SUMMIT
ENVIRONMENTAL CONSULTANTS INC.
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Final Report

Eagle Industrial Minerals Corporation

Site Water Balance at Former Whitehorse Copper Mine Site

Project: 2010-2690.000.020

March 2011

SUMMIT ENVIRONMENTAL CONSULTANTS INC.
A Member of the Associated Engineering Group of Companies

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March 10, 2011

File: 2010-2690-000.010

Mr. Charles Eaton
President
Eagle Industrial Minerals Corp.
7 Fielding Circle
Mill Valley CA 94941

Via email: chuckeaton@sbcglobal.nettu

Re: Site water balance at former Whitehorse Copper mine site – final report

Dear Mr. Eaton:

Summit Environmental Consultants Inc. is pleased to provide a final report on the water balance at the site of a proposed tailings reprocessing project at the former Whitehorse Copper mine.

The report provides a tailings water balance for current conditions and for the periods during and following the proposed tailings reprocessing operation. The analysis concludes that the movement of process water dominates the natural components of the water balance, and that there will be sufficient decanted water available to provide nearly all of the water needed during the reprocessing operation. The report also assesses regional hydrogeologic conditions in the vicinity of the Little Chief Pit in support of the water balance work and to assist Eagle Industrial Minerals in refining its plans for the proposed project.

Please contact the undersigned if you have any questions or require further information.

Yours truly,

Brian T. Guy, Ph.D., P.Geo.
Vice President and General Manager
Senior Geoscientist

Bryer R. Manwell, M.Sc., P. Eng.
Groundwater Engineer/Hydrogeologist

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1 Introduction

Eagle Industrial Minerals Corporation (EIM) plans to reprocess and reclaim the tailings deposits at the inactive Whitehorse Copper Mine site, 8 km south of Whitehorse, Yukon Territory (Figures 1 and 2). Through this reclamation, the environmental impacts and land use will be improved, such that less dust will be produced, and the former tailing storage areas will become suitable for use as industrial land or green space. The residual magnetite in the tailings will be recovered by a multi-step separation process and sold as iron ore. The proposed reprocessing facility would operate 24 hours a day, for about seven months per year (March /April through October) for a period of about seven years.

A description of the proposed tailings reprocessing project is provided by EIM (2011). In brief, the former Whitehorse Copper Mine included underground workings and an open pit (the Little Chief Pit). The underground workings have partially collapsed, forming a “subsidence area” on the property. The Little Chief Pit contains water at the elevation of the regional groundwater table. Tailings are presently stored in three tailings areas: the ”Old Pond”, the “A” valley, and the “B” valley. EIM plans to move tailings from each of these three areas to a reprocessing plant, add water to form a slurry, remove the magnetite (about 20% of the tailings), and return the barren tailings in slurry form. After draining to their residual water content of about 20%, the barren tailings will occupy about 90% of the volume of the existing tailings. Barren tailings will be returned to the Old Pond and the Little Chief Pit and subsidence areas. Following tailings placement, water will very quickly separate from the slurry, and the tailings will dry to about 26% water content within about 2 hours, then take about 3 years to dry to the equilibrium water content of about 20% (EIM, 2011). The A and B valleys will be free of tailings following completion of the project.

This report presents site water balances corresponding to several key time periods before, during, and following completion of the reprocessing project. It also presents a hydrogeological characterization intended to assist EIM in finalizing the operational plan for the proposed project. The “site” for the purposes of this report includes the three tailings areas, the Little Chief Pit, and the subsidence areas. The water balances focus on the three tailings areas.

The report is prepared as an attachment to EIM’s application in support of the proposed project. The application includes Volume 1: a project description (EIM 2011) as well as Volume 2: an environmental and socio-economic assessment prepared by EDI (2011).

2 Objectives and Scope

This report has two broad objectives:
(1) To compute tailings water balances for the following time periods:
- Current conditions (for an average year, a dry year, and a wet year);
- During tailings reprocessing;

- Following completion of the project, but before the returned barren tailings have achieved their equilibrium water content of 20%; and
- Following completion of the project and after tailings have dried to 20% water content.

(2) To characterize the regional hydrogeology in order to assist EIM in planning the most effective use of the Little Chief Pit during the project.

The main reason for computing the water balances is to determine whether the project is likely to have an impact on adjacent and downstream receptors (humans and water bodies). They are also intended to confirm volumes of process water that will be available for recapture and recycling. EIM plans to return 53% of the barren tailings to the Old Pond and 47% to the Little Chief Pit and subsidence areas (EIM 2011). However, to demonstrate a worst-case scenario – i.e. maximum volumes of process water moving to the Old Pond, and maximum volumes of recaptured decant and seepage water returning to the magnetite plant - our water balance calculations have assumed that 100% of the barren tailings will be returned to the Old Pond. The water balances are presented in Appendix B, Tables 1 through 8 and summarized in the text of the report.

The Little Chief Pit has potential for use as process source water. The hydrogeological assessment involved the following:

- Developing a conceptual model of groundwater occurrence and flow at the site;
- Evaluating hydraulic properties of the granodiorite bedrock, and the underground workings near the Little Chief Pit; and
- Estimating groundwater discharge through the Pit and underground workings area.

3

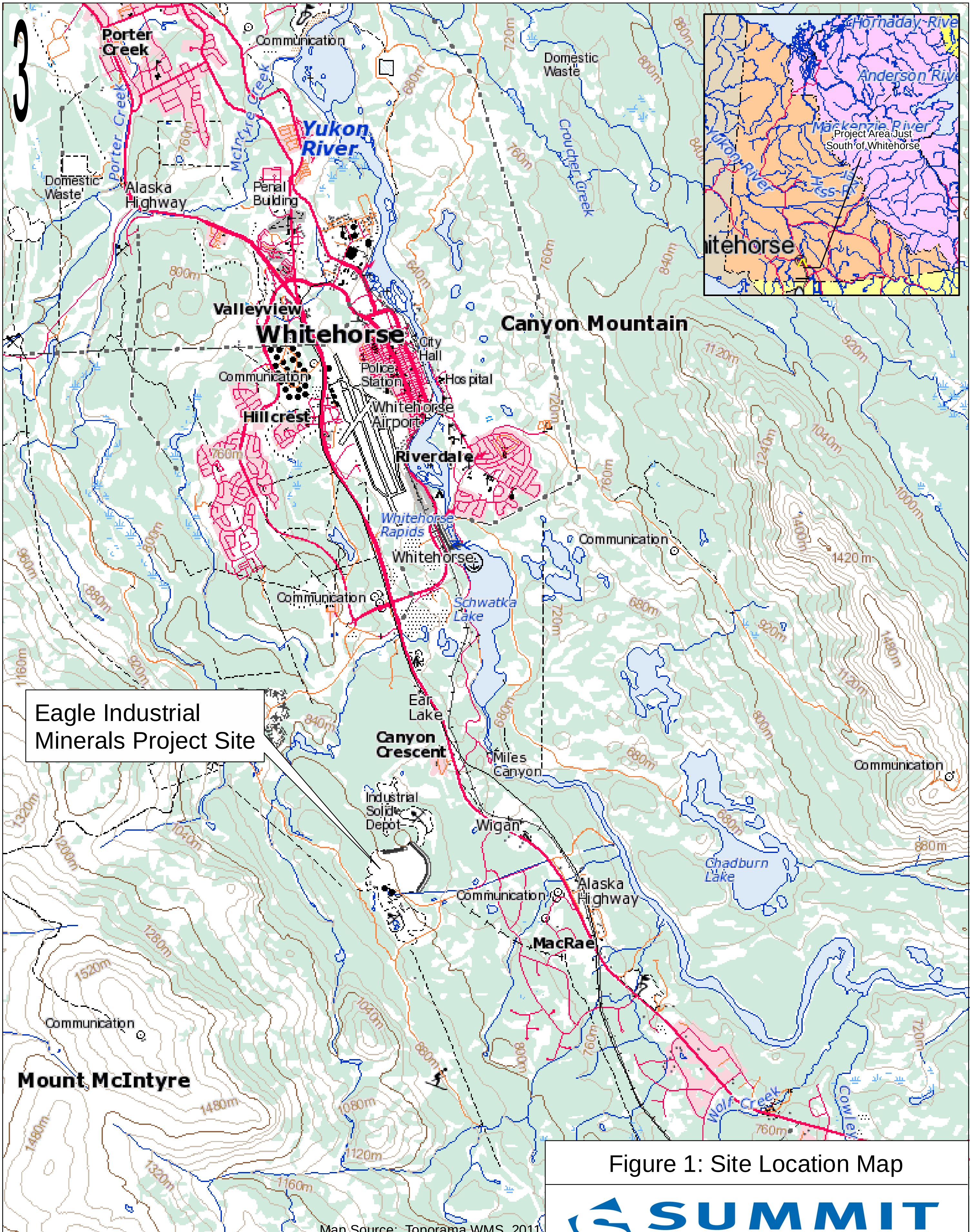

Figure 1: Site Location Map

DATE:	PROJECT:	PREPARED FOR:
Jan 2011	2010-2960.000	Eagle Industrial Minerals
DRAWN BY: DA		

