0.00087	in compliance	0.01592	0.00098	in compliance	0.01622	0.00099	in compliance
Copper	0.003	CCME	0.017	0.003	in compliance	0.018	0.003	in compliance	0.019	0.003	in compliance
Iron	1	BC –tot	0.663	0.635	in compliance	0.574	0.627	in compliance	0.571	0.624	in compliance
Lead	0.004	CCME	0.003	0.001	in compliance	0.003	0.001	in compliance	0.003	0.001	in compliance
Manganese	0.05	BC - dw	0.049	0.058	**16%**	0.051	0.058	**16%**	0.050	0.058	**16%**
Mercury	0.00003	CCME	0.00007	0.00001	in compliance	7.15398E-05	1.03676E-05	in compliance	0.00007	0.00001	in compliance
Molybdenum	0.073	CCME	0.055	0.003	in compliance	0.060	0.003	in compliance	0.062	0.003	in compliance
Nickel	0.11	CCME	0.031	0.003	in compliance	0.034	0.004	in compliance	0.034	0.004	in compliance
Selenium	0.002	BC	0.005	0.001	in compliance	0.005	0.001	in compliance	0.006	0.001	in compliance
Silver	0.0001	CCME	0.00122	0.00014	**43%**	0.001332522	0.000145762	**46%**	0.00136	0.00014	**43%**
Thallium	0.0008	BC	0.00099	0.00008	in compliance	0.001079486	8.64011E-05	in compliance	0.00110	0.00009	in compliance
Uranium	0.015	dr CCME	0.024	0.003	in compliance	0.025	0.003	in compliance	0.026	0.003	in compliance
Zinc	0.03	CCME	0.015	0.007	in compliance	0.015	0.007	in compliance	0.015	0.007	in compliance

M:\1\01\00290\04\A\Correspondence\VA11-01586_Eagle Gold - Passive Treatment Letter\[R10_tables-FINAL.xlsx]Table 3 - PG

NOTES:

1. ALL VALUES PROVIDED BY STANTEC (NOV. 21, 2011); REFERRING TO SHORT-TERM POST-CLOSURE (10-30 YEARS) ASSUMING NO TREATMENT IN PLACE; 20% INFILTRATION IN BASIN

2. WQO = WATER QUALITY OBJECTIVES
BC = BC WATER QUALITY GUIDELINES
SSWQO = SITE-SPECIFIC WATER QUALITY OBJECTIVE
CCME = CANADIAN COUNCIL OF THE MINISTERS OF THE ENVIRONMENT GUIDELINES

3. NOTE SITE SPECIFIC WATER QUALITY OBJECTIVE FOR ARSENIC

0	28NOV'2011	ISSUED WITH LETTER VA11-01586	STANTEC	CA	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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TABLE 4

VICTORIA GOLD CORPORATION
EAGLE GOLD PROJECT

POST-CLOSURE WATER QUALITY ESTIMATES
HLF TO MIXING POINT B

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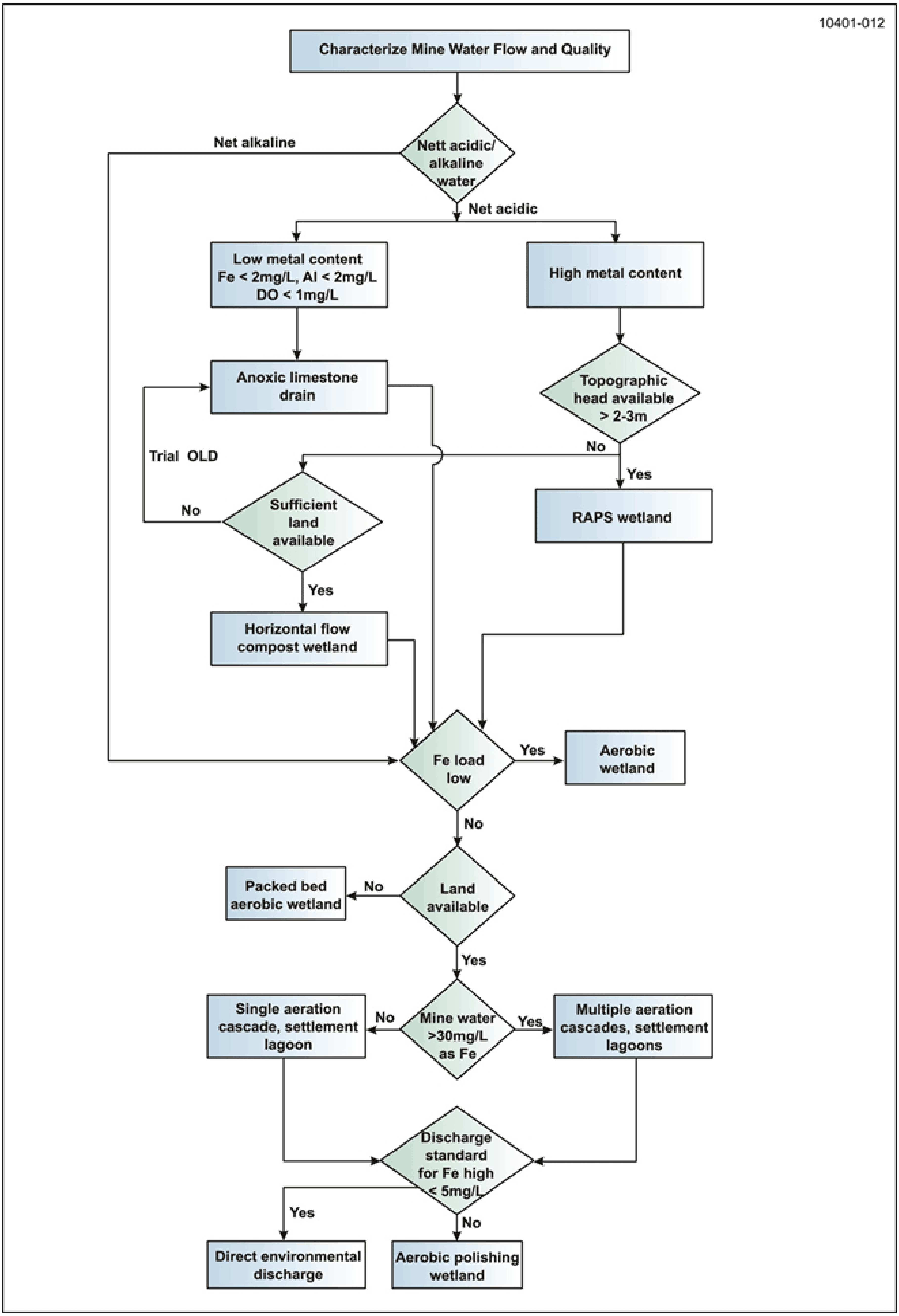
Parameter	Receiving Water WQO	WQO Basis	HLF to Mixing Point B - Dry Scenario			HLF to Mixing Point B - Average Scenario			HLF to Mixing Point B - Wet Scenario		
			Concentration of Raw Effluent from Source	Concentration of Mixed Water (Raw + Receiving)	% Exceedance (Mixed Raw / WQO)	Concentration of Raw Effluent from Source	Concentration of Mixed Water (Raw + Receiving)	% Exceedance (Mixed Raw / WQO)	Concentration of Raw Effluent from Source	Concentratio n of Mixed Water (Raw + Receiving)	% Exceedance (Mixed Raw / WQO)
	mg/L		mg/L	mg/L		mg/L	mg/L		mg/L	mg/L	
Sulphate	100	BC	294	59	in compliance	294	64	in compliance	294	69	in compliance
Fluoride	0.3	BC	0.322	0.097	in compliance	0.322	0.102	in compliance	0.322	0.107	in compliance
Nitrate			3.596	0.182		3.596	0.257		3.596	0.330	
Ammonia			0.102	0.004		0.102	0.006		0.102	0.008	
Phosphate			0.019	0.003		0.019	0.003		0.019	0.003	
Aluminum	0.1	BC – dis	0.285	0.018	in compliance	0.285	0.023	in compliance	0.285	0.029	in compliance
Antimony	0.02	BC	0.171	0.003	in compliance	0.171	0.007	in compliance	0.171	0.011	in compliance
Arsenic	**0.014**	**SSWQO**	0.632	0.012	in compliance	0.632	0.026	**84%**	0.632	0.039	**179%**
Boron	1.2	BC	0.054	0.006	in compliance	0.054	0.007	in compliance	0.054	0.008	in compliance
Cadmium	0.0003	Dr CCME	0.00040	0.00003	in compliance	0.00040	0.00004	in compliance	0.00040	0.00004	in compliance
Chromium	0.0089	CCME	0.00060	0.00026	in compliance	0.00060	0.00026	in compliance	0.00060	0.00027	in compliance
Copper	0.003	CCME	0.012	0.000	in compliance	0.012	0.001	in compliance	0.012	0.001	in compliance
Iron	1	BC –tot	0.105	0.130	in compliance	0.105	0.129	in compliance	0.105	0.128	in compliance
Lead	0.004	CCME	0.019	0.000	in compliance	0.019	0.001	in compliance	0.019	0.001	in compliance
Manganese	0.05	BC - dw	0.066	0.083	**67%**	0.066	0.083	**66%**	0.066	0.083	**65%**
Mercury	0.00003	CCME	0.00005	0.00001	in compliance	0.00005	0.00001	in compliance	0.00005	0.00001	in compliance
Molybdenum	0.073	CCME	0.022	0.000	in compliance	0.022	0.001	in compliance	0.022	0.001	in compliance
Nickel	0.11	CCME	0.002	0.002	in compliance	0.002	0.002	in compliance	0.002	0.002	in compliance
Selenium	0.002	BC	0.023	0.001	in compliance	0.023	0.001	in compliance	0.023	0.002	in compliance
Silver	0.0001	CCME	0.003	0.000	in compliance	0.003	0.000	**22%**	0.003	0.000	**85%**
Thallium	0.0008	BC	0.00008	0.00005	in compliance	0.00008	0.00005	in compliance	0.00008	0.00005	in compliance
Uranium	0.015	dr CCME	0.037	0.002	in compliance	0.037	0.003	in compliance	0.037	0.003	in compliance
Zinc	0.03	CCME	0.061	0.006	in compliance	0.061	0.007	in compliance	0.061	0.009	in compliance

M:\1\01\00290\04\A\Correspondence\VA11-01586_Eagle Gold - Passive Treatment Letter\[R10_tables-FINAL.xlsx]Table 4 - HLF

NOTES:

1. ALL VALUES PROVIDED BY STANTEC (NOV. 21, 2011); REFERRING TO SHORT-TERM POST-CLOSURE (10-30 YEARS) ASSUMING NO TREATMENT IN PLACE; 10% INFILTRATION IN BASIN
2. WQO = WATER QUALITY OBJECTIVES
   BC = BC WATER QUALITY GUIDELINES
   SSWQO = SITE-SPECIFIC WATER QUALITY OBJECTIVE
   CCME = CANADIAN COUNCIL OF THE MINISTERS OF THE ENVIRONMENT GUIDELINES
3. NOTE SITE SPECIFIC WATER QUALITY OBJECTIVE FOR ARSENIC

0	28NOV'2011	ISSUED WITH LETTER VA11-01586	STANTEC	CA	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTE:

1. REFERENCE: PIRAMID CONSORTIUM, 2003. ENGINEERING GUIDELINES FOR THE PASSIVE REMEDIATION OF ACIDIC AND METALLIFEROUS MINE DRAINAGE AND SIMILAR WASTEWATERS. EUROPEAN COMMISSION 5TH FRAMEWORK RTD PROJECT EVK1-CT-1999-000021, UNIVERSITY OF NEWCASTLE UPON TYNE, NEWCASTLE UPON TYNE, UK.

0	18NOV'2011	ISSUED WITH LETTER	CA	JEM	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

VICTORIA GOLD CORPORATION

EAGLE GOLD PROJECT

DECISION TREE FOR THE SELECTION OF PASSIVE TREATMENT SYSTEMS

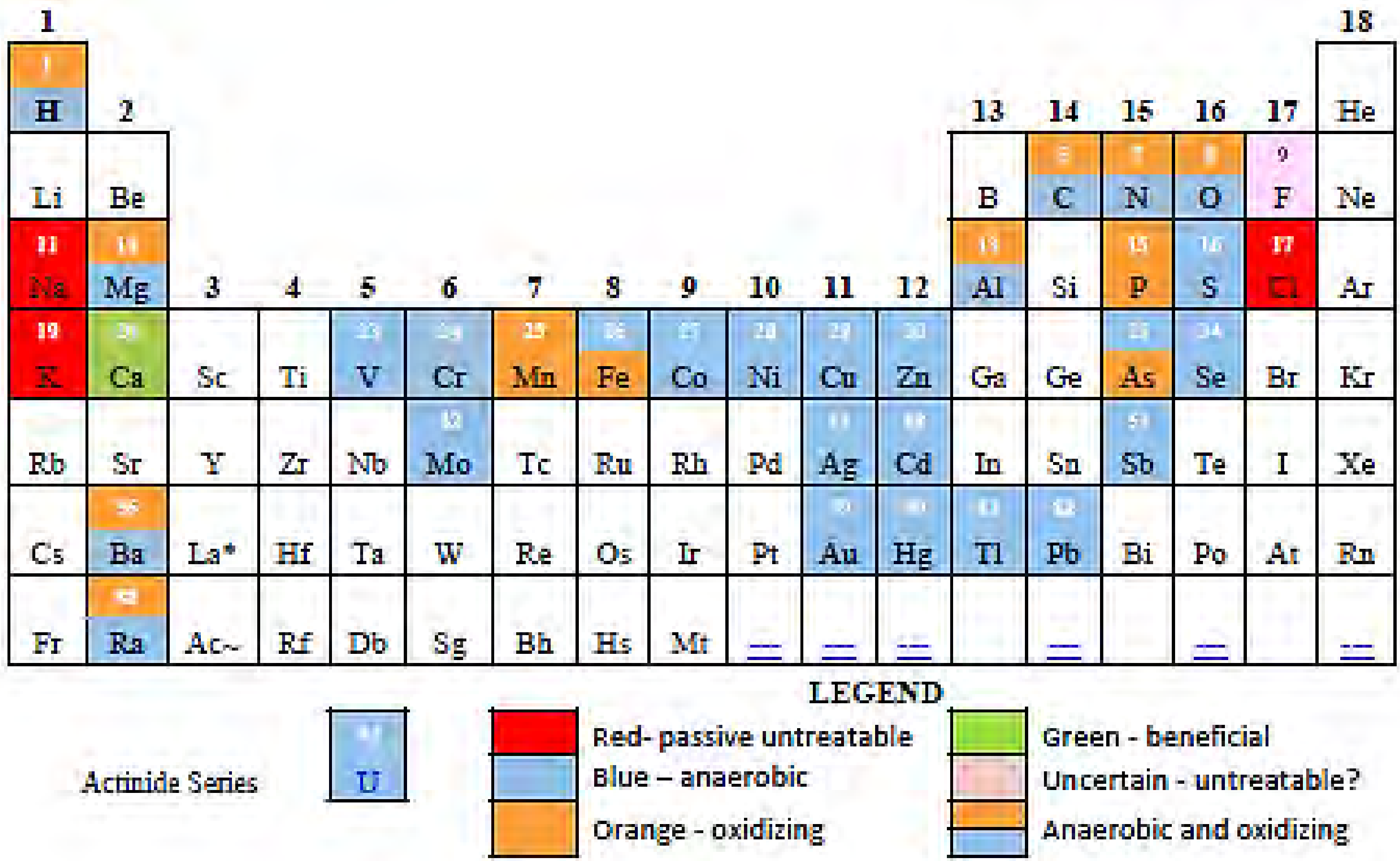
Knight Piésold CONSULTING

P/A NO. VA101-290/4

REF. NO. VA11-01586

FIGURE 1

REV 0



NOTE:
1. REFERENCE: GUSEK, JAMES J., (2009). A PERIODIC TABLE OF PASSIVE TREATMENT FOR MINING INFLUENCED WATER.

0	18NOV'2011	ISSUED WITH LETTER	CA	JEM	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

VICTORIA GOLD CORPORATION

EAGLE GOLD PROJECT

PERIODIC TABLE OF PASSIVE TREATMENT SYSTEMS

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REF. NO. VA11-01586

FIGURE 2

REV 0

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CONSULTING

APPENDIX A

PASSIVE TREATMENT DESIGN FORMULAE

(Pages A-1 to A-3)

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PASSIVE TREATMENT DESIGN FORMULAE

Residence Time

The residence time to achieve the performance objectives may be estimated using reasonable first-order rate constants and the maximum concentration present (IRTC, 2011). The solution to a first-order decay rate is as follows:

$$C_t = C_0 e^{-(kt)}$$

Rewritten, solving for t as:

$$t = -\ln(\frac{C_t}{C_0})/k$$

Where:

t = residence time (days)
C_t = the concentration (mass per unit volume or μg/L) at time t (days)
C_0 = the initial concentration (μg/L)
k = the first-order degradation coefficient (per day)

Migration Rate and Seepage Velocity

The rate of migration of the MIW through a PTS can be approximated using Darcy's law:

$$Q = -KA(\frac{dh}{dl})$$

Where:

Q = the volumetric flow rate through a porous media ($[L^3/T]$)
K = proportionality constant (length divided by time [L/T])
A = the cross-sectional area of flow ($[L]^2$)
dh/dl = the horizontal hydraulic gradient (unitless)

Converting this into a *specific discharge* yields the following equation:

$$q = \frac{Q}{A} = -K(\frac{dh}{dl})$$

The equation above does not account for flow through different pore spaces at differing rates; therefore it is often useful to utilize the average linear velocity (also known as the seepage velocity), expressed as:

$$v = -K(\frac{dh}{dl})/n_e$$

Where:

v = pore water (seepage) velocity [L/T]
n_e = effective porosity of the aquifer matrix (unitless)

Typical seepage velocities range from about 10 to 300 m/yr for permeable reactive barriers (PRBs) (IRTC, 2011). Both K and dh/dl are typically determined from site investigation activities while n_e is a specified parameter of the reactive media that is to be used.

Applications

These calculations provide the basis for residence time and thus the quantity of reactive material required and the scale of the passive treatment cell necessary to perform as required for PRB design.

Similar calculations apply to the design of biochemical reactors (BCRs) using rate constants appropriate to the removal processes anticipated in the BCR cells. The following equations may be used to describe flow through a porous media.

For treatment wetlands, the following equations govern:

Residence time:

$$t = \left(\frac{V}{Q}\right) * 86{,}400\frac{sec}{day}$$

Where:

t = residence time (days)
V = wetland volume (m^3)
Q = average flow rate (m^3/s)

Hydraulic loading:

$$q = Q/A$$

Where:

q = hydraulic loading (m/day)
Q = average flow rate (m^3/day)
A = wetland area (m^3)

Areal loading rate (for subsurface wetland designs):

$$ALR = \frac{QC}{A}$$

Where:

ALR = areal loading rate
Q = average flow rate (m^3/day)
C = pollutant concentration (mg/L or g/m^3)
A = surface area of subsurface flow wetland (m^2)

The area required to treat a particular pollutant is given by (IRTC, 2003):

$$A = \frac{-Q}{k_A}\ln\left\{\frac{[pollutant]_{outflow} - P^*}{[pollutant]_{inflow} - P^*}\right\}$$

Where:

Q = flow rate (m^3/day)
k_A = 1st order rate coefficient
$[pollutant]_{outflow}$ = the pollutant concentration leaving the system (mg/L)
$[pollutant]_{inflow}$ = the pollutant concentration entering the system (mg/L)
P^* = background pollutant concentration (mg/L)

The equations described above are appropriate for the level of detail required at this time. More detailed chemical kinetic studies that incorporate the competing chemical species and higher order reactions will be required prior to detailed design, which would follow from bench and pilot-scale testing programs.

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APPENDIX B

A BRIEF DISCUSSION ON ARSENIC

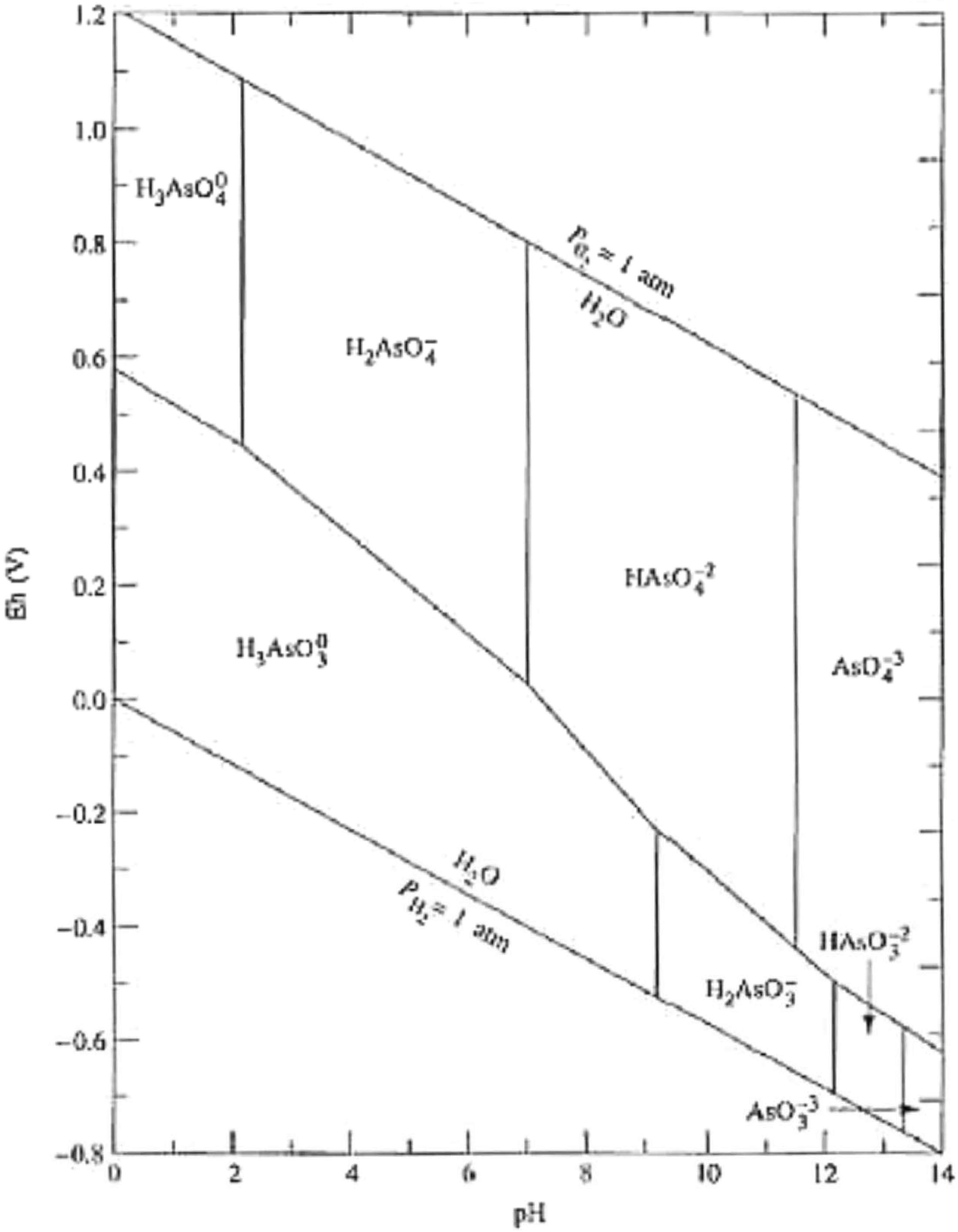
(Pages B-1 to B-3)

A BRIEF DISCUSSION ON ARSENIC

As arsenic has been a noted parameter of concern for the Eagle Gold Project, an additional discussion is warranted. Dissolved species of arsenic can be adsorbed by ferric hydroxides (with arsenate sorbing more effectively than arsenite).

Pourbaix diagrams are useful for mapping out the stable equilibrium phases of aqueous electro-chemical systems. The oxidization potential of the aqueous solution (Eh) plotted against the pH of the aqueous solution for arsenic species under standard conditions are depicted in Figure B-1 (Pourbaix diagram, from Fetter, 1999). This suggests that in an oxidizing environment with pH above 4.1 it is likely that ferric iron hydroxides will sorb arsenic and remove it from solution. Conversely, under strong reducing conditions, if both iron and hydrogen sulfide are present, arsenic sulfide co-precipitates with iron sulfides. Arsenic can be expected to be most mobile under mildly reducing conditions as iron would be in the soluble ferrous state and arsenic would be in the form of As(III). (Fetter, 1999). Additional stability fields for sulphur-arsenic-water and iron-sulphur-arsenic water systems are provided on Figure B-2.

Given that neutral pH conditions are anticipated for Eagle Gold post-closure, it is reasonable to assume that arsenic removal will continue unabated provided that the environmental conditions (pH) remain the same and sufficient reagent (iron) is available. Based upon the existing understanding of the site geochemistry, it is unlikely that pH will shift out of the normal neutral range, suggesting that this approach is feasible from a long-term perspective.



NOTES:

1. POURBAIX DIAGRAM SHOWING ARSENIC STABILITY IN WATER UNDER STANDARD CONDITIONS.
2. REFERENCE: A.H. WELCH, M.S. LICO, AND J.L. HUGHES, *GROUND WATER* 26, NO. 3 (1988): 333-47.

VICTORIA GOLD CORPORATION

EAGLE GOLD PROJECT

ELECTROCHEMICAL STABILITY OF ARSENIC IN WATER

Knight Piésold CONSULTING

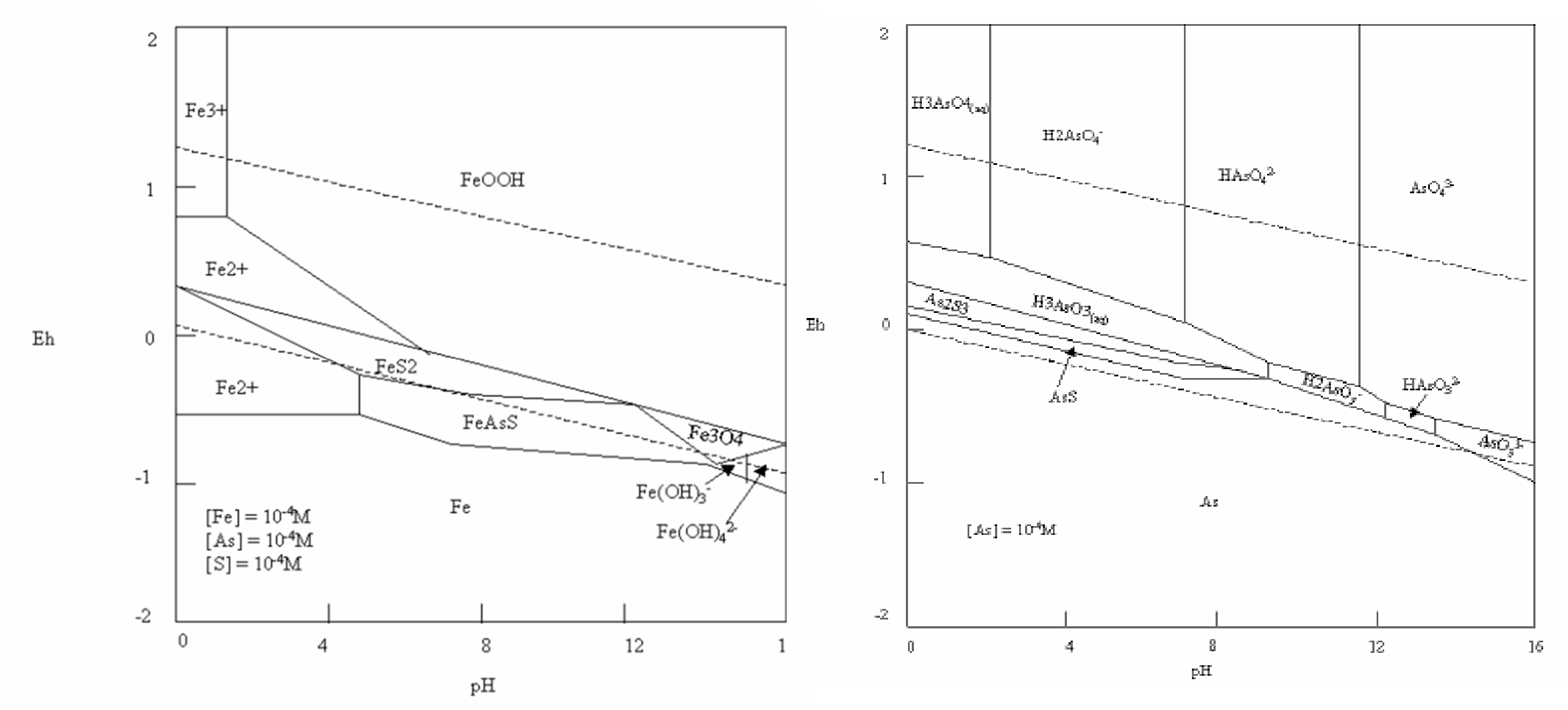
P/A NO. VA101-290/4

REF. NO. VA11-01586

FIGURE B-1

REV 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	18NOV'2011	ISSUED WITH LETTER	CA	JEM	KJB



NOTES:
1. THE LEFT POURBAIX DIAGRAM DEPICTS FE-S-AS STABILITY IN WATER UNDER STANDARD CONDITIONS.
2. THE RIGHT POURBAIX DIAGRAM DEPICTS S-AS STABILITY IN WATER UNDER STANDARD CONDITIONS.
3. REFERENCE: RUBIDGE, G.R., (2004). EVALUATION AND OPTIMIZATION OF SELECTED METHODS OF ARSENIC REMOVAL FROM INDUSTRIAL EFFLUENT. NELSON MANDELA METROPOLITAN UNIVERSITY.

0	18NOV'2011	ISSUED WITH LETTER	CA	JEM	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

VICTORIA GOLD CORPORATION

EAGLE GOLD PROJECT

ELECTROCHEMICAL STABILITY OF ARSENIC COMPLEXES IN WATER

Knight Piésold CONSULTING	P/A NO. VA101-290/4	REF. NO. VA11-01586
	FIGURE B-2	REV 0

APPENDIX R12

Kappes, Cassiday & Associates
Agglomeration Testing Procedure

Victoria GOLD CORP

Stantec

Kappes, Cassiday & Associates Agglomeration Testing Procedure

The agglomeration testing procedure used by Kappes, Cassiday & Associaties (KCA) for the Eagle Gold Project is KCA's standard method used for assessing ore characterisitics and providing input to heap leach facility designs. The procedure involves a series of steps including cement agglomeration, vertical loading (testing under various stress conditions), column flooding and drainage, and slump assessment. Some of the the testing protocols used in the mid 1990s have been improved and modified slightly for tests conducted in 2009. Noted variations from the 2009 test procedure with the historical procedure are indicated in parenthesis.

- In the tests where composites were agglomerated with cement, the material was placed into a drum and a specified amount of cement was added. The drum was rotated for several minutes to mix the ore and cement thoroughly. The material was sprayed with tap water to form the agglomerates. These agglomerates were then allowed to cure for 24 hours prior to being used in the compacted permeability tests.
- The test cell utilized for modeling the permeability of stacked ore at various heap heights was a steel column. Vertical loading of the test material was utilized to simulate the pressures at the bottom of a heap at various heights.
- The test apparatus consisted of a column with a cross sectional surface area equivalent to 0.018 square meters and 0.15 m in diameter (0.15 and 0.075 m diameter columns in earlier tests). A hydraulic H-frame press was utilized to apply the loads to the material in the column. A hydraulic ram outfitted with a pressure gauge was utilized to accurately measure the actual load applied. The applied load was also checked by use of a load cell located underneath the column.
- At the top and at the base of the ore column were drainage layers. The load was applied to the charge of material utilizing a perforated steel plate of a known diameter. The diameter of the plate was such that the plate moved freely within the walls of the column. A test charge of 10 kg, dry weight, was utilized for each compacted permeability test (earlier work tested 2 kg samples in the 0.075 m diameter columns and 10 to 20 kg samples in the 0.15 m diameter columns). The test charge was loaded in lifts and each lift was compacted prior to adding additional material.
- Solution was allowed to flow into the base of the column by a constant head tank at a pressure equal to 3,200 mm of water, or 4.5 psig. The column was allowed to flood and the resulting solution in the column was allowed to build up until a solution head of 25 to 50 mm above the sample was obtained.
- The solution was then allowed to drain from the column while the solution head on the test sample was maintained. The rate at which solution drained from the column was then measured multiple times. Overall slump of material in the column was measured.

The agglomeration tests were intended to simulate the heap percolation rate at the bottom of a heap under the compressive load at the respective total heap height. The flow rate and percent slump test results are examined to determine sample performance.

APPENDIX R13

Initial Design Basis for In-Heap Pond Sizing

Victoria GOLD CORP

Stantec

TETRA TECH

Appendix R13 - Initial Design Basis for In-Heap Pond Sizing

In-Heap Pond Ore Solution Storage Calculations

Equations:

$$\gamma_{dry} = \frac{\gamma_{bulk}}{1+w}$$

$$V = V_a + V_w + V_s = 1$$ assuming 1 m^3 of ore

$$W_w = wW_s$$

$$V_v = V_a + V_w$$

$$V_w = \frac{W_w}{\gamma_w}$$

$$n = \frac{V_v}{V}$$

$$V_s = \frac{W_s}{G_s \gamma_w}$$

$$Se = wG_s$$

$$V_a = 1 - V_s - V_w$$

Initial Conditions (Ore as Delivered)

Specific Gravity G_s =	2.7	
Density of Water (γ_w) =	1000	kg/m^3
Water Content as Delivered (w) =	5.00%	
Ore Density (γ_{bulk}) =	1,800	kg/m^3
Ore Density (γ_{dry}) =	1714.29	kg/m^3
Weight of Water (W_w) =	85.71	kg/m^3
Volume of Water (V_w) =	0.0857	m^3
Volume of Solids (V_s) =	0.6349	m^3
Volume of Air (V_a) =	0.2794	m^3/m^3 of ore
porosity (n) =	0.3651	
void ratio (e) =	0.5750	
Saturation (S) =	23.48%	

Leaching Conditions/Ore Solution Storage Capacity

Water content (w) =	13.30%		
Weight of Water (W_w) =	228.00	kg/m^3	
Volume of Water (V_w) =	0.2280	m^3	
Volume of Solids (V_s) =	0.6349	m^3	
Volume of Air (V_a) =	**0.1371**	m^3/m^3 of ore	⟸ Ore Solution Storage Capacity at 13.3% initial water content
void ratio (e) =	0.5750	check - OK	(water required to bring to full saturation S=1)
Saturation (S) =	62.45%		

APPENDIX R15A

Prefeasibility Study Excerpt 1: 6-43 to 6-60

processor. The total groundwater discharge rate is predicted to be low, ranging from approximately 37 m^3/d (6.8 USgpm) in Year 3 to approximately 470 m^3/d (86 USgpm) in Year 6. Results of simulations which incorporated pumping wells as the primary method of depressurization indicated that the hydraulic conductivity of the bedrock is likely too low to make this option practical. Thus, depressurization of the pit slopes will have to be achieved through the use of horizontal drains.

Based on these predicted groundwater flows, it is estimated that approximately 100-120 horizontal drains will be required over the life of the mine with an average drainhole length of about 120 m. To aid in local depressurization of pit slopes where pockets of ground with higher than average hydraulic conductivities may exist, BGC also recommends that Victoria plan for 5-10 pumping wells throughout the life of mine. Pumping wells could still prove to be more effective for depressurizing the rock mass if areas of enhanced permeability due to fracturing are encountered, or, where local instability of the highwall is occurring.

WASTE ROCK STORAGE AREAS

The waste rock storage areas (WRSAs) are located on either side of the proposed open pit, largely downslope and within a kilometre of the pit edges. The Eagle Pup WRSA is located in the lower part of the Eagle Pup catchment area, covering approximately 80 ha of the 127.2 ha catchment area. The Platinum Gulch WRSA occupies 33 ha of the upper section of the Platinum Gulch catchment.

The Eagle Pup WRSA is designed to provide permanent storage for approximately 55 Mt of waste rock, with potential capacity for more. The Platinum Gulch WRSA is designed to provide permanent storage for approximately 11 Mt of waste rock. Waste rock will be deposited year-round, at a rate of approximately 8 million tonnes per year, or 10,000 m^3/day. The dumps will be constructed in lifts with a maximum height of 100 m, with benches between successive lifts to provide a final overall slope of 2.5H:1V.

A series of previous studies are relevant to the WRSA designs, including a feasibility design carried in the late 1990s of a facility on the Eagle Pup site, of comparable dimensions and location. Certain aspects of these studies, particularly stability and water balance are therefore directly applicable to the current Eagle Gold Project and are reviewed and adopted in the light of field observations and investigations and modifications to Project parameters.

SITE SELECTION

Four potential sites for the location of WRSAs were identified, including all the main catchments draining the proposed open pit area i.e., Platinum Gulch, Stuttle Gulch, Eagle Pup and Stewart Gulch.

Based on a comparison of capacity, location and geology, the preferred locations for waste rock disposal are the Platinum Gulch and Eagle Pup catchments. Although Stuttle Gulch is closer to the open pit than Eagle Pup, it would interfere with crushing and conveying infrastructure. Platinum Gulch is proposed for use in the initial years of operation, followed by Eagle Pup.

The design of the various elements of the Eagle Pup WRSA is developed in the following sections, together with supporting sections on water balance and stability assessment. These design elements were used to assess the Platinum Gulch WRSA, a late addition to the PFS, however, a separate detailed assessment is required for the feasibility design.

SITE CHARACTERISTICS

TOPOGRAPHY AND GEOLOGY

The Eagle Pup valley has narrow upper reaches at an elevation of approximately 1,500 masl, with relatively shallow slopes draining the ridge behind the open pit, but then the valley opens out with particularly steep slopes in its mid reaches. These slopes flatten in a downstream northerly direction in the central valley area (see Figure 6-9) to an elevation of approximately 900 masl at the confluence with the Dublin Gulch valley. On the western side, valley slopes include rock bluffs, below which the valley kinks north-west. The lower part of the valley is characterised by a narrowing valley outlet bordered by rounded catchment divides to Stewart and Stuttle Gulches.

The geology of the lower catchment bedrock conditions were investigated in the late 1990s (for the Rescan 1996 Feasibility Study) and also in 2009 (BGC, 2009), with a series of over 30 trial pits, three boreholes, laboratory testing of samples and in-situ geotechnical testing. Bedrock conditions comprise intrusive granodiorites, the outcrop of which strikes SW-NE and is located in a central section cutting through the Eagle Pup catchment. The intrusion occurred into a series of clastic rocks (metasediments comprising schists, phyllites, quartzites etc.).

The superficial materials of the lower catchment area comprise largely colluvium derived from bedrock weathering. Talus covered slopes are present on some of the steeper slopes below rock bluffs (north-west facing slopes between 970 masl and 1,320 masl, and to a lesser extent, the east facing slopes of the western ridge). In the centre of the kilometre long, 100 m wide valley floor, in the lower central part of the valley, some fluvial reworking of the colluvium sediments is present. The Sitka 1996 report also identified the presence of till. This surficial (potential overburden) material has been shown to vary considerably in thickness from 0.5 m to 14 m and is estimated as follows:

- upper catchment areas, shallow slopes less than 20 degrees – up to 7 m of weathered bedrock
- ridge lines – 0.5 m to 1.0 m of weathered bedrock
- valley side slopes > 20 degrees – rock outcrops or colluvium of between 1 m and 2 m, and
- creek bed and valley floor – colluvium up to 3 m and alluvium in the lower valley floor up to 6.5 m over weathered bedrock to >10 m.

Organic soils are widespread but are of limited thicknesses up to depths of 0.3 m.

The upper catchment area has not been investigated, however, comparable flat-topped ridge locations in the granodiorite and metasediments indicate a thin organic soil over a deep, up to 6.5 m, weathered bedrock profile.

The variable surficial thickness is an issue for the foundation conditions for defining depths to competent free draining soils or bedrock.

The specific local features of the Eagle Pup WRSA include a north-facing aspect and an elevation of between 900 masl and 1,150 masl.

HYDROLOGY

The hydrology of the Project area, including the WRSA sites, is presented in detail in Stantec's report (2009). Of particular note for the WRSAs is that the peak stream flows occur in the spring in association with freshet events, (snow melt or rain-on-snow events) with flows gradually disappearing following the disappearance of the snow. Sizeable flood events may also occur in the late summer due to intense rainstorms and are particularly significant for small catchments. The smallest discharges occur in mid winter, when streams such as Eagle Pup freeze entirely, reducing their winter flows to zero.

The peak flows are pertinent to the design of the WRSA foundation rock drains and surface runoff collection and diversion ditches. Knight Piésold (1996) provided a feasibility analysis of the flows for small catchments based on the Rational Method described in the MOE Manual of Operational Hydrology in B.C. and the Hathaway. The analysis for structures in a similar-sized catchment in the same location is presented in Table 6-14.

TABLE 6-14 GROUND AND SURFACE WATER PEAK FLOW DESIGN ASSUMPTIONS
Victoria Gold Corp. – Eagle Gold Project

WRSA Structure	Return Period	Event Size	Peak Flow (m^3/s)
Surface diversion ditches around the WRSA	1 in 200 year	24 hour event	0.5 to 1.2
Operational surface collection ditches on the WRSA benches	1 in 10 year	24 hour storm event.	0.6
Foundation Rock Drain	1 in 200 year	24 hour storm event.	1.5

HYDROGEOLOGY

The hydrogeology of the Project area, including the WRSA sites, is presented in detail in Stantec's report (2009). Of particular note for the WRSAs is the unconfined flow system within the bedrock. Groundwater is recharged at higher elevations in the thick weathered horizons of the upland areas (above the proposed open pit area) and slowly discharges throughout the year onto the steep slopes of the upper part of the catchment from a series of small springs. The resulting surface flows are intermittent and the flows sink back into the valley colluvium and alluvial materials, only to finally reappear lower down the catchment valley (observed at elevations of around 950 masl in late summer of 2009).

Measurements of groundwater levels in the Eagle pup catchment indicate water levels present within the superficials and weathered bedrock a few metres below ground level, however, this is variable across the catchment, reflecting a subdued form of the topography, but altered by thickness of superficials and weathered bedrock. Typical values of between two metres and seven metres below ground level are reported (Sitka 1996), however, seasonal variations were not identified.

The hydraulic conductivity of the bedrock is relatively low and assessed to be 1.5×10^{-6} m/s (Knight Piésold 1996), and the foundation soils of sand and gravel with some silt beneath the WRSA are of the order of 1.9×10^{-5} m/s in a thawed state and 10^{-11} m/s in a frozen state.

For the WRSA water balance the groundwater losses into the bedrock foundations have been estimated at 2% (Knight Piésold 1996).