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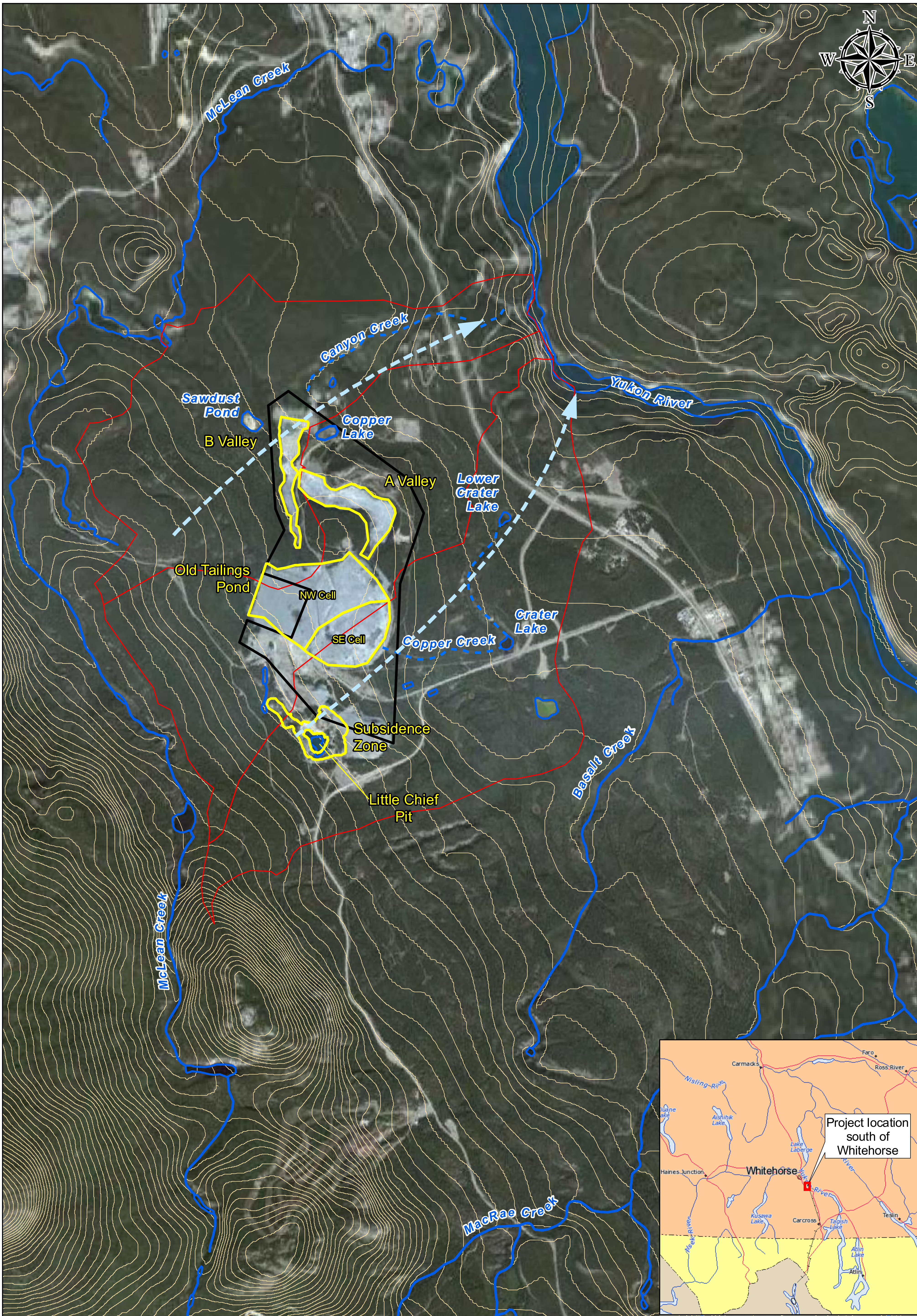

Inferrred Groundwater Flow Direction (based on topographic gradient)

Potential Ephemeral Stream

Major Groundwater Divide (Gadsby Consultant Ltd., 1991 as per Thompson Geotechnical Consultants Ltd., 1982)

Mineral Lease Boundary

0 1,000 m

PREPARED FOR:

Eagle Industrial Minerals

Figure 2: Eagle Industrial Minerals Site South of Whitehorse, Yukon

PROJECT NO.:	**2010-2690.000**
DATE:	**March 2011**
FILE:	**Base Map1.mxd**

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3 Data Sources and Information Used in the Study

3.1 Previous Reports

The water balance and site hydrogeological assessment were created by reviewing relevant literature. Appendix A provides a detailed review of the site geologic and hydrologic characteristics as summarized from the following sources:

- Aubertin et. al. - Hydraulic conductivity of homogenized tailings from hard rock mines.(1996)
- Brodie - Whitehorse Copper Mine Reclamation Review (1995).
- Carey and Woo - Spatial variability of hill slope water balance, Wolf Creek basin, subarctic Yukon. Hydrological Processes (2001)
- EIM – Project Description - Whitehorse Copper Tailings Reprocessing & Reclamation Project. (2011)
- EDI - Whitehorse Copper existing environmental and socio-economic conditions, potential effects, and proposed mitigations (2011)
- Environment Canada - Archived Climate Records and 1971 – 2000 Climatic Normals for Whitehorse A Station (accessed 2011)
- FLSmidth - Laboratory Testing Report for Eagle Industrial Minerals Corp. Sedimentation, Filtration, and Rheology Tests on Magnetite Concentrate and Tails for Whitehorse Project (2011)
- Gartner Lee - Preliminary Groundwater Assessment of the Proposed Whitehorse Copper & Mount Sima Development Area (2002)
- Gadsby - Whitehorse Copper Mine, Yukon Territory, Conceptual Decommissioning Plan(1992)
- Geological Survey of Canada - Whitehorse Copper Mine Reclamation Review (1995)
- Piteau Engineering Ltd. - Phase II Investigation – Field Evaluation of Potential Special Waste Storage Sites. Letter report (1991)
- Piteau Engineering Ltd. - Phase I Hydrogeological Investigation – Copper Mine Site. Report (1992)
- Tenny - The Whitehorse Copper Belt: Mining, Exploration and Geology (1981)
- Thompson Geotechnical - Whitehorse Copper Mines, Tailing Storage Water Reclaim System, Final Operations and Abandonment. Report (1982)
- Wels and Robertson - Conceptual model for estimating water recovery in tailings impoundments (2003)
- Werner and Murdock - Changes in Past Hydro-climatology and Projected Future Change – for the City of Whitehorse (2008)

3.2 Climate Data

The project site has a sub-arctic, transitional maritime-continental climate (Werner and Murdock 2008). Precipitation data are available from monthly records from Environment Canada (2011a) for the Whitehorse A (Airport) climate station. The airport is about 7 km north of the site, at about the same elevation, and so is suitable for representing the site climatic conditions. From the available records, twenty years of data from 1982 to 2006 were reviewed (not including 5 years with incomplete data), and the wettest and driest years were chosen (1991 and 2002, respectively). The Environment Canada precipitation normal values from 1971 to 2000 were chosen as the average values (Environment Canada 2011b).

The wettest and driest years each had about the same average temperatures, which were used for the evaporation calculations, and included in the water budget spreadsheets (Appendix B).

4 Study Methods

4.1 Water Balance

The water balances were computed for the tailings areas, for the following scenarios:

- Current conditions: before the proposed project begins: an average year, a wet year, and a dry year;
- During the first year of operation;
- The first, second, and third years after the operation has ceased (i.e. year 7); and
- Post project: after the tailings have drained to a residual water content of 20%.

For the current conditions and the post project scenarios, water balances are driven by natural processes. For the operational period scenarios, it is assumed in this report that all tailings are returned to the “Old Pond”, as noted above. Process water is associated with the returned tailings, and this process water along with seepage from the tailings will be recaptured and returned to the magnetite plant. During the operational period there will be no surface runoff or seepage from the tailings ponds, as this water will all be captured and returned to the plant.

Data to estimate the natural inputs (rain, snow) and outputs (evaporation, snow sublimation, surface runoff, infiltration to the tailings, and groundwater input) were compiled from available information. Data sources included regional Environment Canada climate records (Environment Canada 2011a). Process water information was obtained from EIM (2011)

The following equation represents the water balance for the surface of a tailings pond for a specified time period:

$$(R_{rain} + S) - (E + I + R_{runoff} + SL) = \Delta S$$

Where:

Inputs

R_{rain} = Rainfall (from Environment Canada)

S = Snowfall (from Environment Canada)

Outputs

E = Evaporation (Priestley-Taylor estimates based on Environment Canada data, reduced to account for restricted water availability)

I = Infiltration to tailings (estimated from literature)

R_{runoff} = Runoff from the surface of the tailings (runoff coefficient estimated based on surface conditions)

SL = Sublimation of snow (from literature)

Difference between the inputs and outputs

ΔS = Change in storage at the surface over the time period.

During operations, the water balance of the body of a tailings pond includes inputs of water from the tailing surface (through infiltration of rainfall and snowmelt), and inputs of water from the tailings slurry. Outputs include evaporation, seepage through the base of the tailings, and water recapture for return to the magnetite plant. Any surface runoff and seepage will be captured and returned to the magnetite plant.

Figure 3 shows a schematic of the site water balance indicating the key elements of the water balance and water movement at the site.

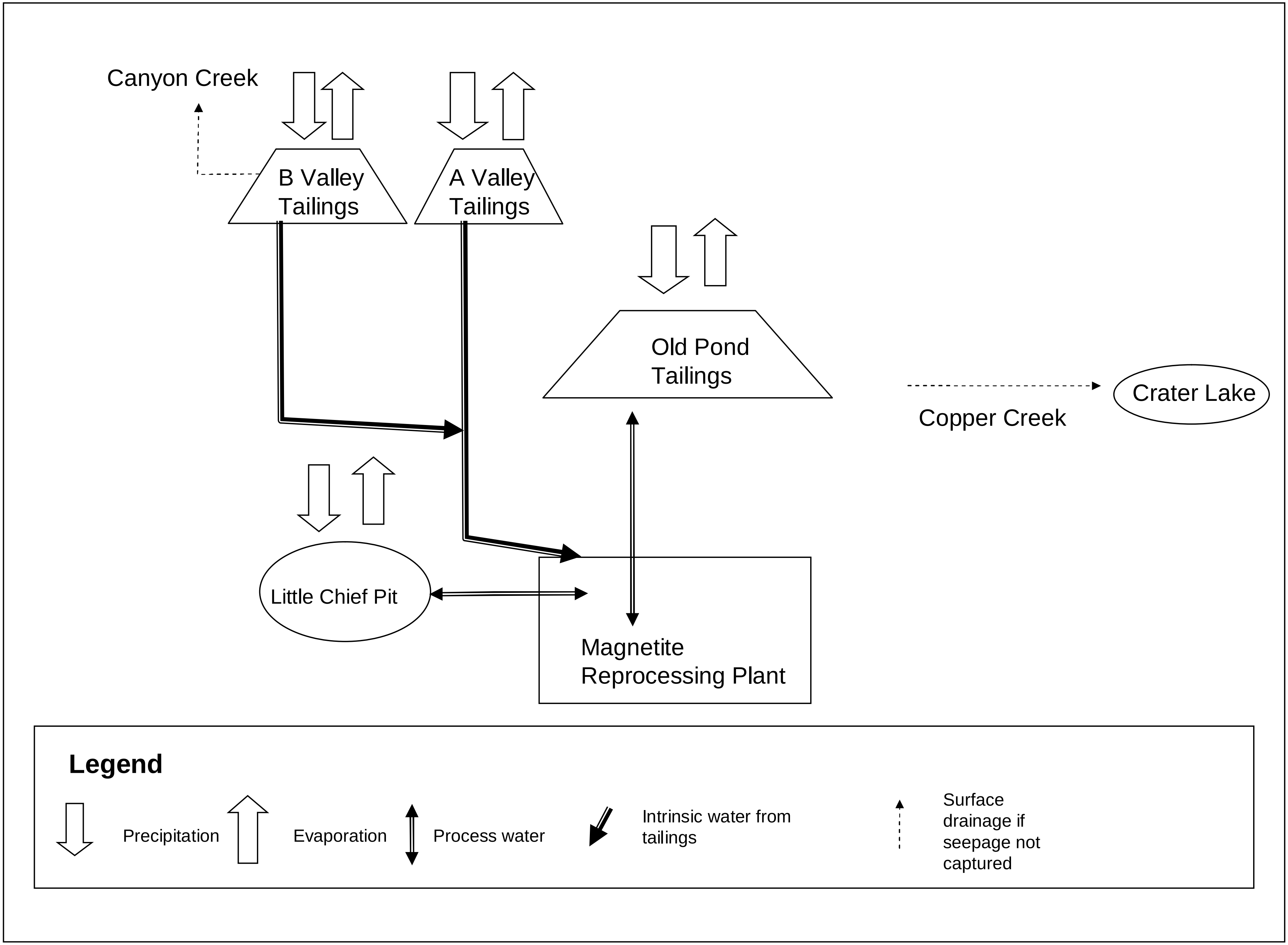

Figure 3: Tailings Reprocessing Water Balance Schematic

4.1.1 Evaporation

Evaporation was estimated using the Priestley-Taylor equation following procedures described in Shuttleworth (1993). The Priestley-Taylor equation is a simplified version of the Penman-Monteith equation that enables estimate of evaporation using standard climate stations data. For this site, the Whitehorse A data the Whitehorse A data for monthly temperature (maximum, minimum, and average) and sunshine hours were employed (Environment Canada 2011a). There is negligible vegetation on the tailings, so the albedo value that was used in the calculation is the one for open water. The estimate is therefore for evaporation rather than evapotranspiration, and the results are referred to hereafter as evaporation.

4.1.2 Water Balance Assumptions

No field investigations have been completed at the existing tailings onsite or for other nearby sites in the southern Yukon, to provide guidance in assessing the partitioning of available surface water into runoff, evaporation and tailings infiltration. Therefore, to derive a reasonable water balance, we made several assumptions, as follows:

- For the current conditions and post-project scenarios, the tailings were assumed to be at their equilibrium water content of 20%.
- In summer, it was estimated that about 33% of snowmelt and rainfall contributes to runoff, 33% to evaporation, and 33% to tailings infiltration (though much of this water is soon removed by further evaporation). During winter, evaporation and runoff were assumed to be zero during frozen conditions. Snowmelt is assumed to occur in April and May.
- Research at Wolf Creek southwest of the site (Carey and Woo 2001) has indicated that, at the sub-alpine elevations, about 10% of the winter snowpack is removed through sublimation and/or wind transport. For the subject site, a monthly sublimation reduction of 10% was applied to the snowpack. We assumed no wind-driven transport of snow onto the site from surrounding drainage basins.
- We assumed that there is active capillary wetting of the tailings surface from water in the subsurface whenever temperatures are above zero, and when free water is available. Nonetheless, it is assumed that only the top 0.25 m of tailings is seasonally wetted due to the low hydraulic conductivity and lack of soil structure and rooting in the tailings. The average yearly storage balance for the top 0.25 m of tailings was assumed to be zero, with any infiltration depleted by evaporation.
- Darcy's equation was used to estimate groundwater recharge into the bedrock aquifer.
- Of particular importance to the water balance is EIM's estimate of process water needs for the project. According to EIM, the magnetite processing will require a flow of 3,200 gallons-per-minute (gpm) to create tailings slurries used in the separation process, plus another 1,000 gpm will be required to support operations elsewhere in the processing operation, for a total flow of 4,200 gpm. EIM proposes that this water would be sourced originally from Little Chief Pit, or from deep wells drilled into the saturated underground workings area near the Little Chief Pit, or both; then

sustained through recycling the process water, with make-up water as required from the Pit or wells. Processed ore shipped off-site would contain a small fraction of this water: EIM estimates that 145 m^3/day of water will leave the site via the magnetite, which is only about 0.6% of the process water.

For the water balance scenarios during processing and after processing is complete but before the tailings have drained, the following assumptions were made:

- 100% of the tailings slurry is added to the Old Pond – a conservative assumption since the plan is to deposit only 53% into the Old Pond, and 46% into the Pit and subsidence areas;
- The tailing slurry added to the Old Pond will be at about 75% water by weight, and will be placed during April to October. From laboratory studies (FLSmidth 2011), the tailings slurry will settle to approximately 26% by volume water within 2 hours. Based on EIM (2011), we have assumed that it will take three years for the moisture content of the reprocessed tailings to consolidate to the equilibrium moisture content of the existing tailings (20% by volume water).
- The tailings discharge pipe will deposit tailings slurry onto no more than 20% of the surface of the Old Pond at any one time, i.e. no more than 20% of the surface of the Old Pond will contain tailings that have not yet drained to 26% moisture content.
- There will be a subsurface drainage collection system for the tailings to capture process water and return it to the magnetite plant.
- There will be no runoff during processing, in order to reclaim as much water as possible. All precipitation, runoff, free surface water, and seepage will be collected and recycled back into the process.

4.2 Hydrogeological Site Assessment

To evaluate the hydrogeological setting of the project site, a desktop review of available maps, orthophotos, and historic reports was performed. This work is summarized in Appendix A. Aquifer properties and bedrock groundwater recharge/discharge rates were compiled from past reports and compared to present calculations. A qualitative evaluation of the certainty of the data is presented and implications of the hydrogeological conceptual model on the proposed reprocessing project are discussed in Section 5.2.

5 Results

This section summarizes the water balance calculations and the desktop hydrogeological investigation. Potential implications of the findings on the operation of the reprocessing project are also provided.

5.1 Water Balance Calculations

Water balance results for the four scenarios are presented in Tables 1 through 8 of Appendix B, as follows:

- Current conditions: Tables 1, 2 and 3 (for average, dry, and wet years, respectively);
- During the first year of reprocessing (Table 4);
- Following processing: Tables 5, 6, and 7 (first second and third years respectively after the 7–year project is complete);
- Following processing and after the barren tailings have drained to 20% (Table 8).

The volumes for the tailings areas are provided in Table 5-1 (from EIM 2011).

Table 5-1 Tailings Deposits Areas and Volumes

Tailings Area	Area (ha)	Average Depth (m)	Volume (m^3)
Old Pond	54.5	7.5	4.07 million
A Valley	12.6	10.5	1.33 million
B Valley	7.8	9.5	0.68 million
Total	74.9		6.08 million

As indicated above, when replaced into the Old Pond, the barren tailings will occupy about 90% of their original volumes.

Evaporation calculations indicate that the normal potential evaporation is 688 mm (this is the depth of water that would be evaporated if there was an unlimited supply of water). The normal annual total precipitation is 267 mm, and there is a significant moisture deficit from April to October, the period when the reprocessing operations will take place.

The tailings ponds consist of wide pads of low permeability fine-grained sediment. In general, the tailings areas act much like aquitards, with limited vertical infiltration. The hydraulic conductivity of the dry tailings is estimated to be on the order of 10^{-6} to 10^{-7} m/s (Aubertin *et al.* 1996). Therefore, groundwater recharge into the bedrock aquifer through the base of the tailings areas was calculated to be less the 1 mm per year, and was therefore ignored on the water balance spreadsheets in Appendix B.

5.1.1 Current Conditions

Tables 1, 2, and 3 in Appendix B provide the estimated monthly water balances for the tailings surfaces. On a monthly basis, snowfall accumulation for several months of the year contributes to a monthly surface water surplus in these months, but due to sublimation, infiltration, evaporation, and surface runoff, the surface water balance on an annual basis is zero. Because of low hydraulic conductivities, groundwater recharge is assumed to be close to zero on both a monthly and an annual basis.

Table 5-2 summarizes the annual precipitation used for the 3 current conditions scenarios.

Table 5-2 Precipitation Totals

Climate	Total Rainfall (mm) (R)	Total Snowfall (mm SWE) (S)	Total Precipitation (mm) (R + S)
Average Year (climatic normals 1971-2000) (Table 1, Appendix B)	163	104	267
Wet Year (1991) (Table 2, Appendix B)	231	140	371
Dry Year (2002) (Table 3, Appendix B)	126	49	175

Table 5-3 presents the summarized results of surface runoff estimates from the various tailings areas as total cubic metres per year, and averaged as m^3/s, for average, wet and dry years. Based on site visits made by EDI in 2010 (EDI 2011), we understand that any surface runoff from the tailings areas infiltrates into the ground, and that no runoff leaves the site on the surface.

Table 5-3 Current Conditions – Annual Surface Runoff

Tailings Area	Dry Year (2002)		Wet Year (1991)		Average Year	
	Total Discharge (m^3)	Average Discharge (m^3/s)	Total Discharge (m^3)	Average Discharge (m^3/s)	Total Discharge (m^3)	Average Discharge (m^3/s)
Current						
Old Pond, Northwest	23,010	0.001	71,760	0.004	50,700	0.003
Old Pond, Southeast	9,145	0.000	28,570	0.002	20,150	0.001
A Valley	7,434	0.000	23,184	0.001	16,380	0.001
B Valley	4,602	0.000	6,786	0.000	10,140	0.001
Total	44,191	0.002	130,250	0.007	97,370	0.005

NB: the northwest and southeast areas of the Old Pond are indicated on Figure 2.

5.1.2 Water Balance During Reprocessing Operations

Reprocessing the tailings will require about 16 m^3/min (4,200 US gpm) of water (EIM 2011), for the three stage magnetic separation from slurry. The process water will be sourced from water recaptured from the Old Pond and from make-up water from the Little Chief Pit or one or more new groundwater wells.

Table 4 in Appendix B presents the monthly water balance for the Old Pond during the first year of the reprocessing operation. That table indicates that the rates of process water input and output from the Old Pond are much larger than the rates of input and output of the natural components of the water balance. Data in Table 4 assumes that water is returned to the Old Pond in a slurry at a rate of 4200 US gpm, the tailings decants to a water content of 26% two hours after the slurry is deposited (FLSmidth 2011) and it takes three years for the tailings to dewater from 26% to 20% water content (EIM 2011). In addition, a maximum of 20% of the surface of the Old Pond will contain wet tailings at any one time. Based on the assumption that all surface water and seepage water will be returned to the plant, Table 4 indicates that there will be a total of 8501 mm of water (spread over the surface of the Old Pond) available to be returned to the plant, which averages 3,956 US gpm during the 7-month operating period. Not all the process water can be returned from the Old Pond because there is some loss of water due to evaporation, and some water remains temporarily stored in the body of the tailings for about 3 years, as it slowly returns to the groundwater system. Nonetheless, 94% of the 4,200 US gpm required for the process can be obtained from recycling. The remainder will come from the Little Chief Pit or new wells.