PERMAFROST

Permafrost will generate issues for the WRSA design in two regards, the potential for thawing of:

- seasonal frost zones, and
- permafrost zones that include excess ice.

A zone of near surface seasonal frost is recorded in the test pitting and is very evident in frost heave soils and the frost-jacking (out of the ground) of the monitoring well KP 95-151 installed in 1995 (Knight Piésold 1996). Thermistor measurements indicate the marginal temperatures in this zone and thaw analysis by Knight Piésold support the observation of about three metres of seasonal thaw. With the stripping of the insulating organic layer, the seasonal frost zone can be expected to thaw earlier and more deeply, leading to excess pore water pressures. Thawing rates were investigated and assessed to generate limited excess pore pressures that would dissipate rapidly once thawing occurs (Knight Piésold 1996).

The permafrost of the Project area, including the WRSA sites, is assessed in BGC's report (BGC 2009). Of particular note for the WRSAs is the presence of a discontinuous permafrost zone within the valleys in both the superficials and in the near surface weathered bedrock. The permafrost depth is recorded as typically occurring from about three metres depth (Sitka 1996 and BGC 2009). Where bedrock or overburden is frozen without excess ice, the permafrost is unlikely to affect the WRSA stability. Test pits, however, have encountered zones of permafrost with excess ice, and these areas will require treatment by stripping to encourage thawing and drainage, or excavation to thaw stable soils or bedrock before being covered with waste rock, and if necessary monitoring and limited dump heights.

SEISMICITY

A review of the seismicity of the project area was undertaken for the Heap Leach Facility (HLF) and is presented in Section 9. The design Base Earthquake of 0.078 g for operational conditions and a Maximum Design Earthquake of 0.10 g for post closure conditions as developed for the HLF are also appropriate for the design of the WRSAs.

DESIGN BASIS

DESIGN CRITERIA

Taking in to account regulations, guidelines, best practice and experience, the following design criteria are established for WRSA facility design:

- **provide permanent, secure storage** and total confinement of mine waste rock within a fully engineered facility
- **minimize potential impacts** to the local groundwater system and surface water flows both during operations and post closure long-term
- **rehabilitate the facility** to a condition compatible with the original land use and is stable under extreme precipitation events and seismic events, and
- **satisfy the environmental regulatory requirements** of the Yukon territory and the Department of Indian and Northern Development (DIAND).

PROJECT OBJECTIVES

Taking in to account regulations, guidelines, best practice and design criteria, the principal project objectives of the PFS design of the WRSAs are to:

- develop the facilities in stages to minimize the environmental disturbances at one time during construction and operations and to distribute capital expenditures over the life of the facility

- minimize disturbance to catchment area(s)
- effectively collect and convey drainage beneath the WRSAs
- minimize the quantity of surface water runoff entering the facilities and coming into contact with the waste rock
- provide additional external facilities (sediment ponds) to accommodate drainage and rainfall/snowmelt when hydrological events generate discharges
- address the presence of permafrost and provide appropriate foundation drainage requirements to satisfy stability criteria
- monitor all aspects of the facilities to ensure that the design objectives are met and that there are no adverse environmental impacts, and
- reclaim the facilities to a condition compatible with the original land use and stable under extreme precipitation events and design seismic events.

OPERATIONAL PARAMETERS

The following operational assumptions have been made for the PFS design of the WRSAs:

- mine waste rock schedule is based on outputs from the design of the open pit mine
- a total waste rock production of 65 Mt
- annual waste rock production averaging 8 Mtpa
- hauling and placement of waste rock operations for 365 days/year
- placement of waste materials in benches up to 100 m, by end-dumping from the face of an advancing lift, and
- waste material comprises variable grain size up to boulders of granodiorite and meta-sedimentary rock types.

WRSA DESIGN

GENERAL ARRANGEMENT

The general arrangement of the WRSAs is presented in Figure 6-9 and includes the following elements:

- rock dump and foundation drainage
- starter embankments

- sediment control pond (SCP)
- surface runoff diversion channels, and
- closure works.

The Eagle Pup WRSA is contained within the Eagle Pup lower catchment area, between the elevations of 1,385 masl and 925 masl at the toe. The facility is based on 60 Mt at a density of 1.9 t/m^3, and a phased construction behind a starter embankment that traverses the valley from ridge line to ridge line.

The Platinum Gulch WRSA is located within the upper catchment area of Platinum Gulch, between the elevations of 1,380 masl and 1,000 masl at the toe.

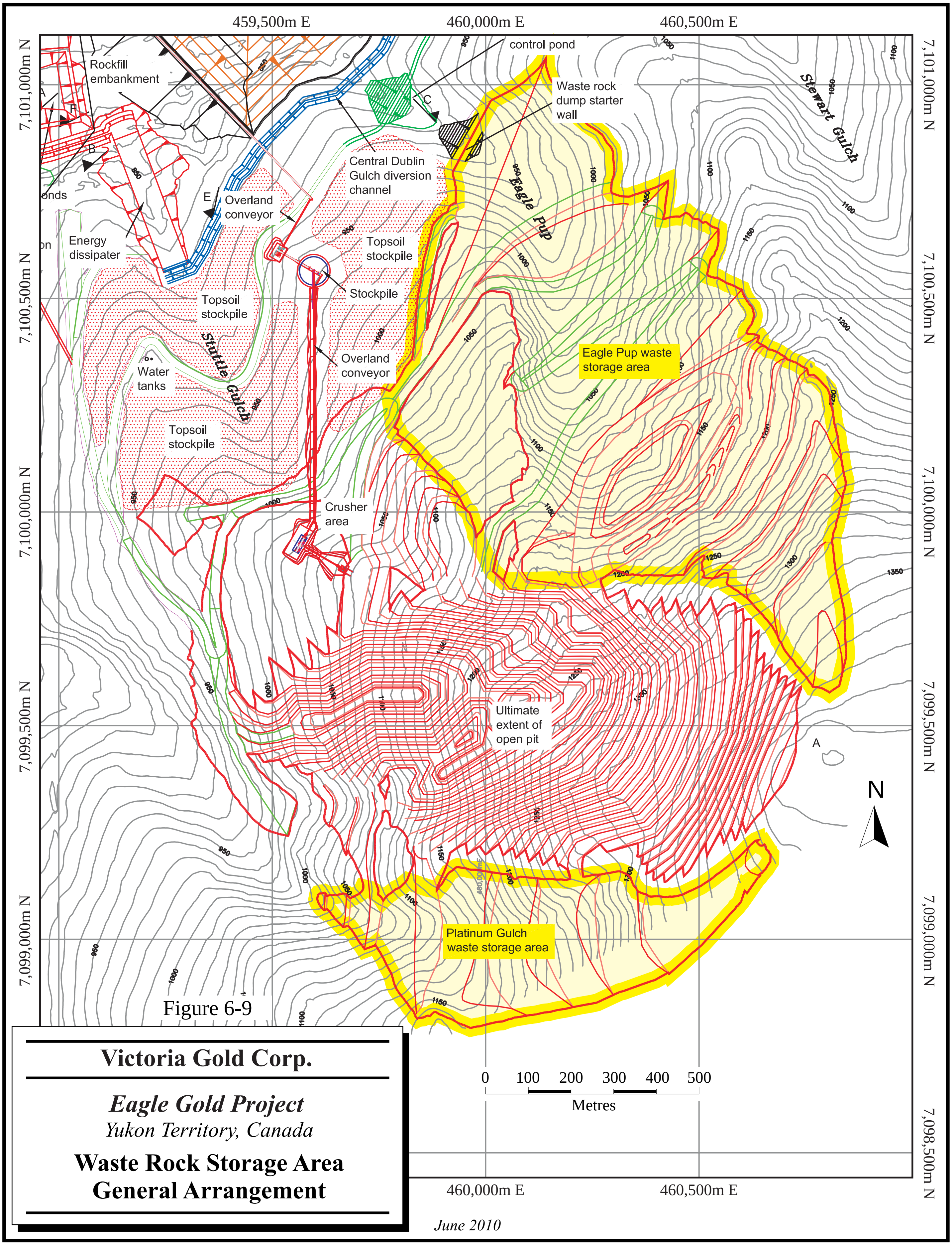


Figure 6-9

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Waste Rock Storage Area General Arrangement

June 2010

ROCK DUMP AND FOUNDATIONS

The rock dump is constructed through a hybrid of ascending lifts waste-rock terraces and some areas of descending platforms and wrap-arounds. The hybrid approach addresses issues of heap stability, environmental impact and provides flexibility for the early mining operation. The approach also mitigates against various operational risks including:

- instability and Health and Safety impacts on operatives and downstream infrastructure from
  - excessive rates of advance on limited lengths of end-tip crests
  - boulder roll out
  - rapid ground pressure build-up
  - thaw-instability beneath the waste rock
- uncontrolled segregation with implications for drainage
- reducing sediment generation and the potential for contamination
- waste rock avalanches in winter.

The design also:

- allows for progressive stripping of topsoil where practical, and
- minimizes disturbance to the environment of one catchment.

The stripping of organic materials is limited to approximately 30 ha of the catchment that comprises continuous slopes of less than 20 degrees. The balance of the catchment is assessed as too steep to be accessed or comprises surficial materials with limited organic material that warrants stripping.

This overall approach to rock dump construction also addresses the availability of waste rock, the anticipated differences in waste rock quality differences, and the requirement for selected materials for drainage to be tipped in the lower terraces and thus provide adequate WRSA stability during operations and post closure.

STABILITY CONSIDERATIONS

The physical stability of the WRSA is critical to its short-term (operational) and long-term (post closure) performance. The WRSA is designed against failure of the waste rock and/or the foundations. The design therefore considers the operational design events and post closure extreme events, of seismic loading under an Operational and Maximum Design Earthquake (ODE and MDE) and Probable Maximum Precipitation (PMP).

Particular aspects that are key to determining stability include:

- waste rock material properties particularly strength characteristics with increased normal stress
- geometry and loading cases (static and seismic)
- location of phreatic surfaces
- pore pressures and thaw instability in the foundations
- mechanisms of failure, and
- deformation strength changes.

MECHANISMS OF FAILURE

Case studies and theory have established that modes of failure in waste rock slopes are dependent in-part on the method of construction. Where material is end-tipped at the crest, the slope remains at an the angle of repose for the waste rock and through a combination of factors not least segregation and height of slope, and failure is commonly along a parallel plane and consists commonly of a number of wedges or segments (Campbell 2000).

Where ascending terrace lifts are utilised, relative increases in strength characteristics are achieved through improved state of particle packing during construction, reduced segregation and reduced (bench) slope heights. Failure mechanisms are more likely to include toe failures, circular and non-circular failures contained within the waste rock and into the foundation materials.

Failure mechanisms post closure can be linked to long-term effects of chemical and physical weathering and moisture-softening mechanisms leading to progressive failure. Settlement can also be expected of between 2% and 7% of the waste rock (Williams 2000).

Given the proposed ascending construction method, the critical failure mechanisms for the WRSA are assessed to include circular and wedge failures through the variable foundation material identified in the catchment, particularly in early years where the WRSA is an isolated structure, with limited stabilising benefit from the side slopes.

STABILITY ANALYSIS - MATERIAL PROPERTIES

The selection of geotechnical material properties for stability design of a WRSA is a significant part of the geotechnical process of design.

The waste rock is expected to contain coarse, angular fragments of metasedimentary and intrusives (granodiorites) up to one metre in diameter. The absence of a significant weathering horizon in the vicinity of the open pit, and limited clay coatings on the intrusive, ensures that other than the fine-grained metasediments, the waste rock is primarily clean, durable and free of any significant fines content.

A comparison of shear strength material parameters considered for stability analyses are presented in Table 6-15.

TABLE 6-15 WASTE ROCK MATERIAL PARAMETERS COMPARISON (MIN – MEAN – MAX)

Victoria Gold Corp. – Eagle Gold Project

Parameter		BGC (2009)	Sitka Corp (1996)	Knight Piésold (1996)	Reference
Base angle of friction, (°)	Metasediments	32	-	-	1a
	Intrusives	28	-	-	1a
Peak angle of friction, (°)	Metasediments	40	40	42.3	1a, 2, 3b
	Intrusives	40	-	42.3	1a, 2, 3b
Residual angle of friction (°)	Metasediments	35	37	-	1a, 3b
	Intrusives	38	-	-	1a, 3b
Joint Roughness Coefficient (JRC)	Bedrock	11 (55% of the dataset)	-	8 -12 (based on assessment from discontinuity logs)	1b
Uniaxial Compressive Strength, (MPa)	Metasediments	21 -77 -168	86	55 (2a) 55 - 100 -190 (2b)	1c, 2a, 2b, 3a
	Intrusives	3 - 134 - 224	127	63 (2a) 63 - 178 - 260 (2b)	1c, 2a, 2b, 3a
	Weathered Bedrock	-	-	4 - 34 - 93	2b

1a. BGC. 2009. Direct Shear Strength Testing Results.pdf and
Direct Shear Results Summary.xls / Direct Shear Strength Testing Results.pdf

1b. BGC. 2009. Rock Mass and Discon Information.xls

1b. BGC. 2009. Point Load Testing Results.xls / Intact Strength.pdf

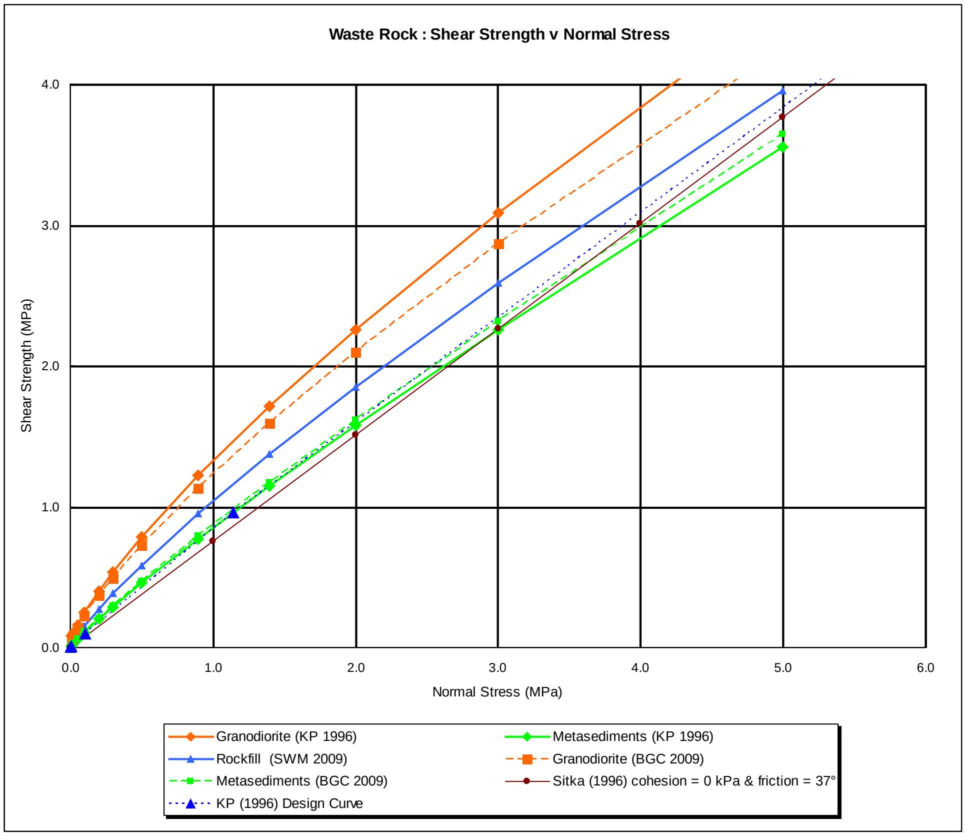
2a. Knight Piésold. 1996. Dublin Gulch Project - Report on the Feasibility of Heap Leach Pad and Associated Structures. (Report No. 1882/4)

2b. Knight Piésold. 1996. Dublin Gulch Project - Report on the Open Pit Slopes. (Report No. 1882/3)

3a. Sitka Corp. 1996. Pit Slope Re-Assessment- Design Memorandum. (Dated: 18/09/96)

3b.Sitka Corp. 1996. Dublin Gulch Project - IEE Addendum Section 8.0, Eagle Pup MWRSA). (Dated 17/10/96).

FIGURE 6-10 WASTE ROCK SHEAR STRENGTH



The core discontinuity data acquired by BGC (2009) has been assumed to reflect to a degree the waste rock surfaces for a consideration of rockfill shear strength based on an empirical relationship developed by Barton and Kjaerlski (1981). A comparison of these waste rock shear strengths with those used in previous analyses are presented in Figure 6-10, and indicate a similarity in the adopted material properties for waste rock.

For the foundation conditions, the assumption of a friction angle of 32º for a shear strength was adopted in previous studies (KP 1996), based on observations and design guidance for the surface stripped of organic material (the remaining superficials) over ‘bedrock’, whilst Sitka (1996) adopted a friction angle of 30º, based on silt shear testing for the organic material assumed to be left in situ, over weathered bedrock superficials with a friction angle of 40º. These assumptions regarding the friction angle and thickness of the superficials are assessed to be the most critical to potential WRSA failures.

PIEZOMETRIC SURFACES

Previous studies have assumed the absence of a piezometric surface in the WRSA due to the limited infiltration and the drainage characteristics of the rockfill. To ensure this condition a rock drain is proposed along the valley floor of Eagle Pup ensuring the continuity of foundation drainage and the removal of unsuitable organic material.

PORE PRESSURE DEVELOPMENT FROM THAWING

Analyses have also accounted for pore pressures developing in early years from thawing of an assumed extensive seasonal frost zone of up to three metres depth (KP 1996).

ANALYSIS

Stability analysis of the WRSA has been previously conducted for both static and pseudo-static (earthquake) conditions for a variety of both operational and post closure configurations (Refs. KP and Sitka 1996). These analyses are based on similar assumptions regarding groundwater and seismic loadings, and conclude a 1: V to 2 H overall slope in the WRSA achieves the minimum factors of safety against slope stability under static and pseudo-static design events.

However, the most marginal of cases is the early, static loading as the WRSA is developed through the valley area and encounters thaw instability and/or weaker foundation materials. Satisfactory stability is only achieved by ascending terraces, with gradual loading of foundations, the removal of organic material and unsuitable alluvial deposits, and controlled deposition over seasonal permafrost.

ROCK DRAIN

The Eagle Pup lower catchment will be progressively stripped of organic material and enhanced with selected and durable granular waste rock to ensure:

- the removal of organic material for stockpiling for closure and uncover for removal any unsuitable material in the foundations of the WRSA, and

- a piezometric surface does not build up significantly within the WRSA during:
    - operational design storm events by passing flows through a central drain designed to pass a 1 in 200 year 24 hour event with a peak flow estimated at 1.5 m^3/s, and

    - post closure PMP events by passing peak flows through the rockfill drain designed to pass a PMP event.

STARTER EMBANKMENT

An 18 m high starter embankment, consisting of durable and clean waste rock of selected particle size range is designed to:

- ensure good toe drainage in areas of highest flow gradients
- protect the outlet and drainage so as to not be damaged by waste rock disposal
- provide a buffer zone to protect the SCP and its liner from any boulder rollout, and
- provide post closure a physical and hydrological stable toe of the rehabilitated WRSA.

WATER BALANCE

A full water balance for a WRSA was conducted by Knight Piésold for a comparable Eagle Pup WRSA in location and size for the 1997 Rescan feasibility study. The 1996 evaluation assumed precipitation to range between 231 mm minimum to 527 mm maximum and averaging 374 mm, with runoff coefficients of 0.65 and 0.3 from the undisturbed area and WRSA respectively. Based on these parameters, and allowing for evaporation, losses to groundwater and lock-up in the Eagle Pup WRSA, the predicted inflows to the SCP are of the order of 33,400 m^3/month. Any interception and diversion of the observed springs and seeps in the upper catchment would typically reduce only this flow by about 1,400 m^3/month per spring.

RUNOFF CONTROL

Two specific WRSA runoff controls are designed to reduce inflows and minimise erosion. These controls include an interception and diversion ditch system of the upper-catchment springs and specific construction constraints on the WRSA benches.

A number of springs issue surface water throughout the year into the upper part of the catchment. The long-term impact of dewatering for the open pit is likely to impact on these, however, in early years of operation, these primary sources of water into the catchment will be redirected into the neighbouring catchment of Stewart Gulch. The steepness of the catchment slopes precludes practical diversion of any other surface runoff and therefore this will be allowed to infiltrate into the waste rock.

Rainfall onto the highly permeable WRSA in the operational period is unlikely to pond and generate surface runoff. Horizontal benches will mitigate against the concentration of runoff and potential for erosion.

All precipitation infiltrating the WRSA will report to the rock drain and finally as seepages from the toe of the waste rock and into the SCP.

SEDIMENT CONTROL POND DESIGN

The Eagle Pup SCP will be located in the narrow valley at the bottom of Eagle Pup. The design includes an embankment constructed from rockfill, an HDPE-lined pond and variable height decant. The SCP is designed to accommodate a 1:100 year event, with a volume of 25,000 m^3.

An SCP for the Platinum Gulch WRSA is shown on drawings and will be similar to that for the Eagle Pup SCP, but has not been assessed in detail for this study.

MONITORING

The performance of the WRSA will be monitored during construction through both survey and geotechnical inspection. This will include instrumentation to assist in the assessment of slope stability of the WRSA benches, the starter embankment in front of the WRSA, and the SCP, and enable comparisons of actual against forecast behaviour. Given the size of the facility, observations and measurements will be taken to detect pore pressure changes, strains and settlement in the WRSA, as possible precursors to major instability.

Monitoring of the SCP will include water levels, sediment volumes, flows and water quality. Boreholes downstream of the SCP will provide a final check on the groundwater quality emanating from the Eagle Pup catchment.

CONSTRUCTION

The construction of the WRSA follows the construction of the site sediment collection pond in the Dublin Gulch valley. The sequence comprises:

- WRSA SCP embankment construction with waste rock from mining operations
- lining of the SCP

- stripping of valley organics and placement of selected durable boulders
- starter embankment construction

APPENDIX R15B

Prefeasibility Study Excerpt 2: 9-1 to 9-43

9 HEAP LEACHING

The proposed Heap Leach Facility (HLF) is located approximately 1.2 km north of the Eagle Zone orebody. The majority of the HLF is located in the Ann Gulch catchment, a tributary to Dublin Gulch. The base of the HLF is in the valley floor of Dublin Gulch at an elevation of 840 masl and at full height, the HLF extends up Ann Gulch to an elevation of 1,080 masl.

This section of the report presents the Scott Wilson HLF design, used to support the PFS cost estimates. Summaries of meteorology, hydrology, seismicity, geological, geotechnical, and hydrogeological conditions that were used as inputs to those designs are also presented. These summaries are taken from BGC and Stantec reports, found in the appendices to this report.

The HLF comprises a number of elements: a rock-filled embankment to provide stability to the HLF, a lined storage area for the ore to be leached, an in-heap storage pond to contain the pregnant solution, pumping wells for the extraction of solution, ponds to contain excess solution in extreme events, diversions, Sediment Control Ponds (SCP), and leak detection, recovery and monitoring systems to ensure the containment of solution. An associated structure is the relocated Dublin Gulch waterway (channelled to the south side of the valley).

Engineering of these components is discussed in the following sections and drawings are presented in Appendix F. Capital and operating costs have been prepared and are included in Sections 14 and 15.

PREVIOUS STUDIES

Previous studies undertaken include reports on the 1996 Feasibility design (Knight Piésold, 1996) and the Initial Environmental Evaluation (Sitka, 1996). Reports on investigations, laboratory testing and other information prepared in support of these reports have been reviewed but not referenced.

SITE SELECTION

Site selection for the HLF site was based on a two stage assessment of the suitability of potential locations:

- Stage 1 - an engineering assessment (see Appendix F), and
- Stage 2 - a Project-wide assessment of impacts from the various HLF site options.

POTENTIAL SITE OPTIONS

Following initial screening of a variety of potential heap leach sites in the wider Dublin Gulch catchment area, six sites were considered for taking forward (see Figure 9-1), with four of these selected for the geotechnical investigation, Options 1, 4, 5 and 6. The potential site options for the HLF include:

- Option 1 – Cross valley type HLF within Dublin Gulch (lower valley)
- Option 2 – Cross valley type HLF within Dublin Gulch (mid valley)
- Option 3 – Valley type HLF on Potato Hills within Bawn Boy headwaters
- Option 4 – Side valley type HLF on slopes below the Eagle Zone ore deposit
- Option 5 – Valley type HLF on granodiorite ridge within Olive Gulch headwaters
- Option 6 – Side valley type HLF in Ann Gulch headwaters.

ENGINEERING ASSESSMENT

The engineering assessment considered the factors that influence the suitability of the facility at each location, using a qualitative comparison of each site against a set of significant engineering (cost-related) criteria. These criteria are drawn from Scott Wilson's experience of the design, construction, and closure of heap leach facilities.

A variable degree of compliance was applied in regard to each criterion, with non-compliance scoring negatively (-5) and full compliance positively (+3). The approach aimed to identify favourable sites based on these engineering criteria, thus establishing options for further consideration. Quantitative data were scored on a basis of 1 point per US$1 million of differential cost between options.

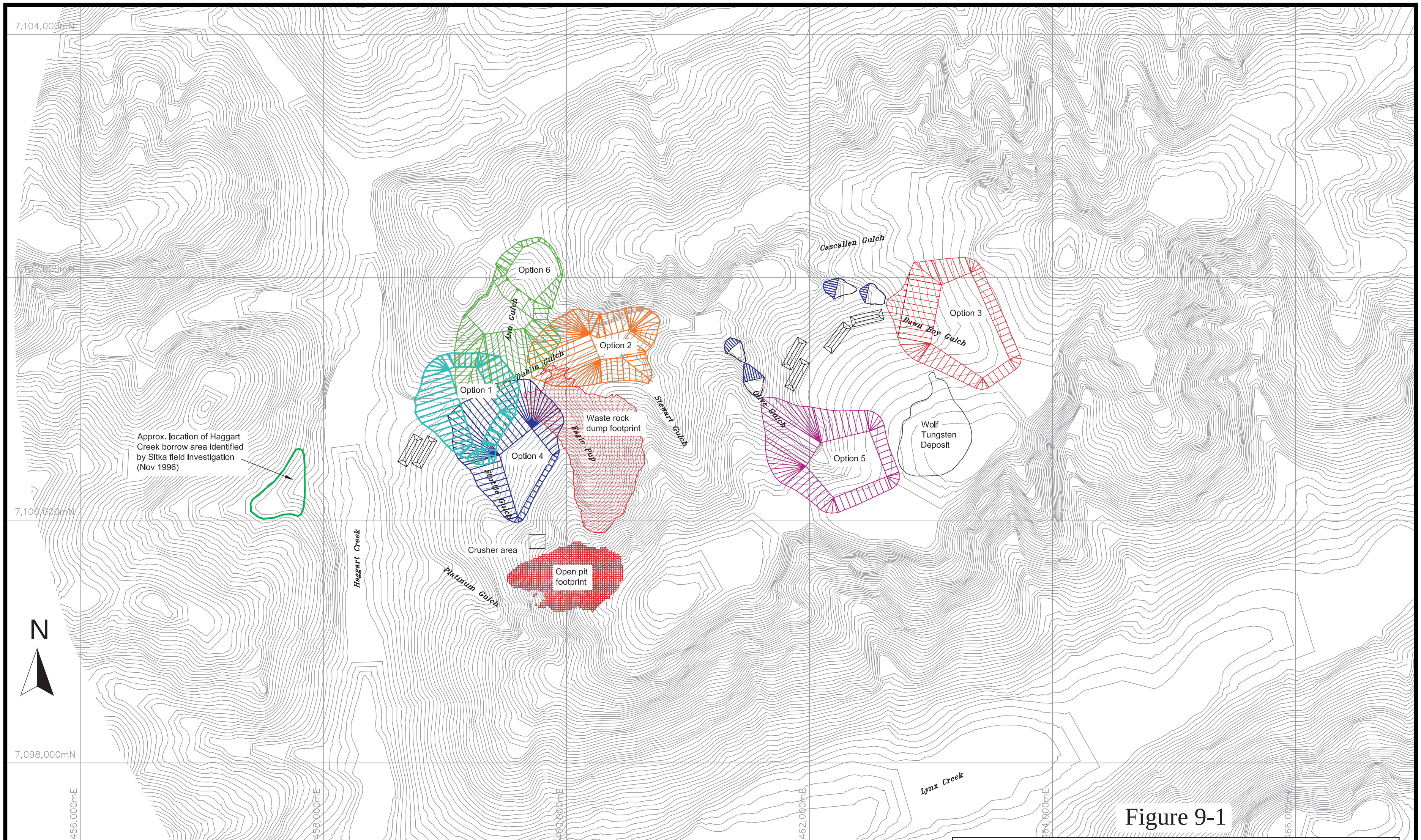


Figure 9-1

0 500 1000 1500 2000

Metres

Victoria Gold Corp

Eagle Gold Project

Yukon Territory, Canada

Heap Leach Site Options

June 2010

Source: Scott Wilson, KCA, 2010.

The engineering assessment of alternatives is summarised in Table 9-1 and established a group of Options, numbers 3, 5 and 6 that score significantly higher than Options 1, 2 and 4. From an engineering and construction perspective of the heap leach pad, Option 3 - Potato Hills is the most favourable of the leading group and Options 1 and 2 the least favourable from the latter group.

TABLE 9-1 ENGINEERING SITE ASSESSMENT OF POTENTIAL HEAP LEACH SITE OPTIONS
Victoria Gold Corp. – Eagle Gold Project

Criteria		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Engineering	Land Surface Area	3	3	3	1	1	1
	Topography	1	-5	3	1	1	1
	Heap leach facility shape	1	1	1	1	1	1
	Materials handling access	3	3	1	3	1	3
	Preparatory Works	1	1	3	1	3	3
Geotechnical	Earthworks for starter embankment	3	1	3	1	1	3
	Other Geotechnical Concerns	-5	-5	3	-5	1	3
Closure		-5	-5	3	1	3	1
	TOTAL	**2**	**-6**	**20**	**4**	**12**	**16**

PROJECT WIDE ASSESSMENT

A Project-wide consideration of the options was undertaken in regard to impacts of the HLF site on:

- mining operations – particularly haulage and access
- other infrastructure layouts
- mineral resources - condemnation requirements, and
- environment – notably on surface and ground water, fauna (fisheries), flora, and visual as well as consideration for archaeological, air quality, sociology.

The scores, as assessed by the various project study leaders (environmental, mining etc.) for the HLF site options are presented in Table 9-2.

TABLE 9-2 HEAP LEACH SITE OPTIONS PROJECT ASSESSMENT SCORING TABLE

Victoria Gold Corp. – Eagle Gold Project

			Engineering			Mining				Environmental										
Option No.	Name	Description	Heap Leach Engineering	Geotechnical - Ground Works	Closure	Operations	Resources	Infrastructure	Expandability	Fauna	Fisheries	Flora	Archaeological/ Heritage	Visual Impact	Climatic	Remediation Closure	Surface Water	Ground Water	Score	Ranking
			Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score	Score		
Group 1																				
3	Potato Hills	Valley	8	9	3	-24	-1	1	3	0	1	-1	0	0	0	3	1	-5	-2	3
5	Olive Gulch	Valley	4	5	3	-16	-2	1	-5	0	1	1	0	0	0	3	1	-5	-9	4
6	Ann Gulch	Side Valley	6	9	1	-2	0	3	1	0	0	1	0	0	0	1	-5	1	16	1
Group 2																				
1	Dublin Gulch	Cross Valley	8	-1	-5	Screened out at Engineering Assessment Stage														
2	Dublin/Eagle Pup	Cross valley	2	-3	-5	Screened out at Engineering Assessment Stage														
4	Eagle Zone	Side Valley	6	-3	1	0	-1	3	1	0	0	1	0	0	0	1	-5	1	5	2

CONCLUSIONS

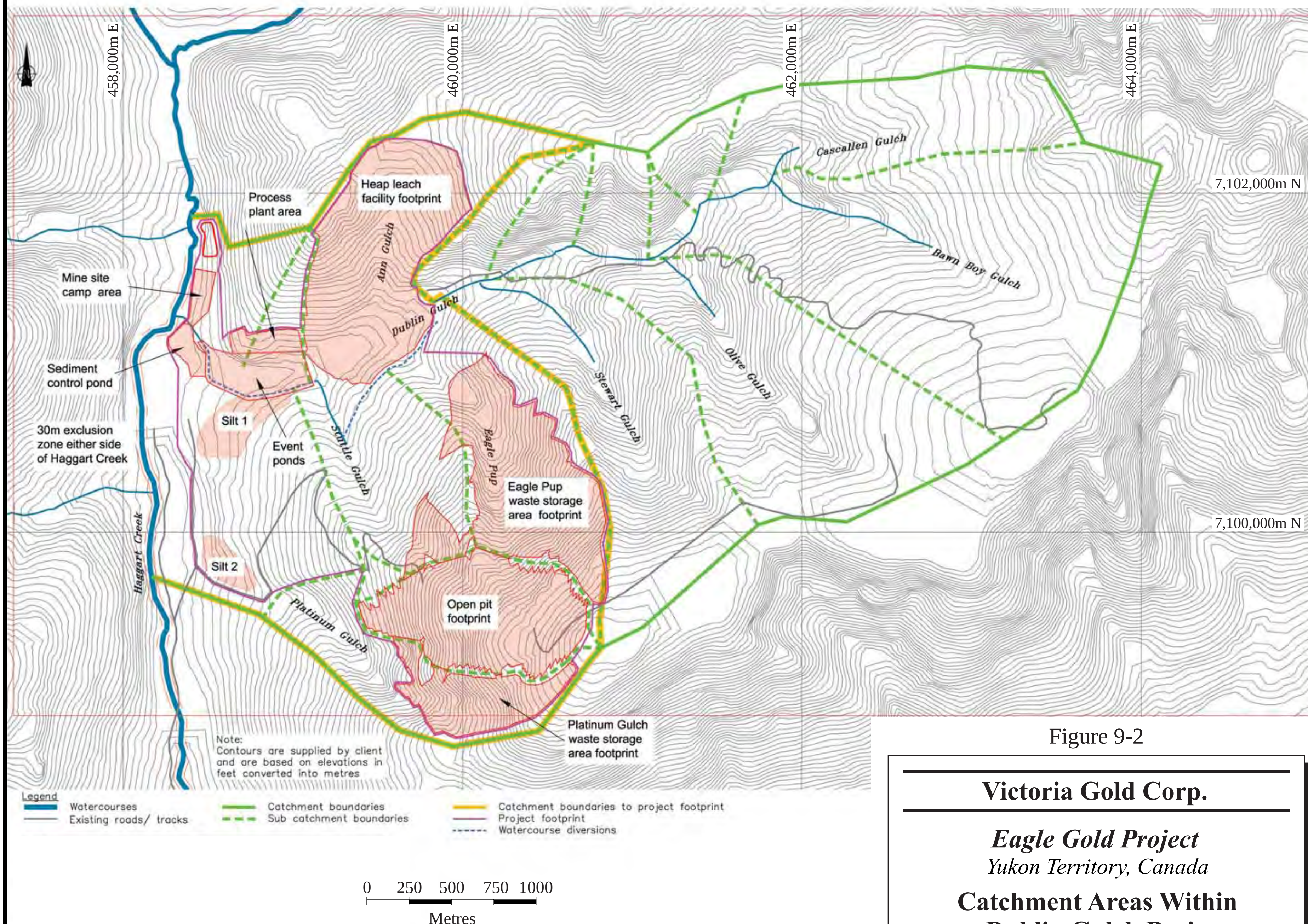
The results of the Project-wide review of the leading three sites established a clear site location preference in Option 6 - Ann Gulch, with similar neutral scores as compared to other sites, but much lower impacts on (costs to) mining and infrastructure. Option 6 was taken forward for pre-feasibility engineering.

SITE CHARACTERISTICS

TOPOGRAPHY AND GEOLOGY

The site of Option 6 - Ann Gulch is located on the southern side of an east-west orientated ridge, on relatively shallow slopes (of largely less than 3H:1V). The slopes drain southwards via a shallow central valley (see Figure 9-2) and down into a confluence with the Dublin Gulch valley. The catchment is south-facing, and short in length (~ 2 km). The catchment ridge rises to an elevation of approximately 1,210 masl and the confluence is at an elevation of approximately 850 masl. On the western side, the valley slopes include isolated steeper sections and the catchment divide on the east side marks a rapid change in slope gradient to the neighbouring catchment.

The geology of the catchment was investigated in 2009 (BGC 2009) through a series of 15 test pits, a few boreholes in the Dublin Gulch valley (see Figure 9-3) and laboratory testing of samples. Bedrock conditions comprise a series of clastic rocks (metasediments comprising schists, phyllites and quartzites), overlain by a variable profile of overburden materials. These surficials include a distinctive weathered bedrock horizon of up to four metres thickness, beneath silty sands and gravels (colluvium) - up to 6.1 m thick, and a 0.3 m organic soil layer. Considerable variation occurs, however, depth to bedrock is typically no greater than 6.5 m in the proposed heap leach pad area. At the lower end of the HLF, the surficials in Dublin Gulch comprise placer tailings deposits (sand and gravel) and are up to 15 m in thickness.



June 2010

Figure 9-2

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Catchment Areas Within Dublin Gulch Basin

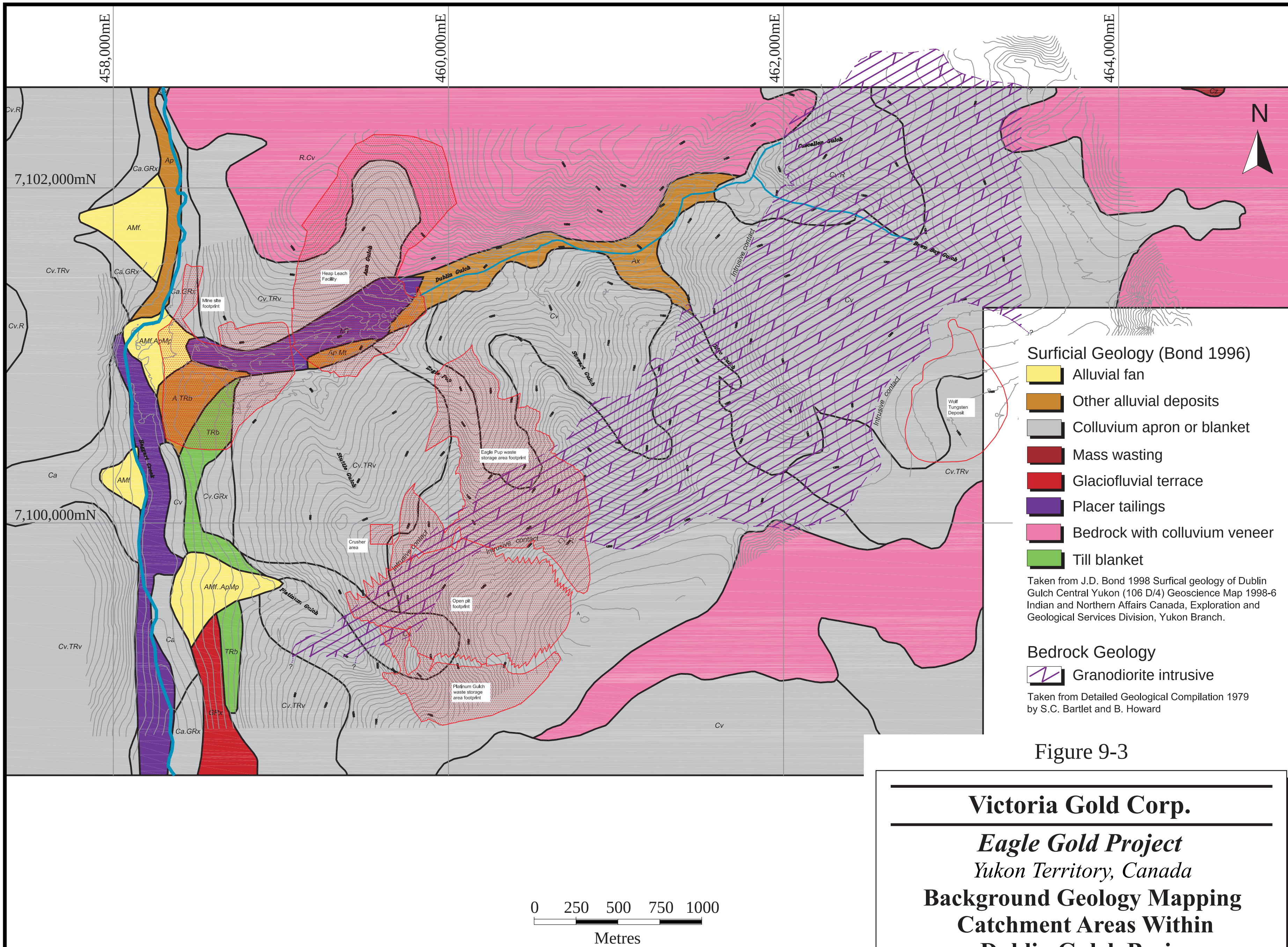


Figure 9-3

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Background Geology Mapping Catchment Areas Within Dublin Gulch Basin

June 2010

HYDROLOGY

The hydrology of the Project area, including the HLF site, is presented in detail in Stantec's report and summarised in this report in Section 6. Of particular note for the HLF is that the peak stream flows occur in the spring in association with freshet events, (snow melt or rain-on-snow events) with flows gradually disappearing following the disappearance of the snow. Sizeable flood events may also occur in the late summer due to intense rainstorms and are particularly significant for small catchments. Ann Gulch is ephemeral, with zero discharges in mid winter when the small stream freezes.

The peak flows are pertinent to the design of the HLF foundation drains and surface runoff collection and diversion ditches and summarised in Table 9-3.

TABLE 9-3 SURFACE AND GROUNDWATER FLOW DESIGN ASSUMPTIONS
Victoria Gold Corp. – Eagle Gold Project

Structure	Return Period	Event Size	Peak Flow (m^3/s)
Surface diversion ditches around the HLF	1 in 200 year	24 hour event	0.5 to 1.2
Operational surface collection ditches on the HLF benches	1 in 10 year	24 hour storm event.	0.6
Foundation Drainage	1 in 200 year	24 hour storm event.	1.5

HYDROGEOLOGY

The hydrogeology of the project area including the HLF site is presented in detail by Stantec (2009) and summarised in this report in Section 6. Of particular note for the HLF is the unconfined flow system within the bedrock and the slow release of groundwater throughout the summer months. The resulting springs are ephemeral, and only where they coalesce in the lower catchment at approximately 950 masl, are surface flows observed in the summer months.