Process water associated with tailings that are placed into the Little Chief Pit will be directly returned to the groundwater system. Process water associated with tailings that are placed into the subsidence areas will decant from the tailings and return to the groundwater system, except to the extent that evaporation will remove some of this water.

Therefore the process water loop is closed except to the extent that losses occur due to evaporation and water lost in the magnetite shipped off-site.

5.1.3 Water Balance After Completion of Reprocessing and Before Tailings are Drained

At the end of the 7-year process, the total volume of tailings (6.08×10^6 m^3) will have been processed. Assuming a worst-case scenario that all these tailings will be placed in the Old Pond, the volume of tailings in the Old Pond would be about 5.4×10^6 m^3 (after allowing for magnetite removal and some expansion). These tailings would be about 10 m deep over the 54.5 ha surface of the Old Pond. It is assumed that the bottom four annual layers of tailings will have drained to the residual 20% water content by this time, and the upper three layers will contain water at about 22% (layer 5), 24% (layer 6), and 26% (layer 7), respectively, such that the total water contained in the tailings will be about 2.2 m, of which about 0.2 m will drain out over a three year period as the tailings continue to drain down to the residual water content of 20%. This water will amount to approximately 174 mm, or 95,000 m^3, under the conservative assumption that all tailings are placed into Old Pond. Over this time, this water will seep into the shallow surficial aquifer or be captured and routed to the Little Chief Pit, as appropriate.

Tables 5, 6, and 7 in Appendix B present monthly water balances for the Old Pond during the first, second, and third year, respectively, following completion of the 7-year project. These tables show the tailings drying out by losing 84, 60, and 30 mm of water in each of these three years. These values are based on the above-noted conservative assumption that all the barren tailings will be placed into the Old Pond.

5.1.4 Water Balance after Reprocessing and After Tailings are Drained

After three years the reprocessed tailings in Old Pond will have drained down to about 20% moisture content, and the rate of seepage out of the Old Pond will be nearly zero.

Table 8 in Appendix B provides the monthly water balance for the Old Pond for this situation, and calculations of monthly and total annual runoff from the Old Pond and from the now tailings-free A and B valleys. The monthly water balance is assumed to be the same as for the current conditions, with one exception: because there will be no tailings left in A and B valleys, and the valley soils will be more permeable than the existing tailings surfaces, there will be less runoff from these areas than at present. We have assumed that runoff will be 20% smaller than at present. For the runoff calculations, we have ignored the likelihood that the barren tailings in the Old Pond will be slightly coarser in texture than the existing tailings. That the estimated runoff is smaller is not a significant finding, as it is understood that all runoff from the site presently infiltrates to ground, and this will continue to be the case post project.

Table 5-4 presents the runoff calculations for the Old Pond, and the now tailings-free A and B valleys after reprocessing has been completed and the reprocessed tailings have drained to approximately 20% water content. At the end of the project, all water used will have been returned to the groundwater system, with the exception of water lost to evaporation during the placement of wet tailings onto the Old Pond and subsidence areas, and the water lost in the magnetite.

Table 5-4 Runoff for the Tailings Areas after Reprocessing and after Drainage is Complete

Tailings Area	Total Yearly Discharge (m^3)	Average Discharge (m^3/s)
Old Pond, Northwest	20,150	0.001
Old Pond, Southeast	50,700	0.003
A Valley (now tailings-free)	13,104	0.001
B Valley (now tailing-free)	8,112	0.000
Total	92,066	0.005

5.2 Results of Hydrogeological Assessment

The overall conceptual model of groundwater occurrence at the site is described in Appendix A. The following section presents the calculation of relevant hydraulic properties, groundwater recharge and discharge rates, and implications for management of groundwater during and after the reprocessing project.

5.2.1 Hydraulic Properties

Underground Workings

The former underground workings have partially collapsed. There is no information currently available regarding the hydraulic properties of the underground workings. However, we believe it likely that vertical and horizontal hydraulic conductivity of the rock in this area is significantly higher than in the undisturbed bedrock areas. We estimate the hydraulic conductivity of the underground workings to be on the order of $1x10^{-3}$ m/s based on literature values for highly fractured igneous and metamorphic rocks (Freeze and Cherry 1979).

In the vicinity of Little Chief Pit, rock above the former underground mine workings has sunk and caved in, creating a subsidence zone with higher permeability than the surrounding bedrock aquifer. As for the underground workings, there is no quantitative knowledge of the hydraulic properties of this zone.

Bedrock Aquifer

The bulk hydraulic conductivity of the granodiorite bedrock was estimated to range between $7.8x10^{-7}$ and $2.8x10^{-6}$ m/s (Piteau 1991 and 1992), and the hydraulic gradient was estimated to be 0.037. This hydraulic gradient agrees well with the regional topographic gradient calculated to be 0.05 from topographic maps of the area. The similarity between the topographic gradient and the hydraulic gradient supports the assumption that groundwater flow in the bedrock aquifer generally matches the topography.

To arrive at a convergent value of the bulk hydraulic conductivity (K) for the bedrock aquifer underlying the site, the Darcy flux equation was used to calculate a K value. This estimate of K is based on the concept that the de-watering pumping rate used during the former mining operation represents the groundwater discharge within the vicinity of the mine workings. The empirical Darcy's flux equation was applied as follows:

$$Q = -K\ i\ A$$

Where:

Q = Groundwater discharge, taken to be the de-watering rate at the former mine (m^3/s)
K = Bulk hydraulic conductivity (m/s)
i = Hydraulic gradient (unitless)
A = Cross sectional area of mine workings (m^2)

The mine de-watering rate (Q) was presented as 477 L/min (Pazour 1979) or 7.95×10^{-3} m^3/s. The hydraulic gradient was taken to be the topographic gradient or 0.05. The cross sectional area of the mine workings was estimated from Drawing No. 8 Gadsby (1992) to be 1.83×10^5 m^2. With these values K is estimated to be **9.5×10^{-7} m/s**. This estimate is in good agreement with the values derived during the 1991 and 1992 Piteau investigation where K ranged between 7.8×10^{-7} and 2.8×10^{-6} m/s for the bedrock aquifer. From this assessment we can be confident that we have a reasonable understanding of the natural discharge of the bedrock aquifer underlying the site, although it must be stressed that these are bulk or area averaged values and significant heterogeneity is likely to exist at the scale of the site.

5.2.2 Bedrock Groundwater Discharge / Recharge

Further confirmation of our understanding of the discharge capacity of the bedrock aquifer underlying the site was obtained by calculating the recharge rate of the underground workings and the Little Chief Pit upon decommissioning of the mining operation. Upon decommissioning, the underground workings and the Little Chief Pit slowly filled with groundwater from water seeping into the pit from the surrounding granodiorite fractured bedrock aquifer. From the literature (Brodie 1995 and Gartner Lee 2002) it appears that it took a total of 20 years (between 1982 and 2002) to recharge the underground workings and fill the Little Chief Pit. The estimated volume of the underground workings is 0.46×10^6 m^3 (Brodie 1995) and the estimated volume of the Little Chief Pit is 1.34×10^6 m^3 based on an assessment of site maps. If the underground workings and the open pit took 20 years to recharge from groundwater, then the recharge rate would be the total volume of the underground workings and the pit divided by the recharge time or **1×10^5 m^3/year**. This recharge rate is less than (but within an order of magnitude of) the de-watering pumping rate of 477 L/min (2.5×10^5 m^3/year) that occurred during mining operations (note however that this de-watering pumping rate would be radial flow, which likely had vertical components, and would not strictly obey Darcy's Law or the Dupuit Assumption).

Therefore, in the vicinity of the Little Chief Pit the natural groundwater discharge rate is on the order of $1x10^5$ m^3/year. This value represents an approximation of the groundwater flow rate within the bedrock aquifer in the vicinity of the underground workings and Little Chief Pit towards the Yukon River.

5.2.3 Implications of Site Hydrogeology on the Reprocessing of Tailings

As indicated above, the tailings reprocessing water budget is nearly water-neutral. The annual discharge of reprocessed tailings to be disposed of is on the order of $1x10^6$ m^3/year (Exhibit 6.1, EIM 2011). The approximate transmitting capacity of the bedrock aquifer in the vicinity of the Little Chief Pit is on the order of $1x10^5$ m^3/year. The volume of water that the regional bedrock aquifer can "absorb" before mounding is an order of magnitude lower than the tailings produced on an annual basis.

This finding constrains the rate of tailings deposition into Little Chief Pit. EIM is proposing to dispose of the reprocessed tailings into the Little Chief Pit, the subsidence area and the Old Tailings Pond. If tailings disposal in the form of slurry into the Little Chief Pit occurs at a rate less than $1x10^5$ m^3/year, pit lake water will dissipate into the regional bedrock system without mounding of water in the Little Chief Pit.

With an infiltration rate of $1x10^5$ m^3/year it would take approximately 3.5 years for the current volume of water from the Little Chief Pit to dissipate into the surrounding bedrock water as tailings are added to the lake. This estimate assumes that introduction of tailings into the pit and subsidence area will not clog bedrock fractures and reduce the overall hydraulic connection between the lake and the aquifer. Therefore if EIM fills the Pit with tailings over a time frame of more than 3.5 years, the lake level will not rise.

6 Conclusions

The work reported herein leads to the following conclusions:

1) Annual precipitation contributes 267 mm per year on average, ranging from less than 200 mm in dry years to nearly 400 mm in wet years. There is very little surface runoff from the tailings ponds, and no permanent streams leave the site. The low hydraulic conductivity of the tailings results in low infiltration to the tailings, and very little groundwater input at the base of the tailings.

2) During reprocessing operations, 6.08×10^6 m^3 of tailings will be reprocessed and about 5.4×10^6 m^3 will be redeposited onto the Old Pond and into the Little Chief Pit and subsidence areas. Water will decant rapidly from barren tailings deposited onto the Old Pond, and decanted water and seepage water will be captured and returned to the magnetite plant. By collecting this water, there will be no runoff or seepage to groundwater during the operation.

3) The volumes of process water input and output from the tailings are significantly larger than the inputs and outputs of natural components such as precipitation and evaporation.