Measurements of groundwater levels in Ann Gulch catchment indicate water levels present within the superficials and weathered bedrock of a few metres below ground level, however, this is variable across the catchment, reflecting a subdued form of the topography, altered by thickness of superficials and weathered bedrock. Typical values of between 2 m and 7 m below grade level are anticipated, however, seasonal variations are not identified.

The hydraulic conductivity of the bedrock is relatively low and assumed to be 1.5 x 10^{-6} m/s (Knight Piésold 1996), and the foundation soils of sand and gravel with some silt beneath the HLF are of the order of 1.9 x 10^{-5} m/s in a thawed state.

PERMAFROST

Permafrost generates significant potential issues for the HLF design in two regards, the potential for thawing of:

- seasonal frost zones, and
- permafrost zones that include excess ice.

Only a scattering of permafrost is identified from the Ann Gulch investigations (BGC 2009) and the potential for the HLF catchment area as a whole is assessed to be as low as 5%.

SEISMICITY

A review of the seismicity records of the Project area, and the Knight Piésold 1996 and RESCAN 1996 reports, has confirmed the appropriateness of previous seismic design assumptions. A design Base Earthquake of 0.078 g for operational conditions is considered conservative as compared to a range of deterministic methods of calculation. The adoption of a 50% of a Maximum Critical Event for a Maximum Design Earthquake (MDE) located on the nearest significant fault is an appropriate methodology for the generated MDE of 0.10 g for post closure conditions.

In 2005, the National Building Code of Canada (NBCC) was revised with respect to seismic design parameters. Scott Wilson RPA notes that the NBCC applies to buildings, not to geotechnical structures (such as the heap embankment), however, reconciliation to the applicable standard (in consultation with regulators) should be settled prior to embarking on Feasibility-level design.

HEAP LEACH FACILITY DESIGN

DESIGN BASIS

A Scott Wilson technical note on the design basis (see Appendix F), presents the standards, objectives and operating parameters used for the PFS design, a summary of which is presented below.

Heap leach design standards adopted for the project include:

- regulatory requirements of Yukon and Canada;
- permitting requirements of the State of Nevada. These are not regulatory requirements in the Yukon, but are considered as standards for best practice, and
- guidelines from the International Finance Corporation.

Taking in to account the requirements of the various stakeholders, the principal objectives of the Eagle Gold Project HLF are to:

- ensure complete protection of the regional groundwater and surface water flows both during operations and in the long-term;
- to satisfy the environmental regulatory requirements of the Yukon territory and the Federal Government;
- provide permanent, secure storage and total confinement of the leach ore within a fully engineered facility;
- effectively collect and convey solutions for in-heap pregnant solution storage to ensure maximum recovery. In-heap storage of solution will be utilised to provide the necessary winter time storage of solution in an above freezing environment;
- minimise the quantity of surface water runoff entering the facility and coming into contact with the process solutions;
- provide additional external facilities (events ponds) to accommodate excess solution and rainfall/snowmelt when hydrological events exceed the storage capacity of the heap;
- develop the facility in stages, where possible, to minimize the environmental disturbance at any one time and to distribute capital expenditure over the life of the facility;
- monitor all aspects of the facility to ensure that the design objectives are met and that there are no adverse environmental impacts; and

- rehabilitate the facility to a condition compatible with the original land use and is stable under extreme precipitation events and seismic events.

In conjunction with these objectives are a series of input parameters and criteria developed for the PFS design of the HLF.

GENERAL ARRANGEMENT

The general arrangement of the HLF is presented in Figure 9-4 and consists of the following features.

HEAP LEACH PAD

The heap leach pad will be a 240 m high combination valley and side valley heap leach. The pad will be constructed from within Dublin Gulch and up Ann Gulch side valley. This will allow space for Dublin Gulch to be re-directed around the HLF, rather than underneath. The heap will be constructed in three phases:

- Phase 1 - all facilities to provide 2 years of operation, including (in order of construction):
  - sediment control ponds;
  - surface runoff diversions;
  - events pond No.1;
  - confining embankment;
  - lining system; and
  - in-heap pond.

- Phase 2 - Extension to the HLF (additional lined area), and
  - construction of events pond 2

- Phase 3 - Extension to the HLF (additional lined area)

SEDIMENT CONTROL PONDS AND SURFACE RUNOFF DIVERSIONS

Control of surface water runoff and sediment will be achieved with construction of runoff diversions around the HLF and sediment control features. A permanent SCP will be located at the downstream extent of the HLF and events ponds infrastructure as shown in Figure 9-6. The SCP will have a volume of 36,000 m^3 and is sized to accommodate run-off events during construction and operations. Temporary use will be made of one of the events ponds, providing 100,000 m^3 of storage for sediment control whilst constructing the Dublin Creek Diversion.

EVENTS PONDS

Two events ponds will be located downstream of the HLF and process plant to allow gravity drainage. The events ponds will have a total storage volume of 200,000 m^3 and cater for excess solution in storm events from the HLF and plant drain-downs. As the in-heap capacity is significant, an event pond is not anticipated to be required in Years 1 and 2, however, the first pond will be constructed at start-up, as a conservative measure. During construction, this pond will act as a temporary stormwater collection pond, and will provide water storage for start-up.

Cross sections are provided in Figure 9-5 and Figure 9-6.

CONFINING EMBANKMENT

In order to provide a satisfactory initial operational area to confine the heap leach pad and in-heap storage pond, an embankment will be constructed at the base of the facility in the Dublin Gulch valley. The embankment will be 50 m high, with an upstream width of 560 m and a total fill volume of 2.2 million m^3. It will be constructed from selected durable waste rock from the mining process, placed on a suitable foundation, with a filter zone on the upstream face to provide a transition to the sub-grade of the liner.

LINING SYSTEM

The heap leach pad will be provided with an engineered lining system to prevent loss of solution and contamination of groundwater. The final lining system will cover approximately 87 ha, and will consist of a multiple composite PVC liner system, with dual leak detection, and a leachate recovery and collection systems to convey solution to the extraction well.

IN-HEAP POND

Solution storage capacity for normal operations of 435,000 m^3 will be provided with an in-heap pond, which consists of storing the solution within the pore space of the ore. This will allow operation in the cold winter and spring climate conditions. As the heap is raised and the catchment area increases, additional storage (the event ponds) will be required for extreme rainfall events. Provision of external storage for this requirement is more economical than increasing the size of the in-heap pond.

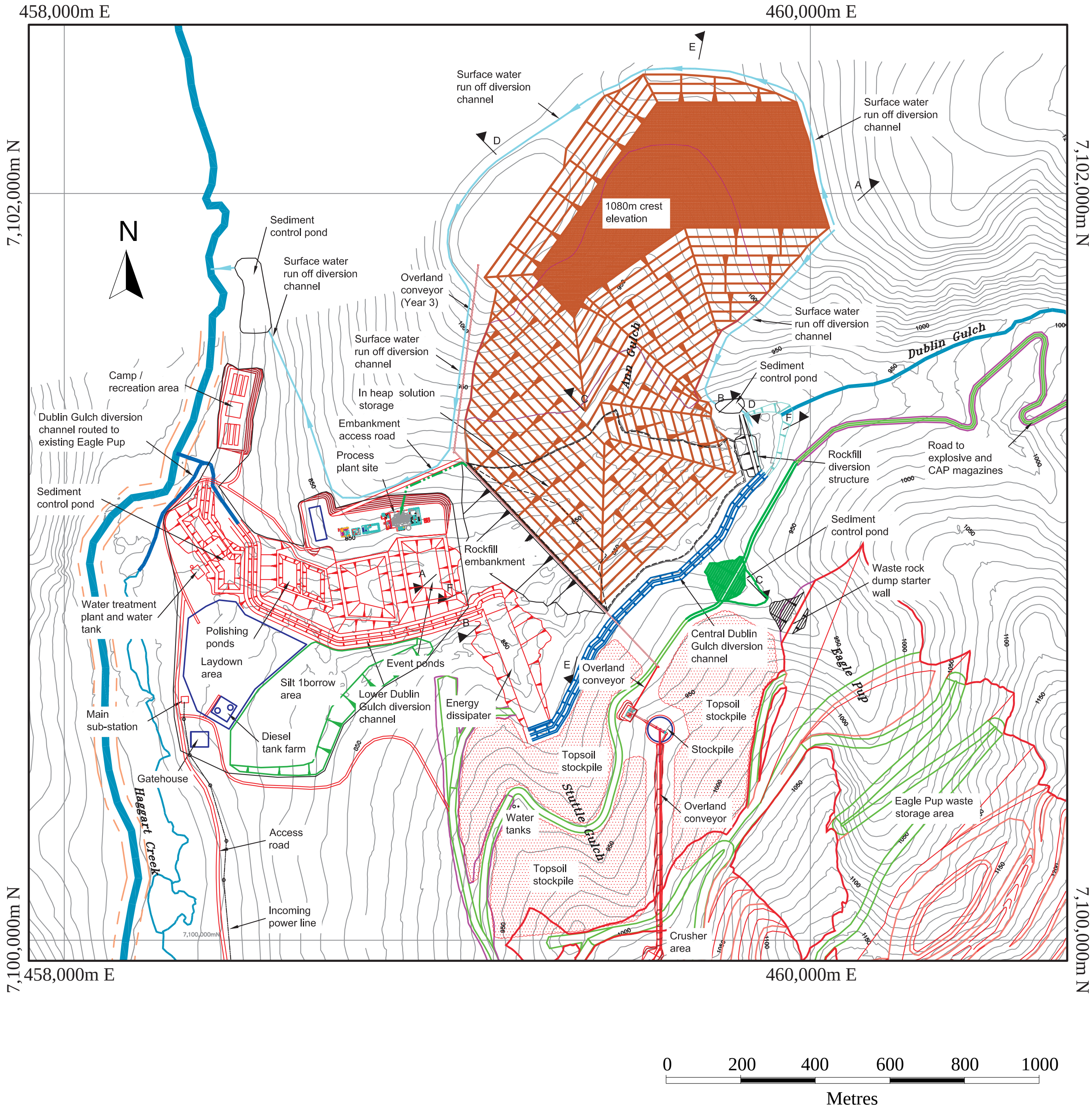


Figure 9-4

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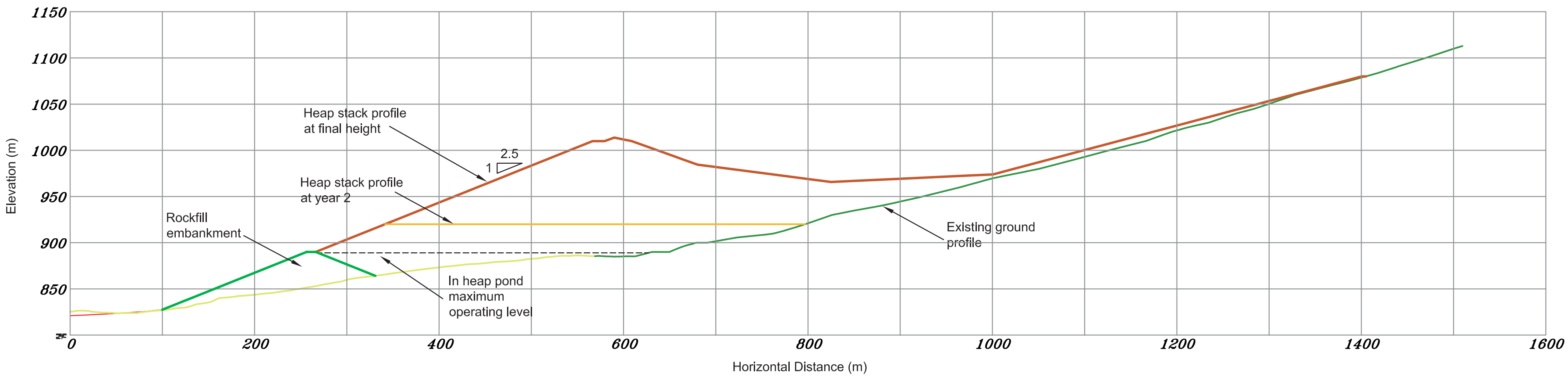
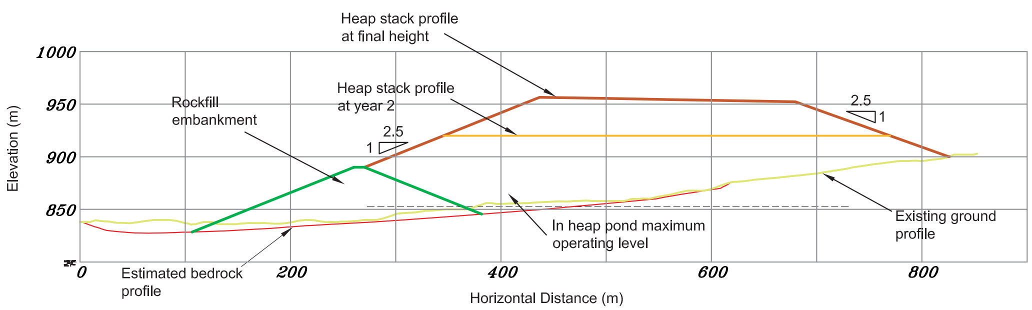
Yukon Territory, Canada

General Arrangement at Final Stack Height

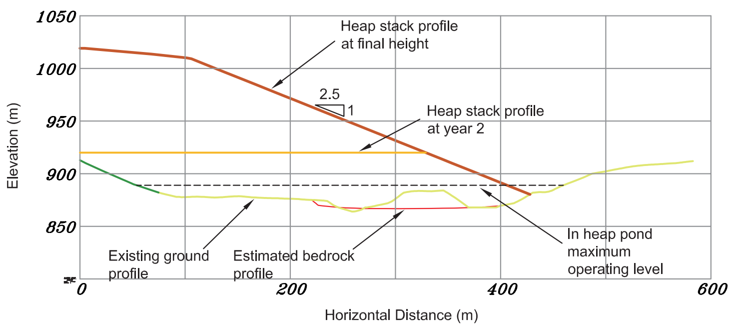
June 2010



Section A–A



Section B–B



Section C–C

Note
1. All dimensions are in millimetres and elevations in metres unless noted otherwise.
2. All sections are provisional, awaiting geological profile data.

0 100 200 300 400
Metres

Figure 9-5

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Yukon Territory, Canada

HLF Cross Sections Sheet 1

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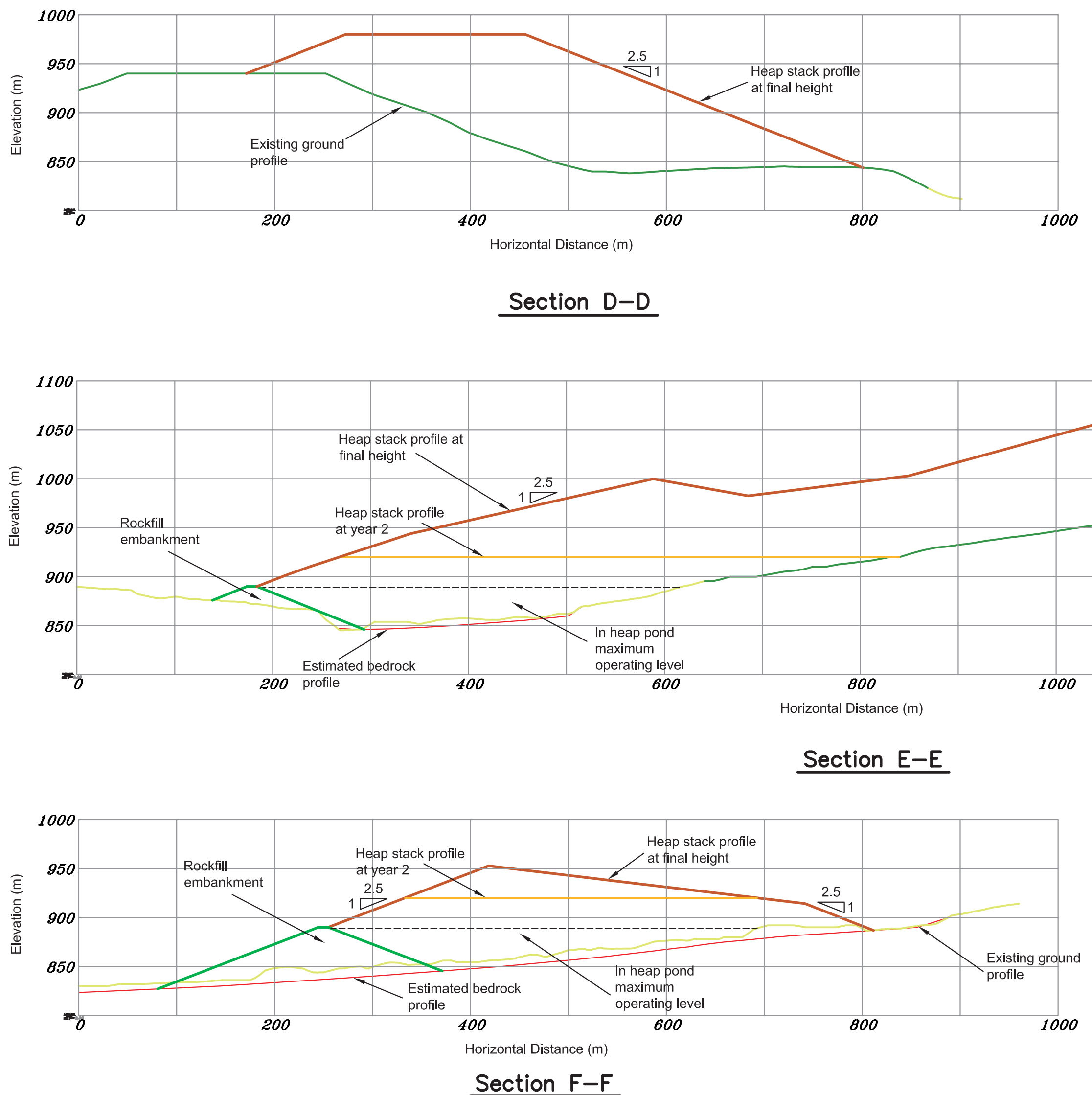

Note
1. All dimensions are in millimetres and elevations in metres unless noted otherwise.
2. All sections are provisional, awaiting geological profile data.

0 100 200 300 400

Metres

Figure 9-6

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Yukon Territory, Canada

HLF Cross Sections Sheet 2

June 2010

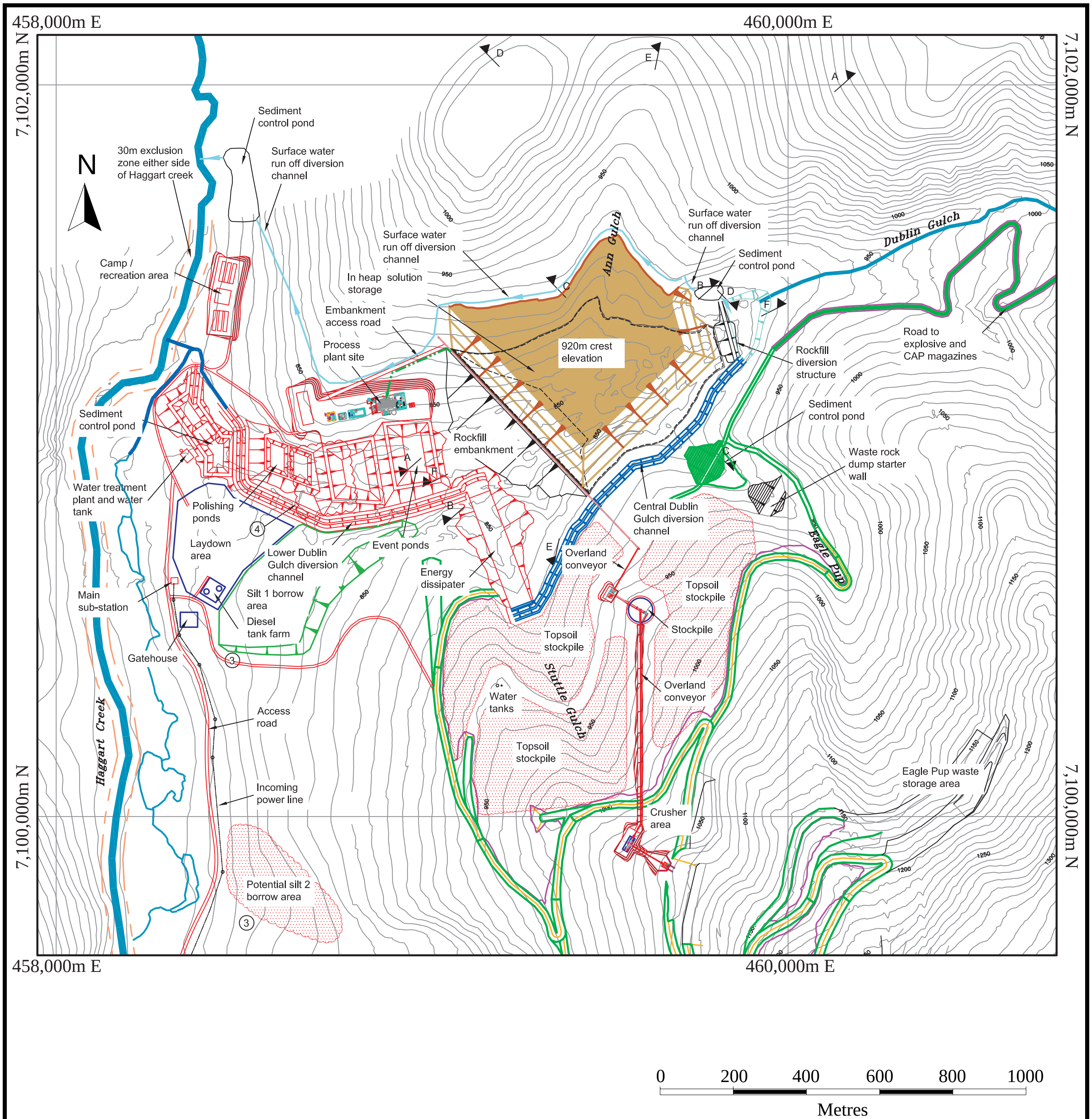

Figure 9-7

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Yukon Territory, Canada

HLF Layout at Year 2

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LINER SYSTEM DESIGN

The heap leach pad and in-heap pond areas will be provided with an engineered lining system to prevent loss of solution and contamination of groundwater. The lining system will cover approximately 87 ha, and consist of a multiple composite PVC liner system, with dual leak detection.

DESIGN BASIS

The Yukon Territory does not have regulations specifically developed for heap leach facilities, but instead relies on regulations from other regions and precedence from other projects. It is understood that the only HLF that has been permitted in the Yukon is at Brewery Creek, the design and permitting of which, according to previous design work by Sitka Corporation (1996), was based on the Nevada State guidelines and associated permitting limitations. The liner system has been designed, therefore, to ultimately achieve compliance with these guidelines.

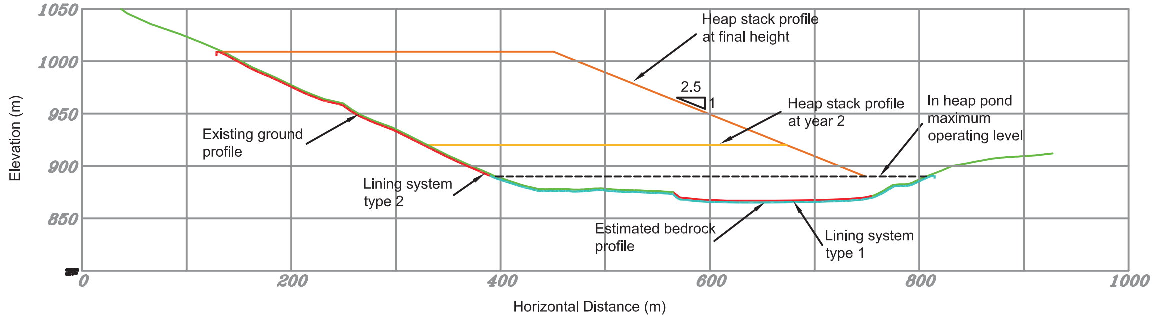
Based on the recommendations of Giroud and Bonaparte (1989), in general, it is expected that "one [puncture] hole per acre" (4,000 m^2) with an effective area of 10 mm^2 would have a reasonable potential to exist for a geomembrane liner placed with a high level of construction quality control. It is on this basis that potential leakage rates through the liner have been assessed to check compliance with the Nevada guidelines.

LINER SYSTEM DESIGN

The lining system elements are illustrated in Figure 9-8. The HLF liner system design provides:

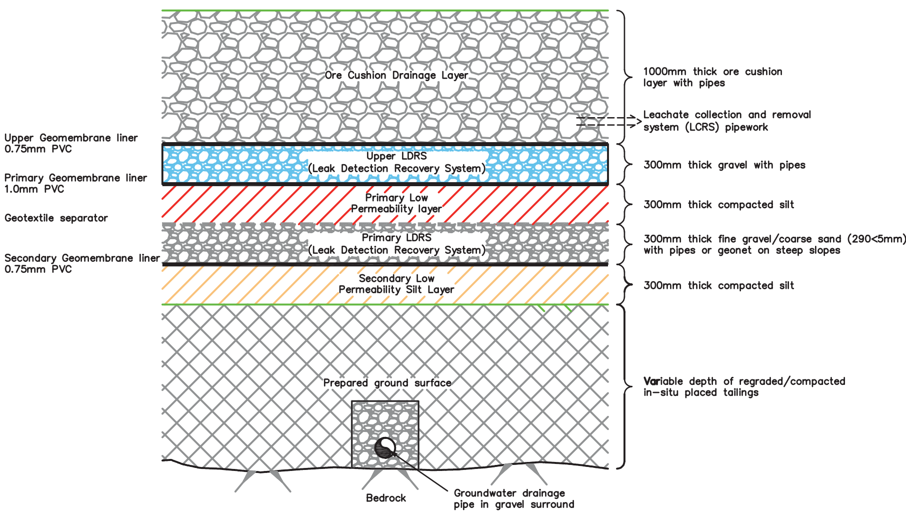
- a double composite liner in the upslope area of the pad (above the in-heap pond maximum operating level), and
- a triple liner in the in-heap storage pond area.

The events ponds will also be double-lined and incorporate a geonet separation layer.

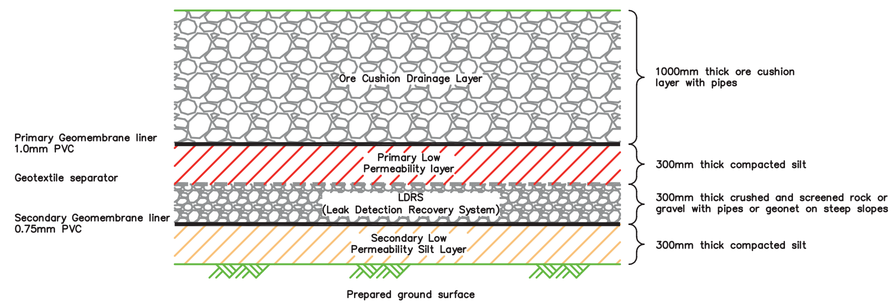


Typical Section Through Heap Leach Facility

Note
All sections are provisional, awaiting geological profile data



Lining System Type 1
In Heap Triple Liner Area
(Below in heap pond maximum operating level)



Lining System Type 2
Heap Pad Double Liner Area
(Above in heap pond maximum operating level)

Figure 9-8

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Eagle Gold Project
Yukon Territory, Canada
Lining System Details

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HEAP LEACH PAD AREA

The liner system in the heap leach pad upslope area comprises the following elements from top to bottom:

- a cushion layer of 1 m thick ore, with Leachate Collection and Removal System (LCRS) pipework

- primary composite liner system comprising:
  - Primary 1.0 mm PVC geomembrane liner
  - 300 mm thick compacted silt

- geotextile separator

- primary Leak Detection and Recovery System (LDRS) comprising 300 mm thick fine gravel to coarse sand with pipes. On steep slopes, this is replaced with geonet

- secondary composite liner comprising:
  - secondary 0.75 mm PVC geomembrane liner
  - 300 mm thick compacted silt.

Potential leakage through the primary liner into the LDRS in the upslope pad area will be minimised by provision of a closely spaced network of leachate collection interceptor. These drains effectively reduce the hydraulic head over the liner.

IN-HEAP STORAGE POND AREA

In order to achieve compliance with the Nevada permitting guidelines with respect to liner leakage in the in-heap storage pond area, an additional liner element is required above the primary composite liner. This additional element comprises an upper 0.75 mm PVC geomembrane over an upper LDRS gravel layer. This upper liner serves to minimise the hydraulic head on the primary composite liner and therefore reduce the potential leakage rates into the primary LDRS. The liner system in the in-heap storage pond area comprises the following elements from top to bottom:

- a 1 m thick ore cushion layer with Leachate Collection and Removal System (LCRS) pipework

- Upper 0.75 mm PVC geomembrane liner

- Upper LDRS 300 mm thick gravel with pipes;

- Primary composite liner system

- Geotextile separator

- Primary LDRS 300 mm thick fine gravel to coarse sand with pipes, and
- Secondary composite liner system.

By using a double composite liner in the upslope section and triple liner in the storage section of the pad, leakage into the LDRS will be below the limiting rates stipulated in the Nevada guidelines, and any subsequent leakage out of the system into the ground will be negligible.

EVENT PONDS

The liner system to the events ponds comprises the following elements from top to bottom:

- Primary 2.0 mm thick HDPE geomembrane liner
- Primary LDRS geonet layer
- Secondary 1.0 mm thick HDPE geomembrane liner, and
- 300 mm thick compacted silt.

LINER COMPONENT SELECTION

CUSHION LAYER

The cushion layer is effectively a load-bearing drainage layer, in which the LCRS pipework can be installed. It will be formed from coarse sand/fine gravel-sized durable ore.

The cushion layer material is assumed to wholly comprise particle sizes less than 5 mm diameter, so that the underlying geomembrane liner will not require any additional protection from damage by large particles or sharp protrusions. If the ore contains particles of greater than 5 mm diameter, then it will be necessary to screen it before use as a cushion layer.

It is recommended that further testing of the puncture resistance of the PVC liner, when placed in combination with the selected cushion layer material, be carried out under the anticipated heap loads to confirm suitability at feasibility design stage.

GEOMEMBRANE LINERS

PVC geomembrane has been selected for the heap leach pad and in-heap storage pond areas due to good cold weather performance, high interface strength (frictional and tensile) characteristics and excellent chemical resistance to the anticipated solutions. It possesses a high degree of flexibility, which enhances its puncture resistance and has proven long-term performance under heaps with high normal loads.

Since the PVC has a relatively low long-term resistance to ultraviolet radiation, all exposed areas will need to be covered with cushion layer material soon after installation.

High Density Polyethylene (HDPE) has been selected for the event ponds, due to good long-term resistance to ultraviolet radiation, excellent chemical resistance and proven performance as an exposed pond liner. The event pond primary liner thickness of 2.0 mm (compared to 1.0 mm thickness for the heap leach secondary liner) has been selected due to its increased exposure to potential wear and to the elements.

LDRS GRAVEL AND GEONET

The primary and upper LDRS layers will comprise free-draining fine gravel to coarse sand material, with typically 90% finer than 5 mm particle size, with minimal fines (i.e., less than 10% finer than 1 mm). The grading of the material will be such that it is capable of transmitting any leakage through the liner system at a rate that ensures minimal head build up over the underlying PVC liner, and also prevents damage to the adjacent (either overlying or underlying) PVC liner associated with large particle protrusions.

It is recommended that, in addition to the cushion layer testing outlined above, testing of the puncture resistance of the PVC liner placed adjacent to the proposed LDRS gravel-sand material be carried out to confirm suitability at feasibility design stage.

The geomembrane liners to the events ponds will be separated by a geonet fluid transmission layer on the side slopes and a gravel layer on the base, which is capable of transmitting leaked fluids at a rate that ensures that excessive head will not develop on the secondary liner.

It is anticipated that the proposed geonet will be a high compressive strength HDPE type product; although further testing will be required during feasibility design to confirm fluid transmission capacities will be adequate for anticipated liner leakage.

COMPACTED SILT

The compacted silt material component of the lining system will be prepared to form a competent low permeability base to receive the PVC geomembrane liners to form a composite lining system. The compacted silt will be a minimum of 300 mm thick and will have a smooth surface, free of sharp protrusions and will be in direct contact with the PVC geomembrane.

It is important to achieve good contact conditions between the PVC geomembrane and compacted silt layer, as the effectiveness of the composite liners depends on the quality of contact between the two elements.

In order to comply with the Nevada guidelines for composite liner systems and permitted leakage rates into LDRS systems, the target permeability of the compacted silt is $1x10^{-7}$ m/s.

It is recommended that permeability testing under consolidated conditions, taking into account that this material will be significantly loaded by heap material above, be carried out to confirm that this permeability value can be realistically and consistently achieved.

GEOTEXTILE

A layer of non-woven geotextile has been included at the interface between the fine grained primary compacted silt layer and the underlying fine gravel to coarse sand LDRS layer. This geotextile is included to provide effective separation of the two materials and prevent any undesirable migration of fine particles and associated instability and settlement that could potentially occur as a result.

LEAK DETECTION AND RECOVERY SYSTEMS

The performance of the lining system, as measured in terms of preventing loss of solution into the ground, will be assessed by monitoring leak detection drains constructed below the liners. Separate LDRS will be installed below each liner, and all collected solution will be returned to the heap.

The LDRS will consist of a series of 100 mm diameter pipes within a 300 mm thick layer of 20 mm gravel, feeding to a 200 mm diameter collector pipe, also located within the gravel layer. Any leakage reporting to the drains will flow to a sump below the in-heap pond, from where it will be pumped back to the heap.

For the in-heap liner, there will be a second LDRS, beneath the upper liner. This is similar to the primary LDRS, except that there are more pipes to cater for the potentially higher flow and convey the solution with minimal pressure on the liner beneath. Any drainage collected will be conveyed to a separate sump below the in-heap pond, from where it will be pumped back to the heap.

The location of the leak detection and collection systems, between the liner layers, makes access for pumping difficult. The proposed design requires installation of down-hole pumps in pipes on the embankment slope, which is not ideal for pump operation. In the event of blockage, replacement of pipes would not be practicable and therefore three pipes for pumping have been provided. Consideration was given to constructing a pipe beneath the embankment, however, this is generally not considered good practice as it is a potential source of leaks. Typical details are shown on Figure 9-8.

The practicability of using borehole pumps to drain potential leaks should be confirmed.

HEAP LEACH PAD - MONITORING

Monitoring will consist of recording the quantity and occasionally quality of solution returned in the LDRS in relation to the location of the heap being irrigated at the time. In addition monitoring boreholes will be installed downstream of the heap leach facility and events ponds and will be sampled regularly for water quality as backup to the LDRS monitoring.

EVENT POND - LEAKAGE DETECTION

The events ponds are designed to work on an infrequent basis, to take the solution in the event of high rainfall events and plant shutdowns. The likelihood for leaks is reduced, together with reduced impact from a dilute solution. The leak detection system will discharge potential seepage to a collection sump, where it will be monitored on a regular basis, and any leakage returned back into the pond with a dewatering pump.

The events ponds will be constructed above the presumed groundwater level. The base of the events ponds is presumed to be free-draining alluvial material and consequently groundwater drainage is not included. This will be investigated further during detailed design.

The events ponds LDRS consists of 100 mm diameter slotted chlorinated polyethylene (CPE) drainage pipes in a 300 mm thick layer of 10 mm gravel feeding a sump in a constructed low point within the event pond. From the sump, two 150 mm diameter HDPE pipes are provided on the slope, connected to the 100 mm drainage pipes. A down-hole pump is installed in one of the pipes, together with an electronic depth sensor.

EVENT POND - MONITORING

Monitoring will consist of recording water depth in the sump and recording the quantity returned to the event pond. Occasional sampling of the quality will also be undertaken. Monitoring boreholes downstream of the events pond will be provided as part of the HLF monitoring and will be sampled regularly for water quality.

GROUNDWATER DRAINAGE - DESCRIPTION OF WORKS

A groundwater drainage system will be installed beneath the lowest liner of the HLF to prevent uplift pressures developing beneath the liner (see Figure 9-9). The drainage system will be comprised of a network of pipes placed in gravel-filled trenches and wrapped in geotextile. The pipe network will be comprised of 100 mm diameter slotted corrugated polyethylene pipes (CPP) pipes in a 300 mm x 300 mm gravel-filled trench at a spacing of 25 m, feeding 200 mm diameter HDPE un-perforated collector pipes at 200 mm centres in 1,200 mm x 1,200 mm gravel-filled trench. In the base of the HLF, beneath the in-heap pond, the 200 mm pipes will feed into a 300 mm diameter HDPE pipe. The 300 m pipe will require a gravelled-filled trench with cross-sectional area of 12 m^2 to convey the post-closure flow from the heap.

GROUNDWATER DRAINAGE - MONITORING

Monitoring of flow and quality will be undertaken on a regular basis. Water that meets the effluent standards will be released via a pipeline to the SCP. If the water does not meet the required standards, it will be pumped to the events pond for treatment or recycling. For this purpose, a sump is provided at the embankment toe with valves to isolate flow.

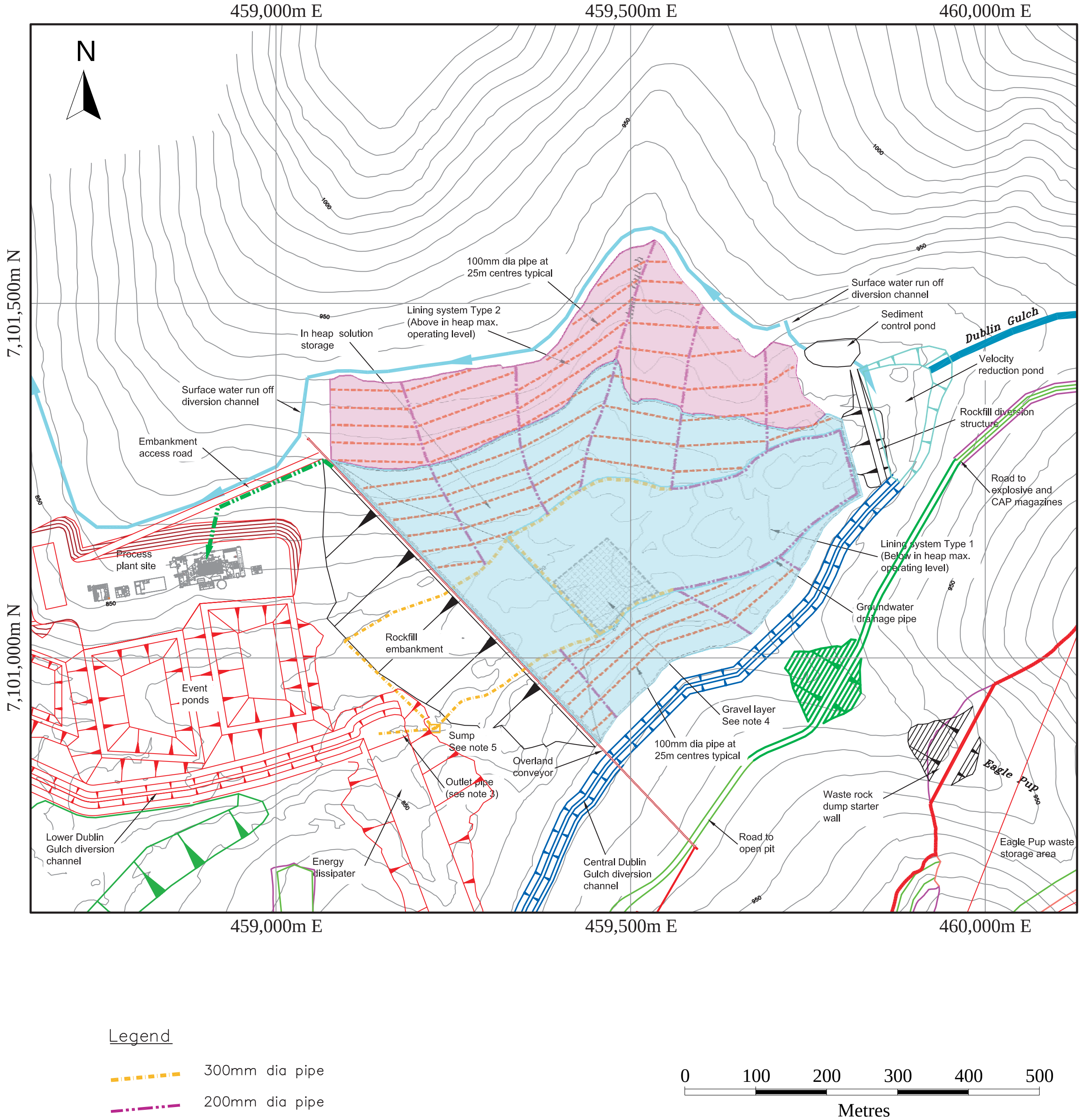

Figure 9-9

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Eagle Gold Project

Yukon Territory, Canada

Groundwater Drainage Pipework Layout at Year 2 Stack Height

June 2010

DUBLIN GULCH RELOCATION

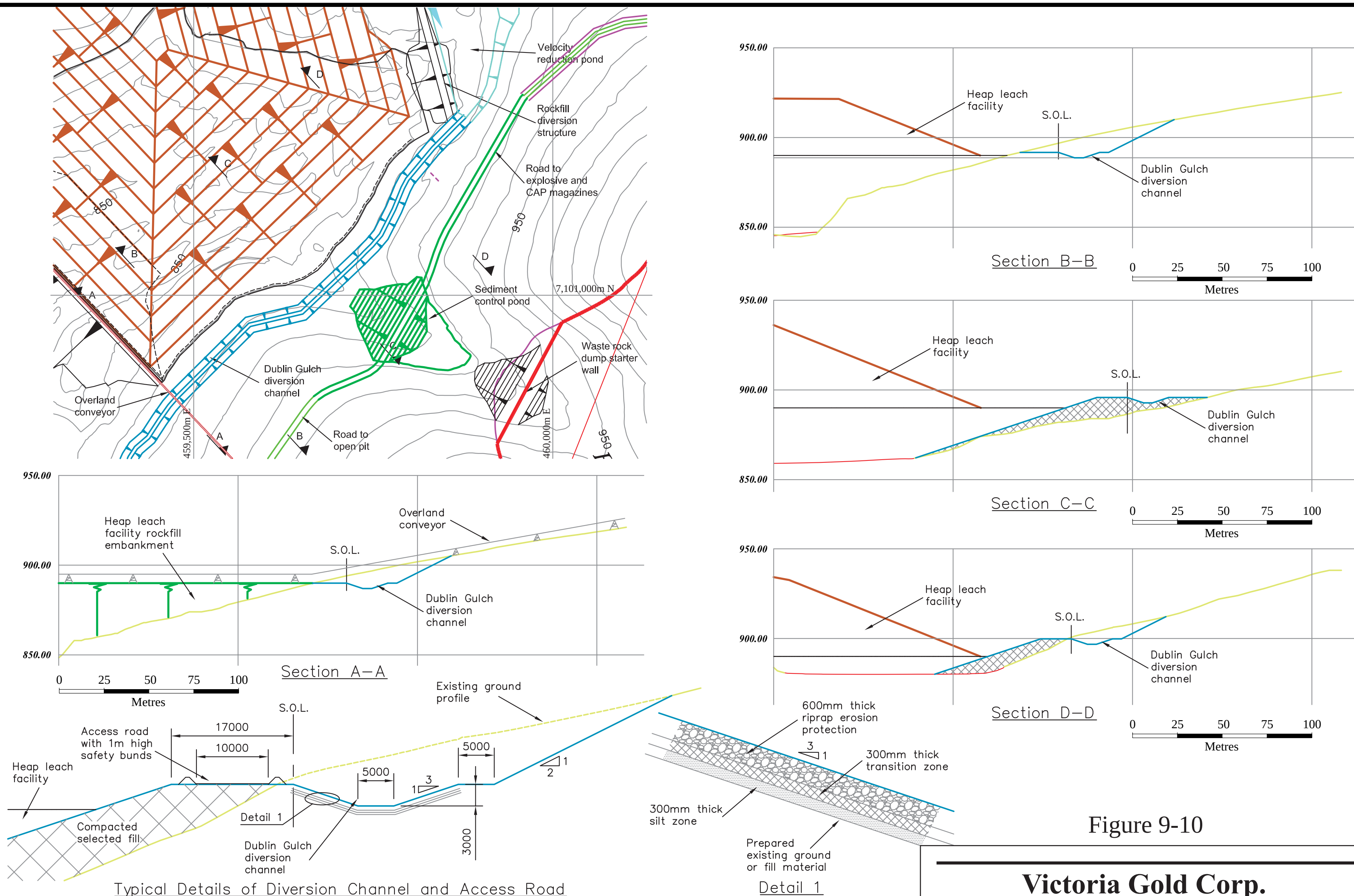
The relocation of the Dublin Gulch streambed is designed to convey streamflow safely past the HLF and return it back to the current course, approximately 1,500 m downstream of the diversion structure inlet. The diversion will be comprised of:

- an upstream inlet structure that intercepts all Dublin Gulch streamflow and directs flow into a diversion channel
- a 900 m long diversion channel ("the upper diversion") 3 m deep with a slope of 1:100 leading to Stuttle Gulch
- channelization of the Stuttle Gulch flow with additional energy dissipation and erosion protection measures
- an enlarged and re-routed channel diversion ("the lower diversion") around the Event Ponds and Polishing Ponds, and
- a reconnection of the flow into the current course of Dublin Gulch.