4) Of the 4,200 US gpm process water delivered to the Old Pond when tailings are being deposited there, about 4,000 US gpm (94%) will be available to be recycled to the magnetite plant. The remainder is lost to evaporation, or goes into short-term storage in the body of the tailings. Make-up water will be required, either from the Little Chief Pit or from one or more groundwater wells.

5) As reprocessed tailings are replaced in the Little Chief Pit, process water will be immediately returned to the groundwater system. The tailings placed in the Old Pond and subsidence areas will also return to the groundwater system, although not immediately because these tailings will not drain immediately. Nearly all the water used in the process will ultimately return to the groundwater system, with the only losses due to evaporation and shipment of water off-site with the magnetite. The loss of water in the magnetite will be approximately 145 m^3 per day.

6) After reprocessing is finished, the redeposited tailings in Old Pond will continue to dewater to 20% water content over about 3 years and this water will seep into the shallow surficial aquifer or be captured and routed to the Little Chief Pit.

7) After reprocessing, A Valley and B Valley tailings deposits will be gone, and the re-exposed surface soils will likely have higher hydraulic conductivity than they do now, allowing for greater infiltration and smaller runoff.

8) The hydraulic conductivity of the bedrock aquifer underlying the site is low, with a hydraulic conductivity on the order of 9.5×10^{-7} m/s and therefore recharge to the bedrock aquifer is limited.

9) The natural groundwater discharge rate in the vicinity of the underground workings and the Little Chief Pit is on the order of 1×10^{5} m^3/year. This value represents an approximation of the groundwater flow rate within the bedrock aquifer in the vicinity of the underground workings and Little Chief Pit towards the Yukon River.

10) Deposition of water with tailings slurry into the Little Chief Pit at a rate less than 1×10^{5} m^3/year will allow for the transmittal of pit lake water into the regional bedrock system and avoid mounding of water in the Little Chief Pit.

11) It will take approximately 3.5 years for the current volume of water from the Little Chief Pit to dissipate into the surrounding bedrock water as tailings are added to the lake. If EIM fills the Pit over a time frame of more than 3.5 years, the lake level will not rise due to the operation.

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Appendix A - Review Of Site Geologic And Hydrologic Characteristics

Appendix A: Review of Site Geologic and Hydrologic Characteristics

Summit assessed the major features of the site based upon literature and reports, focusing on information sources related to site characteristics and hydrologic responses. The decommissioned Whitehorse Copper Mine Site has three main areas of tailings storage: the Old Tailings Pond, the A Valley, and the B Valley (Figure 2). A description of the general site geology, the tailings areas and the hydrogeology of the site is provided below.

General geology and drainage characteristics of the site

The hydrologic characteristics of the surficial deposits and bedrock determine how water travels before it enters the tailings area, and after it leaves the tailings through runoff, along with shallow and deep groundwater flow. Thompson Geotechnical Consultants (TGC 1982) and Gadsby Consultants Ltd. (Gadsby 1992) reviewed the surficial and bedrock geology as part of a site decommissioning study, and their findings are summarized herein.

A cobbly, silty, relatively dense glacial till overlies the bedrock in areas of high relief, such as adjacent to the Little Chief Pit and north towards the tailings impoundments. The till mantles the bedrock and varies up to two metres in thickness. Kame terraces (i.e. glacial outwash terraces) of poorly sorted sands and gravels, in beds up to 100 feet thick, adjoin the till slopes.

Glacial meltwater channels are present over the site area, which cut through fluvial terraces leading down to the Yukon River. The A Valley and B Valley are interpreted to be former meltwater channels (Bond *et al.* 2005). Canyon and Copper Creek valleys appear to also be meltwater channels, with some kettles or plunge pools found along their length. Crater Lake (located in Copper Creek valley) has no surface outflow.

Gadsby (1992) reported that surface and groundwater drain east through Copper Creek to Crater Lake, east through A Valley and east through B Valley to Canyon Creek. The groundwater boundaries were reported to closely follow the surface water boundaries and for this reason we have presented only the groundwater divides derived by TGC (1982) on our site map (Figure 2 within the text). Summit interprets the groundwater divides derived by TGC to be based on surface topography and represent only potential shallow groundwater divides. The groundwater flowing through the bedrock aquifer will not follow these local scale divides but will occur in a generally easterly direction towards the Yukon River. There is interpreted to be three watersheds at the site, those being Copper Creek, A Valley and Canyon Creek watersheds (Figure 2). There are no well defined drainage courses off site, west of the highway, and it is interpreted that surface water dissipates through the fluvial and glaciofluvial sand and gravel deposits (as shallow groundwater) prior to entering the Yukon River.

In the mine decommissioning plan (Gadsby 1992), Map 6 indicated the original topography and surface water drainage. The Old Pond tailings area was originally a hummocky bench with flow into Copper Creek watershed and Crater Lake. A Valley and B Valley, and the area upslope to the topographic high, originally flowed into Canyon Creek, and downslope towards the Yukon River (Figure 2). Based on topographic and stream maps, it is interpreted that flow in Copper and

Canyon Creeks does not reach the Yukon River directly overland, but percolates through the creek beds, contributing to shallow or deep groundwater flow.

Bedrock is present at surface or under shallow overburden at both the Little Chief Pit and the Old Pond tailings pond. The copper deposits extracted during the original mine operation (skarn or pyro-metasomatic deposits) were present at the contact between the granodiorite and the limestone and quartzite wall rocks. Mining occurred at and below the Little Chief Pit and to the north underground (Figure 2 in text). Granodiorite bedrock is present east and west of the Little Chief Pit and tailings areas, with some limestone and quartzite bedrock at the Pit.

After decommissioning of the mine, the bedrock above the underground workings subsided and created a zone of severely fractured bedrock surrounding the Little Chief Pit. The underground workings and the Little Chief Pit have since filled with water (interpreted to be sourced mainly from groundwater inflow), and this water storage area is of interest as source water for the tailings reprocessing project.

Tailings Deposits

During operations, Whitehorse Copper utilized three tailings areas: Old Pond, A Valley and B Valley. Old Pond was enlarged in the late 1960s, A Valley was developed in about 1968, and B Valley was developed in about 1979 (TGC 1982). Generally, only one tailings storage area was in use at one time. The tailings ponds were operated in conjunction with two water reclaim ponds, Copper Lake (artificial) and Crater Lake (natural). The hydrologic characteristics of the tailings strongly determine the nature of the water balance and the water routing from rainfall and snowmelt.

Mineralogical analysis indicates that the tailings are composed mainly of two silicate minerals (quartz and garnet) and one iron oxide mineral (magnetite) (Gadsby 1992). The tailings were produced through milling of limestone, dolomite, diorite and quartzite bedrock, producing particles generally less than 111 microns (0.000111 m or 135 mesh) (finer than fine sand). With such fine material, infiltration of surface water tends to occur slowly. Previous and recent test holes into the tailings indicate thicknesses of 10 to 115 feet (3 to 91.5 m), with moisture content generally increasing downwards from about 10% at surface to 29% at depth. In some locations a thin water table has been observed about 0.3 m above the base of the tailings (EDI 2011). The tailings are described from auger hole cuttings as damp to wet sandy fines of light to dark grey colour. The hydraulic conductivity of the tailings is estimated at 10^{-6} to 10^{-7} m/s (Aubertin *et al.* 1996; Renken *et al*. 2004).

The tailings ponds constitute large, flat pads of low permeability surficial deposit, and in terms of hydrologic response, would be similar to un-vegetated lacustrine deposits or low permeability bedrock. The nearby native glacial till and outwash area (which are forested) would exhibit different hydrologic responses, with higher evapotranspiration and soil/organic cover wetting, and considerably less runoff potential for areas of similar topography. EIM reports that some rainwater and snowmelt drains off the tailings surface, and some infiltrates through the tailings. Small, shallow and long-lasting ponds are reported to form after rainfall and snowmelt on the tailings areas. Wetland areas downstream of the site along Canyon Creek are evidence of long term surface runoff and shallow groundwater flow. No water quality issues such as acidification or elevated metals or other parameters are evident in the groundwater wells sampled down-gradient from the tailings areas (EDI 2011).

Old Pond

Gadsby (1992) indicated that the Old Pond tailings have a surface area of about 135 acres (55 ha), and a surface elevation between about 2600 and 2575 ft (792.7 m and 785.1 m). More recent measurements have indicated a surface area of 54.5 ha (EIM 2011). Previous piezometer holes and recent auger test holes show the tailings here are between 6.1 and 19.8 m (20 and 65 ft thick). EIM (2011) used an average tailings depth of 7.5 m (25 ft) to derive tonnage estimates. While no detailed construction records are available, Old Pond is probably underlain by glacial till, outwash sands and gravels and bedrock.

The tailings are contained by constructed embankments of local sand and gravel on the south, east and north sides, and by natural topography on the west. No construction details or stability conditions are known for the perimeter embankment. The embankments were later decommissioned by excavating and armouring spillways through the berms for the stormwater management ditches. There are embankments 6.1 to 20.7 m (20 to 68 ft) high around the periphery, which will be re-evaluated for placement of tailings during the reprocessing project.

The arrangement of internal embankments and the stormwater ditch routes divide the Old Pond into a north and west area of about 39 ha which drains north to the A and B Valley and then to Canyon Creek. A southeast area of about 15.5 ha drains east to Copper Creek (Figure 2).

Through reference to the pre-mine development topography and drainage basins (Gadsby 1992, Drawings 6 and 17), it appears the drainage division in Old Pond has been moved about 500 m (1600 ft) north of the natural location, decreasing the watershed area for Canyon Creek and enlarging the Copper Creek watershed by about 25%. Copper Creek watershed has no surface outlet and any increased local runoff would be expected to report to the subsurface.

There is a long-lasting surface pond formed in the southeast part of Old Pond, about 305 m (1000 ft) by 60 m (200 ft) by 1 m (3 ft) deep. This suggests low permeability tailings due to consolidation over time. The pond functions to reduce runoff peaks by providing a small amount of retention.

A and B Valleys

The A Valley tailings deposit has an area of about 12.6 ha, and B Valley has an area of about 7.8 ha. In A Valley, the tailings are up to 90 ft (27 m) thick upstream of the embankment. The average depth of A Valley tailings is 10.5 m (EIM 2011). For B Valley, the average tailings depth is indicated as 9.5 m (EIM 2011). These tailings deposits are contained by earth and rockfill embankments at the northern ends and by the natural valley sides of till, and sand gravel terraces on the west and east. The materials used to construct the embankments were excavated from the valley floor within the impoundment area and 4.6 to 6.1 m (15 to 20 ft) below the embankment foundation level (Gadsby 1992).

These two tailings areas were built on glacial till, outwash and alluvium down the valley bottom, and bedrock is exposed at the heads of the valleys (TGC 1982). The bedrock near the outlet of A Valley is quite weathered. While used for wet tailings impoundment, A Valley dam exhibited significant seepage through the alluvial deposits and dam, with flow downstream to Copper Lake. The A Valley dam had a documented surficial failure on the downstream slope in spring 1980 due to uncontrolled seepage through and beneath the dam. The dam was later stabilized and raised in summer 1981. The pond behind the dam was kept in a drained condition.

The B Valley dam has an impermeable layer in the upstream face, and so holds back some surface water as a pond, and has higher water content tailings (EIM 2011). In decommissioning A Valley and B Valley, a drainage channel was constructed but appears to be at too high an elevation to allow surface ponds on the B Valley tailings area.

Surface Drainage

Before mine development, there were not likely any permanent streams over the areas now occupied by tailings. Gadsby (1992) indicated that no permanent streams capable of supporting fish occurred in the mine site area. There are currently no gauged streams close to the site area. No recent field investigations or mapping of surface streams, seepages and high water table areas near the tailings deposits have been conducted.

South of the mine site, Basalt Creek and MacRae Creek are present, extending over the wide western valley side, down to the Yukon River. North of the mine site, Canyon Creek drains east over the valley side to the Yukon River. McLean Creek drains north just west of the mine site, and then turns east to join the Yukon River.

Gadsby indicated that surface drainage from A Valley, B Valley and Copper Creek (Crater Lake) watershed were measured during 1980 to 1987 by Thompson Geotechnical Consultants. The maximum flows occurred in May, with the combined flow from the two watersheds at about 0.01 m^3/s (i.e. 10 L/s). This flow rate is interpreted to represent both natural stream flow and dewatering of the tailings, as the mine had ceased operations in about 1982. The original drainage measurements are not available as Appendix C is missing from the original document on file at the Whitehorse Library.

Berms and dams remain in the tailings areas and date to active mine operations, when they were used for storing and decanting water from fresh wet tailings. At mine decommissioning, stormwater management ditches were created to control the runoff, and armoured spillways were put in the berms, to allow runoff out. Decanting drainage pipes under the tailings were then decommissioned and plugged.

Currently, the north and west parts of Old Pond drain east out of the old tailings area, then north to pass through A Valley and B Valley and out to Canyon Creek. The east part of Old Pond drains to the east out of the old tailings area, and then to Copper Creek to Crater Lake, which has no outflow stream.

Copper Lake is located about 122 m (400 ft) downstream of the toe of A Valley embankment. It served as reclaim pond for A valley impoundment, where decanted water and seepage collected. Copper Lake was about 46 m (150 ft) wide, 91.5 m (300 ft) long, 1.8 m (6 ft) deep, and discharged from the north lake end through a V-notch weir, through a drainage channel, and into downstream alluvial deposits.

In summary, combined flow during the 1980s peaked during the month of May in the range of 0.01 m^3/s and is probably lower currently, though no data exist to confirm this. Due to climate change occurring since the 1980s, it is possible that peak runoff occurs earlier (perhaps early May or late April).

Hydrogeological Conceptual Model

Summit developed a hydrogeological conceptual model primarily to develop a framework for assessing how surface and groundwater levels will respond to the proposed operations. This includes a) effects of pit and adjacent groundwater level drawdown when water (up to 4,200 gpm) is extracted for use in processing; and b) effects of pit and adjacent groundwater level build-up when tailings are placed in the Little Chief Pit and surrounding subsidence areas, resulting in physical displacement of stored water.

The following sections summarize the hydrogeological understanding of the site.

Regional Groundwater Flow

The decommissioned mine site is interpreted to occupy parts of three watersheds - Canyon Creek, A Valley and Copper Creek (TGC 1982). The groundwater divides for the three watersheds as derived by TGC (1982) were digitized and appear on Figure 2. The site and the area to the southwest are considered groundwater recharge areas. The area off site, to the northeast in the vicinity of the Yukon River is considered a groundwater discharge area. The regional bedrock groundwater flow beneath the local watersheds is topographically-driven and is inferred to occur from southwest to northeast, with discharge to the Yukon River.

Shallow Groundwater Flow

No significant overburden (surficial) aquifer is present in the vicinity of the mine site (Piteau 1991, 1992 and Gartner Lee 2002). However, shallow groundwater flow appears near the surface northeast of the site near Canyon Creek where wetlands are present and where the creek appears to terminate prior to reaching the Yukon River. Wetlands were also observed at the base of the tailings dams (EDI 2011).

It is inferred that only a small amount of shallow groundwater flow infiltrates through the surficial deposits within the watersheds, under or around the tailings areas, and toward the Yukon River. While a thin water table has been observed in some tailings areas (EDI 2011), infiltration is not thought to be significant through the tailings because of the low hydraulic conductivity of the material.

Bedrock Groundwater Flow

Very little, if any recharge to the bedrock groundwater system is occurring at the site due to the dry climate and minimal runoff during the spring melt. The Canyon Creek and Copper Creek watersheds are of limited areal extent and it is likely that the bedrock aquifer within these watersheds is hydraulically connected to the McLean Creek watershed via regional scale bedrock faults and fissures.

Piteau (1992) described two bedrock aquifers (one shallow, one deep) in the vicinity of the mine site. One bedrock aquifer reportedly had a depth to water averaging around 5 m below ground surface (bgs) and the other displayed a deeper piezometric surface of approximately 15 m bgs. The shallower bedrock aquifer is likely surface-fed and has limited storage volume. Based on Piteau's information, it is likely that the source of the deeper bedrock aquifer is more regional in nature, and may extend beyond the surface watershed boundary. There are large scale bedrock fractures trending east – west that likely transmit flow from upgradient (west to east).

Groundwater flow through the fractured bedrock (both shallow and deep) is limited due to the low bulk hydraulic conductivity of the granodiorite bedrock; found to range between 7.8×10^{-7} and 2.8×10^{-6} m/s (Piteau 1991 and 1992) and a moderately low hydraulic gradient towards the Yukon River. It was found that the fractured zones of the granodiorite aquifer are not well-connected. This was inferred from the variable piezometric surfaces for wells completed at the same depth south of the mine site (Piteau 1992). This discontinuity of flow can create "dead zones" where pockets of groundwater stored in bedrock do not readily flow toward a downgradient discharge area.

During the copper mining operation, the underground workings were dewatered at a rate of 477 L/min (105 US gpm) (Pazour 1979). The dewatering rate is taken to be the natural discharge of the granodiorite aquifer in the vicinity of the underground mine area, now known as the 'subsidence area' (Figure 2).

Upon decommissioning of the mine and the end of dewatering, the underground mine workings gradually filled with infiltrated surface water or groundwater. It is understood that recharge of the underground workings occurred between 1982 and at least 1995, taking approximately 13 years (EIM 2011). Subsequently, between 1995 and 2002 the Little Chief Pit filled with groundwater and a small portion of surface runoff over the period between 1982 and 1995.

Groundwater Occurrence in the Underground Workings

Upon closure of the copper mine, the underground mine workings collapsed and created a zone of subsidence beneath and in the vicinity of the Little Chief Pit. As noted above, after dewatering ended this subsidence zone was subsequently recharged by the regional groundwater flow. The underground workings essentially represent a man-made aquifer storage area with bulk hydraulic conductivity potentially orders of magnitude higher then the surrounding natural bedrock aquifer. The actual value of hydraulic conductivity is unknown but it is estimated to be on the order of $1X10^{-3}$ m/s. Based on the cross sections of the old mine workings (Gadsby 1992), it is understood that there is a direct hydraulic connection between the underground workings and the Little Chief Pit. As the subsidence aquifer storage area is hydraulically connected to the open pit, the underground workings acts as part of the recharge zone for the open pit. Although subsidence probably collapsed a significant portion of the major underground workings, it is highly likely that relatively large connected void spaces still exist, and thus an artificially high hydraulic conductivity probably remains within the underground workings to the present day.

Appendix B - Water Balance Spreadsheets

Appendix B **Table 1 Tailings Water Balance - Current State Before Reprocessing - Average Year**

Using 1971 to 2000 Climatic Normals

									End of Water Budget Year	Start of Water Budget Year				
	Month													
Inputs to tailings surface	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total Annual**	
Rainfall (mm)	0.2	0.1	0	1.3	13	29.7	41.4	38.5	29.3	8.8	0.7	0.3	**163**	
Snowfall (mm swe)	16.5	11.3	10.4	5.7	2.2	0.6	0	0.9	4.8	15	18.5	18.2	**104**	
													267	
Outputs from tailings surface														
Snow sublimation (mm)	2	2	2	1	0	0	0	0	0	1	1	1	**10**	
Runoff (mm)	0	0	0	38	36	10	14	13	12	7	0	0	**130**	
Infiltration into tailings (mm)	0	0	0	5	5	10	13	13	11	7	0	0	**64**	
Evaporation from near surface of tailings (mm)	0	0	5	5	5	10	14	13	11	0	0	0	**63**	
													267	
Change in Storage (mm)														
Change in surface water storage (mm)	15	9	3	-42	-31	0	0	0	0	9	18	18	**0**	
Climate Factors														
Average temp. (deg. C)	-17.7	-13.7	-6.6	0.9	6.9	11.8	14.1	12.5	7.1	0.6	-9.4	-14.9	-0.7	
Potential evapotranspiration (mm)	0	0	7	57	121	161	164	125	52	0	0	0	688	
Runoff														**Units**
Old Pond SE Cell (15.5 ha)	0	0	0	5890	5580	1550	2170	2015	1860	1085	0	0	20150	m3/yr
													0.001	m3/s
Old Pond NW Cell (39 ha)	0	0	0	14820	14040	3900	5460	5070	4680	2730	0	0	50700	m3/yr
Flow (m3/s)				0.006	0.005	0.002	0.002	0.002	0.002	0.001			0.003	m3/s
A Valley (12.6 ha)	0	0	0	4788	4536	1260	1764	1638	1512	882	0	0	16380	m3/yr
													0.001	m3/s
B Valley (7.8 ha)	0	0	0	2964	2808	780	1092	1014	936	546	0	0	10140	m3/yr
													0.001	m3/s
Total													**97370**	**m3/yr**
													0.005	**m3/s**

Assumptions

Priestley Taylor evapotranspiration estimate
no plants in tailings area so just evaporation no transpiration
assume active capillary wetting of surface from soil
low permeability of tailings, top 25 cm wetted
in summer, assume evaporation, runoff, and infiltration each take 33% of precipitation
assume snowpack builds nov to march, no runoff or soil water,
swe = snow water equivalent