Guidelines for diversions require design for a 1 in 200 year storm event, however, the diversion remains post-closure and therefore a design to the Probable Maximum Flow (PMF) is appropriate. Consequently the diversion is designed for a peak flow based on the PMF of 105 m^3/s.

The inlet will consist of a 12 m high embankment, designed to intercept all surface flows and the majority of sub-surface flows. The embankment will consist of rock fill with a filter zone on the upstream face to provide a transition to the sub-grade of an HDPE liner. Placer tailings and alluvial material in the valley floor will be removed, and an impervious zone barrier created, to direct sub-surface flows into the diversion. The HDPE liner will be provided with damage protection measures grading from gravel back to rockfill.

From the upstream diversion structure, the 900 m long diversion will run nearly parallel to the contour at a 1:100 slope to Stuttle Gulch. The construction of the upper diversion will consist of earth-fill, HDPE liner and rock-fill erosion protection. The up-slope cut surfaces will be provided with erosion protection measures and flow from the disturbed surfaces will be channelled through a SCP until runoff meets the suspended solids requirements (see Figure 9-10).



Notes:
1. All dimensions are in millimetres and elevations in metres unless noted otherwise.

Figure 9-10

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Central Dublin Gulch Diversion Channel Details

June 2010

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The flow from the upper diversion will then be directed into Stuttle Gulch, through energy dissipation and erosion protection measures to handle the PMF (see Figure 9-11). These measures will comprise large size rock-fill, placed on a gravel bed on a heavy duty geotextile. Stability of the slope, keying the structure into the slope and permafrost are issues to be reviewed further in the feasibility design.

The flow from the Stuttle Gulch energy dissipation channel will re-enter the lower diversion of the Dublin Gulch valley floor at a channel inlet, which is an enlarged section of the lower diversion, provided with erosion protection measures. The stream at this point is then designed to be part of the Dublin Gulch fish habitat and detailed design will need to take this into account. The invert of the channel is presumed to be on competent bedrock and will intercept and drain the groundwater beneath the events ponds. Lining is not considered necessary, however, erosion protection to the banks will be provided. Detailed investigations of the geotechnical and groundwater conditions along the route of the diversion will be undertaken as part of the detailed engineering.

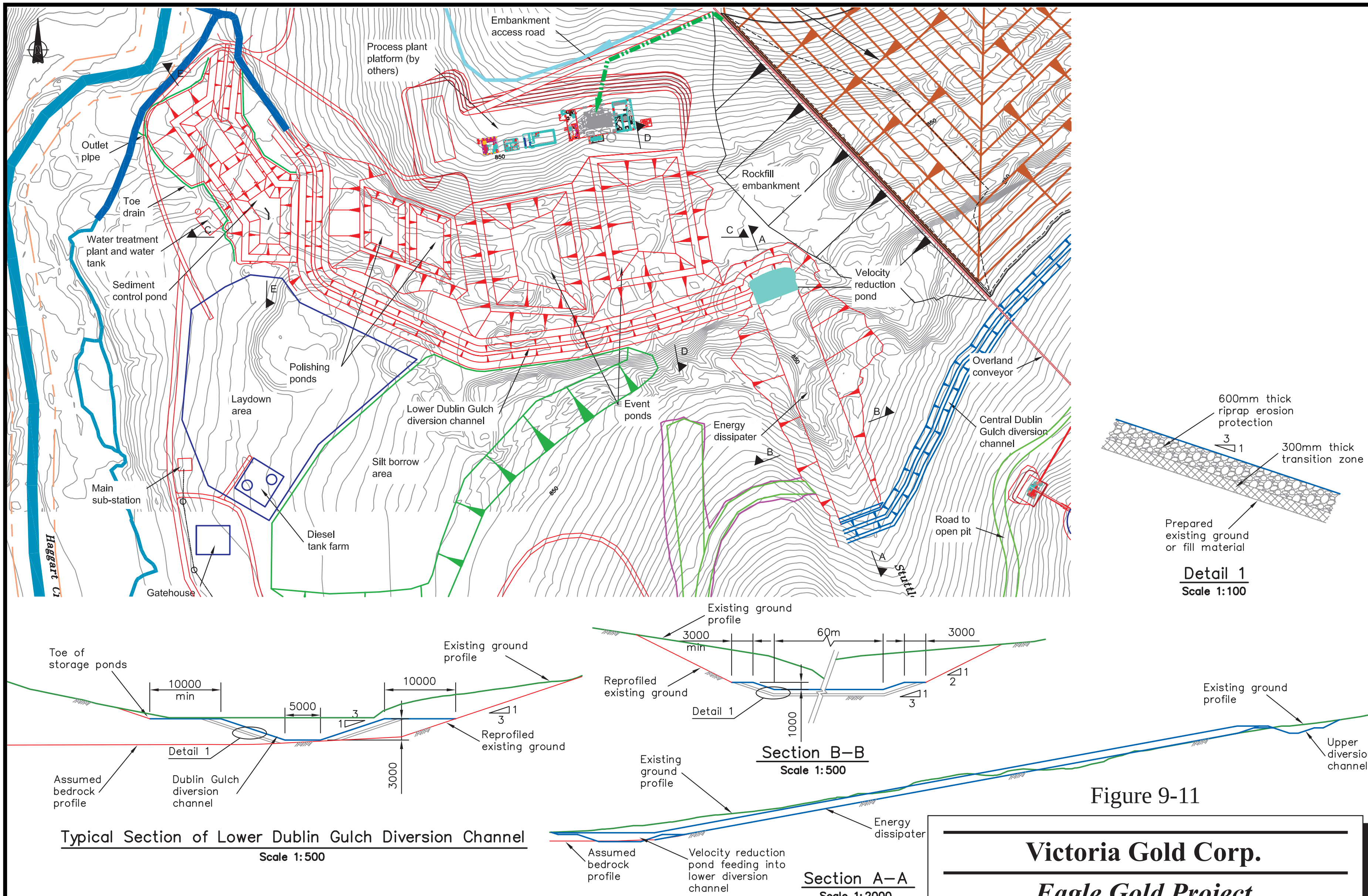

Figure 9-11

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Lower Dublin Gulch Diversion Channel Details and Energy Dissipater

June 2010

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FURTHER WORK

In addition to a general progression of design, the following items are specifically noted for advancing in the feasibility study:

- selection of the backfill material, whether waste rock from the mine or locally excavated materials and ensuring availability i.e., matching waste rock production to use and undertaking borrow pit assessments to determine available suitable volumes
- further design of the Stuttle Gulch erosion protection measures
- further geotechnical data along the route of the proposed diversion, and
- design of the lower Dublin Gulch diversion with regard to providing suitable fish habitat.

STABILITY DESIGN

The physical stability of the HLF is critical to its short-term (operational) and long-term (post closure) performance. The HLF is designed against failure of the ore and/or the foundations that could overstress the liner system and thereby compromise the integrity of the containment system. The design therefore considers the operational design events and post closure extreme events, of seismic loading under an Operational and Maximum Design Events (ODE and MDE), Probable Maximum Flood (PMF) and Probable Maximum Precipitation (PMP).

Particular aspects that are key to determining stability:

- ore material properties particularly strength
- geometry and loading cases (static and seismic)
- shear strength of the:
  - soil/liner interface
  - ore/liner interface
- location of phreatic surfaces:
  - groundwater level beneath the soil/liner interface, and
  - hydraulic solution head above the liner.
- deformation strength changes, and
- normal loading changes in geo-synthetic strength properties.

Stability issues for further evaluation in feasibility studies include:

- permanent displacement assessments to address post seismic deformation strengths, which can be significantly lower and mobilised through only small deformation, and
- shear testing of the compacted soil/geosynthetic liner interface to assess the appropriate shear strength relationship to be adopted for analysis.

MECHANISMS OF FAILURE

Case studies and theory establish the modes of failure in HLFs can include both shallow and deep seated failures, the latter having the potential to damage the liner system. Failure modes considered at this PFS stage include:

- circular and non-circular failures contained within the ore
- wedge failures through the ore and along the ore/liner interface
- circular ad non-circular failures though the ore and into the foundation materials, and
- liquefaction of the ore (particularly as the heap develops above the in-heap pond).

ANALYSIS

METHOD

Stability analysis for the Eagle Project HLF adopted the following approach:

- identifying critical stability sections and developing representative cross sections (two dimensional)
- selecting a method of analysis and determining the appropriate material types and geotechnical parameters
- identifying boundary conditions and loading cases for each section, and
- performing evaluations of stability against design criteria for each loading case.

Figures 9-5 to 9-6 (above) present the locations of the critical cross sections. Other areas in the HLF have configurations that have higher factors of safety as compared to these sections and are therefore not considered.

A deterministic limit equilibrium approach was selected to consider the stability of the structure. In this approach shear stress is compared to the available shear strength. The ratio between the two is the Factor of Safety (FoS). Applicable FoS are presented in the Design Basis (see Appendix F).

To simulate earthquakes loading, a pseudo-static approach was used for the PFS stage. Seismic loading in this approach is simulated as a constant horizontal force, which is computed from an applied acceleration, based on assessments of the ODE and MDE events.

For the feasibility study, more detailed analyses will be required, to determine the amount of movement under earthquake loading. This will include deformation analyses, which are of particular importance as deformation in the liner needs to be assessed to ensure that the liner system can operate post deformation.

MATERIAL PROPERTIES

The selection of geotechnical material properties for stability design of a HLF is a significant part of the geotechnical process of design. The selection needs to attend to the requirements of the proposed analyses whilst the reflecting the ground model for the failure mechanism being considered. The introduction of synthetic materials which are typically of lower shear strength than the surrounding ore and soil materials need to be accounted for in the stability analysis. A summary of the material parameters used in the cross-sections are presented in Table 9-4.

PIEZOMETRIC SURFACES

Piezometric water levels in the ore can impact HLF stability, thus the permeability of the ore and drainage system are significant controls on head in the secondary liner system. For the PFS, stability has been assessed with water levels of up to five metres above the liner.

At the feasibility stage, geotechnical testing of the ore, seepage analyses and further stability analyses need to be undertaken.

TABLE 9-4 GEOTECHNICAL PARAMETERS

Victoria Gold Corp. – Eagle Gold Project

Material Type	Unit Weight (kN/m^3)	Cohesion (kN/m^2)	Friction Angle (°)	Material Description	Ref
Ore	18	0	32	In the absence of laboratory testing, based on previous slope stability analysis parameter	4
Placer Tailings	20	0	37	Sand and Gravel (SP); based on EBA Particle Size Analysis: generally, < 10% fines, 20 - 60% sand and 30 to 70% gravel.	1
Colluvium (Type 1)	14	38	28	Gravelly Silt (ML). Generally, consists of > 30 - 50% fines (silt and clay) content.	1
Colluvium (Type 2)	22	0	36	Sand and Gravel (SW, SM, GW, GM); with occasional silt, medium compacted, unsaturated. Generally, consists of 30 - 50% fines (silt and clay) content.	1, 4
Weathered Bedrock	22	0	38	Weathered Granodiorite, described as sand (SP) with occasional boulders and cobbles. Strength = S2 (approximately 25 MPa), Weathering Grade 4 -5.	
Bedrock	26	Based on shear strength vrs normal strength envelope		Based on field estimation and observations, bottom of DG option 6; in the absence of laboratory strength properties; .RocLab used. UCS = 45 MPa, GSI =60, m_i = 9, D = 0, based on similar materials	2
Waste Rock	26	Based on shear strength vrs normal strength envelope		In the absence of laboratory rock strength, based on UCS = 45 MPa with Barton and Kjærnsli (1981) strength model	3
Compacted Sand and Gravel	24	0	40	In the absence of laboratory testing, based on dense Colluvium type 2 and previous slope stability	4

References

1. Carter, M.; Bentley, S.P., 1991. Correlations of soil properties. Pentech Press. 1st Edition.

2 SRK. 2008. NI 43-101 Preliminary Assessment Dublin Gulch Property – Mar-Tungsten Zone Mayo District, Yukon Territory, Canada (Table 17.2.2.2.)

3. Barton, N., and Kjærnsli, B., 1981. Shear strength of rockfill. J. of the Geotech. Eng. Div., Proc. of ASCE, Vol. 107:GT7: 873-891. Proc. Paper 16374, July.

4. Rescan. 1996. Dublin Gulch Prefeasibility Study - Volume 2. (Table 7.9.1)

CONFINING EMBANKMENT DESIGN

Slope stability calculations were undertaken for the confining embankment with the heap in place up to the final elevation. A slope of 3H:1V was adopted for the embankment based on stability assessments, which allows for a variety of earth and mine waste-rock or rock-fill materials to be used. Unweathered waste rock can be built to a steeper slope, but with an embankment volume of 2,000,000 m^3 required, quantities of waste rock may not be available in the required timeframe.

Toe- and side-drains will be provided to intercept groundwater from the abutments. Drainage beneath the embankment will be provided by a groundwater drainage system, which is linked to that beneath the liner. There will also be groundwater drainage systems at the inlets to the Dublin Gulch diversion and along the route of the diversion, which intercept groundwater before it reaches the main embankment. The main source of water within the embankment will be from rainfall infiltration onto the embankment, which will not be sufficient to build up a significant phreatic surface.

There will be pipes passing beneath the embankment conveying groundwater from beneath the liner. They will not pass through a liner and will be in a gravel trench. Potential for “piping” (loss of material due to flow of water along a pipe through an embankment) will therefore be negligible. There will be no other features passing through the embankment.

The main source of the earth/rock-fill will be from overburden and waste rock generated during mine development. Characteristics and availability (co-ordination with mining schedule) requires confirmation.

The embankment requires a transition zone on the upstream face where particle size reduces from boulder size in the rockfill to silt beneath the lower liner. Specific filter relationships are required for the particle sizes of the zones in order to prevent washing away of materials into the coarser zone in the event of a leak through the liner. Two zones have been assumed at this stage and this will need to be reviewed during both feasibility and detailed design and confirmed during construction.

Foundation preparation beneath the embankment will consist of removing loose sand and gravel from the valley floor, potentially to bedrock at a depth of two to ten metres. For the abutments, topsoil will be removed and excavated down to competent material, to a depth of one to two metres, with isolated pockets of deeper loose material.

SOLUTION MANAGEMENT

Solution management of the HLF comprises the efficient management of the solution delivered to, permeating through, and reporting from under the stacked heap; and the secure containment of pregnant and barren leachate leading to optimum metal recovery.

The solution management objectives of the heap leach facility are:

- the system is to operate as a closed system with zero release of solution to the environment
- the solution ponds are to contain operational flows with run-off during normal operational and storm rainfall events, and
- in extremely wet seasons, excess solution is to be stored and treated until the quality of the water meets the required regulatory quality requirements for release.

Figure 9-12 presents a schematic of the solution flow and is described as follows:

- Barren and recycled solution will be applied to the heap through a series of buried dripper type and (summer only) sprinkler applicators.
- The solution will permeate through the heap, where it will be contained by the lining system and directed via collection pipes to the collection well.
- Pregnant solution will be pumped to the Adsorption/Desorption/Recovery (ADR) plant.
- A spillway will be provided at the top of the in-heap pond to discharge excess solution to the events pond via 450 mm dia. HDPE pipes.
- The event ponds will be zero release and all solution will be pumped to the ADR plant.
- After removal of gold in the ADR plant, barren solution will be pumped to the heap leach pad.
- In extremely wet seasons, the resulting excess barren solution in the ADR plant will be treated and released to the polishing pond before release via the SCP.

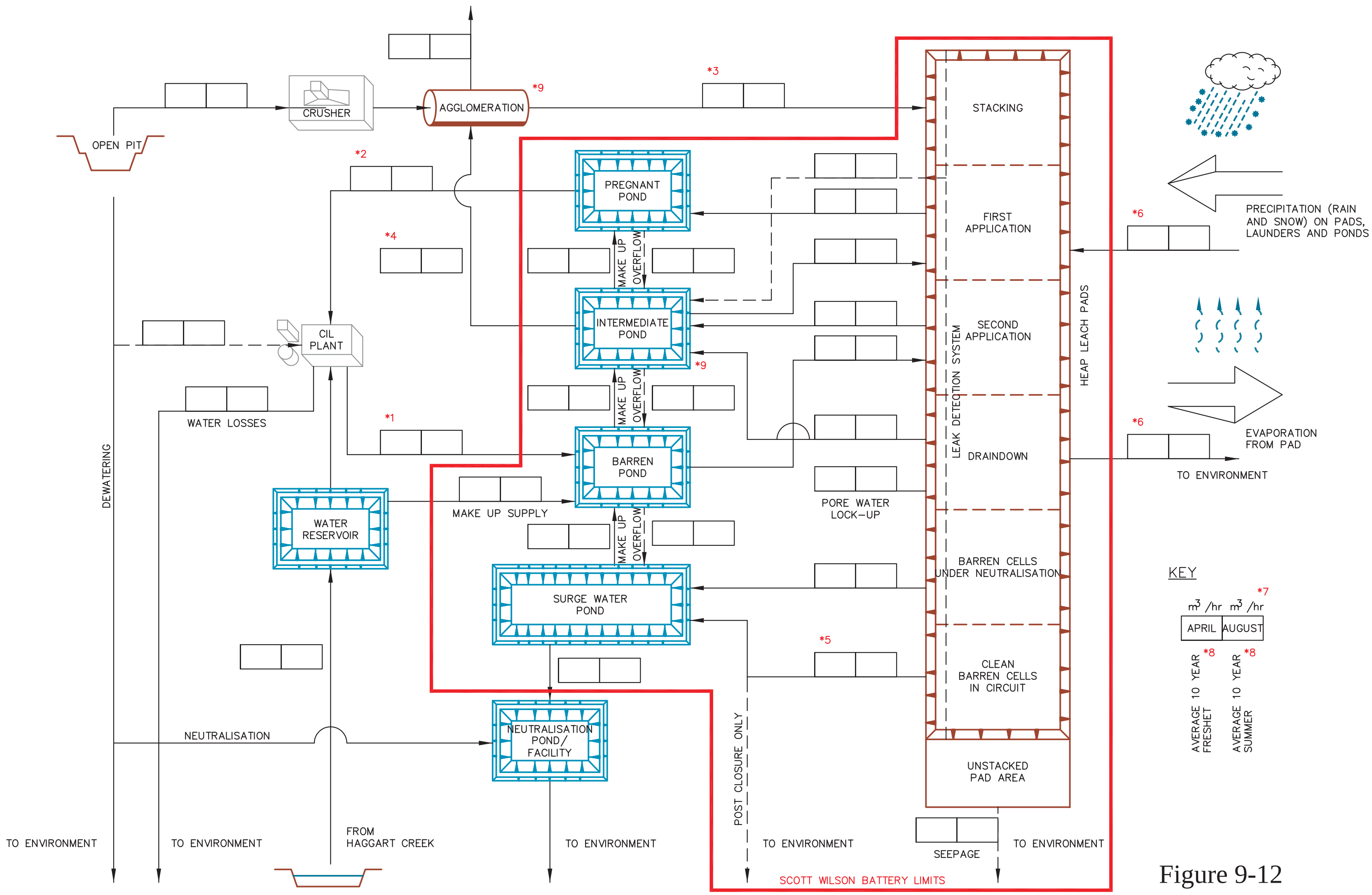

Figure 9-12

CASE	SUMMER 10 YEAR AVERAGE

NOTES
*1 KCA IRRIGATION RATE
*2 KCA CIL PLANT DEMAND
*3 KCA WATER IN ORE
*4 KCA AGGLOMERATION DEMAND
*5 KCA DETOXIFICATION TIME
*6 STANTEC DATA
*7 PROJECT UNITS
*8 PROJECT DESIGN BASIS
SNOW AND STORM IN MAY
*9 KCA REQUIREMENTS

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Process Water Balance

June 2010

The above process will be repeated until cessation of operations, when the heap will be rinsed and treated until the quality of the untreated rinse water meets the required regulatory requirements for release.

IN-HEAP POND SIZE SELECTION

The in-heap pond is designed to provide for the fluctuating water volumes in the system caused by precipitation events, operational parameters, dead storage and heap drain-down. The gross volume of the in-heap pond will be 3,247,000 m^3. The available volume is the difference between the saturated water content (22%) and the residual water content (8.6%), which results in a net volume of 435,000 m^3. A summary of the pond volume calculations and assumptions are summarised below:

- *Dead Storage.* Pumps require a minimum operating head, which results in a volume that cannot be pumped. The facility has been designed with a sump to minimise this volume and it is assumed to be negligible (less than 100 m^3).

- *Minimum Operational Volume.* Based on ensuring the supply of solution to the ADR plant for a period of 2 days at an abstraction rate of 1,300 m^3/hr, a minimum operational volume of 61,680 m^3 is required.

- *Maximum Operational Volume.* To provide the required storage for snow melt, the in-heap pond should be at minimum operational volume by the end of April. To achieve this for Phase 1, a maximum operational volume of 215,000 m^3 is required in October of each year to be able to accommodate the snowmelt.

- *Storm events.* The total rainfall in a 24-hour, 1 in 100 year storm event is 60 mm. For Phase 1, the heap leach area is 300,000 m^2, which results in a storm water volume of 18,000 m^3.

- *Heap Drain-down.* In the event of an operational power loss where pumping of the solution stops, the saturated heap will continue to drain-down. The worst case scenario is where drain-down occurs from the highest lift. The maximum volume of solution within the pore space that will be released from the heap for Phase 1 (30 m lift height) is assessed as 188,000 m^3 based on the difference between the leaching (13.5%) and residual moisture content (8.6%).

- *Freeboard.* If the in-heap pond reaches the spillway level, a further depth of 1 m is required for the overflow to reach the maximum capacity of the spillway pipe. An additional 500 mm freeboard is provided.

In normal operating conditions the in-heap pond can store freshet, storm and drain-down volumes. For Phase 1, the in-heap pond (435,000 m^3) can store the combined worst case scenario of maximum operational volume, storm event and drain-down (426,000

m^3). In Phases 2 and 3, this combination will result in the in-heap pond discharging via the spillway into the events ponds, which provides additional storage.

FURTHER WORK

Optimisation and improvements to the solution management will be undertaken during feasibility study and could include:

- confirming sources of winter make-up water to reduce the maximum operating volume
- consideration of inter-lift liners to reduce the heap drain-down volume
- verifying the residual, leaching and saturated moisture contents and the variability under the varying pressures within the heap
- assess viability for removal of snow from the HLF
- developing management criteria for solution volumes to address annual and seasonal variations, i.e., to establish rules for controlling pond levels (make-up water and treat and release) in advance of freshet and storm events and planned shut downs
- assess the events ponds for winter plant drain-downs, and
- review the potential for collector pipes on the side valley with separate collector pipes to direct the flow by gravity direct to the plant. It may be feasible to use these collectors to intercept the flow from specific heaps and thus manage the various solution grades.

LEACHATE COLLECTION SYSTEM

To provide the required flow to the leachate collection sump, a pipe network will be provided beneath the heap (Figure 9-13). Pipes will also be provided up the slope of the heap to reduce the phreatic surface and reduce the retention time of solution in the heap. The pipes will be located immediately above the liner, within the liner cushion layer and consist of:

- 100 mm diameter HDPE perforated pipes at 25 m centres placed in a 300 mm wide by 600 mm deep trench backfilled with clean gravel, connecting to
- 300 mm diameter HDPE un-perforated collector pipes placed in a 600 mm wide by 600 mm deep trench; backfilled with excavated material;

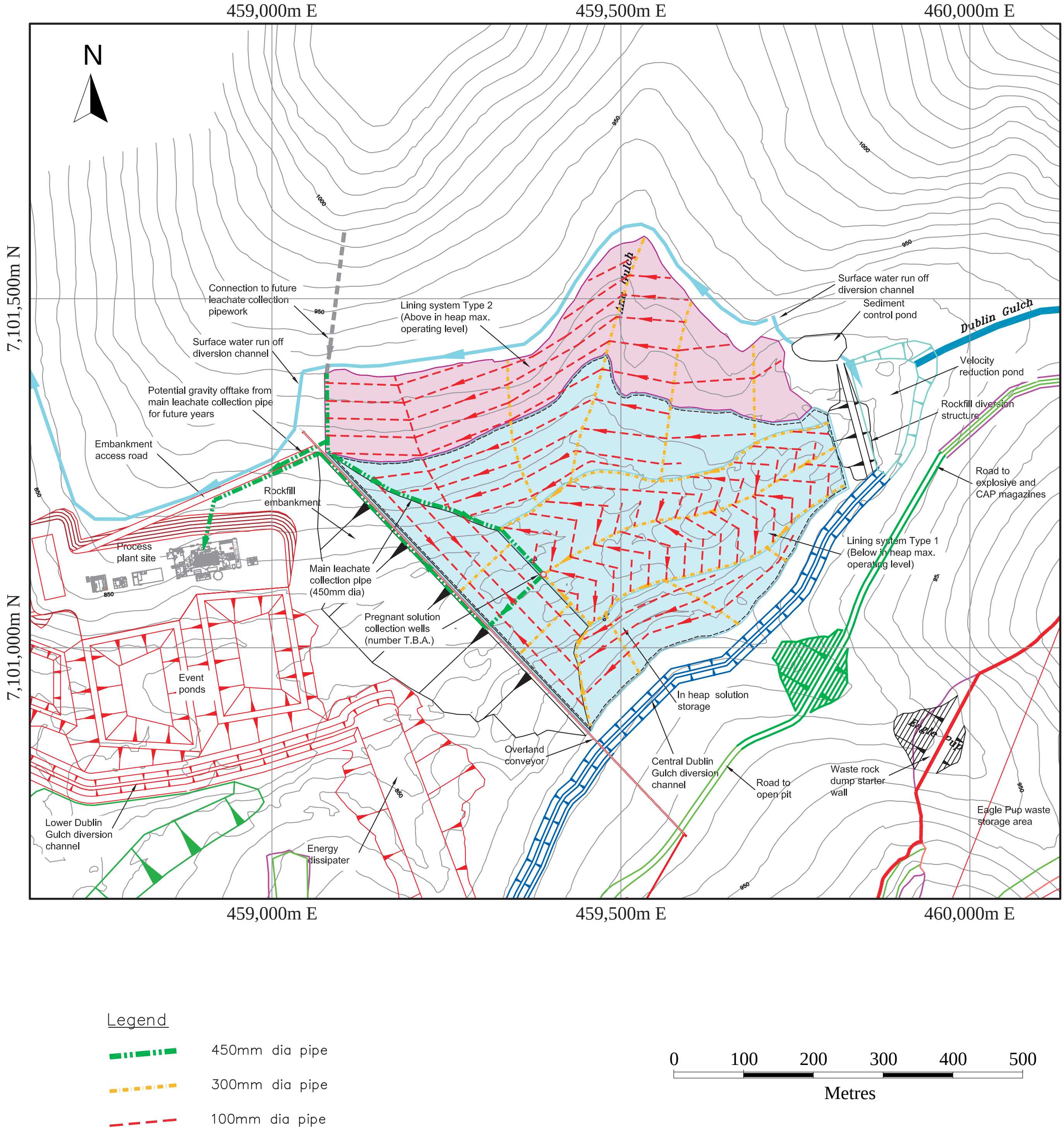

Figure 9-13

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Leachate Collection and Removal System Pipework Layout at 2014 Stack Height

June 2010

For the high earth pressure in the heap, creating a trench for the pipes is important to prevent crushing of the pipes, i.e., the cushion layer will be placed first and compacted, with the pipes placed in excavated trenches.

SEDIMENT CONTROL

Sediment control comprises two key elements

- runoff diversion and sediment control features, and
- infrastructure surface runoff collection and SCPs.

These structures will prevent sediment impacting the environment, and will be constructed at locations to prevent sediment from entering streams at source, or prior to runoff discharge into a natural water courses.

Sediment control works at site will include minimizing land clearing in advance of heap expansion, provision of silt fences, location of temporary diversions, stabilising diversion channels, temporary piping to the SCPs, etc. These works will be detailed as part of feasibility design.

Runoff from undisturbed areas above the catchment of the HLF and WRSAs is conveyed through channels, provided with erosion protection and routed through a SCP before release. When the facilities are raised, these same channels are used to intercept runoff from the disturbed catchments. The runoff diversions have not been detailed as part of this study and are shown only on the general arrangement drawings.

Runoff from the heap leach, although unlikely, will be prevented from discharging into the environment by constructing a minimum 1 m high bund wall around the toe of the HLF.

The highest potential for generating sediments is during construction of the facilities when topsoil is removed and the subsoil disturbed. Since the HLF and WRSAs will be constructed in phases throughout the mine life, interim stages require additional sediment control works. Sediment control works constructed at the start of the works are designed to take into account the phased construction.

There are two key SCPs;

- the HLF and plant site SCP, and
- the WRSAs and open pit SCP.

There will also be additional, smaller, SCPs or other appropriate sediment control measures for roads.

The volume required for the HLF and plant site SCP varies throughout the project. The largest capacity required is 130,000 m^3 for construction of the Dublin Gulch diversion. Throughout the remainder of the project, the capacity required is 30,000 m^3. Since the larger capacity is for a relatively short duration, it is proposed to make use of one of the events pond (capacity 100,000 m^3) and provide a permanent SCP for the remaining 30,000 m^3.

The start-up construction sequence ensures that sediment control is provided ahead of the main works. The main SCP will be constructed first, to enable works at the plant site and HLF to commence. Secondly, the Dublin Gulch diversion will be constructed. This will convey the drainage from the SCP at the toe of the Eagle Pup WRSA, which is to be constructed third. Runoff from the Platinum Gulch WRSA will be directed into a small SCP, and then directed down to the main SCP, along with water from the open pit.

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APPENDIX R15C

Geotechnical Design Basis for Mine Site Infrastructure in the Project Proposal

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BGC Project Memorandum

To:	**Victoria Gold**	**Doc. no:**	**0792-004-M6.2-2011**
Attention:	**Mike Padula**	**cc:**	**Marten Regan, Wardrop** **Glen Barr, Stantec**
From:	**Pete Quinn**	**Date:**	**May 11, 2011**
Subject:	**Eagle Gold – Geotechnical Design Basis for Mine Site Infrastructure in the Project Proposal**		
Project no:	**0792-004**		

1.0 INTRODUCTION

1.1. General

BGC Engineering Inc. (BGC) has been retained by Victoria Gold Corp. (Victoria) to complete geotechnical investigations for the open pit and mine site infrastructure for the Eagle Gold project at Dublin Gulch, Yukon to support prefeasibility study (PFS) and feasibility study (FS) level designs.

BGC undertook subsurface investigations for the open pit and mine site infrastructure at the PFS level in 2009, and provided geotechnical recommendations for the pit walls and pit depressurization. The geotechnical basis for mine site infrastructure, including the heap leach pad and associated facilities, waste rock storage areas, crushing and conveying facilities, roads, buildings and other related facilities, was developed by Scott Wilson RPA (SWRPA). Their geotechnical design basis was supported by investigation work completed by BGC in 2009, and also relied on prior geotechnical work conducted by Knight Piesold and Sitka Corp. in 1995 and 1996.

Ore will be extracted from an open pit located on the ridge line above Dublin Gulch to the south, and between the headwaters of Eagle Pup and Platinum Gulch. Gold is to be extracted from the ore by heap leaching using a valley fill heap located in a small valley drained by Ann Gulch, spanning over and partially filling the middle reach of Dublin Gulch.

The project will involve a number of other major facilities, including: two primary waste rock storage areas (one in Eagle Pup, and one in Platinum Gulch); a water diversion system to carry surface water from the upper reach of Dublin Gulch around the heap leach pad;

process water ponds for management of heap solution; a process plant; crushers, conveyors and stockpiles; borrow pits; temporary spoil stockpiles; and miscellaneous other facilities, including truck shop, offices, warehouse space, fuel and water tanks, power and water transmission facilities; and explosives management facilities. The General Arrangement (GA) developed in the prefeasibility study (PFS) design by Scott Wilson RPA (SWRPA, 2010) is illustrated in Drawing 01, which also illustrates the distribution of available subsurface information.

The PFS engineering designs prepared by SWRPA (2010) were described at a relatively high level in the Project Proposal (Stantec 2010). Significantly more detail regarding engineering assumptions is provided in the PFS report (SWRPA 2010). This memo presents and summarizes the geotechnical design basis developed by SWRPA, as presented in the PFS report. This memo does not present any engineering work done by BGC.

2.0 SITE CONDITIONS

2.1. Background Reports

Site investigations have been completed at the project site over several years by different geotechnical firms working for different mining companies. Subsurface data are available in most areas of proposed development, and have been obtained by a variety of intrusive techniques. Geotechnical site conditions at the Eagle Gold site are described in several reports:

- Report on 1995 Geotechnical Investigations for Four Potential Heap Leach Facility Site Alternatives, First Dynasty Mines, and Dublin Gulch Property. (Knight Piesold, 1996a).
- Report on Feasibility Design of the Mine Waste Rock Storage Area, First Dynasty Mines, and Dublin Gulch Property. (Knight Piesold, 1996b).
- Field Investigation Data Report, Dublin Gulch Project, New Millennium Mining. (Sitka Corp, 1996).
- Hydrogeological Characterization and Assessment, Dublin Gulch Project, New Millennium Mining. (GeoEnviro Engineering, 1996).
- Site Facilities Geotechnical Investigation Factual Data Report. Eagle Gold Project, Victoria Gold Corporation. (BGC Engineering Inc. 2009).
- Project Proposal for Executive Committee Review. Pursuant to the Yukon Environmental and Socio-Economic Assessment Act. Eagle Gold Project, Victoria Gold Corporation. (Stantec. 2010).
- 2010 Geotechnical Investigation for Mine Site Infrastructure, Factual Data Report. Eagle Gold Project, Victoria Gold Corporation. (BGC Engineering Inc. 2011).

2.2. Generalized Site Conditions in the Mine Site Area

The site topography involves moderate to high relief, with ground elevation varying from approximately 800 to 1400 m ASL.

Ground conditions are highly variable across the site. Further, due to limitations of the drilling equipment used and the evolution of the general arrangement, there is limited information and significant uncertainty in the subsurface conditions at many areas of the site.

Groundwater was observed at varying depths across the site, generally close to the elevation of streams in the valley bottoms. On the hillsides the water table was often below the depth of test pit excavation and therefore was not encountered.

Overburden soils encountered on the sloping ground at the mine site typically consist of a veneer of organic soils overlying a blanket of colluvium, which overlies weathered bedrock. Glacial till is generally encountered on the lower flanks of the north- and west-facing slopes north and west of the proposed open pit, above Dublin Gulch and Haggart Creek. Placer tailings (fill) cover most of the valley bottom of Dublin Gulch and Haggart Creek. Alluvial soils are occasionally encountered along the undisturbed valley-bottom areas.

The bedrock encountered at the mine site is classified as either intrusive (i.e. granodiorite, typically in the uplands) or metamorphosed sedimentary rock, with a variably deep weathering profile. The intact rock strength of the encountered rock types is highly variable, with observed strength typically ranging between R0 class (i.e. corresponding to < 1 MPa Unconfined Compressive Strength, UCS) and R4 (50-100 MPa).

Permafrost is present in the area, and is warm (i.e. typically 0 to -1 degrees Celsius), discontinuous and occasionally contains excess ground ice. Although not specifically controlled by slope aspect, permafrost is found more frequently in the north-facing lower slopes above the south side of Dublin Gulch.

The terrain involves moderate relief, including some steep slopes. A number of geological hazards have been identified across the mine site area, as identified by Stantec (2010). These are illustrated in Drawing 02.

3.0 GEOTECHNICAL DESIGN BASIS FOR MINE SITE INFRASTRUCTURE

3.1. General

The engineering for mine development evolves through several stages of planning and design, from preliminary scoping assessments, through prefeasibility (PFS) and feasibility (FS) design, to basic engineering and/or detailed design, and finally to construction and operation. The project described in the Project Proposal reflects the PFS level of design. It should be pointed out that BGC did not develop the geotechnical design basis for the PFS. However, BGC is currently working with Victoria Gold's design team on the FS level of design, which will represent a refinement of the PFS design. Thus, this memo summarizes the work of others.

The proposed General Arrangement for the mine site infrastructure is illustrated in Drawing 01, which also shows the distribution of all subsurface data (i.e. boreholes and test pits). Drawing 02 shows the location of geological hazards identified by Stantec (2010).

3.2. Heap Leach Pad, Water Diversion and Impoundment Structures

3.2.1. General

The complete design basis for the facilities associated with heap leaching, as developed and reported by SWRPA (2010), is presented in Appendix A, and summarized in more concise form by SWRPA in Appendix B. Issues of relevance to the geotechnical design are summarized here in point form, following the same outline as used by SWRPA in the PFS report. Interested readers may refer directly to Appendices A and B if further detail is required to understand the context associated with specific issues.

The proposed Heap Leach Facility (HLF) is located approximately 1.2 km north of the Eagle Zone orebody. The majority of the HLF is in the Ann Gulch catchment, with its base in the valley floor of Dublin Gulch at an elevation of 840 m above sea level (m ASL), extending up Ann Gulch to an elevation of 1080 m ASL.

The HLF comprises a number of elements, including: a rock-filled embankment to provide stability; a lined storage area for the ore to be leached; an in-heap storage pond to contain the pregnant solution; pumping wells for extraction of the solution; ponds to contain excess solution in extreme events; diversions; sediment control ponds (SCPs); and leak detection, recovery and monitoring systems.

3.2.2. Site Selection

Site selection for the HLF was based on a two stage assessment of the suitability of six potential locations. The first stage involved an engineering assessment, weighing the options against engineering, geotechnical and closure considerations. This first stage resulted in the six options being grouped into two sets of options: three higher scoring Group 1 options; and, three lower scoring Group 2 options.

The second stage of assessment involved a project-wide assessment of impacts from the various HLF site options. This stage considered a variety of factors with an impact on mining operations, other infrastructure layouts, mineral resources and the environment. The results of both stages of assessment are tabulated in Appendix A.

The results of the project-wide review of the three leading Group 1 sites established a clear preference for Option 6 – Ann Gulch. This alternative was therefore carried forward for prefeasibility engineering.

3.2.3. Site Characteristics

The topography and geology are described for the HLF in Appendix C, including a discussion of observations from subsurface investigation. Basic hydrology and hydrogeology characteristics are presented. The HLF components are affected by discontinuous permafrost, which may contain excess ice. Areas of permafrost with excess ice require treatment by stripping to encourage thawing and drainage, or excavation and removal to expose thaw stable soils before covering with waste rock. Seismic design parameters are presented as peak ground accelerations for the Design Basis Earthquake (0.078 g) and Maximum Design Earthquake (0.10 g).

3.2.4. Heap Leach Facility Design

The design basis for the HLF is summarized in Appendix B, which includes standards, objectives and operating parameters used for the PFS design. The general arrangement for the HLF facilities is illustrated in Figures included in Appendix A, and includes the following primary components:

- Heap Leach Pad;
- Sediment Control Ponds and Surface Runoff Diversions;
- Events Ponds;
- Confining Embankment;
- Lining System; and
- In-heap Pond.

3.2.5. Liner System Design

The heap leach pad, in-heap pond and other solution control ponds will be provided with an engineered lining system to prevent loss of solution and contamination of groundwater. The lining system will cover approximately 87 ha, and consist of a multiple composite polyvinyl chloride (PVC) liner system with dual leak detection.

The liner system has been designed to achieve compliance with Nevada State guidelines, as these were used as the basis for design and permitting of the Brewery Creek HLF, which is understood to be the only HLF permitted in Yukon. Estimated liner leakage rates are based on the assumption of “one [puncture] hole per acre’’ with an effective area of 10 mm^2 for a liner placed with a high level of quality control.

The HLF liner system design provides: a double composite liner in the upslope area of the HLF pad (above the in-heap pond); and, a triple liner in the in-heap storage pond. The liner system in the heap leach pad upslope area includes, from top to bottom: 1 m thick ore cushion, with leachate collection and removal system (LCRS) pipework; primary composite liner with 1 mm PVC geomembrane and 300 mm compacted silt; geotextile separator; primary leak detection and recovery system (LDRS) comprising 300 mm thick fine gravel to coarse sand with pipes, or geonet on steep slopes; and, secondary composite liner with 0.75 mm PVC geomembrane and 300 mm compacted silt.