Appendix B **Table 2** **Tailings Water Balance - Current State Before Reprocessing - Dry Year**

Whitehorse Copper Dry Year 2002

									End of Water Budget Year	Start of Water Budget Year				
	Month													
Inputs to tailings surface	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total Annual**	
Rainfall (mm)	0	0	0	0	8.1	12.8	31.4	42.8	27.4	1.8	1.6	0	**126**	
Snowfall (mm swe)	11.5	8.2	6	1.4	1.7	0	0	0	0	4.1	6.5	9.4	**49**	
													175	
Outputs from tailings surface														
Snow sublimation (mm)	2	1	1	0	0	0	0	0	0	0	1	1	**6**	
Runoff (mm)	0	0	0	13	8	3	10	14	9	2	0	0	**59**	
Infiltration into tailings (mm)	0	0	0	7	7	2	10	14	9	0	0	0	**49**	
Evaporation from near surface of tailings (mm)	0	0	2	7	9	8	11	15	9	0	0	0	**61**	
													175	
Change in Storage														
Change in surface water storage (mm)	10	7	3	-26	-14	0	0	0	0	4	7	8	**0**	
Climate Factors														
Average temp. (deg. C)	-12.2	-11.5	-11.7	-3.8	6.3	12.1	13.8	12.1	7.5	3.7	-1.4	-9.3	0.5	
Potential Evaporation (mm)	0	0	7	57	121	161	164	125	52	0	0	0	688	
Runoff														**Units**
Old Pond SE Cell (15.5 ha)	0	0	0	2015	1240	465	1550	2170	1395	310	0	0	9145	m3/yr
													0.000	m3/s
Old Pond NW Cell (39 ha)	0	0	0	5070	3120	1170	3900	5460	3510	780	0	0	23010	m3/yr
Flow (m3/s)				0.002	0.001	0.000	0.001	0.002	0.001	0.000			0.001	m3/s
A Valley (12.6 ha)	0	0	0	1638	1008	378	1260	1764	1134	252	0	0	7434	m3/yr
													0.000	m3/s
B Valley (7.8ha)	0	0	0	1014	624	234	780	1092	702	156	0	0	4602	m3/yr
													0.000	m3/s
Total													**44191**	**m3/yr**
													0.002	**m3/s**

Assumptions

Priestley Taylor evapotranspiration estimate
no plants in tailings area so just evap no transpiration
assume active capillary wetting of surface from soil
low permeability of tailings, top 25 cm wetted
in summer, assume evaporation, runoff, and infiltration each take 33% of precipitation
assume snowpack builds nov to march, no runoff or soil water
assume most sublimation during dry winter conditions
swe = snow water equivalent

Appendix B **Table 3** **Tailings Water Balance - Current State Before Reprocessing - Wet Year**

Whitehorse Copper Wet Year 1991

									End of Water Budget Year	Start of Water Budget Year				
	Month													
Inputs to tailings surface	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total Annual**	
Rainfall (mm)	0	0.2	0	0	10.6	36.2	57.1	70	37.4	19.9	0	0	**231**	
Snowfall (mm swe)	18	13.9	10.3	2	0	0	0	0	0	18.6	38.1	39	**140**	
													371	
Outputs from tailings surface														
Snow sublimation (mm)	2	2	2	1	0	0	0	0	0	2	2	2	**13**	
Runoff (mm)	0	0	0	50	41	12	27	32	12	10	0	0	**184**	
Infiltration into tailings (mm)	0	0	0	10	10	12	15	18	12	10	0	0	**87**	
Evaporation from near surface of tailings (mm)	0	0	5	10	12	12	15	20	13	0	0	0	**87**	
													371	
Change in Storage														
Change in surface water storage (mm)	16	12	3	-69	-52	0	0	0	0	17	36	37	**0**	
Climate Factors														
Average temp. (deg. C)	-18.8	-7.4	-7.2	2.6	8.3	12.7	13.3	11.7	8.4	-2.1	-9.2	-11.2	0.1	
Potential Evapotranspiration (mm)	0	0	7	57	121	161	164	125	52	0	0	0	688	
Runoff														**Units**
Old Pond SE Cell (15.5 ha)	0	0	0	7750	6355	1860	4185	4960	1860	1550	0	0	28520	m3/yr
													0.002	m3/s
Old Pond NW Cell (39 ha)	0	0	0	19500	15990	4680	10530	12480	4680	3900	0	0	71760	m3/yr
Flow (m3/s)					0.006	0.002	0.004	0.005	0.002				0.004	m3/s
A Valley (12.6 ha)	0	0	0	6300	5166	1512	3402	4032	1512	1260	0	0	23184	m3/yr
													0.001	m3/s
B Valley (7.8 ha)	0	0	0	780	780	936	1170	1404	936	780	0	0	6786	m3/yr
													0.000	m3/s
Total													**130250**	**m3/yr**
													0.007	**m3/s**

Assumptions

Priestley Taylor evapotranspiration estimate

no plants in tailings area so just evaporation no transpiration

assume active capillary wetting of surface from soil

low permeability of tailings, top 25 cm wetted

in summer, assume evaporation, runoff, and infiltration each take 33% of precipitation

assume snowpack builds nov. to march, no runoff or soil water

assume most sublimation during dry winter conditions

swe = snow water equivalent

Appendix B **Table 4** **Tailings Water Balance for the Old Pond During First Year of Reprocessing (process begins in April)**

Using 1971 to 2000 climatic normals

Tailings Surface	**Month**								Sept: End of Water Budget Year	Oct: Start of Water Budget Year			
Inputs to tailings surface (mm)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total Annual**
Rainfall (mm)	0.2	0.1	0	1.3	13	29.7	41.4	38.5	29.3	8.8	0.7	0.3	**163**
Snowfall (mm swe)	16.5	11.3	10.4	5.7	2.2	0.6	0	0.9	4.8	15	18.5	18.2	**104**
													267
Outputs from tailings surface (mm)													
Snow sublimation (mm)	2	2	2	1	0	0	0	0	0	1	1	1	**10**
Runoff (returned to process)	0	0	0	38	36	10	14	13	12	7	0	0	**130**
Infiltration into tailings (mm)	0	0	0	5	5	10	13	13	11	7	0	0	**64**
Evaporation from near surface of tailings (mm)	0	0	5	5	5	10	14	13	11	0	0	0	**63**
													267
Change in Storage (mm)	15	9	3	-42	-31	0	0	0	0	9	18	18	**0**
Body of Tailings (Old Pond - 54.5 ha)													
Process water input (mm)	0	0	0	1265	1265	1265	1265	1265	1265	1265	0	0	**8855**
Evaporation from body of tailings (mm)	0	0	0	10	23	30	30	22	8	0	0	0	**124**
Recaptured process water (mm)	0	0	0	1200	1187	1181	1181	1188	1202	1211	0	0	**8350**
residual drainage towards 20% water (recaptured) (mm)	0	0	0	2	2	2	2	2	2	2	2	2	**21**
Change in Storage (mm)	0	0	0	52	52	52	52	52	52	52	0	0	**364**
total water returned to process (mm)	0	0	0	1241	1226	1193	1197	1204	1217	1220	2	2	**8501**
Climate Factors													
Average temp. (deg. C)	-17.7	-13.7	-6.6	0.9	6.9	11.8	14.1	12.5	7.1	0.6	-9.4	-14.9	**-0.7**
Potential Evapotranspiration (mm)	0	0	7	57	121	161	164	125	52	0	0	0	**688**

Assumptions during reprocessing

100% of baren tailings returned to the Old Pond
Priestley Taylor evapotranspiration estimate
no plants in tailings area so just evaporation no transpiration
assume active capillary wetting of surface from soil
swe = snow water equivalent
assume runoff recaptured
at surface assume evaporation, runoff, and soil wetting each take 33% of precipitation
the wet tailings body evaporates water such that surface evaporation and evaporation from the tailings body equals the potential rate of evapotranspiration
Only 20% of the Old Pond surface is fully wet at any time - i.e the tailings discharge pipe deposits tailings slurry over a maximum of 20% of the surface at a time.
The other 80% is at 26% moisture content - and draining towards 20%, with the drainage water captured and returned to the plant

Appendix B **Table 5** **Water Balance for the Old Pond During First Year after Reprocessing Finished (reprocessing complete end Sept of year 7)**

Using 1971 to 2000 Climatic Normals

									End of Water Budget Year	Start of Water Budget Year				
Tailings Surface	**Month**													
Inputs to Tailings Surface (mm)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total Annual**	
Rainfall (mm)	0.2	0.1	0	1.3	13	29.7	41.4	38.5	29.3	8.8	0.7	0.3	**163**	
Snowfall (mm swe)	16.5	11.3	10.4	5.7	2.2	0.6	0	0.9	4.8	15	18.5	18.2	**104**	
													267	
Outputs from Tailings Surface (mm)														
Snow sublimation (mm)	2	2	2	1	0	0	0	0	0	1	1	1	**10**	
Runoff (mm)	0	0	0	38	36	10	14	13	12	7	0	0	**130**	
Infiltration into tailings (mm)	0	0	0	5	5	10	13	13	11	7	0	0	**64**	
Evaporation from near surface of tailings (mm)	0	0	5	5	5	10	14	13	11	0	0	0	**63**	
													267	
Change in Storage (mm)	15	9	3	-42	-31	0	0	0	0	9	18	18	**0**	
Body of Tailings (Old Pond)														
Reprocessed tailings water stored in tailings after 7 years of reprocessing operation (end Sept) (mm)										2170			**2170**	
Residual drainage towards 20% water (recaptured if necessary)	7	7	7	7	7	7	7	7	7	7	7	7	**84**	
End of month water stored in tailings (mm)	2142	2135	2128	2121	2114	2107	2100	2093	2086	2163	2156	2149	**2086**	
Climate Factors														
Average temp. (deg. C)	-17.7	-13.7	-6.6	0.9	6.9	11.8	14.1	12.5	7.1	0.6	-9.4	-14.9	-0.7	
Potential Evapotranspiration (mm)	0	0	7	57	121	161	164	125	52	0	0	0	688	
Runoff														**Units**
Old Pond SE Cell (15.5 ha)	0	0	0	5890	5580	1550	2170	2015	1860	1085	0	0	20150	m3/yr
													0.001	m3/s
Old Pond NW Cell (39 ha)	0	0	0	14820	14040	3900	5460	5070	4680	2730	0	0	50700	m3/yr
													0.003	m3/s
A Valley (12.6 ha)	0	0	0	3830	3629	1008	1411	1310	1210	706	0	0	13104	m3/yr
													0.001	m3/s
B Valley (7.8 ha)	0	0	0	2371	2246	624	874	811	749	437	0	0	8112	m3/yr
													0.000	m3/s
Total													**92066**	**m3/yr**
													0.005	**m3/s**