The in-heap storage pond area liner design includes an additional liner element above the primary composite liner, comprising an upper 0.75 mm PVC geomembrane over an upper LDRS gravel layer.

The event ponds will be double-lined and will incorporate a geonet separation layer. The liner system includes: primary 2 mm thick high density polyethylene (HDPE) geomembrane liner; primary LDRS geonet layer; secondary 1 mm thick HDPE geomembrane; and, 300 mm compacted silt.

The cushion layer is a load-bearing drainage layer at the bottom of the ore, above the composite liner system, in which the LCRS pipework can be installed. It will be formed from coarse sand or fine gravel sized durable ore.

PVC geomembrane has been selected for the liner systems due to its good cold weather performance, high interface strength and chemical resistance. All exposed areas of PVC need to be covered soon after installation to protect from ultraviolet radiation. HDPE geomembrane has been selected for the events ponds due to good long term ultraviolet resistance, chemical resistance and performance as an exposed pond liner. A thicker liner (2 mm) has been selected due to increased exposure to potential wear and the elements.

The LDRS layers will comprise free draining fine gravel to coarse sand, with typically 90 % finer than 5 mm particle size, and less than 10 % finer than 1 mm. Where the liners are placed on steeper slopes, such as along events ponds side slopes, a geonet will be used as a drainage layer in place of coarse sand or fine gravel.

The compacted silt layers will be prepared to form a competent low permeability base to receive the PVC geomembrane liners to form a composite liner system. The compacted silt will have a minimum thickness of 300 mm, and a target permeability of 1×10^{-7} m/s, consistent with Nevada guidelines for composite liner systems.

A layer of non-woven geotextile is included at the interface between the compacted silt and underlying fine gravel to coarse sand LDRS layer to provide separation and prevent particle migration.

3.2.6. Leak Detection and Recovery Systems Design

Separate LRDS systems will be installed below each liner, and all collected solution returned to the heap. The LDRS will consist of a series of 100 mm pipes within a 300 mm thick layer of gravel, feeding to a 200 mm collector pipe. Leakage will be collected in sumps and pumped back to the heap.

The in-heap liner will have a second LDRS beneath the upper liner, with more pipes to account for potentially higher flow. The proposed design calls for down-hole pumps on the embankment slope. Three pipes have been provided for pumping to provide redundancy in the event of blockage.

The quality and quantity of solution returned in the LDRSs will be monitored in relation to the location of the heap being irrigated at the time. Monitoring boreholes downstream of the heap leach facility and events ponds will be sampled regularly as backup for LDRS monitoring.

3.2.7. Dublin Gulch Relocation Design

The relocation of the Dublin Gulch streambed is designed to convey streamflow safely past the HLF. The diversion will include: an upstream inlet structure; a 900 m long diversion channel; channelization of the Stuttle Gulch flow with additional energy dissipation; an enlarged and re-routed channel diversion (the “lower diversion”) around the Event Ponds and Finishing Ponds; and, a reconnection of the flow into the existing course of Dublin Gulch.

The diversion is designed for the Probable Maximum Flow (PMF) of 105 m^3/s, since it remains post-closure. The inlet includes a 12 m high diversion structure, constructed of rock fill with upstream filter zone and HDPE liner on the upstream face, constructed on bedrock after removing placer tailings and alluvial soils from the foundation. The 900 m long diversion structure will run nearly parallel to slope contours at 1:100 grade to Stuttle Gulch. Up-slope cut surfaces will be provided with erosion protection measures, and flow from disturbed surfaces will be channeled through a sediment control pond (SCP).

The following design aspects require further development in the feasibility study: selection of backfill material; further design of Stuttle Gulch erosion protection measures; further geotechnical data along the proposed diversion; and, design of the lower Dublin Gulch diversion with regard to providing suitable fish habitat.

3.2.8. Stability Design

The HLF is designed against failure of the ore and/or the foundations, considering operational design events and post closure extreme events, of seismic loading under Operational Design Event and Maximum Design Event (ODE and MDE), Probable Maximum Flood (PMF) and Probable Maximum Precipitation (PMP). The following aspects were considered: ore material properties particularly strength; geometry and loading cases (static and seismic); shear strength of soil/liner and ore/liner interfaces; location of phreatic surfaces; deformation strength changes; and normal loading changes in geosynthetic strength properties.

The following stability issues require further assessment at the feasibility study stage: permanent displacement assessments to address post seismic deformation strengths; and, shear testing of the compacted soil/geosynthetic liner interface.

Failure modes considered at the PFS stage include: circular and non-circular failures contained within the ore; wedge failures through the ore along the ore/liner interface; circular and non-circular failures through the ore and into the foundation materials; and, liquefaction of the ore.

Stability analysis adopted the following approach: identification of critical stability sections; selection of methods and appropriate material types and geotechnical parameters; identification of boundary conditions and loading cases; and, evaluation of stability against design criteria.

A deterministic limit equilibrium approach was selected for stability analysis, applying the following Factors of Safety: 1.5 for static loading of impounding structures; 1.3 for static stability of non-impounding structures; and, 1.15 for seismic loading. A pseudo-static approach was used to simulate earthquake loading. More detailed analysis, including deformation analysis, will be required for the feasibility study.

Piezometric water levels were assumed at 5 m above the liner. Further work is required at the feasibility study to conduct geotechnical testing of the ore, seepage analysis and further stability analysis.

Geotechnical material parameters used for stability analysis are summarized in SWRPA's Table 9-4, which is presented as Figure 1.

SCOTT WILSON RPA *www.scottwilson.com*

TABLE 9-4 GEOTECHNICAL PARAMETERS
Victoria Gold Corp. – Eagle Gold Project

Material Type	Unit Weight (kN/m^3)	Cohesion (kN/m^2)	Friction Angle (°)	Material Description	Ref
Ore	18	0	32	In the absence of laboratory testing, based on previous slope stability analysis parameter	4
Placer Tailings	20	0	37	Sand and Gravel (SP); based on EBA Particle Size Analysis: generally, < 10% fines, 20 - 60% sand and 30 to 70% gravel.	1
Colluvium (Type 1)	14	38	28	Gravelly Silt (ML). Generally, consists of > 30 - 50% fines (silt and clay) content.	1
Colluvium (Type 2)	22	0	36	Sand and Gravel (SW, SM, GW, GM); with occasional silt, medium compacted, unsaturated. Generally, consists of 30 - 50% fines (silt and clay) content.	1, 4
Weathered Bedrock	22	0	38	Weathered Granodiorite, described as sand (SP) with occasional boulders and cobbles. Strength = S2 (approximately 25 MPa), Weathering Grade 4 -5.	
Bedrock	26	Based on shear strength vrs normal strength envelope		Based on field estimation and observations, bottom of DG option 6; in the absence of laboratory strength properties; .RocLab used. UCS = 45 MPa, GSI =60, m_i = 9, D = 0, based on similar materials	2
Waste Rock	26	Based on shear strength vrs normal strength envelope		In the absence of laboratory rock strength, based on UCS = 45 MPa with Barton and Kjærnsli (1981) strength model	3
Compacted Sand and Gravel	24	0	40	In the absence of laboratory testing, based on dense Colluvium type 2 and previous slope stability	4

References

1. Carter, M.; Bentley, S.P., 1991. Correlations of soil properties. Pentech Press. 1st Edition.
2 SRK. 2008. NI 43-101 Preliminary Assessment Dublin Gulch Property – Mar-Tungsten Zone Mayo District, Yukon Territory, Canada (Table 17.2.2.2.)
3. Barton, N., and Kjærnsli, B., 1981. Shear strength of rockfill. J. of the Geotech. Eng. Div., Proc. of ASCE, Vol. 107:GT7: 873-891. Proc. Paper 16374, July.
4. Rescan. 1996. Dublin Gulch Prefeasibility Study - Volume 2. (Table 7.9.1)

Figure 1 Assumed Geotechnical Parameters from PFS Report (SWRPA 2010)

3.2.9. Confining Embankment Design

Design of the HLF confining embankment assumes a slope of 3H:1V to allow for use of a variety of earth and mine waste rock or rock fill materials to be used. Toe- and side-drains will be provided to intercept water from the abutments. Groundwater drainage will be used beneath the embankment and at the inlets to the Dublin Gulch diversion and along the route of the diversion.

The main source of earth/rock fill for embankment construction will be overburden and waste rock generated during mine development. Characteristics and availability require confirmation. The embankment requires a transition zone on the upstream face where particle size reduces from boulder size in the rock fill to silt in the lower liner. Two filter zones have been assumed, and this will need to be reviewed at feasibility and detailed design, and confirmed during construction.

Foundation preparation will consist of removing loose sand and gravel from the valley floor, potentially to bedrock, at a depth of 2 t 10 m. Topsoil will be removed from the abutments to expose competent material.

3.3. Waste Rock Storage Areas

The complete design basis for the Waste Rock Storage Areas (WRSAs) is presented in Appendix C. Issues of relevance to the geotechnical design are summarized here following the same outline as used by SWRPA in the PFS report (SWRPA 2010). Interested readers may refer directly to Appendix C if further detail is required to understand the context associated with specific issues.

General

Four sites were considered by SWRPA: Eagle Pup, Platinum Gulch, Stuttle Gulch and Stewart Gulch, and compared based on capacity, location and geology. Stewart Gulch is the farthest from the proposed open pit and therefore the least economically attractive waste rock storage area. Placing waste rock in Stuttle Gulch would interfere with crushing and conveying operations. Based on these considerations, the Eagle Pup and Platinum Gulch sites were selected for waste rock storage.

The WRSA planned at Eagle Pup will store approximately 55 Mt of waste rock, with capacity for additional waste rock. The WRSA at Platinum Gulch has been designed to store approximately 11 Mt of waste rock. Platinum Gulch WRSA will be developed first, followed by Eagle Pup WRSA. Waste rock will be deposited year-round at roughly 10,000 m^3/day. The dumps will be constructed in lifts with maximum height of 100 m, with benches between successive lifts to provide overall slopes of 2.5H:1V.

Site Characteristics

The topography and geology are described for both WRSAs in Appendix C, including a discussion of observations from subsurface investigation. Basic hydrology and hydrogeology characteristics are presented. Both WRSAs are affected by discontinuous permafrost, which may contain excess ice. Areas of permafrost with excess ice require treatment by stripping to encourage thawing and drainage, or excavation and removal to expose thaw stable soils before covering with waste rock. Seismic design parameters are presented as peak ground accelerations for the Design Basis Earthquake (0.078 g) and Maximum Design Earthquake (0.10 g).

Design Basis

This section of the PFS report presents assumed design criteria and operational parameters. Those pertinent to the geotechnical design basis include:

- Facilities to be developed in stages over time;
- Drainage below the WRSAs to be collected and conveyed effectively;
- Presence of permafrost to be addressed, and appropriate foundation drainage requirements to satisfy stability criteria;
- All aspects to be monitored to ensure design objectives are met;
- Several operational assumptions guide the design:
    - Waste rock production schedule depends on outputs from design and operation of the open pit;
    - Total waste rock production estimated as 65 Mt, with average production of 8 Mt per annum;
    - Hauling and placement of waste rock will occur 365 days/year;
    - Placement of waste materials in benches up to 100 m, primarily by end-dumping from the surface of the advancing lift; and
    - Waste materials will be comprised of variable grain sizes and rock types (granodiorite and metasediments) up to boulder size.

WRSA Design

Design considerations relevant to the geotechnical design included in the pre-feasibility study by SWRPA (2010) are outlined in Table 1 below. Additional details, including conceptual drawings, are available in Appendix C.

Table 1 Summary of Geotechnical Design Considerations as extracted from SWRPA PFS (2010)

Design Component	Notes
General Arrangement	WRSAs include the following elements: rock dump and foundation drainage; starter embankments; sediment control pond; surface runoff diversion channels; and, closure works. The Eagle Pup WRSA is contained within the lower catchment area of Eagle Pup, with plans for 60 Mt at a density of 1.9 t/m^3, and phased construction behind a starter embankment traversing the valley. The Platinum Gulch WRSA is located within the upper catchment of Platinum Gulch.
Rock Dump and Foundations	To be constructed through a hybrid of ascending lifts waste rock terraces and in some areas descending platforms and wrap-arounds. This approach is expected to mitigate against rapid ground pressure build-up, thaw-instability beneath the waste rock, and uncontrolled segregation which would have implications for drainage.
Stability Considerations	The WRSAs are designed against failure of the waste rock and/or foundations. The design considers the operational design events and post closure extreme events, of seismic loading under and Operational and Maximum Design Earthquake (ODE and MDE) and Probable Maximum Precipitation (PMP). The following items have been identified as being key in determining stability: waste rock material properties, particularly strength properties; geometry and loading cases (static and seismic); location of phreatic surfaces; pore pressures and thaw instability in the foundations; mechanisms of failure; and, deformation strength changes.
Stability Analysis – Material Properties	Waste rock is expected to contain coarse, angular fragments of metasedimentary and intrusive rock up to 1 m in diameter. Other than the fine-grained metasediments, the waste rock is assumed to be primarily clean, durable and free of significant fines content. Assumed material properties are summarized in Figure 2. The assumptions regarding friction angle and thickness of superficial soils are assessed to be the most critical to WRSA stability. Previous studies had adopted a friction angle of 30^o for surficial soils and 40^o for the underlying bedrock.
Piezometric Surfaces	A rock drain is proposed along the valley floors to preclude the presence of a piezometric surface within the waste rock.
Pore Pressure Development from Thawing	Analyses have accounted for development of pore pressures in the early years from thawing of an assumed extensive seasonal frost zone of up to three meters depth.
Analysis	Stability analysis for static and pseudo-static (earthquake) conditions were conducted in previous studies for a variety of operational and post closure configurations. These analyses conclude a 2H:1V overall slope achieves the minimum factors of safety against slope stability under static and pseudo-static events. The most marginal stability cases involve the early static loading as the WRSA is developed through the valley area and encounters thaw instability and/or weaker foundation materials. Satisfactory stability is achieved only by ascending terraces, with gradual loading of foundations, removal of organic material and unsuitable alluvial deposits, and controlled deposition over seasonal permafrost.
Rock Drain	The Eagle Pup lower catchment will be progressively stripped of organic

Design Component	Notes
	material and enhanced with selected durable granular waste rock.
Starter Embankment	An 18 m high starter embankment, consisting of durable and clean waste rock of selected particle size range will be designed to ensure good toe drainage and provide a stable toe for the operational and rehabilitated (post closure) WRSA.
Monitoring	The performance of the WRSA will be monitored during construction through both survey and geotechnical inspection. Observations will be made to record pore pressure changes, strains and settlements in the WRSAs as possible precursors to major instability.

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TABLE 6-15 WASTE ROCK MATERIAL PARAMETERS COMPARISON (MIN – MEAN – MAX)
Victoria Gold Corp. – Eagle Gold Project

Parameter		BGC (2009)	Sitka Corp (1996)	Knight Piésold (1996)	Reference
Base angle of friction, (°)	Metasediments	32	-	-	1a
	Intrusives	28	-	-	1a
Peak angle of friction, (°)	Metasediments	40	40	42.3	1a, 2, 3b
	Intrusives	40	-	42.3	1a, 2, 3b
Residual angle of friction (°)	Metasediments	35	37	-	1a, 3b
	Intrusives	38	-	-	1a, 3b
Joint Roughness Coefficient (JRC)	Bedrock	11 (55% of the dataset)	-	8 -12 (based on assessment from discontinuity logs)	1b
Uniaxial Compressive Strength, (MPa)	Metasediments	21 -77 -168	86	55 (2a) 55 - 100 -190 (2b)	1c, 2a, 2b, 3a
	Intrusives	3 - 134 - 224	127	63 (2a) 63 - 178 - 260 (2b)	1c, 2a, 2b, 3a
	Weathered Bedrock	-	-	4 - 34 - 93	2b

1a. BGC. 2009. Direct Shear Strength Testing Results.pdf and Direct Shear Results Summary.xls / Direct Shear Strength Testing Results.pdf

1b. BGC. 2009. Rock Mass and Discon Information.xls

1b. BGC. 2009. Point Load Testing Results.xls / Intact Strength.pdf

2a. Knight Piésold. 1996. Dublin Gulch Project - Report on the Feasibility of Heap Leach Pad and Associated Structures. (Report No. 1882/4)

2b. Knight Piésold. 1996. Dublin Gulch Project - Report on the Open Pit Slopes. (Report No. 1882/3)

3a. Sitka Corp. 1996. Pit Slope Re-Assessment- Design Memorandum. (Dated: 18/09/96)

3b.Sitka Corp. 1996. Dublin Gulch Project - IEE Addendum Section 8.0, Eagle Pup MWRSA). (Dated 17/10/96).

Figure 2 Assumed Waste Rock Material Properties from PFS Report (SWRPA 2010)

4.0 CONCLUSIONS

This memorandum has been prepared to summarize the geotechnical design basis for major earthworks structures to be developed as part of mine development at Eagle Gold. It is emphasized that the preceding overview of the geotechnical design basis for mine site infrastructure summarizes the work of others, specifically Scott Wilson RPA.

5.0 CLOSURE

At the request of Victoria Gold Inc., BGC has summarized the geotechnical design basis developed by others for the Pre-Feasibility Study (SWRPA, 2010) and this document does not necessarily reflect the views of BGC.

BGC Engineering Inc. (BGC) prepared this document for the account of Victoria Gold Corp. The material in it reflects the judgment of BGC staff in light of the information available to BGC at the time of document preparation. Any use which a third party makes of this document or any reliance on decisions to be based on it is the responsibility of such third parties. BGC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this document.

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Yours sincerely,

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Knight Piesold, 1996a. Report on 1995 Geotechnical Investigations for Four Potential Heap Leach Facility Site Alternatives, First Dynasty Mines, Dublin Gulch Property.

Knight Piesold, 1996b. Report on Feasibility Design of the Mine Waste Rock Storage Area, First Dynasty Mines, Dublin Gulch Property.

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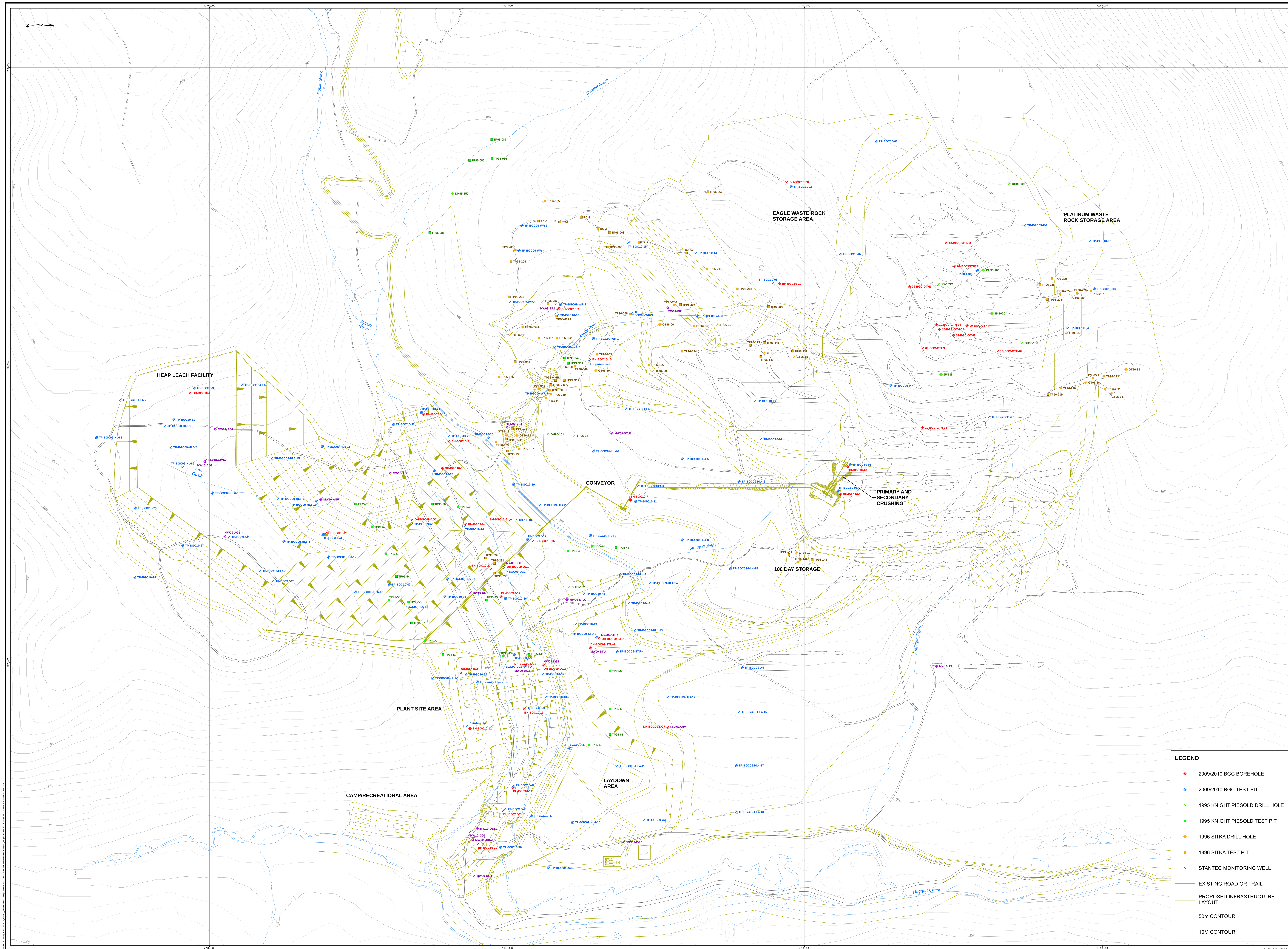
DRAWINGS



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NOTES:
PRE-FEASIBILITY INFRASTRUCTURE LAYOUT RECEIVED FROM SCOTT WILSON, FEB.23, 2011.

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	1:4,000
DATE:	APR 2011
DRAWN:	LL
DESIGNED:	LGT
CHECKED:	AKU
APPROVED:	PQ

PROFESSIONAL SEAL:

DRAFT

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

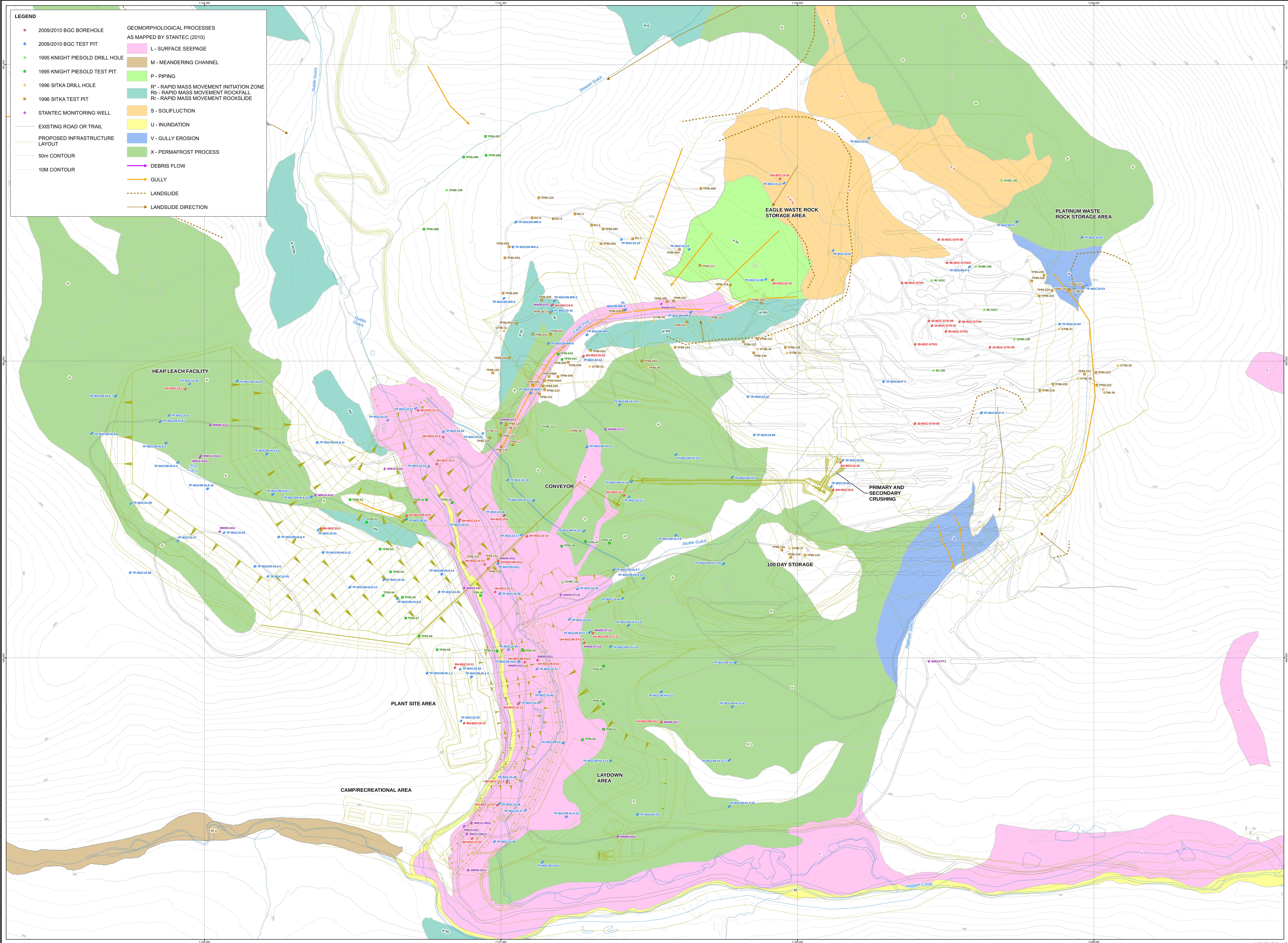
CLIENT:
VICTORIA GOLD CORPORATION

PROJECT:
EAGLE GOLD – GEOTECHNICAL DESIGN BASIS FROM SCOTT WILSON RPA PREFEASIBILITY STUDY

TITLE:
PROPOSED GENERAL ARRANGEMENT OF MINE SITE INFRASTRUCTURE

PROJECT No.:	DWG No.:	REV.:
0792-004	01	

DWG TO BE READ WITH BGC MEMO TITLED "EAGLE GOLD – GEOTECHNICAL DESIGN BASIS FROM SCOTT WILSON RPA PREFEASIBILITY STUDY" DATED APR 2011



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NOTES:
1. PRE-FEASIBILITY INFRASTRUCTURE LAYOUT RECEIVED FROM SCOTT WILSON, FEB.23, 2011.
2. IDENTIFIED GEOLOGICAL HAZARDS ARE FROM TERRAIN MAPPING PRODUCED BY STANTEC (2010).

REV.	DATE	REVISION NOTES	DRAWN	CHECK	APPR.

SCALE:	1:4,000
DATE:	APR 2011
DRAWN:	LL
DESIGNED:	LGT
CHECKED:	AKU
APPROVED:	PQ

PROFESSIONAL SEAL:

DRAFT

BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

CLIENT: VICTORIA GOLD CORPORATION

PROJECT: EAGLE GOLD – GEOTECHNICAL DESIGN BASIS FROM SCOTT WILSON RPA PREFEASIBILITY STUDY

TITLE: GEOLOGICAL HAZARDS AS INTERPRETED BY STANTEC (2010)

PROJECT No.:	DWG No.:	REV.:
0792-004	02	

DWG TO BE READ WITH BGC MEMO TITLED "EAGLE GOLD – GEOTECHNICAL DESIGN BASIS FROM SCOTT WILSON RPA PREFEASIBILITY STUDY" DATED APR 2011

APPENDIX A
SCOTT WILSON RPA PREFEASIBILITY STUDY SECTION FOR HEAP LEACH PAD AND ASSOCIATED FACILITIES

9 HEAP LEACHING

The proposed Heap Leach Facility (HLF) is located approximately 1.2 km north of the Eagle Zone orebody. The majority of the HLF is located in the Ann Gulch catchment, a tributary to Dublin Gulch. The base of the HLF is in the valley floor of Dublin Gulch at an elevation of 840 masl and at full height, the HLF extends up Ann Gulch to an elevation of 1,080 masl.

This section of the report presents the Scott Wilson HLF design, used to support the PFS cost estimates. Summaries of meteorology, hydrology, seismicity, geological, geotechnical, and hydrogeological conditions that were used as inputs to those designs are also presented. These summaries are taken from BGC and Stantec reports, found in the appendices to this report.

The HLF comprises a number of elements: a rock-filled embankment to provide stability to the HLF, a lined storage area for the ore to be leached, an in-heap storage pond to contain the pregnant solution, pumping wells for the extraction of solution, ponds to contain excess solution in extreme events, diversions, Sediment Control Ponds (SCP), and leak detection, recovery and monitoring systems to ensure the containment of solution. An associated structure is the relocated Dublin Gulch waterway (channelled to the south side of the valley).

Engineering of these components is discussed in the following sections and drawings are presented in Appendix F. Capital and operating costs have been prepared and are included in Sections 14 and 15.

PREVIOUS STUDIES

Previous studies undertaken include reports on the 1996 Feasibility design (Knight Piésold, 1996) and the Initial Environmental Evaluation (Sitka, 1996). Reports on investigations, laboratory testing and other information prepared in support of these reports have been reviewed but not referenced.

SITE SELECTION

Site selection for the HLF site was based on a two stage assessment of the suitability of potential locations:

- Stage 1 - an engineering assessment (see Appendix F), and
- Stage 2 - a Project-wide assessment of impacts from the various HLF site options.

POTENTIAL SITE OPTIONS

Following initial screening of a variety of potential heap leach sites in the wider Dublin Gulch catchment area, six sites were considered for taking forward (see Figure 9-1), with four of these selected for the geotechnical investigation, Options 1, 4, 5 and 6. The potential site options for the HLF include:

- Option 1 – Cross valley type HLF within Dublin Gulch (lower valley)
- Option 2 – Cross valley type HLF within Dublin Gulch (mid valley)
- Option 3 – Valley type HLF on Potato Hills within Bawn Boy headwaters
- Option 4 – Side valley type HLF on slopes below the Eagle Zone ore deposit
- Option 5 – Valley type HLF on granodiorite ridge within Olive Gulch headwaters
- Option 6 – Side valley type HLF in Ann Gulch headwaters.

ENGINEERING ASSESSMENT

The engineering assessment considered the factors that influence the suitability of the facility at each location, using a qualitative comparison of each site against a set of significant engineering (cost-related) criteria. These criteria are drawn from Scott Wilson's experience of the design, construction, and closure of heap leach facilities.

A variable degree of compliance was applied in regard to each criterion, with non-compliance scoring negatively (-5) and full compliance positively (+3). The approach aimed to identify favourable sites based on these engineering criteria, thus establishing options for further consideration. Quantitative data were scored on a basis of 1 point per US$1 million of differential cost between options.

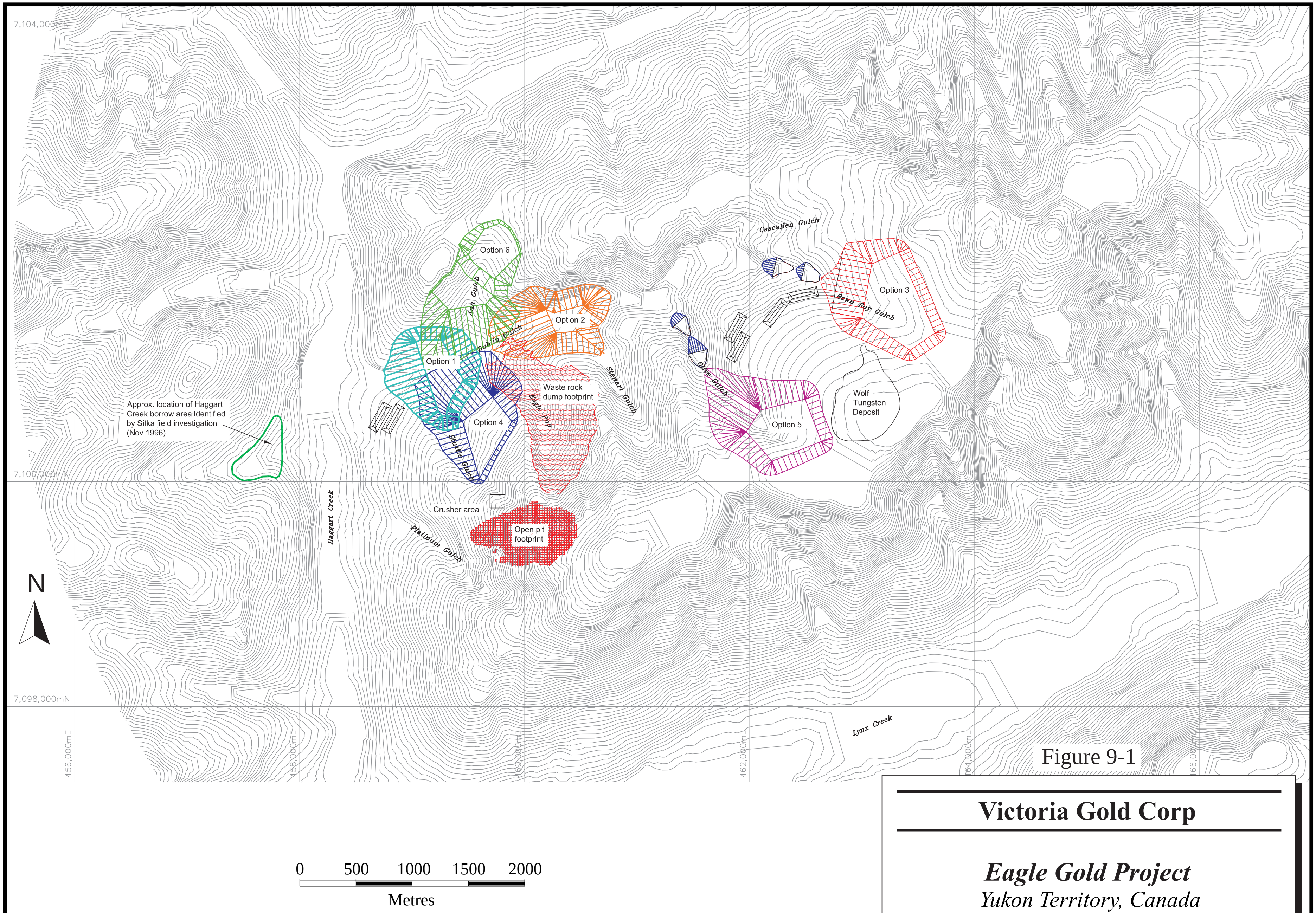

Figure 9-1

Victoria Gold Corp

Eagle Gold Project

Yukon Territory, Canada

Heap Leach Site Options

June 2010

Source: Scott Wilson, KCA, 2010.

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The engineering assessment of alternatives is summarised in Table 9-1 and established a group of Options, numbers 3, 5 and 6 that score significantly higher than Options 1, 2 and 4. From an engineering and construction perspective of the heap leach pad, Option 3 - Potato Hills is the most favourable of the leading group and Options 1 and 2 the least favourable from the latter group.

TABLE 9-1 ENGINEERING SITE ASSESSMENT OF POTENTIAL HEAP LEACH SITE OPTIONS
Victoria Gold Corp. – Eagle Gold Project

Criteria		Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Engineering	Land Surface Area	3	3	3	1	1	1
	Topography	1	-5	3	1	1	1
	Heap leach facility shape	1	1	1	1	1	1
	Materials handling access	3	3	1	3	1	3
	Preparatory Works	1	1	3	1	3	3
Geotechnical	Earthworks for starter embankment	3	1	3	1	1	3
	Other Geotechnical Concerns	-5	-5	3	-5	1	3
Closure		-5	-5	3	1	3	1
	TOTAL	**2**	**-6**	**20**	**4**	**12**	**16**

PROJECT WIDE ASSESSMENT

A Project-wide consideration of the options was undertaken in regard to impacts of the HLF site on:

- mining operations – particularly haulage and access
- other infrastructure layouts
- mineral resources - condemnation requirements, and
- environment – notably on surface and ground water, fauna (fisheries), flora, and visual as well as consideration for archaeological, air quality, sociology.

The scores, as assessed by the various project study leaders (environmental, mining etc.) for the HLF site options are presented in Table 9-2.

TABLE 9-2 HEAP LEACH SITE OPTIONS PROJECT ASSESSMENT SCORING TABLE

Victoria Gold Corp. – Eagle Gold Project

			Engineering			Mining				Environmental										
Option No.	**Name**	**Description**	**Heap Leach Engineering**	**Geotechnical - Ground Works**	**Closure**	**Operations**	**Resources**	**Infrastructure**	**Expandability**	**Fauna**	**Fisheries**	**Flora**	**Archaeological/ Heritage**	**Visual Impact**	**Climatic**	**Remediation Closure**	**Surface Water**	**Ground Water**	**Score**	**Ranking**
			Score	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**		
									Group 1											
3	Potato Hills	Valley	8	9	3	-24	-1	1	3	0	1	-1	0	0	0	3	1	-5	-2	3
5	Olive Gulch	Valley	4	5	3	-16	-2	1	-5	0	1	1	0	0	0	3	1	-5	-9	4
6	Ann Gulch	Side Valley	6	9	1	-2	0	3	1	0	0	1	0	0	0	1	-5	1	16	1
									Group 2											
1	Dublin Gulch	Cross Valley	8	-1	-5					Screened out at Engineering Assessment Stage										
2	Dublin/Eagle Pup	Cross valley	2	-3	-5					Screened out at Engineering Assessment Stage										
4	Eagle Zone	Side Valley	6	-3	1	0	-1	3	1	0	0	1	0	0	0	1	-5	1	5	2

CONCLUSIONS

The results of the Project-wide review of the leading three sites established a clear site location preference in Option 6 - Ann Gulch, with similar neutral scores as compared to other sites, but much lower impacts on (costs to) mining and infrastructure. Option 6 was taken forward for pre-feasibility engineering.

SITE CHARACTERISTICS

TOPOGRAPHY AND GEOLOGY

The site of Option 6 - Ann Gulch is located on the southern side of an east-west orientated ridge, on relatively shallow slopes (of largely less than 3H:1V). The slopes drain southwards via a shallow central valley (see Figure 9-2) and down into a confluence with the Dublin Gulch valley. The catchment is south-facing, and short in length (~ 2 km). The catchment ridge rises to an elevation of approximately 1,210 masl and the confluence is at an elevation of approximately 850 masl. On the western side, the valley slopes include isolated steeper sections and the catchment divide on the east side marks a rapid change in slope gradient to the neighbouring catchment.

The geology of the catchment was investigated in 2009 (BGC 2009) through a series of 15 test pits, a few boreholes in the Dublin Gulch valley (see Figure 9-3) and laboratory testing of samples. Bedrock conditions comprise a series of clastic rocks (metasediments comprising schists, phyllites and quartzites), overlain by a variable profile of overburden materials. These surficials include a distinctive weathered bedrock horizon of up to four metres thickness, beneath silty sands and gravels (colluvium) - up to 6.1 m thick, and a 0.3 m organic soil layer. Considerable variation occurs, however, depth to bedrock is typically no greater than 6.5 m in the proposed heap leach pad area. At the lower end of the HLF, the surficials in Dublin Gulch comprise placer tailings deposits (sand and gravel) and are up to 15 m in thickness.

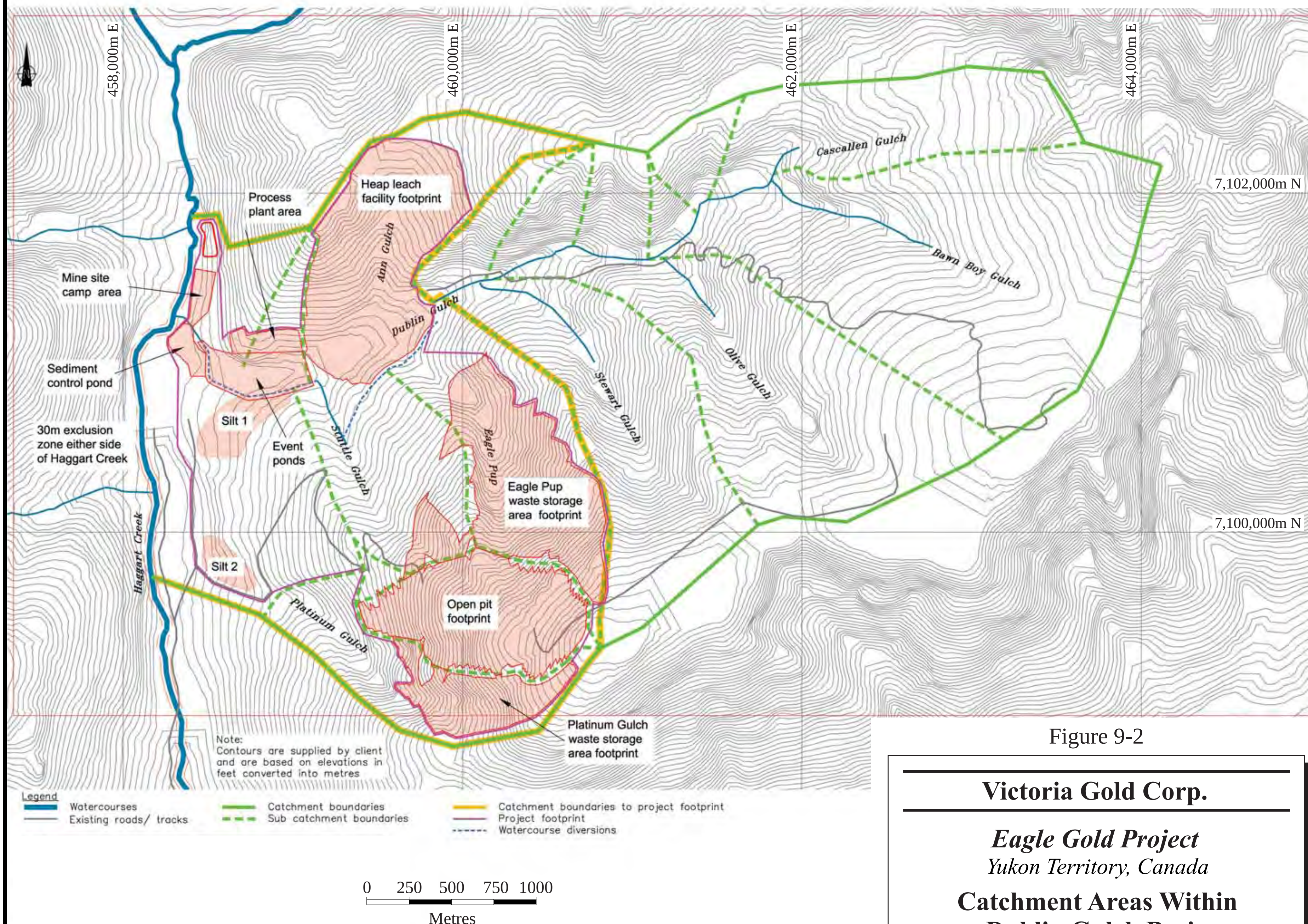

Figure 9-2

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Catchment Areas Within Dublin Gulch Basin

June 2010

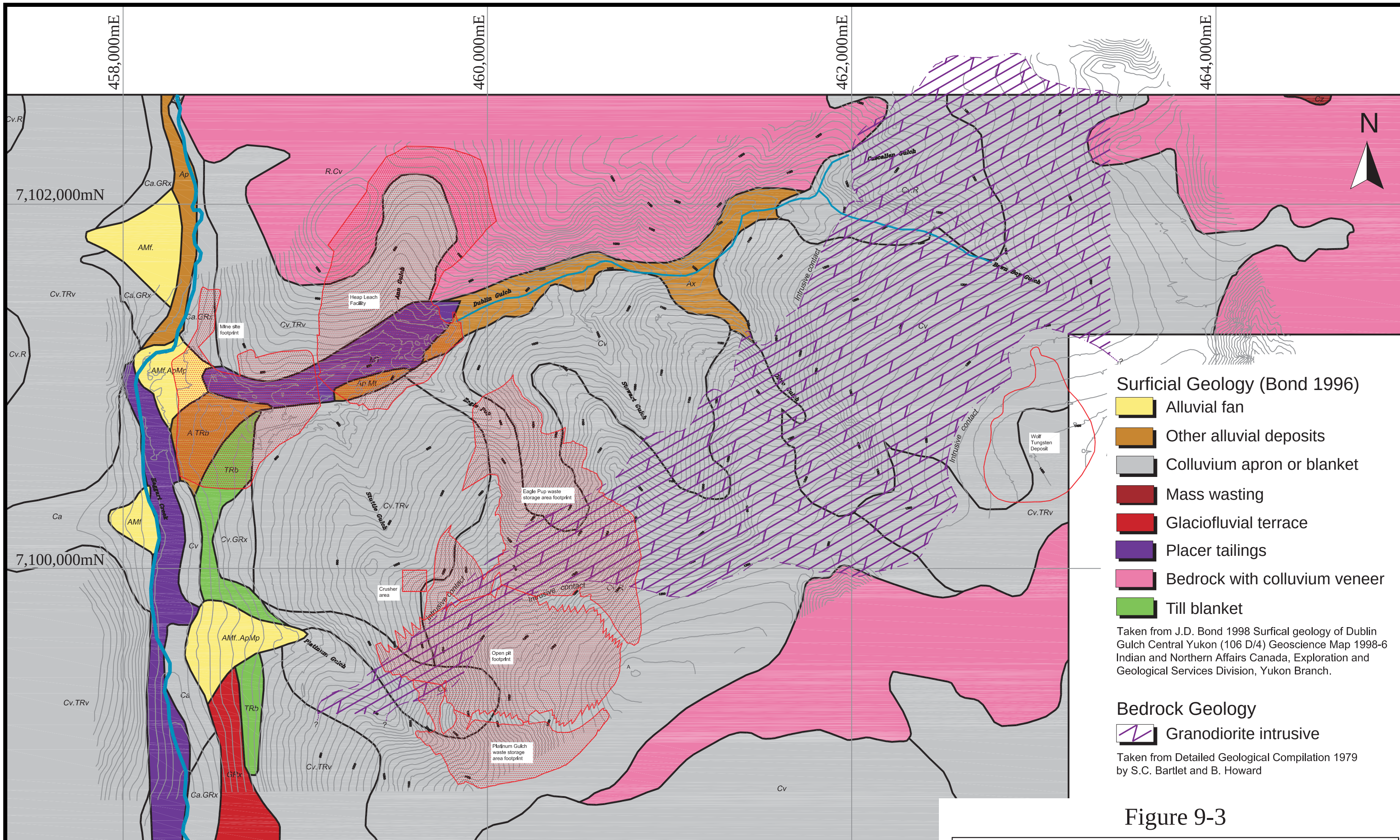

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Figure 9-3

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Background Geology Mapping Catchment Areas Within Dublin Gulch Basin

June 2010

HYDROLOGY

The hydrology of the Project area, including the HLF site, is presented in detail in Stantec's report and summarised in this report in Section 6. Of particular note for the HLF is that the peak stream flows occur in the spring in association with freshet events, (snow melt or rain-on-snow events) with flows gradually disappearing following the disappearance of the snow. Sizeable flood events may also occur in the late summer due to intense rainstorms and are particularly significant for small catchments. Ann Gulch is ephemeral, with zero discharges in mid winter when the small stream freezes.

The peak flows are pertinent to the design of the HLF foundation drains and surface runoff collection and diversion ditches and summarised in Table 9-3.

TABLE 9-3 SURFACE AND GROUNDWATER FLOW DESIGN ASSUMPTIONS
Victoria Gold Corp. – Eagle Gold Project

Structure	Return Period	Event Size	Peak Flow (m^3/s)
Surface diversion ditches around the HLF	1 in 200 year	24 hour event	0.5 to 1.2
Operational surface collection ditches on the HLF benches	1 in 10 year	24 hour storm event.	0.6
Foundation Drainage	1 in 200 year	24 hour storm event.	1.5

HYDROGEOLOGY

The hydrogeology of the project area including the HLF site is presented in detail by Stantec (2009) and summarised in this report in Section 6. Of particular note for the HLF is the unconfined flow system within the bedrock and the slow release of groundwater throughout the summer months. The resulting springs are ephemeral, and only where they coalesce in the lower catchment at approximately 950 masl, are surface flows observed in the summer months.

Measurements of groundwater levels in Ann Gulch catchment indicate water levels present within the superficials and weathered bedrock of a few metres below ground level, however, this is variable across the catchment, reflecting a subdued form of the topography, altered by thickness of superficials and weathered bedrock. Typical values of between 2 m and 7 m below grade level are anticipated, however, seasonal variations are not identified.

The hydraulic conductivity of the bedrock is relatively low and assumed to be 1.5 x 10^{-6} m/s (Knight Piésold 1996), and the foundation soils of sand and gravel with some silt beneath the HLF are of the order of 1.9 x 10^{-5} m/s in a thawed state.

PERMAFROST

Permafrost generates significant potential issues for the HLF design in two regards, the potential for thawing of:

- seasonal frost zones, and
- permafrost zones that include excess ice.

Only a scattering of permafrost is identified from the Ann Gulch investigations (BGC 2009) and the potential for the HLF catchment area as a whole is assessed to be as low as 5%.

SEISMICITY

A review of the seismicity records of the Project area, and the Knight Piésold 1996 and RESCAN 1996 reports, has confirmed the appropriateness of previous seismic design assumptions. A design Base Earthquake of 0.078 g for operational conditions is considered conservative as compared to a range of deterministic methods of calculation. The adoption of a 50% of a Maximum Critical Event for a Maximum Design Earthquake (MDE) located on the nearest significant fault is an appropriate methodology for the generated MDE of 0.10 g for post closure conditions.

In 2005, the National Building Code of Canada (NBCC) was revised with respect to seismic design parameters. Scott Wilson RPA notes that the NBCC applies to buildings, not to geotechnical structures (such as the heap embankment), however, reconciliation to the applicable standard (in consultation with regulators) should be settled prior to embarking on Feasibility-level design.

HEAP LEACH FACILITY DESIGN

DESIGN BASIS

A Scott Wilson technical note on the design basis (see Appendix F), presents the standards, objectives and operating parameters used for the PFS design, a summary of which is presented below.

Heap leach design standards adopted for the project include:

- regulatory requirements of Yukon and Canada;
- permitting requirements of the State of Nevada. These are not regulatory requirements in the Yukon, but are considered as standards for best practice, and
- guidelines from the International Finance Corporation.

Taking in to account the requirements of the various stakeholders, the principal objectives of the Eagle Gold Project HLF are to:

- ensure complete protection of the regional groundwater and surface water flows both during operations and in the long-term;
- to satisfy the environmental regulatory requirements of the Yukon territory and the Federal Government;
- provide permanent, secure storage and total confinement of the leach ore within a fully engineered facility;
- effectively collect and convey solutions for in-heap pregnant solution storage to ensure maximum recovery. In-heap storage of solution will be utilised to provide the necessary winter time storage of solution in an above freezing environment;
- minimise the quantity of surface water runoff entering the facility and coming into contact with the process solutions;
- provide additional external facilities (events ponds) to accommodate excess solution and rainfall/snowmelt when hydrological events exceed the storage capacity of the heap;
- develop the facility in stages, where possible, to minimize the environmental disturbance at any one time and to distribute capital expenditure over the life of the facility;
- monitor all aspects of the facility to ensure that the design objectives are met and that there are no adverse environmental impacts; and

- rehabilitate the facility to a condition compatible with the original land use and is stable under extreme precipitation events and seismic events.

In conjunction with these objectives are a series of input parameters and criteria developed for the PFS design of the HLF.

GENERAL ARRANGEMENT

The general arrangement of the HLF is presented in Figure 9-4 and consists of the following features.

HEAP LEACH PAD

The heap leach pad will be a 240 m high combination valley and side valley heap leach. The pad will be constructed from within Dublin Gulch and up Ann Gulch side valley. This will allow space for Dublin Gulch to be re-directed around the HLF, rather than underneath. The heap will be constructed in three phases:

- Phase 1 - all facilities to provide 2 years of operation, including (in order of construction):
    - sediment control ponds;
    - surface runoff diversions;
    - events pond No.1;
    - confining embankment;
    - lining system; and
    - in-heap pond.

- Phase 2 - Extension to the HLF (additional lined area), and
    - construction of events pond 2

- Phase 3 - Extension to the HLF (additional lined area)

SEDIMENT CONTROL PONDS AND SURFACE RUNOFF DIVERSIONS

Control of surface water runoff and sediment will be achieved with construction of runoff diversions around the HLF and sediment control features. A permanent SCP will be located at the downstream extent of the HLF and events ponds infrastructure as shown in Figure 9-6. The SCP will have a volume of 36,000 m^3 and is sized to accommodate run-off events during construction and operations. Temporary use will be made of one of the events ponds, providing 100,000 m^3 of storage for sediment control whilst constructing the Dublin Creek Diversion.

EVENTS PONDS

Two events ponds will be located downstream of the HLF and process plant to allow gravity drainage. The events ponds will have a total storage volume of 200,000 m^3 and cater for excess solution in storm events from the HLF and plant drain-downs. As the in-heap capacity is significant, an event pond is not anticipated to be required in Years 1 and 2, however, the first pond will be constructed at start-up, as a conservative measure. During construction, this pond will act as a temporary stormwater collection pond, and will provide water storage for start-up.

Cross sections are provided in Figure 9-5 and Figure 9-6.

CONFINING EMBANKMENT

In order to provide a satisfactory initial operational area to confine the heap leach pad and in-heap storage pond, an embankment will be constructed at the base of the facility in the Dublin Gulch valley. The embankment will be 50 m high, with an upstream width of 560 m and a total fill volume of 2.2 million m^3. It will be constructed from selected durable waste rock from the mining process, placed on a suitable foundation, with a filter zone on the upstream face to provide a transition to the sub-grade of the liner.

LINING SYSTEM

The heap leach pad will be provided with an engineered lining system to prevent loss of solution and contamination of groundwater. The final lining system will cover approximately 87 ha, and will consist of a multiple composite PVC liner system, with dual leak detection, and a leachate recovery and collection systems to convey solution to the extraction well.

IN-HEAP POND

Solution storage capacity for normal operations of 435,000 m^3 will be provided with an in-heap pond, which consists of storing the solution within the pore space of the ore. This will allow operation in the cold winter and spring climate conditions. As the heap is raised and the catchment area increases, additional storage (the event ponds) will be required for extreme rainfall events. Provision of external storage for this requirement is more economical than increasing the size of the in-heap pond.

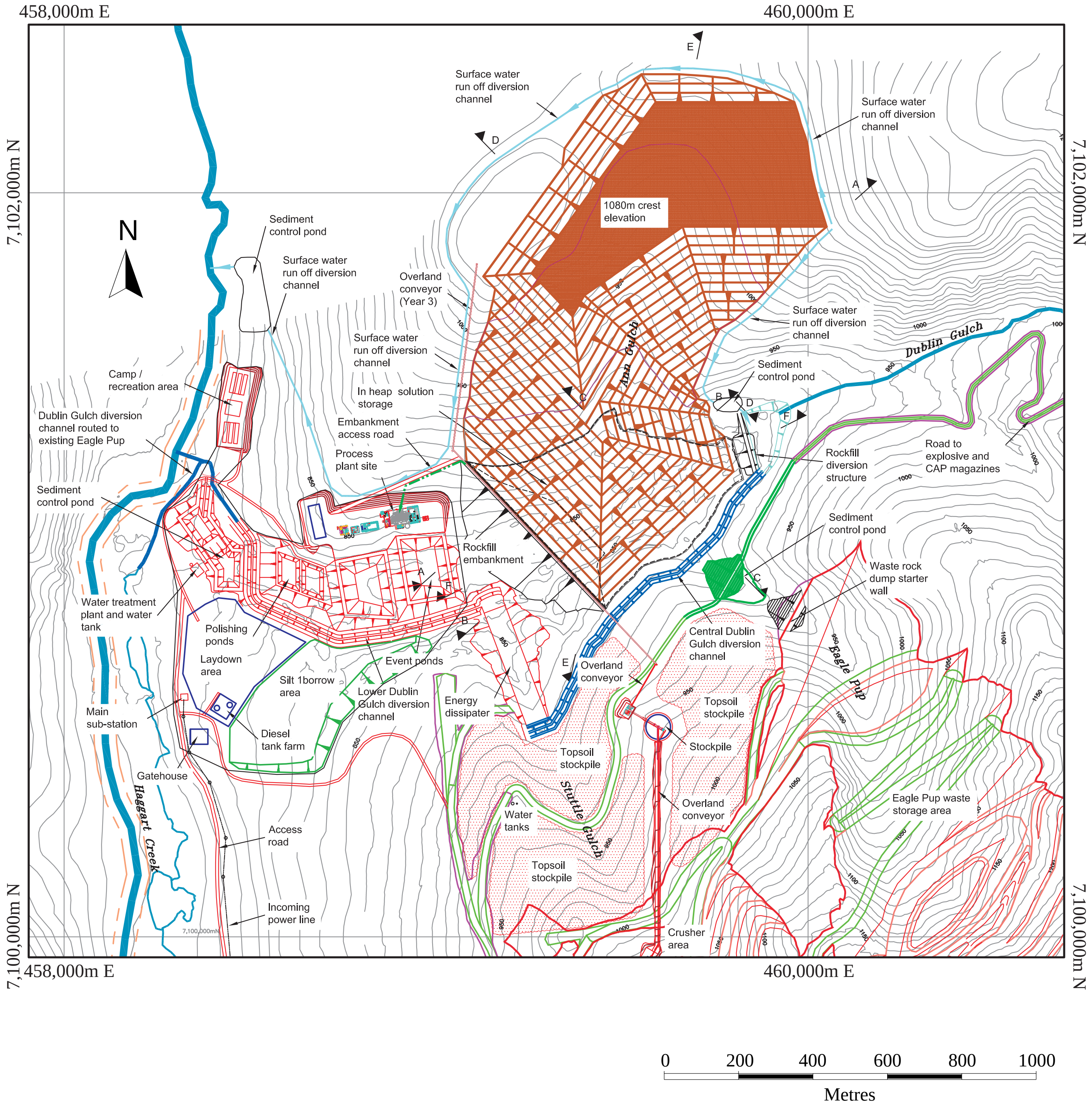


Figure 9-4

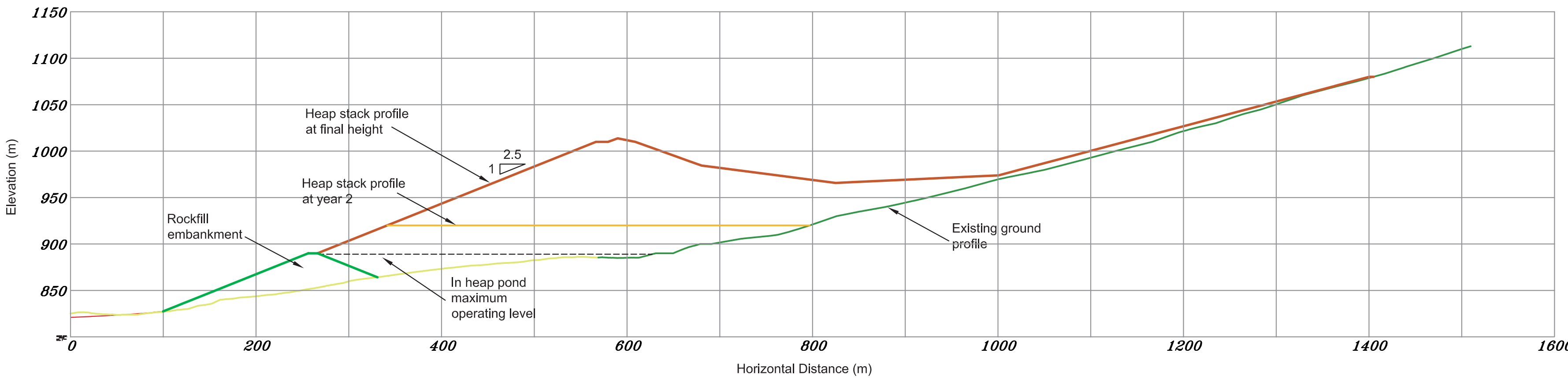
Victoria Gold Corp.

Eagle Gold Project

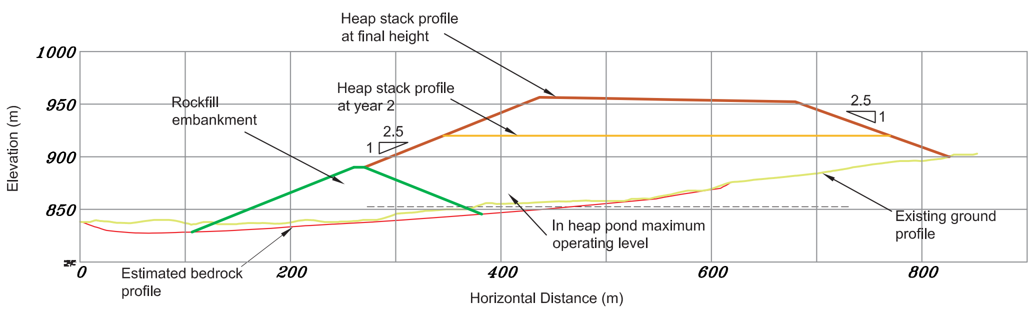
Yukon Territory, Canada

General Arrangement at Final Stack Height

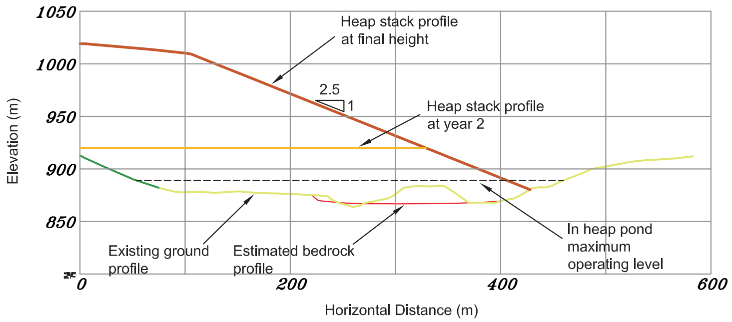
June 2010



Section A–A



Section B–B



Section C–C

Note
1. All dimensions are in millimetres and elevations in metres unless noted otherwise.
2. All sections are provisional, awaiting geological profile data.

0 100 200 300 400
Metres

Figure 9-5

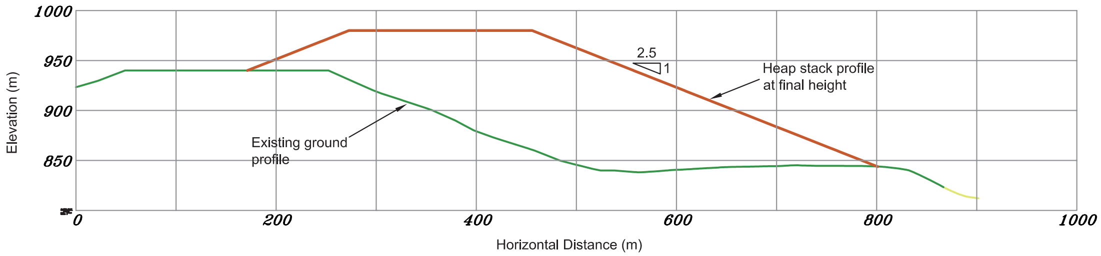
Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

HLF Cross Sections Sheet 1

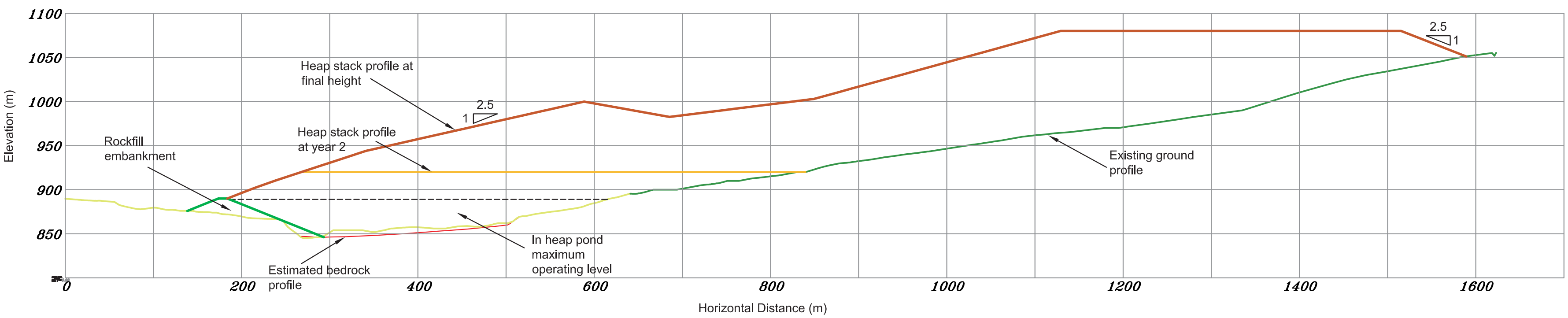
June 2010



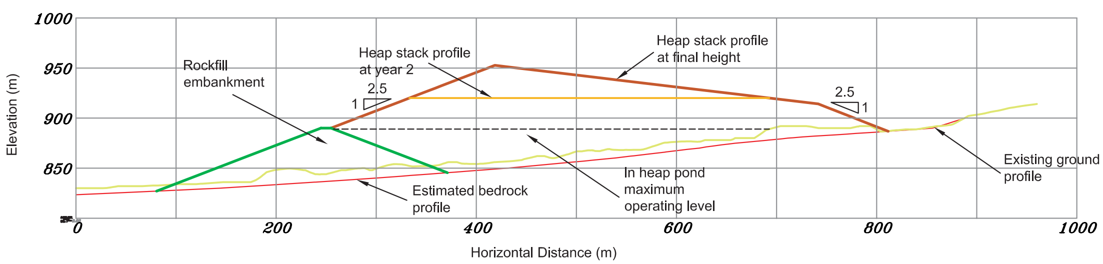
Section D–D

Note

1. All dimensions are in millimetres and elevations in metres unless noted otherwise.
2. All sections are provisional, awaiting geological profile data.



Section E–E



Section F–F

0 100 200 300 400
Metres

Figure 9-6

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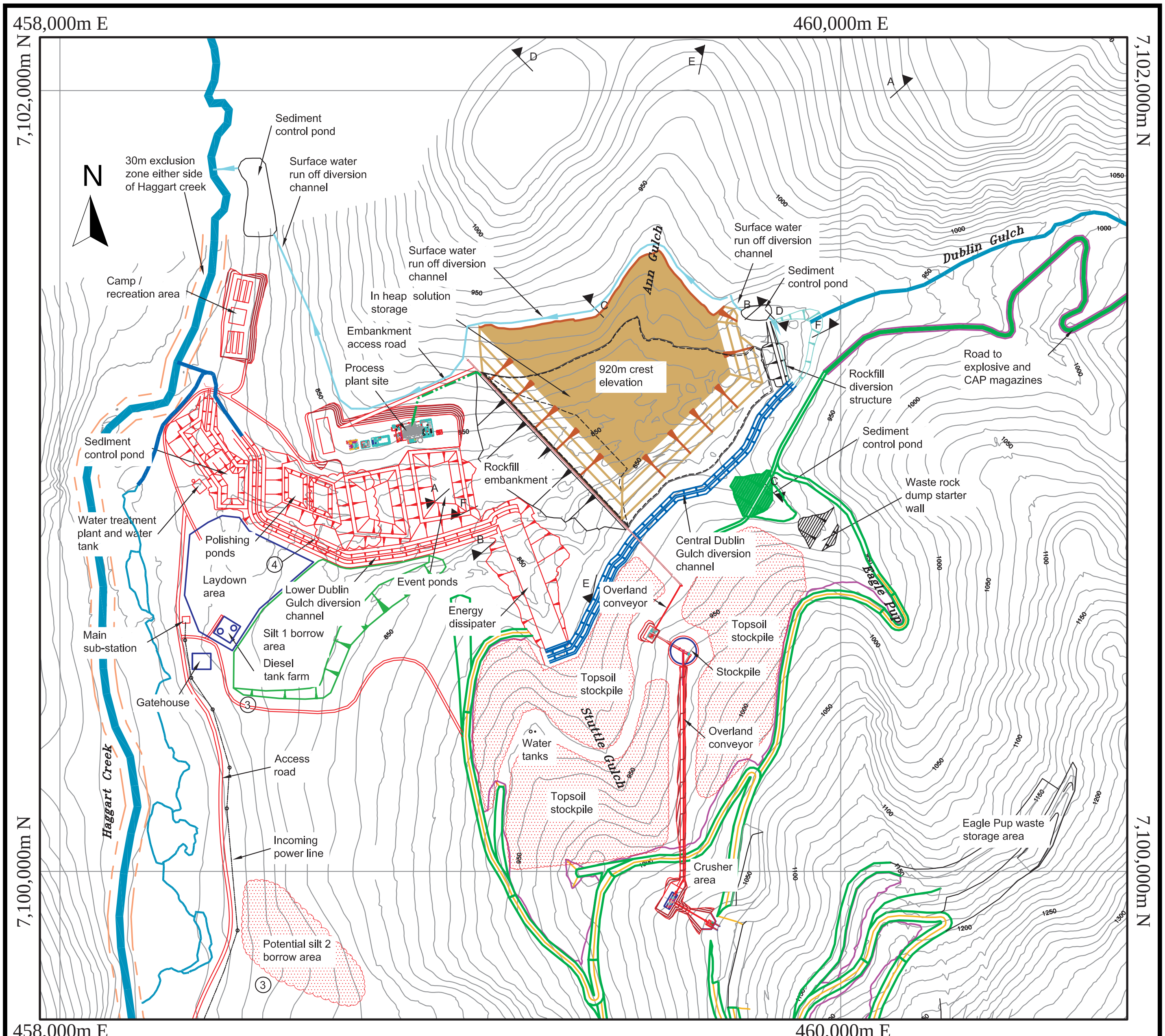
Yukon Territory, Canada

HLF Cross Sections Sheet 2

June 2010



0 200 400 600 800 1000

Metres

Figure 9-7

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

HLF Layout at Year 2

June 2010

LINER SYSTEM DESIGN

The heap leach pad and in-heap pond areas will be provided with an engineered lining system to prevent loss of solution and contamination of groundwater. The lining system will cover approximately 87 ha, and consist of a multiple composite PVC liner system, with dual leak detection.

DESIGN BASIS

The Yukon Territory does not have regulations specifically developed for heap leach facilities, but instead relies on regulations from other regions and precedence from other projects. It is understood that the only HLF that has been permitted in the Yukon is at Brewery Creek, the design and permitting of which, according to previous design work by Sitka Corporation (1996), was based on the Nevada State guidelines and associated permitting limitations. The liner system has been designed, therefore, to ultimately achieve compliance with these guidelines.

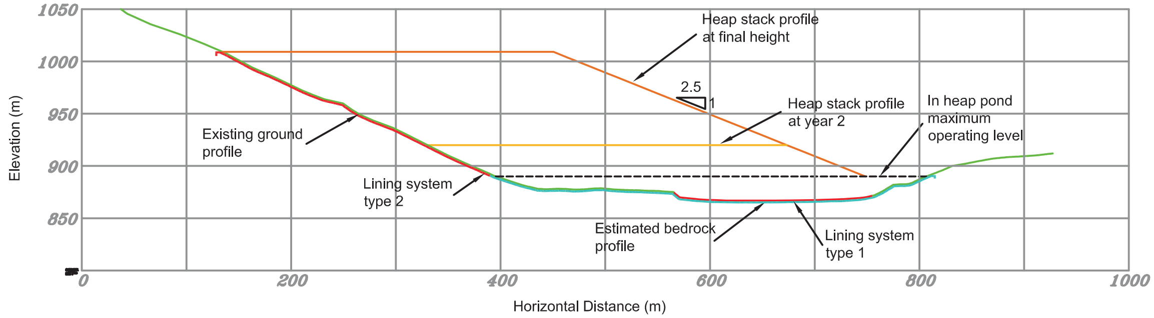
Based on the recommendations of Giroud and Bonaparte (1989), in general, it is expected that "one [puncture] hole per acre" (4,000 m^2) with an effective area of 10 mm^2 would have a reasonable potential to exist for a geomembrane liner placed with a high level of construction quality control. It is on this basis that potential leakage rates through the liner have been assessed to check compliance with the Nevada guidelines.

LINER SYSTEM DESIGN

The lining system elements are illustrated in Figure 9-8. The HLF liner system design provides:

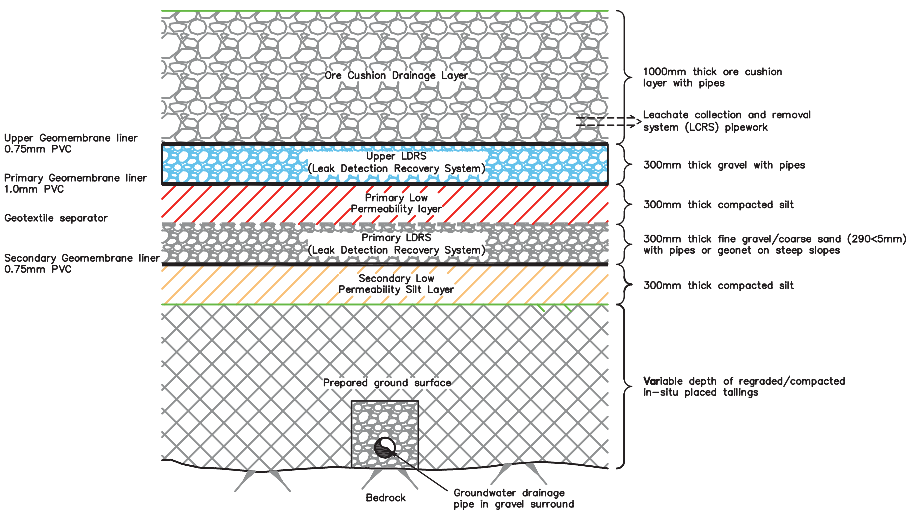
- a double composite liner in the upslope area of the pad (above the in-heap pond maximum operating level), and
- a triple liner in the in-heap storage pond area.

The events ponds will also be double-lined and incorporate a geonet separation layer.

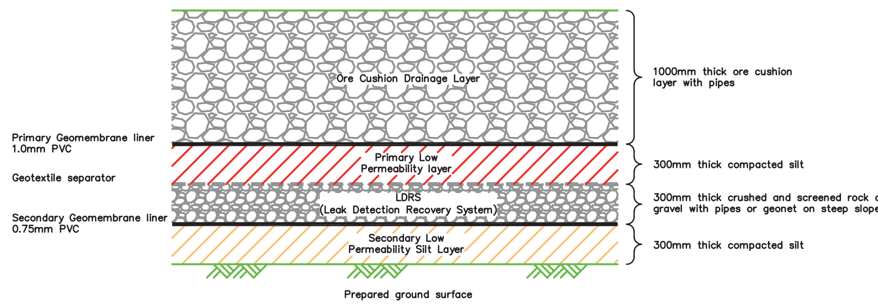


Typical Section Through Heap Leach Facility

Note
All sections are provisional, awaiting geological profile data



Lining System Type 1
In Heap Triple Liner Area
(Below in heap pond maximum operating level)



Lining System Type 2
Heap Pad Double Liner Area
(Above in heap pond maximum operating level)

Figure 9-8

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Eagle Gold Project
Yukon Territory, Canada

Lining System Details

June 2010

HEAP LEACH PAD AREA

The liner system in the heap leach pad upslope area comprises the following elements from top to bottom:

- a cushion layer of 1 m thick ore, with Leachate Collection and Removal System (LCRS) pipework

- primary composite liner system comprising:
    - Primary 1.0 mm PVC geomembrane liner
    - 300 mm thick compacted silt

- geotextile separator

- primary Leak Detection and Recovery System (LDRS) comprising 300 mm thick fine gravel to coarse sand with pipes. On steep slopes, this is replaced with geonet

- secondary composite liner comprising:
    - secondary 0.75 mm PVC geomembrane liner
    - 300 mm thick compacted silt.

Potential leakage through the primary liner into the LDRS in the upslope pad area will be minimised by provision of a closely spaced network of leachate collection interceptor. These drains effectively reduce the hydraulic head over the liner.

IN-HEAP STORAGE POND AREA

In order to achieve compliance with the Nevada permitting guidelines with respect to liner leakage in the in-heap storage pond area, an additional liner element is required above the primary composite liner. This additional element comprises an upper 0.75 mm PVC geomembrane over an upper LDRS gravel layer. This upper liner serves to minimise the hydraulic head on the primary composite liner and therefore reduce the potential leakage rates into the primary LDRS. The liner system in the in-heap storage pond area comprises the following elements from top to bottom:

- a 1 m thick ore cushion layer with Leachate Collection and Removal System (LCRS) pipework

- Upper 0.75 mm PVC geomembrane liner

- Upper LDRS 300 mm thick gravel with pipes;

- Primary composite liner system

- Geotextile separator

- Primary LDRS 300 mm thick fine gravel to coarse sand with pipes, and
- Secondary composite liner system.

By using a double composite liner in the upslope section and triple liner in the storage section of the pad, leakage into the LDRS will be below the limiting rates stipulated in the Nevada guidelines, and any subsequent leakage out of the system into the ground will be negligible.

EVENT PONDS

The liner system to the events ponds comprises the following elements from top to bottom:

- Primary 2.0 mm thick HDPE geomembrane liner
- Primary LDRS geonet layer
- Secondary 1.0 mm thick HDPE geomembrane liner, and
- 300 mm thick compacted silt.

LINER COMPONENT SELECTION

CUSHION LAYER

The cushion layer is effectively a load-bearing drainage layer, in which the LCRS pipework can be installed. It will be formed from coarse sand/fine gravel-sized durable ore.

The cushion layer material is assumed to wholly comprise particle sizes less than 5 mm diameter, so that the underlying geomembrane liner will not require any additional protection from damage by large particles or sharp protrusions. If the ore contains particles of greater than 5 mm diameter, then it will be necessary to screen it before use as a cushion layer.

It is recommended that further testing of the puncture resistance of the PVC liner, when placed in combination with the selected cushion layer material, be carried out under the anticipated heap loads to confirm suitability at feasibility design stage.

GEOMEMBRANE LINERS

PVC geomembrane has been selected for the heap leach pad and in-heap storage pond areas due to good cold weather performance, high interface strength (frictional and tensile) characteristics and excellent chemical resistance to the anticipated solutions. It possesses a high degree of flexibility, which enhances its puncture resistance and has proven long-term performance under heaps with high normal loads.

Since the PVC has a relatively low long-term resistance to ultraviolet radiation, all exposed areas will need to be covered with cushion layer material soon after installation.

High Density Polyethylene (HDPE) has been selected for the event ponds, due to good long-term resistance to ultraviolet radiation, excellent chemical resistance and proven performance as an exposed pond liner. The event pond primary liner thickness of 2.0 mm (compared to 1.0 mm thickness for the heap leach secondary liner) has been selected due to its increased exposure to potential wear and to the elements.

LDRS GRAVEL AND GEONET

The primary and upper LDRS layers will comprise free-draining fine gravel to coarse sand material, with typically 90% finer than 5 mm particle size, with minimal fines (i.e., less than 10% finer than 1 mm). The grading of the material will be such that it is capable of transmitting any leakage through the liner system at a rate that ensures minimal head build up over the underlying PVC liner, and also prevents damage to the adjacent (either overlying or underlying) PVC liner associated with large particle protrusions.

It is recommended that, in addition to the cushion layer testing outlined above, testing of the puncture resistance of the PVC liner placed adjacent to the proposed LDRS gravel-sand material be carried out to confirm suitability at feasibility design stage.

The geomembrane liners to the events ponds will be separated by a geonet fluid transmission layer on the side slopes and a gravel layer on the base, which is capable of transmitting leaked fluids at a rate that ensures that excessive head will not develop on the secondary liner.

It is anticipated that the proposed geonet will be a high compressive strength HDPE type product; although further testing will be required during feasibility design to confirm fluid transmission capacities will be adequate for anticipated liner leakage.

COMPACTED SILT

The compacted silt material component of the lining system will be prepared to form a competent low permeability base to receive the PVC geomembrane liners to form a composite lining system. The compacted silt will be a minimum of 300 mm thick and will have a smooth surface, free of sharp protrusions and will be in direct contact with the PVC geomembrane.

It is important to achieve good contact conditions between the PVC geomembrane and compacted silt layer, as the effectiveness of the composite liners depends on the quality of contact between the two elements.

In order to comply with the Nevada guidelines for composite liner systems and permitted leakage rates into LDRS systems, the target permeability of the compacted silt is $1x10^{-7}$ m/s.

It is recommended that permeability testing under consolidated conditions, taking into account that this material will be significantly loaded by heap material above, be carried out to confirm that this permeability value can be realistically and consistently achieved.

GEOTEXTILE

A layer of non-woven geotextile has been included at the interface between the fine grained primary compacted silt layer and the underlying fine gravel to coarse sand LDRS layer. This geotextile is included to provide effective separation of the two materials and prevent any undesirable migration of fine particles and associated instability and settlement that could potentially occur as a result.

LEAK DETECTION AND RECOVERY SYSTEMS

The performance of the lining system, as measured in terms of preventing loss of solution into the ground, will be assessed by monitoring leak detection drains constructed below the liners. Separate LDRS will be installed below each liner, and all collected solution will be returned to the heap.

The LDRS will consist of a series of 100 mm diameter pipes within a 300 mm thick layer of 20 mm gravel, feeding to a 200 mm diameter collector pipe, also located within the gravel layer. Any leakage reporting to the drains will flow to a sump below the in-heap pond, from where it will be pumped back to the heap.

For the in-heap liner, there will be a second LDRS, beneath the upper liner. This is similar to the primary LDRS, except that there are more pipes to cater for the potentially higher flow and convey the solution with minimal pressure on the liner beneath. Any drainage collected will be conveyed to a separate sump below the in-heap pond, from where it will be pumped back to the heap.

The location of the leak detection and collection systems, between the liner layers, makes access for pumping difficult. The proposed design requires installation of down-hole pumps in pipes on the embankment slope, which is not ideal for pump operation. In the event of blockage, replacement of pipes would not be practicable and therefore three pipes for pumping have been provided. Consideration was given to constructing a pipe beneath the embankment, however, this is generally not considered good practice as it is a potential source of leaks. Typical details are shown on Figure 9-8.

The practicability of using borehole pumps to drain potential leaks should be confirmed.

HEAP LEACH PAD - MONITORING

Monitoring will consist of recording the quantity and occasionally quality of solution returned in the LDRS in relation to the location of the heap being irrigated at the time. In addition monitoring boreholes will be installed downstream of the heap leach facility and events ponds and will be sampled regularly for water quality as backup to the LDRS monitoring.

EVENT POND - LEAKAGE DETECTION

The events ponds are designed to work on an infrequent basis, to take the solution in the event of high rainfall events and plant shutdowns. The likelihood for leaks is reduced, together with reduced impact from a dilute solution. The leak detection system will discharge potential seepage to a collection sump, where it will be monitored on a regular basis, and any leakage returned back into the pond with a dewatering pump.

The events ponds will be constructed above the presumed groundwater level. The base of the events ponds is presumed to be free-draining alluvial material and consequently groundwater drainage is not included. This will be investigated further during detailed design.

The events ponds LDRS consists of 100 mm diameter slotted chlorinated polyethylene (CPE) drainage pipes in a 300 mm thick layer of 10 mm gravel feeding a sump in a constructed low point within the event pond. From the sump, two 150 mm diameter HDPE pipes are provided on the slope, connected to the 100 mm drainage pipes. A down-hole pump is installed in one of the pipes, together with an electronic depth sensor.

EVENT POND - MONITORING

Monitoring will consist of recording water depth in the sump and recording the quantity returned to the event pond. Occasional sampling of the quality will also be undertaken. Monitoring boreholes downstream of the events pond will be provided as part of the HLF monitoring and will be sampled regularly for water quality.

GROUNDWATER DRAINAGE - DESCRIPTION OF WORKS

A groundwater drainage system will be installed beneath the lowest liner of the HLF to prevent uplift pressures developing beneath the liner (see Figure 9-9). The drainage system will be comprised of a network of pipes placed in gravel-filled trenches and wrapped in geotextile. The pipe network will be comprised of 100 mm diameter slotted corrugated polyethylene pipes (CPP) pipes in a 300 mm x 300 mm gravel-filled trench at a spacing of 25 m, feeding 200 mm diameter HDPE un-perforated collector pipes at 200 mm centres in 1,200 mm x 1,200 mm gravel-filled trench. In the base of the HLF, beneath the in-heap pond, the 200 mm pipes will feed into a 300 mm diameter HDPE pipe. The 300 m pipe will require a gravelled-filled trench with cross-sectional area of 12 m^2 to convey the post-closure flow from the heap.

GROUNDWATER DRAINAGE - MONITORING

Monitoring of flow and quality will be undertaken on a regular basis. Water that meets the effluent standards will be released via a pipeline to the SCP. If the water does not meet the required standards, it will be pumped to the events pond for treatment or recycling. For this purpose, a sump is provided at the embankment toe with valves to isolate flow.