Assumptions

100% of barren tailings returned to the Old Pond
Priestley Taylor evapotranspiration estimate
no plants in tailings area so just evaporation no transpiration
assume active capillary wetting of surface from soil
low permeability of tailings, top 25 cm wetted
swe = snow water equivalent
at surface assume evaporation, runoff, and soil wetting each take 33% of precipitation
After A and B tailings removed, runoff reduced by 20% due to increased infiltration
assume snowpack builds Nov. to March, no runoff or soil water
assume most sublimation during dry winter conditions
7 annual layers; top 3 at 26%, 24%, and 22% respectively at start of year; lower 4 layers at 20% moisture

Appendix B **Table 6** **Water Balance for the Old Pond During Second Year after Reprocessing Finished (reprocessing complete end Sept of year 7)**

Using 1971 to 2000 Climatic Normals									End of Water Budget Year	Start of Water Budget Year				
Tailings Surface	**Month**													
Inputs to Tailings Surface (mm)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total Annual**	
Rainfall (mm)	0.2	0.1	0	1.3	13	29.7	41.4	38.5	29.3	8.8	0.7	0.3	**163**	
Snowfall (mm swe)	16.5	11.3	10.4	5.7	2.2	0.6	0	0.9	4.8	15	18.5	18.2	**104**	
													267	
Outputs from Tailings Surface (mm)														
Snow sublimation (mm)	2	2	2	1	0	0	0	0	0	1	1	1	**10**	
Runoff (mm)	0	0	0	38	36	10	14	13	12	7	0	0	**130**	
Infiltration into tailings (mm)	0	0	0	5	5	10	13	13	11	7	0	0	**64**	
Evaporation from near surface of tailings (mm)	0	0	5	5	5	10	14	13	11	0	0	0	**63**	
													267	
Change in Storage (mm)	15	9	3	-42	-31	0	0	0	0	9	18	18	**0**	
Body of Tailings (Old Pond)														
Reprocessed tailings water stored in tailings after 7 years of reprocessing operation and one year post-process (end Sept) (mm)										2086			**2086**	
Residual drainage towards 20% water (recaptured if necessary)	5	5	5	5	5	5	5	5	5	5	5	5	**60**	
End of month water stored in tailings (mm)	2066	2061	2056	2051	2046	2041	2036	2031	2026	2081	2076	2071	**2026**	
Climate Factors														
Average temp. (deg. C)	-17.7	-13.7	-6.6	0.9	6.9	11.8	14.1	12.5	7.1	0.6	-9.4	-14.9	-0.7	
Potential Evapotranspiration (mm)	0	0	7	57	121	161	164	125	52	0	0	0	688	
Runoff														**Units**
Old Pond SE Cell (15.5 ha)	0	0	0	5890	5580	1550	2170	2015	1860	1085	0	0	20150	m3/yr
													0.001	m3/s
Old Pond NW Cell (39 ha)	0	0	0	14820	14040	3900	5460	5070	4680	2730	0	0	50700	m3/yr
													0.003	m3/s
A Valley (12.6 ha)	0	0	0	3830	3629	1008	1411	1310	1210	706	0	0	13104	m3/yr
													0.001	m3/s
B Valley (7.8 ha)	0	0	0	2371	2246	624	874	811	749	437	0	0	8112	m3/yr
													0.000	m3/s
Total													**92066**	**m3/yr**
													0.005	**m3/s**

Assumptions
100% of barren tailings returned to the Old Pond
Priestley Taylor evapotranspiration estimate
no plants in tailings area so just evaporation no transpiration
assume active capillary wetting of surface from soil
low permeability of tailings, top 25 cm wetted
swe = snow water equivalent
at surface assume evaporation, runoff, and soil wetting each take 33% of precipitation
original soil under A Valley and B Valley well consolidated by pressure, less hydraulic conductivity than originally, rehab will provide soil layer.
After A and B tailings removed, runoff reduced by 20% due to increased infiltration
assume snowpack builds Nov. to March, no runoff or soil water
assume most sublimation during dry winter conditions
7 annual layers; top 2 at 24% and 22% respectively at start of year; lower 5 layers at 20% moisture

Appendix B **Table 7** **Water Balance for the Old Pond During Third Year after Reprocessing Finished (reprocessing complete end Sept of year 7)**

Using 1971 to 2000 Climatic Normals

									End of Water Budget Year	Start of Water Budget Year				
Tailings Surface	**Month**													
Inputs to Tailings Surface (mm)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total Annual**	
Rainfall (mm)	0.2	0.1	0	1.3	13	29.7	41.4	38.5	29.3	8.8	0.7	0.3	**163**	
Snowfall (mm swe)	16.5	11.3	10.4	5.7	2.2	0.6	0	0.9	4.8	15	18.5	18.2	**104**	
													267	
Outputs from Tailings Surface (mm)														
Snow sublimation (mm)	2	2	2	1	0	0	0	0	0	1	1	1	**10**	
Runoff (mm)	0	0	0	38	36	10	14	13	12	7	0	0	**130**	
Infiltration into tailings (mm)	0	0	0	5	5	10	13	13	11	7	0	0	**64**	
Evaporation from near surface of tailings (mm)	0	0	5	5	5	10	14	13	11	0	0	0	**63**	
													267	
Change in Storage (mm)	15	9	3	-42	-31	0	0	0	0	9	18	18	**0**	
Body of Tailings (Old Pond)														
Reprocessed tailings water stored in tailings after 7 years of reprocessing and two years post-process (end Sept) (mm)										2026			**2026**	
Residual drainage towards 20% water (recaptured if necessary)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	**30**	
End of month water stored in tailings (mm)	2016	2014	2011	2009	2006	2004	2001	1999	1996	2024	2021	2019	**1996**	
Climate Factors														
Average temp. (deg. C)	-17.7	-13.7	-6.6	0.9	6.9	11.8	14.1	12.5	7.1	0.6	-9.4	-14.9	-0.7	
Potential Evapotranspiration (mm)	0	0	7	57	121	161	164	125	52	0	0	0	688	
Runoff														**Units**
Old Pond SE Cell (15.5 ha)	0	0	0	5890	5580	1550	2170	2015	1860	1085	0	0	20150	m3/yr
													0.001	m3/s
Old Pond NW Cell (39 ha)	0	0	0	14820	14040	3900	5460	5070	4680	2730	0	0	50700	m3/yr
													0.003	m3/s
A Valley (12.6 ha)	0	0	0	3830	3629	1008	1411	1310	1210	706	0	0	13104	m3/yr
													0.001	m3/s
B Valley (7.8 ha)	0	0	0	2371	2246	624	874	811	749	437	0	0	8112	m3/yr
													0.000	m3/s
Total													**92066**	**m3/yr**
													0.005	**m3/s**

Assumptions

100% of barren tailings returned to the Old Pond
Priestley Taylor evapotranspiration estimate
no plants in tailings area so just evaporation no transpiration
assume active capillary wetting of surface from soil
low permeability of tailings, top 25 cm wetted
swe = snow water equivalent
at surface assume evaporation, runoff, and soil wetting each take 33% of precipitation
After A and B tailings removed, runoff reduced by 20% due to increased infiltration
assume snowpack builds Nov. to March, no runoff or soil water
assume most sublimation during dry winter conditions
7 annual layers, top one at 22% at start of year, lower 6 at 20% moisture

Appendix B

Table 8 Water Balance for the Old Pond After Reprocessing and Rehabilitation, After Tailings Drained

Using 1971 to 2000 Climatic Normals

									End of Water Budget Year	Start of Water Budget Year				
	Month													
Inputs to tailings surface	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total Annual**	
Rainfall (mm)	0.2	0.1	0	1.3	13	29.7	41.4	38.5	29.3	8.8	0.7	0.3	**163**	
Snowfall (mm swe)	16.5	11.3	10.4	5.7	2.2	0.6	0	0.9	4.8	15	18.5	18.2	**104**	
													267	
Ooutputs from tailings surface (mm)														
Snow sublimation (mm)	2	2	2	1	0	0	0	0	0	1	1	1	**10**	
Runoff (mm)	0	0	0	38	36	10	14	13	12	7	0	0	**130**	
Infiltration into tailings (mm)	0	0	0	5	5	10	13	13	11	7	0	0	**64**	
Evaporation from surface of tailings (mm)	0	0	5	5	5	10	14	13	11	0	0	0	**63**	
													267	
Change in Storage														
Change in surface water storage (mm)	15	9	3	-42	-31	0	0	0	0	9	18	18	**0**	
Body of Tailings (Old Pond)														
Reprocessed tailings water stored in tailings after 7 years of reprocessing operation and three years post-process (end Sept) (mm)										1996			**1996**	
Residual drainage towards 20% water (recaptured if necessary)	0	0	0	0	0	0	0	0	0	0	0	0	**0**	
End of month water stored in tailings (mm)	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996	1996	**1996**	
Climate Factors														
Average temp. (deg. C)	-17.7	-13.7	-6.6	0.9	6.9	11.8	14.1	12.5	7.1	0.6	-9.4	-14.9	-0.7	
Potential Evapotranspiration (mm)	0	0	7	57	121	161	164	125	52	0	0	0	688	
Runoff														**Units**
Old Pond SE Cell (15.5 ha)	0	0	0	5890	5580	1550	2170	2015	1860	1085	0	0	20150	m3/yr
													0.001	m3/s
Old Pond NW Cell (39 ha)	0	0	0	14820	14040	3900	5460	5070	4680	2730	0	0	50700	m3/yr
													0.003	m3/s
A Valley (12.6 ha)	0	0	0	3830	3629	1008	1411	1310	1210	706	0	0	13104	m3/yr
													0.001	m3/s
B Valley (7.8 ha)	0	0	0	2371	2246	624	874	811	749	437	0	0	8112	m3/yr
													0.000	
Total													**92066**	**m3/yr**
													0.005	**m3/s**

Assumptions

100% of barren tailings returned to the Old Pond
Priestley Taylor evapotranspiration estimate
no plants in tailings area so just evaporation no transpiration
assume active capillary wetting of surface from soil
low permeability of tailings, top 25 cm wetted
swe = snow water equivalent
at surface assume evaporation, runoff, and soil wetting each take 33% of precipitation
After A and B tailings removed, runoff reduced by 20% due to increased infiltration
assume snowpack builds Nov. to March, no runoff or soil water