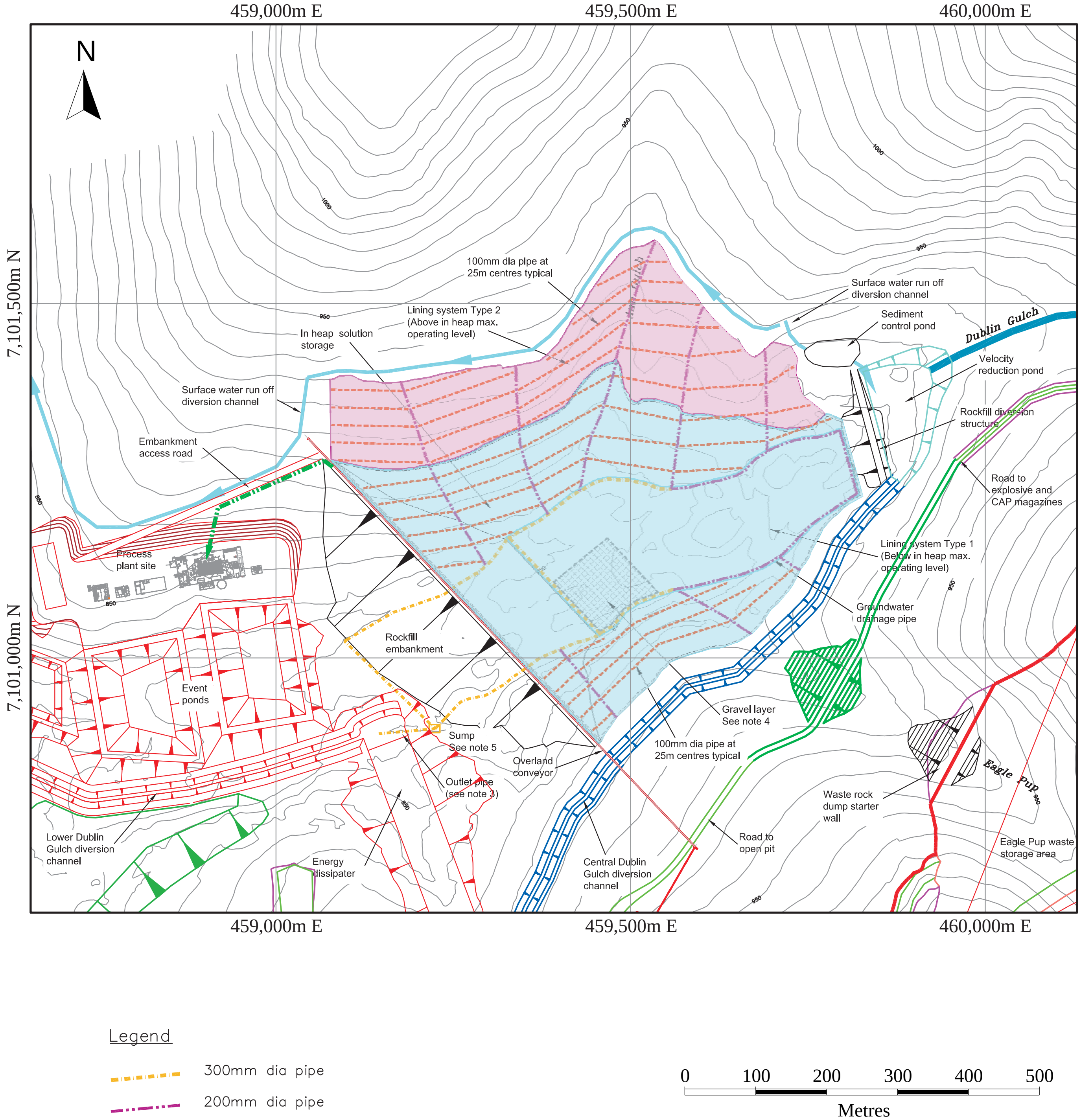


Figure 9-9

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Groundwater Drainage Pipework Layout at Year 2 Stack Height

June 2010

DUBLIN GULCH RELOCATION

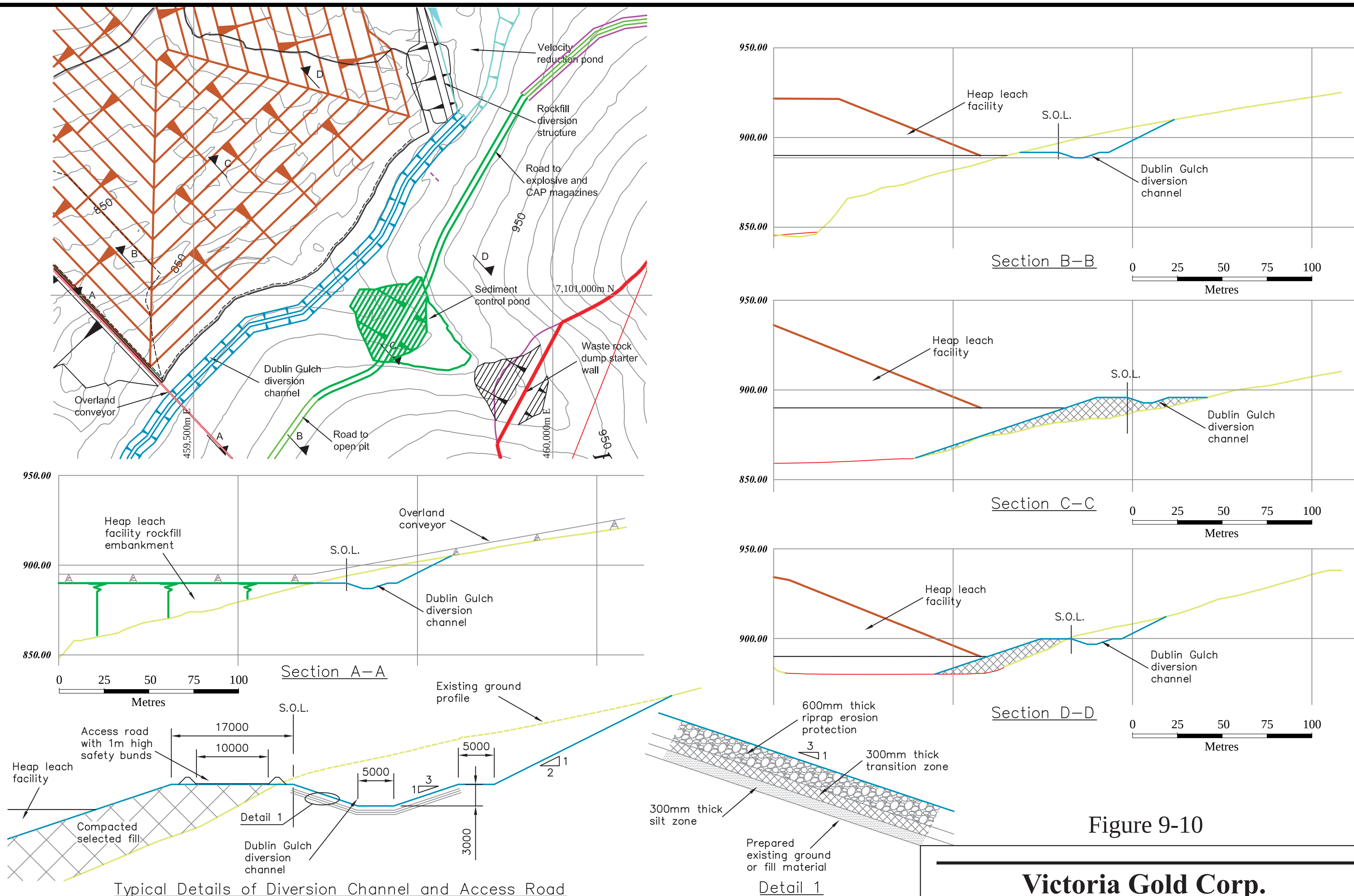
The relocation of the Dublin Gulch streambed is designed to convey streamflow safely past the HLF and return it back to the current course, approximately 1,500 m downstream of the diversion structure inlet. The diversion will be comprised of:

- an upstream inlet structure that intercepts all Dublin Gulch streamflow and directs flow into a diversion channel
- a 900 m long diversion channel ("the upper diversion") 3 m deep with a slope of 1:100 leading to Stuttle Gulch
- channelization of the Stuttle Gulch flow with additional energy dissipation and erosion protection measures
- an enlarged and re-routed channel diversion ("the lower diversion") around the Event Ponds and Polishing Ponds, and
- a reconnection of the flow into the current course of Dublin Gulch.

Guidelines for diversions require design for a 1 in 200 year storm event, however, the diversion remains post-closure and therefore a design to the Probable Maximum Flow (PMF) is appropriate. Consequently the diversion is designed for a peak flow based on the PMF of 105 m^3/s.

The inlet will consist of a 12 m high embankment, designed to intercept all surface flows and the majority of sub-surface flows. The embankment will consist of rock fill with a filter zone on the upstream face to provide a transition to the sub-grade of an HDPE liner. Placer tailings and alluvial material in the valley floor will be removed, and an impervious zone barrier created, to direct sub-surface flows into the diversion. The HDPE liner will be provided with damage protection measures grading from gravel back to rockfill.

From the upstream diversion structure, the 900 m long diversion will run nearly parallel to the contour at a 1:100 slope to Stuttle Gulch. The construction of the upper diversion will consist of earth-fill, HDPE liner and rock-fill erosion protection. The up-slope cut surfaces will be provided with erosion protection measures and flow from the disturbed surfaces will be channelled through a SCP until runoff meets the suspended solids requirements (see Figure 9-10).



Notes:
1. All dimensions are in millimetres and elevations in metres unless noted otherwise.

Figure 9-10

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Central Dublin Gulch Diversion Channel Details

June 2010

SCOTT WILSON RPA

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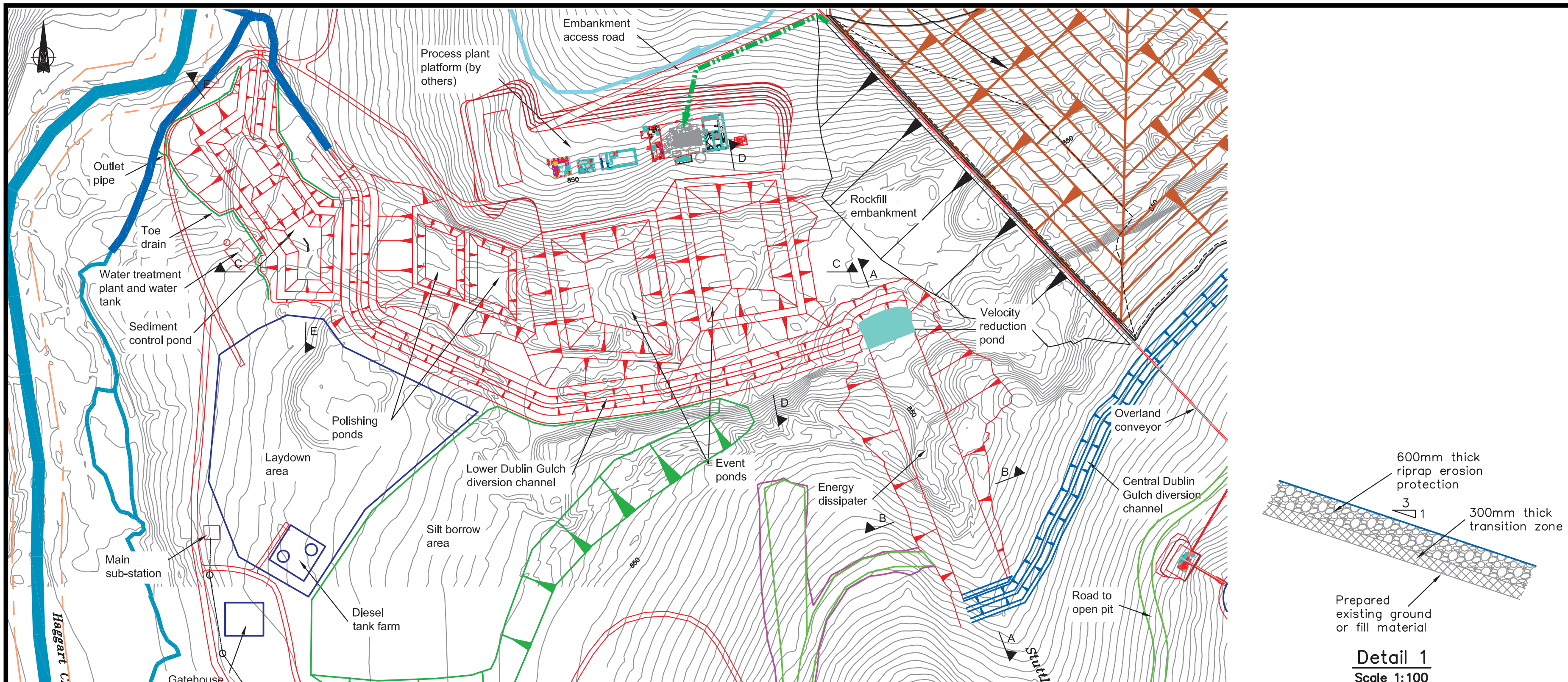
The flow from the upper diversion will then be directed into Stuttle Gulch, through energy dissipation and erosion protection measures to handle the PMF (see Figure 9-11). These measures will comprise large size rock-fill, placed on a gravel bed on a heavy duty geotextile. Stability of the slope, keying the structure into the slope and permafrost are issues to be reviewed further in the feasibility design.

The flow from the Stuttle Gulch energy dissipation channel will re-enter the lower diversion of the Dublin Gulch valley floor at a channel inlet, which is an enlarged section of the lower diversion, provided with erosion protection measures. The stream at this point is then designed to be part of the Dublin Gulch fish habitat and detailed design will need to take this into account. The invert of the channel is presumed to be on competent bedrock and will intercept and drain the groundwater beneath the events ponds. Lining is not considered necessary, however, erosion protection to the banks will be provided. Detailed investigations of the geotechnical and groundwater conditions along the route of the diversion will be undertaken as part of the detailed engineering.



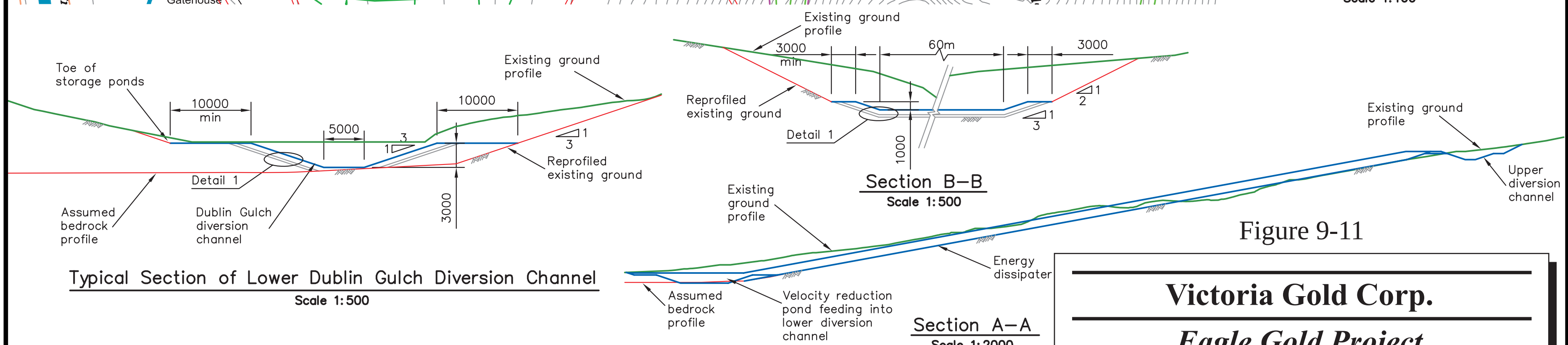


Figure 9-11

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Lower Dublin Gulch Diversion Channel Details and Energy Dissipater

June 2010

FURTHER WORK

In addition to a general progression of design, the following items are specifically noted for advancing in the feasibility study:

- selection of the backfill material, whether waste rock from the mine or locally excavated materials and ensuring availability i.e., matching waste rock production to use and undertaking borrow pit assessments to determine available suitable volumes
- further design of the Stuttle Gulch erosion protection measures
- further geotechnical data along the route of the proposed diversion, and
- design of the lower Dublin Gulch diversion with regard to providing suitable fish habitat.

STABILITY DESIGN

The physical stability of the HLF is critical to its short-term (operational) and long-term (post closure) performance. The HLF is designed against failure of the ore and/or the foundations that could overstress the liner system and thereby compromise the integrity of the containment system. The design therefore considers the operational design events and post closure extreme events, of seismic loading under an Operational and Maximum Design Events (ODE and MDE), Probable Maximum Flood (PMF) and Probable Maximum Precipitation (PMP).

Particular aspects that are key to determining stability:

- ore material properties particularly strength
- geometry and loading cases (static and seismic)
- shear strength of the:
  - soil/liner interface
  - ore/liner interface
- location of phreatic surfaces:
  - groundwater level beneath the soil/liner interface, and
  - hydraulic solution head above the liner.
- deformation strength changes, and
- normal loading changes in geo-synthetic strength properties.

Stability issues for further evaluation in feasibility studies include:

- permanent displacement assessments to address post seismic deformation strengths, which can be significantly lower and mobilised through only small deformation, and

- shear testing of the compacted soil/geosynthetic liner interface to assess the appropriate shear strength relationship to be adopted for analysis.

MECHANISMS OF FAILURE

Case studies and theory establish the modes of failure in HLFs can include both shallow and deep seated failures, the latter having the potential to damage the liner system. Failure modes considered at this PFS stage include:

- circular and non-circular failures contained within the ore

- wedge failures through the ore and along the ore/liner interface

- circular ad non-circular failures though the ore and into the foundation materials, and

- liquefaction of the ore (particularly as the heap develops above the in-heap pond).

ANALYSIS

METHOD

Stability analysis for the Eagle Project HLF adopted the following approach:

- identifying critical stability sections and developing representative cross sections (two dimensional)

- selecting a method of analysis and determining the appropriate material types and geotechnical parameters

- identifying boundary conditions and loading cases for each section, and

- performing evaluations of stability against design criteria for each loading case.

Figures 9-5 to 9-6 (above) present the locations of the critical cross sections. Other areas in the HLF have configurations that have higher factors of safety as compared to these sections and are therefore not considered.

A deterministic limit equilibrium approach was selected to consider the stability of the structure. In this approach shear stress is compared to the available shear strength. The ratio between the two is the Factor of Safety (FoS). Applicable FoS are presented in the Design Basis (see Appendix F).

To simulate earthquakes loading, a pseudo-static approach was used for the PFS stage. Seismic loading in this approach is simulated as a constant horizontal force, which is computed from an applied acceleration, based on assessments of the ODE and MDE events.

For the feasibility study, more detailed analyses will be required, to determine the amount of movement under earthquake loading. This will include deformation analyses, which are of particular importance as deformation in the liner needs to be assessed to ensure that the liner system can operate post deformation.

MATERIAL PROPERTIES

The selection of geotechnical material properties for stability design of a HLF is a significant part of the geotechnical process of design. The selection needs to attend to the requirements of the proposed analyses whilst the reflecting the ground model for the failure mechanism being considered. The introduction of synthetic materials which are typically of lower shear strength than the surrounding ore and soil materials need to be accounted for in the stability analysis. A summary of the material parameters used in the cross-sections are presented in Table 9-4.

PIEZOMETRIC SURFACES

Piezometric water levels in the ore can impact HLF stability, thus the permeability of the ore and drainage system are significant controls on head in the secondary liner system. For the PFS, stability has been assessed with water levels of up to five metres above the liner.

At the feasibility stage, geotechnical testing of the ore, seepage analyses and further stability analyses need to be undertaken.

TABLE 9-4 GEOTECHNICAL PARAMETERS

Victoria Gold Corp. – Eagle Gold Project

Material Type	Unit Weight (kN/m^3)	Cohesion (kN/m^2)	Friction Angle (°)	Material Description	Ref
Ore	18	0	32	In the absence of laboratory testing, based on previous slope stability analysis parameter	4
Placer Tailings	20	0	37	Sand and Gravel (SP); based on EBA Particle Size Analysis: generally, < 10% fines, 20 - 60% sand and 30 to 70% gravel.	1
Colluvium (Type 1)	14	38	28	Gravelly Silt (ML). Generally, consists of > 30 - 50% fines (silt and clay) content.	1
Colluvium (Type 2)	22	0	36	Sand and Gravel (SW, SM, GW, GM); with occasional silt, medium compacted, unsaturated. Generally, consists of 30 - 50% fines (silt and clay) content.	1, 4
Weathered Bedrock	22	0	38	Weathered Granodiorite, described as sand (SP) with occasional boulders and cobbles. Strength = S2 (approximately 25 MPa), Weathering Grade 4 -5.	
Bedrock	26	Based on shear strength vrs normal strength envelope		Based on field estimation and observations, bottom of DG option 6; in the absence of laboratory strength properties; .RocLab used. UCS = 45 MPa, GSI =60, m_i = 9, D = 0, based on similar materials	2
Waste Rock	26	Based on shear strength vrs normal strength envelope		In the absence of laboratory rock strength, based on UCS = 45 MPa with Barton and Kjærnsli (1981) strength model	3
Compacted Sand and Gravel	24	0	40	In the absence of laboratory testing, based on dense Colluvium type 2 and previous slope stability	4

References

1. Carter, M.; Bentley, S.P., 1991. Correlations of soil properties. Pentech Press. 1st Edition.

2 SRK. 2008. NI 43-101 Preliminary Assessment Dublin Gulch Property – Mar-Tungsten Zone Mayo District, Yukon Territory, Canada (Table 17.2.2.2.)

3. Barton, N., and Kjærnsli, B., 1981. Shear strength of rockfill. J. of the Geotech. Eng. Div., Proc. of ASCE, Vol. 107:GT7: 873-891. Proc. Paper 16374, July.

4. Rescan. 1996. Dublin Gulch Prefeasibility Study - Volume 2. (Table 7.9.1)

CONFINING EMBANKMENT DESIGN

Slope stability calculations were undertaken for the confining embankment with the heap in place up to the final elevation. A slope of 3H:1V was adopted for the embankment based on stability assessments, which allows for a variety of earth and mine waste-rock or rock-fill materials to be used. Unweathered waste rock can be built to a steeper slope, but with an embankment volume of 2,000,000 m^3 required, quantities of waste rock may not be available in the required timeframe.

Toe- and side-drains will be provided to intercept groundwater from the abutments. Drainage beneath the embankment will be provided by a groundwater drainage system, which is linked to that beneath the liner. There will also be groundwater drainage systems at the inlets to the Dublin Gulch diversion and along the route of the diversion, which intercept groundwater before it reaches the main embankment. The main source of water within the embankment will be from rainfall infiltration onto the embankment, which will not be sufficient to build up a significant phreatic surface.

There will be pipes passing beneath the embankment conveying groundwater from beneath the liner. They will not pass through a liner and will be in a gravel trench. Potential for "piping" (loss of material due to flow of water along a pipe through an embankment) will therefore be negligible. There will be no other features passing through the embankment.

The main source of the earth/rock-fill will be from overburden and waste rock generated during mine development. Characteristics and availability (co-ordination with mining schedule) requires confirmation.

The embankment requires a transition zone on the upstream face where particle size reduces from boulder size in the rockfill to silt beneath the lower liner. Specific filter relationships are required for the particle sizes of the zones in order to prevent washing away of materials into the coarser zone in the event of a leak through the liner. Two zones have been assumed at this stage and this will need to be reviewed during both feasibility and detailed design and confirmed during construction.

Foundation preparation beneath the embankment will consist of removing loose sand and gravel from the valley floor, potentially to bedrock at a depth of two to ten metres. For the abutments, topsoil will be removed and excavated down to competent material, to a depth of one to two metres, with isolated pockets of deeper loose material.

SOLUTION MANAGEMENT

Solution management of the HLF comprises the efficient management of the solution delivered to, permeating through, and reporting from under the stacked heap; and the secure containment of pregnant and barren leachate leading to optimum metal recovery.

The solution management objectives of the heap leach facility are:

- the system is to operate as a closed system with zero release of solution to the environment
- the solution ponds are to contain operational flows with run-off during normal operational and storm rainfall events, and
- in extremely wet seasons, excess solution is to be stored and treated until the quality of the water meets the required regulatory quality requirements for release.

Figure 9-12 presents a schematic of the solution flow and is described as follows:

- Barren and recycled solution will be applied to the heap through a series of buried dripper type and (summer only) sprinkler applicators.
- The solution will permeate through the heap, where it will be contained by the lining system and directed via collection pipes to the collection well.
- Pregnant solution will be pumped to the Adsorption/Desorption/Recovery (ADR) plant.
- A spillway will be provided at the top of the in-heap pond to discharge excess solution to the events pond via 450 mm dia. HDPE pipes.
- The event ponds will be zero release and all solution will be pumped to the ADR plant.
- After removal of gold in the ADR plant, barren solution will be pumped to the heap leach pad.
- In extremely wet seasons, the resulting excess barren solution in the ADR plant will be treated and released to the polishing pond before release via the SCP.

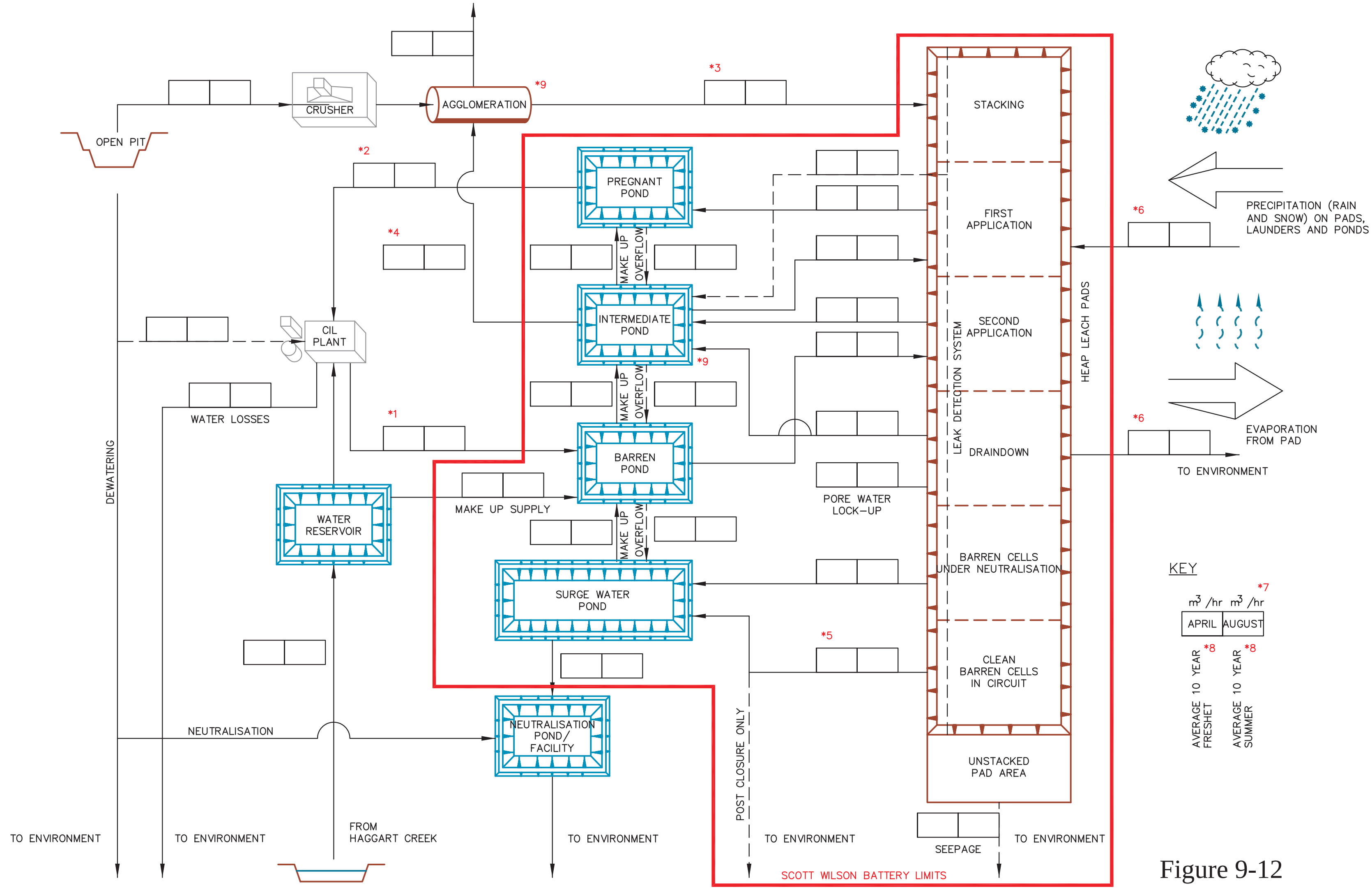


Figure 9-12

CASE	SUMMER 10 YEAR AVERAGE

NOTES
*1 KCA IRRIGATION RATE
*2 KCA CIL PLANT DEMAND
*3 KCA WATER IN ORE
*4 KCA AGGLOMERATION DEMAND
*5 KCA DETOXIFICATION TIME
*6 STANTEC DATA
*7 PROJECT UNITS
*8 PROJECT DESIGN BASIS
SNOW AND STORM IN MAY
*9 KCA REQUIREMENTS

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Process Water Balance

The above process will be repeated until cessation of operations, when the heap will be rinsed and treated until the quality of the untreated rinse water meets the required regulatory requirements for release.

IN-HEAP POND SIZE SELECTION

The in-heap pond is designed to provide for the fluctuating water volumes in the system caused by precipitation events, operational parameters, dead storage and heap drain-down. The gross volume of the in-heap pond will be 3,247,000 m^3. The available volume is the difference between the saturated water content (22%) and the residual water content (8.6%), which results in a net volume of 435,000 m^3. A summary of the pond volume calculations and assumptions are summarised below:

- *Dead Storage.* Pumps require a minimum operating head, which results in a volume that cannot be pumped. The facility has been designed with a sump to minimise this volume and it is assumed to be negligible (less than 100 m^3).

- *Minimum Operational Volume.* Based on ensuring the supply of solution to the ADR plant for a period of 2 days at an abstraction rate of 1,300 m^3/hr, a minimum operational volume of 61,680 m^3 is required.

- *Maximum Operational Volume.* To provide the required storage for snow melt, the in-heap pond should be at minimum operational volume by the end of April. To achieve this for Phase 1, a maximum operational volume of 215,000 m^3 is required in October of each year to be able to accommodate the snowmelt.

- *Storm events.* The total rainfall in a 24-hour, 1 in 100 year storm event is 60 mm. For Phase 1, the heap leach area is 300,000 m^2, which results in a storm water volume of 18,000 m^3.

- *Heap Drain-down.* In the event of an operational power loss where pumping of the solution stops, the saturated heap will continue to drain-down. The worst case scenario is where drain-down occurs from the highest lift. The maximum volume of solution within the pore space that will be released from the heap for Phase 1 (30 m lift height) is assessed as 188,000 m^3 based on the difference between the leaching (13.5%) and residual moisture content (8.6%).

- *Freeboard.* If the in-heap pond reaches the spillway level, a further depth of 1 m is required for the overflow to reach the maximum capacity of the spillway pipe. An additional 500 mm freeboard is provided.

In normal operating conditions the in-heap pond can store freshet, storm and drain-down volumes. For Phase 1, the in-heap pond (435,000 m^3) can store the combined worst case scenario of maximum operational volume, storm event and drain-down (426,000

m^3). In Phases 2 and 3, this combination will result in the in-heap pond discharging via the spillway into the events ponds, which provides additional storage.

FURTHER WORK

Optimisation and improvements to the solution management will be undertaken during feasibility study and could include:

- confirming sources of winter make-up water to reduce the maximum operating volume
- consideration of inter-lift liners to reduce the heap drain-down volume
- verifying the residual, leaching and saturated moisture contents and the variability under the varying pressures within the heap
- assess viability for removal of snow from the HLF
- developing management criteria for solution volumes to address annual and seasonal variations, i.e., to establish rules for controlling pond levels (make-up water and treat and release) in advance of freshet and storm events and planned shut downs
- assess the events ponds for winter plant drain-downs, and
- review the potential for collector pipes on the side valley with separate collector pipes to direct the flow by gravity direct to the plant. It may be feasible to use these collectors to intercept the flow from specific heaps and thus manage the various solution grades.

LEACHATE COLLECTION SYSTEM

To provide the required flow to the leachate collection sump, a pipe network will be provided beneath the heap (Figure 9-13). Pipes will also be provided up the slope of the heap to reduce the phreatic surface and reduce the retention time of solution in the heap. The pipes will be located immediately above the liner, within the liner cushion layer and consist of:

- 100 mm diameter HDPE perforated pipes at 25 m centres placed in a 300 mm wide by 600 mm deep trench backfilled with clean gravel, connecting to
- 300 mm diameter HDPE un-perforated collector pipes placed in a 600 mm wide by 600 mm deep trench; backfilled with excavated material;

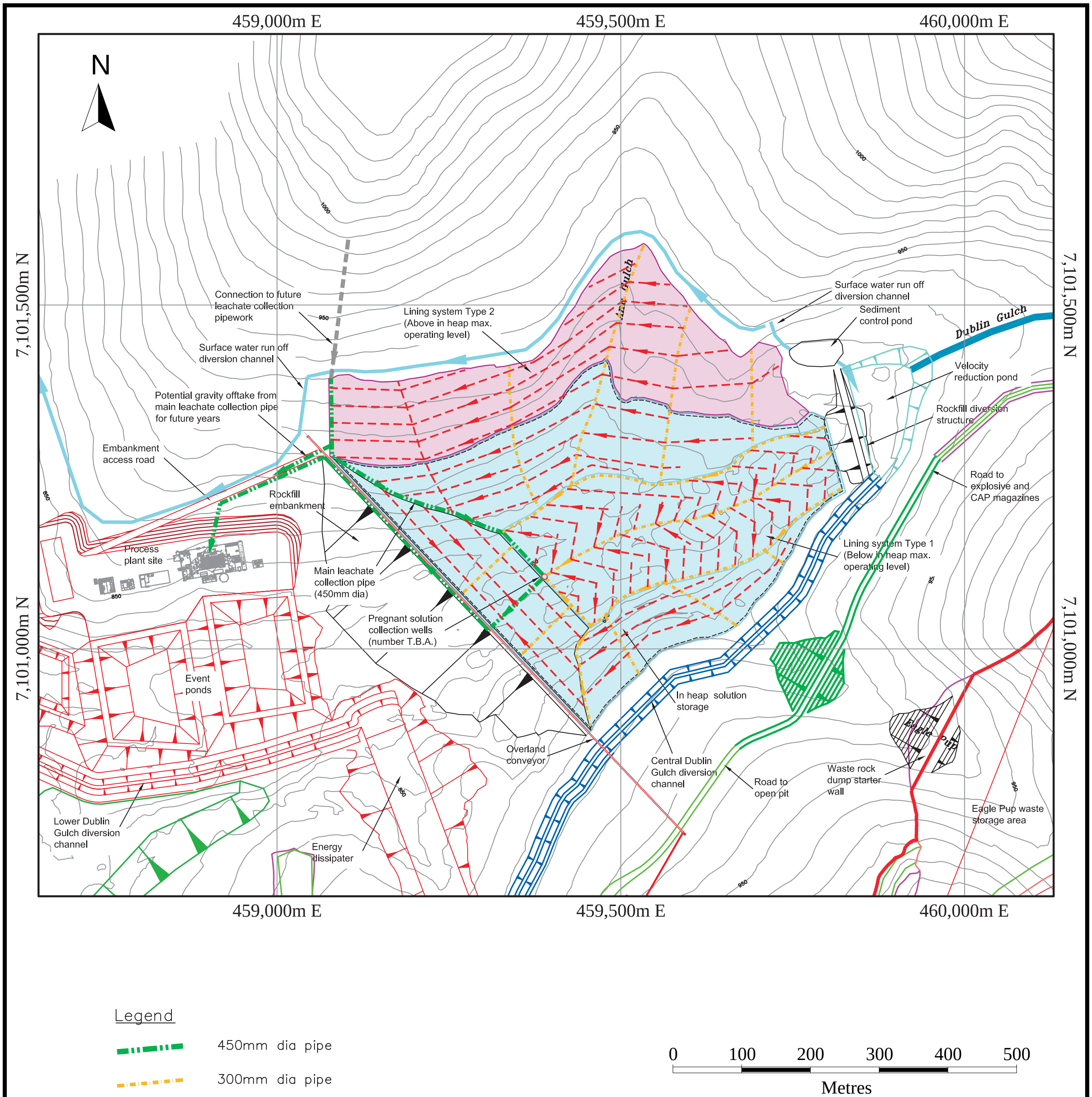

Figure 9-13

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Leachate Collection and Removal System Pipework Layout at 2014 Stack Height

June 2010

For the high earth pressure in the heap, creating a trench for the pipes is important to prevent crushing of the pipes, i.e., the cushion layer will be placed first and compacted, with the pipes placed in excavated trenches.

SEDIMENT CONTROL

Sediment control comprises two key elements

- runoff diversion and sediment control features, and
- infrastructure surface runoff collection and SCPs.

These structures will prevent sediment impacting the environment, and will be constructed at locations to prevent sediment from entering streams at source, or prior to runoff discharge into a natural water courses.

Sediment control works at site will include minimizing land clearing in advance of heap expansion, provision of silt fences, location of temporary diversions, stabilising diversion channels, temporary piping to the SCPs, etc. These works will be detailed as part of feasibility design.

Runoff from undisturbed areas above the catchment of the HLF and WRSAs is conveyed through channels, provided with erosion protection and routed through a SCP before release. When the facilities are raised, these same channels are used to intercept runoff from the disturbed catchments. The runoff diversions have not been detailed as part of this study and are shown only on the general arrangement drawings.

Runoff from the heap leach, although unlikely, will be prevented from discharging into the environment by constructing a minimum 1 m high bund wall around the toe of the HLF.

The highest potential for generating sediments is during construction of the facilities when topsoil is removed and the subsoil disturbed. Since the HLF and WRSAs will be constructed in phases throughout the mine life, interim stages require additional sediment control works. Sediment control works constructed at the start of the works are designed to take into account the phased construction.

There are two key SCPs;

- the HLF and plant site SCP, and
- the WRSAs and open pit SCP.

There will also be additional, smaller, SCPs or other appropriate sediment control measures for roads.

The volume required for the HLF and plant site SCP varies throughout the project. The largest capacity required is 130,000 m^3 for construction of the Dublin Gulch diversion. Throughout the remainder of the project, the capacity required is 30,000 m^3. Since the larger capacity is for a relatively short duration, it is proposed to make use of one of the events pond (capacity 100,000 m^3) and provide a permanent SCP for the remaining 30,000 m^3.

The start-up construction sequence ensures that sediment control is provided ahead of the main works. The main SCP will be constructed first, to enable works at the plant site and HLF to commence. Secondly, the Dublin Gulch diversion will be constructed. This will convey the drainage from the SCP at the toe of the Eagle Pup WRSA, which is to be constructed third. Runoff from the Platinum Gulch WRSA will be directed into a small SCP, and then directed down to the main SCP, along with water from the open pit.

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APPENDIX B
SCOTT WILSON RPA DESIGN BASIS FOR HEAP LEACH PAD AND ASSOCIATED FACILITIES

Design Basis
Eagle Gold Project - Heap Leach Facility

<table>
<tr><td rowspan="2">Job Title</td><td colspan="4" rowspan="2">CANADA: DUBLIN GULCH, EAGLE ZONE, HEAP LEACH PREFEASIBILITY STUDY</td><td>Job no.</td><td colspan="2">D125666</td></tr>
<tr><td>Reference</td><td colspan="2">TN-DSNB</td></tr>
<tr><td>Originator</td><td>Reviewer</td><td>Revision</td><td>V2</td><td>V3</td><td>V4</td><td>V5</td><td rowspan="2">Template Version 02</td></tr>
<tr><td>SD</td><td>DJB/AMW</td><td>Date</td><td>21-09-09</td><td>23-09-09</td><td>29-10-09</td><td>18-11-09</td></tr>
</table>

INTRODUCTION

This document presents the assumed civil, hydrological and geotechnical engineering design parameters for the Eagle Gold Project Heap Leach Facility (HLF) and summarises applicable design standards and design criteria and defines the battery limits for the design scope.

The presented design parameters have been largely based on information supplied by other project parties and, where new data is not available, information contained in previous studies carried out for the project site.

DESIGN STANDARDS

There are currently no published international standards for the design and construction of dump and heap leach facilities; however there is significant reference material highlighting the pertinent design and operational issues.

Similarly, the Yukon Territory does not have regulations specifically for heap leach facilities, but instead relies on regulations from other regions and precedence from other projects. It is understood that the only HLF that has been permitted in the Yukon is at Brewery Creek, the design and permitting of which, according to previous design work by Sitka Corporation, was based on the Nevada State guidelines (Ref. 2). Also, the Walter Creek Valley Fill Heap Leach Facility, located at Fort Knox Mine near Fairbanks, Alaska (Ref 1) might be used as a reference facility. The design and operation of the Fort Knox HLF is likely to encounter similar obstacles to those present at the Dublin Gulch site.

Previous studies for a HLF at the project site have been published and therefore it has been assumed that the new pre-feasibility facility design will be required to meet the same standards.

Table 1 summarises the main technical and permitting requirements for the State of Nevada for the key elements of the HLF design.

Table 1: Heap Leach Pad Permitting Requirements (State of Nevada, USA)		
Heap Leap Feature	**Description**	**Reference**
Leach Pad Liner	System must have containment capability equal to or greater than that of a composite liner consisting of a synthetic liner over one foot of compacted soil at a permeability of 1×10^{-6} centimetre per second or 1×10^{-5} centimetre per second if a leak detection system is used beneath portions of the liner with the greatest potential for leakage	Ref 2
	Synthetic liners must be rated as having resistance to fluid passage equal to a permeability of less than or equal to 1×10^{-11} centimetre per second	Ref 2
	Allow a maximum quarterly average leakage rate of 300 litres per day per cell into the leak detection and recovery system and a maximum yearly average of 100 litres per day per cell.	Ref 3
Solution Ponds	System must have a primary synthetic liner and a secondary liner that meet the above-described liner specifications. The synthetic liners must be separated by a fluid transmission layer which is capable of transmitting leaked fluids at a rate that will ensure that excessive head will not develop on the secondary liner	Ref 2
Solution Management and Containment	Process components must be demonstrated to have the capacity to "withstand" the runoff from a 100-year, 24-hour precipitation event. In addition, facility fluid management systems must demonstrate the capability of remaining "fully functional and fully contain all process fluids including all accumulation resulting from a 25-year, 24 hour precipitation event. The foregoing standards are minimal and additional containment capacity may be required if surface water bodies or human populations are in close proximity to the facility, or if groundwater is shallow	Ref 2
Foundations	Consider static / dynamic loads and differential movement or shifting	Ref 2
Construction QA/QC	Regulations require that each applicant develop and carry out a quality assurance and quality control program for liner construction. A summary of the QA/QC program must be submitted with as-built drawings after construction has been completed	Ref 2
Neutralization/Detoxification of Spent Ore	Spent ore, whether it is to be left on pads or removed from a pad, must be rinsed until it can be demonstrated either the remaining solid material, when representatively sampled does not contain levels of contaminants that are likely to become mobile and degrade the waters of the state under the conditions that will exist at the site, or, the spent ore is stabilized in such a manner as to inhibit meteoric waters from migrating through the material and transporting contaminants that have the potential to degrade the waters of the state"	Ref 2

Compliance with the aforementioned permitting criteria in the most part also implies that more general requirements, such as the International Finance Corporation's (IFC) World Bank guidelines (Ref. 11) are also met. The IFC guidelines apply to mining operations in general with one section specific to HLF as follows:

"*Operators should design and operate surface heap leach processes with:*

- *Infiltration of toxic leach solutions should be prevented through the provision of appropriate liners and sub-drainage systems to collect or recycle solution for treatment, and minimize ground infiltration;*
- *Pipeline systems carrying pregnant solutions should be designed with secondary bunded containment;*
- *Leak detection equipment should be installed for pipeline and plant systems with appropriate leak response systems in place;*

- *Process solution storage ponds and other impoundments designed to hold non-fresh water or non-treated leach process effluents should be lined, and be equipped with sufficient wells to enable monitoring of water levels and quality."*

With reference to the last bullet point above, it would be appropriate to consider installing monitoring wells around the HLF to monitor water levels and quality.

The pre-feasibility (PFS) report is to include a table demonstrating compliance with these criteria and guidelines.

PRINCIPAL DESIGN OBJECTIVES

Taking in to account regulations, guidelines, best practice and experience, the principal objectives of the PFS design of the Eagle Gold Project HLF are to:

- Ensure complete protection of the regional groundwater and surface water flows both during operations and in the long-term.

- To satisfy the environmental regulatory requirements of the Yukon territory and the Department of Indian and Northern Development (DIAND)

- Provide permanent, secure storage and total confinement of the leach ore within a fully engineered facility.

- Effectively collect and convey solutions for in-heap pregnant solution storage to ensure maximum recovery. In-heap storage of solution will be utilised to provide the necessary winter time storage of solution in an above freezing environment.

- Minimise the quantity of surface water runoff entering the facility and coming into contact with the process solutions.

- Provide additional external facilities (events ponds) to accommodate excess solution and rainfall/snowmelt when hydrological events exceed the storage capacity of the heap.

- Stage develop the facility where possible to minimize the environmental disturbance at any one time and to distribute capital expenditure over the life of the facility.

- Monitor all aspects of the facility to ensure that the design objectives are met and that there are no adverse environmental impacts.

- Reclaim the facility to a condition compatible with the original land use and is stable under extreme precipitation events and seismic events.

PROJECT PARAMETERS AND CRITERIA

The parameters and criteria presented in Table 2 form the basis of design for the HLF. A number of parameters require to be confirmed (marked TBC) on completion of work by others. The owner of the presented parameters and criteria are also indicated. Where current data is not available applicable source references to previous studies are provided.

Table 2: Heap Leach Facility - Project Parameters and Criteria			
ITEM	**Quantity/Criteria**	**Owner**	**Reference**
Operations			
Mine Life	10 years TBC	Project	TBC
Life of mine (LOM) ore quantity to be stacked on heap leach pad	52 – 65 Mt TBC	Project	TBC
Crushing rate, stages	Delivery to primary crusher 24,000 t/d (6Mtpa) Primary Crusher Type Gyratory Secondary Crusher Type Open circuit Tertiary/Quaternary Crusher Type MP/HPGR	KCA	
Final ore crush size	5 mm TBC	Project	TBC
Ore geotechnical parameters	32 degrees, 0 Cohesion, unit weight 18kN/m^3	SWM	
Leach pad type	Permanent, multiple lift	Project	
Initial stacking capacity	Minimum of 2 years	Project	
Stacking schedule	250 days per year	Project	
Stacking Rate	1430 t/h	KCA	
Process flow diagram	TBC	KCA	TBC
Agglomeration	Belt Type, 2 – 3 kg/t cement, 1 kg/t lime.	KCA	
Stacking method	Conveyor-stacker	Project	
Stacked dry density of ore	Initial - 1.60 t/m^3	KCA	
Stack / lift height	10 m lifts, max heap height - TBC	Project	TBC
Overall slope angle of stacked ore	1h : 2.5 v (22 degrees)	SWM	Ref. 4
Coefficient of permeability of stacked ore	0.05 cm/s (typical). Initial permeability and post-leach permeability at confining pressures 10m to 100m TBC	KCA	Ref. 5
Ore solution storage	0.26 m^3 of solution per m^3 of ore TBC	KCA	TBC - Ref. 4
Ore moisture contents	Initial 3.0%, leaching 12.8%, residual 6.9% TBC	KCA	TBC - Ref. 7
Leach schedule	350 days per year	Project	
Solution application method	Drip emitters (buried during cold weather operations)	KCA	
Solution application rate	10 l/hr/m^2	KCA	
Irrigation area	160,000 m^2 TBC (Calculated based on the nominal solution application flow of 1600 m^3/hour and solution application rate of 10 l/hr/m^2)	KCA	TBC
Solution application flow	1,600 m^3/hour (nominal) 1,900 m^3/hour (design)	KCA	
Hydrology and Climate (1,000 m elevation)	**Quantity/Criteria**	**Owner**	**Reference**
Total annual precipitation	454 mm Superseded – see Stantec data	Stantec	Ref 6,8
Annual Rainfall (57% total annual precipitation)	259 mm Superseded – see Stantec data	Project	Ref 6,8
Annual Snowfall (43% total annual precipitation)	195 mm Superseded – see Stantec data	Project	Ref 6,8
Maximum Rainfall – one month, two month, three month	94 mm, 143 mm, 188 mm Superseded – see Stantec data	Project	Ref 6,8
Average extreme 24-Hour Rainfall	22.9 mm Superseded – see Stantec data	Project	Ref 6,8
100-yr 24-Hour Rainfall	43.7 mm Superseded – see Stantec data	Project	Ref 6,8

Maximum Snowpack (mm water)	164 mm Superseded – see Stantec data	Project	Ref 6,8
Annual Lake Evaporation (mm)	450 mm Superseded – see Stantec data	Project	Ref 6,8
Sublimation (% of snowfall)	13 % Superseded – see Stantec data	Project	Ref 6
Mean Annual Temperature	-3.7°C Superseded – see Stantec data	Project	Ref 6,8
Seismicity	**Quantity/Criteria**	**Owner**	**Reference**
Design Basis Earthquake (DBE)	0.078g (1 in 475 yr return period)	SWM	Ref 5
Maximum Design Earthquake (MDE)	0.10g (1 in 1000 yr return period)	SWM	Ref 5
Geotechnical Stability	**Quantity/Criteria**	**Owner**	**Reference**
Minimum embankment Factor of Safety	Static Loading - 1.5 (impounding), 1.3 (non-impounding), Seismic Loading - 1.15	SWM	Ref 4
Permafrost	Permafrost encountered in the pad or pond foundations, if thaw unstable, will be removed	SWM	Ref 4
Containment Dyke	**Quantity/Criteria**	**Owner**	**Reference**
General	To provide stable confinement of the ore and in-heap storage of solution.	SWM	Ref 4 Ref 10
Standards	Designed to Canadian Dam Safety Association (CDSA) standards	SWM	Ref 4
In-heap storage	To attenuate variation in flows into the heap to allow a constant flow to the process plant and minimise treatment and release. 1. Minimum storage volume (to ensure supply to process plant) equivalent to 48 hours supply. 2. Maximum storage volume to allow for 1:100 year, 24-hour storm event 3. Maximum storage volume to allow for draindown of water stored in voids above in-heap pond level.	SWM	Ref 5
Overflow spillway	Sized to pass 100 year return period peak flow assuming heap storage is at capacity at the start of the event.	SWM	Ref 4 (and Nevada)
Groundwater	**Quantity/Criteria**	**Owner**	**Reference**
General	A drainage system is required beneath the liner system to control groundwater pressures. The system is to collect groundwater in a controlled manner before discharge downslope of the containment embankment. Note, unforeseen seepage may be encountered during construction, for which additional measures may be required.	SWM	Ref 4
Pad Liner System	**Quantity/Criteria**	**Owner**	**Reference**
Ore cushion	To protect the lining system from damage by ore placement whilst not impacting the conveyance of solution to the recovery wells.	SWM	Ref 4
Geosynthetic liner	Suitable liner material to provide required puncture resistance, elastic strain range and resistance to solution attack together with good cold weather performance.	SWM	Ref 4
Soil liner	Compacted fine grained soil below the geosynthetic liner to provide a composite liner to minimise leakage. Objective maximum permeability 1×10^{-5} cm/s.	SWM	Ref2//Ref 4
Geotextile	To be used where filter relationships are not satisfactory between soil materials in the lining system.	SWM	Ref 4
Leak detection and recovery system (LDRS)	A system to collect leakage through the composite liner and convey it to monitoring points. The system to comprise drainage gravel and a network of drainage pipes to collect and convey any leaked solution.	SWM	Ref 4
LDRS monitoring	Monitoring of the flow into the LDRS to ensure that allowable rates (determined by permitting authorities) are not exceeded.	SWM	Ref 3/Ref4

	Mitigation procedures to be defined should rates be exceeded.		
Frost protection	Liner to be protected from seasonal frost penetration by maintaining a minimum of 3 m of dry ore above the cushion layer.	SWM	Ref 4
Solution Recovery Wells	**Quantity/Criteria**	**Owner**	**Reference**
General	Solution is to be recovered from the heap through vertical pumped wells installed in the in-heap solution storage area TBC	SWM	TBC - Ref 4
Event Pond(s)	**Quantity/Criteria**	**Owner**	**Reference**
General	Events pond(s) to be constructed downstream of the pad to store excess solution and natural inflow that cannot be stored in the in-heap storage.	SWM	Ref 4
Standards	Confining structure to be designed to same standards as the ore containment embankment	SWM	Ref 4
Overflow spillway (from HLF)	Sized for 100 year return period peak flow assuming heap storage is at capacity at the start of the event. No spillway to be provided in the events pond (all flows to be pumped).	SWM	Ref 4
Storage Capacity	Sized to store 48-hour draindown volume, the design hydrological inflow and the operating solution volume less the storage volume provided in-heap	SWM	Ref 4/Ref 5
Liner system	Lining to comprise a primary and secondary geosynthetic liner separated by a geonet drain (LDRS layer) and a compacted soil layer between the secondary liner and the subgrade.	SWM	Ref 4
Polishing Pond(s)	**Quantity/Criteria**	**Owner**	**Reference**
General	Effluent from the water treatment plant to be directed to the polishing pond for detention and precipitation of suspended solids. After polishing, water to be pumped to the sedimentation pond before discharge. TBC	KCA	TBC - Ref 4
Surface Water Diversion	**Quantity/Criteria**	**Owner**	**Reference**
General	Surface water diversions to be provided around the pad and ponds to divert natural run-off water away from the structures. Diversion channels to be designed to convey peak flows from a 100 year return period storm event with appropriate erosion protection measures.	SWM	Ref 4
Sediment Control	**Quantity/Criteria**	**Owner**	**Reference**
General	Sediment control to be provided for the pad, the events and polishing ponds, pit and waste rock areas using conventional settling ponds. Settling ponds to be sized to remove inflowing suspended sediment down to medium silt sizes for events up to a 10 year return period 24 hour duration storm. Emergency spillways to be provided for each pond with a capacity sufficient to convey the flow from a 100 year return period storm event. TBC	SWM	TBC - Ref 4
Construction Material Sources	**Quantity/Criteria**	**Owner**	**Reference**
General	All engineering fill materials shall be sourced locally where possible.	SWM	Ref 4
Topsoil stockpiles	Stockpile topsoil such that it is suitable for re-use at closure	Stantec	

DESIGN BATTERY LIMITS

Scott Wilson (Ashford) shall be responsible for the design, to pre-feasibility level, to the identified battery limits of the elements identified in Table 3.

Table 3: Heap Leach Facility – Design Battery Limits		
ITEM	**SW Ashford scope**	**Battery Limit**
Heap leach pad.	Liner, leak detection, recovery systems and in-heap solution storage pond.	Top of cushion layer (above liner)
In-heap pond spillway	Spillway and pipeline to events pond	None
Leachate collection and removal system (LCRS)	In-heap pipework and vertical solution pump well	Inlet at vertical solution well pump
Leak detection and recovery system (LDRS upper and lower)	LDRS layers and pipe network.	Inlet at inter-liner pumps
Confining embankment	Embankment	Access road surface
Events ponds	Embankments, liner and inflow pipeline from HLF	Inlet of outflow pump to plant and HLF
Surface water runoff diversions for pad and ponds	Channel to sediment control pond	None
Sediment control ponds	Embankments, liner, inflow channel or pipeline and outflow pipeline.	Inlet from plant, inlet from polishing pond and inlet from camp
Polishing ponds	KCA scope	-
Closure and site reclamation.	Closure of all SW (Ashford) designed items. Physical stability of re-contoured surfaces.	Top of re-contoured surface. Chemical stability

REFERENCES

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7. Clearwater Consultants Ltd. 1996. Heap Leach Facility Water Balance Design Memo CCL-DG4.

8. Hallam Knight Piésold. 1996. Dublin Gulch Initial Environmental Evaluation Vol II Environmental Setting.

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APPENDIX C
SCOTT WILSON RPA PREFEASIBILITY STUDY SECTION FOR WASTE ROCK STORAGE AREAS

WASTE ROCK STORAGE AREAS

The waste rock storage areas (WRSAs) are located on either side of the proposed open pit, largely downslope and within a kilometre of the pit edges. The Eagle Pup WRSA is located in the lower part of the Eagle Pup catchment area, covering approximately 80 ha of the 127.2 ha catchment area. The Platinum Gulch WRSA occupies 33 ha of the upper section of the Platinum Gulch catchment.

The Eagle Pup WRSA is designed to provide permanent storage for approximately 55 Mt of waste rock, with potential capacity for more. The Platinum Gulch WRSA is designed to provide permanent storage for approximately 11 Mt of waste rock. Waste rock will be deposited year-round, at a rate of approximately 8 million tonnes per year, or 10,000 m^3/day. The dumps will be constructed in lifts with a maximum height of 100 m, with benches between successive lifts to provide a final overall slope of 2.5H:1V.

A series of previous studies are relevant to the WRSA designs, including a feasibility design carried in the late 1990s of a facility on the Eagle Pup site, of comparable dimensions and location. Certain aspects of these studies, particularly stability and water balance are therefore directly applicable to the current Eagle Gold Project and are reviewed and adopted in the light of field observations and investigations and modifications to Project parameters.

SITE SELECTION

Four potential sites for the location of WRSAs were identified, including all the main catchments draining the proposed open pit area i.e., Platinum Gulch, Stuttle Gulch, Eagle Pup and Stewart Gulch.

Based on a comparison of capacity, location and geology, the preferred locations for waste rock disposal are the Platinum Gulch and Eagle Pup catchments. Although Stuttle Gulch is closer to the open pit than Eagle Pup, it would interfere with crushing and conveying infrastructure. Platinum Gulch is proposed for use in the initial years of operation, followed by Eagle Pup.

The design of the various elements of the Eagle Pup WRSA is developed in the following sections, together with supporting sections on water balance and stability assessment. These design elements were used to assess the Platinum Gulch WRSA, a late addition to the PFS, however, a separate detailed assessment is required for the feasibility design.

SITE CHARACTERISTICS

TOPOGRAPHY AND GEOLOGY

The Eagle Pup valley has narrow upper reaches at an elevation of approximately 1,500 masl, with relatively shallow slopes draining the ridge behind the open pit, but then the valley opens out with particularly steep slopes in its mid reaches. These slopes flatten in a downstream northerly direction in the central valley area (see Figure 6-9) to an elevation of approximately 900 masl at the confluence with the Dublin Gulch valley. On the western side, valley slopes include rock bluffs, below which the valley kinks north-west. The lower part of the valley is characterised by a narrowing valley outlet bordered by rounded catchment divides to Stewart and Stuttle Gulches.

The geology of the lower catchment bedrock conditions were investigated in the late 1990s (for the Rescan 1996 Feasibility Study) and also in 2009 (BGC, 2009), with a series of over 30 trial pits, three boreholes, laboratory testing of samples and in-situ geotechnical testing. Bedrock conditions comprise intrusive granodiorites, the outcrop of which strikes SW-NE and is located in a central section cutting through the Eagle Pup catchment. The intrusion occurred into a series of clastic rocks (metasediments comprising schists, phyllites, quartzites etc.).

The superficial materials of the lower catchment area comprise largely colluvium derived from bedrock weathering. Talus covered slopes are present on some of the steeper slopes below rock bluffs (north-west facing slopes between 970 masl and 1,320 masl, and to a lesser extent, the east facing slopes of the western ridge). In the centre of the kilometre long, 100 m wide valley floor, in the lower central part of the valley, some fluvial reworking of the colluvium sediments is present. The Sitka 1996 report also identified the presence of till. This surficial (potential overburden) material has been shown to vary considerably in thickness from 0.5 m to 14 m and is estimated as follows:

- upper catchment areas, shallow slopes less than 20 degrees – up to 7 m of weathered bedrock
- ridge lines – 0.5 m to 1.0 m of weathered bedrock
- valley side slopes > 20 degrees – rock outcrops or colluvium of between 1 m and 2 m, and
- creek bed and valley floor – colluvium up to 3 m and alluvium in the lower valley floor up to 6.5 m over weathered bedrock to >10 m.

Organic soils are widespread but are of limited thicknesses up to depths of 0.3 m.

The upper catchment area has not been investigated, however, comparable flat-topped ridge locations in the granodiorite and metasediments indicate a thin organic soil over a deep, up to 6.5 m, weathered bedrock profile.

The variable surficial thickness is an issue for the foundation conditions for defining depths to competent free draining soils or bedrock.

The specific local features of the Eagle Pup WRSA include a north-facing aspect and an elevation of between 900 masl and 1,150 masl.

HYDROLOGY

The hydrology of the Project area, including the WRSA sites, is presented in detail in Stantec's report (2009). Of particular note for the WRSAs is that the peak stream flows occur in the spring in association with freshet events, (snow melt or rain-on-snow events) with flows gradually disappearing following the disappearance of the snow. Sizeable flood events may also occur in the late summer due to intense rainstorms and are particularly significant for small catchments. The smallest discharges occur in mid winter, when streams such as Eagle Pup freeze entirely, reducing their winter flows to zero.

The peak flows are pertinent to the design of the WRSA foundation rock drains and surface runoff collection and diversion ditches. Knight Piésold (1996) provided a feasibility analysis of the flows for small catchments based on the Rational Method described in the MOE Manual of Operational Hydrology in B.C. and the Hathaway. The analysis for structures in a similar-sized catchment in the same location is presented in Table 6-14.

TABLE 6-14 GROUND AND SURFACE WATER PEAK FLOW DESIGN ASSUMPTIONS
Victoria Gold Corp. – Eagle Gold Project

WRSA Structure	Return Period	Event Size	Peak Flow (m^3/s)
Surface diversion ditches around the WRSA	1 in 200 year	24 hour event	0.5 to 1.2
Operational surface collection ditches on the WRSA benches	1 in 10 year	24 hour storm event.	0.6
Foundation Rock Drain	1 in 200 year	24 hour storm event.	1.5

HYDROGEOLOGY

The hydrogeology of the Project area, including the WRSA sites, is presented in detail in Stantec's report (2009). Of particular note for the WRSAs is the unconfined flow system within the bedrock. Groundwater is recharged at higher elevations in the thick weathered horizons of the upland areas (above the proposed open pit area) and slowly discharges throughout the year onto the steep slopes of the upper part of the catchment from a series of small springs. The resulting surface flows are intermittent and the flows sink back into the valley colluvium and alluvial materials, only to finally reappear lower down the catchment valley (observed at elevations of around 950 masl in late summer of 2009).

Measurements of groundwater levels in the Eagle pup catchment indicate water levels present within the superficials and weathered bedrock a few metres below ground level, however, this is variable across the catchment, reflecting a subdued form of the topography, but altered by thickness of superficials and weathered bedrock. Typical values of between two metres and seven metres below ground level are reported (Sitka 1996), however, seasonal variations were not identified.

The hydraulic conductivity of the bedrock is relatively low and assessed to be 1.5 x 10^{-6} m/s (Knight Piésold 1996), and the foundation soils of sand and gravel with some silt beneath the WRSA are of the order of 1.9 x 10^{-5} m/s in a thawed state and 10^{-11} m/s in a frozen state.

For the WRSA water balance the groundwater losses into the bedrock foundations have been estimated at 2% (Knight Piésold 1996).

PERMAFROST

Permafrost will generate issues for the WRSA design in two regards, the potential for thawing of:

- seasonal frost zones, and
- permafrost zones that include excess ice.

A zone of near surface seasonal frost is recorded in the test pitting and is very evident in frost heave soils and the frost-jacking (out of the ground) of the monitoring well KP 95-151 installed in 1995 (Knight Piésold 1996). Thermistor measurements indicate the marginal temperatures in this zone and thaw analysis by Knight Piésold support the observation of about three metres of seasonal thaw. With the stripping of the insulating organic layer, the seasonal frost zone can be expected to thaw earlier and more deeply, leading to excess pore water pressures. Thawing rates were investigated and assessed to generate limited excess pore pressures that would dissipate rapidly once thawing occurs (Knight Piésold 1996).

The permafrost of the Project area, including the WRSA sites, is assessed in BGC's report (BGC 2009). Of particular note for the WRSAs is the presence of a discontinuous permafrost zone within the valleys in both the superficials and in the near surface weathered bedrock. The permafrost depth is recorded as typically occurring from about three metres depth (Sitka 1996 and BGC 2009). Where bedrock or overburden is frozen without excess ice, the permafrost is unlikely to affect the WRSA stability. Test pits, however, have encountered zones of permafrost with excess ice, and these areas will require treatment by stripping to encourage thawing and drainage, or excavation to thaw stable soils or bedrock before being covered with waste rock, and if necessary monitoring and limited dump heights.

SEISMICITY

A review of the seismicity of the project area was undertaken for the Heap Leach Facility (HLF) and is presented in Section 9. The design Base Earthquake of 0.078 g for operational conditions and a Maximum Design Earthquake of 0.10 g for post closure conditions as developed for the HLF are also appropriate for the design of the WRSAs.

DESIGN BASIS

DESIGN CRITERIA

Taking in to account regulations, guidelines, best practice and experience, the following design criteria are established for WRSA facility design:

- **provide permanent, secure storage** and total confinement of mine waste rock within a fully engineered facility
- **minimize potential impacts** to the local groundwater system and surface water flows both during operations and post closure long-term
- **rehabilitate the facility** to a condition compatible with the original land use and is stable under extreme precipitation events and seismic events, and
- **satisfy the environmental regulatory requirements** of the Yukon territory and the Department of Indian and Northern Development (DIAND).

PROJECT OBJECTIVES

Taking in to account regulations, guidelines, best practice and design criteria, the principal project objectives of the PFS design of the WRSAs are to:

- develop the facilities in stages to minimize the environmental disturbances at one time during construction and operations and to distribute capital expenditures over the life of the facility

- minimize disturbance to catchment area(s)
- effectively collect and convey drainage beneath the WRSAs
- minimize the quantity of surface water runoff entering the facilities and coming into contact with the waste rock
- provide additional external facilities (sediment ponds) to accommodate drainage and rainfall/snowmelt when hydrological events generate discharges
- address the presence of permafrost and provide appropriate foundation drainage requirements to satisfy stability criteria
- monitor all aspects of the facilities to ensure that the design objectives are met and that there are no adverse environmental impacts, and
- reclaim the facilities to a condition compatible with the original land use and stable under extreme precipitation events and design seismic events.

OPERATIONAL PARAMETERS

The following operational assumptions have been made for the PFS design of the WRSAs:

- mine waste rock schedule is based on outputs from the design of the open pit mine
- a total waste rock production of 65 Mt
- annual waste rock production averaging 8 Mtpa
- hauling and placement of waste rock operations for 365 days/year
- placement of waste materials in benches up to 100 m, by end-dumping from the face of an advancing lift, and
- waste material comprises variable grain size up to boulders of granodiorite and meta-sedimentary rock types.

WRSA DESIGN

GENERAL ARRANGEMENT

The general arrangement of the WRSAs is presented in Figure 6-9 and includes the following elements:

- rock dump and foundation drainage
- starter embankments

- sediment control pond (SCP)
- surface runoff diversion channels, and
- closure works.

The Eagle Pup WRSA is contained within the Eagle Pup lower catchment area, between the elevations of 1,385 masl and 925 masl at the toe. The facility is based on 60 Mt at a density of 1.9 t/m^3, and a phased construction behind a starter embankment that traverses the valley from ridge line to ridge line.

The Platinum Gulch WRSA is located within the upper catchment area of Platinum Gulch, between the elevations of 1,380 masl and 1,000 masl at the toe.

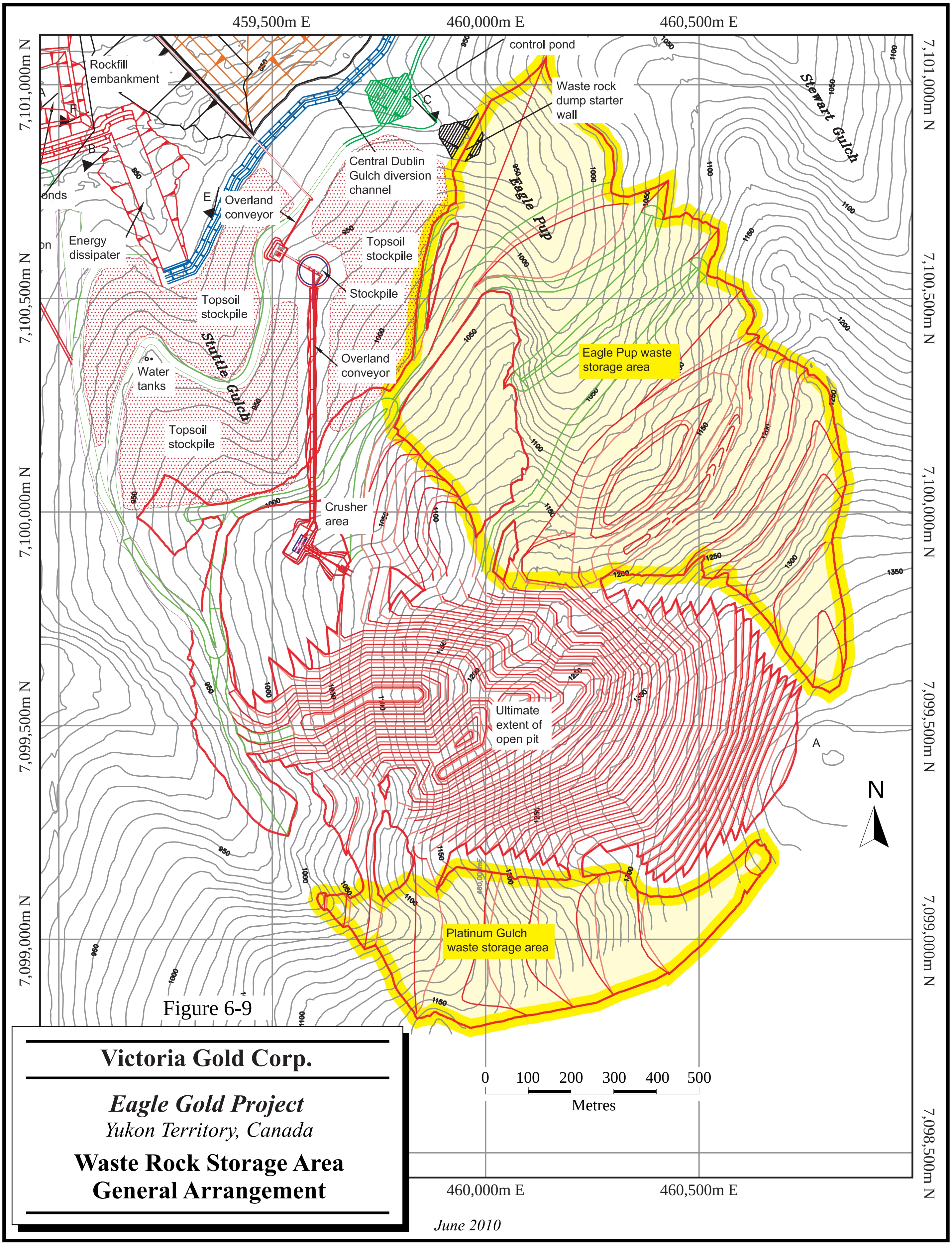


Figure 6-9

Victoria Gold Corp.

Eagle Gold Project

Yukon Territory, Canada

Waste Rock Storage Area General Arrangement

June 2010

ROCK DUMP AND FOUNDATIONS

The rock dump is constructed through a hybrid of ascending lifts waste-rock terraces and some areas of descending platforms and wrap-arounds. The hybrid approach addresses issues of heap stability, environmental impact and provides flexibility for the early mining operation. The approach also mitigates against various operational risks including:

- instability and Health and Safety impacts on operatives and downstream infrastructure from
    - excessive rates of advance on limited lengths of end-tip crests
    - boulder roll out
    - rapid ground pressure build-up
    - thaw-instability beneath the waste rock
- uncontrolled segregation with implications for drainage
- reducing sediment generation and the potential for contamination
- waste rock avalanches in winter.

The design also:

- allows for progressive stripping of topsoil where practical, and
- minimizes disturbance to the environment of one catchment.

The stripping of organic materials is limited to approximately 30 ha of the catchment that comprises continuous slopes of less than 20 degrees. The balance of the catchment is assessed as too steep to be accessed or comprises surficial materials with limited organic material that warrants stripping.

This overall approach to rock dump construction also addresses the availability of waste rock, the anticipated differences in waste rock quality differences, and the requirement for selected materials for drainage to be tipped in the lower terraces and thus provide adequate WRSA stability during operations and post closure.

STABILITY CONSIDERATIONS

The physical stability of the WRSA is critical to its short-term (operational) and long-term (post closure) performance. The WRSA is designed against failure of the waste rock and/or the foundations. The design therefore considers the operational design events and post closure extreme events, of seismic loading under an Operational and Maximum Design Earthquake (ODE and MDE) and Probable Maximum Precipitation (PMP).

Particular aspects that are key to determining stability include:

- waste rock material properties particularly strength characteristics with increased normal stress
- geometry and loading cases (static and seismic)
- location of phreatic surfaces
- pore pressures and thaw instability in the foundations
- mechanisms of failure, and
- deformation strength changes.

MECHANISMS OF FAILURE

Case studies and theory have established that modes of failure in waste rock slopes are dependent in-part on the method of construction. Where material is end-tipped at the crest, the slope remains at an the angle of repose for the waste rock and through a combination of factors not least segregation and height of slope, and failure is commonly along a parallel plane and consists commonly of a number of wedges or segments (Campbell 2000).

Where ascending terrace lifts are utilised, relative increases in strength characteristics are achieved through improved state of particle packing during construction, reduced segregation and reduced (bench) slope heights. Failure mechanisms are more likely to include toe failures, circular and non-circular failures contained within the waste rock and into the foundation materials.

Failure mechanisms post closure can be linked to long-term effects of chemical and physical weathering and moisture-softening mechanisms leading to progressive failure. Settlement can also be expected of between 2% and 7% of the waste rock (Williams 2000).

Given the proposed ascending construction method, the critical failure mechanisms for the WRSA are assessed to include circular and wedge failures through the variable foundation material identified in the catchment, particularly in early years where the WRSA is an isolated structure, with limited stabilising benefit from the side slopes.

STABILITY ANALYSIS - MATERIAL PROPERTIES

The selection of geotechnical material properties for stability design of a WRSA is a significant part of the geotechnical process of design.

The waste rock is expected to contain coarse, angular fragments of metasedimentary and intrusives (granodiorites) up to one metre in diameter. The absence of a significant weathering horizon in the vicinity of the open pit, and limited clay coatings on the intrusive, ensures that other than the fine-grained metasediments, the waste rock is primarily clean, durable and free of any significant fines content.

A comparison of shear strength material parameters considered for stability analyses are presented in Table 6-15.

TABLE 6-15 WASTE ROCK MATERIAL PARAMETERS COMPARISON (MIN – MEAN – MAX)

Victoria Gold Corp. – Eagle Gold Project

Parameter		BGC (2009)	Sitka Corp (1996)	Knight Piésold (1996)	Reference
Base angle of friction, (°)	Metasediments	32	-	-	1a
	Intrusives	28	-	-	1a
Peak angle of friction, (°)	Metasediments	40	40	42.3	1a, 2, 3b
	Intrusives	40	-	42.3	1a, 2, 3b
Residual angle of friction (°)	Metasediments	35	37	-	1a, 3b
	Intrusives	38	-	-	1a, 3b
Joint Roughness Coefficient (JRC)	Bedrock	11 (55% of the dataset)	-	8 -12 (based on assessment from discontinuity logs)	1b
Uniaxial Compressive Strength, (MPa)	Metasediments	21 -77 -168	86	55 (2a) 55 - 100 -190 (2b)	1c, 2a, 2b, 3a
	Intrusives	3 - 134 - 224	127	63 (2a) 63 - 178 - 260 (2b)	1c, 2a, 2b, 3a
	Weathered Bedrock	-	-	4 - 34 - 93	2b

1a. BGC. 2009. Direct Shear Strength Testing Results.pdf and
Direct Shear Results Summary.xls / Direct Shear Strength Testing Results.pdf

1b. BGC. 2009. Rock Mass and Discon Information.xls

1b. BGC. 2009. Point Load Testing Results.xls / Intact Strength.pdf

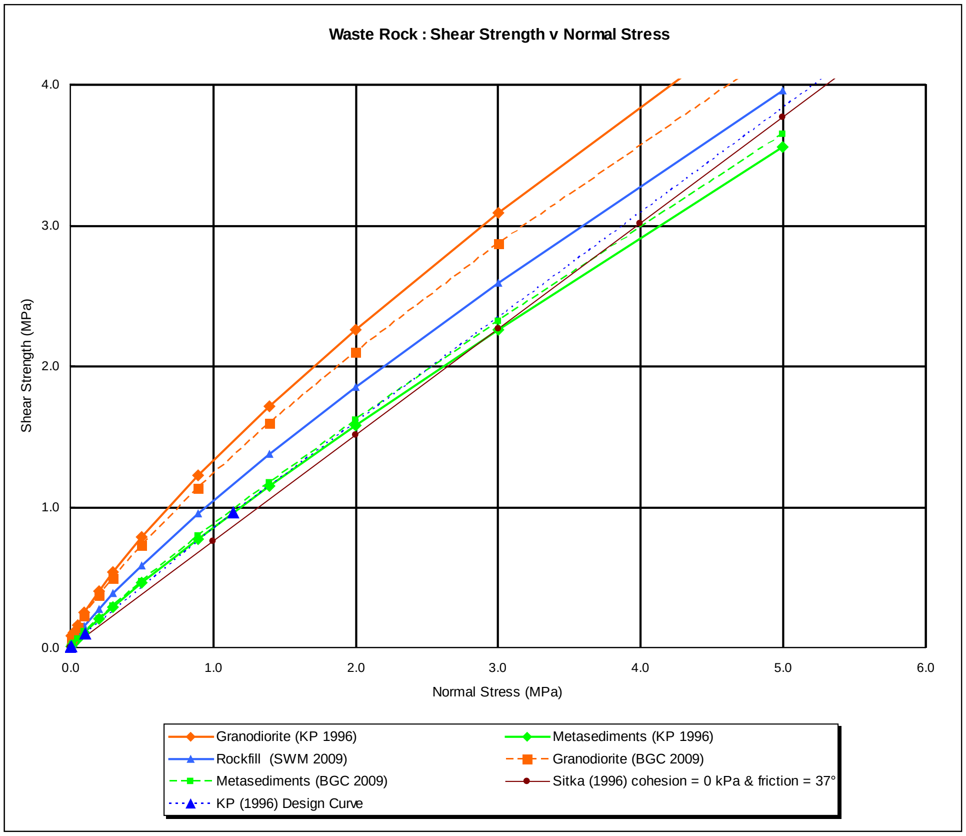
2a. Knight Piésold. 1996. Dublin Gulch Project - Report on the Feasibility of Heap Leach Pad and Associated Structures. (Report No. 1882/4)

2b. Knight Piésold. 1996. Dublin Gulch Project - Report on the Open Pit Slopes. (Report No. 1882/3)

3a. Sitka Corp. 1996. Pit Slope Re-Assessment- Design Memorandum. (Dated: 18/09/96)

3b.Sitka Corp. 1996. Dublin Gulch Project - IEE Addendum Section 8.0, Eagle Pup MWRSA). (Dated 17/10/96).

FIGURE 6-10 WASTE ROCK SHEAR STRENGTH



The core discontinuity data acquired by BGC (2009) has been assumed to reflect to a degree the waste rock surfaces for a consideration of rockfill shear strength based on an empirical relationship developed by Barton and Kjaerlski (1981). A comparison of these waste rock shear strengths with those used in previous analyses are presented in Figure 6-10, and indicate a similarity in the adopted material properties for waste rock.

For the foundation conditions, the assumption of a friction angle of 32º for a shear strength was adopted in previous studies (KP 1996), based on observations and design guidance for the surface stripped of organic material (the remaining superficials) over 'bedrock', whilst Sitka (1996) adopted a friction angle of 30º, based on silt shear testing for the organic material assumed to be left in situ, over weathered bedrock superficials with a friction angle of 40º. These assumptions regarding the friction angle and thickness of the superficials are assessed to be the most critical to potential WRSA failures.

PIEZOMETRIC SURFACES

Previous studies have assumed the absence of a piezometric surface in the WRSA due to the limited infiltration and the drainage characteristics of the rockfill. To ensure this condition a rock drain is proposed along the valley floor of Eagle Pup ensuring the continuity of foundation drainage and the removal of unsuitable organic material.

PORE PRESSURE DEVELOPMENT FROM THAWING

Analyses have also accounted for pore pressures developing in early years from thawing of an assumed extensive seasonal frost zone of up to three metres depth (KP 1996).

ANALYSIS

Stability analysis of the WRSA has been previously conducted for both static and pseudo-static (earthquake) conditions for a variety of both operational and post closure configurations (Refs. KP and Sitka 1996). These analyses are based on similar assumptions regarding groundwater and seismic loadings, and conclude a 1: V to 2 H overall slope in the WRSA achieves the minimum factors of safety against slope stability under static and pseudo-static design events.

However, the most marginal of cases is the early, static loading as the WRSA is developed through the valley area and encounters thaw instability and/or weaker foundation materials. Satisfactory stability is only achieved by ascending terraces, with gradual loading of foundations, the removal of organic material and unsuitable alluvial deposits, and controlled deposition over seasonal permafrost.

ROCK DRAIN

The Eagle Pup lower catchment will be progressively stripped of organic material and enhanced with selected and durable granular waste rock to ensure:

- the removal of organic material for stockpiling for closure and uncover for removal any unsuitable material in the foundations of the WRSA, and
- a piezometric surface does not build up significantly within the WRSA during:
  - operational design storm events by passing flows through a central drain designed to pass a 1 in 200 year 24 hour event with a peak flow estimated at 1.5 m^3/s, and
  - post closure PMP events by passing peak flows through the rockfill drain designed to pass a PMP event.

STARTER EMBANKMENT

An 18 m high starter embankment, consisting of durable and clean waste rock of selected particle size range is designed to:

- ensure good toe drainage in areas of highest flow gradients
- protect the outlet and drainage so as to not be damaged by waste rock disposal
- provide a buffer zone to protect the SCP and its liner from any boulder rollout, and
- provide post closure a physical and hydrological stable toe of the rehabilitated WRSA.

WATER BALANCE

A full water balance for a WRSA was conducted by Knight Piésold for a comparable Eagle Pup WRSA in location and size for the 1997 Rescan feasibility study. The 1996 evaluation assumed precipitation to range between 231 mm minimum to 527 mm maximum and averaging 374 mm, with runoff coefficients of 0.65 and 0.3 from the undisturbed area and WRSA respectively. Based on these parameters, and allowing for evaporation, losses to groundwater and lock-up in the Eagle Pup WRSA, the predicted inflows to the SCP are of the order of 33,400 m^3/month. Any interception and diversion of the observed springs and seeps in the upper catchment would typically reduce only this flow by about 1,400 m^3/month per spring.

RUNOFF CONTROL

Two specific WRSA runoff controls are designed to reduce inflows and minimise erosion. These controls include an interception and diversion ditch system of the upper-catchment springs and specific construction constraints on the WRSA benches.

A number of springs issue surface water throughout the year into the upper part of the catchment. The long-term impact of dewatering for the open pit is likely to impact on these, however, in early years of operation, these primary sources of water into the catchment will be redirected into the neighbouring catchment of Stewart Gulch. The steepness of the catchment slopes precludes practical diversion of any other surface runoff and therefore this will be allowed to infiltrate into the waste rock.

Rainfall onto the highly permeable WRSA in the operational period is unlikely to pond and generate surface runoff. Horizontal benches will mitigate against the concentration of runoff and potential for erosion.

All precipitation infiltrating the WRSA will report to the rock drain and finally as seepages from the toe of the waste rock and into the SCP.

SEDIMENT CONTROL POND DESIGN

The Eagle Pup SCP will be located in the narrow valley at the bottom of Eagle Pup. The design includes an embankment constructed from rockfill, an HDPE-lined pond and variable height decant. The SCP is designed to accommodate a 1:100 year event, with a volume of 25,000 m^3.

An SCP for the Platinum Gulch WRSA is shown on drawings and will be similar to that for the Eagle Pup SCP, but has not been assessed in detail for this study.

MONITORING

The performance of the WRSA will be monitored during construction through both survey and geotechnical inspection. This will include instrumentation to assist in the assessment of slope stability of the WRSA benches, the starter embankment in front of the WRSA, and the SCP, and enable comparisons of actual against forecast behaviour. Given the size of the facility, observations and measurements will be taken to detect pore pressure changes, strains and settlement in the WRSA, as possible precursors to major instability.

Monitoring of the SCP will include water levels, sediment volumes, flows and water quality. Boreholes downstream of the SCP will provide a final check on the groundwater quality emanating from the Eagle Pup catchment.

CONSTRUCTION

The construction of the WRSA follows the construction of the site sediment collection pond in the Dublin Gulch valley. The sequence comprises:

- WRSA SCP embankment construction with waste rock from mining operations
- lining of the SCP

- stripping of valley organics and placement of selected durable boulders
- starter embankment construction